











## TRANSACTIONS

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## OF THE

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## CONTENTS

Page

|   | -  |
|---|----|
| Foreword to the Forum on Kentucky Education                   | 1  |
| Forever In the Forties?<br>William S. Taylor                  | 2  |
| Education In Kentucky<br>W. P. King                           | 6  |
| Elementary Education In Kentucky<br>Richard E. Jaggers        | 9  |
| Secondary Education In Kentucky<br>John Fred Williams         | 12 |
| Problems of Higher Education In Kentucky<br>J. J. Oppenheimer | 15 |
| The Density of Ether<br>Olus J. Stewart                       | 20 |
| Leaf Glands in Ailanthus altissima<br>P A Davies              | 31 |

#### TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

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## FOREWORD

Due to wartime restrictions, the regular meeting of the Kentucky Academy of Science for the spring of 1945 could not be held. Among the events planned for that occasion was a forum on Kentucky education. The scheduled speakers for this forum were invited to publish their papers in the Transactions of the Kentucky Academy of Science. The editorial board expresses its pleasure with the manner in which the authors have responded. We hope that the Academy has contributed in this way to the cause of good education in Kentucky.

We wish to affirm our editorial policy of accepting papers at any time, in addition to accepting those papers which are submitted as part of the programs of the annual meetings. We feel that in this way only can the Transactions be considered truly a quarterly journal. Authors may send their papers to the appropriate assistant editor or to the managing editor.

The papers contributed to the Forum on Kentucky Education follow immediately. Each paper in this series is so designated. Mr. Charles Farnsley was the chairman of the Forum and to him we are indebted for its initial stimulus.

## FOREVER IN THE FORTIES?\*

#### WILLIAM S. TAYLOR

#### Dean, College of Education, University of Kentucky, Lexington, Ky.

Kentucky is still in the forties! Since the first rating of the states educationally, in 1918, Kentucky has been apologizing for its position. At first many persons maintained that the rating was unfair; that Kentucky had a better school system than the evaluation indicated. Other rating scales have been developed since that time and Kentucky has been scored on these. By every test Kentucky has been rated in the forties.

Great progress has been made in Kentucky in the past quarter of a century—but other states have made progress too. We are still in the forties and we cannot get out by pointing to our educational accomplishments or by feeling sorry for ourselves. If we want to improve our educational rank we must recognize our deficiencies and improve our program where it is weak.

Under present conditions to be born in Kentucky is to be born with a potential educational handicap. It is true that some of our cities and counties have excellent school systems but in far too many school districts of the state teachers are poorly qualified, buildings are inferior, teaching materials and equipment are inadequate, school terms are short, attendance is low, and learning is meager. Children attending such schools never have a chance to learn what education should do for them and for the communities in which they live. As citizens they will lack vision because they now lack opportunity to learn the things that contribute to effective citizenship. We are in a vicious circle. Poor schools make poor citizens; poor citizens are content with poor schools.

What are some of our handicaps in Kentucky? Why do we receive an embarrassingly low rating every time the states in the Union are ranked as to educational efficiency? Some of the most difficult problems we have to overcome are the result of constitutional limitations. Under a provision of the constitution the superintendent of public instruction must be selected on a political rather than a professional basis and his term of office is limited to four years. No intelligent person would think of requiring the president of the University and the presidents of the teachers colleges to seek their offices on a political basis. The position of state superintendent of schools in any state should be

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free from political influences and should be comparable in importance to the presidency of the state university. And not one reason can be found for limiting the term of office of the state superintendent to four years. It should be possible for a superintendent of public instruction to stay in office as long as he is giving efficient service. No superintendent, however strong and efficient, can project and carry through a constructive state program of education in a period of four years.

An additional handicap is the constitutional limitation of \$5,000 on the salary that can be paid to any person in public education, including the state teachers colleges and the University. The Legislature has added a further restriction in that it has authorized a salary of only \$4,000 for the state superintendent of public instruction. The salary for this office is so small that few men can afford to offer themselves for the position. It takes a brave man to resign from a good school position in Kentucky, run for office on a political ticket, without prospect of a position when his four-year term of office is over.

Another great handicap to the development of a strong educational program in Kentucky is the meager financial support which has been given by the Legislature to the State Department of Education. It has been difficult for the Department to procure men and women with the highest qualifications for leadership because of the low salaries paid and the uncertainty of tenure which results from the election of the superintendent on a party ballot. There has never been the security of office in the State Department of Education that has existed in the publicschool systems of the state, in the teachers colleges, or in the University.

A long-recognized need in Kentucky is a coordinated system of education from the elementary school through college or university. Great strides have been made in recent years in coordinating the programs of elementary and secondary education. These programs are still not so well articulated with the program of higher education as they should be. Most authorities in the field of school administration agree that there are in Kentucky too many different boards administering the program of publicly supported education. This question needs serious study to discover the steps that could be taken to strengthen Kentucky's educational program.

Closely related, if not actually a part of the question of a better coordinated system is the problem of reducing the number of school administrative units in the state. We have at present too many small districts which are in most cases weak. There are many reasons for combining city and county programs of education. Around our larger cities are great suburban areas that have all the problems of city school systems; in many instances, however, these areas are parts of county systems. The concentration of wealth within cities makes it easier for urban centers than for rural areas to support their programs of education. If larger school units could be established, the burden of support would be more nearly equalized and a more effective program would be realized.

Not only must the tax laws be revised but property assessments must be increased to more nearly their actual value. But at best, Kentucky would not be able to compete with the wealthiest states or even with the average state of the nation. Federal support for education must be provided if Kentucky is to approximate the national average in the provision of educational opportunity for its citizens. Kentucky does not have wealth to produce the income necessary for an educational program comparable to those of the upper 50 per cent of the states of the nation.

Kentucky ranks lowest of all of the states in the Union in the percentage of its children between the ages of fourteen and seventeen who are enrolled in high school. Our secondary schools in America have frequently been called the peoples' colleges. These are the schools in which the children of America should be given the kinds of education that will make possible richer lives and better work. Kentucky has not been able, in many areas, to provide transportation to high school for rural children. While there is a high school in every county in Kentucky, in a great number of counties the enrollments are exceptionally low. Elementary education is not enough for Kentucky's children. Some means must be found of making secondary education available to all of the children of the state.

All of us are agreed that longer terms must be made available in rural elementary schools. A rural child cannot learn as much in seven months in a poor school under an inadequately prepared teacher as a city child learns in nine months in a good school under a well-educated teacher.

Public school programs in every state are affected by the colleges and universities of that state. The institutions of higher learning in Kentucky have served well with the limited resources available. To insure adequate help from her state supported institutions of higher education, Kentucky must provide a larger measure of support for these schools. The teachers colleges and

the University need greatly increased funds if they are to give to the state the best possible service. The University should not only offer programs for the high school graduates who come to the campus for education, but it should also provide in-service education on the adult level for many groups of people who need training for the work they are doing or will do. Newly elected city and county officials should be able to come to the University for short courses before they take office; such public officials as county clerks, city clerks, county judges, city judges, and sheriffs should find at the University the help they need to enable them to give effective service. Business executives should have an opportunity to come to the University for training which would help them to improve their organization and management. Employees of business and industry should receive services through the Extension Division of the University that would enable them to improve their earning power and to give better service to the organizations that employ them. There has been in existence for a long time an unusually effective in-service education program for farmers and for homemakers. Similar services should be extended to people in other occupations.

These are only a few of the many things that need to be done to give Kentucky an educational program that will meet the needs of her people. We must stir ourselves to vigorous effort. We are not a pauper state. We can finance better schools than we now have, but we cannot provide schools as good as our children deserve from money raised in Kentucky alone. We must procure for our state the help necessary to give to children and adults an adequate educational program.

## **EDUCATION IN KENTUCKY\***

## W. P. KING

#### Executive Secretary, Kentucky Education Association

There are in Kentucky 120 county school systems and 137 independent systems, or a total of 257 school units each administered by a board of education and a superintendent. The schools are financially supported by local tax and appropriations from the state. The latter consists of (1) a fund which is distributed on a per capita basis, and (2) an equalization fund which is distributed on the basis of need. Districts which cannot raise from their local tax plus their per capita allotment from the state an amount equal to \$40.00 for each pupil may participate in the equalization fund.

Kentucky has struggled for a number of years under a tax system for schools which differentiated between districts. For example, a county could levy a maximum of 75 cents on each \$100 of assessible property while independent districts could levy within a range from \$1.00 to \$1.50 for the same purpose. This inequality has been removed during the current session of the Legislature by the passage of a law which permits \$1.50 tax in all districts. This law will become operative July 1, 1946.

Under the tax system which has prevailed, 55 counties have only 7 months of school while most of the other 65 counties have 8 or 9 months as do nearly all independent districts. The new tax program will remedy this condition.

There are slightly under 4,000 one-teacher schools in Kentucky. These are rural schools and are chiefly in the seven-month counties. Most of these counties are levying all the tax permitted by law. Many of them would be willing to raise their tax for schools if it were not for legal restrictions.

Another retarding factor for the schools and other departments of the state government is the great inequality in the assessment of property. The range of assessments runs all the way from approximately 35 per cent of the fair cash value as indicated by sales, to approximately 85 per cent in some of the highest counties. On the other hand there is much potential wealth in the state owned and operated by corporations out of the state, which does not bear its part of the educational load.

The circumstances set out above result in the very low ranking

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of Kentucky in so many categories. For example, among the 49 states including the District of Columbia, according to the latest data, Kentucky ranks 48th in number of days of school taught, 43rd in school attendance, 39th in per cent of persons 25 years of age and above who have completed less than five years of school. 40th in median school years completed by persons 25 years of age and older, 42nd in current expenditures for education per child in average daily attendance, 41st in average salary per teacher and 45th in the value of school property per child. Latest data also shows that Kentucky ranks as follows in items measuring the well being of her people: 45th in per capita income, 44th in per capita retail sales, 42nd in per capita output of industries, 39th in per capita life insurance in effect, 38th in per cent of homes having mechanical refrigeration, 40th in per cent of homes with running water and 43rd in per capita circulation of 18 national magazines.

A question which logically arises is whether or not Kentucky is able to support a system of public education. Let us examine the facts.

Three measures are frequently used to determine the economic ability of a state to support education and other governmental services by taxation. They are per capita economic income, per capita output of industry, including farming and mining, and per capita retail sales.

In 1940, according to the Survey of Current Business, August, 1941, the per capita economic income in Kentucky was \$298 and the average for the U. S. was \$532. Judged by this measure, Kentucky therefore has only 56 per cent of the ability to support taxation of the average for the entire country.

The U. S. Bureau of the Census reported in a special study in September, 1942, that the per capita value of the output of industries, including farming and mining, was \$161 in Kentucky and \$277 in the U. S. for the year 1939. On this basis Kentucky has 58 per cent of the ability of the U. S. as a whole.

In 1939, according to the same study by the U. S. Bureau of the Census the per capita retail sales was \$185 in Kentucky whereas the average for the nation was \$322. Using this criterion, Kentucky's ability to support taxation is 57 per cent of the nation's average.

Combining these three measures we find that the state of Kentucky has 57 per cent of the economic ability of the U. S. as a whole, to support a program of taxation to pay the cost of education and other governmental services.

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Let us now take a look at the tax burden carried by Kentuckians and compare it with the tax load of the average citizen of the United States. In 1941, according to the special study of the U. S. Bureau of the Census, the per capita tax burden for local purposes amounted to \$39.89 in the United States as a whole and only \$13.97 or 35 per cent of that amount for the state of Kentucky. Thus Kentuckians have 57 per cent of the tax paying ability of the average for the United States and they carry a local tax burden equal to only 35 per cent of the average for the nation.

On the basis of these facts taxation for local purposes could be increased by 63 per cent before reaching the ratio of per capita local taxes to per capita taxpaying ability which now exists for the entire country.

The facts recited here make a drab picture with very few high-lights. What it shall be in the future depends upon the recognition of the fact that the deficiencies in our program of education constitute a problem for all the people.

## **ELEMENTARY EDUCATION IN KENTUCKY\***

RICHARD E. JAGGERS Chief Bureau of Instruction Frankfort, Kentucky

One of the chief functions of elementary education is to help the child take the first steps in becoming a practicing citizen of the social group in which he finds himself. This means that the elementary school must, if it serves this purpose, help him to learn the languages common to the group: he must learn the language of communication, oral and written; he must learn the language of numbers; he must learn the language of health and physical fitness; he must learn the language of human relationship; he must learn the language of space relations; and he must learn every language which will help him to become a part of the social, civic, economic and spiritual life of the group. He must be made to act, in a great measure, like the other members of the group in which he lives and works and plays.

The other major function of elementary education is to discover in each child the ways in which he differs from other members of the social group. This means that from the time the child enters school until he leaves special effort must be made to find his chief interest and chief aptitude. It is generally recognized that the thing for which a child has the greatest aptitude is generally the thing in which he is most interested. It is generally believed that when the chief interest-aptitude is found the strength of the child is likely to be within that area. It means, then, that the elementary school program of living and learning should offer opportunity for discovering these strengths, i.e., interest-aptitudes. It follows that there must be means of developing the total child with due respect for his interestaptitude. The effective achievement of this function lays the foundation for personal happiness and for vocational efficiency.

It is believed that all the functions of elementary education may be grouped under the two functions mentioned, i.e., integration of the child into the group in which his life is lived, and differentiation to discover and develop his individual aptitude. If this view is taken, then it is economy to provide the type of elementary school in which this kind of program operates.

There must be an educated teacher who believes that an 1. individual human being is of immense worth, who believes that all children can learn, who understands how children

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#### The Kentucky Academy of Science

*learn, and who is able to lead them in learning.* Her education should be anchored in the biological sciences, psychologies, child growth and development and human problems of living. It is only in rare instances that a person can become this kind of a teacher unless she has had a good elementary school experience, has attended a good secondary school, and has followed this with four or five years in a teacher-educating institution which bases its programs upon the functions as suggested in this statement. This must be followed by continued study on the job.

- 2. The elementary school must be housed in a plant suited to the needs of the program undertaken. The place where children live-and-learn must be as good as or better than the home. This means that it must be as attractive and livable, not like but as the home. As much attention must be given to the health and happiness of a child in school as is given his health and happiness in the home by his parents whose beloved child he is. There should be absolute certainty that nothing in the physical environment of the school shall in any way prevent a child from developing at his best rate.
- 3. Then the elementary school if it is to perform its function must be equipped with whatever is needed to provide the best learning conditions. Supplies suited to the needs of pupils at the elementary age level must be provided.

Kentucky has, during all her life as a state, treated the elementary school as her educational step-child. We, by law will employ a teacher for the elementary school who has only two years of college preparation, while we refuse by law to permit a person to teach in secondary schools until and unless he has at least four years of preparation in college. In 45 of our counties, we permit the operation of a minimum term of seven months for elementary children and require 9 months for secondary schools. We, therefore, give the child in the elementary grades a short term and a teacher with the low minimum level of training. The pupil cost is much larger in secondary schools than in the elementary schools. The maximum teacher load is approximately 30 pupils in secondary schools while there is no limit to the number of pupils that may be assigned an elementary teacher. The secondary school is generally better housed.

To sum up, the elementary child may have a poorly trained teacher, employed for the shortest term, with no load limit. The result is that pupils become retarded. The number of children who have to repeat the first grade is appalling!

To place the elementary school in a position where it will cease to be the educational step-child, the following appear to be necessary:

- 1. There should be a uniform school term throughout the state for grades 1 to 12.
- 2. Elementary as well as secondary teachers should be required to have at least four years of training which will fit them for the job they are to fill.
- 3. The number of pupils per teacher should be limited to not more than 20 for the first grade and increased grade by grade with possible maximum number per teacher in the twelfth grade limited to 40. The principle followed should be: The younger the pupils, the smaller number to be assigned per teacher.
- 4. There should be at least as much money spent per teacher unit in the elementary grades as in the secondary grades.
- 5. All salaries should be calculated on an annual basis.

When the war came the average elementary teacher in Kentucky had less than three years of college preparation while the average teacher in the secondary school had slightly more than four years of college preparation. The salary policy of the state as a whole is based upon the principle of the single salary schedule. This is a good principle. It means that a teacher in the elementary grades will be paid as much as the secondary teacher if she has as much training and experience. The fallacy in the application of the principle lies in the fact that it is applied on a monthly basis. For example, the salary of a teacher who has a bachelor's degree is \$120 per month. This applies to the elementary teacher who has a degree just as it does to the secondary teacher, but when we give the elementary teacher this salary for 7 months and the secondary teacher the salary for 9 months, it means that the annual salaries are \$840 for the elementary teacher and \$1,080 for the secondary teacher. One is without a job for five months and the other for three months.

The curricula for the education of elementary teachers now required for the standard certificate meet the needs with reasonable effectiveness. As soon as conditions of salary, term, and teacher load in the elementary grades are equitably adjusted there will be no reason why any person should be admitted to teaching in the elementary school until she has been graduated from a four year teacher training curriculum.

## SECONDARY EDUCATION IN KENTUCKY\*

JOHN FRED WILLIAMS Superintendent of Public Instruction Frankfort, Kentucky

The chief function of secondary education is to develop young people so that they may become individually and socially useful members of society as it is constituted in a democracy such as ours. This means that secondary education must provide for (1) the maximum development of the individual as a person, (2) opportunity for the individual to develop wholesome human relations, (3) opportunity to develop the ability to attain economic security, and (4) to accept the responsibilities of citizenship. It means that the secondary school must so be planned, organized, staffed and financed that these ends may be achieved by pupils of secondary school age.

To carry out its chief function, the secondary school must be a citizenship leadership laboratory. This means that it must meet the needs of all young people of secondary school age who are to become functioning citizens. It is not a school devoted exclusively to preparing young people for college; nor is it a school devoted only to those who would prepare for the professions; nor is it devoted only to the needs of those who live in favored areas. The secondary school must meet the needs of all its prospective citizens, regardless of what they will choose to do, regardless of where they live, regardless of race, regardless of what their needs may be.

The secondary school is the people's school, and this means all the people. This means that the people in a community served by a secondary school should have a voice in planning the program to be offered in their school. It means that the program offered in the secondary schools must grow out of the needs which are to be served by the program. The interests and aptitudes of the young people in each area, as well as the opportunities and needs for their services should determine to a large degree what kind of a secondary school should be established. These problems as they affect the locality, the county, the state, the nation and the world-at-large should be a part of the planning for secondary schools.

The secondary schools in Kentucky are not serving the needs of all young people of secondary school age. There were in

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1943-44 in Kentucky 239,515 young people of secondary school age (14-17) but only 81,068 were enrolled in public high schools. For every young person of secondary school age in secondary school there were two of secondary school age not in school. Said in another way it means that of every 100 young people of secondary school age, there were 34 in school and 66 out of school. This means that the needs of 66 out of every 100 young people of secondary school age were not met by the secondary school. They did not go to school.

There are 546 public secondary schools in Kentucky. During peace time the enrollment reached approximately 100,000 but that constituted only about 36 per cent of young people of secondary school age. The number of secondary schools in counties is 352 and in independent cities and villages 194. Approximately 4 in 10 secondary schools have 100 or fewer pupils, and 3 out of 4 have 200 or fewer. Forty per cent have from three to five teachers, and another 35 per cent have from six to ten teachers. It follows that small schools have few teachers and are unable to offer other than the most restricted program, usually the college preparatory program.

There are excellent programs in most of the large secondary schools, and in a few of the small schools. There are 200 or 300 small secondary schools which have added agriculture, home economics or commerce, while a smaller number have all three courses.

A large secondary school does not necessarily mean there will follow an effective secondary school program. There is, however, very little chance to have an effective secondary school program until a large school is provided. Most of the small secondary schools are in rural areas. It means that if we are to lay the foundation for an improved secondary school program, the attendance unit must be enlarged through consolidation. This must be accompanied by an effective and economical plan of county highway construction. Much has been done during the past ten years toward increasing the size of the secondary school through the consolidation of very small schools.

If the secondary schools are to serve the function stated in the opening statement of this paper the people must take education seriously. We have never effectively done this. The people of the state must have faith that education is an investment for all the children and not a luxury to be shared by only one-third of the children. They must not permit all the people to maintain a secondary school program which meets the needs of only one-third of the children. They must invest enough in the enterprise to make it useful for everybody. Two-thirds of the people must be taught that they are investing their money and getting no return.

All arms of the government at the state and local level should work cooperatively in making the schools effective. They should get the correct, truthful, statesmen's answers to such questions as:

- 1. Should all children of secondary school age have a school which will help them to achieve their life purposes? If not, who should be left out?
- 2. What should the secondary school do for a young person to make him an effective citizen?
- 3. What will it cost to provide such a school?
  - a. What kind of teachers must be employed and what will it cost to employ them?
  - b. What kind of a school plant will be needed to house the kind of program young people need? What will it cost?
  - c. How can we procure the money with which to finance such a school?
- 4. What will be the penalty if such a program is not provided?
- 5. Can we afford not to offer a secondary school for our young people?

The correct answers to these questions must be found! We can provide such a program but it will involve complete cooperation. There must be maximum of local effort in planning and financing the program, maximum efforts on the part of the state in planning and financing, and there must be a sane plan of federal aid to schools without federal control of education in any way. In this way only, it seems, can we change the secondary school from a minority institution to one which serves the majority or even all of the children.

# PROBLEMS OF HIGHER EDUCATION IN KENTUCKY\*

#### J. J. OPPENHEIMER

Dean, College of Liberal Arts, University of Louisville Louisville, Kentucky

Problems of the Colleges in Kentucky. No one can prophesy with any degree of assurity about the specific nature of higher education in the postwar period. However, general trends seem to be shaping up at the present time. The prophets of gloom, who predicted that most American colleges would close up during the war, have failed in their dire prediction. The colleges of Kentucky have weathered the war period much better than anyone would have predicted. The recent Roper poll (Fortune, April, 1945) on higher education indicates that the American public has greater faith in our higher education program than ever before. This poll gives the strongest sort of approval to the continuation of higher education and the desirability for both public and private support.

The veterans are returning to the colleges, not in great numbers at the present time, but there is every indication that the colleges will have a greatly increased enrollment in the very near future. Most public institutions in Kentucky, and some of the private institutions, have had some kind of military program. These have been of great assistance in keeping colleges alive.

It is probably true that the world is in the greatest revolution it has ever experienced and no world-wide change can take place without affecting higher education. Undoubtedly, higher education will change, and should change, but the change will be gradual and certainly one can make this statement with a great deal of assurance: The general outlines which we now have will carry over for many years to come.

The Returning Veteran and the College. The prospect of good wages at the present time is holding back the enrollment of veterans in colleges in Kentucky. A relatively small number has returned, but that is a good thing for the colleges inasmuch as it gives the colleges a better chance to understand the returning veterans and to attempt to adjust programs to their needs and do a better job of counseling. Up to date the veteran has fit into the present program in an unusually satisfactory pattern.

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They have been interested in pre-professional study, business administration, teaching, journalism, etc. It is true that they are looking forward to vocational adjustment when they withdraw from college, but they certainly have not expressed antagonism to liberal arts education. In fact, many of them are getting a distinct reward in studying the more general subjects. In regard to the vocational objective of the college, the aforementioned Roper survey indicated that the public thought that colleges should prepare students for vocational competence. That was the first objective; the second objective was that of citizenship.

The adjustment of the veteran to college life has been better than some of the college administrators thought it would be. The colleges have already found that the returning veterans must be given a period of adjustment. Usually this takes two or three months. It is likewise true that a great deal of guidance and social contacts with both students and faculty are basic requirements. No great demand has been made on the colleges for short courses or any other type of short vocational training. This may be due to the counseling which has been given by the Veterans Administration and the fact that when men want technical training in short order they are put under apprenticeships.

Interest in General Education. For many years the colleges have been deeply concerned with the problem of providing basic aids for all citizens. It is important for society to have a common cultural background. The older organizations followed the fixed requirements of freshman and sophomore years. These were usually group requirements. They included first courses in a number of departments. In more recent days colleges have been interested in providing specific courses of general character which would reorganize not only much of the older knowledge, but newer knowledge needed for common understanding and appreciation of modern living. In Kentucky considerable interest has been indicated in this problem. Centre College and the College of Liberal Arts of the University of Louisville have done considerable reorganization to meet this need. The problem is a persistent one. Many critics, professional and lay people believe that there should be a greater unity in the education on the college level. Colleges should help modern men and women comprehend a great unity in living. How to provide this unity in subject matter, in ideals and methodology is a most serious problem. Survey courses, independent study, compre-

#### Problems of Higher Education in Kentucky

hensive examinations and integrating courses for majors or divisions are some of the ways in which greater integration has been attempted. More and more pre-professional study in the fields of medicine, dentistry, law, engineering, and teaching requires fundamental training in general education. People are not satisfied with the simple problem of arithmetic, of adding together one hundred and twenty semester hours and calling it a college education.

Vitalizing the College Curriculum. In addition to a greater unity in the curriculum offerings of the college and a genuine integration of understanding in the student himself, the problem of values is probably the most persistent one. In the early American college, there was much concern with the problem of values. Most of the institutions were denominational. The education of the ministry was an important function. This interest in religion and moral philosophy has faded out of the modern college to an alarming degree. The fact that higher education is so highly compartmentalized, our recent experience with totalitarian countries in which science has been used to such destructive human ends, and the little regard for moral values in modern living have all intensified the question of whether or not the college must not concern itself with some kind of moral undergirding in the education of youth. Modern science is too dangerous without moral direction. Modern economic practices are too tied into national welfare to be selfdirective. The study of human goals should be the common concern of all college students. How is this to be done? A second problem in vitalizing the college is that of selection of content which is more modern and functional. There is much dead wood in courses, textbooks and curriculum. Students, whether they be veterans or civilians, will be more critical of college offerings in the future. The same complacency of taking what the professor "hands out" will be questioned.

Referring again to the Roper survey, the non-college educated public is more sympathetic to higher education than the college graduate. What does this mean? Certainly this is a danger signal to the colleges themselves. If college administrators and professors are wise, they will seriously consider their offerings.

*Work-study*. There is some reason to believe that interest in work-study programs on the college level will become more important in the future. Berea College has been a pioneer among the colleges of Kentucky. Its experience certainly should be of great value to the other colleges. The Speed Scientific School

of the University of Louisville has had a cooperative plan of education since its inception. The clinical years in the Medical School of the University of Louisville have shown the tremendous importance of connecting theory and good practice.

Cooperative Study in Teacher Education. Under the leadership of the State Department of Education, all of the state institutions and two non-state colleges have worked in a cooperative plan to improve teacher education. Workshops have been held, county educational systems and a few separate schools have been sponsored by seven colleges of the state. This is a "grass roots" program inasmuch as the sponsoring institutions have gone back to local schools to see what could be done to improve the quality of living in the communities in which the schools exist. In actually attempting to improve the lives of people, the colleges undoubtedly will learn much which will influence general education and technical teacher education. This plan of cooperative study suggests wider uses of the general plan of higher education. One of the great needs in this state, as well as in other states, is for the colleges to study their mutual problems in a cooperative manner. They would do well to carry this type of program into their own constituent communities. Adult education lags far behind.

Utilization of Natural Resources. Under the joint sponsorship of the Department of Conservation and the State Department of Education, a project is now under way to study better utilization of the natural and human resources of this state. Many separate studies have been made of utilization of natural and human resources by institutions and individuals. This material has been widely scattered and many times has been in a form which is not understandable to the citizens nor to the school child. Before much improvement can be made in this area these materials must be made available to all. The colleges of Kentucky have a genuine contribution to make, not only in furnishing materials but also in seeing to it that these materials are made available to students, adult citizens and pupils in our schools. This brings up the larger question of state planning.

State Planning. The three agencies now concerned with postwar plans for Kentucky indicates the wide interest that the state is taking in its future. There must be some over-all planning in which education has a prominent part, but without economical planning so that the basic wealth of the state can be increased there is little hope for any improvement in education in the state, higher, secondary or elementary. To improve the quality of

#### Problems of Higher Education in Kentucky

living in Kentucky will require a great deal of expenditure of money and energy in fundamental research. Kentucky institutions have not had the opportunity to promote research. They have done well to maintain their instructional programs. Incidentally, a major problem is to get more young people to go to high school and then get the proper ones to go on to college. Our state is notably low in percentage of youth going to high school and college. The state and individual citizens have not supported research programs and yet any long-time policy of fundamental improvement of living is dependent upon scientific research. Of course, this research must not only concern itself with physical problems, but also with the human ones. The late President Roosevelt was eminently right in suggesting that we had much to do in the field of the science of social relations. The logical place for research is in the universities and colleges. When the people see the fundamental need of research, undoubtedly support will be forthcoming. But the research must be tied in with the total program of education of men and women. In other words, there must be an integration of what the research scientists find and the study of values and the other liberal studies which make for all-round living.

## THE DENSITY OF THE ETHER\*

## The Wave Length of Photons Effecting Atomic Motion The Gas Constant—An Anomalous Doppler Shift

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#### Part 1

#### THE DENSITY OF ETHER

An earlier paper (1) sought to create a unitary system of matter and energy by invoking a new kind of ether. This unique ether is not static, but is conceived to flow at the velocity of light along the time axis of the space-time continuum, a property which defies detection by the Michelson-Morley experiment. This paper, the third in the series, proposes to estimate the density of ether. To do this we recall that the first paper (1) accounted for gravitation by declaring it to be the result of the operation of the Bernoulli principle. To be more specific, two bodies in the ether stream constitute, in effect, a Venturi tube, or a constriction. This is thought to be true because one would expect matter to exclude the ether, at least partially, from the region in which the matter is located. The velocity of the stream along the far sides of the two bodies should then be less than that along the near; consequently the pressures created by the flow would be greater along the far sides than along the near; hence the two bodies would be forced together. The argument will now be developed further by studying the Bernoulli effect as the ether stream flows past two selected portions of matter.

Consider the proton, an atomic building block of great density. Its diameter is of the order,  $1 \ge 10^{-13}$  cm. The smallest cube that will contain the proton has a volume of  $1 \ge 10^{-39}$  cm.<sup>3</sup>; and a spherical pile consisting of  $6.06 \ge 10^{23}$  of these cubes will weigh a gram, and have a radius of  $4.88 \ge 10^{-6}$  cm. Place two such one gram masses of protons adjacent to one another, the centers of the two spherical piles, a and b, Fig. 1, being one cm. apart. The two parallel planes, c and d, introduced to simplify the discussion, bisect these spheres; and the small cylinder, indicated by the dotted lines, extending from plane to plane, contains one

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half of each sphere. In other words, the free space in the cylinder has been reduced by an amount equal to the volume of a one gram spherical pile of protons. As a consequence, the ether fluid flowing between the two bodies is accelerated by these obstructions proportionate to the lessened free space in the cylinder. Likewise the ether's velocity increases proportionate to the shortening of the free space across the throat of the constriction, the shortening of the distance being from 1 cm to  $(1-2 \times 4.88 \times 10^{-6})$ , or 0.99999024 cm.

This number is slightly in error because the two piles of protons are not solid masses of matter, but are composed of particles which we here assume to be spherical. The ether will therefore freely penetrate the piles in proportion to their porosity. Since the protons themselves, if spherical and solid, occupy only two thirds of the space in their immediate region, recalculation shows that the effective width at the constriction is roughly 0.999994 cm., and the velocity of the ether stream at the throat is 2.9978 x  $10^{10}$  / 0.999994 = 2.99782 x  $10^{10}$ cm./sec. This figure is still somewhat in error for, according to the theory proposed in the first paper, all ultimate particles are vortices in the ether, and the charges which such particles carry are due to the flow of the ether stream through the properly oriented vortices. However, the uncertainties of the problem force us to neglect the correction for this type of porosity.

Nevertheless, there is another correction that requires attention. If the measurements under consideration were made on this planet, the two masses of protons would be in motion relative to the ether because of the earth's spin, orbital motion about the sun, and migration toward the northern constellation of Cygnus (2), as is brought out in the second section of this paper. This motion would reduce the relative velocity of the ether past the two bodies, and lessen the "force of attraction" between them. With this in mind, we deduct  $3.5 \times 10^7$  cm/sec., the velocity of the two bodies due to the earth's spin, orbital motion, and drift toward Cygnus, from 2.998 x  $10^{10}$  cm/sec., the theory's assumed velocity of the ether stream, obtaining 2.9945 x  $10^{10}$ cm/sec. as the velocity of the ether stream relative to the two bodies. Then the velocity of the ether stream at the throat of the constriction will be 2.9945 x  $10^{10}/0.999994$  cm/sec.

The Bernoulli equation may take the form,  $p - P = (1 - 1)^{-1}$  $v^2/V^2$ )  $\rho V^2/2$ , or, p - P =  $(V^2 - v^2) \rho/2$ , where P and V represent respectively the pressure and velocity of the fluid at some distance, p and v the pressure and velocity at some other point on the same stream-line, say at the throat, and  $\rho$  is the density of the fluid. However, in the absence of other objects, there will be no important constrictions on the far sides of the two bodies. and P will then be also the pressure on the far sides tending to force the bodies together. Now it is our contention that, after multiplying both sides of the Bernoulli equation by (unit cm<sup>2</sup>) to change the dimensions to that of force, the p - P term should equal the gravitation constant, 6.66 x 10-sdyne. However, since P > p, the p - P term is negative in sign. So by substituting the required quantities in the equation, and solving for  $\rho$ , we have,  $\rho = -6.66 \times 10^{-8} \times 2/(2.9945 \times 10^{10})^2 - (2.99452 \times 10^{10})^2 =$  $1.21 \ge 10^{-23} \text{ g/cm}^3$ .

#### Part 2

## THE WAVE LENGTH OF PHOTONS EFFECTING ATOMIC MOTION

It is well known that atomic and molecular motion, wherein heat makes itself manifest, is initiated most characteristically by radiation from the infrared band, but the mechanism by which radiant energy brings about this motion has escaped discovery. Recently, however, the author of this paper succeeded in visualizing a mechanism to account for atomic motion (3), and he proposes now to test the validity of his theory of heat and motion by observing whether a study, closely adhering to the tenets of the theory, leads to the conclusion that it is infrared radiation that produces the atomic motion. It is quite true that atomic motion may result from the absorbtion of radiation other than infrared, especially in black body absorbers. Nevertheless infrared radiation is definitely to be classed primarily as a source of heat.

In order to estimate the wave length of the radiation which causes atomic motion, the temperature, mean free path and mean velocity of the atom under consideration being known, we resort to the use of the concept, "parasite drag", an aerodynamic term which one might say loosely designates the force of the wind against a bluff body, tending to carry it down-wind. Quantitatively the term is defined by the equation (4),  $D_p = 0.5 \times C_p \times \rho \times V^2 \times A$ , where  $C_p$  is the dimensionless coefficient of parasite drag,  $\rho$  is the density of the medium (air in aerodynamic studies), V is the velocity of the dragged body relative to the medium, and A is the body's cross-sectional area projected on a plane orthogonal to the stream. In this paper the postulated ether replaces the atmospheric medium of aerodynamics, and we assume that the laws of aerodynamics also apply in "ethodynamics", to coin a new term.

The theory proposed by the author asserts that vortices in the ether stream are to be identified by their frequencies of rotation as photons, i.e., corpuscles of radiation, electrons, neutrons, etc. Also, the stream is conceived to have the ability to accelerate quickly, and drag along with itself at its own constant velocity c, the relatively voluminous and almost massless photons, in somewhat the same fashion as autumn leaves are blown by the wind. But denser bodies, such as atoms, do not accelerate rapidly. However, if there are photons attached to the atoms, or combined with them in a loose chemical fashion, (this is equivalent, in conventional language, to saying the atoms possess energy), they accelerate more rapidly. Thus, all atoms whose temperatures are above  $0^{\circ}$ K have attached to themselves one or more photons, and in consequence of this, are in ceaseless motion.

A military illustration of an effect not unlike the one related, is that of a paratrooper landing in a breeze. Unless the parachute collapses promptly, it may drag the trooper and his heavy equipment violently over the rough terrain, and be a serious hazard to life and limb. But once the chute has collapsed, and its dragging force vanished, the trooper suffers no ill effect of the wind's drag on his own person, for his mass is considerable compared with the projected area of his body. In this fashion the theory seeks to account for the motion of material bodies.

To apply the concept of parasite drag to the problem, we consider the behavior, at standard conditions, of a helium atom to which photons are attached. When the atom-photon assemblage accelerates from a state of rest to one of motion, it does so because of the action of some force,  $\mathbf{F} = \mathbf{ma}$ , whose magnitude is measured by the acceleration and mass of the helium atom. Equating F and  $D_p$ , one writes,  $C_p \ge \rho \ge V^2 \ge A/2 = \mathbf{m} \ge a$ , and  $\mathbf{A} = 2 \ge \mathbf{m} \ge a \ge (C_p \ge \rho \ge V^2)$ . Hence by evaluating the right hand terms, the area of the photons will be known.

In aerodynamics, the value of  $C_p$  for bluff bodies, in contrast with those having streamline contours, may be approximately unity (4). In lieu of better information, we shall adopt this figure. The mass of the helium atom is found in the usual way,  $4/(6.06 \times 10^{23})$  g. The velocity of the helium atom at 273.1°K relative to the ether stream is estimated as follows:

| a. | 44000 | cm./sec., | velocity | of | f th | ie he | elium  | at | om, | at   | $\mathbf{rest}$       |
|----|-------|-----------|----------|----|------|-------|--------|----|-----|------|-----------------------|
|    |       |           | relative | to | the  | eart  | n, due | to | ear | th's | $\operatorname{spin}$ |
|    |       |           | on axis. |    |      |       |        |    |     |      |                       |

- b. 2960000 cm./sec., velocity of helium atom, at rest relative to earth, due to earth's orbital motion around the sun.
- c. 32000000 cm./sec., velocity of helium atom, at rest relative to earth, due to solar system's drift toward the northern constellation of Cygnus (2).
- d. 120000 cm./sec., velocity of helium atom relative to earth at 273.1°K. This is the atom's mean velocity.
- e. 35120000 cm./sec., velocity of helium atom at 273.1°K, relative to a three dimensional axis system, origin at Cygnus.

f.  $c - v = V = 2.998 \times 10^{10} - 3.51 \times 10^7 = 2.9945 \times 10^{10} \text{ cm./sec.}$ , velocity of helium atom at 273.1°K, relative to the ether stream, or reciprocally, the velocity of the ether stream relative to the helium atom. For the present we shall consider the northern constellation of Cygnus fixed in space.

Item (a) in the preceding paragraph, depends on the latitude; but maximum latitude change would affect the final results only to the extent of one in  $10^{\circ}$ . Item (b) is a variable quantity, and affects the results only 1:10000. Item (c) may lack precision, but to omit it altogether would affect the results to the extent of only 1:1000. Item (d), the mean velocity of the helium atom at 273.1°K, even if doubled to represent a possible maximum velocity, can affect the final result only 1 : 300000. If then, those enumerated are the only types of motion to be considered, the value,  $V = 2.9945 \times 10^{10}$  cm./sec., is to be regarded as the velocity of the ether stream relative to the helium atom.

In order to estimate the acceleration, a, of the helium atom, we discard kinetic theory's pure assumption that the collisions are perfectly elastic, and instead, assume that they are perfectly inelastic. Thus we assume that when a helium atom collides with another body, it stops; and it regains velocity chiefly by virtue of the drag of the ether stream on the photons attached to the atom. This description is believed to be in accord with known fact. For example, at  $0^{\circ}$ K, the atom, lacking photons, fails to accelerate.

The magnitude of a helium atom's kinetic energy in one direction may be stated in the terms,  $E = mv^2/2 = kT/2$ . It is immaterial whether the velocity, v, is constant, or is merely a momentary value reached during acceleration. That is,  $E = mv^2/2 = m(L/t^2)L/2 = maL/2 = kT/2$ . Hence, its acceleration is, a = kT/mL, where k is the Boltzmann constant, T is the temperature, and m and L, for our purposes, are respectively the mass and the mean free path of the helium atom at standard conditions. Substitution of numerical values yields,  $a = 1.37 \times 10^{-16} \times 273.1 \times 6.06 \times 10^{23} \times 4^{-1} \times 2.51^{-1} \times 10^{5} = 2.26 \times 10^{14} \text{ cm./sec}^2$ .

It is necessary to comment briefly on the use here made of the term,  $L = 2.51 \times 10^{-5}$  cm., the mean free path of the helium atom. It is assumed that the atom, starting from a state of rest, accelerates constantly along the mean free path until, at the end of this path, the instantaneous velocity,  $v = 1.2 \times 10^5$  cm./sec., or the mean velocity, has been reached. At this point the atom normally collides, and the cycle starts again. In other words, whereas classical kinetic theory assumes that the atom, traveling at constant velocity, v, collides, stops, rebounds, and immediately is again traveling at the same constant velocity, v, this theory assumes that the atom, after being stopped in a collision, constantly accelerates until it again collides; and it never acquires a constant velocity until it has accelerated to the velocity of light. This latter state cannot be realized except in the



absence of all interference, as in the perfect vacuum of internebular space, where such a speed, as suggested earlier (3), heralds the birth of a cosmic ray.

Now, since all the terms are known, the value of A can be calculated thus:  $A = 2 \times 4/(6.06 \times 10^{23}) \times 2.26 \times 10^{14} \times 1/$  [1.2 x  $10^{-23} \times (2.9945)^2 \times 10^{20}$ ] = 2.75 x  $10^{-7}$  cm.<sup>2</sup>, area of all photons. Let A' = area of one photon. Then nA' = A. Let  $n_{273.1} = 273.1$ . By this we mean the following: let us simply guess that the distribution of photons is one photon per atom per degree change of temperature. This arrangement leaves the atom devoid of photons at  $0^{\circ}$  K. Then  $A/n = 2.75 \times 10^{-7}/273.1 = A' = 1.007 \times 10^{-9}$  cm.<sup>2</sup>, the area of one photon.

In estimating the wave length  $\lambda$  of this photon whose area we have just calculated, we recall the assumption made by the author (1) that a photon, like sub-atomic particles, is an ethereal vortex whose force impulse, as the photon is dragged through space at velocity c, traces a wave-like path, as illustrated in Fig. 2, wherein the force-impulse, a, of the disk-like photon, b, traces the wave-like path, c, of wave-length,  $\lambda$ . By the time the ether stream has dragged the photon from x to y, the point, a, will have reached the point, a', and the overall result will be equivalent to rolling the disk one revolution along the line, d - e. Hence the circumference of the photon equals the wave-length  $\lambda$ . Then A' =  $\pi$  r<sup>2</sup> = 1.007 x 10<sup>-9</sup>; r = (1.007 x 10<sup>-9</sup> x  $\pi^{-1})^{\frac{1}{2}}$ ; and 2  $\pi$  r =  $\lambda$  = 2  $\pi$  (1.007 x 10<sup>-9</sup> x  $\pi^{-1})^{\frac{1}{2}}$  = 1.13 x 10<sup>-4</sup> cm., or 1.13 $\mu$ .

Since the infrared, or heat rays, are said to extend in the electromagnetic spectrum from 0.8  $\mu$  to 420  $\mu$ , the result just found indicate that our surmise as to the distribution of photons, i.e., one photon per atom per degree change in temperature, was

26

probably correct, for the value, 1.13  $\mu$ , lies within this band. In this connection it is also worth observing that the area of the photon, 1.007 x 10<sup>-9</sup> cm<sup>2</sup>., where  $\lambda = 1.13 \times 10^{-4}$ cm., is  $1.3 \times 10^{17}$  times as large as the cross-sectional area of the helium nucleus. Hence the drag of the ether on the attached photons will be enormously greater than that on the nucleus alone. It is also an essential part of the theory that the ether stream flows freely through the outer part of the atom where the electrons are located. For this reason, the cross-sectional area of the drag of the ether stream on the atom stripped of photons, but rather the projected area of the much smaller nucleus, together possibly with the cross-sectional area of all the electrons.

#### Part 3

## THE GAS CONSTANT. AN ANOMALOUS DOPPLER SHIFT.

The classical derivation of the gas constant was guided by kinetic theory, and consequently employed constant molecular velocities. Since the author of this paper has reason to doubt that atoms and molecules have constant velocities, and suspects that they have changing velocities and constant acceleration, it is desirable to derive R through the use of atomic acceleration. This will be done by employing the language and logic of the two preceding sections.

Consider one mole of helium at standard conditions, and, anywhere within its bulk, select a small cubical portion, L cm. on the edge, containing  $N_o \propto L^3/22400$  atoms, where L is the mean free path, and  $N_o$  is the Avogadro number. Attached to each atom are 273.1 photons (See Part 2) which accelerate the atom through ether drag, and the force applied by the ether stream equals that which the accelerating atom, because of inertia, exerts in the opposite direction. To avoid confusion, this article will hereafter confine its attention to the force of the atom, even though the ether is to be regarded as the prime mover. With this in mind, we fix our attention first on the gas in the small cube.

The mean acceleration, a, of the atoms in space may be resolved into three component accelerations,  $a_x$ ,  $a_y$  and  $a_z$ , referred to a three dimensional co-ordinate system with axes x, y and z; thus  $a^2 = a^2_x + a^2_y + a^2_z$ . As the number of molecules is very large, one may say without sensible error,  $a^2_x = a^2_y = a^2_z = a^2/3$ , and the acceleration of atoms parallel to the

x-axis,  $a_x$ , equals  $a/3^{\frac{1}{2}}$ . Then the force exerted by one helium atom toward one side is,  $4/N_0 \ge a/3^{\frac{1}{2}}$ , and the force exerted by 1/6 th, the total number of atoms toward the same side is,  $4/N_0 \ge a/3^{\frac{3}{2}} \ge L^3/22400 \ge N_0/6$  dyne. Dividing by L<sup>2</sup>, the area of the side, gives,  $4/N_0 \propto a/3\frac{1}{2} \propto L^3/22400 \propto N_0/6 \propto L^{-2} = p$ dyne/cm<sup>2</sup>. Now multiply by L/L, or unity, and have,  $4/N_0$  x  $a/3^{\frac{1}{2}} \ge L^{\frac{3}{2}}/22400 \ge N_0/6 \ge L^{-2} \ge L/L = p$ . Since  $L^2 \ge L = v$ , the volume of the small cube, we may multiply both sides by v, and obtain  $4/N_0 \ge a/3^{\frac{1}{2}} \ge L^3/22400 \ge N_0 \ge L/6 = pv$ . This operation leaves on the left the mass of 1/6 th, the helium atoms in the cube, multiplied by the acceleration of each atom, times the distance each atom travels between collisions, i.e., the mean free path, vielding ergs, or work, and equals pv. On multiplying both sides by 6, we have,  $4/N_0 \ge a/3^{\frac{1}{2}} \ge L^3/22400 \ge N_0/6 \ge L \ge 6$ 6pv = p'v', the work done by all the atoms in the cube during the time they travel the mean free path. But the main bulk of gas contains  $22400/L^3$  small subes. Hence,  $4/N_0 \propto a/3^{\frac{1}{2}} \propto$  $L^{3}/22400 \ge N_{0}/6 \ge L \ge 6 \ge 22400/L^{3} = 22400/L^{3} \ge p'v' = PV$ ergs, the work done by a mole. Canceling,  $4aL/3^{\frac{1}{2}} = PV$ . But experimentally, PV is proportional to T. Hence PV = cT, where c is a constant. Then  $4aL/3^{\frac{1}{2}} = PV = cT$ , and  $4aL = 3\frac{1}{2}cT = RT$ , where  $3\frac{1}{2}c = R$ . Hence, 4aL/T = R. Now, from Part 2, a =2.26 x  $10^{14}$  cm./sec.<sup>2</sup>, and L has the value 2.51 x  $10^{-5}$  cm. Therefore, 4 x 2.26 x  $10^{14}$  x 2.51 x  $10^{-5}/273.1$  = R = 8.3 x  $10^{7}$ ergs/mole/degree. Closer agreement with the accepted value,  $8.31 \times 10^{7}$ , awaits more precise knowledge of atomic mean velocity, and mean free path.

Naturally, R divided by  $N_o$ , yields  $1.37 \times 10^{-16}$  erg/atom/ degree, the Boltzmann constant. However, the figure,  $1.37 \times 10^{-16}$ , may have another significant interpretation. We may write,  $4/6.06 \times 10^{-23} \times 2.26 \times 10^{14} \times 2.51 \times 10^{-5}/273.1 = 1.372 \times 10^{-16}$ erg/atom/photon. Here we have multiplied the mass of one helium atom by its acceleration, and its mean free path, to obtain erg/atom. If each atom has 273.1 photons attached to itself at 273.1° K. then the quotient gives ergs per atom accomplished by the dragging effect of the ether on one photon.

Questions occur when contemplating the problems under discussion. For example: what becomes of the atom's energy at the time of collision? This paper does not insist that absolutely all atomic collisions are entirely inelastic. Occasionally some energy may be passed on to the struck atoms. However, it appears that most of the energy built up by the acceleration of the atoms is completely destroyed when the atom stops. How
then can this view be made to harmonize with the common belief that energy is conserved? The answer is that photons are conserved; then, after collision, the ether stream again accelerates the atom-photon assemblage to replace the lost energy. But, while the atoms accelerate, the ether decelerates. However, the rate of deceleration is slow. Taking the radius of the observable universe to be 500 million light years (5), a distance undoubtedly far short of the unobservable limits, the mass of ether filling the corresponding sphere is  $5 \ge 10^{57}$  grams, a quantity  $10^{30}$  times that of the earth. Since the velocity of the ether is c. its kinetic energy is of the order,  $10^{58}$  ergs. Little matter stands in the way to oppose the ether's progress. Although the ether's own momentum, plus that of photons in flight, is sufficient to keep it going for a great period of time, nevertheless, a slow retardation is inevitable. If this is true, light reaching us now from the outer boundaries of space, is traveling slower now than it did when setting out.

The deduction just reached, that the speed of light may be less now than it formerly was, has a bearing on an important problem in astronomy. The Doppler effect is counted on to detect the approach or recession of heavenly bodies. It is disturbing then to discover with the newer instruments that the most distant nebulae show only the red shift, increasing directly with distance, indicating that these bodies are receding without exception. Do these Doppler effects represent, in fact, recession of the nebulae, "or the action of some hitherto unrecognized principle in nature"? (5). The deductions to follow tend to discredit Doppler shifts if the radiation investigated originated in the most distant regions.

Let the wave length of a photon,  $v = mc^2/h$  at the time of emission, be measured when the light reaches the earth at the termination of the photon's journey from the outer regions of observable space, a distance of some 500 million light years (5). The measurement showed,  $v_1 = mc^2_1/h$ , where  $c_1$ , the velocity of light at the present time, is less than c, the velocity of light at the time the photon set out, because of the deceleration of light. The wave length of another photon is examined at the same time. The second photon, emitted during an atomic energy change identical with that which occurred when the first photon was emitted  $5 \times 10^8$  years earlier, arrived after only an eight minute journey from the sun. The frequency of the second photon is,  $v = m_1c^2_1/h$ ; that is, its frequency is identical with that which the first photon had when it was measured at the end of its long journey. Of necessity, the mass, m, of the first photon is less than  $m_1$ , the mass of the second, because, at the time of emission, both had the same frequency, and  $c > c_1$ . Hence  $v_1$ , the frequency of the ancient photon at the time of its arrival on this planet, is found to be less than  $\nu$ , the frequency of the 8-minute-old photon, even though the two frequencies were equal at the time of emission.

The argument just presented accounts then for a red shift which is not due to a receding emitter. The value of the conclusions, of course, depends on whether the speculations, relative to the ether and the deceleration of light, have their foundations in truth. Indeed, it is the purpose of this paper to investigate the verity of the ether theory; and the fact that the theory, in Part 2, finds that atomic motion is initiated by infrared radiation, and now, in Part 3, discovers a fairly satisfactory explanation of an anomalous red shift, is an accomplishment which, in a small way, helps to establish the truth of the ether theory.

The use, in Part 3, of the quantity,  $a = 2.26 \times 10^{14}$ Note. cm./sec.<sup>2</sup>, as found in Part 2, is illogical because k, the Boltzmann constant, which is related to R through N<sub>o</sub>, entered into the calculation of a. However, the estimation of R, as carried out in Part 3, is not without value, for it indicates that a, discovered by any other method not involving k, would yield a figure for R identical with that found. A rather rough approximation of a, but one avoiding the use of k altogether, follows.

One may write,  $a = L/t^2$ , for accelerating particles, and t = L/v, for non-accelerating particles. Kinetic theory regards the quantity, v =  $1.2 \times 10^5$  cm./sec., as the mean velocity of helium atoms at standard conditions. Then t =  $2.51/(10^5 \text{ x } 1.2 \text{ x})$  $10^{5}$ ) sec. is the mean time required for the atom to travel the mean free path L at constant velocity. But whether the atom moves at constant velocity, or starts from rest and reaches the velocity v by acceleration, the time required for either journey over the mean free path will be of the same order of magnitude. Hence one may substitute this value of t into the first equation and have without great error,  $a = 6 \ge 10^{14}$  cm./sec.<sup>2</sup>. This rough value of a, obtained without using k, compares quite favorably with the more precise figure obtained in Part 2.

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## LEAF GLANDS IN AILANTHUS ALTISSIMA\*

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Two types of leaf glands are present in *Ailanthus altissima*: (1) simple glands that are scattered over the surface of young leaflets and are the outgrowths of epidermal cells, and (2) more specialized glands found along the basal margins of the leaflets.

Although the epidermal glands are dispersed over the surface of the leaflets, they are more abundant along the veins. These simple glands are either one-celled hair-like projections of epidermal cells, or many-celled knob-like growths which arise by the division of epidermal cells.

The first indication of a simple gland, regardless of type, is the outward arching of an epidermal cell. This takes place when the young leaflets are from 0.10 to 0.130 millimeters long. The initial arching shows that a gland is in the process of formation but does not indicate the kind. The nucleus which is large and stains heavily appears to have this controlling influence. If the nucleus does not divide, the cell continues to elongate and produces the simple single-celled tubulary trichome, but if division of the nucleus occurs, a many celled knob-shaped gland develops.

In the hair-like glands, illustrated in figure 1, the outward growth continues until at maturity they vary from 0.07 to 0.32 millimeters in length. The young gland possesses a thin wall and a single large nucleus, but at maturity the wall thickens (0.0012-0.0015 millimeters) and the nucleus disappears.

The planes of the first cellular divisions of the many-celled epidermal glands are parallel and form the stalk (2-6 cells) while the remaining divisions which occur in different planes form the knob-like head. The growth of this type of gland is shown in figures 2, 3, 4, and 5. These glands vary from 0.020 to 0.192 millimeters in length and contain 4 to 56 cells. Both kinds of epidermal glands lack a vascular system, so the growth materials are obtained from the surrounding leaf cells. The secretion filters through the wall of the gland and evaporates from the surface. This method of secreting has been observed in three species of *Pelargonium* by Hannig.<sup>1</sup>

Specialized leaf glands appear as small visual masses of secretory tissue on the auriculiform teeth at the base of the leaflets

<sup>\*</sup> Received for publication January 15, 1946.

(figure 6). Statistical studies of one thousand leaflets show that the glands vary from 1 to 8 for each leaflet, with an average of 2.606.

The shape and external features of the marginal gland are illustrated in figure 7. The outer surface is spherical with a small depressed opening near the center. Each gland is supplied by one or more veins that pass into the tooth.

Microscopic examinations of expanding leaf buds show that marginal glands first appear on the tenth unit. Twelve per cent of these leaves show glands, while all leaves developing after the tenth possess glands (figures 8, 9, 10, and 11).

In studying the position and structure of glands in members of the family *Simarubaceae*, Solereder states: "So far as I know, the marginal leaf glands in *Ailanthus* have not as yet been examined in detail." <sup>2</sup> Figure 12 is a drawing of an auriculiform tooth made from a series of photomicrographs which shows a cross-section of a normal mature marginal gland. The glandular area is large and distinct from the remaining tissues of the tooth. The epidermal cells of the glandular portion of the tooth are elongated and lack uniformity in shape that are characteristic of normal cells. The opening in the center of the gland is produced by the breaking of the epidermal layer in this area. The short cavity which is present below the opening is formed by the parting of secreting cells.

The actively secreting cells are spindle-shaped, polygonal and rather uniform, and in mass appear to converge toward the cavity. The marginal cells of the gland are more granular and deeply stained than the surrounding non-glandular cells.

The vascular system which extends into the tooth passes along the margins of the secreting area but does not enter it. The secretion passes from cell to cell until the border cells secrete it into the cavity.

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Fig. 1. A small section of the surface tissue of a young leaflet showing the position and manner of growth of a hair-like gland.

- Figs. 2-5. Illustrating four stages in the development of a many-celled epidermal gland.
- Fig. 6. Two leaflets from a mature leaf showing the position of the marginal glands on the basal portion of the leaflet.
- Fig. 7. Enlarged section of the basal part of a leaflet showing the position of the marginal glands and the distribution of the vascular systems to them.
- Figs. 8-11. Showing the 9, 10, 11, and 12 units in the budscale-leaf series and indicating the stage at which the marginal glands appear.
- Fig. 12. Section through a marginal leaf gland showing the vascular distribution, secretory tissues, secretory cavity, and the ostiole.



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## TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

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## CONTENTS

| Editorial:  |    |
|---|----|
| A more active Academy. Alfred Brauer  | 2  |
| Science in Society. Paul Kolachov   | 5  |
| Studies on flavone-like substances isolated from tobacco.<br>Anna Shoulties Naff and Simon H. Wender                    | 10 |
| Effect of glucose upon the viability of Lactobacillus casei.<br>Mary Muedeking  | 14 |
| Research Notes:   |    |
| A note on the elimination of <i>Endamoeba coli</i> in the human host.<br>David Richard Lincicome and Robert Arthur Gold | 17 |
| Occurrence of Neoechinorhynchus emydis (Acanthocephala)<br>in Snails. David Richard Lincicome and Allie Whitt, Jr.      | 19 |
| News and Notes  | 20 |
| Abstracted Minutes of 1944 and 1946 meeting of the Kentucky<br>Academy of Science                                       | 22 |

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## TRANSACTIONS

of the

## KENTUCKY ACADEMY OF SCIENCE

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DR. ALFRED BRAUER President, Kentucky Academy of Science, 1947-48

## EDITORIAL

## A MORE ACTIVE ACADEMY

The Kentucky Academy of Science, one of about thirty-five such state or regional societies, endeavors to carry the torch of scientific enlightenment within its environs. Its purpose is to advance science by investigation and by the dissemination of discovered knowledge. It has a membership of slightly over 300, and among these are a representative number of the State's outstanding research men and scholars. Among its members are also a considerable number who advance its cause as teachers, or as community, or as industrial leaders. The Academy's scientific accomplishments are presented, and its business largely transacted at the one annual meeting. Also at this meeting, its new business for the coming year is initiated, and, in the brief period of about one hour, this is presented, discussed, and legislated. Whatever legislation is enacted is turned over to the Executive Committee for execution.

Although most of its members thoroughly believe in the Academy and its purposes, this is no indication that they think the Academy is all it should be. Almost all of them can see its shortcomings. Individually its members believe in it to the extent that they can help to make it the kind of organization they most desire.

In this column I wish to point out some failings which can be corrected, but first, as one who has been a member of the Executive Committee for several years let me come to the defense of that body and thereby attempt to disqualify one of the criticisms most often directed at it and at the Academy as a whole.

It is not entirely correct for example, that we go to the annual meeting, hear some papers presented, initiate some business, and then proceed to forget about it till the next annual meeting. The members of the committee have their work to do, and as your representatives feel their responsibilities and do their utmost to do the work with which they are charged. On numerous occasions, and especially during the war years. the committee not only executed duties, but initiated and set tasks for itself. Briefly this work consisted of letters to congressmen and senators first, in regard to the scientific manpower bill, and second, in regard to the eternal question of opening national preserves to exploitation. It initiated a new measure in regard to conservation within the state and contributed to the work of the Committee for Kentucky. It initiated and set in motion a study on the conditions under which science is taught in secondary schools, with the motive of improving them. To go into further detail theseregarding movements here would be missing the real point of this communication, so, let me also point out wherein we have failed and, if possible, how we can make improvements.

First: we have not yet scratched the surface of possibilities in obtaining sustaining memberships which are so necessary for carrying out the work of the Academy. These are open to educational and industrial institutions, to their departments, or to their libraries. In return for each membership of this kind all the privileges of the society are granted namely, a voting membership and subscription to the **Transactions**.

The possibilities in this direction are endless, and the ease of obtaining them makes us wonder why we have not ten times the present number. The only thing lacking here is a little effort, not only on the part of the salesman, but also on the part of those who present research and do not make it available for publication, on the part of those who have research but do not present it, and finally on the part of those who have charge of the publication of the Transactions. In other words when we sell such a membership, it is positively necessary that we fulfill our obligations in the contract, and give something in return for the membership.

Second: bring into the Academy a greater number of workers from industrial research laboratories, where so much is done in the application of science, as well as in making real fundamental discoveries. In obtaining these memberships we could approximately double our present membership.

Third: bring into affiliation with the Academy other scientific associations. We do not have adequate representation from several engineering societies, for example.

Semiscientific societies are often interested in, and worthy of membership. In this category are natural history groups, astronomical study groups, groups for the study of physical sciences. The Academy can aid such organizations in much the same manner it does the Junior Academy, and in so doing, can advance science by the dissemination of knowledge.

Fourth: do a great deal more than we are doing toward conservation of resources generally. This is a broad term, and we are sometimes not in harmony with one another as to its real meaning. Here we have reference to mineral, land, and biological conservation. In connection with the latter, there are many representatives of fish and game societies who have learned what constitutes the fundamentals of their chief interests, and would be interested members of the society.

Fifth: greater productiveness on the part of all members is highly desirable. Lack of this is now reflected in the number, if not in the quality of papers presented at the annual meeting. In the past, from 1938 to 1942, between 40 and 60 papers were read at meetings at Morehead, Richmond, Lexington, and Louisville. These were divided among six divisional meetings. At Louisville and at Morehead, demonstrational meetings were also successful. Since that time and especially since the war, there has been a dearth of papers. At the last annual meeting at Bowling Green, only three divisional meetings were held, and 15 papers were read. The Biology division arranged a program only during the last week before the meeting when it was discovered that an insufficient number of papers were forthcoming from its membership to hold a meeting of the division. This was the only time in over fifteen years that this division had even approximated failure.

## A More Active Academy

Otherwise the meeting might have been very successful, since about 140 members and their guests from outside the host city participated in the meetings. Productiveness on the part of the younger members would be especially encouraging and stimulating. If you have something worth while, get it on the program and present it.

Finally, if you would like to see the Academy function as it should between annual meetings, and if you have ideas for making it more vigorous, bring those ideas to the business sessions and present them either in the form of motions, or in the form of resolutions which can be legislated in the same manner as motions. If carried, they will be executed during the year if at all possible. Herein all members can take a part whether or not they ever present a research paper. Resolutions may be presented by any member even though he is not on the resolutions committee, and in the past some of the most worth-while actions of the Academy have resulted from them.

> ALFRED BRAUER President, Kentucky Academy of Science

## **SCIENCE IN SOCIETY\***

PAUL KOLACHOV Technical Counselor Jos. E. Seagram & Sons

No doubt this eminent Society of Kentucky scientists did not know what they were letting themselves in for, when they elected this "crazy Russian" to be their president—not only a "crazy Russian" but a fermentologist at that! So if I trouble you with problems and keep you in a state of "suspended fermentation" do not blame me—but blame yourselves!

Since August of last summer when atom bombs fell on two Japanese cities, science has been forced to face social and political responsibilities of staggering proportion. In many places and on many levels, men of science who think in terms of humanity are searching their minds and are coming to certain conclusions with regard to this historic challenge; among such men is Dr. A. J. Carlson, distinguished Professor of Physiology at the University of Chicago. In his address as the retiring president of the American Association for the Advancement of Science delivered at St. Louis on March 27th of this year, Dr. Carlson made these solemn remarks:

"On the basis of my understanding of man and acquaintance with human history, I have ... advocated in the past that a man's social responsibility is commensurate with his understanding of man and nature ... Men of science are urged to 'knock at the door of politics' ... I think that our social responsibility compels us to knock at this door not only as individuals but as organized professional people." But Dr. Carlson is not alone in his opinion. Indeed scientific societies in many centers are stepping upon the economic, the industrial, and the political scene. As you no doubt know there is "fermentation" for a National Science Foundation whose duty would be to promote fundamental and basic sciences for national defense, for public health, for better use of national resources.

In the past, science has been the pioneer in society and economics and politics have followed. But I venture to predict that since the release of nuclear energy, science will examine very carefully the social consequences of its inventions. It will ask itself continuously WHAT IS THE FUNCTION OF SCIENCE IN SOCIETY?

Now I am proud to say that in our own state of Kentucky, science is not alone in social progress. Two organizations which are not afraid to face facts have been started within the past two years: one is the Postwar Advisory Planning Commission of Kentucky, created by Executive Order of our Governor; the other is the Committee for Kentucky, a voluntary fact-finding committee.

The Postwar Advisory Planning Commission of Kentucky was created to study and investigate the physical and human resources of the state and make plans and recommendations for the full development of such resources for the aid of agriculture, labor, manufacture, mining, transportation, conservation, and all other interests of the state.

Here in our commonwealth the

<sup>\*</sup>Address of the retiring president, Kentucky Academy of Science, April, 1946

very door of government is opening to science and certainly it is our duty and opportunity to walk in and offer our services. This hour contains a challenge of great good; if we let the hour pass, we do not deserve the name either of scientist or Kentuckian.

Now what are the jobs to be done as set forth by the two fact-finding groups of aroused citizens; let me note but a few—the rehabilitation of veterans through training, education, and jobs. There is the complex of public interest programs, as health, conservation of natural resources of all kinds, water supply, natural gas, electricity, forests, and mines. There is the challenge of inadequate education! Lastly because I like to press home the point—the many unsolved problems of agriculture.

Even if we had no social conscience, still long-view selfishness would demand that soil conditions be improved, that new crops be developed, that old crops be brought into balance, that surplus crops be processed and saved, not wasted.

As we all know, Kentucky is a state of contrasts: in the Bluegrass region the product value per acre is about twice that of the national average per acre. Yet on the basis of value PER PERSON engaged in farming, Kentucky falls near the bottom of the list of states. In other words, we have some of the most valuable farm land in the whole United States, yet we have some of  $\mathbf{the}$ most impoverished farmers. Since in a democracy, the HUMAN element counts most, it is the work of science to improve agriculture so that the standard of living for farm families can be raised.

We cannot delay this kind of job; improvement must be made and made **right now**. World famine would never have come about if internationally, men of science had given their energies to the welfare of mankind instead of being forced to invent methods of destruction. So then, while there is yet time, let us make Kentucky a commonwealth laboratory where science and government work hand in hand for the betterment of all.

In the past, society expected a great lag between scientific discovery and practical application. In this regard, I like to recall my own experience with the Russian dandelion named KOK-SAGYZ from which rubber can be produced. When I started to talk about this back in 1941, I was laughed at by official agriculture. Now in February of 1946, in the first draft of the Inter-Agency Policy Rubber Report the following appears on pages 40-41: "Seeds of the Russian dandelion, a plant used as a rubber source by the U. S. S. R., were flown here in 1942. The Department of Agriculture has not yet had the time fully to explore the potentialities of this plant. Such research as has been conducted experimental plantings with indicates that rubber from Russian dandelion is of better quality than guayule . . . Government research on plant improvement and cultivation of guayule and Russian dandelion should continue." I merely mention this official apathy in getting started on such needed research and utilization as the sort of thing we should avoid in Kentucky. Slowness in making use of scientific improvements is an offense against our economy and welfare. We failed to develop native sources of muchneeded quinine — another example of national waste. During the war especially in the mechanical field, science was translated very quickly into practical application. What was done in war for the purpose of destruction surely can be done in peace-time in order for men to live —and live better. The world is too sick, too critically explosive for us to go to sleep—scientifically.

Perhaps you have been aware, ladies and gentlemen, that underneath my thoughts as expressed here today, there runs a theme: concern for the HUMAN element in society. Just what can science do to raise the HUMAN element? How can we, as men of science, help develop hightype individuals, the very base of our commonwealth? Since we are a democracy, that is the most fundamental of all our problems. I believe democracy is only workable where the citizens are secure economically and well-informed politically. Hungry people do not think straight; despair leads to tyranny!

How then can the Kentucky Academy of Science help raise the intellectual level of its fellow citizens?

Let me quote again from the speech of Dr. Carlson with regard to the function of science in the training of men's minds. He said:

"Men in science have or should have greater experience, training, and conditioning than the rest of mankind because the scientific method and scientific research demand absolute integrity, the absolute sticking to the facts as known or discovered."

As we must admit, men of science are not born more honest than other men, but by virtue of their training, they must face facts and draw conclusions from them. INSIDE the laboratory, at least, the man of science must be honest or his experiment will fail. This is the type of mental training which is one of the most valuable contributions of science to society. It is the kind of thinking needed most urgently in state, and national, yes, and even in international fields. Wishful thinking will not built a new world; but science can start a sound framework. Let me add here, I believe that without social conscience science ends in destruction of society-as witness Germany. But social conscience without science is also a Our democracy is grave danger. very subject to the troubles rising from a conscience without knowledge of HOW to implement that conscience. Only confusion can result from this, as we Americans know bitterly.

Implementing social conscience is not always easy. The man of science, when knocking at the door of politics, often finds himself speaking a different language from the administrator and the statesman. The statesman and the politician may look upon us as "odd ducks" or "old fogies".

Why this gulf between us?

Let us examine our education and try to discover if there is some lack that explains this lack of understanding. After examining the curricula of many colleges, I am forced to the unhappy conclusion that the training of the scientist, even in the best schools, includes little or no awareness of the social consequences of his work. On the other hand, the education of the administrator and the politician is without sufficient information and adjustment as to the rapid changes taking place in our society because of scientific and technical discoveries and inventions. Here is a very serious inability of two vital parts of our society to

understand each other. For instance, read the arguments pro and con for giving or not giving out information on the atomic bomb.

But here, in the Commonwealth of Kentucky, we are in a very fortunate position. Our politicians, our industrialists, our economists have reached out the hands of co-operation to us. They have in their reports pointed out the jobs that are unfinished and that cry out to be We cannot hold back. done. We DARE NOT shun the challenge. Here, at least in Kentucky, we talk the same language-the language of social betterment for all our citizens. When we look abroad, we see the world standing on the threshold of a new era: progress untold, or utter destruction. Internationally, men of science must lead humanity into the good light of decency and progress; nationally, we must find the paths of health and stability; and inside our own state, we cannot rest until all "unfinished business" is taken care of-and in good measure.

My friends, the historians tell me that the word KENTUCKY means the "dark and bloody ground." That name was given to this region of ours because, being rich with natural resources, men gave their lives, shedding their blood to possess that wealth.

Much was lost in that battle. Man's greed was short-sighted. It is up to us, as the Kentucky Academy of Science, to lead the way in restoring their resources, and to increasing our wealth in order to raise the level of our state's standard of living. We cannot rest until Kentucky takes her place among the leading progressive states of the Union. Let us then change the name KENTUCKY from "dark and

bloody ground" to the **rich and ruddy** ground. This, then, must be our goal, function, our duty, in the society of Kentucky.

There is always the danger at meetings of this kind, particularly at meetings which come together but once a year, to ventilate noble sentiments, exchange opinions — and then afterwards to go home and forget all about it until next time. I do not want you to do this. As I said in the opening of my address, I should like to put you, my colleagues, into a ferment of activity with regard to Kentucky's problems and their solution.

To examine, to investigate, and to inform ourselves about statewide problems is not enough. We cannot be content to be mere paper scientists, with elegant plans inscribed on books and pamphlets. We want to get into action. So then, that is my program of "continuous cooking", if I may borrow a phrase from the institution where I have the honor of earning my bread—and sometimes a little refreshment on the side.

My opinion is that our Academy should come together oftener than once a year. At a time like this, when the world finds itself in a new era—The Atomic Age—certainly people like ourselves have to get together often enough to keep informed as to what is happening in science and society. Therefore, I suggest we consider how often we can meet, where we can meet, and if we should met by sections, or by communities.

I feel our state should be divided into various "problem areas" so we can apply ourselves to those problems and help get the jobs done. We should get to know the various members on the Postwar Advisory Planning Commission of Kentucky and the Committee for Kentucky and get busy with these men—so their postwar plans and their reports use the spark-plug of science. Thus we all can move forward faster together than any one group could, alone.

Another suggestion: I should like to see the Divisions of our Society be increased in number to include engineers of all types, sociologists especially those interested in rural problems, and experts in city planning and improvement.

Still another thought: industry should be stimulated to co-operate with science so that educational facilities in research and training can be stepped up greatly. Better education, more education is basic to all Kentucky problems. Industry will help science if it sees clearly that only in this way can it obtain the high-type personnel which  $_{\rm it}$ needs. No matter what product is made, its quality depends in large part on the integrity and skill of the men who make it. Our state is in great need of technically trained men to help solve our problemsyet the very men we need most go OUTSIDE the state for jobs. This is economic nonsense and we can't afford it! It is sound investment, not charity, for industry to help establish scholarships, fellowships, aid education in every way possible. The rewards will come back to industry -and in good measure. In a highly developed society, technical men

hold the key. If we are foolish enough to let public machinery get into the hands of dishonest or incompetent men—we are giving over the future into the hands of children —or worse.

Our Society then should have continuous vital contact with the industries of the state and make plans and programs to encourage new industries to come here and settle. This will enrich the state and in turn aid education.

To sum up: Let us meet more often; let us so organize our membership that we keep in touch with community problems in order to cooperate in their solution; let us report more often to the Society as a whole with regard to local and regional problems; let us work with industry in order to step up education within the Commonwealth. If we do follow a vital program such as this, I am certain we shall begin to feel new blood coursing in our veins; we shall sense the excitement and satisfaction of creating a Kentucky even better than the old. We should certainy keep the best of the old but let us infuse into it the finest of the new. As men of science we are well-equipped to help Kentucky make that transition-without dislocation, without class hate, without disaster. As I see it, to help lead the way into a better life for all, to open the doors to a more just future -these are the functions of science in society! Let us now apply these principles at home-in our own Commonwealth of Kentucky!

 $\sim$ 

## STUDIES ON FLAVONE-LIKE SUBSTANCES ISOLATED FROM TOBACCO

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A method for the separation of certain flavone-like substances from tobacco has been described elsewhere by the authors (1). In this paper, the authors report the results of the chemical and physical analyses conducted on these water-soluble pigments separated from tobacco.

The pigments studied were: (a) a pigment called 'W', which was adsorbed on talc from 95% ethyl alcohol, but was eluted by water; (b) a pigment called 'I', which was not adsorbed on talc nor on activated alumina from 95% ethyl alcohol solution; (c) a pigment called '2', which was not adsorbed on talc, but was adsorbed on activated alumina from 95% ethyl alcohol solution: it was eluted from the alumina by water; (d) and a pigment called '3', which was not adsorbed on talc, was adsorbed on activated alumina from 95% ethyl alcohol solution, but was not eluted by water; it was eluted, however, with very dilute hydrochloric acid solution.

The following methods were used in the qualitative analysis of the samples: (Each test was carried out separately.)

1. Two milliliters of each solution were saturated with ammonia gas.

2. Three drops of a 10 per cent sodium hydroxide solution were added to two milliliters of each solution.

3. Three drops of alkali carbonate were added to 2 milliliters of each solution.

4. A drop of concentrated sul-

furic acid was added to two milliliters of each solution.

5. Two drops of ferric chloride solution were added to 2 milliliters of each solution.

6. Two drops of lead acetate solution were added to two milliliters of each solution.

7. Two drops of basic lead acetate solution were added to two milliliters of each solution.

8. Four drops of Tollen's reagent were added to two milliliters of all the solutions except the hydrochloric acid solution. The chloride ion would interfere with the test.

9. One milliliter of concentrated hydrochloric acid, then small quantities of magnesium powder were added to 5 milliliters of the water solutions. Reduction takes place with a change in color. The mixture was shaken from time to time. Amyl alcohol was added, and the mixture shaken. Amyl alcohol should extract the color.

The results of these qualitative tests are listed in Table 1.

When a base such as ammonia, sodium carbonate, or 10% sodium hydroxide was added to the pigment solution, the color of each of the pigments under study deepened to form an intense yellow to brown solution. Flavone solutions react with ammonia, sodium carbonate, and 10%sodium hydroxide solution to form a deeper yellow solution (2).

With sulfuric acid, an intensification of the yellow color of the pigment solutions being tested, resulted. Flavone solutions treated with concentrated sulfuric acid become deeper in yellow color, and in some cases the solution exhibits a fluorescence.

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## Studies on Flavone-like Substances Isolated from Tobacco

Three pigment solutions, on investigation, exhibited a green coloration when treated with ferric chloride, while the solution of pigment '2' turned brown with this reagent. A green to brown coloration is observed when flavone solutions are treated with ferric chloride.

A yellow to orange precipitate formed when the pigment solutions under test were treated with lead acetate and basic lead acetate. Flavones

| TABLE 1   |  |   |  |   |
|---|--|---|--|---|
| Pigment   | Pigment W  | Pigment 1   | Pigment 2  | Pigment 3   |
| Ammonia<br>NH <sub>3</sub>  | Color of<br>solution<br>deepened.<br>Medium<br>yellow<br>precipitate<br>formed | Yellow<br>color<br>deepened.<br>No precipi-<br>tate ob-<br>served.  | Solution<br>turned<br>bright<br>yellow.<br>A flocculent<br>precipitate<br>formed         | A deep<br>yellowish<br>brown<br>solution<br>resulted      |
| Sodium<br>Hydroxide<br>10%  | Yellow<br>color<br>changed to<br>amber   | A light<br>yellow<br>amber<br>color<br>produced                     | Intensifica-<br>tion of<br>yellow<br>color of<br>solution                                | Solution<br>became<br>bright<br>yellow in<br>color        |
| Alkali<br>Carbonate   | Color<br>changed<br>from<br>pale to<br>lemon<br>yellow                         | Very little<br>if any<br>intensifica-<br>tion of<br>yellow<br>color | The color<br>of the<br>solution<br>deepened<br>from a<br>pale to an<br>intense<br>yellow | Bright<br>yellow<br>solution<br>resulted                  |
| Sulfuric<br>Acid<br>(Conc.)   | In all cases<br>The final col  | a slight intensi<br>or contained tra                                | fication of color<br>aces of orange  | was produced.   |
| Alcoholic<br>Ferric<br>Chloride   | Green<br>solution  | Yellowish<br>green<br>solution                                      | Greenish<br>brown<br>solution  | Deep olive<br>green<br>solution                           |
| Lead<br>Acetate   | Orangish<br>Yellow<br>precipitate  | Yellow<br>precipitate   | Yellow<br>precipitate  | Yellow<br>precipitate<br>contained a<br>trace of<br>brown |
| Basic<br>Lead<br>Acetate  | Orange<br>yellow<br>precipitate  | Yellow<br>precipitate   | Yellow<br>brown<br>precipitate   | Orangish<br>yellow<br>precipitate                         |
| Mg plus HCl<br>Extract<br>Amyl<br>AlcoholYellow color deepened in all cases. The yellow color was<br>extracted with amyl alcohol except in the case of pigment 1. |  |   |  |   |
| Ammoniacal<br>Silver<br>Nitrate   | Blackish dep   | osit formed   |  |   |

also form yellow to orange-red percipitates with lead acetate and with basic lead acetate.

Thus, the qualitative tests described indicated flavone-like properties for the pigments under investigation.

## ABSORPTION SPECTRA

Cenco-Sheard 'Spectrophotolo-A meter' was used in making absorption spectral measurements of the pigments being studied. A blue filter was used for determinations below 385 millimicrons. In the procedure used to make the determination, a blank of pure solvent was placed in cell 1, and cell 2 was filled with the pigment solutions. For the curves of pigments 'W' and '2', distilled water was used as the solvent; for the curve of pigment '1', 95% ethyl alcohol; and for the curve of pigment '3', 1% hydrochloric acid solution was used.

Sets of readings 5 millimicrons apart were taken over the range 335-620 millimicrons. A curve was plotted using wave length in millimicrons as abscissa and the ratio of incident light to transmitted, Io/I, as the ordinate. The curves for the pigments are shown in the accompanying figures.

The absorption spectral curve for pigment 'W' in water shows a sharp maximum absorption at 380 millimicrons, and no minimum for the range mentioned above. The curves for the pigments '1', '2', and '3' s h o w e d only one sharp maximum and no minimum for each in the range tested. The values for the maxima were 385 millimicrons for '1'; 375 millimicrons for '2'; and 418 millimicrons for '3'.

Samples of pigments 'W', '1', and '2' were sent to Mr. Dirk Verhagen, Chemist, Lyle Branchflower Company,

Seattle, Washington for absorption spectral studies in the 240-330 millimicron range. The authors are very grateful to him for his co-operation. In order to obtain significant readings, he made up his solutions at different dilutions from those obtained above. He found that pigment 'W' had a maximum at 262-266 millimicrons, with a minimum in the 310-330 millimicron region; that pigment '1' has a maximum at 262 millimicrons with a minimum in the 330-335 millimicron region, and that pigment '2' has a maximum at 246-248 millimicrons, with a minimum in the 320-335 millimicron region.

Flavones show maximum absorption usually between 340 and 390 millimicrons with a second maximum in the 235-300 millimicron region. Pigments 'W', '1' and '2' definitely show the characteristic type of absorption spectral curves exhibited by flavones.

Since both the qualitative tests and the transmission curves for pigments 'W' '1', and '2' indicated the presence of flavones, these three pigments have been fentatively placed in the flavone group. Further studies are now in progress.

#### SUMMARY

1. Qualitative tests and absorption spectral curves have been run on four pigments separated from tobacco.

2. The results of these studies indicate that at least three of these pigments, called 'W', '1' and '2', are flavone-like in properties.

#### REFERENCES

1. Schoulties, Anna L. and Wender, Simon H. 1947

Proc. Okla. Acad. of Science 2. Klein, G. 1932

Handbuch der Pflanzenanalyse, J. W. Edwards, Ann Arbor, Michigan. Vol. V, Part 1.

 $\sim \sim \sim$ 12



## Effect of Glucose Upon the Viability of Lactobacillus Casei

## MARY MUEDEKING

Department of Bacteriology University of Kentucky Lexington, Ky.

In discussing the bacterial growth curve with respect to the viable count, it is often stated that the population begins to decrease soon after reaching a maximum, and a logarithmic death phase ensues (Porter, 1946). Evidence that, under certain conditions, the viable count may remain close to the maximum for a considerable time relative to the preceding phases of the growth curve, was obtained in connection with a study of the lactic acid fermentation. Evidence was also found that this was not due to balanced multiplication and death rates, but rather to the maintenance of a stationary population. It is believed that the results are of sufficient interest to warrant publication as a preliminary note.

The organism used was Lactobacillus casei, A. T. C. C. 7649. It was grown in yeast extract-glucose broth cultures, with excess calcium carbonate added as a buffer. The media were made up in a 1-200 dilution of salt solution B of the Snell-Strong (1939)riboflavin assay medium; 0.04% (final concentration) dibasic potassium phosphate was added after autoclaving. Cultures were incubated at 37°C. The viable counts were determined by plating the cultures upon a medium containing 2% yeast extract, 0.5% glucose, and 1.5% agar. Usually six plates per culture were made; two at each of three critical dilutions, or three at two.

It was observed that the viable count decreased several fold between 48 and 72 hours in a culture in which the glucose (2% initial concentration) was exhausted at about 24 hours. Addition of glucose to such a culture resulted in utilization of the glucose and an increase in the viable count.

In a culture with an initial glucose concentration of 12% the count at 86 hours was  $4.8 \ge 10^{\circ}$  cells per ml., as compared to the maximum of  $5.9 \ge 10^{\circ}$  cells per ml. at 40 hours. At 32 hours the population was  $5.4 \ge 10^{\circ}$ ; thus this culture had an apparently nearly stationary population during the 32-86 hour period. During this time glucose analyses showed that the fermentation proceeded at a constant rate, and at 86 hours 1.2% glucose remained.

To study further the effect of glucose upon maintenance of the viable count the following experiment was done. Three cultures of *L. casei*, similar except that two had an initial glucose concentration of 2%, and one had 12%, were plated out at 24, 48, 72, and 96 hours. To one of the cultures with 2% glucose at 24hours, and subsequently every 24hours, enough sterile glucose solution was added to bring the concentration to 1%. Data obtained are given in Table 1.

According to these results, in the presence of fermentable sugar, the population stays close to the maximum until the culture is at least 96 hours old, whereas it falls off markedly in the same time if the sugar is depleted.

To determine if the stationary vi-

able count was due to balanced multiplication and death rates a similar experiment using direct counts was done. Two cultures, containing 2%and 12% glucose, were prepared. The salts concentrations, slightly different from Solution B, were as follows: 10 g. Mg. SO4·7H2O; 0.5 g. Na Cl; 1.0 g. (Fe)2(SO4)3 (anhydrous), and 0.5 g. Mg. SO4·H2O in 250 ml. glass-distilled water. Final were chosen at random and counted. Every cell distinguishable in a chain was counted. Two,three, and four cells in a chain were common. The average number of individual cells per field was determined, and from this the total number of cells per ml. culture was computed. Results are given in Table 2.

The discrepancy between the total and viable counts may possibly

|                 | TA<br>Plate Count  | BLE 1<br>ts—cells per ml.  |                                      |
|-----------------|--|--|--------------------------------------|
| Time<br>Hours   | 1<br>2% glucose<br>none added  | 2<br>2% glucose<br>5cc. 24%<br>glucose solution<br>added every 24<br>hours | 12%<br>glucose                       |
| $\frac{24}{48}$ | 3.2 x 10 <sup>9</sup><br>3.8 x 10 <sup>9</sup>                             | 5.7 x 10 <sup>9</sup><br>9.3 x 10 <sup>9</sup>                             | 1.7 x 10»<br>7.3 x 10»               |
| $\frac{72}{96}$ | ${}^{6.6 \mathrm{~x}~ 10^{\mathrm{s}}}_{3.4 \mathrm{~x}~ 10^{\mathrm{s}}}$ | 7.9 x 10 <sup>9</sup><br>8.3 x 10 <sup>9</sup>                             | $8.7 \ge 10^{9}$<br>$6.4 \ge 10^{9}$ |

concentrations were equivalent to a 1-200 dilution of this solution. After sterilization enough K2HPO4 to make a final concentration of 0.01% was added. Cultures were plated at 24 and 120 hours, and direct counts were done at 24, 50, 72 and 96 hours. Technique of the direct

be because short chains of cells, counted as several individuals in the direct count, produced only one colony on a plate. Since both plate and direct counts were not done at 96 and 120 hours the results are not absolutely comparable; yet they indicate very clearly the effect of glu-

|                               | Plate counts   | and Direct Count                         | of L .casei Cultur   | res                                      |
|-------------------------------|--|--|--|--|
| Time<br>Hours                 | 2%<br>Glucose  |  | 12%<br>Glucose   |  |
| $24 \\ 50 \\ 72 \\ 96 \\ 120$ | Direct Count<br>6.7 x 10 <sup>3</sup><br>5.7 x 10 <sup>3</sup><br>7.1 x 10 <sup>3</sup><br>5.7 x 10 <sup>3</sup> | Plate Count<br>2.3 x 10 <sup>9</sup><br> | Direct Count<br>5.1 x 10 <sup>9</sup><br>5.4 x 10 <sup>9</sup><br>6.9 x 10 <sup>9</sup><br>4.0 x 10 <sup>9</sup> | Plate Count<br>2.6 x 10 <sup>3</sup><br> |

TARE 2

counts was as follows: 0.01 ml. of a 1-10 dilution of the culture was smeared as evenly as possible over an area of 6 sq. cm. in two loopfuls of nigrosin. The smear was allowed to air-dry, and from 13 to 20 fields cose in maintaining the viable count, and show that the total count is no greater in the medium containing 12% glucose. Therefore, the constant viable count must be the result of a truly stationary population and not equal multiplication and death rates. Autolysis of dead cells can be discounted since in the 2% culture the viable count had decreased nearly 100 fold; yet the direct count remained the same within experimental error at 96 hours. Thus many of the cells visible on the slide were actually dead. Glucose probably remained in the culture containing 12%; in a similar experiment glucose analysis showed 1.6 mg. per ml. remaining at 135 hours.

#### Discussion

Apparently the presence of a fermentable sugar, with the energy available from the fermentation, is sufficient to keep the great majority of cells of *Lactobacillus casei* alive (capable of growth when transferred to a fresh medium) for a period of 96 to 120 hours. If the energy source is exhausted, however, the cells begin to die in 48 to 72 hours. The death of the cells cannot be ascribed to a low pH, to the accumulation of toxic metabolic products, or to the exhaustion of essential growth factors or nitrogen, since these factors would, if they were influencing the viability of the cells, tend to be more injurious in the culture with 12% initial glucose. The presence of an adequate energy source is apparently the only important difference between a culture having a viable count of  $2.3 \times 10^{\circ}$  cells per ml. at 120 hours, and one with  $3.3 \times 10^{\circ}$ cells per ml. End products of metabolism, in this case calcium lactate, do not adversely affect viability or fermentation.

The time of occurrence of the logarithmic death phase in relation to the rest of the bacterial growth cycle, in the case of *Lactobacillus casei*, is dependent upon certain environmental conditions.

#### References

- Porter, J. R. 1946. Bacterial Chemistry and Physiology, p. 102. John Wiley and Sons, Inc.
- (2) Snell, E. E. and Strong, F. M. 1939. Ind. Eng. Chem. Anal. Ed, 11: 346.



## **RESEARCH NOTES**

## A Note on the Elimination of *Endamoeba coli* Cysts in the Human Host

The irregularity in occurrence of Endamoeba histolytica and Endamoeba coli cysts and trophozoites in human stools has been observed by several investigators. Quantitative studies on the elimination of these parasites from the human body have been carried out by only a few. Cropper (1918-1919. Proc. Roy. Soc. Med. 12 Marcus Beck Lab Reports No. 8: 1-14) concluded from his work on E. coli that no "periodicity" was indicated "either in the number of cysts per gramme of stool or in the number excreted per day". Von Brand (1932. Zentralbl. f. Bakt. Abt. 1. Orig. 123: 358-365) also was unable to describe any "periodic" elimination of cysts in his study of E. histolutica from a human case. Tsuchiya (1932. Proc. Soc. Exp. Biol. and Med. 29: observed an "encystment 930-932) cycle" in a study of the same organism.

Lincicome (1942. Amer. J. Hyg. 36: 321-337) reported cysts of Endamoeba histolytica and Endamoeba coli were eliminated with a certain frequency in the stools of rhesus monkeys under prescribed standard and controlled conditions. Maximum numbers of cysts were discharged on the average of every 7 days with a range of 4 to 10 days, occasionally as long as 14 days. The numbers of cysts present in the stool usually declined rapidly after a maximum output, and remained at a lower level until the next rise occurred. Such frequencies were found in animals maintained on a high carbohydrate diet.

Using a method previously developed (Lincicome, 1942) observations have been made on the elimination of *Endamoeba coli* cysts in the stools of a male human volunteer.

On October 6, 1942, a human volunteer naturally infected with Endamoeba coli and passing cysts of this organism, was placed on a low-residue diet. An adequate amount of metamucil was included for soft, non-fibrous bulk. "Embo" was added to furnish sufficient vitamin-B complex intake (Thanks are expressed here to Dr. Statie Erikson, Professor of Home Economics, University of Kentucky, who has kindly helped in arranging the diet). The dietary carbohydrate level was maintained high while the protein level was kept at a point as low as was commensurate with health.

Beginning October 16, 1942, twentyfour-hour stool specimens were collected and the cysts of  $E. \ coli$  enumerated. Since it was physically impossible to analyze quantitatively each daily specimen, twenty - four - hour stools on alternate days were prepared for cyst counts. Alternate daily counts continued through November 23, 1942. No trophozoites were encountered.

The text figure is a graph showing the number of E. coli cysts eliminated per twenty-four-hour period per milliliter of a one-in-ten saline suspension of the fecal sample from October 16 through November 23, 1942. Presentation of the numerical fluctuation of cysts in this manner eliminates the factor of stool-volume variation which



might in itself account for increases or decreases in numbers of cysts. No cysts were observed in the stools until October 24. After this there occurred three maximum rises in numbers of cysts. Following each maximum output the number of cysts declined to a minimum whence they arose again. One one day, November 17, no stool was deposited.

There is here evidence of an orderly fluctuation in numbers of E. coli cysts

not wholly unlike that already described for the same organism in the rhesus monkey. Fourteen days elapsed between the first two maximum rises while ten days elapsed between the second and third. Further study of the discharge of *E. coli* cysts in the stools of human volunteers is in progress.—David Richard Lincicome and Robert Arthur Gold, Parasitology Laboratory, Department of Zoology, University of Kentucky, Lexington.

## Occurrence of Neoechinorhynchus emydis (Acanthocephala) in Snails

In June 1942 an acanthocephalan was found in the foot of the snail Campeloma rufum (Haldeman) collected from a point on the North Elkhorn Creek known as Johnson's Mill, about 12 miles northwest of Lexington, Kentucky. Numerous collections have been made subsequently and the snails found infected indicating that the infection is probably not accidental. Ceriphasia semicarinata (Sav) collected from the same locality has also been infected but less consistently than C. rufum. (The snails in this report have been identified by Dr. J. P. E. Morrison, Division of Mollusks. U. S. National Museum, Washington, D. C.).

The worms have been identified as Neoechinorhynchus emydis (Leidy 1851) a common parasite of turtles, although they possess certain characteristics apparently heretofore unreported. These are being reported in a separate communication.

All worms were in a post-larval or juvenile stage of development, enclosed in a cystic membrane. Usually but one worm was found within a cyst wall. Cysts ordinarily were situated superficially in the foot tissue, occasionally at the base of tentacles or in the tissue around the mouth or in the mantle.

This is apparently the third published record of acanthocephala from snails, and constitutes the first record for C. rufum and C. semicarinata. The first published record was by Meyer in his monograph (1932-1933. Acanthocephala. Bronn's Klassen and Ordnungen des Tierreichs 4 Abt. 2, Buch 2) in which he says regarding Neoechinorhynchus rutili "und experimentell im Lymnaea . . ." This is without bibliographical citation, and is therefore assumed to be the result of Meyer's work (personal communication from H. J. Van Cleave, January 1947). However, on p. 293 of his monograph Meyer makes no mention of Lymnaea in discussing the life cycle of N. rutili.

Whitlock (1939. Snails as Intermediate Hosts of Acanthocephala. J. Parasit. 25: 443) records a species of *Neoechinorhynchus* from *Campeloma decisum* and *Pleurocera acuta* in Grand River near Lansing, Michigan.

Cable (January, 1947) in a personal communication indicated that Hopp working in his laboratory had found a Neoechinorhynchus in snails.— David Richard Lincicome and Allie Whitt, Jr. Parasitology Laboratory, Department of Zoology, University of Kentucky, Lexington.

## **NEWS and NOTES**

Dr. Paul O. Ritcher has been elected Vice-President of the North Central States Branch of the American Association of Economic Entomologists.

Dr. Ravid Richard Lincicome has been elected Fellow of the Royal Society of Tropical Medicine and Hygiene in London, England.

Dr. Frank Pattie of the Rice Institute, Houston, Texas, will become Head of the Department of Psychology, University of Kentucky on 1 July 1947. Dr. Pattie holds the A. B. from Vanderbilt University and the Ph. D. from Princeton.

It is with regret that the death of Dr. Henry Beaumont, Professor of Psychology, University of Kentucky, in March 1947 is noted.

Dr. Paul P. Boyd retires on 16 June 1947 as Dean of the College of Arts and Sciences, University of Kentucky.

Dr. M. M. White, Professor of Psychology and Associate Dean of Arts and Sciences, University of Kentucky, will become Dean of the college upon retirement of Dr. Boyd.

Mr. Elisha B. Lewis, Assistant Chemist, Experiment Station, University of Kentucky, has resigned to become Research Chemist with Engineering Company of Ohio in Dayton, Ohio, effective 16 June 1947.

The Department of Bacteriology, University of Kentucky announces the institution of the Ph. D. degree in the following fields: morphology and physiology of microorganisms, immunology and serology and public health bacteriology.

Dr. Robert N. Jeffrey, Plant

Physiologist, Department of Agronomy, Experiment Station, University of Kentucky, is now Plant Physiologist with the Firestone Plantations Corporation in Harbel, Liberia.

Dr. James W. Archdeacon has been promoted to Associate Professor of Anatomy and Physiology, University of Kentucky.

Dr. Joe Kendall Neel will become Assistant Professor of Zoology, University of Kentucky, on 1 September 1947. Dr. Neel holds the B. S. in 1937 and M. S. in 1938 from the University of Kentucky and the Ph. D. from the University of Michigan in 1947.

Dr. William R. Brown has been promoted to Associate Professor of Geology, University of Kentucky.

The Department of Psychology, University of Kentucky, is one of the first in the United States to be selected by the American Psychological Association to give the Ph. D. in Psychology with a major in clinical psychology.

Mr. A. S. Bradshaw, Assistant Professor of Biology, Transylvania College, will spend the summer quarter at the Franz Theodore Stone Laboratory at Put-in-Bay, Lake Erie.

The Keeneland Foundation has placed an electron microscope in the laboratories of the Department of Bacteriology, University of Kentucky, Dr. O. F. Edwards, in charge of the microscope, has completed a special study of techniques for the microscope at the National Institute of Health.

Dr. David Richard Lincicome, Assistant Professor of Zoology, University of Kentucky, has resigned to become Assistant Professor of Parasitology, School of Medicine, University of Wisconsin, on 1 July 1947.

Dr. Morris Scherago has been awarded a research grant of \$1,500.00 from the American College of Allergists for work on the standardization of allergens.

The Department of Bacteriology, University of Kentucky, announces the following promotions: Dr. Margaret Hotchkiss to full Professor; Dr. O. F. Edwards to Associate Professor and Dr. Mary Muedeking to Assistant Professor.

Dr. L. A. Brown, Professor of Biology at Transylvania College spent the winter quarter at Harvard University preparing a curriculum in biology in the field of General Education to be instituted at Transylvania. Dr. L. K. Wood, Assistant Soil Scientist, Oregon State College at Corvallis, Oregon, has become Chemist and spectroscopist, Department of Chemistry, Experiment Station, University of Kentucky.

Dr. H. B. Lovell, Associate Professor of Zoology, University of Louisville, will spend part of the summer in study of birds in the Allegheny Mountains of Eastern Kentucky and Tennessee.

Drs. P. A. Davies and H. B. Lovell, University of Louisville, represented the Academy at the Field Day of the Indiana Academy of Science in May.

Dr. William M. Clay, instructor in Biology, University of Louisville, will be a member of the party studying the herpetofauna of Southern Arizona under the auspices of the Chicago Academy of Sciences.

## Abstracted Minutes of 1944 and 1946 Meetings of the Kentucky Academy of Science

THIRTY-FIRST ANNUAL MEETING

University of Kentucky April 28 and 29, 1944 Officers:

PRESIDENT-L. A. Brown, Transylvania College, Lexington, Ky.

PAST PRESIDENT—J. T. Śkinner, W. S. T. C., Bowling Green, Ky. VICE PRESIDENT—Paul Kolachov, Joseph E. Seagram & Sons, Louisville, Ky.

SECRETARY-Alfred Brauer, University of Kentucky, Lexington, Ky. TREASURER-William J. Moore, E. K. S. T. C.

REPRESENTATIVE TO A. A. S.—Austin R. Middleton, University of Louisville.

COUNSELOR TO JR. ACADEMY-Anna Schneib

Local Committee on Arrangements:

H. P. Riley

D. G. Steele

A. J. Bradshaw (Transylvania)

Dave Young

Reports were read by the Secretary, Treasurer, Representative to the A. A. A. S. and the Counselor to the Junior Academy.

Elected to Membership were:

University of Louisville

David Armstrong, Manual High School, Louisville

Glenn Dooley, Dept. of Chemistry, W. K. S. T. C., Bowling Green Paul Maizlick, Dept. of Physics, E. K. S. T. C., Richmond

Vernon S. Gentry, Georgetown College, Georgetown

A constitutional amendment providing for sustaining memberships was passed. A by-law fixing the annual dues of sustaining members at ten dollars was passed.

Officers for a following year were elected.

THIRTY-SECOND ANNUAL MEETING

April 26 and 27, 1946

PRESIDENT—Paul Kolachov, Joseph E. Seagram & Sons, Inc., Louisville PAST PRESIDENT-L. A. Brown, Transylvania College, Lexington VICE PRESIDENT-Ward Sumpter, W. K. S. T. C., Bowling Green, Ky.

SECRETARY—Alfred Bauer, U. of Ky., Lexington, Ky. TREASURER—W. J. Moore, E. K. S. T. C., Richmond, Ky. REP. ON COUNCIL OF A. A. A. S.—Austin R. Middleton, U. of

Louisville

COUNSELOR TO JR. ACADEMY-Anna Schneib

Reports were read by the Treasurer, Representative to the Council of the A. A. A. S. and the Counselor to the Ky. Jr. Acad. Now Members Elected to Academy.

| LICO MICHOCIO LICCCCO CO | 1 could neg i        |                        |
|--------------------------|----------------------|------------------------|
| Adams, Carl E.           | Grossman, James A.   | Roberts, V. D.         |
| Balen, Virgil A.         | Houchins, John       | Sloan, Earl P.         |
| Bennett, E. M.           | Hutter, Harry K.     | Roth, George           |
| Carey, Henry             | Jeffery, Robert N.   | Schwendeman, Jos. R.   |
| Cole, Mrs. Constance L.  | Lewis, Elisha Betts  | Snyder, Marion         |
| Coy, Fred                | MacLaury, Donald W.  | Steen, Russell         |
| Crawley, Clyde B.        | Mayo, Mrs. Elizabeth | Stevens, Russell       |
| Dawson, Lyle R.          | McErlean, George     | Sutherland, William R. |
| Erickson, R. J.          | Nelson, Vincent E.   | Townsend, Lee Hill     |
| Gardner, Jos. H.         | Ormsby, Robert L.    | Westad, J. W.          |
| Hotchkiss, Margaret      | Pauls, Franklin B.   | Wetzel, Harold F.      |
| Heimerdinger, Jane       |                      | Wharton, Mary E.       |

No new business was forthcoming. Officers for the following year were elected.

## NOTICE TO CONTRIBUTORS

The TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE is a medium for the publication of original investigations in science. As the official organ of the Kentucky Academy of Science it publishes in addition programs of the annual meetings of the society, abstracts of papers presented before the annual meetings, reports of the society's officers and committees, as well as news and announcements of interest to the membership.

Manuscripts may be submitted at any time to the co-editors:

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| Jos. E. Seagram and Sons | Department of Zoology  |
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Papers should be submitted typewritten, double-spaced, with wide margins, in an original and 1 carbon copy, on substantial quality paper. Articles are accepted for publication with the understanding that they are to be published exclusively in the TRANSACTIONS. Each paper will be reviewed by one or more persons qualified in the field covered by the article in addition to the editors before a contribution is accepted for publication.

Bibliographic citations should follow textual material (except in Research Notes, see later). Abbreviations for the names of periodicals should follow the current system employed by either Chemical Abstracts or Biological Abstracts. Bibliographic citations in Research Notes should be in the same form as for longer papers but enclosed in parentheses within the text of the note.

Footnotes should be avoided. Titles must be clear and concise, and provide for precise and accurate catologuing.

Tables and illustrations are expensive, and should be included in an article only to give effective presentation of the data. Articles with an excessive number of tables or illustrations, or with poorly arranged or executed tables or illustrations may be returned to the author for modification.

Textual material should be in clear, brief and condensed form in order for a maximum amount of material to be published.

Reprints may be obtained from the publisher and must be ordered at the time galley proof is returned.

Authors are requested to submit an abstract of their papers when galley proof is returned. This abstract must be no longer than 250 words, nor to exceed in any case 3% of the length of the original article. Abstracts will be submitted to *Biological Abstracts* for publication.



73 K37

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Number 4

# TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

**Offiicial Organ** 

KENTUCKY ACADEMY OF SCIENCE

## CONTENTS

| Editorial:<br>Power and Punch. The Editors  | _ 55 |
|---|------|
| Physiological variation in isolates of <i>Polyporus schweinitzii</i> Fr.<br>(Fungi; Basidiomycetes). William D. Gray  | _ 59 |
| Pollination in Asclepias. H. H. La Fuze and V. A. Greulach  | . 79 |
| A comprehensive survey of controlled grain alcohol production methods<br>A. I. Zarow                                  | . 82 |
| A planned economy for Kentucky's waters. W. R. Allen  | - 89 |
| Alcoholic fermentation under reduced pressure.<br>M. C. Brockmann and T. J. B. Stier                                  | 94   |
| Report of the committee for the Kentucky Junior Academy.<br>Anna A. Schnieb   | .101 |
| Report of the representative of the Kentucky Academy of Science on the<br>Council of the A.A.A.S. Austin R. Middleton | 105  |
| News and Notes  | .110 |
| Index to Volume 12  | .112 |

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## TRANSACTIONS

## of the

## **KENTUCKY ACADEMY OF SCIENCE**

## Editors

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# EDITORIAL

# **POWER AND PUNCH**

At nine o'clock on the morning of May 8, 1914, a group of about twenty-five persons assembled in the Physics Building, the University of Kentucky, to organize the Kentucky Academy of Science. Forty-six persons had earlier indicated in a signed statement their sympathy with and their approval for an Academy of Science in the State.

The secretary's report read at the second annual meeting of the Academy on May 15, 1915, showed that the roll of members had increased to some sixty individuals who had either signed the organizational statement or who otherwise had indicated they wished to become members. A balance of two dollars was on hand in the treasury.

By the next year 81 names were on the membership list, and by 1917 there were 91, of whom 39 were active members in good standing and 39 whose dues were in arrears.

The membership in the Kentucky Academy of Science since the early organizational days in 1914, 1915 and 1916 has grown slowly by small yearly increments to the present membership of about 330 for 1947.

Stated thus it might be said that the Academy has done well in view of the many obstacles encountered during the thirty odd years of its life. Not only has there been an annual growth in membership, however small, but a journal, the TRANSACTIONS, has been launched since 1924 under circumstances that

have been a little more than difficult and discouraging and is now completing its twelfth volume. With this volume a new policy has been inaugurated which provides for a broader editorial horizon than was possible at any time previously.

The Academy has weathered World War I, the great depression of the thirties, World War II and so far has maintained fair balance in post World War II inflation, although how much longer seems a matter of conjecture in view of the tremendous rise in cost of everything including printing of the journal.

The Academy has now advanced to an age of maturity in a powerful new world with vast new horizons stretching out before her. They bring new and greater responsibilities and emphasize old problems that have never been solved.

Dr. Paul P. Boyd in the presidential address of 1920 viewing the future of the Kentucky Academy of Science, laid before the members a series of goals that are still today short of attainment. In 1947 as in 1920 the Academy is still ineffective as the representative organization of Science in the State. Our membership still does not encompass all fields of scientific thought, and largely because of this the roster roll remains at a relatively low figure. We have yet to cooperate to the fullest extent with educational and industrial leaders and businesses, the public still looms as a vast uninformed mass and

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12

our fundamental excuse for birth, the zealous advancement of knowledge and the dissemination thereof, still lies abandoned for want of sufficient support.

In order to have a vigorous, healthy society new horizons in attainable objectives must ever be befor us, and all effort must be directed toward accomplishment of these objectives. The Academy has too long been content to remain a mediocre organization, impotent in attainments and offering nothing to prospective members, sustaining or otherwise, for their participation.

The time has now come, the crossroads are before us, for us to re-examine ourselves to discover what the reasons are for thirty-three years of coasting along. We must then overhaul our organization to give it **power** and **punch**.

It is the opinion of the writers that one of the fundamental causes of our disease is a species of stagnation resulting from an attitude of general indifference. It is an attitude that has permeated through many levels of society in the State. The Academy collectively is but reflecting this state of mind of the population, and is taking what seems to be the path of least resistance as the guide to conduct.

This stagnation now and then raises its dark countenance in many forms, for example: the indignant letters of citizens to newspaper editors protesting the paying of respectable and adequate salaries to the faculty of our institutions of higher learning, the orations of political candidates for high office demanding that the University deny the right of freedom of speech, investigation and publication to its faculty members. This educational decay is reflected in the shameful salaries paid to teachers in our schools, and it reflects in the amount of money available in our colleges for research, facilities and salaries. Everywhere the forces of ignorance, intolerance and indifference resist progress.

The Academy is doubly guilty of neglect of duty when it fails in its mission to promote truth and its dissemination, for after all ignorance, intolerance, indifference, and inaction as well, are attributes that follow in the absence of truth.

Stagnation immediately within the Academy is marked in many ways, but principally in our lack of critical, constructive and progressive action. The membership is content with a single general meeting once in every year at which time it repeats many words of fine and noble sentiment and then promptly forgets the whole thing. The general attitude does not encourage or breed enthusiasm and a deep desire to render service or to pursue research, and it does not serve as a stimulus for others who are not members to join with us. We offer nothing in return for participation in the Academy. We take no bold or aggressive action in the name of Science. On this basis there seems little excuse to warrant the Academy's existence.

The Academy has no alternative, no choice or selection from which to choose success but through enthusiastic, hard sacrifice to work. We have got to sell ourselves first on the worthwhileness of the Academy. Then we have got to sell it to others.

The immediate necessity is to enlarge the membership to all fields of scientific endeavor in the State whether educational or industrial. Increase in membership **per se** is not a notable objective for the Academy, but it is as necessary as the very food we eat to our metabolic processes.

The aftermath of World War II has brought important sequelae directly concerned with Academy members both as individuals in a frustrated society and as responsible scientists. As informed and enlightened citizens in a democracy we owe it to ourselves and fellow statemen and countrymen to contribute to the sane and wise deliberations on the establishment and keeping of just peace in the world. Again as informed andenlightened citizens. Academy members are responsible for disseminating truth as a means of conquering fear and distrust. Public education then is a continuing and necessary objective that this society has too long ignored. It is now past time that the Academy formulate and execute plans for public education on matters that pertain to its dominion.

The broad general function of any Academy of Science incorporates the injunction to promote and foster research or the acquisition and dissemination of truth. Research and the search for truth in the old days was a matter of a room with a bench. a shelf for books, perhaps a microscope, and a keen, burning, passionate desire for knowledge. The cost was not more than the simple implements that it required. The thirst for truth lay deep and powerful within the individual. In the course of years research has undergone change, it has evolved or undergone evolution, and the old way has passed into the great beyond.

Research today is spelled with a capital "R." It requires the cooperation of many persons, institutions, and considerable physical assets. Considerable sums of money are necessary to pay the hire of assistants, for purchasing instruments and material. Travel abroad from one's immediate environment is often a sine **quo non.** Research today has metamorphosed from the general store era to the age of streamlined specialties,

Has the Kentucky Academy kept pace with this evolution in Research? The answer is not difficult to find.

There are many Academy members who have had the enthusiasm to be "companions in zealous research" only to have it wither and die away as the years have gone by because research was and is not supported well, either morally or financially, either by the state government or by industry at large. Many of the newspapers throughout the State have decried the fact that teachers in colleges of Kentucky have been leaving for more lucrative positions in other states, and all have uniformly assigned "low salaries" as the main reason for doing so. While it cannot be denied that higher salaries elsewhere do in many instances account for resignations, lack of facilities for, financial support of, and philosophic sympathy with, research has played no small part in the decision of a faculty man to go elsewhere. The statement that Kentucky's institutions of higher learning are serving "as the happy hunting ground" for other institutions is rightly and justly made, but the question why has not been correctly answered in full. There seems little doubt that stagnation in philosophy and provision for research play a mighty important role in the decision of an individual to go elsewhere. There has been an adage somewhere down the line that one gets in return as much as one is willing to put into a thing. This may be applied to support for research. As long as the people of the State are content to spend very little toward support of research, their benefits, their rewards, their return on such will be proportionately small.

The individual Academy member has been cognizant of this situation for many years, there can be little doubt; and the Academy as a whole has been aware of the general attitude, but has taken few if any steps to remedy the condition.

The only research fund available to the Academy has been supplied from the national offices of the A.A.A.S., and that has rarely exceeded fifty or sixty dollars a year! Can there be, therefore, any doubt or hesitation as to the course of action this Academy ought to take to fulfill so important an injunction as that of the promotion of research? We must at once consider the establishment of a fund for the development, encouragement and execution of research at all levels in the State. This fund must come from the people and it must be wisely and justly administered in the interests of those who have supported it.

### THE EDITORS



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Of the many forest tree diseases caused by wood-rotting fungi, one of the most widespread and most destructive is that caused by Poluporus schweinitzii Fries. Commonly called brown cubical rot, red-brown butt rot, brown rot, butt rot, red rot, or stump rot, this disease is known to foresters of both Europe and North America. Hartig (1900)reported that in Europe this fungus attacks only pine, but in the United States its host list includes most conifers. The disease has been reported as occurring on nine species of Abies, four species of Larix, eight species of Picea, thirty species of *Pinus*, two species of *Tsuga*, two species of Thuja, Chamaecuparis thyoides Britt., Libocedrus decurrens Torr., Taxus brevifolia Nutt., and Pseudotsuga taxifolia (Lam.) Britt.-a total of fifty-nine coniferous hosts. In addition to this large number of conifers, several broadleaf species have also been reported as hosts of P. schweinitzii; Hubert (1931, p. 356) reported its occurrence on Quercus spp. and Liquidambar styraciflua L., and Rhoads (1921) reported Eculayptus globulus Labill. as another hardwood host. In the United States the disease is most prevalent in the northern forests but is found to some extent wherever conifers occur. Apparently the fungus may attack young trees as well as older ones, entering the tree through the root system and growing up into the trunk (von Schrenk, 1900).

Childs (1937), working with isolates of Polyporus schweinitzii from numerous, and, in some instances, widely separated sources, has shown that there exist certain cultural types within the species. In culture upon artificial media these isolates all had a few characters in common, but with the exception of isolates which were taken from within a few feet of each other, no two were identical. His conclusion was that this species of fungus is made up of many individuals which differ rather widely from each other. This investigator also reported a difference in wood-decaying ability between different isolates; however, only a small number of samples was used, and only two isolates were involved in this study. It is the purpose of the present investigation to ascertain whether such physiological differences, as evidenced by (1) variability in wood-decaying ability, (2) variations in appearance when cultured on wood blocks or artificial media, and (3) variations in growth rate, do exist among isolates of this fungus.

The concept of physiological specialization in fungi may be considered as relatively new, since the majority of the work in this field has been conducted since 1880. In this regard the rusts have received particular attention as it evidenced by the work of Eriksson (1894, 1902), Dietel (1889), Stakman (1914) and Hungerford and Owens (1923). There are also accounts of physiological variation in

<sup>\*</sup>Paper No. 504 from the Department of Botany, Ohio State University.

species of such fungi as Erysiphe, Glomerella, Sphaeropsis, Rhizoctonia, Sentoria and others, but strangely enough, little work has been done with regard to the problem of physiological variation in wood-destroying basidi-Since the character and omvcetes. general properties of the host plant are thought by some to exert certain influences upon the fungi infecting it, tending to produce physiological specialization, a study of the various wood-destroving fungi should prove a most fruitful investigation. These fungi remain in close proximity with their hosts for a considerable period of time, and if they are susceptible to any type of host influence should prove to be excellent material for the detection of an influence of this na-Bovce (1920) has determined ture. that Polyporus amarus may vegetate in the trunk of the incense cedar (Libocedrus decurrens) for a period of three hundred years: it would seem quite reasonable to postulate that unsuch conditions the der chances would be very good for the production of specialized forms or varieties among the wood-destroving basidiomycetes. Several references to investigations concerning this particular problem have been encountered; such references will be discussed in conjunction with the results herein presented.

### MATERIALS AND METHODS

Ten different isolates of *Polyporus* schweinitzii were used throughout the present study.\* These isolates were from rather widely separate localities and were obtained from several different coniferous hosts. The following list gives the isolate number, host and locality from which each isolate was obtained: No. 1—*Pinus strobus*, Springwater, N. Y.

- No. 10—*Pinus strobus*, Springwater, N. Y.
- No. 19—*Pinus strobus*, Springwater, N. Y.
- No. 31—Pinus strobus, Honeoye, N. Y.
- No. 32—Pinus strobus, Weston, Ont.
- No. 38—*Pinus sylvestris*, Great Britain.
- No. 39—Pinus rigida, Medford, N. J.
- No. 40—*Pinus mughus*, Central Experimental Farm. Ottawa. Ontario.
- No. 40e—Fifth monosporus generation from No. 40.
- No. 40j—Tenth monosporus generation from No. 40.

Stock cultures were maintained on 2% Fleischman's Malt agar, and this same medium was employed in the studies which involved observations on the characteristics of single colonies of the various isolates as well as the behavior of paired isolates on the same petri plate.

For studies concerned with determination of the capacities of the various isolates for decaying wood (as measured by weight loss of the wood), white pine sapwood was used. Several hundred blocks were cut from sapwood of white pine (Pinus stobus L.) obtained by Dr. Harlan H. York at Springwater, N. Y., during the summer of 1936. These blocks were cut approximately the same size to (<sup>3</sup>/<sub>4</sub> x <sup>3</sup>/<sub>4</sub> x 4 inches) and were carefully selected: any showing a trace of heartwood or incipient decay being discarded. The resultant number of sound blocks selected for use was two hundred; these blocks were then numbered consecutively, airdried, and weighed at intervals to the nearest 0.1 gm. until the weight of each block was constant. After their air-dry weights had been obtained, the

<sup>\*</sup>Supplied to the writer by Dr. Thomas Childs.

blocks were placed in distilled water and allowed to absorb as much as possible. Each block was then placed in a 38x200 mm. test tube, 10 ml. of two per cent malt was added, the tube stoppered with a tightly rolled cotton plug and then autoclaved. Inoculations were made on Dec. 12, 1936 by dropping a small piece of agar, upon which mycelium was growing, into the liquid medium in each tube; twenty wood-block cultures were prepared for each of the isolates under consideration. Since these cultures were maintained for a period of ten months, considerable loss of moisture through evaporation occurred, and it was necessary to add water to the tubes at intervals: 15 ml. of sterile, distilled water were added to each tube on January 15, 1937; 25 ml. were added on May 15, 1937; 20 ml. were added on July 30, 1937. Air-dry, the blocks used in this experiment varied in weight from 11.0 to 14.5 gms.; initial weight data for the entire series of blocks are presented in to remove surface mycelia and sporebearing structures, air-dried, and final weights determined.

In order to determine if growth rate was correlated with destructiveness to wood blocks, one experiment was designed to determine growth rates of the various isolates on artificial medium. In this experiment the medium employed was a modification of Reitsma's nutrient medium and was prepared as follows:

| 2%   | Bacto                           | pep  | tor | ıe | - | 250.00 | ml. |
|------|---------------------------------|------|-----|----|---|--------|-----|
| M/2  | dextros                         | e    | -   | -  | - | 300.00 | ml. |
| M/2  | sucrose                         | -    | -   | -  | - | 200.00 | ml. |
| 0.4% | $MgS0^4$                        | .H2( | )   | ~  | - | 49.00  | ml. |
| 1.0% | ferric                          | cit  | rat | te | - | 1.00   | ml. |
| N/2  | H <sup>3</sup> PO <sup>4</sup>  | -    | -   | -  | - | 9.00   | ml. |
| N/2  | K <sup>2</sup> HPO <sup>4</sup> | -    | -   | -  | - | 3.22   | ml. |

Cultures were made in 38x200 mm. test tubes by inoculating exactly 75 ml. of the above medium (which had been found satisfactory for all isolates) with a single loopful of hyphae from ten-day old stock cultures growing in 2% Fleischman's Malt. Ten replicate tubes were prepared for each isolate; these were

**TABLE 1.**—Weights and numbers of white pine sapwood blocks used in experiments involving the determination of weight losses of wood by different isolates of **P. schweinitzii**.

| Isolate | Block   | Total  | Average |
|---------|---------|--------|---------|
| No.     | Nos.    | Weight | Weight  |
| 1       | 1-20    | 249.2  | 12.460  |
| 10      | 21-40   | 236.3  | 11.815  |
| 19      | 41-60   | 247.0  | 12.350  |
| 31      | 61- 80  | 251.0  | 12.510  |
| 32      | 81-100  | 247.4  | 12.370  |
| 38      | 101-120 | 251.9  | 12.595  |
| 39      | 121-140 | 250.1  | 12.505  |
| 40      | 141-160 | 243.5  | 12.175  |
| 40i     | 161-180 | 246.8  | 12.340  |
| 40e     | 181—200 | 259.4  | 12.970  |

### Table I.

Observation on woodblock cultures were recorded at intervals during the ten month incubation period and at the end of this time the experiment was terminated. The blocks were removed from the tubes, washed lightly then placed in the dark at a temperature of 23 degrees—25 degrees C. and incubated for 35 days. At the end of the incubation period a large mycelial mat had formed in each tube. The mats were filtered on numbered, dried, weighed filter papers, dried in an oven at 105 degrees C. and placed in a desiccator. The dry weight of each mat was then obtained and average weights were calculated for each series.

### RESULTS

Appearance of single colonies on petri plates.—In culture on artificial medium, the isolates varied widely in such characters as color, density of growth, presence or absence of concentric zonation, and rapidity of spread. A summary of the observed growth characters of each isolate is presented in Table II, while photographs of representative cultures of each of the various isolates are shown in Figures 1-10. Plate I.

Behavior of isolates in paired cultures. - Several workers have described the line of demarcation that generally develops when two different fungal mycelia are grown on the same substratum: Schmitz (1925)and Mounce (1929) have described this phenomenon for Fomes pinicola (Sw.) Cooke, and Childs (1937) described the same reaction for P. schweinitzii. Accordingly, paired cultures were prepared using the ten isolates being studied: the cultures were arranged so that all possible combinations of two isolates per petri dish were obtained. In every instance a line of demarcation appeared when the two colonies met except in those petri dishes in which there had been placed two pieces of inoculum from the same isolates. This was found to be true even for pairings involving Nos. 40, 40e and 40j, which is rather surprising in view of the fact that Nos. 40e and 40j are monospore cultures derived from No. 40.

Three different types of reactions were observed when two different isolates were grown on the same substratum. The first, and most striking type was that in which a definite line of avoidance about 1 mm, wide occurred between the two colonies. and the agar in this line became very dark brown: this type of reaction is illustrated in Figure 11, Plate I (paired culture of Nos. 1 and 32) and Figure 12, Plate I (paired culture of Nos. 1 and 39). The second type of reaction was similar to the first with the exception that the agar between the colonies did not change color: this is interpreted as being a reaction in which the antagonism between the two mycelia is not as great as that shown by isolate pairings exhibiting the first type of reaction. In the third type the region between the two colonies was not discolored, was quite narrow, and one of the two mycelia formed a solid line of fluffy aerial hyphae immediately adjacent to the line of demarcation. This third type of reaction occurred only in pairings involving Isolate No. 38, and it was always this isolate which formed the line of aerial hyphae. In practically all pairings there was an enhancement of color of both isolates. The types of reactions (1, 2 or 3) occurring with all possible combinations of two isolates are indicated in Table III: in this table "N" indicates that no line of demarcation was formed.

Appearance of five month old wood block cultures.—Within each series the cultures were remarkably uniform in so far as color, amount of growth, wood discoloration, and wood cracking were concerned. That cultures of different series differed widely from each other is shown by the following summation of the general appearance of each series of cultures five months after inoculation.

Isolate 1 (Blocks 1-20): Surface growth slight, mycelium appressed, somewhat powdery in

| Iso |                                     | CHARACTER (                              | ог скомтн                           |                     |
|-----|-------------------------------------|--|-------------------------------------|---------------------|
| NO. | NEAR INOCULUM                       | INTERMEDIATE REGION                      | Margin                              | CONCENTRIC ZONATION |
| -   | Light, sparse, closely<br>appressed | Derk, brownish yellow                    | Bright yellow                       | Fairly distinct     |
| 2   | Brown, with yellov at<br>margin     | Sparse, very light,<br>closely-appressed | Bright yellow, denso                | Distinct            |
| 19  | Brown, sparse                       | Yellow; deep pile                        | Brownish, grading<br>into tan       | Fairly dictinct     |
| ま   | Fale yellow; dense pile             | Lemon-yellow; sparse                     | <b>Brownish-yellow</b>              | Indistinct          |
| 32  | Pale yellow                         | Pale; closely-appressed                  | Bright yellow; dense<br>pile        | Distinct            |
| 38  | Closely-appressed;<br>little growth | Pale yellow; deep pile                   | White; sparse;<br>closely-appressed | None                |
| 66  | Reddish-yellow; deep<br>pile        | Pale yellow; very sparse                 | growth; closely-<br>appressed       | None                |
| 3   | Almost white; closely-app           | ressed                                   | Bright yellow; deep<br>pile         | Distinct            |
| â   | e Very little growth                | White, with a few patche                 | s of yellow; dense pile             | None                |
| \$  | Jull yellow; closely-               | Purpitsh-yellov<br>closely-spressed      | Brownish-yellew; dense              | Distinct            |

TABLE II.-Growth characters of isolates of P. schweinitzii.

appearance, white - brown where dry. Blocks showing a dark pink discoloration. Figure 1, Plate II.

- Isolate 10 (Blocks 21-40): Surface growth slight except for the occurrence of occasional large clumps of bright yellow, fluffy hyphae. Wood block discoloration darker than in Series 1. Figure 2, Plate II.
- Isolate 19 (Blocks 41-60); Surface growth slight; mycelium appressed, pale creamcolored; no clumping of hyphae. Wood blocks with reddish-brown discoloration, and almost every block exhibited one or more large areas which had been eroded by the fungus. Figure 3, Plate II.
- Isolate 31 (Blocks 61-80) Surface growth for the most part slight but there were occasional fluffy masses of hyphae which were almost white in color. Wood block discoloration was reddish-brown and rather evenly distributed. A few small eroded areas, similar to those of the preceding series, were found. Figure 1. Plate III.
- Isolate 32 (Blocks 81-100): Mycelium bright yellow, covering the surfaces of the blocks, and forming both fluffy and compact masses of hyphae; very little mycelial growth on tops of blocks. Reddish discoloration unevenly distributed over the blocks. Figure 2, Plate III.
- Isolate 38 (Blocks 101-120): Mycelium yellow in color, sparsely and reticulately covering the sides of the blocks but concentrating in dense, compact, darker masses at the tops. Block discoloration in the form of reddish streaks. Figure 3, Plate III.
- Isolate 39 (Blocks 121-140): Even growth over surfaces of blocks; the few clumpings of hyphae that occurred were small and were fluffy rather than compact. Mycelium very pale yellow. Reddish-orange discoloration occurring irregularly through the wood blocks. Figure 1, Plate IV.
- Isolate 40 (Blocks 141-160): Mycelium bright yellow, forming large fluffy masses which occurred largely near the bases of the blocks. Wood block discoloration was orange and was distributed irregularly. Figure 2, Plate IV.

- Isolate 40e (Blocks 181-200): Surface growth of bright yellow, fluffy hyphae. Growth rather dense near the tops of the blocks. Very dark, irregularly distributed, discoloration of wood blocks. Figure 1, Plate V.
- Isolate 40j (Blocks 161-180): Mycelium yellow, showing a tendency to form small, rather compact masses near the bases and along the sides of the wood blocks. Discoloration of blocks reddish, distributed irregularly. Figure 3, Plate IV.

Production of fruiting bodies in wood block cultures.-After the five months observations were made, the wood block cultures were observed at intervals until the end of the incubation period (ten months) in order to determine if fruiting bodies were produced, and, if so, if there were any observable differences between isolates with regard to this characteristic. Of the ten isolates, five produced sporebearing structures on wood blocks. Childs (1937) mentioned the production of sporophores by P. schweinitzii on agar medium, but this was not observed in the present study.

The isolates varied widely in the total number of spore-bearing structures they produced as well as in lengths of time required for their production. The series inoculated with Isolate 40 produced the most fruiting bodies (nineteen of the twenty tubes contained such structures), a total of fifty-four being produced; Isolate 39 produced the next greatest

**TABLE III.**—Types of reactions obtained in paired cultures of isolates of of *P. schweinitzii.* (Type of reaction is indicated by number of explanation in text). "N" indicates that there was no line of demarcation.

| No. | : | 1 | 10 | 19 | 31       | 32 | 38 | 39 | 40 | 40e | 40j |
|-----|---|---|----|----|----------|----|----|----|----|-----|-----|
|     | : |   |    |    |          |    |    |    |    |     | _   |
| 1   | : | N |    |    |          |    |    |    |    |     |     |
| 10  | : | 2 | Ν  |    |          |    |    |    |    |     |     |
| 19  | : | 2 | 2  | Ν  |          |    |    |    |    |     |     |
| 31  | : | 1 | 1  | 1  | Ν        |    |    |    |    |     |     |
| 32  | : | 1 | 2  | 2  | 1        | Ν  |    |    |    |     |     |
| 38  | : | 3 | 3  | 3  | 3        | 3  | N  |    |    |     |     |
| 39  | : | 1 | 2  | 1  | 1        | 1  | 3  | Ν  |    |     |     |
| 40  | : | 2 | 2  | 1  | 1        | 2  | 3  | 1  | Ν  |     |     |
| 40e | : | 2 | 2  | 2  | <b>2</b> | 2  | 3  | 1  | 2  | Ν   |     |
| 40j | : | 2 | 2  | 2  | 1        | 2  | 3  | 1  | 2  | 2   | -N  |

number, No. 40e was next, then No. 40j, and No. 32 produced the least. Isolates 1, 10, 19, 31 and 38 produced no fruiting bodies during the ten months incubation period.

None of the fruiting bodies that were produced in culture resembled the normal sporophores of P schwein*itzii* either in shape or size, but nearly all of them produced spores in great abundance. Isolates 32, 40, 40e and 40j produced fruiting bodies which were largely of a cerebroid or lamellate type with a tendency in some instances toward a porose condition; Isolate 39, however, produced fruiting bodies which macroscopically were clavaria-like in their appearance. Although Nos. 40e and 40j, which were monospore cultures from No. 40, did not correlate with the parent isolate in the number of fruiting bodies produced, they did produce structures of the same type. Fruiting bodies varied in diameter from 2 mm. to 2 cm.; most of them being roughly hemispherical except when produced on the corner or edge of a wood block. Figure 2. Plate V and Figure 3, Plate VI, show the type of fruiting bodies produced by Isolates 32, 40, 40e, and 40j; Figure 3, Plate V, shows the clavarialike type produced by Isolate 39; Figure 2, Plate VI, shows a normal sporophore of P. schweinitzii. The order of appearance and number of spore-bearing structures produced by each of the five isolates are shown in Table IV.

Appearance of wood blocks after ten months.—Cultures were discontinued on October 12, 1937, after having been maintained for a period of ten months. The wood blosks were removed from their tubes, wiped carefully with a moist cloth to remove all surface mycelia and fruiting bodies, and were then air-dried. The appearance of the air-dry wood blocks were as follows:

- Blocks 1-20 (inoculated with No. 1): Dark, reddish-brown discoloration in spots: cubical cracking occurring in the discolored areas. Discolored spots occurring largely near the middle portions of the wood blocks, in which regions the moisture content of the wood was probably more nearly optimum for the mycelium.
- Blocks 21-40 (inoculated with No. 10): Brown discoloration as in the first series, but the discolored areas were greatly depressed and cubical cracking was much more pronounced.
- Blocks 41-60 (inoculated with No. 19): Discolored spots reddish-brown, small, and in every instance confined to the middle portions of the blocks. Cubical cracking was very obvious; deprossion in discolored areas was slight.
- Blocks 61-80 (inoculated with No. 31): Infected blocks were only slightly darker than uninfected ones. Eroded, dark red areas very scarce and quite small. Cubical cracking only in one or two instances and then it was confined to the dark red, eroded areas.
- Blocks 81-100 (inoculated with No. 32): Brown discolored areas occupying approximately the middle two-thirds of each block. Shrinkage slight; cubical cracking evident in every block.
- Blocks 101-120 (inoculated with No. 38): Slight discoloration; cubical cracking apparent; slight shrinkage at the middle regions of the blocks.
- Blocks 121-140 (inoculated with No. 39): Tan discoloration; large eroded areas evident in a few instances; shrinkage evident in the lower portions of most blocks.
- Blocks 141-160 (inoculated with No. 40): Middle two-thirds of all blocks greatly shrunk; dark brown discoloration; cubical cracking quite evident.
- Blocks 161-180 (inoculated with No. 40j): discoloration, occurring mostly in small depressed areas where cubical cracking was evident.
- Blocks 181-200 (inoculated with No. 40e): Central portions of blocks brown, slightly shrunk; cubical cracking very obvious in these areas.

From the above summation of the appearance of the various wood block series, it is evident that the isolates behave somewhat differently when cultured in this manner. In most blocks, wherever destruction reached any considerable degree, the cubical cracking, so characteristic of attack by *P. schweinitzii*, was quite evident. As

| TABLE | IV.—Fruiting     | body | production | in | wood | culture | $\mathbf{b}\mathbf{y}$ | isolates | of |
|-------|------------------|------|------------|----|------|---------|------------------------|----------|----|
| of    | f P. schweinitzi | i.   |            |    |      |         |                        |          |    |

|         | Mycelium                                |            |            |    |     |    |  |  |  |
|---------|---|------------|------------|----|-----|----|--|--|--|
| Date    |   | 40         | 400        | 59 | 40j | 32 |  |  |  |
| July 2  | No. of cultures<br>with fruiting bodies | 13         | 15         |    |     |    |  |  |  |
|         | No. of<br>fruiting bodies               | 13         | 15         |    |     |    |  |  |  |
| July 24 | No. of cultures<br>with fruiting bodies | 17         | 16         |    |     |    |  |  |  |
| bury be | No. of<br>fruiting bodies               | 34         | 36         |    |     |    |  |  |  |
| Julv 28 | No. of cultures<br>with fruiting bodies | 19         | 16         | 5  | 1   |    |  |  |  |
| July 28 | No. of<br>fruiting bodies               | 39         | <u>4</u> 0 | 9  | 1   |    |  |  |  |
| July 31 | No. of cultures<br>with fruiting bodies | 19         | 16         | 7  | 1   |    |  |  |  |
|         | No. of<br>fruiting bodies               | 43         | <b>4</b> 0 | 24 | 1   |    |  |  |  |
| Aug. 5  | No. of cultures<br>with fruiting bodies | 19         | 16         | 7  | 3   |    |  |  |  |
| Aug. 5  | No. of<br>fruiting bodies               | <b>4</b> 7 | 43         | 28 | 4   |    |  |  |  |
| Oct.3   | No. of cultures<br>with fruiting bodies | 19         | 18         | 12 | 10  | 1  |  |  |  |
|         | No. of<br>fruiting bodies               | 54         | 46         | 53 | 25  | 2  |  |  |  |

noted above, in some series the blocks were greatly discolored, whereas in others there was almost no discoloration. Figure 1, Plate VI, shows a group of attacked blocks selected to show differences in amount of cracking, degree of discoloration, and of shrinkage.

Weight losses from infected wood blocks.---When the infected wood blocks were completely air-dry, each was weighed and its percentage of weight loss was calculated. Average percentage weight losses were then calculated for each series; these average percentage weight losses and their probable errors are presented in Table V.

From the results shown in Table V it may be seen that the isolates

aried considerably in their wood-deaying abilities when grown in pure ulture on wood blocks. In a comarison of the percentage weight osses caused by any two isolates, two probable errors must be taken into account, and the probable error of the lifference is always greater than ither of the two probable errors inolved; however, the probable error of the difference is so small in a numper of instances that the difference s a significant figure. Isolate No. 40 nay be said to be the most destrucive and Isolate No. 19 the least detructive of the isolate studied, with various intergradations occurring beween these two extremes. On the basis of percentage weight losses the en isolates may be arranged accordng to the following series: 40 > 40e >10j > 38 > 32 > 10 > 39 > 1 > 31 > 19.

ent lengths of time, and perhaps their differences may be explained on this basis; however, the possibility exists that, even under natural conditions, subsequent monospore generations may have a tendency to become attenuated in degree of destructiveness.

In Table VI, the differences in percentage weight losses induced by the various isolates are presented; the table is so arranged that the difference in percentage weight loss caused by any two isolates may be found at the intersections of the horizontal and vertical rows of the isolates being compared. Standard deviation was calculated by means of the formula: S. D.= V fid Probable error of av-N-1 calcu!ated bv erage was the formula: P. E.=<sup>0.6745</sup> S. D. prob-

**TABLE V.**—Differences in percentage of weight losses from white pine sapwood blocks induced by isolates of **P. schweinitzii**.

|         |         | Average                      |
|---------|---------|------------------------------|
| Isolate | Block   | Percentage                   |
| No.     | Nos.    | Weight Losses                |
| 1       | 1-20    | $9.25 \pm (\text{or-}) 0.38$ |
| 10      | 21-40   | 12.99 + (or) 0.52            |
| 19      | 41-60   | $7.29 \pm (\text{or-}) 0.38$ |
| 31      | 61- 80  | 8.52 + (or) 0.33             |
| 32      | 81-100  | 13.30 + (or-)0.60            |
| 38      |         | $14.12 \pm (\text{or}) 0.50$ |
| 39      |         | 11.75 + (or) 0.55            |
| 40      |         | $20.28 \pm (\text{or}) 1.23$ |
| 40j     |         | $14.42 \pm (\text{or}) 0.90$ |
| 40e     | 181—200 | 18.10 + (or-)0.66            |
|         |         |                              |

It has already been pointed out that Isolate No. 40j varied more widely than No. 40e from the parent isolate (No. 40) both in culture on artificial medium and on wood blocks as well as in the number of fruiting bodies produced. It is interesting to note also that both Nos. 40e and 40j were less destructive than No. 40, and that No. 40j was less destructive than No. 40e. Naturally, these mycelia have been cultured on artificial media for differable error of difference by the formula: P.E. (d) =  $\sqrt{P.E.} \frac{2}{a} + P.E. \frac{2}{b}$ Statisticians are not in complete agreement as to which should be considered significant in analyses of this type; however, many will agree that the figure is probably a significant one if the difference is three times as great as the probable error of the difference, and, if the difference is six times as great as the probable error of the difference, it is agreed

**TABLE VI.**—Differences in percentage of weight losses from white pinesapwood blocks induced by isolates of **P. schweinitzzi**. The isolates,on the basis of their destructivenessmay be arranged as follows:40>40e>40j>38>32>10>39>1>31>19.

|             |   |                       |               |                   |                           |                           |               |                       |                | _                     |
|-------------|---|-----------------------|---------------|-------------------|---------------------------|---------------------------|---------------|-----------------------|----------------|-----------------------|
| 40 <b>j</b> |   |                       |               |                   |                           |                           |               |                       |                |                       |
| 40e         |   |                       |               |                   |                           |                           |               |                       | 8<br>9<br>8    | 3.63±<br>1.11         |
| 40          |   |                       |               |                   |                           |                           |               |                       | 2.21±<br>1.39  | 5.84±<br>1.52         |
| 39          |   |                       |               |                   |                           |                           |               | 8.53 <u>±</u><br>1.34 | 6.32±<br>0.85  | 2.69 <u>†</u><br>1.05 |
| 38          |   |                       |               |                   |                           |                           | 2.37±<br>0.74 | 6.16±<br>1.31         | 3.95±<br>0.82  | 0.324<br>1.02         |
| 32          |   |                       |               |                   | 8                         | 0.82 <del>1</del><br>0.78 | 1.55±<br>0.81 | 6.98±<br>1.36         | 4.77±<br>0.89  | 1.14 <b>±</b><br>1.08 |
| 31          |   |                       |               |                   | 4.78 <del>1</del><br>0.68 | 5.60±<br>0.59             | 3.23±<br>0.60 | 11.76±                | 9.45±<br>0.73  | 5.92±<br>0.95         |
| 19          |   |                       | 8             | 1.23±<br>0.50     | 6.01±                     | 6,83±<br>0,62             | 4.46±<br>0.66 | 12.99±<br>1.28        | 12.78±<br>0.76 | 7.15±                 |
| 10          |   | 8                     | 5.70±<br>0.64 | <u>4.47±</u> 0.61 | 0.31±<br>0.79             | 3.13±<br>0.72             | 1.24±<br>0.76 | 7.294                 | 5.08±<br>0.84  | 1.75±<br>1.03         |
| ٦           |   | <u>3.74</u> ±<br>0.64 | 1.16±<br>0.53 | 0.73±<br>0.50     | 4.05±<br>0.71             | 4.87±<br>0.62             | 2.50±<br>0.66 | 11.03±<br>1.28        | 8.82±<br>0.76  | 5.19±<br>0.97         |
| No.         | 1 | 10                    | 19            | 31                | 32                        | 38                        | 39            | 40                    | 40e            | 40,                   |

that the difference is a certainty. In Table VI, the differences which are at least three times as great as their probable error are underlined once; those which are at least six times as great as their probable error are underlined twice. Out of a possible forty-five comparisons, thirty-three may be considered to represent significant differences.

In a series of similar wood-decay studies, Schmitz (1925) found similar variations among different isolates of Fomes pinicola Fr. This author, working with four isolates from Douglas fir, western hemlock, western white pine, and white fir, found differences in percentage weight losses caused by the action of the different isolates on various woods: he also reported differences in enzymatic activities of the different isolates. Percival (1933), working with mvcelia of Fomes pini(Thore) Llovd, which had been isolated from specific hosts, found no differences such as those described by Schmitz for F. pinicola or by the present writer for P. schweinitzii. Percival stated of P. pini: "The extent of decay in spruce judged by loss in specific gravity and crushing strength showed as great variation when produced by cultures from the same host as that produced by cultures from different hosts. . ." On the basis of Percival's results it must be admitted that physiological specialization within the species need not necessarily occur in all wood-destroying fungi. This would scarcely be expected, however, because in all groups of organisms there are some species in which individuals occur which are subject to variation over a rather wide range in their activities, whereas there are other species in which the individuals are confined to more

narrow limits. It is to be expected that further investigation of the activities of many wood-destroying fungi will reveal species of both types.

Growth rates of isolates in liquid medium. Since the results of the weight loss measurement experiment showed definitely that differences between isolates do exist, the question concerning the cause for such differences naturally arises. The simplest explanation might be that the differences were due to differential growth rates and for that reason an attempt was made to measure the growth rates of the different isolates in liquid medium. Growth rates (based upon weight of mycelium produced in five weeks) were determined; the average weights (based on ten replicates) of the mycelial mats produced by each isolate were as follows:

| [solate | 1   |        | mg. |
|---------|-----|--------|-----|
| lsolate | 10  |        | mg. |
| Isolate | 19  |        | mg. |
| Isolate | 31  |        | mg. |
| Isolate | 32  |        | mg. |
| Isolae  | 38  |        | mg. |
| Isolate | 39  |        | mg. |
| Isolate | 40  |        | mg. |
| Isolate | 40e |        | mg. |
| Isolate | 40  | j116.5 | mg. |

As may be seen from the above figures, No. 40e produced the smallest amount of mycelium (88 milligrams per culture), whereas No. 39 produced the greatest amount (169.5 milligrams per culture). This does not correlate in any way with the wood-destroying activity of the isolates, since No. 19, not No. 40e, was least destructive to wood blocks, and No. 40, not No. 39 caused the greatest destruction. This lack of correlation is well-illustrated in Text Figure 1.

### SUMMARY AND CONCLUSIONS

Ten different isolates of Polyporus



Physiological Variation in Isolates of Polyporus schweinitzii Fr. (Fungi; Basidiomycetes)

schweinitzii Fr., which were derived from different sources and were shown to differ in color, gross colonial appearance, and rate of spread on agar medium, were tested in order to determine their growth rates in liquid medium and also to determine their relative capacities for destruction of white pine sapwood. This destructive capacity was judged by loss of inoculated wood weight blocks. From these studies the following conclusions may be drawn:

- 1. Isolates vary as widely from each other in appearance in wood-block culture as they do upon artificial medium.
- 2. Isolates of this species differ in fruiting body production not only as to number and rate of production, but also as to form. Of the ten isolates examined only five produced fruiting bodies on wood-blocks during a ten month incubation period. Isolate No. 39 produced structures which were clavarialike in appearance; the other four produced cerebroid or lamellate fruiting bodies. The number of fruiting bodies (per twenty cultures) developed by such isolate was as follows: No. 40-54, No. 39-53, No. 40e-46, No. 40j-25, and No. 32-2. It should be noted that No. 40 produced a greater number than No. 40e (fifth monosporous generation from No. 40), and that No. 40e in turn pro-duced a greater a greater number than No. 40j (tenth monosporous generation from No. 40). These data seem to indicate the loss of capacity for fruiting body production in succeeding monospore generations; however, this point will need further investiga-tion before a definite statement may be made.
- 3. When the destructive capacity of the isolates on white pine sapwood was measured it was again found that iso-

lates varied widely. Average percentage weight losses from twenty replicate blocks varied from 7.29+(or-)0.38 per cent in wood blocks inocolated with Isolate 19 to 20.26+(or-)1.23 per cent in blocks inoculated with Isolate 40. With regard to Isolate 40 and the two monospore generations derived from it, it is obvious that the destructive capacity of No. 40>No. 40e>Nc. 40j. Under the conditions of the experiment, subsequent monospore generations show a tendency to become attenuated in degree of destructiveness.

- 4. Further evidence as to the existence of differences between the ten isolates is obtained by comparing the differences in weight losses induced by the isolates. In such a comparison, there exist forty-five possible combinations using two isolates for each; of these forty-five possibilities, thirty-three yielded differences, which on the basis of standard statistical methods may be considered significant.
- 5. Studies made on the growth rates of isolates show clearly that there is no correlation between capacity for destruction of wood and growth in liquid medium.

The general conclusion which may be drawn from the above studies is in agreement with the opinion of Childs (1937) who concluded that Poluporus schweinitzii Fr. is a species composed of many widely differing individuals. Subjection of the various individuals to critical biochemical studies would undoubtedly reveal still further differences.

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PLATE 1



| 1 1 1 1 1 |      | Gunture  | 01 130 | nate  | χ,      | 1 11 10 | WUULS  | anci n   | iocutation. |              |
|-----------|------|----------|--------|-------|---------|---------|--------|----------|-------------|--------------|
| Fig.      | 2.   | Culture  | of Isc | late  | 10,     | two     | weeks  | after in | oculation   |              |
| Fig.      | 3.   | Culture  | of Ise | late  | 19,     | two     | weeks  | after in | oculation   |              |
| Fig.      | 4.   | Culture  | of Ise | late  | 31,     | two     | weeks  | after ir | oculation   |              |
| Fig.      | 5.   | Culture  | of Isc | late  | 32,     | two     | weeks  | after ir | oculation   |              |
| Fig.      | 6.   | Culture  | of Isc | olate | 38,     | two     | weeks  | after ir | oculation   |              |
| Fig.      | 7.   | Culture  | of Isc | late  | 39,     | two     | weeks  | after ir | oculation   |              |
| Fig.      | - 8, | Culture  | of Ise | late  | 40,     | two     | weeks  | after ir | oculation   |              |
| Fig.      | 9.   | Culture  | of Iso | late  | 40e,    | two     | weeks  | after in | oculation   |              |
| Fig.      | 10.  | Culture  | of Ise | late  | 40j,    | two     | weeks  | after ir | oculation   |              |
| Fig.      | 11.  | Paired c | ulture | of I  | solates | ; 1     | and 32 | showing  | line of     | demarcation. |
| Fig.      | 12.  | Paired c | ulture | of I  | solates | 1       | and 39 | showing  | line of     | demarcation. |
|           |      |          |        |       |         |         |        |          |             |              |

### PLATE II



### **EXPLANATION OF PLATE II.**

Fig. 1. Five month old wood block culture of Isolate 1. (Magnification x 2/3). Fig. 2. Five month old wood block culture of Isolate 10. (Magnification x 2/3). Fig. 3. Five month old wood block culture of Isolate 19. (Magnification x 2/3).

PLATE III



# **EXPLANATION OF PLATE III.**

Fig. 1. Five month old wood block culture of Isolate 31. (x 2/3). Fig. 2. Five month old wood block culture of Isolate 32. (x 2/3). Fig. 3. Five month old wood block culture of Isolate 38. (x 2/3).

# PLATE IV



### EXPLANATION OF PLATE IV.

Fig. 1. Five month old wood block culture of Isolate 39. (x 2/3). Fig. 2. Five month old wood block culture of Isolate 40. (x 2/3). Fig. 3. Five month old wood block culture of Isolate 40j. (x 2/3).



PLATE V

### **EXPLANATION OF PLATE V.**

Fig. 1. Five month old wood block culture of Isolate 40c. (x 2/3).
Fig. 2. Fruiting body of the type developed by Isolates 32, 40, 40e and 40j in wood block culture. (x 4).
Fig. 3. Clavaria-like fruiting body developed by Isolate 39 in wood block culture. (x 2.5).

### PLATE VI

### EXPLANATION OF PLATE VI.

- Fig. 1. White pine sapwood blocks showing destruction caused by P. schweinitzii, block at extreme left uninfected. (x 1).
- Fig. 2. Normal sporophore of P. schweinitzii growing on needle-duff of forest floor. (x 1/2).
  Fig. 3. Fruiting bodies of the type developed by Isolates 32, 40, 40e and 40j in wood block culture. (x 2).

# **POLLINATION IN ASCLEPIAS**

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### Introduction

Possible commercial uses of milkweek (2, 17) suggest the value of knowing how milkweeds propagate. The production of fruits and seeds in angiosperms usually depends on the process of pollination. That this is accomplished only by insects in milkweeds has long been assumed but never clearly demonstrated.

In the Asclepiadaceae are found species in which the pollen grains are not separate as in other families but are bound into waxy masses or pollinia. In the formation of a pollinium pollen masses from two neighboring stamens become joined by stalks and a disc-shaped corpusculum. Between the pollinia is a slit which is open from below and leads upward to a point near the corpusculum. When the insect alights on a flower its legs slip down into the flower and as the leg is moved a hair, claw or other part is caught in the slit below the corpusculum. As the insect leaves the corpusculum the two attached pollinia are pulled out of the flower. The pollinia are thus carried to other flowers in the process of pollination.

The problem of milkweed pollination seems to have been approached indirectly by several investigators (3-16) who reported trapping different kinds of insects in milkweed flowers. Those insects usually included in these reports were of the orders Hymenoptera, Diptera, Lepidoptera and Coleoptera. In most cases, the insects were examined to determine if pollinia were carried on their leg

parts. Distinction was drawn between milkweed visiting insects carrying pollinia and those not carrying pollinia or corpuscula.

The manner in which pollinia are removed from one flower and introduced into another has been observed (14). Within a few seconds after removal of the pollinia and corpusculum from a flower the stalks supporting the pollinia were reported to twist in such a way as to bring the pollinia into a new plane, thus enabling them to be more easily introduced through the corpuscular slit into the stigmatic chamber of the next flower. Knuth (8) stated that flowers on a milkweed plant are selfsterile and an anonymous author (1) commented without scientific evidence that Asclepias syriaca was never self-pollinating. Several botanists have expressed opinions to one of the authors that the elaborate apparatus of the milkweed flower may have been greatly overrated and that it may be worthless, or even a handicap (1). The purpose of this study was to determine if milkweeds may nollinate themselves without the aid of insects.

### Observations

General observations showed that on twenty purple inflorescences of Asclepias syriaca there was an average of 90.6 flowers per inflorescence as compared with Nordham's (11) count of 60 for purple flowers and 95 for white flowers. The average number of fruits initiating from these inflorescences was 7.8 pair or 8.6 percent of the number of flowers in an inflorescence. As the fruits mature, however, all but a few die. On ten plants observed there was an average of five inflorescences per plant and only three, or six percent of the 53 inflorescences, failed to develop fruit. These figures suggest a higher percentage of fruit development in milkweed than has been generally recognized.

The pollinia on the legs of several insects were examined to determine their relative position following removal from the flower. The pollen masses were found to be oriented face to face, even after a period of several days, which appears to contradict the earlier report (14) that the pollinia stalks twist soon after being removed from the flower. Bees were observed to be by far the most common pollinating agent-everv bee trapped in the neighborhood having pollinia or corpuscula on its legs.

To study the role of insects in pollination, inflorescences were covered with bags to exclude the insects. At first paper bags were used but the flowers appeared to mature abnormally in these cases. In later experiments when light weight muslin bags were used the flowers developed normally and the visitation of insects to the flowers was prevented. Extreme care was taken to make certain no flowers had been partially opened and that the inflorescence did not conceal any hidden insects at the time of bagging. The bagged infloresences were inspected after one week when the flowers had opened and again two weeks later to determine if fruit had set. In most cases, the bags were allowed to remain in place until the fruits on uncovered plants had fully developed. All bags were inspected for holes and their contents were examined for bodies or parts of insects which may have penetrated the bags.

In July, 1939, at Columbus, Ohio, 28 inflorescences of Asclepias syriaca covered with paper bags failed to set fruit. The flowers within the bags were observed to be pale and somewhat "cooked" looking.

In June, 1943, near Richmond, Kv., 48 inflorescences of Asclepias syriaca were bagged with paper and muslin bags. Twelve of these initiated fruit but in each case the bag had been penetrated by an insect (usually a bee) and parts of the insects were found within the bag. It thus appeared that insect pollination had occurred. The fruit, however, aborted early and never matured. only attaining a length of one and one-quarter inches. The inflorescence stalk seemed uninjured at the conclusion of the experiment and the flowers appeared normal one week after bagging. No explanation for the failure of continued development following pollination was evident. However, it is possible that in milkweed any fruit initiated as the result of self-fertilization may fail to mature due to self-sterility. The remaining 36 inflorescences did not initiate fruit of any kind. Ten mature inflorescences on the same plants exposed to insects before bagging developed normally.

Fifty-five inflorescences of Asclepias purpurescens were bagged in muslin near Richmond, Ky., in June, 1944. None of these initiated fruit. The peduncles of 28 of these remained firm and green, while the remaining 27 dried up and turned brown as if injured.

These observations and experiments indicate that pollination by insects is essential for the normal development of milkweed fruit.

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# A COMPREHENSIVE SURVEY OF CONTROLLED GRAIN ALCOHOL PRODUCTION METHODS

# A I ZAROW1

### GENERAL DISTILLERS CORPORATION OF KENTUCKY LOUISVILLE 6. KENTUCKY

Scientific control of production depends upon the application of rapid, reliable<sup>2</sup>, and valid<sup>3</sup> methods of analvses of variables and their effect upon unit operations.

The time requirements of a control method should not exceed the time of the unit operation being controlled.

The distilling industry is undergoing an evolutionary change of production methods-from an art to a science. The former is a result of post-mortem analyses, utilizing unreliable and invalid control methods.

It is the purpose of this paper to identify rapid, reliable, and valid methods suitable for distillery control

#### Starch Determination

Corn, rye, milo, wheat, and malt are the chief sources of starch for grain alcohol production. The conversion of grain starch to ethyl alcohol is nearly quantitative; therefore.

point of departure. Fermentation Efficiency equals Actual Proof

gallons/56<sup>††</sup> of grain over Theoretical Proof

gallons/56<sup>††</sup> of grain. Theoretical Proof gallons/56<sup>††</sup> equals % starch x 1.725. of grain

5S. Em equals Standard error of the mean equals " over N-1.

S. Em equals 2.3 ", or 95% of the cases considered

¶ equals Standard deviation

N equals Number of cases

N-1 equals Number of cases less than 25

a theoretical amount of alcohol can be calculated from the known amount of starch. The amount of starch in the grain varies with the grades and type of grain, and since distilleries use various grades and types of grain, the only method for the determination of fermentation efficiency4, anticipated yield, and econoical operations, is based on starch determination. The grain is processed in the following manner: (A) The grain is ground on roller, hammer. attrition mills. (B) To the or ground grain, water and stillage (screened residue from distillation) are added, and this mixture is cooked either under pressure or atmos-(C) The cooked pheric conditions. mixture is cooled to 148-150°F and then converted to sugar (primary conversion) by the addition of either a water slurry of ground malt or dried ground malt that contains amylases. (D) The resulting sugar from the initial, converted starch plus residual starch and various intermediate starch-sugar molecules is cooled to 70-86°F and fermented to ethyl alcohol and by-products by the addition of veast.

The polarimetric method for the determination of fermentable starch in grain is more rapid and reliable, and contains fewer sources for errors than other methods, such as numerous transfers of material, temperature control, and the skill of the Seagram's results (1) on analyst. wheat when using cold hydrochloric acid for the solubilization of starch previously washed with ether, alco-

actuality indicates a night degree of corre-lation between two sets of independent results obtained under theoretical identical conditions. "Validity is the correlation between opera-tional data and the criterion which serves as the

hol, and water, produced results which had a S.  $Em^5$  of 0.28. The amount of starch in the wheat determined by the polarimetric method and the ASSOCIATION OFFICIAL AGRICULTURAL CHEMIST method was correlated with fermentation efficiencies. The actual proof gallons per 56 lb. bushel of grain was obtained by laboratory fermentations. Canadian method (2, 2a), which uses CaCl<sup>2</sup> in place of HCl has therefore been tentatively accepted by the A. O. A. C. as the method of choice. Based on the correlation obtained between the amount of starch in grain and fermentation efficiency using the A. O. A. C. method minus pentosans, the validity of the polarimetric method without a factor is not ef-

(DRY

BASIS)

69

59.5

\*FERMENTATION

EFFICIENCIES

83.8--- 87.6

91.6-95.9

90.9 - 100.4

### TABLE 1—FERMENTATION EFFICIENCIES APPARENT STARCH

#### METHOD

1. A. O. A. C. (Diastase-HCl)

2. A. O. A. C. (Diastase-HCl minus Pentosans) 63

3. Polarimetric (No Factor)

\* M equals 2.3 plus minus.

The wheat starch was determined by the A. O. A. C. (Diastase—HC1) (10) and Polarimetric methods. The results are illustrated in Table I.

Metzner's work (3b) indicates the pentosans in grain, especially in wheat, give high results in starch determinations by the A. O. A. C. method, and thus low fermentation efficiency.

In order to correct for the amount of pentosans, the pentosans were determined by the A. O. A. C. method, and the resulting amount was subtracted from the total starch determined by the A. O. A. C. method. Often a factor is used to convert starch equivalents from the polarimetric method to the A. O. A. C. method. The angle of rotation used is 200.

The A. O. A. C. method measures starch and other material such as pentosans and hemicelluloses (3, 3a). Methods 2 or 3 in Table I appear more reasonable. This is based on 95 percent conversion of starch to reducing sugar, and 2-3 percent sugar utilization for yeast growth, and 2-3 percent converted to non-fermentable material such as dextrins. However, cold concentrated hydrochloric acid may cause partial hydolysis of hemicelluloses and pentosans. The fected. In addition the polarimetric method is more rapid, reliable, and practical than the colorimetric (4), Rask (5), or the A. O. A. C. (diastase HCl) method (10).

# Percent Conversion of Mash-Maltose-Dextrin Ratio

The conversion of starch to fermentable sugar is a function of the following factors: (A) conversion temperature; (B) conversion power of malt; (C) holding time; (D) pH. Thus the percent conversion of starch to sugar reveals whether variables that govern the conversion of starch are within the limits of good operations, and if not, what variable or combination of variables are causing low results.

The procedure consists of the following steps: (A) The converted grain solution is filtered; (B) a measured amount of the filtrate is placed into a flask containing (sp. gr. 1.125) hydrochloric acid and refluxed 2 1-2 hours. (C) the refluxed solution is cooled and neutralized with sodium hydroxide to pH 7; (D) The neutral-

ized solution is made up to a known volume which is used to titrate a known amount of standard Fehling's solution according to the Lane-Eynon procedure (10)—this result indicates the total possible amount of reducing sugar in the cooked grain solution. The initial or primary amount of sugar in the grain cook is determined by titrating a measured amount of standard Fehling's solution before acid hydolysis.

% Conversion equals initial reducing sugar as glucose x 100% over total reducing sugar as glucose.

A modification of the above method decreases the total time from three hours to one hour. The reliability is not altered. This is accomplished by the use of concentrated instead of (sp. gr. 1.125) hydrochloric acid for the hydrolysis of the dextrins. As a result, the reflux time is reduced from two and one half hours to one-half hour. The effect of the concentrated acid on the pentosan or hemicelluloses is minimized by the partial insolubility of these substances.

#### Amlyase

The initial conversion of the grain starch to reducing sugar by the addition of ground malt or a malt slurry containing the amylases is approximately 70-85%; therefore, there is 10-25% starch present at the start of fermentation, and this residual starch must be converted to sugar, to large extent, by the residual amylase in malt for the production of the maximum amount of alcohol. Thus, the amount of active amylases present in the fermenter is essential, The amount of active residual amvlase present during fermentation is a function of pH, alcohol concentration, concentration of sugar, and temperature.

The determination of amylase in

grain alcohol fermentation mash can be completed within six minutes, and with a minimum of equipment; whereas, the modified Wohlgemuth method (7) takes one and one-half hours and uses comparatively large, precision equipment. In addition, the latter method has many possible sources of errors such as preparation of the starch solution and water bath temperature control.

The test for residual amylase activity is conducted by the addition of tincture of guaiac (7a) to 5 milliliters of filtered mash. A blue colored compound is formed. The retention and extinction point of this color appears to be a function of the concentration of the amylase in the mash.

The method appears specific for amvlase. Starch, protein hydrolyzates, inorganic or organic nitrogen, and glucose do not interfere with the test: ethyl alcohol tends to dissolve the precipitate but does not influence the formation and intensity of color other than the tolerance of alcohol on amylase. The reliability of this determination is signified by a S. Em equal 0.50 minute. The validity of this method is based on the correlation of the guaiac time of malt and the amount of reducing sugar formed from starch by the addition of various alcoholic malt slurries to 2% starch solution. Tt appears that guaiac time of four minutes signifies that there is sufficient amylase to convert 5-10% starch, 10 minutes-25% starch, and 15 minutes-35% starch, or in Wohlgemuth units 110-330 is equivalent 4-8 minutes guaiac time

### Contamination Determination

For maximum alcohol production, milling, cooking, conversion, and fermentation operations must conform

to a high level of sanitary practices. If contaminants are present in the plant mash the amount of alcohol produced will be low. These contaminants will utilize the sugars and starch for the production of products other than ethyl alcohol. Therefore, in the control of production it is essential that the amount of contamination (and the level of contamination) in a plant be known.

An acid rise-bacteria count-yield curve, (Figure 1) can be established in each distillery. This curve will set. Therefore, once the acid rise at x hours is known, the corresponding acid rise at the time the fermenter is distilled can be determined from the chart, figure 2.

The media used for these studies were thioglycollate and tryptone, both of which were prepared by Difco. Besides producing rapid results, the method eliminates a great deal of time in preparation of material for the bacteriological test. However, any specific part of the system which contains bacteria that



reveal immediately that amount of contamination in the plant. The method of approach is illustrated in Figure 2. In this second figure, each total acid, from the set time (the time when a fermenter containing yeast is filled to a designated volume) to the time the fermenter is ready for distillation has a corresponding increase at x hours after act as a seed can only be found by the use of bacteriological media. Bacteria counts were determined by the use of the Halverson and Ziegler's (11) Probability table.

#### Crude Fiber

The residue from alcohol distillation is further processed for the production of animal feed. This process produces two types of feed (A)

light or dark dried grain. and (B) distillers' solubles. Light grain is produced by screening the alcohol-free distillation residue: the coarse material which is retained on the screen is pressed, and finally dried to 8-10% moisture in a rotary drier. If syrup is added to this material before it is fed to a rotary drier, the product is known as dark dried grain. The syrup is produced by evaporating to a solids content of 25-30%, the fluid portion of the alcohol-free distillation residue in multiple effect evaporators. In production of distillers' solubles this syrup is dried on drum dryers. Distillers' solubles is a high nutritive animal feed, and since it is usually used in various mixed feeds, its chemical composition (nitrogen, fats, fibers, mineral salts, and vitamins) is important. In the marketing of by-products grain residues a statement of moisture. protein, fat, and fiber is required. Since the determination of the crude fiber content of grain products requires more time than any other analyses it is essential that a rapid, reliable, and valid method for determining the amount of crude fiber be employed.

Whitehouse's (8) method for the determination of crude fiber in dried grain is twice as rapid as the A. O. A. C. method. The inherent errors are reduced by the decrease in the number of transfers of the material. The above determination had a S. Em equal 0.03 compared to 0.08 for the A. O. A. C. procedure (10). Therefore, the distribution of the data is significantly greater in case of the A. O. A. C. method as compared to the Whitehouse's procedure.

The new method eliminates separate digestions with caustic and acid, and instead uses one digestion with a mixture of glacial acetic, nitric, and trichloracetic. The Whitehouse method markedly accelerates filtration time after treatment compared to extended periods with the A. O. A. C. procedure

### **Protein Determination**

The determination of the amount of protein in grain aids in establishing the cooking procedure, as proteins indirectly effect the percentage starch converted to sugar (9); also, the protein content of dried grain and dried solubles (products of alcohol-free residue after distillation) is required for marketing.

The method for determining the amount of protein in grain, dried grain, and solubles developed by Whitehouse (6) can be completed within an hour and has a reliablity of S. Em equal 0.04 compared to a minimum of 3 hours and S. Em. equal 0.12 for the A. O. A. C. (10) method. The Whitehouse method uses H2O2, and P2O5 as oxidizing agents, HgO as catalyst, and K2SO4 to elevate the boiling point of the mixture. Based on values obtained with the A. O. A. C. method the validity is not affected by the use of the above reagents.

### Discussion

The application of these methods in distilleries has aided to a great extent in producing high efficiencies, economical operations, and simultaneously, uniformity and quality of product. These fundamental objectives can be realized by the establishment of operational limits based on reliable and valid analytical methods. All phases of operations can be measured. Reliable and valid methods correlated with normal operations will produce economical operations, uniformity and quality of product. Normal operations are defined as

A Comprehensive Survey of Controlled Grain Alcohol Production Methods



phases of productions of constant variability within fixed limits.

The methods discussed above all meet the time requirements for controlled operations; in addition neither skilled technicians nor elaborate equipment is necessary; in other words, these methods give the production man the tools essential for the attainment of the principles mentioned here.

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# A Planned Economy For Kentucky's Waters\*

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If all Kentucky's rainfall should happen to be precipitated in an instant, it might be considered her greatest crop, standing, as it would. some forty inches deep over lands. rooftops and roads. If it should fall in the form of snow, it would average more than thirty feet upon field, forest and town. This crop is one produced without labor, without expenditure for seed, rentals, or overhead of any kind. It falls almost equally upon all of the lands of the state, without regard to fertility or other variable. The total production of some 120 billion tons at the domestic rate of 8.4 cents per ton, delivered at the kitchen sink, would amount to more than ten At this so-called billion dollars. cheap rate Kentucky's rainfall should pay off the national debt within the lifetime of many persons here present.

The above calculations are without value except to emphasize the magnitude of a natural resource, which together with the sunshine and air, claim little attention. Possibly no political division of the United States gives less consideration to water-supply and what might be done about it.

Ideally this resource should be evenly distributed at perhaps weekly intervals throughout the year, just enough to mature crops and replenish ground-water, with none left over. But actually it is uneven as between one year and another, one season and another, and between the weeks of the same season. The range is between total failure and great excess at any time of the year. Of course mankind can do nothing about it—or can we? The tradition is now and has always been THAT MAN IS HELPLESS IN THE HANDS OF A **RELENTLESS FATE**—that neither the individual nor the State may hope to control so great a force of Nature. We either believe that or behave as though we do. In some of the more level lands of the prairie states, the farm owner has more or less successfully controlled the excess rainfall through artificial subsurface drainage and systems of public ditches. But in Kentucky most of the land lies on a decided slope and is closely underlain by its parent rock, so drain-tile is no answer to excessive rainfall here. The more than one-hundred billion tons of water therefore dashes precipitously toward the streams, except as restrained by the porosity of the soil, the rock, and the root-systems of vegetation.

The fate of the cargo of soil swept down into the streams has begun but recently to be a matter of general public concern, and one about which it was believed that united action might be taken. Yet to this moment little planning has related directly to the *water* itself, or otherwise than as the agent of erosion.

From the point of view of those citizens whose theory of government is strongly on the side of statesovereignty and state responsibility, it may appear unfortunate that Kentucky has done so little on her own initiative. She has awaited the nation-wide program of conservation so belatedly handed down to her in recent years from higher up. Being the oldest of the mid-western states, she has suffered from this neglect longer

<sup>\*</sup>Presented before the annual meeting of the Kentucky Academy of Science, April, 1947.

than most of her neighbor-states. Not only that, but Kentucky has failed to this moment to assume the leading part in her own restoration. As the situation may be summarized today, Kentucky is playing only the supporting role in the soil and forest conservation, while neither the federal nor state government is attacking the problems of water-control and aquatic resources through any equitable and all-round plan.

In the early history of the state, while there was sufficient forested land to restrain the turbulence of rainfall on hillsides. streamflow was sufficiently constant to contribute to the industry of many communities. especially in transportation and in the operation of flour-mills. Records well attest their further usefulness to the inhabitants in the matters of food and water-supply. Since the passing of the primitive social and economic organization of that day, the water-resources, then largely a smallscale, private concern, have been lost in our preoccupation with greater matters-lumbering, mining, railroading, etc. Interest in our streams has lagged for generations and a new population has grown up which knows them not. It is not to be wondered at, then, that the Federal Government found our people ready to welcome the flood-control project without suspicion, especially as it came upon us during the stress of the Depression and that of the 1937 Flood-a period of anxiety, deprivation, and uncertainty. Public work-made work of any kind were the accepted panacea everywhere.

In the experience of a decade, what is Kentucky gaining and what is she losing in the transaction?

We entered the New Deal period with one of the most magnificent systems of streams to be found on the map. Encircling the great arch of the Blue Grass country the 120 billions of tons of annual precipitation of the state had sculptured out the sweeping arcs of the wide Tennessee. the scarcely less impressive Cumberland, Green River, the Tradewater and the Kentucky-and flanking the other side, the Licking and the Big Sandy. One by one these assets are being traded in on a system of storage reservoirs. sold to the public under the name of Lakes, which is more euphonious and unintentionally phony as well. Lakes they are not, nor any longer rivers-only so much water. Their necessary system of operation precludes the development of established stages, of fixed shore-lines, stationary boat-docks, littoral planting of feeding-grounds for wildlife. Α further exchange has been that of temporary floods downstream for permanent floods up-river-at least until the not remote time when they are silted up full and revert to alluvial land. The engineer's dream has become the valley-farmer's nightmare and a disappointment to the vacationer and sportsman.

Meanwhile the smaller streams suggest a second line of defense-a refuge from the encroachment of the flood-control engineer and his onetrack program-a refuge where other interests may still be much better represented. A wealth of such tributary waters is available, most of them masterpieces of beauty and adaptibility. The roll-call of these streams in itself evokes mental images of what Kentucky's outdoors with its wildlife might come to be: Rockcastle river, Nolin river, Rough river, Barren river, Salt river; such creeks as Troublesome and Quicksand, Kinniconnick, Elkhorn, Bluebird, Rolling Fork, Fishing creek, Beaver creek, Muddy fork, Station Camp creek, and a hundred more.

Shall Kentucky's master-planners now begin the strategy of acquiring some of those streams for the use of the public? What are some of the arguments for and against?

For: A common-sense reason is that water areas have been shown to be capable of producing more food than equal areas of land. On top of that count the income from hunters and fishermen - sale of ammunition. boat-hire, cabin rentals. Thus more or less waste land can be, and often has been, made to produce revenue. Thus all the recreation, and healthgiving activity, all the intellectual and spiritual advantages which Nature affords, and the aesthetic advancement of which Kentucky is capable, come gratis, or at least within the bounds of reason.

Against: 1. The backwaters from the impoundments of main rivers have already drowned, and will drown more, of the lower courses of the secondary streams. 2. Power-interests and flood-control engineers not only have their eyes upon our minor streams, but have already driven stakes along their courses, in some instances. Thus there is something of an emergency about the acquisition of these waters, if the Commonwealth of Kentucky cares to administer any of them for the benefit of its citizens.

Should the state go out for conservation of all natural resources in a big way, there are numerous fields into which it might enter. To name a few only: the increase of the furbearing aquatic-mammal population, of commercial fisheries, of buttonshell resources, in addition to the hunting and fishing usually thought of in this connection. In the aggregate these have never been considered a matter of first importance to the business of the state, comparable, if not of equal magnitude, with a roadbuilding program, for example.

Meanwhile we have assigned impossible responsibilities to the various conservation agencies of the state. We have made them attempt the production of large amounts of timber and of wildlife on small tracts of land and with few men and tools to do the work. But large populations of living organisms require large areas, and thus on the present scale of operation, we are doomed to be disappointed in the results, so long as we expect adequate output. The timber requirements and the recreational possibilities within a population of three million people should be very high. We have the people, but not the acreage of publicly owned land, in a situation of superabundant land suitable for such exploitation.

In addition to the hundreds of thousands of people who could get profit and enjoyment from frequent excursions into Kentucky's outdoors and the other thousands who would break the long drive to Florida or Michigan if Kentucky had facilities to offer, we have made no significant gestures in behalf of numerous groups of citizens and young people. Among these so very inadequately provided for are: the 4H clubs. sportsmen's clubs, the youth-hostel movement. Boy Scouts and Girl Scouts, Natural History Clubs, school clubs and classes in Biology and Nature Study. All these groups are carrying on, but they are missing valuable experiences from which our urban civilization is isolating them. The situation has only one right solution: state parks greatly amplified, hunting preserves and fish and game refuges, much more extensive state forests, hiking trails and trailside museums, so-called, trained personnel. They should be matched by smaller regional and municipal facilities, both terrestrial and aquatic.

What does all this have to do with Science and with an Academy of Science? As a matter of fact all that I have said is only a preface to a paragraph or two which deal with matters pertaining to Science. Parenthetically I may be permitted to repeat here what I have said on another occasion: that I myself believe that the peculiar function which a state academy of science should assume should be that of counsellor in matters scientific, to the state-bringing science into the service of the state, in much the same manner as the National Academy of Science in its relation to the Federal Government

Kentucky's 120 billion tons of water should be ample for all public and private necessities. including its function of chief sculptor of the landscape, and even though so much as one-third of it be lost by evaporation. That would still leave some 25,000 tons or more for each man, woman, and child, and I should like to vote my share and those of my family as wisely as possible. There are, however, many agencies now in sharp competition for this major resource. some of which are:

- 1) Flood-control 4) Sanitation
- 2) Navigation 5) Fisheries
- 3) Water-supply 6) Recreation

As many additional lesser demands, actual and potential, might be named. Among these rivalries, both open and covert, some well entrenched, the public interest is not well represented. Although it is now later than we think, the State of Kentucky owes it to herself and to her citizens that the machinery be set up to handle the matter. Possibly two agencies of the state government not now in existence could do so.

The first of these agencies should include those functions usually associated with state tourist or travel bureaus, together with the all phases of conservation and public recreation. It should therefore be composed in part of persons representing recreational activities, conservation, hotel. tourist camp, transportation and other This group should get tointerests. gether and lay out a workable program for the location and acquisition of lands for state parks, state forests. camps, etc., in accordance with the needs of three million people, a program to be submitted to the legislature for action.

A second, more specialized body might be considered essential-to have the functions, whether or not the name of, Water Control Board. Its membership chosen from among power. flood-control, water - s u p p l y, sanitation, and biological resources, including forestry, personnel, should work out an over-all state program for administering the public waters of Kentucky. Thus the various interests of Kentuckians might have a more equitable representation in dealing with internal affairs than is now the case, with all the emphasis on flooding Kentucky valleys to withhold floodwaters from down-river. This paper is intended not so much a criticism of the flood-control program as a defensive gesture in favor of other equally important aspects of the water-supply program, not getting much public consideration.

The water-control board would require a technical staff, of course, consisting of engineers, geologists, sanitarians, biologists, and no doubt others, who would initiate and carry out the necessary preliminary research on which action by the main body could be based under sound principles—principles of equity and law included.

This is where Science comes in, then, in any sweeping public program by which Kentucky might see fit to assay her remaining natural resources, and to salvage all that she can. I have emphasized the matter of the waters rather than the land because that is far more neglected. In an enhanced conservation program I can visualize the Academy of Science assuming some share in either a general advisory way, or in some fractional part of the enterprise which may be assigned to it. The job needs the academy; perhaps the academy needs certain concrete objectives. Certainly various members of the biological section should have an important share in the survey, or advisory phases of such a program; in the custodianship of certain activities such as a guide service for parks; in the training of personnel.



# ALCOHOLIC FERMENTATION UNDER REDUCED PRESSURE<sup>1</sup>

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The experiments here presented are related to the fermentative behavior of yeast cultures maintained at 30°C. under an absolute pressure of water while being vigorously sparged with water vapor. The primary objective of the experimental approach, which represents virtually a steam distillation under vacuum, was to study the effect on the production of glycerol of the partial removal of acetaldehyde formed in the course of fermentation.

Several authors, e.g. Joslyn (1940) and Wallerstein and Stern (1945). have stated without reference to specific data that fermentation under reduced pressure or under strong aeration during the so-called induction period materially increases the rate of glycerol production, presumably, by removing the acetaldehyde. From the classical work of Neuberg and co-workers (Kobel and Neuberg. 1933), it is known that a marked increase in the formation of glycerol is produced by the addition to a fermenting medium of chemical agents interfering with the ultimate reduction of acetaldehvde to alcohol.

A secondary objective of this investigation was concerned with the frequently discussed problem of the inhibitory effect of alcohol on cell multiplication and on the rate of fer-

2 Seagram Research Associate at the Laboratory of Cell Physiology, Indiana University, 1944-1946; on special assignment from Joseph E. Seagram & Sons, Inc., Louisville, Kentucky. mentation. The experimental method employed, steam distillation under vacuum, made it possible to maintain the ethyl alcohol concentration of the cultures at relatively low values throughout the observation periods. In such an experimental environment, rates of growth and sugar utilization should be higher than in the control cultures in which "inhibitory" metabolic products, such as alcohol, can accumulate, see Gause (1934) and Rahn (1932).

### Experimental

Yeast strain. A distillery type yeast designated as **Saccharomyces** cerevisiae, strain DCL, in the stock culture collection of Joseph E. Seagram & Sons, Inc., Louisville, Kentucky, was used for all experiments.

Medium. The medium used in all experiments contained 10 g. glucose, 0.7 g. dehydrated yeast extract (Difco, and 0.5 g KH2PO4 per 100 ml. This medium was autoclaved at 120° C. for 10 minutes.

Preparation of inoculum and inoculation. In the development of inoculum, veast was transferred at 24hour intervals through the following steps: (a) from the stock slant to 10 ml. of medium, (b) 1 ml. from (a) to each of two tubes containing 10 ml. of medium apiece, (c) the contents of each tube from (b) to 150 ml. of medium in a 250 ml. centrifuge bottle. Cultures were incubated at 30 C. At the time of incubation, yeast cells were centrifuged from the cultures of step (c), washed twice with KH2PO4 solution (0.5 g. per 100 ml.) and transferred to 1300 ml. of experimental medium.

<sup>1</sup> Presented before the Kentucky-Tennessee Branch of the Society of American Bacteriologists at the thirty-third annual meeting of the Kentucky Academy of Science, Bowling Green, April 26, 1947.

Management of fermentation. After a thorough mixing, 160 ml. portions of inoculated medium were transferred to seven 500 ml. round bottom flasks. Each flask received two drops of cottonseed oil to control foaming. Six of these flasks were attached to the apparatus illustrated in Fig. 1; the seventh flask was plugged with cotton and carried as a control. The remaining medium was analyzed as the initial (zero time) sample. As shown in Fig. 1, the fermentation vessel was closed with a rubber stopper through which passed two tubes: one extending almost to the bottom of the flask, the other terminating a short distance below the stopper. The shorter tube was attached through a 0.75 mm. capillary to a manifold which was connected through a condenser to a mechanical vacuum pump. Also attached to this exhaust manifold were a manostat, a mercury manometer and water vapor manifold. The connection with the water vapor manifold was made through a 0.25 mm. capillary. This connection caused a flow of water vapor through the length of the manifold and thus helped to eliminate the accumulation of condensate. The external end of the tube extending to the bottom of the fermentation vessel was connected through a 0.25 or a 0.75 mm. capillary with the water vapor manifold. This latter manifold had its origin in a one liter suction flask partially filled with water and held over a variable temperature electric hot plate.

In this system the temperature of the medium in the low pressure flasks was maintained very close to the temperature of the bath (30 C.). Heat was supplied to the flasks by the water vapor (temperature of vapor in steam generator, 41-44 C.) to balance approximately the heat loss through evaporation. Since the vacuum pump attached to the system had a capacity far in excess of that required to maintain the system at the required pressures, the rate of gas flow into and out of the flasks was regulated by the diameter of the capillary tubes inserted in the lines leading into and out of the flasks.

The fermentation flasks together with their manifolds were attached to a frame supported by coil springs over a water bath. During the fermentation period, the flasks were held partially immersed in the water bath and subjected to continuous agitation. At intervals throughout the observation period a flask was removed from the vacuum system for analysis. Before analysis the initial volume in each flash was restored by the addition of distilled water.

The setting up of a suitable control for the vacuum fermentations presented a major problem. The experimental medium was under not only a lower absolute pressure but also under a lower oxygen tension than prevailed in that portion of the inoculated medium which was held at atmospheric pressure in a cotton plugged flask. On the basis of earlier experiments (Brockman and Stier, unpublished) it was established that the oxygen tension of the medium, particularly during the first few hours following inoculation has a marked influence on the ultimate yeast population, on the rate of gluclose utilization and, to a lesser extent, on the yield of glycerol. Consequently, two types of control fermentations were employed. For Type I control, a portion of inoculated medium was held in a cotton-plugged flask in the same water bath as the low pressure fermentations. Here no attempt was made to alter the oxy-





gen tension of the control culture. For the Type II control, 1200 ml. of medium was sparged with tank CO2 for a short period following inoculation in order to reduce the oxygen tension of the medium to a level comparable to that in the low pressure cultures. The total volume of CO2 blown through the medium was roughly equivalent to the volume of the free space in the flask above the medium. This medium was then fermented in rubber-stoppered flasks which were vented through water seals. Both types of control cultures were held under continuous agitation in a 30 C. water bath.

Analytical operations. Glucose concentration and yeast population were determined according to the procedure described by Brockmann and Stier (1947).

Glycerol concentration was determined according to the procedure described by Amerine and Dietrich (1943) for use in the determination of the glycerol concentration of wine containing less than 5 g. of sugar per ml. Because the yeast extract present in the medium contributed to the observed glycerol concentration, the apparent glycerol concentration of the medium immediately after inoculation was subtracted from the observed concentration of subsequent samples; this difference was recorded as "glycerol formed."

In the determination of alcohol concentration, 50 ml. of fermentation medium was subjected to distillation. The alcohol concentration in the distillate was evaluated with an immersion refractometer according to the procedure of the A. O. A. C.. (1940).

For the determination of aldehyde concentration, another 50 ml. portion of the fermentation medium was distilled. The aldehyde present in the distillate was determined according to the A. O. A. C. (1940) procedure for the aldehyde content of distilled spirits.

# **Results and Discussions**

In Fig. 2 representative date are summarized for fermentations held under greatly reduced pressure while being sparged with water vapor; also included in this figure are single points (open squares and triangles) or curves (open circles) illustrating the two types of control cultures.

An examination of the curves characterizing glucose utilization as a function of time indicates that under reduced pressure the rate of glucose utilization may be slightly higher than at atmospheric pressure. However, a study of the curves for yeast population shows a direct relationship between yeast populations and rates of glucose utilization. Thus the apparent differences in rates of glucose utilization can be accounted for by corresponding differences in yeast population.

From an examination of the curves showing the concentration of alcohol in the fermenting medium there can be no doubt that the low pressure steam distillation was effective in maintaining a low concentration of alcohol in the experimental medium: the alcohol concentration of the cultures maintained under reduced pressure never exceeded 0.65 g. per 100 ml. In view of the parallelism between the yeast populations and the rates of glucose utilization in cultures of similar oxygen tension, the evidence here presented suggests that a reduced alcohol concentration tends to favor yeast growth. The higher year population in turn elevates the rate of glucose utilization of the culture. With the relatively low concentrations of alcohol here involved. there is no evidence of a direct connection between alcohol concentra-

## Alcoholic Fermentation Under Reduced Pressure

Figure 2. Representative data for fermentations maintained under reduced pressure.

Solid triangles and squares represent periodic observations on fermentations conducted with exhaust manifold pressures of 40-41 and 20-21 mm Hg. respectively. Open triangles and squares represent final data for controls (Type I) in cotton plugged flasks which correspond to low pressure runs represented by solid triangles and squares. Circles represent average data for 5 runs conducted at atmospheric pressure (Type II control) with medium of reduced oxygen tension (sparged with tank CO2).



tion and the rate of glucose utilization.

As seen from the data of Fig. 2. cultures held under reduced pressure have significantly higher rates of glycerol production than cultures held under atmospheric pressure. After about eight hours the rate of glycerol producion in low pressure cultures appears to diminish as evidenced by a reduced slope in the glycerol formed-time curves. A somewhat parallel rate decrease is seen in the glucose used-time curves for the same cultures. From the curves characterizing glycerol formation as a function of glucose consumed it is evident that throughout the observation periods, glycerol is formed in a relatively stable relationship to glucose consumed.

While there can be no doubt that the production of glycerol was significantly increased under reduced pressure, it should be pointed out that the theoretical yield of glycerol has been increased only from 7 to 12 percent, calculated on the basis of the equation for Neuberg's second type of fermentation:

glucose glycerol + actaldehyde+carbon dioxide.

The concept that glycerol formation is controlled by the availability of acetaldehyde, which in the course of normal alcoholic fermentmation is reduced to alcohol, is difficult to align with the data here reported. The aldehyde concentration of the medium maintained under reduced pressure averaged approximately onehalf of that of the CO2 sparged control. Nevertheless, the rate of glucose utilization in the low pressure cultures was approximately the same as the CO2 sparged control. Consequently, the concentration of acetaldehyde in the low pressure cultures cannot be regarded as limiting the

rate of glucose utilization. Moreover, even in the control culture, the aldehyde content of the medium showed a marked tendency to decrease after fermentation became well established. This decrease appears to be without influence either on the rate of glucose utilization for the culture as a whole or on the amount of glycerol formed per unit of glucose metabolized. Furthermore, according to the previously mentioned Neuberg equation, glycerol and acetaldehyde should be formed in equal molar ratios, 92 g. of glycerol and 44 g. of acetaldehyde. However, on the basis of the observed glycerol, only a very small part of the theoretically formed aldehyde appears in the medium, and instead of increasing along with the formed glycerol, the aldehyde content of the culture diminishes during the greater part of the observation period. Moreover, the authors have observed a marked increase in the aldehyde content of yeast cultures following the addition of various surface active agent, which depress yeast multiplication. This increase is not attended by an alteration in the amount of glycerol produced per unit of glucose metabolized. These observations present an interesting problem, namely, what is the disposition of the 2 or 3 carbon oxidation compound which must be formed simultaneously with the reduction of a portion of the glucose molecule to glycerol under the conditions of normal alcoholic fermentation.

Under the conditions of the experiments here reported no significance can be attached to the aldehyde content of the culture. A possible explanation for the observed relationship between acetaldehyde and glycerol is suggested by the disclosure of Negelein and Bromel (1939) that acetaldehyde is much more readily reduced by a reduced yeast pyridine nucleotide than dihydroxyacetone. It appears quite possible that in the low pressure cultures the depressed aldehyde concentration favored the reduction of slightly greater amounts of dihydroxyacetone.

### Summary

Data have been presented for glucose utilization, yeast population. glycerol formation and the concentrations of alcohol and acetaldehyde in cultures continuously sparged with water vapor while held at a pressure close to the vapor pressure of water. In comparison with cultures having a similar oxygen tension and maintained at atmospheric pressure, the slight elevation in rate of glucose utilization seen in the low pressure cultures is accounted for on the basis of the somewhat higher yeast populations. It appears probable that the low alcohol concentration of the cultures maintained under reduced pressure favored a somewhat greater veast population and thus, indirectly, an increased over-all rate of glucose utilization.

In cultures maintained under reduced pressure glycerol formation is definitely elevated. No conclusion is forthcoming regarding the relationship between the increased glycerol formation and the lowered aldehyde concentration of the cultures.

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# REPORT OF THE COMMITTEE for the

# **KENTUCKY JUNIOR ACADEMY**

The Committee, H. B. Lovell, W. R. Sebastian, Tandy Chenault, Austin Durham, Hazel Nollau, and Anna A. Schnieb, submits the following report:

### I. Work of the Committee

1. Conferences held with indidividual members of the committee and much additional business transacted through correspondence with high school science teachers.

2. The third Sponsor-Delegate conference held in October, Eastern Teachers College, with seventy-six present. The officers were installed. List of problems previously sent to the clubs were discussed and plans for the year's work were made.

3. Directed the Christmas Bird Census for the Junior Academy.

4. Assisted in securing financial contributions.

5. Assisted in organizing five new clubs.

6. Appointed the honorary members to A.A.A.S.:

Mrs. Alice Summers, Atherton, Louisville.

Mr. Jimmy Garritson, Tilghman, Paducah.

7. Answered many letters.

### II. Junior Academy Activities:

1. Five issues of Junior Science Bulletin, two eight page and three six page issues, published.

2. Definite efforts taken to improve the articles in the Bulletin.

3. A decided increase noted in the number and the size of the *Special Financial* contributions.

4. Formulated a standard for conferring honors:

a. Quality and number of articles contributed to Bulletin.

b. Sustained interest in sci-

ence and in the Academy.

- c. Cooperation on the part of members and sponsors.
- d. Effort and interest shown in organizing new clubs.
- e. Some financial contribution made.

5. Much effort put forth to organize new clubs, especially on the part of the members.

### **III. Annual Convention:**

The thirteenth annual convention was held Friday and Saturday, March 18 and 19 at Maysville High School with the Maysville science clubs as hosts. Mr. Tandy Chenault and Supt. Laukhuf were in charge of the convention assisted by Dr. Schnieb, state counselor. The Friday evening program was entirely social and was planned by the Maysville High School P. T. A.

About three hundred attended the Saturday meeting which was presided over by the president, Burt Monroe. The program consisted of addresses, exhibits, demonstrations, a trip to the Carnation Plant, music, and conferring the honors and the awards. Considering the deep snow which fell on Thursday, the attendance was considered good.

# IV. Highlights of the Convention:

1. The quality and the wide range of interests shown in the exhibits and demonstrations. Each exhibit as well as demonstration included a clear statement of the problem, and what was learned.

2. The interest shown by the members and the sponsors in the exhibits and in the demonstrations. They wanted to see just what made them good. Many took close notes.

3. The interest of the judges who were rather critical. "Some sloppy work." "Yes, this is good, but they must be taught to do better," were statements frequently made by the iudges.

4. The interest of Maysville in science and in the convention. Not only the newspapers, but the mayor, the churches, and the citizens in general showed much interest by attending the sessions and by making favorable comments, as well as giving invaluable assistance in making the meeting a success.

### V. Affiliation:

The Junior Academy today has a membership of 950 representing 16 Class A and 18 Class B Clubs.

### VI. Outstanding Accomplishments:

1. Five new clubs organized and only two fatalities.

2. Decided increase in the number of Christmas Bird Census.

3. Improvement in the quality and arragnement of exhibits.

4. Decided improvement in the Bulletin.

5. The Junior Science Bulletin maintaining the rating as an outstanding publication issued regularly by the members.

6. Decided increase in the Special Financial Contributions.

7. Decided improvement in the Sponsor-Delegate Conference.

8. Better judgment noted in making the nominations for officers.

# VII. Honors Received:

1. Recognition by The Kentucky Academy of Science in offering honorary memberships to four club sponsors and to four junior members.

2. The Library at Havana, Cuba, requesting to be placed on the mailing list for the Junior Science Bulletin and sending a check to meet the expenses of mailing the Bulletin.

3. Citation received from the Michigan Junior Academy of Science quote: "For excellent set-up of the Kentucky Junior Academy and for the outstanding publication—The Junior Science Bulletin."

### SUMMARY

### 1. New Clubs

| Breathitt County High                 | 130 | Members  |
|---------------------------------------|-----|----------|
| T. S. Moore, Sponsor                  | 56  | Members  |
| Mrs. Dickerson, Sponsor               | 49  | Members  |
| Robert Sentz, Sponsor                 | 25  | Members  |
| Ormsby Village, Mrs. Searles          | 16  | Members  |
| Valley Station, Mrs. H. B. Lovell     | 50  | Members  |
| 2. Financial Contributions from Clubs |     | \$201.00 |
| Total Expenses                        |     | 438.64   |
| Awards                                |     |          |
| Bulleting                             |     |          |

K.A.S. Affiliation

Postage, Long Distance, Telegrams

Sponsor-Delegate Conference

Dues, contributions from interested friends, and sponsorship of the Kentucky Academy of Science give a balance to be carried for 1947-1948. 3. Clubs with Distinction:

Cane Run, Jefferson County Kingston, Madison County Maysville Model High, Richmond Report of the Committee for the Kentucky Junior Academy

|                           | Morehead   |
|---------------------------|--|
|                           | Owensboro  |
|                           | Waco   |
| 4.                        | Honorary Members to A.A.A.S.:                    |
|                           | Miss Rlice Summers, Atherton, Louisville         |
|                           | Mr. Jimmy Garritson, Tilghman, Paducah           |
| 5.                        | Honorary Members to Kentucky Academy of Science: |
|                           | Sponsors:  |
|                           | Mr. Tandy Chenault, Maysville                    |
|                           | Mrs. M. S. Dickerson, Jackson                    |
|                           | Miss Hazel Nollau, Morehead                      |
|                           | Miss Elizabeth Maupin, Kingston                  |
|                           | Junior Members:                                  |
|                           | Burt Monroe, Anchorage                           |
|                           | Proctor Riggins, Harrodsburg                     |
|                           | Susanne Newell. Maysville                        |
|                           | Geraldine Maupin, Waco                           |
| 6.                        | Officers Elected:                                |
|                           | President: Turner Burns, Owensboro               |
|                           | Vice President: Harold Cox, Model High, Richmond |
|                           | Secretary: Mary Buetel, Atherton, Louisville     |
|                           | Treasurer: Chad Christine, Maysville             |
| 7.                        | Club Affiliation                                 |
| An                        | chorage27  |
| Atl                       | 1erton 48  |
| Be                        | llevue 40  |
| Bre                       | eathitt County (T. S. Moore) 56                  |
| Bre                       | eathitt County (Mrs. Dickerson) 49               |
| $\operatorname{Bre}$      | eathitt County (Robert Sentz). 25                |
| Ca                        | mpbell County25                                  |
| Ca                        | ne Run 38  |
| Ce                        | ntral  |
| du                        | Pont Manual                                      |
| $\mathbf{E}_{\mathrm{S}}$ | 28   |
| Fra                       | ankfort 19                                       |
| $\mathbf{Gr}$             | eendale 10                                       |
| Ha                        | rrodsburg 18                                     |
| Hi                        | ghlands Ft. Thomas 30                            |
| Ki                        | ngston   |
| Ki                        | cksville 14                                      |
| Kr                        | ox Central                                       |
| La                        | fayette Junior                                   |
| La                        | fayette Senior 20                                |
| La                        | Grange   |
| Ma                        | ysville Junior                                   |
| Ma                        | sysville Senior                                  |
| Mo                        | 24   |
| Mo                        | odel   |
| M                         | prehead Junior 22                                |

# Report of the Committee for the Kentucky Junior Academy

| Morehead Senior         | 13  |
|-------------------------|-----|
| Nicholasville           | 10  |
| Ormsby Village          | 16  |
| Owensboro               | 33  |
| Paducah Tilghman        | 45  |
| Paint Lick              | 15  |
| Valley High             | 50  |
| Waco                    | 26  |
| -                       | 919 |
| Sponsors                | 31  |
|                         | 950 |
| Respectfully submitted, |     |

April 25, 1947

ANNA A. SCHNIEB, Counselor



# Report of the Representative of the

# Kentucky Academy of Science on the Council of the

# Amer. Assoc. for the Advancement of Science Boston, Dec. 1946

# Minutes of the A.A.A.S. Academy Conference

The first meeting of the Council of the A.A.A.S. was concerned with routine business, i.e., the report of the Administrative Secretary, election of emeritus members, the operating budget, etc.

It was explained that under its new constitution the A.A.A.S. now will have, each year, a Retiring President, a President and a President Elect. The President Elect serves one year in that capacity, the succeeding year as President, and the third year as Retiring President, who delivers the Annual Address.

The Second Council Meeting was concerned with the presidential elections. It was necessary to elect a President and a President Elect to meet the provisions of the new constitution. Dr. Shapley was elected President and Dr. Sinnot was elected President Elect.

Dr. Baitsell and Dr. Martin were elected to the Executive Committee.

There followed a long discussion of the proposed National Science Foundation at the conclusion of which the **President** was instructed to designate representatives of the A.A.A.S. on an Inter-Society Committee on the National Science Foundation and to invite all scientific societies of national scope to do so. This was done because of the failure of adoption of past national legislation was largely due to lack of agreement among scientists as to its provisions.

### Report of the Proceedings of the Conference of State Academies of Science

The minutes of the meeting of the

Conference of State Academies is appended hereto, together with the paper presented by Dr. E. C. L. Miller of the Virginia Academy.

Dr. Degering, Indiana Academy, Chairman, had prepared an agenda for the conference which centered about three problems, to wit, improvement of the services to and its relations with its own state by the state academy. The development of valuable additional scientific personnel. How can the academy supplement its research funds?

Your representative wishes to bring to the critical attention of the Kentucky Academy of Science certain suggestions that were presented at the Conference. (1) That the academy form a special committee to contact industrial firms to initiate a study of problems of mutual interest and of means of funneling funds to research workers. (2) That the Academy use its influence toward the promotion of research in the smaller institutions of higher education in the state. (3) The participation of the Academy in the administration of national and other grants for research in the state. (4) The guidance of young people of ability into research, and (5) the devising of some means for the education of the layman in the advances of science and its needs. This last carried the further suggestion that the academy organize a speakers' bureau among the public speakers of its membership and also bring in occasionally some scientist of national repute. These five suggestions were incorporated in the address of Dr. Miller.

A great deal of the discussion following that address centered on the importance of the Junior Academy in developing young scientists. The Tennessee Academy conducts a Science Talent Search in its state which gives awards to young people who were not selected in the National Science Talent Search.

It was pointed out that more attention should be given to high school teachers of science to encourage them and to demand high quality teaching by them. There is a need for abstracts of new developments in science for use by these high school teachers of science in their work in the science club.

Your representative wishes to urge upon the Academy the serious consideration of these proposals, with especial attention to the matter of informing the lavman about science and its needs, the committee on cooperative study with industry, the matter of the administration of grants from all sources, and the matter of the encouragement of the high school science teacher, since the high school is the ultimate source from which will come the scientists of the future. Dr Michaud of Purdue was elected Chairman of the Conference and Dr. Middleton, of Kentucky, Secretary.

> Respectfully submitted, Austin R. Middleton Representative of the Academy on Council of A.A.A.S.

# Minutes of the A.A.A.S. Academy Conference

The A.A.A.S. Academy Conference was called to order at 4:00 P. M., Friday, December 27, 1946, in Parlor C of the Statler Hotel, Boston, Massachusetts, by the Chairman, Dr. Ed. F. Degering of Purdue University. There were 28 delegates present representing 24 Academies of Science. Dr. F. R. Moulton, Permanent Secretary and Dr. Otis W. Caldwell, General Secretary were present, representing the American Association for the Advancement of Science.

Previous to the opening of the meeting, Dr. Degering appointed a nominating committee composed of the following persons:

Dr. Arthur H. Bragg, Chairman, Oklahoma Academy of Science.

Dr. Austin R. Middleton, Kentucky Academy of Science.

Dr. Glenn W. Blaydes, Ohio Academy of Science.

The Committee nominated Dr. Howard H. Michaud, Purdue University as Chairman of the Academy Conference for 1947; and Dr. Austin R. Middleton, University of Louisville, as Secretary. Both the nominees were unanimously elected by the Academy Conference group.

Chairman Degering introduced Dr. Otis Caldwell, who presented greetings from the A.A.A.S. to the Academy delegates. He spoke of the great responsibility borne by the affiliated Academies for improvement of services and relations to state educational and industrial enterprises, the preparation of scientific personnel, the sponsoring of Science Clubs and development of the Junior Academy as a valuable educational procedure and channels for directing interested and competent young people into the field of science. He spoke briefly on federal research subsidies.

This led to consideration of the agenda prepared by Dr. Degering as follows:

- 1. In what ways may a State Academy improve its services and relations with its own state educational and industrial enterprises?
- 2. What can be done by the State Academy toward de-

veloping valuable additional scientific personnel?

- 3. How may the services of the Junior Academy be increased?
- 4. Should the State Academies supplement their research funds? If so, how and for what specific purposes?

Mr. Glenn O. Carter, representing the American Institute of the City of New York suggested that the Academies could make substantial contributions to education and industry by sponsoring lecture programs on human relationships throughout the year. He indicated that industry has much to offer education and that closer cooperation should be secured between the Academies of Science and industrial organizations.

From New Hampshire, Professor H. D. Carle described their mountain experiment station which was sponsored by that Academy. Cooperation and financial aid has been obtained from industry and the Federal Government in its development. Studies in meterology, and the effects of severe weather condition on various materials of industry are being studied. Also biological surveys are being conducted.

Dr. Otis W. Caldwell spoke of the many grants being made from the Federal Government, particularly under the auspices of the Army and Navy, made to relatively isolated groups. The grants are of such a number that they affect the assignment of research funds from the A.A.A.S.

Dr. Ed. F. Degering of Purdue University suggested that the State Academies of Science have the responsibility of sponsoring research in the smaller institutions, where the larger Federal funds will likely not be available.

Dr. G. W. Prescott, Michigan State

College, believes that the State Academies of Science should have committees who have the duties of contacting industrial concerns for research aid.

Dr. Austin R. Middleton of Kentucky pointed out that the Kentucky Academy has made valuable industrial contacts, and that the past President is head of research in one of Louisville's large industrial organizations.

Dr. Joseph C. Gilman, Iowa State College, suggested that the A.A.A.S. research grants should be directed to the smaller institutions. He indicated that there is some difficulty in placing research funds at present because of the excessive teaching and administrative burdens being carried by the personnel of the smaller schools.

Dr. C. L. Porter of the Colorado-Wyoming Academy of Science, suggested that the Academies should invite industrialists to take part in the Academy meetings, and in this way cultivate a better understanding between the Academies and industry.

Dr. Waldo Schmidt, of the Washington, D. C. Academy said that the small grants of the A.A.A.S. are of importance and may mean a great deal to many investigators.

Dr. E. C. L. Miller of the Virginia Academy of Science, presented a paper on the responsibilities of the State Academies of Science. A copy of this paper is attached to these minutes.

Dr. H. A. Webb of the Tennessee Academy, spoke of the importance of continuing and developing the Science Talent Search. Tennessee has in addition developed a State Science Talent Search. He suggested that this may be of great importance in guiding the most talented young people into the field of science.

From Wisconsin, Dr. L. E. Noland expressed himself concerning the in-

spiration they had received because of the development of the Junior Academy of Science in Virginia and Tennessee. In Wisconsin, the Junior Academy has a program of meetings at several centers in the State. Papers are presented by the Junior scientists. The best from each center are selected and sent to the Senior Academy meeting. This appears to be of much importance in guiding talented young people into further science studies. He enthusiastically told of the work of Dr. John Thompson of Wisconsin, who has the duty of traveling about the State aiding in science teaching in the secondary schools.

From the American Institute of the City of New York, Mr. Glenn O. Carter, suggested that we do something for the Junior scientists through industry. Industry does not know about these needs. Closer cooperation of the Academies with industry is very desirable.

Dr. Otis W. Caldwell pointed out that there are 10,500 Science Clubs in the United States, with an average enrollment of 25 per club. A new feature of the A.A.A.S. meeting this year is the Junior Scientific Assembly, announced by Dr. Morris Meister, president of N.S.T.A. It is expected that this will be an annual feature of the A.A.A.S. meetings.

From Minnesota, Dr. John W. Moore indicated that in his Academy each member acts as a committee of one to contact new members. Small grants are made to the Junior Academy. Considerable care is taken in selecting a sponsor of the Junior group.

Dr. Howard H. Michaud from Indiana, spoke of the 52 Science Clubs in Indiana. Representatives from these clubs meet with the Senior Academy at their regular autumn meeting. The assembling of youngsters at meetings is a considerable problem. In about 50% of the schools, teachers lose salary for days away on Junior Academy trips. Teachers are so over-burdened that it is difficult to get them to stimulate students to enter contests.

Dr. Joseph C. Gilman of Iowa, suggested that there is the difficulty in interesting and stimulating high school teachers to organize and direct the activities of Science Clubs. In Iowa a high school teacher acts as a permanent secretary of the Junior Academy. This is regarded as an important feature of their success.

Dr. Martin D. Young of South Carolina indicated that there are 151 Science Clubs in that State, which are affiliated with the S. C. Academy of Science. A Junior Academy congress is planned and will be held in conjunction with the Senior Academy meeting. Several of the Clubs have entered the Westinghouse Science Talent Search Examination.

Mr. Glenn O. Carter of New York, presented a motion which was ammended by Dr. Ditmer of New Mexico. The motion as ammended is as follows:

We request the officers and directors of the A.A.A.S. to consider possible measures of working through the Academies of Science for the encouragement of Junior Academies, or Junior Science Activities, and prepare a report for publication on the present status of Junior Academies of Science in the United States, with recommendations.

The motion was seconded and accepted by the Academy Conference.

Dr. Otis W. Caldwell, while speaking of the fourth item of the agenda, pointed out that in order to obtain research funds from the A.A.A.S., application must be made by each acad-

emy for these funds. Such funds cannot be used for publication purposes. As to supplementing these grants from the A.A.A.S., he suggested that a resolution might be made to state some kind of principle of obtaining ways of setting up and underwriting

funds for the sole use of the Academy of Science for research.

Respectfully submitted, GLENN W. BLAYDES, The Ohio State University Acting Secretary.



# **NEWS and NOTES**

Editors' Note: Pagination for Number 3, Vol. 12 of the Transactions was not made continuous with the preceding journal number through error. The pages of this issue (Number 4) are numbered in sequence from Number 3 had the latter been correctly paged. Page numbers for Number 3 will be considered from 34 to and including 54 in the volume index.

The Springfield conference of the Kentucky Geological Society was held on May 2, 3, and 4, 1947. Approximately seventy-five geologists assembled at Tazewell, Tennessee, and examined sections of the Knox dolomite under the direction of Dr. Charles R. L. Oder of the American Zinc Company. The party was conducted over the Thorn Hill, Halls Mill, and Jockey Creek sections. Dr. Oder spoke on the paleogeographic, stratisgraphic and lithologic features of the Knox dolomite.

The annual business meeting of the Kentucky Geological Society was held Saturday 4 May, 1947. The following papers were presented:

- 1. The Geology of Pickett County, Tennessee, by Willard R. Jillson.
- 2. The Warwick Abandoned Channel of the Kentucky River by Willard R. Jillson.
- 3. Paleogeographic Elements During Knox Deposition by Dan K. Hamilton.

Dr. Frank Fisher, Ashland Oil and Refining Co., Ashland, Kentucky, has been elected President of the Kentucky Geological Society at its annual meeting in May 1947.

Dr. David Richard Lincicome in collaboration with the Manitoba Mu-

seum, Winnipeg, Manitoba, spent two weeks in August making extensive collections of parasites from birds in the spruce forests of upper Manitoba.

The annual meeting of the Kentucky section of the Mathematical Association of America was held at the University of Kentucky on Saturday, May 10, 1947.

The following papers were presented:

- 1. Trisection of an angle by means of higher plane curves, by Paul P. Boyd.
- 2. Development of the Frenet Formulas for N-dimensions, by S. J. Jasper.
- 3. Contrasting two solutions of a certain problem in Modern Geometry, by W. R. Hutcherson.
- 4. Application of mathematics in Meteorology, by McClellan Cook, Jr.
- 5. The Graphic Construction of a Human Eclipse, by F. V. Rohde. Rohde.

Prof. D. W. Pugsley, Berea College, has been elected chairman of the Kentucky Section of the Mathematical Association of America.

Dr. Sallie Pence, University of Kentucky, has been elected Secretary of the Kentucky Geological Society.

Mr. W. M. Insko, University of Kentucky, has been elected 2nd Vicepresident of the Poultry Science Association at the annual meeting at Clemson College, South Carolina, 25-28 August.

Dr. Dan K. Hamilton, University of Kentucky, has been elected Secretary of the Kentucky Geological Society.

Dr. W. D. Gray is now associate professor of Botany at the Ohio State University, Columbus, Ohio.

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# INDEX TO VOLUME 12

# TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

| Academy<br>A more active                                    | 34  |
|---|-----|
| Kentucky, Science, minutes of 1944 and 1946 annual meetings | 54  |
| Ailanthus altissima, leaf glands in                         | 31  |
| Alcohol<br>Survey of production methods                     | 82  |
| Fermentation under reduced pressure                         | 94  |
| Allen, W. R   | 89  |
| Asclepias, pollination in                                   | 79  |
| Brauer, Alfred  | 34  |
| Portrait  | 33  |
| Brockmann, M. C.  | 94  |
| Committee reports<br>Kentucky Junior Academy1               | 01  |
| Representative to A.A.A.S. Council1                         | 05  |
| Davis, P. A.  | 31  |
| Density of Ether  | 20  |
| Editorial<br>A more active academy                          | 34  |
| Power and Punch   | 55  |
| Editor's Note1  | .09 |
| Education<br>Forever in Forties                             | 2   |
| In Kentucky   | 6   |
| Elementary in Kentucky                                      | 9   |
| Secondary in Kentucky                                       | 12  |
| Problems of Higher  | 15  |
| Endamoeba coli, elimination of                              | 49  |
| Ether, density  | 20  |
| Fermentation, alcoholic under reduced<br>pressure           | 94  |
| Forum on Kentucky Education<br>Forword                      | 1   |
| Forever in the forties                                      | 2   |
| Education in Kentucky                                       | 6   |
| Elementary Education in Kentucky                            | 9   |
| Secondary Education in Kentucky                             | 12  |
| Problems of Higher Education in<br>Kentucky                 | 15  |
| Flavone-like substances in tobacco                          | 42  |
| Glucose, effect on viability on                             |     |
| Bactobactitas cases   | 46  |

|   | Greulach, V. A.   | 79         |
|---|---|------------|
|   | Jaggers, Richard E.   | 9          |
|   | Kentucky<br>Academy representative to A.A.A.S.<br>Council report] | 105        |
|   | Academy, minutes of 1944 and 1946                                 | 54         |
|   | Education in  | 6          |
|   | Elementary Education in   | 9          |
|   | Forum on Education  | 1          |
|   | Higher Education in   | 15         |
|   | Junior Academy, committee report                                  | 101        |
|   | Planned Economy of Waters   | 89         |
|   | Secondary Education in  | 12         |
|   | King, W. P  | 6          |
|   | Lactobacillus casei, effect of glucose on                         | 46         |
|   | La Fuze, H. H.  | 79         |
|   | Leaf Glands in Ailanthus altissima                                | 31         |
|   | Lincicome, D. R49,  | 51         |
|   | Middleton, Austin R.  | 105        |
|   | Milkweed, Pollination   | 79         |
|   | Minutes, Kentucky Academy, 1944 and 1946 meetings                 | 54         |
|   | Muedeking, Mary   | 46         |
|   | Naff, Anna S.   | 42         |
|   | Neoechinorhynchus emydis, occurrence<br>in snails                 | 51         |
|   | News and Notes52,   | 110        |
|   | Oppenheimer, J. J   | 15         |
|   | Pollination, in milkweed  | 79         |
|   | Polyporus schweinitzii, physiological variations of               | 59         |
|   | Power and Punch   | 55         |
|   | Presidential address<br>Kolachov, Paul                            | 37         |
|   | Science in Society  | . 37       |
|   | Research notes<br>Elimination of <i>Endamoeba coli</i> in man     | . 49       |
|   | Neoechinorhynchus emydis, occurrence in snails                    | 51         |
|   | Schnieb, Anna A.  | 101        |
|   | Science in Society  | . 37       |
|   | Stewart, Olus J   | . 20       |
|   | Stier, T. J. B  | . 94       |
|   | Taylor, William S.  | . 2        |
|   | Tobacco, flavone-like substances in                               | . 42       |
|   | Waters, planned economy for Kentucky's                            | . 89       |
|   | Wender, Simon H   | . 42       |
|   | Whitt, Allie, Jr.   | . 51       |
|   | Williams, John F  | . 12<br>82 |
| 1 | JJ LAIUN, FL. L   |            |





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# Volume 13 1949-1952

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# TABLE OF CONTENTS

# No. 1

| Heat Pumps. E. B. Penrod   | 1  |
|--|----|
| A Bacteriological Survey of Well Waters From Central Ken-  |    |
| tucky Counties. Rafael A. Cartin and R. H. Weaver  | 38 |
| Comparison of the Sherman Tests With the Chapman Plate<br>for Identification of the Streptococci From Teeth. C. B. |    |
| Hamann and Frank J. Gruchalla  | 45 |
| A Modified Procedure for the Formol Titration. A. A. Rosen   |    |
| and B. S. Andrews  | 48 |
| A Preliminary List of Kentucky Cicadellidae (Homoptera).   |    |
| David A. Young, Jr.  | 54 |
| Academy Holds Spring Meeting   | 68 |

# No. 2

| Effect of Commercial Malt Sprouts on the Anaerobic Growth of |     |
|--|-----|
| Distillers' Yeast. R. E. Scalf and T. J. Stier               | 69  |
| Preparation of Ketones by the Sommelet Reaction. M. I. Bow-  |     |
| man, Irving B. Joffe, W. W. Rinne and James C. Wilkes        | 78  |
| Economic Status of Lespedeza Seed Oil. Richard H. Wiley      | 80  |
| Performance of an Earth Heat Pump on Intermittent Operation. |     |
| E. B. Penrod, E. L. Dunning, and H. H. Thompson              | 82  |
| The Effects of Small Amounts of Glycine and Ethyl Glycine on |     |
| Food Ingestion in the Dog. J. W. Archdeacon and A. B.        |     |
| Carreiro   | 100 |
| The Precision and Accuracy of Meter Sticks. Sigfred Peterson | 102 |
| The Effects of Composition on the Specific Gravity of Binary |     |
| Wax Mixtures. John R. Koch and Sister M. Concetta            | 104 |
| Chromosome Behavior in a Second Gasteria-Aloe Hybrid. Her-   |     |
| bert Parkes Riley  | 111 |
| Academy Affairs  | 116 |

# No. 3

| Bibliography of Sarah F. Price, Kentucky Naturalist.                 |     |
|--|-----|
| Harvey B. Lovell   | 121 |
| The Electrical Conductance of Solutions of Ferric Chloride in        |     |
| Acetone at $20^{\circ}$ and $40^{\circ}$ C. Lyle R. Dawson and Ralph |     |
| L. Belcher   | 129 |
| The Distribution of Alkali Iodides Between Ethylene Glycol           |     |
| and Ethyl Acetate. Lyle R. Dawson and Edward J.                      |     |
| Griffith   | 137 |
| The Free Energy of Copper Chromate. Sigfred Peterson and             |     |
| Orland W. Cooper   | 146 |

| Emissivities of Protective Coatings. W. R. Barnes and N. P. Shah<br>Performance of an Earth Heat Pump Operating Intermittently on  | 149 |
|--|-----|
| Effects of Staphylococcus aureus Infections on Blood and Liver<br>Catalase in Mice. I. Titrimetric Method. Sister Mary<br>Adeline O'Leary, S.C.N., Sister Virginia Heines, S.C.N.,<br>Sister Roderick Juhasz, S.C.N., Sister Rose Agnes Green-<br>well, S.C.N., and Corenlius W. Kreke | 156 |
| Effects of Staphylococcus aureus Infections on Blood and Liver<br>Catalase in Mice. II. Gasometric Method. Sister Mary<br>Adeline O'Leary, S.C.N., Sister Virginia Heines, S.C.N.,<br>Sister Roderick Juhasz, S.C.N., Sister Rose Agnes Green-   |     |
| well, S.C.N., and Corenlius W. Kreke   | 178 |
| Antibotic-Producing Species of <i>Bacillus</i> from Well Water.<br><b>R. H. Weaver and Theodore Boiter</b>   | 183 |
| Subsurface Earth Exploration By Electrical Resistivity Method.   |     |
| L. C. Pendley  | 189 |
| Mailing List   | 201 |
| Academy Affairs  | 208 |

# No. 4

| Preparation of Acylaminoacid Esters. Richard H. Wiley and<br>Olin H. Borum   | 213 |
|--|-----|
| Animal Habitats on Big Black Mountain in Kentucky. <b>Roger</b><br>W. Barbour  | 215 |
| Electrical Conductances of Moderately Concentrated Solutions of<br>Several Salts in Dimethylformamide. L. R. Dawson, M.<br>Golben, G. R. Leader, and H. K. Zimmerman | 221 |
| Structure and Function of the Mature Glands on the Petals of<br>Frasera carolinensis. P. A. Davies   | 228 |
| Performance of a Domestic Heat Pump Water Heater. E. B.<br>Penrod  | 235 |
| Comparison of Electron and Optical Photomicrographs of a Cop-<br>per-beryllium Alloy. H. W. Maynor, Jr., C. J. McHargue,   | 940 |
| and U. F. Edwards  | 248 |
| Branchart Settlement Computations, John L. Heer, Jr.   | 258 |
| Ray Estes and Albert Tockman   | 265 |
| A Look at Kentucky Woodlands. Eugene Cyperi. Jr.   | 270 |
| Geological Sketch of the Jackson Purchase. E. B. Wood  | 275 |
| Adsorption of Aliphatic Acids on a Weak Base Anion Exchanger   |     |
| Sigfred Peterson and Robert W. Jeffers   | 277 |
| Research Notes:  |     |
| An Albino Snake (Elaphe obsoleta). William M. Clay   | 285 |
| Academy Affairs  | 286 |
| Index  | 288 |

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November, 1949

Number 1

# TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

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KENTUCKY ACADEMY OF SCIENCE

### CONTENTS

| Heat Pumps. E. B. Penrod  | 1  |
|---|----|
| A Bacteriological Survey of Well Waters From Four Central<br>Kentucky Counties. Rafael A. Cartin and R. H. Weaver                                     | 38 |
| Comparison of the Sherman Tests With the Chapman Plate for Identifica-<br>tion of the Streptococci From Teeth. C. B. Hamann and Frank<br>J. Gruchalla | 45 |
| A Modified Procedure for the Formol Titration. A. A. Rosen and B. S.<br>Andrews   | 48 |
| A Preliminary List of Kentucky Cicadellidae (Homoptera). David A.<br>Young, Jr.   | 54 |
| Academy Holds Spring Meeting  | 68 |

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### HEAT PUMPS

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### INTRODUCTION

Three distinct types of heat pumps which may be used for continuous air conditioning are considered in this paper; namely, the Peltier heat pump, the absorption heat pump, and the compression heat pump. Commercial heat pumps of the last type have been developed to a high state of perfection and can be recommended whenever a good application presents itself (1). The domestic heat pump systems are in the experimental stage at the present time and considerable research must be done before the most economical heat exchanger can be designed for extracting the heat from its source. At the present time there are over three hundred domestic heat pump systems (pilot-plants) in operation in the United States.

In this paper attention will be given primarily to heat pumps for continuous air conditioning and some consideration will be given to fundamental principles. A heat pump may be defined as a device arranged so that heat is absorbed from one medium at a low temperature level and delivered to another medium at a higher temperature level. A heat pump system is a heat pump plus the auxiliary equip-ment such as fans, pumps, and automatic controls. This distinction is made primarily for the purpose of determining the performance characteristics of different heat pump systems.

### THE REVERSIBLE CYCLE

In 1824 Sadi Carnot described an engine that could transform heat into mechanical work with the minimum unavoidable waste. He pointed out also that the efficiency of his reversible engine depends on the absolute temperatures of the source and sink, and that the efficiency is independent of the nature of the working substance. Twenty-four years later kelvin, after making a careful study of the Carnot cycle, introduced the thermodynamic scale of temperature. According to this temperature scale, any two temperatures on it are proportional to the quantities of heat absorbed and rejected by a reversible Carnot engine working between

# APR 1 7 1950

these temperatures.

$$\frac{Q_h}{T_h} = \frac{Q_c}{T_c} - - - (1)$$

where T<sub>h</sub>, T<sub>c</sub> are the absolute temperatures of the source and sink respectively,  $Q_h$  and  $Q_c$  are the quantities of heat absorbed and rejected. It can be seen that the ratio of the heat taken in (or given out) to the absolute temperature at which it is taken in (or given out) is the same for all isothermal changes between any two adiabatics. This suggested to Clausius, in 1851, that the quantity  $\frac{Q}{T}$  is the change in a certain property of the working substance which remains constant during any reversible adiabatic process, but changes when the substance passes from one adiabatic to another. Clausius named this property entropy. If the Carnot cycle is plotted on the temperature-entropy plane, Fig. 1, it has the form of the rectangle ABCD. The area ABFE represents the quantity of heat taken from the source, in a reversible way, at the absolute temperature Th, and the area DCFE represents the unavoidable waste or the heat discharged, in a reversible way, to the sink at the absolute temperature  $T_c$  (2). The area ABCD represents the maximum amount of useful mechanical work that can be obtained from the Carnot engine. The efficiency of a Carnot engine is given by the equation

$$\eta = \frac{T_h - T_c}{T_h} - - -(2), \text{ or } \eta = \frac{q_h - q_c}{q_h} - - - (3)$$

If the Carnot engine were reversed it would absorb a quantity of heat, in a reversible way, represented by the area DCFE from a cold body at the absolute temperature  $T_c$ , and discharge an amount of heat, in a reversible way, represented by the area ABFE to a hot body at the absolute temperature  $T_h$ . The area ABFE to a hot body at the absolute temperature  $T_h$ . The area ABCD now represents the minimum amount of mechanical work that must be supplied to the reversed Carnot engine. If the function of the reversed Carnot engine is to cool a given space, its efficiency is called the coefficient of performance and is given by the equation

tion C O P as a cooling machine  $= \frac{T_c}{T_h - T_c} - - - (4)$ .

If the purpose of the reversed Carnot engine is to heat a given space, or medium, then

$$C O P as a heating machine = \frac{1h}{Th - Tc} = I + \frac{1c}{Th - Tc} (5)$$
Carnot never suggested that his reversed engine be used as a heating machine. Now it is impossible to make an actual engine that will operate on the Carnot cycle and therefore no refrigeration machine has ever been constructed that operates on the reversed Carnot cycle. The actual compression refrigeration cycle used today is a cycle in its own right and should not be considered as a reversed engine of any type. If a compression refrigeration plant is used for continuous air conditioning, for example, the events of the refrigeration cycle are not altered in any way whatsoever when the machine is changed from heating to cooling, or vice versa. If the refrigeration machine is to have a special name it is preferable to call it a heat pump instead of "the reversed cycle". A heat pump may be changed from a heating to a cooling machine either by the use of a system of dampers (3), or by the use of several valves (4). In the former the functions of the two heat exchangers are unchanged, while in the latter the functions of the two heat exchangers are interchanged although the various events of the refrigeration cycle are unaltered.\*

In 1852 Kelvin suggested that a building could be heated or cooled with the same equipment (5). A year later, in order to determine the size of his heating and cooling machines, Kelvin showed that it would require 0.286 horsepower for changing the temperature of one pound of air per second from 50 F to 80 F and that the volume of the compression cylinder should be 15.63 cubic feet, requiring a diameter of 2.23 feet and a length of 4 feet (6). Kelvin's proposed machine had to be modified considerably in changing over from heating to cooling, and consequently was never built. However, refrigeration machines operating on the Kelvin air cycle came into common use.

<sup>\*</sup> The events of an ordinary compression refrigeration machine are: (a) the compression of a vapor at low temperature and pressure to a higher temperature and pressure; (b) the condensation of the vapor; (c) the expansion of the liquid through a valve or capillary tube; and (d) the evaporation of the liquid. These events are always followed in the same cyclic order no matter whether the plant is used for heating or cooling a given space or medium.



Fig. 1.— The Carnot cycle on the temperature-entrophy plane.



Fig. 2.— A simple Peltier heat pump.

#### THE PELTIER HEAT PUMP

In 1821 Seebeck discovered that electric charges flow in a circuit composed of two metallic conductors of different materials if the temperatures of the two junctions are different (7)(8). The combination of two such conductors is generally referred to as a thermocouple. The energy expended as the electric charges flow in the circuit is supplied by the absorption of heat from external sources, assuming the temperature at every point in the circuit is maintained unchanged since there is no other means of supply. In 1834 Peltier found that when electric charges flow across the junction of two dissimilar metals it gives rise to an absorption or liberation of heat. If electric charges flow across the junction in one direction, heat is absorbed, while if they flow in the opposite direction heat is liberated. The Peltier heat liberated or absorbed at either junction of the thermocouple is given by

 $Q = \pi I \tau$ ,

where Q represents the quantity of heat,  $\pi$  the Peltier e.m.f., I the electric current, and  $\tau$  the time (9).

In 1854 Kelvin noticed that when electric charges flow through a wire of homogeneous material and cross-section, but of non-uniform temperature, heat must be supplied in order to maintain the temperature gradient. The amount of heat imparted for a temperature rise dt in time  $\gamma$  is given by the equation

# $dQ = \sigma I \tau dt,$

where dQ is the quantity of heat absorbed in time  $\mathcal{C}$ , I the electric current, and  $\mathcal{P}$  the specific heat of electricity.\* This phenomenon is known as the Thomson effect and is perfectly reversible.

\* The specific heat of electricity is defined by the equation dQ

 $\sigma = \frac{a\alpha}{\mathbf{I}\tau dt}$ , where  $\sigma$  is the specific heat of electricity, dQ the heat absorbed by an elemental length of a conductor, I $\tau$  the quantity of electricity, and dt is the temperature difference between the two ends of the elemental length of the conductor.

A simple Peltier heat pump is shown schematically in Fig. 2. The arm "a" of a thermocouple is connected to a D. C. power line. If P is the power input the energy supplied in time  $\tau$  is  $P \tau$ , the heat absorbed at the cold junction at temperature  $T_c$  is  $Q_c = \pi_c I \tau$ , and the heat liberated at the hot junction at temperature  $T_h$  is  $Q_h = \prod_r I \tau$ . Thus it can be seen that when electric energy is supplied to a thermocouple as shown in Fig. 2 it is essentially a heat pump capable of absorbing heat from one medium at a low temperature level and delivering heat to another at a higher temperature level.

If the Peltier heat pump is considered as a Carnot engine, the reversible Thomson heat and the irreversible Joule heat being neglected, it can be seen from (1) that  $\frac{\pi_h I \tau}{\pi_c I \tau} = \frac{T_h}{T_c}, \text{ or } \frac{\pi_h}{\pi_c} = \frac{T_h}{T_c}, \text{ and } \frac{\pi_c}{\pi_h} = \frac{\pi_c}{\pi_h}$ The efficiency of the Peltier heat pump is and the energy supplied is  $\pi_c = \frac{\pi_h}{\pi_h}$ 

$$P\tau = Q_h - Q_c = \pi_I \tau - \pi_c I\tau, P = (\pi_h - \pi_c) I, : \eta = \frac{P}{\pi_h I}$$

The coefficients of performance of the Peltier heat nump are given by

$$C \circ P(cooling) = \frac{\pi_c}{\pi_h - \pi_c} - ---(6) s$$
  
and  $C \circ P(heating) = \frac{\pi_h}{\pi_h - \pi_c} = 1 + \frac{\pi_c}{\pi_h - \pi_c} - --(7) .$ 

The Peltier refrigerator has been discussed by Altenkirsch (10), and patents on this type of refrigerator were obtained as far back as 1889. If a pile is made of a large number of thermocouples the capacity of the Peltier heat pump will be increased in proportion to the number used. Fig. 3 is a schematic diagram of one thermocouple in the pile of a Peltier heat pump. The arms "a" and "b" of the thermocouple are thermally insulated. For an elemental section, length dx, of one arm of the thermocouple the irreversible Joule heat absorbed per second is



Fig. 3 — A schematic diagram of one thermocouple in the pile of a Peltier heat pump.

7

$$dQ_{J} = I^{2}dR^{*} = (i A)^{2} \cdot \frac{\rho dx^{**}}{A} = i^{2}\rho dV.$$

The reversible Thomson heat developed per second is

$$dQ_T = \sigma Idt = \sigma iA \frac{dt}{dx} dx = \sigma i \frac{dt}{dx} dV.$$

The irreversible Fourier heat (heat conducted along the element of the couple) per second is

$$dQ_F = Q_{F''} - Q_{F'}$$
, (for steady state heat flow)

where

Hence,

$$Q_{F} = -k A \frac{dt}{dx}$$
,

$$Q_{F''} = Q_{F'} + \frac{dQ_{F'}}{dx} dx = Q_{F'} - k \wedge \frac{d^2t}{dx^2} dx = Q_{F'} - k \frac{d^2t}{dx^2} dV$$

$$dQ_{\rm F} = -k \frac{d^2 t}{dx^2} dV$$

Also 
$$dQ_F = dQ_J + dQ_T$$
, then  $-k \frac{d^2t}{dx^2} dV = i^2 \rho dV + i\sigma \frac{dt}{dx} dV$ 

$$\frac{d^2 t}{dx^2} + \frac{i\sigma}{k} \frac{dt}{dx} + \frac{i^2 \rho}{k} = 0$$
 (8)

where

\* According to Joule's law, the heat produced in a conductor is proportional to the product of the square of the current, the electrical resistance, and the time. \*\* The electrical resistivity of a conductor,  $\rho$ , is the resistance of a bar of the substance one centimeter long and one square centimeter cross-section.

$$\rho$$
 = electrical resistivity

t - temperature

- dt = drop in temperature along dx
- $\frac{dt}{dx}$  = temperature gradient
- L \_ length of an arm of the thermocouple
- dV = A dx or elemental volume

Equation (8) is a linear differential equation of the second order and first degree. Introducing the dimensionless ratios

$$S = \frac{t}{T_h - T_c}$$
 and  $\gamma = \frac{x}{L}$ , equation (8) transforms

to 
$$\frac{d^2 S}{d \eta^2} + \alpha \frac{d S}{d \eta} + \beta = 0$$
 (9)  
where
$$\alpha' = \frac{i \sigma (T_h - T_c)}{\frac{k(T_h - T_c)}{L}},$$

$$\alpha' = \frac{\text{total Thomson heat per unit area}}{\text{Fourier heat per unit area}},$$
and
$$\beta = \frac{i^2 \rho L}{\frac{k(T_h - T_c)}{L}},$$

$$\beta = \frac{\text{Joule heat per unit area per arm}}{\text{Fourier heat per unit area}}$$

Rearranging the terms in equation (9),

$$\frac{d}{d\eta} \left( \frac{d\mathcal{G}}{d\eta} + \alpha \mathcal{G} \right) = -\beta , \text{ integrating}$$

$$\frac{\mathrm{d}S}{\mathrm{d}\eta} + \alpha S = A - \beta \eta \; .$$

The solution of this linear differential equation of the first order is

$$S = e^{-\alpha \eta} \left\{ \int e^{\alpha \eta} (A - \beta \eta) d\eta + B \right\}.$$

Integrating by parts it is seen that

$$S = \frac{1}{\alpha} \left( A - \beta \eta \right) + \frac{\beta}{\alpha^2} + B e^{-\alpha \eta}, \text{ or}$$
$$t = (T_h - T_c) \left\{ \frac{1}{\alpha} \left( A - \frac{\beta}{L} x \right) + \frac{\beta}{\alpha^2} + B e^{-\alpha \eta} \right\} - -- (10)$$

where A and B are constants of integration.

Equation (10) is a general solution of (8); and a particular solution is obtained by applying the boundary conditions

 $t = T_h - T_c$ , for x = 0, t = 0, for  $x = L_*$ 

Hence

Hence 
$$t = (T_{h} - T_{c}) \left\{ 1 - \frac{1 - \frac{\beta}{\alpha}}{1 - e^{-\alpha}} \left( 1 - e^{-\frac{\alpha}{L}x} \right) - \frac{\beta}{\alpha L}x \right\} - (11).$$

Equation (11) shows the variation of the temperature along the arm of the thermocouple. Expanding the exponential terms, equation (11) transforms to

$$t = (T_{h} - T_{c}) \left\{ 1 - \left(\frac{1}{L} - \frac{\beta}{2L}\right) x - \frac{\beta}{2L^{2}} x^{2} + \cdots \right\}^{---(12)}$$

Differentiating equation (12) to obtain the temperature gradient along an arm of the thermocouple, it is seen that

$$\frac{dt}{dx} = (T_{h} - T_{c}) \left( \frac{\beta}{2L} - \frac{1}{L} - \frac{\beta}{L^{2}} \cdot x \right).$$

At the hot junction, x = o, then

$$\frac{dt}{dx}_{x=0} = (T_h - T_c) \left(\frac{\beta}{2L} - \frac{1}{L}\right)$$

Hence,

$$\mathbf{Q}_{\mathbf{x}} = \mathbf{o} = -\mathbf{k} \left(\frac{\beta}{2L} - \frac{1}{L}\right) \left(\mathbf{T}_{\mathrm{h}} - \mathbf{T}_{\mathrm{c}}\right) = \left(1 - \frac{\beta}{2}\right) \mathbf{k} \frac{\left(\mathbf{T}_{\mathrm{h}} - \mathbf{T}_{\mathrm{c}}\right)}{L}$$
$$= \left(1 - \frac{\beta}{2}\right) \mathbf{Q}_{\mathrm{F}}$$
(13)

At the cold junction, x = L, then

$$\frac{dt}{dx}_{x = L} = -\left(\frac{\beta}{2L} + \frac{1}{L}\right) (T_{h} - T_{c}),$$

$$Q_{x = L} = + k \left(\frac{1}{L} + \frac{\beta}{2L}\right) (T_{h} - T_{c}).$$

$$= + (1 + \frac{\beta}{2}) k \left(\frac{T_{h} - T_{c}}{L}\right)$$

$$= (1 + \frac{\beta}{2}) Q_{F} \qquad (14)$$

And

The heat absorbed per unit area,  $Q_{abs}$ , from the sink, or external medium, is equal to the difference between the Peltier heat,  $Q_c$ , and  $Q_x = L^{\cdot}$  Hence

$$Q_{abs} = \pi_c i - (1 + \frac{\beta}{2}) Q_F \cdot But \beta = \frac{i^2 \rho_L}{Q_F},$$

so that

$$\begin{aligned} \text{at} \quad & \mathbb{Q}_{\text{abs}} = \pi_{c} \, i \, - \, (\mathbb{Q}_{\text{F}} + \frac{1}{2} \, i^{2} \, \rho \, \text{L}) \\ & = \pi_{c} \, i \, - \frac{\text{k} \, (\text{T}_{\text{h}} - \text{T}_{\text{c}})}{\text{L}} - \frac{1}{2} \, i^{2} \, \rho \, \text{L}, \text{ or} \\ & = \, i \Big\{ \pi_{c} - \frac{\text{k} (\text{T}_{\text{h}} - \text{T}_{\text{c}})}{\text{iL}} - \frac{1}{2} \, i \, \rho \, \text{L} \Big\} \end{aligned} \tag{15}$$

To obtain the maximum value for the heat absorbed at the cold junction differentiate equation (15) with respect to iL and set the result equal to zero. The value of iL which makes  $Q_{abs}$  a maximum is

$$iL = \sqrt{\frac{2k(T_{h} - T_{c})}{\rho}}$$
(14)

Whence,  

$$Q_{abs}_{max.} = i \left\{ \pi_c - \frac{\kappa (T_h - T_c)}{\sqrt{\frac{2\kappa(T_h - T_c)}{\rho}}} - \frac{1}{2\rho} \sqrt{\frac{2\kappa(T_h - T_c)}{\rho}} \right\}.$$

$$Q_{abs}_{max.} = i \left\{ \pi_c - \sqrt{2\kappa\rho(T_h - T_c)} \right\} - - - (17).$$
Now 
$$\beta = \frac{i^2 \rho L}{\kappa (T_h - T_c)}.$$

Substituting the value of iL from (16) it is readily seen that  $\beta = 2$ . Thus it is seen that for maximum refrigeration, the length and cross-sectional area of the arms of the thermocouple should be constructed so that the Joule heat will be equal to twice the Fourier heat. Placing  $\beta = 2$  in equation (13) it is seen that  $Q_x = 0 = 0$ , which shows that Peltier heat only is transferred to the external medium at the hot junction.

(2-2)

.

From equation (17) it is seen that  

$$Q_{abs} = i \left\{ \pi_c - \sqrt{z(T_h - T_c)} \sqrt{K\rho} \right\}, \text{ (for one arm)}$$

$$Q_{abs} = i \left\{ \pi_c - \sqrt{z(T_h - T_c)} \left[ \sqrt{K_a \rho_a} + \sqrt{K_b \rho_s} \right] \right\} \text{ couple}$$

When the Joule and Thomson heats were neglected it was shown that the power supplied to the Peltier heat pump was given by the equation

$$= (\pi_h - \pi_c) \mathbf{I} \cdot$$

When the irreversible Joule heat is taken into consideration the power supplied per unit area is given by the equation

$$P = i \pi_h - \varphi_{abs}$$
, or

$$P = i \{ \pi_h - \pi_c + \sqrt{2} (\pi_h - \pi_c) [ \sqrt{k_a \rho_a} + \sqrt{k_b \rho_b} ] \} \text{ couple.}$$

If the cross-sectional area of the arms of the thermocouple is sufficiently large so that the current density is relatively small the Peltier heat pump cycle approximates a Carnot refrigerator, and it can be seen that

$$\pi_h - \pi_c = \frac{T_h - T_c}{T_c} \pi_c$$

Hence, the above equation becomes

$$P = i \left\{ \frac{T_h - T_e}{T_e} \prod_{c} + \sqrt{\mathcal{R}(T_h - T_c)} \left[ \sqrt{K_a f_a} + \sqrt{K_b f_b} \right] \right\} \text{ couple.}$$

For substances that obey the Wiedemann-Franz-Lorenz law (11) $K_a f_a = K_b \rho_b = K \rho$ .

$$P = i \left\{ \frac{T_h - T_c}{T_c} \pi_c + \sqrt{8(T_h - T_c)} \sqrt{\kappa \rho} \right\}_{\text{couple.}}^{--(18)}$$

The coefficients of performance of the Feltier heat pump are given by the equations

$$C \circ P(\text{cooling}) = \frac{\pi_c}{T_h - \tau_c} \frac{\pi_c}{\tau_c} + \sqrt{8(\tau_h - \tau_c)} \sqrt{K\rho}$$

$$C \circ P(\text{heating}) = \frac{\pi_h}{\frac{\tau_h - \tau_c}{\tau_c} \pi_c} + \sqrt{8(\tau_h - \tau_c)} \sqrt{K\rho} - --(20)$$

For alloys that obey the Wiedemann-Franz-Lorenz law, the heat absorbed at the cold junction is given by the equation

$$Q_{abs} = i \left\{ \Pi_c - \sqrt{8(T_L - T_c)} \sqrt{K\rho} \right\}.$$

)

Since 
$$Q_{abs}$$
 is positive it follows that  
 $(\pi_c - \sqrt{8(T_h - T_c)} \sqrt{K\rho}) > 0$   
then  
 $\pi_c > \sqrt{8(T_h - T_c)} \sqrt{K\rho}$ ,

squaring,

 $\pi_c^2 > \mathcal{S}(T_h - T_c) \kappa \rho$ ,  $(T_h - T_c)_{max} \left( \frac{\tau T_c^2}{8 K P} \right)$ 

transposing,



FLUE GAS 6500 BTU PER HR.

Fig. 4.— A schematic diagram of an absorption refrigeration heat pump system.

The efficiency of the Peltier heat pump (or that of the Peltier generator) is relatively low when calculated from data on existing metals and alloys (12).\* The efficiency may be improved if alloys having higher Peltier coefficients can be found through research. The Peltier heat pump has no moving parts, and if its efficiency can be improved may have application for continuous air conditioning and in industries that require both warm and cold water for processing.

#### ABSORPTION HEAT PUMP

From tests it has been shown that a 3-ton absorption refrigeration plant, having an efficiency of 54.7 per cent requires 66,000 Btu per hour, produces refrigeration at the rate of 36,000 Btu per hour (13). If a 3-ton absorption refrigeration plant is arranged as shown schematically in Fig. 4, it can be used as a heat pump system capable of delivering approximately 95,500 Btu per hour for heating a given space. The C O P's of the absorption refrigeration heat pump will be about 1.4 and 0.55 respectively for heating and cooling. There will be a saving in the consumption of gas during the heating season which will reduce the annual operating cost for continuous air conditioning as compared to the gas-fired air conditioner that does not function as a heat pump. By the use of a bypass valve enough heat can be absorbed from the flue-gas during the heating period to prevent frosting the evaporator coils when outdoor air drops below 38 F. Applied to domestic air conditioning the absorption heat pump would smooth out the gassending-out curve and make a good load factor for the Gas Utility. On the other hand, the absorption heat pump would be a little more complicated than the gas-fired package air conditioner and therefore would have a higher installation cost. (14). (15).

\* Cullity reports an efficiency of about 6% for a thermoelectric generator in which a bismuth-selenium alloy was used as one arm of the thermocouple and a zinc-antimony alloy as the other. This value compres favorably with the efficiency of a non-compound steam engine which varies from 4 to 8%. "The Thermoelectric Properties and Electrical Comductivity of Bismuth-selenium Alloys" by B. D. Cullity, Metals Technology - A.I.M.E. Vol. 15, No. 1, January 1948, Tech. Publ. No. 2313.

#### COMPRESSION HEAT PUMP

An air-to-air heat pump system is shown in Fig. 5 when the plant is used for heating. The fan that forces air into the rooms to be air conditioned is called the circulating fan, and that which discharges air to the outside after it gives up heat to the evaporator is referred to as the discard fan. The refrigeration cycle and the air-flow for the same heat pump instellation are shown in Fig. 6 when the plant is used for cooling.

The performance characteristics of an air-to-air heat pump system were calculated for a <u>well</u> insulated <u>six-room</u> house in Lexington, Ky. where the outside design temperature is 0 F. The inside dry-bulb temperature was assumed to be kept at 70 F. The building heat losses for different outside mean air temperatures are given in Table I. In making these calculations the following assumptions were made:

- 1. Specific heat of air = 0.24 Btu per 1b per <sup>O</sup>F.
- 2. Freon-12 evaporates at -20 F.
- 3. Evaporator terminal temperature difference = 10 F.
- 4. Condenser terminal temperature difference = 10 F.
- 5. Total static pressure in the air circulating system = 1.25 inches water.
- 6. Interior volume of the house = 15,000 cu.ft.
- 7. One air change per hr., outside air introduced = 250 cfm at 0 F.
- 8. Circulating fan to supply air at the rate of 1,500 cfm.
- 9. Fan efficiency = 50%.
- 10. Fan-motor efficiency = 80%.
- 11. Refrigeration compressor efficiency = 85%.
- 12. Compressor-motor efficiency 90%.
- 13. Expansion at constant enthalpy.
- 14. Isentropic compression.
- 15. Atmospheric pressure = 29.92 inches Hg.

Calculation for the heating period on a  $0^{\circ}$  F:

 $0.24 \le 1500t = 0.24$  (s x 250 x 0 + 0.075 x 1250 x 70)

#### wt=4.375

Heat Pump



Fig. 5.— A schematic diagram of an air-to-air heat pump system showing the refrigeration cycle and the air flow during the heating period. The circulating fan operates continuously while the discard fan operates only when the heat pump is in operation.



Fig. 6.— A schematic diagram of an air-to-air heat pump system showing the refrigeration cycle and the air flow during the cooling period.

Table 1. Air conditioning a well-insulated six-room house using either an air heat pump or an earth heat pump system

| Mean outside air<br>temperature, F | Building heat loss,<br>Btu per hr | Daily heat lost from<br>building, Btu | Operation of heat pump<br>hrs per day | Energy supplied to<br>circulating fan per<br>day, kwhr | Heat delivered by heat<br>pump system per day<br>kwhr |
|------------------------------------|-----------------------------------|---------------------------------------|---------------------------------------|--|---|
| 0                                  | 65,000                            | 1,560,000                             | 24.0                                  | 13.2   | 457.1   |
| 10                                 | 55,000                            | 1,320,000                             | 20.3                                  | 13.2   | 387.0   |
| 20                                 | 45,000                            | 1,080,000                             | 16.62                                 | 13.2   | 317.0   |
| 30                                 | 35,000                            | 840,000                               | 12.92                                 | 13.2   | 246.0   |
| 40                                 | 25,000                            | 601,000                               | 9.24                                  | 13.2   | 176.0   |
| 50                                 | 15,000                            | 360,500                               | 5.54                                  | 13.2   | 105.6   |
| 60                                 | 5,000                             | 120,000                               | 1.85                                  | 13.2   | 35.2  |

Assume t = 57 F, then 57 w = 4.375w = 0.0767 lb per cu ft, where w is the sp.wt. of dry air at 57 F and 29.92 in. Hg.

Temperature of the air leaving the condenser

 $0.24 \times 0.0767 \times 1500 \times 60 \times (t-57) = 65,000$ 

$$t = 96.3$$
 F

The following values were obtained from Freon-12 Table\_ and Charts:

- $h_4 = 32.7$  Btu per 1b  $h_3 = 93.2$  Btu per 1b
- $P_{4} = 143.4 \text{ psia}$   $s_{3} = 0.17275 \text{ Btu per 1b per }^{\circ}R$

 $r_2 = 15.3 \text{ psia}$   $t_3 = 132 \text{ F}$ 

h. = 75.9 Btu per 1b

Coefficient of performance of a reversible heat pump as a heating machine operating between the temperature limits of -20 F and + 132 F

Carnot C O P(heating) = 
$$\frac{T_1}{T_1 - T_2} = \frac{592}{592 - 440} = 3.89$$

Refrigeration effect =  $h_2 - h_1$ = 75.9 - 32.7, since  $h_1 = h_1$ , = 43.2 Btu per lb.

Heat equivalent of compression =  $h_3 - h_2 = 93.2 - 75.9$ 

= 17.3 Btu per 1b.

Heat discharged from condenser =  $h_3 - h_4 = 93.2 - 32.7$ 

Theoretical coefficient of performance for the refriger-tion cycle considered

Then. C O P(heating) = 
$$\frac{h_3 - h_4}{h_3 - h_2} = \frac{60.5}{17.3} = 3.5$$
.

Heat Pump



FLUID FLOW THROUGH THE CONDENSER





Fig. 7.— A schematic diagram showing the temperatures of the air and the refrigerant on passing through the heat exchangers of an air-to-air heat pump on a day when the outside mean air temperature is 0 F.



Fig. 8.— The refrigeration cycle shown on the pressure-enthalpy plane and on the temperature-entropy plane on a day when the outside mean air temperature is 0 F.

Theo. C O P(cooling) = 
$$\frac{h_2 - h_1}{h_3 - h_2} = \frac{h_3 \cdot 2}{17 \cdot 3} = 2.5$$
  
F-12 circulated =  $\frac{65,000 \text{ Btu hr}^{-1}}{(h_3 - h_2) \text{ Btu 1b}^{-1}} = \frac{65,000 \text{ Btu hr}^{-1}}{60.5 \text{ Btu 1b}^{-1}}$   
= 1075 1b hr<sup>-1</sup>  
Capacity of the compressor =  $\frac{h_3 \cdot 2 \text{ Btu 1b}^{-1} \times 1075 \text{ 1b hr}^{-1}}{12,000 \text{ Btu hr}^{-1} \tan^{-1}}$   
= 3.87 tons  
Capacity of compressor-motor =  $\frac{1075 \text{ 1b hr}^{-1} \times 17.3 \text{ Btu 1b}^{-1}}{0.85 \times 0.90 \times 3h_{13} \text{ Btu kwhr}^{-1}}$   
= 7.12 kw, or 9.53 hp.

Energy supplied to heat pump = 24 hr x 7.12 kw = 171.0 kwhr. Compression ratio =  $\frac{143.4}{15.3}$  = 9.34 Power input to circulating fan-motor =  $\frac{0.000157 \times 1500 \times 1.25}{0.50 \times 0.80}$ = 0.736 hp or 0.55 kw.

Energy supplied to circulating fan-motor = 24 hr x 0.55 kw = 13.2 kwhr.

Use discard fan-motor with the same rating as the circulating fan-motor.

Power output = 
$$\frac{65,000 \text{ Btu } \text{hr}^{-1}}{3413 \text{ Btu } \text{kwhr}^{-1}} = 19.04 \text{ kw}$$

Actual C O P(heating) for the heat pump =  $\frac{19.04 \text{ kw}}{7.12 \text{ kw}} = 2.67$ 

Total power input to the heat pump system

-7.12 kw + 0.55 kw + 0.55 kw = 8.22 kw

Actual C O P(heating) for heat pump system =  $\frac{19.04 \text{ kw}}{8.22 \text{ kw}} = 2.32$ 

The daily heat loss from the house on a 0 F day, or the heat delivered by the heat pump system

- 2h hr day<sup>-1</sup> x 65,000 Btu hr<sup>-1</sup>

- 1,560,000 Btu per day - 457.1 kwhr per day.

Energy supplied to heat pump = 24 hr x 7.12 kw = 171.0 kwhr.

Energy supplied to heat pump system = 24 hr x 8.22 kw

= 197.4 kwhr.

Similar calculations were made for various outside mean air temperatures. The results of these calculations are recorded in Tables I and II, and are shown graphically in Fig. 9. This heat pump system was designed to operate continuously when the outside mean temperature was 0 F. The effect of the increase in the mean temperature of the fresh air admitted (and the decrease in the specific weight) upon the head pressure was considered in these calculations. The actual C 0 P's of the heat pump system at 0 F and 60 F were found to be 2.3 and 1.2 respectively (16). It should be pointed out that the heat pump operates only 1.85 hours per day, and at its lowest efficiency, when the outside mean temperature is 60 F.

An earth-to-air heat pump system is shown schematically in Figs. 10 and 11. Calculations were made to determine the performance characteristics of this heat pump system when used to heat a well insulated six-room house under exactly the same conditions as for the above air-to-air heat pump system. The results of these calculations are recorded in Table III and are shown graphically in Fig. 12. In making these calculations the effect of the increase of temperature (and decrease in specific weight) in the 250 cfm fresh air admitted on the increase in the condensing temperature of the refrigerant was considered. The actual C O P's of the earthto-air heat pump system at O F and 60 F were found to be 3.8 and 1.5 respectively. When this effect was neglected the corresponding C O P's were found to be 3.52 and 1.57 respectively (17).

Table II. Performance characteristics of an air-to-air heat pump system for various outside mean air temperatures. Freon-12 evaporates at -20 F. The heat pump was designed to operate continuously at 0 F outside air temperature and intermittently at higher air temperatures. The circulating fan operates continuously and the discard fan intermittently.

| Mean outside air                                       |                  |       |       |        |       |       |       |
|--|------------------|-------|-------|--------|-------|-------|-------|
| temps. F   | 0                | 10    | 20    | 30     | 40    | 50    | 60    |
| Temp. of air enter-<br>ing condenser, F                | 57.0             | 59.0  | 60.9  | 62.9   | 64.8  | 66.7  | 68.2  |
| Temp. of air leav-<br>ing condenser, F                 | 96.3             | 98.4  | 100.4 | 102.6  | 104.7 | 106.6 | 108.2 |
| Temp. of F-12 ente<br>ing condenser, F                 | rī32             | 134   | 137   | 138    | 140   | 143   | 145   |
| Temp. of F-12 leaving condenser, F                     | -<br>106.3       | 108.4 | 110.4 | 112.6  | 114.7 | 116.6 | 118.2 |
| Capacity of com-<br>pressor, tons                      | 3.9              | 3.8   | 3.8   | 3.8    | 3.8   | 3.7   | 3.7   |
| Compression<br>ratio                                   | 9.3              | 9.6   | 9.9   | 10.2   | 10.5  | 10.8  | 11.0  |
| Capacity of com-<br>pressor-motor, hp                  | 9.5              | 9.8   | 9.9   | 10.2   | 10.3  | 10.5  | 10.6  |
| Energy to heat pump<br>per day, kwhr                   | <sup>p</sup> 171 | 149   | 123   | 98     | 71    | 43    | 15    |
| Energy to discard<br>fan-motor per<br>day, kwhr        | 13.2             | 11.2  | 9.1   | . 7.1  | 5.1   | 3.0   | 1.0   |
| Energy to circu-<br>lating fan-motor<br>per day, kwhr  | 13.2             | 13.2  | 13.2  | 2 13.2 | 13.2  | 13.2  | 13.2  |
| Energy to heat<br>pump system per<br>day kwhr          | 197              | 173   | 145   | 118    | 89    | 60    | 29    |
| Heat delivered by<br>heat pump system<br>per day, kwhr | 457              | 387   | 317   | 246    | 176   | 106   | 35    |
| Carnot C O P   | 3.9              | 3.9   | 3.8   | 3.8    | 3'.8  | 3.7   | 3.7   |
| Theo. C O P of the heat pump                           | 3.5              | 3.4   | 3.4   | 3.3    | 3.3   | 3.2   | 3.2   |
| Actual C O P of<br>the heat pump                       | 2.7              | 2.6   | 2.6   | 2.5    | 2.5   | 2.5   | 2.4   |
| Actual C O P of the<br>'eat pump system                | ° 2.3            | 2,2   | 2.2   | 2.1    | 2.0   | 1.8   | 1.2   |



Fig. 9.— Performance characteristics of an air-to-air heat pump system during the heating period. The circulating fan operates continuously. The heat pump and discard fan operate continuously for an outside temperature of 0 F and intermittently for higher temperatures. The refrigerant evaporates at —20 F.

Heat Pump



Fig. 10.— A schematic diagram of an earth-to-air heat pump system for heating a building.



Fig. 11.— A schematic diagram of an earth-to-air heat pump system used for cooling a building.

Table III. Performance characteristics of an earth-to-air heat pump system for various outside mean air temperatures. Freon-12 evaporates at + 20 F. The heat pump was designed to operate continuously at 0 F outside air temperature and intermittently at higher air temperatures. The circulating fan operates continuously.

| Mean outside air<br>temp. F                            | 0     | 10    | 20     | 30     | 40     | 50    | .60     |
|--|-------|-------|--------|--------|--------|-------|---------|
| Temp. of air enter-<br>ing condenser, F                | 57.0  | 59.0  | 60.9   | 62.9   | 64.8   | 66.   | 7 68.2  |
| Temp. of air leav-<br>ing condenser, F                 | 96.3  | 98.4  | 100.4  | 102.6  | 104.7  | 106.0 | 5 108.2 |
| Temp. of F-12 enter-<br>ing condenser, F               | 118   | 122   | 125    | 127    | 129    | 132   | 134     |
| Temp. of F-12 leav-<br>ing condenser, F                | 106.3 | 108.4 | 110.)4 | 112.6  | 114.7  | 116.0 | 5 118.2 |
| Capacity of com-<br>pressor, tons                      | 4.0   | 3.7   | 3.0    | 2.3    | 1.7    | 1.0   | •3      |
| Compression<br>ratio                                   | 4.0   | 4.1   | 4.2    | 4.4    | 4.5    | 4.6   | 4.7     |
| Capacity of com-<br>pressor-motor, hp                  | 6.1   | 5.3   | 4.5    | 3.6    | 2.6    | 1.6   | 0.5     |
| Energy to heat<br>pump per day, kwhr                   | 108   | 96    | 81     | 64     | 47     | 29    | 10      |
| Energy to circu-<br>lating fan-motor<br>per day, kwhr  | 13.2  | 13.2  | 13.2   | 2 13.2 | 2 13.2 | 13.2  | 13.2    |
| Energy to heat<br>pump system per<br>day, kwhr         | 121   | 109   | 94     | 77     | 60     | 42    | 23      |
| Heat delivered by<br>heat pump system<br>per day, kwhr | 457   | 387   | 317    | 246    | 176    | 106   | 35      |
| Carnot C O P <sub>h</sub>                              | 5.9   | 5.7   | 5.6    | 5.5    | 5.4    | 5.3   | 5.2     |
| Theo. C O P <sub>h</sub> of the<br>heat pump           | 5.6   | 5.3   | 5.1    | 5.0    | 4.9    | 4.8   | 4.7     |
| Actual C O Ph of the<br>heat pump                      | 4.3   | 4.1   | 3.9    | 3.8    | 3.8    | 3.7   | 3.6     |
| heat pump system                                       | 3.8   | 3.6   | 3.4    | 3.2    | 2.9    | 2.5   | 1.5     |



Fig. 12.— Performance characteristics of an earth-to-air heat pump system during the heating period. The circulating fan operates continuously. The heat pump operates continuously for a mean outside temperature of 0 F and intermittently for higher temperatures. The refrigerant evaporates at + 20 F.

Comparative results are shown in Table IV for an airto-air and an earth-to-air heat pump system designed to heat the same well insulated six-room house in a locality where the outside temperature is 0 F. From this table it can be seen that the operating cost is less for the earth-to-air than that for the air-to-air heat pump system since less energy is required to operate the former. The earth-to-air heat pump requires a much smaller compressor-motor than the air-to-air type and there is no danger of ice collecting on the evaporator coils. However, the earth coil is much more expensive to install and will be less accessible if and when repairs are required.

#### CONSERVATION OF FUEL

The following calculations were made to show that the compression type heat pump system must have a C O P greater than 3.33 before it can be used to conserve our natural fuel supply: One pound of eastern Kentucky coal (14,500 Btu per 1b) burned in a boiler of a modern steam power plant and converted into electric energy at an efficiency of 24.4% would result in 3537 Btu (0.828 kwhr) available at the terminal of the electric generator. Assume a 20% loss between the generator and a house, 2830 Btu would be available for direct electrical heating for each pound of coal burned. On the other hand, the 2830 Btu (0.828 kwhr) of electric energy supplied to a domestic heat pump system having a C O P of 3.33 would result in 9420 Btu (3.33 x 2830) per pound of coal burned at the power plant available for heating the house. One pound of the same coal burned in a good stokerfired furnace at an efficiency of 65% in a house, would result in 9420 Btu (0.65 x 14,500) available for heating. On this basis of comparison, the domestic heat pump system will only deliver just as much heat per pound of coal burned as the stoker-fired furnace.

#### HEAT PUMP PROGRESS

There are twenty-four commercial heat pump installations in the Americas which provide continuous air conditioning, seven of which are not in offices of electric utilities. Of the latter, three were installed on the Pacific coast in 1947, one of which has a nominal capacity of 225 tons and one 540 tons. A 550-ton heat pump system has been installed in the 'welve-story Equitable Building in Portland, Oregon.

| Table  | IV   | Comparison | of | an | earth-to-air | and | an | air-to-air |
|--------|------|------------|----|----|--------------|-----|----|------------|
| heat ] | pump | system     |    |    |              |     |    |            |

|  | Type<br>Earth-to-Ai | of System<br>r Air-to-Air |
|--|---------------------|---------------------------|
| Outside mean air temperature             | OF                  | O F                       |
| Inside dry-bulb temperature              | 70 F                | 70 F                      |
| Evaporator temperature                   | <b>+</b> 20 F       | -20 F                     |
| Carnot C O P <sub>h</sub>                | 5.9                 | 3.9                       |
| Theoretical C O $P_h$ of heat pump       | 5.6                 | 3.5                       |
| Actual C O $P_h$ of heat pump            | 4.3                 | 2.7                       |
| Actual C O $P_h$ of heat pump systemetry | em 3.8              | 2.3                       |
| Compressor capacity, tons                | 4.0                 | 3.9                       |
| Compression ratio                        | 4.0                 | 9.3                       |
| Compressor-motor, hp                     | 6.1                 | 9.5                       |
| Energy supplied to system, kwhr          | 120.7               | 197.4                     |
| Operating time, hrs per day              | 24                  | 24                        |

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The General Engineering and Manufacturing Co., St. Louis, Mo. manufactured a limited number of domestic heat pump units in 1948 and installed them as pilot-plants in various parts of the United States to obtain performance data. This Company has had one domestic heat pump in operation for several years.

The Webber Engineering Company, Indianapolis, Ind. made experimental heat pump units for electric utilities. Three earth-to-air heat pumps of the direct expansion type are now in operation in the Indianapolis area and two more are now in the process of construction.

In 1938 C. E. Boggs designed and installed a heat pump system to provide panel heating in his new house in Boise, Idaho. During 1947 he designed two domestic heat pumps, waterto-water type, for the Boise area. One of these was installed in a new house to provide panel heating and the other replaced a hot air furnace in a house already constructed. In addition to these, he designed a 3-ton package heat pump system which was installed in the Idaho Power Company System Dispatcher's office where the heat source is waste cooling water from feeder regulators. The Northwestern Heat Pump Company of Boise planned to make about six domestic heat pumps last year. This Company is interested particularly in designing heat pump systems with hot water storage tanks of sufficient size to make off-peak house heating with the heat pump more economical.

Drayer-Hanson, Inc., of Los Angeles, has approximately 300 heat pump units in operation, most of which are semicommercial installations. Recently the Gay Engineering Company of Los Angeles installed a heat pump system in the warehouse of the Spector Produce Co. of Phoenix, Arizone to ripen bananas. Here the heat pump rinciple is used very efficiently since both heat exchangers are used simultaneously, one extracting heat from the frozen food rooms at a low temperature level and the other discharging heat to three banana lockers at a higher temperature level.

#### SUMMARY

1. The Peltier heat pump was proposed nearly sixty years ago. However, a heat pump constructed from alloys available at that time was known to have a low efficiency. Recently research has been done to develop new alloys which obey the

Wiedemann-Franz-Lorenz law and at the same time have a much higher thermoelectric power, in order to improve the efficiency of the thermocouple when used as either a direct current generator or a Peltier heat pump (12). It is hoped that the review of the theory of the Peltier heat pump given here will stimulate research in metallurgy in order to produce alloys which will be malleable, have a very high thermoelectric power, and at the same time obey the Wiedemann-Franz-Lorenz relation.

2. Although the absorption heat pump may have a low C 0 P, if perfected it would lower the annual operating cost as compared to the gas-fired package air conditioner when used for continuous air conditioning, by reducing the gas consumption during the heating season. Research is recommended.

3. The commercial heat pump of the compression type has been applied successfully in industries for processing and for continuous air conditioning. When used for air conditioning, the maintenance cost is comparable with that of the ordinary refrigeration plant. The refrigeration engineer may also find many good applications of the heat pump by making a careful survey of industries other than air conditioning.

4. The domestic heat pump is in the experimental state at the present time. A theoretical analysis has been given here to determine the performance characteristics of an earth-to-air and an air-to-air heat pump system. A waterto-air heat pump system will have performance characteristics similar to that of the earth-to-air type. From Table IV it can be seen that the air-to-air heat pump requires a motor whose capacity is about 50 per cent greater than an earthto-air heat pump for heating the same house under the same conditions. The condensing temperature of the refrigerant could be lowered if panel heating were provided. This in turn would increase the C O P, decrease the compression ratio, and thereby decrease the horsepower of the compressor-motor.

5. At the present time very little engineering data are available on the transient flow of heat through the earth.\*

<sup>\*</sup> Data on the strength of a earth heat source will be published in a bulletin by the Engineering Experiment Station of the University of Kentucky.

In case the time rate of heat flow through the earth is very low the heat transfer surface per ton of refrigeration, in the evaporator, will be larger unless the moisture around the coil is frozen. Considerable research will be necessary before it can be decided whether the earth is a suitable heat source. The cost of digging trenches to install an earth coil at the present time will make this type of heat pump system more expensive than the air-to-air type. However, a machine might be developed for digging deep holes for placing hair-pin coils in the earth.

6. It has been shown that solar house heating may be possible with relatively short-term heat storage (18). It might be possible to supplement an earth heat pump in the northern states and the air heat pump in the southern states with solar heat. However, it should be pointed out that by combining two different types of heating systems the initial installation cost will be increased but the annual operating cost may be reduced.

7. There will be practically no saving of our natural fuels if the heat pump is employed unless the C O P for heating is above 3.33.

8. In general it is not easy to predict the cost of a commodity until it has been made. It is therefore rather difficult to estimate the initial cost of a domestic heat pump system until the manufacturers have produced it. The economics of the heat pump has been discussed recently (19).

9. A domestic heat pump system should be completely automatic and entirely reliable. The reliability of the domestic heat pump system should be determined by installing a large number of pilot plants before it is placed on the market.

35

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# A BACTERIOLOGICAL SURVEY OF WELL WATERS FROM FOUR CENTRAL KENTUCKY COUNTIES

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In the Drinking Water Standards adopted by the Public Health Service in 1942 is the statement: "A brief summary of the pertinent facts relating to the sanitary condition of the water supply, as revealed by the field survey, should be submitted." Among the pertinent facts are listed, "Nature of soil and underlying strata; depth to water table" and "Nature of rock penetrated, noting especially existence of porous limestone."

In the Sanitation Manual for Ground Water Supplies, 1944, is the statement: "Formations such as limestone, broken lava rock, coarse gravel, and brittle rocks whose interstices are in the form of channels, joints, and fissures, provide little filtering action to prevent contamination from reaching the water-bearing stratum."

In spite of these statements, a search of the literature will reveal a deficiency in studies of the effect of soil and rock types on the sanitary quality of water supplies.

Through the cooperation of the U. S. Geological Survey and the Department of Geology of the University of Kentucky, who have been making a survey of the water supplies of four Central Kentucky counties, Bourbon, Fayette, Jessamine and Scott, it has been possible to obtain samples of water from 73 wells in this area, together with geological data concerning the locations of the wells.

Along with studies to correlate the bacteriological quality of the water with the geological surroundings of the well, studies have been made of the effect of storage of the water samples for 24 and 48 hour periods at room temperature on the results of tests for members of the coliform group in the water. Although the Standard Methods for the Examination of water and Sewage (Ninth edition, 1946) specifies that samples of relatively pure waters shall not be held for more than 12 hours (impure waters waters 6 hours) at 6 to 10 C, the majority of water samples from rural regions in Kentucky are examined only after prolonged storage at room temperature. Many of them are mailed to the laboratories where the examinations are made. The work of Hutchison, 1943, on the influence of the presence of antagonists for Escherichia coli in water samples on the results of tests for coliform organisms has suggested that results obtained after such handling of samples may be very unreliable.
## Experimental

#### PROCEDURES

The samples were taken by members of the Geology Department of the University of Kentucky. Three samples were taken from each well, all at the same time, in sterile glass-stoppered bottles of approximately 100 ml capacity. They were brought to the laboratory, uniced. In most cases, the time between sampling and commencement of analysis was less than one hour, and in no case was it greater than two hours.

One of three samples from each well was examined immediately upon receipt in the labortary for bacterial content by means of the standard 37 C plate count and for density of coliform organisms, the most probable number (M. P. N.) being determined. The procedures of the Standard Methods for the Examination of Water and Sewage, 1946, were followed. For the coliform determination five 10-ml portions, five 1-ml portions and five 0.1-ml portions were planted in lactose broth. All positive presumptives were confirmed in brilliant green lactose bile broth.

The remaining two samples from each well were stored at room temperature. At the end of 24 hours, one of the two stored samples was examined for density of coliform organisms, and at the end of 48 hours, the other sample was examined.

#### RESULTS

The results are included in table 1. Information on depth of wells and rock formations in which the wells are located is also included in the table. In some cases such information was not available.

# Transactions of the Kentucky Academy of Science

## TABLE 1

## BACTERIOLOGICAL RESULTS ON CENTRAL KENTUCKY WELL WATERS

| Well<br>No. | Depth<br>feet | Depth Formation at | Standard plate<br>count | M. P. N. coliforms† |            |        |
|-------------|---------------|--------------------|-------------------------|---------------------|------------|--------|
|             |               | bottom of well     |                         | 1                   | Sampi<br>2 | e<br>3 |
|             |               | FAYETT             | e County                |                     |            |        |
| I           | 120           | Curdsville         | 1                       | 7.8                 | 17         | 6.1    |
| 2           | 165           | Hermitage          | 5                       | 0                   | 0          | 0      |
| 3           | 65            | Iessamine          | 70                      | *1600               | 350        | 540    |
| 1           | 2000          | 5                  | 2                       | 0                   | 0          | 0      |
| 5           | 17            |                    | 140                     | 350                 | 130        | 240    |
| 6           | 75            |                    | 230                     | 540                 | 350        | *1600  |
| 7           | 195           | Hermitage          | 6600                    | *1600               | 920        | 920    |
| 8           | 185           | Tyrone             | 70                      | 920                 | 540        | 540    |
| 9           |               | 7                  | 70                      | 4                   | 2          | 4.5    |
| 10          | 185           | Tyrone             | 110                     | 49                  | 0          | 2      |
| 11          | 180           | Curdsville         | -48                     | 49                  | 23         | 45     |
| 12          | 85            | Jessamine          | 31                      | 130                 | 130        | 49     |
| 13          | 65            | Hermitage          | 14                      | 70                  | 33         | 4.5    |
| 14          | 90            | Jessamine          | 85                      | 17                  | 4.5        | 6.8    |
| 15          | 28            | Jessamine          | 180                     | *1600               | *1600      | *1600  |
| 16          | 42            | Jessamine          | 30                      | 0                   | 0          | 0      |
| 17          | 78            | Hermitage          | 325                     | 0                   | 0          | 0      |
| 18          | 135           | Jessamine          | -12                     | 26                  | 33         | 170    |
| 19          |               | 47                 | 375                     | 0                   | 0          | 0      |
| 20          | 75            | Curdsville         | 270                     | 140                 | 220        | 170    |
| 21          | 100           | Hermitage          | 2900                    | 26                  | 23         | 11     |
| 22          | 70            | Ŭ                  | 7                       | 2                   | 2          | 0      |
| 23          |               |                    | 350                     | 11                  | 7.8        | 2      |
| 24          | 60            | Tyrone             | 600                     | *1600               | *1600      | 49     |
| 25          |               |                    | 34                      | 240                 | 79         | 14     |
| 26          | 70            |                    | 5                       | 2                   | 2          | 0      |

| Well<br>No. | Depth<br>feet | Formation at bottom of well | Standard plate<br>count | M. P. | N. colif<br>Sample | orms† |   |
|-------------|---------------|-----------------------------|-------------------------|-------|--------------------|-------|---|
|             |               |                             |                         |       | 1                  | 2     | 3 |
|             |               | JESSAME                     | ne <b>Co</b> unty       |       |                    |       |   |
| 27          |               |                             | 350                     | 130   | 79                 | 17    |   |
| 28          |               |                             | 500                     | 110   | 130                |       |   |
| 29          | 1.4           |                             | 9,600                   | *1600 | *1600              | *1600 |   |
| 30          | 86            |                             | 35                      | -1    | -4                 | 0     |   |
| 31          | 30            |                             | 700                     | 81    | *1600              | 220   |   |
| 32          | 75            |                             | *30,000                 | -49   | 33                 | 17    |   |
| 33          | 170           |                             | 2,900                   | 64    | 540                | 240   |   |
| 34          | 65            |                             | 6                       | 4.5   | 0                  | 0     |   |
| 35          | 85            |                             | 40                      | 19    | 33                 | 17    |   |
|             |               | Scoti                       | County                  |       |                    |       |   |
| 36          | 135           | Jessamine                   | 130                     | 27    | 4.5                | 0     |   |
| 37          | 60            | Woodburn                    | 1                       | 14    | -16                | 23    |   |
| 38          | 190           | Tyrone                      | 75                      | -49   | 17                 | - 22  |   |
| 39          | 80            |                             | 150                     | 6.8   | 0                  | - 0   |   |
| -40         | 500           | Tyrone                      | 110                     | 4.5   | 0                  | - 0   |   |
| 41          | 100           | Curdsville                  | 95                      | 23    | 4.5                | 4.5   |   |
| -42         | -14           | Jessamine                   | 85                      | -41   | 7.8                | 4.5   |   |
| 43          | 60-75         | Jessamine                   | 1                       | 0     | 0                  | 0     |   |
| -1-1        | 25            | Benson                      | 30                      | 240   | -41                | 17    |   |
| 45          | 65            | Benson                      | 38                      | 39    | 140                | 33    |   |
| -46         |               |                             | 30                      | 27    | 33                 | 33    |   |
| 47          | 55            |                             | 15                      | 17    | 21                 | 13    |   |
| -48         | 100           |                             | 2900                    | 7.8   | 4.5                | 0     |   |
| 49          |               |                             | 1-10                    | 920   | 920                | 33    |   |
| 50          | 123           | Tyrone                      | 15                      | 0     | 2                  | 1.8   |   |
| 51          | 76            | Jessamine                   | 80                      | 2     | 2                  | 0     |   |
| 52          | 75            | Benson                      | 85                      | -49   | 130                | 920   |   |
| 53          | 80            | Curdsville                  | 110                     | 110   | 79                 | 130   |   |
| 54          | 50            | Benson                      | 190                     | 540   | 240                | 920   |   |
| 55          | 132           | Hermitage                   | 3                       | 0     | 0                  | - 0   |   |
| 56          | 55            | Tyrone                      | 5                       | 2     | 0                  | 0     |   |
| 57          | 90            | Curdsville                  | 250                     | *1600 | *1600              | *1600 |   |
| 58          | 78            | Jessamine                   | 60                      | 350   | 95                 | 33    |   |
| 59          | 100           | Jessamine                   | 170                     | 0     | 0                  | 0     |   |
| 60          | 90-100        | Jessamine                   | 85                      | -49   | -49                | 4.5   |   |
| 61          | 8-1           | Tyrone                      | 32                      | 11    | 11                 | 13    |   |
| 62          | 150           | Tyrone                      | 325                     | 22    | 23                 | 1-4   |   |
| 63          | 135           | Jessamine                   | 7                       | 0     | 0                  | 0     |   |
| 64          | 135           | Jessamine                   | 46                      | 540   | 7.8                | 5     |   |
| 65          | 200           | Tyrone                      | 31                      | 350   | 31                 | -49   |   |
| 66          | 200           | Jessamine                   | 240                     | 540   | 920                | 920   |   |
| 67          |               | 3                           | 18                      | 21    | 2                  | 4.5   |   |

# A Bacteriological Survey of Well Waters

41

| Well<br>No. | Depth<br>feet | Formation at bottom of well | Standard plate<br>count | М. Р.<br>1 | N. colife<br>Sample<br>2 | orms†<br>3 |
|-------------|---------------|-----------------------------|-------------------------|------------|--------------------------|------------|
|             |               | Bourbo                      | n County                |            |                          |            |
| 68          | 73            |                             | 30                      | 79         | 70                       | 33         |
| 69          |               |                             | 65                      | 240        | 240                      | 350        |
| 70          |               |                             | 350                     | 240        | *1600                    | 2          |
| 71          | 31            |                             | 33                      | 1.8        | 0                        | 0          |
| 72          | 30            |                             | 5                       | 0          | 0                        | 0          |

85

Ω

Ω

Ω

#### Transactions of the Kentucky Academy of Science

† Sample 1 examined immediately after arrival at laboratory.

Sample 2 stored 24 hours at room temperature before examination. Sample 3 stored 48 hours at room temperature before examination.

\* Greater than.

140

73

In accordance with the usual results of water surveys little correlation can be found between the standard plate count results and the results of the tests for members of the coliform group. Judgment of the sanitary quality of the waters should be based primarily upon the coliform results.

Of the 73 wells examined, 62 (84.9%) were positive for coliforms. Standard plate counts of samples from these wells varied from 1 to greater than 30,000; the median was 80. Of the 62 coliform positive samples, 50 had M. P. N. values of over 10 and the wells may be considered as heavily polluted. Standard plate counts on these samples varied between 4 and greater than 30,000; the median was 85. Standard plate counts on the samples from the 12 lightly polluted wells varied between 1 and 2,900; the median was 33. Standard plate counts on the 11 samples that were negative for coliforms varied between 1 and 375; the median was between 5 and 6. While the wells from which these samples were taken should not be considered as polluted, at least 2, with plate counts of 325 and 375, should be viewed with suspicion.

Rock formations in the region studied are Ordovician, and are primarily limestone formations. No correlation could be found between the specific formations in which the wells were located and the sanitary quality of the water; nor could any correlation be found between the depths of the wells and the sanitary quality of the water. Likewise no correlation could be found with the soil types in which the wells were located. For the sake of brevity, data on soil types have not been included in the table of results.

Samples from 61 of the 62 wells that yielded coliform oryanisms when the samples were examined immediately were studied for the complete storage period of 48 hours.

#### A Bacteriological Survey of Well Waters

Of the 61 stored samples, 43 (70.5%) showed decreases in the coliform content during the storage period. Fifteen (24.6%) showed increases. Of the remaining 3 samples, one showed no change in coliform content in the 48 hour period and the other 2 had M. P. N. values greater than 1600, so that the serial dilutions used did not give accurate results.

Of the 62 samples from sources that yielded coliform organisms from the samples that were examined without storage, 6 yielded no coliform organisms after they had been stored for 24 hours at room temperature. Of these, only one was from a source that had a M. P. N. of over 6.8 as determined from the unstored sample. This well had a M. P. N. of 49 from the unstored sample, a M. P. N. of 0 from the sample that was stored for 24 hours, and a M. P. N. of 2 from the sample that was stored for 48 hours.

Of 61 samples from sources that yielded coliform organisms from the samples that were examined without storage, 11 yielded no coliform organisms after they had been stored for 48 hours at room temperature. Of these only one was from a source that had a M. P. N. of over 27 as determined from the unstored sample. This well had a M. P. N. of 540 from the unstored sample, a M. P. N. of 7.8 from the sample that was stored for 24 hours, and a M. P. N. of 0 from the sample that was stored for 48 hours.

## DISCUSSION

Little information was available concerning the construction of the wells from which the samples were obtained. It is probable that some of the wells are not so constructed as to avoid the entrance of surface pollution. Allowing for the presence of some wells of this type in the test group, it is still evident that much of the pollution can only be ascribed to the geological features of the region.

It may be concluded that comparatively few unpolluted wells exist in the area studied. Only 15 per cent of the wells studied were unpolluted on the basis of the coliform test as judged by a single sampling. High plate counts indicate that some of these wells might be found to be polluted at certain times if a series of samples were to be examined.

The results obtained with the stored samples emphasize the importance of the Standard Methods limitations on the storage of samples. Quantitative results to indicate the extent of pollution are

## Transactions of the Kentucky Academy of Science

almost worthless on samples that have been stored for 24 hours or more at room temperature. Qualitatively, pollution can usually be detected with samples that have been stored under these conditions, provided the extent of the pollution is comparatively great. Positive results on stored samples may be trusted but negative results should be looked upon with suspicion.

## SUMMARY

Samples of water from 73 wells in four Central Kentucky counties have been examined. Of these wells 50 were found to be heavily polluted, and 12 to be lightly polluted, as judged by tests for coliform organisms. High plate counts indicate that some of the remaining 11 wells should be viewed with suspicion pending further investigation. The high degree of pollution of well waters in Central Kentucky is associated with the predominantly limestone formation of the region. No correlation could be established, however, between the quality of the well water and the depth of the well or the formation in which the well was located.

Studies on the effect of storage of samples of well water at room temperature before examination emphasizes the importance of following Standard Methods provisions on the handling of samples if correct results are to be obtained.

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# COMPARISON OF THE SHERMAN TESTS WITH THE CHAPMAN PLATE FOR IDENTIFICATION OF THE STREPTOCOCCL FROM TEETH

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The present paper is a part of a larger study involving the flora of infected root canals of teeth.<sup>1</sup> In the course of the study it became apparent that in over 90% of the cases, streptococci were present, usually in pure culture. The clinical men soon observed that not all teeth responded equally well to treatment and as one of the variables was the bacteria, an attempt was made to differentiate the various species of streptococci.

Isolations were made by inserting sterile cotton points into the root canal, dropping into Brewer's Fluid Thioglycollate medium (Bacto), and incubating 24-96 hours. Growth was usually apparent in 24 hours. Blood agar plates were streaked as soon as growth became visible. From these plates pure cultures were started using serum tryptose broth.

As a majority of the cocci isolated gave either an alpha or gamma reaction on blood agar, further identification became a necessity. While the author was aware of Chapman's medium<sup>2</sup> for isolation of the streptococci, it seemed advisable to check the results of this plating medium against the fermentation test and the Sherman series of tests.<sup>3</sup>

Accordingly 44 pure cultures of streptococci isolated from the root canals as well as stock strains of streptococci were subjected to the three techniques.

The substances for fermentation included: adonitol, cellobiose, dextrin, dextrose, dulcitol, maltose, mannitol, mannose, melezitose, raffinose, rhamnose, salacin, sorbitol, sucrose, and xylose. All were sterilized by filtration and tubed in 2 ml. amounts in serological tubes. Phenol red was used as the indicator and was added before sterilization. The pH was adjusted to 7.8. All innoculated tubes were incubated at 37° C. for 96 hours, and read at 24 hour intervals. In addition to the fermentation tests, liquifaction of gelatin was noted.

The Sherman tests included: Growth in litmus milk at  $45^{\circ}$  C., final pH of dextrose broth, growth in  $0.1^{\circ}_{o}$  methylene blue, production of ammonia, growth in  $6.5^{\circ}_{o}$  salt broth and growth in serum tryptose at a pH of 9.6.

## Transactions of the Kentucky Academy of Science

The Chapman technique was carried out as described by him.<sup>2</sup> The results of the fermentation tests may be summarized as follows: All strains fermented dextrin, dextrose, galactose, lactose, maltose, mannose and sucrose. None of the strains fermented dulcitol or inositol. Strains varied in their fermentation of adonitol, cellobiose, esculin, glycerol, inulin, mannitol, melezitose, raffinose, rhamnose, salicin, sorbitol and xylose.

The results of the Sherman tests were interpreted as follows:

No growth in the 0.1% methylene blue, 6.5% salt broth, or in the high pH medium and no production of ammonia, were considered to be *Streptococcus salivarius*.

No growth in the 0.1% methylene blue, but growth in the other media and production of ammonia, were considered to be *Streptococcus mitis*.

Growth in all media and production of ammonia were considered to be *Streptococcus felcalis*, or *liquifaciens*. Those liquifying gelatin were designated *liquifaciens*.

According to this classification of the 44 unknown strains:

16 were Streptococcus salivarius
6 were Streptococcus mitis
17 were Streptococcus fecalis
5 were Streptococcus liquifaciens

Chapman's description of the colonies on the plate was used as the basis of classification.

Pale blue opaque colonies 2-5 mm. in diameter and giving a "gum drop" appearance, (a few were rugose), were considered to be *Streptococcus salivarius*.

Small blue colonies about 0.2 mm. in diameter were called *Streptococcus mitis*.

Dark brown to black, smooth, slightly raised colonies 0.5-1.5 mm. in diameter were considered enterococci and later differentiated on the basis of gelatin liquification. This gave from the 44 strains:

Streptococcus salivarius
 Streptococcus mitis
 Streptococcus fecalis
 Streptococcus liquifaciens
 no growth (salivarius by Sherman's tests)

## Comparison of the Sherman Tests With the Chapman Plate

By the way of correlation: Of three strains determined by the Sherman tests to be *salivarius*, two refused to grow on the Chapman medium and one was considered to be *mitis* by the appearance of the colony. No strains identified as *salivarius* on the plates differed from the determination by the Sherman tests. None of these determined by the Sherman tests to be *salivarius* fermented cellobiose or esculin. While only six strains were determined by the Sherman tests to be *mitis*, five of these six checked with the plate and one gave the black colony of *fecalis*. In addition, three considered to be enterococci by the Sherman test, gave *mitis* colonies, and as noted above, one *mitis* colonial type was *salivarius*. Those considered to be *mitis* by the Sherman test did not ferment cellobiose or esculin, except with one strain and it gave a typical *mitis* colony.

Twenty-two strains were identified as enterococci by the Sherman tests. Three of these gave typical *mitis* colonies and one black colony gave a *mitis* reaction as noted above. Otherwise they correlated in determining this species. Two of the *mitis* colonies were *liquifaciens* and one *fecalis*, according to gelatin liquifaction. All of the strains except one identified as enterococci by the Sherman test, fermented cellobiose and esculin.

As every worker on the streptococci has discovered, the fermentation reaction of these organisms is in general too variable to be of value. However, the very high number of strains of enterococci fermenting cellobiose and esculin may be of some use. The Chapman plate appears to be a rapid and fairly reliable means of identifying *Streptococcus salivarius*, though less reliable in differentiating between *Streptococcus mitis* and the enterococci.

#### References

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<sup>2</sup> Chapman, G. H., J. Bact., 1914, 48, 113-114.

<sup>9</sup> Sherman, J. M., Bact. Rev., 1937, J.

47

## A MODIFIED PROCEDURE FOR THE FORMOL TITRATION\*

#### A. A. ROSEN AND B. S. ANDREWS

#### Joseph E. Seagram & Sons, Inc., Louisville, Kentucky

The formol titration, described in 1907 by Sorensen (6), has been a most valuable tool in the study of protein hydrolysis and for the determination of amino acids. The method is based on the reaction between formaldehyde and amino compounds to produce Schiff compounds (5). When formaldehyde is added to a solution of an amino acid, the end-point of the titration with alkali is displaced from a pH value over 12 to a pH value about 9. Not only is it possible to select an indicator for the lower pH, but the titration curve breaks more sharply under this condition, and the end-point can be determined more precisely.

The nature of the reaction between amino acids and formaldehyde has been the subject of intensive investigation by Levy and others (2) (3). The following conclusions may be drawn from the work of these investigators: (a) the formol titration is essentially a determination of the amino groups, not the carboxyl, of an amino acid; (b) the formaldehyde forms methylol as well as methylene derivatives of the amino group.

The titration can be carried out both electrometrically and colorimetrically, using suitable indicators. Dunn and Loshakoff (1) have described the use of the glass electrode in the formol titration. Their procedure gave greater accuracy and precision than can be obtained by the use of indicators. However, the procedure is tedious and requires apparatus not readily available in many laboratories.

Phenolphthalein is an indicator of suitable pH range for the formol titration. The first appearance of color, however, occurs at a pH somewhat below the stoichiometric end-point for most amino acids, which is pH 9.0 to 9.1 (2). Northrop (4) has devised a procedure which takes advantage of the property of a one-color indicator to fix the end-point more exactly. In his method, the amino acid solution is first adjusted to pH 7 with neutral red indicator, then formalin is added and the titration is completed with phenolphthalein.

<sup>\*</sup> Presented before the Section on Chemistry, Kentucky Academy of Science April, 1947.

#### A Modified Procedure for the Formol Titration

Color standards for each indicator are prepared from the sample under conditions identical to those in the determination. By using half as much phenolphthalein in the color standard as in the titration and developing the maximum color intensity in the standard, this color is matched in the titration of the sample when the pH is in the middle of the range for phenolphthalein.

Two advantages of this method are evident: (a) the volumes of the color standards are automatically equal to the volumes of the sample at the corresponding stages of the titration; (b) the color standards automatically adjust for moderate amounts of color in the sample to be titrated, thus enabling the method to be applied to many protein hydrolyzates.

Several trials of Northrop's method did not produce a desirable degree of accuracy in the titration of pure amino acids. This procedure is a semi-micro one, using 5 ml. of a 0.01 molar solution of the amino acid sample. The formaldehyde concentration at the end of the titration is about 3.5%. The work of Levy (2) suggests an explanation for the inaccuracy of this method. He has shown that increased accuracy is obtained in the formol titration when the concentration of the amino acid is increased, the dilution during titration is held at a minimum, and the formaldehyde concentration at the endpoint is 6 to 9%.

In order to modify the Northrop method to obtain greater accuracy in the light of the factors described above, the concentration of the sample and the standard alkali were increased tenfold and the volumes used were doubled to avoid the use of semi-micro equipment. The optimum proportions of formaldehyde and indicator for the titration were selected. The resulting modification of the formol titration is described in the following Experimental section.

## Experimental

## MODIFIED FORMOL TITRATION

Four 10 ml. aliquots at 0.1 molar concentration are transferred to separate Erlenmever titration flasks.

**NEUTRAL RED STANDARD.**—To the first flask is added 2 ml. of 0.05 M. sodium phosphate and 2 drops of  $1\frac{9}{0}$  neutral red. The solution is titrated to the point of sharp color change.

ALKALINE STANDARD.—To the second flask is added 2 drops of the neutral red indicator and the sample is titrated to neutrality. Then 6 ml. of 37% formalin and 3 drops of 0.2% phenolphthalcin are added

and the standard is titrated with the 0.1 N. alkali to a maximum color, adding a small excess of the alkali.

TITRATION.—The two remaining flasks contain the aliquots to be titrated. To the sample is added 2 drops of neutral red, then the solution is adjusted roughly to neutrality with strong alkali or acid, as required, to avoid excessive dilution of the sample. The neutralization is completed with 0.1 N. reagent, to match the color of the neutral red standard. Six ml. of formalin and 6 drops of the phenolphthalein are added, then the sample is titrated with the standard alkali to match the color of the alkaline standard. The end-point is thus controlled at pH 9.0 to 9.1. The amount of alkali required to bring the solution from the neutral red standard to the alkaline standard provides the titration figure.

FORMALDEHYDE BLANK.—To 6 ml. of formalin in 10 ml. of distilled water is added 3 drops of the phenolphthalein and the solution is titrated wwith the standard alkali. This blank is subsracted from the titration value.

#### EFFECT OF FORMALDEHYDE CONCENTRATION

Accuracy in the formol method requires a 6 to 9% formaldehyde concentration at the end of the titration (2). A 0.1 molar solution of DL-alanine was titrated according to the modified method described above, varying the amount of formalin added from 2 to 10 ml. The results, graphically presented in Figure I, showed that a maximum recovery of the amino acid was obtained with the use of 6 ml. of formalin and that additional formalin did not affect the recovery. The concentration of formaldehyde at the end of the titration was 8.4%, which is within the required range. Therefore 6 ml. of formalin was selected for use in this method.

## EFFECT OF VARIATION IN ALKALINE STANDARD

A variation in the ratio of phenolphthalein used in the titration to the amount used in the alkaline standard will affect the completeness of the titration. In Northrop's procedure (4) the ratio was 6 to 1, which does not agree with the theoretical basis for using the alkaline color standard—a ratio of 2 to 1. A series of titrations were performed to determine the effect of varying the phenolphthalein concentration in the alkaline standard. The variation was from 1 to 4 drops, while in each case 6 drops were used in the sample being titrated. At the end of each titration, the end-point pH was determined by means of a glass electrode. Figure II illustrates the relation between alkaline



standard, recovery of titrated amino acid, and end-point pH. It is noteworthy that when the alkaline standard contained 3 drops of phenolphthalein (half the amount used in the titrated sample) the end-point occurred at pH 9.1. This is the proper value for the stoichiometric end-point.

# APPLICATION OF THE METHOD

The modified procedure for the formol titration described above was applied to a number of different amino acids, each at 0.1 molar concentration. When the amino acid was difficultly soluble in water, a small amount of HCl was used in preparing the solution. The results are contained in Table I (simple amino acids) and Table II (polyfunctional amino acids). In most cases the results were within 2% of the theoretical, a deviation 4 times the theoretical minimum calculated by Levy (2).

## TABLE I

## FORMOL TITRATION OF AMINO ACIDS

| Amino Acid          | Recovery, % |
|---------------------|-------------|
| Alanine             | 102.6       |
| Glycine             | 102.6       |
| Isoleucine          | 97.3        |
| Leucine             | 96.0        |
| Methionine          | 100.4       |
| Norleucine          | 99.7        |
| Phenylalanine       | 100.2       |
| Proline             | 84.6        |
| Serine              | 99.7        |
| Threonine           | 105.1       |
| Tryptophan          | 84.8        |
| Valine <sup>^</sup> | 99.8        |

#### TABLE II

## FORMOL TITRATION OF POLYFUNCTIONAL AMINO ACIDS

| Amino Acid    | Recovery, % | <b>Equivalents</b> Titrated |
|---------------|-------------|-----------------------------|
| Arginine      | 100.6       | . 1                         |
| Aspartic Acid | 99.3        | 1                           |
| Cystine       | 98.1        | 2                           |
| Glumatic Acid | 97.0        | 1                           |
| Histidine     | 101.8       | 1                           |
| Lysine        | 99.1        | 2                           |
| Tyrosine      | 76.9        | 2                           |

Van Slyke and Kirk (7) have shown that under the conditions of this method the titration is a measure of the reactive amino and imino groups. Accordingly, all the amino acids in Table I titrated as one equivalent per mole of amino acid. Of the amino acids listed in Table

#### A Modified Procedure for the Formol Titration

II, the two dicarboxylic amino acids reacted with only one equivalent of alkali, corresponding to their single amino groups. In the case of cystine and lysine, both amino groups of each amino acid were titrated. Because of the very slight solubility of cystine the reaction with alkali was slow. It was necessary to allow the flask to stand several minutes before determining when the end-point was reached. Only one nitrogen atom in the arginine and histidine molecules is sufficiently basic to be determined by the formol method. In the case of histidine, the value obtained was unexpectedly close to the theoretical. This fact may be explained as a compensation of errors in the two end-points in this method, inasmuch as the adjustment to pH 7 with this amino acid involves a large error (2). The stoichiometric end-points for proline and tryptophan occur at pH values more alkaline than is obtained with phenolphthalein in this method (3) (7), thus accounting for the low values obtained. Under the conditions of this method, the phenolic group of tyrosine is incompletely titrated. The titration procedure has been applied with similar convenience to protein hydrolyzates and mixtures of amino acids.

## SUMMARY

A modification of the Northrop procedure for the formol titration is described in which increased accuracy and convenience is obtained through the use of larger and more concentrated samples. The conditions for establishing the indicator end-point have been shown to result in an optimum degree of accuracy. The determination of a large number of amino acids is reported.

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# A PRELIMINARY LIST OF KENTUCKY CICADELLIDAE (HOMOPTERA)

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Since the first World War, many new species of leafhoppers have been described from the United States, and several studies have been carried on to determine the distribution of these insects, many species of which are economically important. Noteworthy among such studies are those of DeLong for Tennessee, Osborn and Johnson for Ohio, Medler for Minnesota, Buys for New York, Lathrop for South Carolina and DeLong for Illinois.

The present study was begun while the writer was a candidate for the degree of M.S. at Cornell University, and continued, with a considerable interruption during the years of World War II, to the present. The present list will receive many additions in the future, for the family is one of the largest in North America. DeLong recently estimated that the Illinois list will exceed 600 forms when complete, and it is probable that the Kentucky fauna will present no fewer forms, when more completely known.

Credit is due Dr. J. S. Bangson (J.S.B.) of Berea College, Miss Liza Spann (L.S.) of Murray State Teachers College, Mr. F. H. Bunce (F.H.B.) formerly at the Otter Creek Recreational Area, all of whom operated trap lights to assist in the project, and to Dr. William M. Clay (W.M.C.) of the University of Louisville who helped during a particularly profitable collecting trip near Henderson. Records of the above collectors are indicated below by the initials employed above. Mr. D. L. Harmon and Miss Genrose Haselwood, students at the University of Louisville, contributed records obtained on the University campus. These are indicated below (D.L.H. & G.H.) also. Records not credited to other collectors were obtained by the author.

Dr. P. W. Oman of the National Museum identified some troublesome specimens and made corrections on a portion of the manuscript.

The writer is greatly indebted to the late Prof. P. A. Readio of Cornell University under whose kind guidance the problem was begun.

The arrangement of genera into subfamilies is essentially that of the recent Evans classification.<sup>1, 2</sup>

<sup>&</sup>lt;sup>1</sup> Evans, J. W., A Natural Classification of Leafhoppers. Trans. Roy. Ent. Soc. Lond. 96 (part 3): 47-60. 1946; 97 (part 2): 39-54. 1946; 98 (part 6): 105-271. 1947.

<sup>&</sup>lt;sup>2</sup> A more recent reclassification appeared while this paper was in the hands of the printer: Oman, P. W. The Nearctic Leafhoppers. A Generic Classification and Index. Mem. Ent. Soc. Wash. No. 3, 253 pp., 1949.

The distribution cited is, in most cases, that listed by DeLong and Knull, in "Check List of the Cicadellidae of America North of Mexico."<sup>1</sup> Where the distribution was taken from another source, the author's name is cited in parentheses after the citation.

#### SUBFAMILY LEDINAE

#### Genus Xerophloea Germar

majesta Lawson. Brandenburg, Aug. 21, 1941; Louisville, Oct. 14, 1942.

DISTRIBUTION: Kans., Miss., S. C., Tex.

*major* Baker, Louisville, May 20, 1948 (G. E. Sproatt); May 2, 1948. (J. McGuire). Distribution: Kans., N. J., N. Y., Tenn., Va.

#### SUBFAMILY HECALINAE

Genus Parabolacratus Fieber

*flavidus* Signoret. Louisville, Aug. 4, 1940. July 17, 1940; Berea, Sept. 7, 1941 (J.S.B.); Murray, Aug. 15, 1941 (L.S.); Pineville, July 3, 1948. DISTRUCTION: Southeastern states and Ark., Kans.

Genus Spangbergiella Signoret

quadripunctata Lawson, Brandenburg, Aug. 21, 1941; Louisville, Sept. 19, 1941; Henderson, July 10, 1948.

DISTRIBUTION: Ála., Ark., D. C., Fla., Kans., Ill., La., Minn.

#### SUBFAMILY TETTIGELLINAE

Genus Carneocephala Ball

*flaviceps* (Riley). Murray, July 18, 1941 (L.S.), July 29, 1941, July 31, 1941, Aug. 1, 1941, Aug. 1, 1941, Aug. 13, 1941, Aug. 14, 1941, Aug. 15, 1941 (all L.S.); Rock Haven, Sept. 21, 1940.

DISTRIBUTION: Ala., Ariz., Ark., Calif., Fla., Ga., Kans., Ky., La., Miss., Mo., Neb., N. Mex., Okla., S. C., Tenn., Tex., Va., Wis.

Genus Acopsis Amyot and Serville

*mollipes* (Say).' Pactolus, Aug. 14, 1948; Grayson, Aug. 14, 1948; Middlesboro, Aug. 3, 1948.

DISTRIBUTION: Eastern and Ariz., Br. Col., Calif., Colo., Kans., Mo., N. Mex.

antica (Walker). Princeton, July 25, 1948: Henderson, July 10, 1948. DISTRIBUTION: Eastern states.

constricta (Davidson and DeLong). Berea, May 29, 1941 (J.S.B.); Louisville, June 7, 1940; Brandenburg, Aug. 21, 1941; Middlesboro, July 3, 1948. DISTRIBUTION: Alberta, Fla., Ill., Ia., Kans., Ky., Me., Mich., Minn., Mo., Nebr.,

DISTRIBUTION: Alberta, Fla., Ill., Ia., Kans., Ky., Me., Mich., Minn., Mo., Nebr., N. J., N. Y., Ohio, Okla., Pa., Que., Tex., Wis.

producta (Walker), Kuttawa, July 25, 1948; Murray, Aug. 11, 1941 (L.S.); Henderson, July 10, 1948; Middlesboro, July 3, 1948. DISTRIBUTION: Fla.

Genus Graphocephala Van Duzee

*coccinca* (Forster), Rock Haven, Sept. 27, 1941; Louisville, Sept. 19, 1941, Feb. 29, 1948, Nov. 1, 1942; Brandenburg, Aug. 21, 1941; Berea, Sept. 20, 1941 (J.S.B); Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Eastern and Kans., Mo., Okla., Tex.

*versuta* (Say). Brandenburg, Aug. 21, 1941, Sept. 14, 1941; Louisville, Sept. 19, 1941, Oct. 14, 1941, Nov. 1, 1942; Berea, July 3, 1941 (J.S.B.); Rock Haven, Sept. 27, 1941; Murray, Aug. 13, 1941 (L.S.); Pactolus, Aug. 14, 1948; Kuttawa, July 25, 1948; Henderson, July 10, 1948 (W.M.C.). DISTRBUTION: Southern states and Mo., Tex.

<sup>1</sup>Ohio State University Press, 1945.

| Genus Helochara Fitch  |
|--|
| communis Fitch. Middlesboro, July 3, 1948.   |
| DISTRIBUTION: Eastern states and Ariz., Calif., Colo., N. Mex., Tex.   |
| Genus Kolla Distant<br>bifida (Say). Berea, Sept. 7, 1941 (J.S.B.); Louisville, Aug. 21, 1941, Sept. 9,<br>1941, Sept. 19, 1941; Rock Haven, Sept. 27, 1941; Brandenburg, Aug. 21, 1941;<br>Kuttawa, July 25, 1948; Grayson, Aug. 14, 1948; Henderson, July 10, 1948; Mid-<br>dlesboro, July 3, 1948; Pineville, July 3, 1948.<br>DISTRIBUTION: Eastern and Kans., Mo., Nebr.          |
| geometrica (Signoret). Louisville. May 8, 1941; May 15, 1941, May 22, 1941;<br>Grayson, Aug. 14, 1948.   |
| DISTRIBUTION: Ark., D. C., Fla., Ill., Ky., La., Mo., Ohio, Tenn.  |
| Genus Neokolla Melichar<br>gothica (Signoret). Louisville, May 16, 1948 (H. C. Soehner).<br>DISTRIBUTION: Eastern and Kans., Mo.   |
| Genus Plesionmata Provancher<br>tripunctata (Fitch). Louisville, Sept. 9, 1941; Sept. 19, 1941; Rock Haven,<br>Sept. 27, 1941.   |
| DISTRIBUTION: Eastern and Mo.  |
| Genus Aulacizes Amyot and Serville<br>irrorata (Fab.). Middlesboro, July 3, 1948.<br>DISTRIBUTION: Eastern and Mo., Tex.   |
| Genus Cuerna Melichar  |
| costalis (Fab.). Brandenburg, June 9, 1938, Aug. 21, 1941; Louisville, Oct. 14, 1942; Kuttawa, July 25, 1948.<br>Distribution: Eastern and Mo., Tex.   |
| Genus Oncometopia Stal   |
| undata (Fab.). Louisville, Oct. 14, 1942, Nov. 11, 1942; Rock Haven, June 8, 1941; Kuttawa, July 25, 1948; Henderson, July 10, 1948.<br>DISTRIBUTION: Fla., Ga., Mass., N. J., N. Mex., N. C., Pa., Que., Tex.   |
| SUBFAMILY MACROPSINAE  |
| Genus Oncopsis Burmeister<br>verticis (Say). Louisville, May 21, 1948, June 7, 1948. Taken on Juglans.<br>DISTRIBUTION: Colo., Ia., Me., Tenn.   |
| Genus Nionia Ball<br>palmeri (Van Duzee). Middlesboro, July 3, 1948; Louisville, May 10, 1948<br>(J. Arnold).  |
| DISTRIBUTION: Solutieastern states.  |
| SUBFAMILY AGALLHNAE  |
| Genus Aceratagallia Kirkaldy<br>sanguinolenta (Provancher). Brandenburg, June 1, 1941, June 9, 1941, Aug. 21,<br>1941; Rock Haven, June 8, 1941; Murray, Apr. 13, 1941 (L.S.); Louisville, Sept.<br>9, 1941; Princeton, July 25, 1948; Dawson Springs, July 24, 1948; Henderson,<br>July 10, 1948; Pineville, July 3, 1948.<br>DISTRIBUTION: Canada and Eastern states to Ariz., Utah. |
| Genus Agallia Curtis<br>constricta Van Duzee. Louisville, Apr. 24, 1941, May 1, 1941, May 9, 1947, May   |

(Jo. 1941, July 17, 1940, July 22, 1940, July 23, 1940, July 24, 1941, May 9, 1947, May
July 30, 1941, Aug. 2, 1940, July 22, 1940; Berea, June 28, 1941 (J.S.B.), July 17, 1940, July 27, 1940;
July 30, 1941, Aug. 2, 1940, Aug. 20, 1940; Berea, June 28, 1941 (J.S.B.), July 11, 1941 (J.S.B.); Brandenburg, Apr. 17, 1941, June 1, 1941, Aug. 21, 1941; Murray, Aug. 11, 1941 (L.S.), Aug. 18, 1941 (L.S.) Aug. 19, 1941 (L.S.); Jefferson Co., May 10, 1941; Madison Co., Apr. 26, 1941; Boyle Co., Apr. 26, 1941; Rock Haven, June 8, 1941, Sept. 21, 1948; Dawson Springs, July 24, 1948; Princeton, July 25, 1948; Kuttawa, July 25, 1948; Pactolus, Aug. 14, 1948; Grayson, Aug. 14, 1948; Henderson, July 10, 1948; Middlesboro, July 3, 1948; Pineville, July 3, 1948.

DISTRIBUTION: Southeastern states, Ill., Ind., Ia., Nebr., Ohio, Okla., Tex. quadripunctata (Provancher). Louisville, May 8, 1941, May 9, 1947, May 10, 1941 (all females). DISTRIBUTION: Br. Col., Calif., Canada, Colo., Ida., Northeastern States, Ore., S. D., Vanc.

Genus Agalliopsis Kirkaldy

novella (Say). Louisville, Apr. 24, 1941, Apr. 26, 1941, May 1, 1941, May 8, 1941, July 22, 1940, Sept. 9, 1941, Sept. 19, 1941; Brandenburg, Aug. 21, 1941; Madison Co., Apr. 26, 1941; Henderson, July 10, 1948; Middlesboro, July 3, 1948. Distribution: Eastern states.

#### SUBFAMILY IDIOCERINAE

Genus Idiocerus Lewis

fitchii Van Duzee. Jefferson Co., June 25, 1940; Louisville, Aug. 4, 1940. DISTRIBUTION: Eastern states and Ia.

alternatus Fitch. Louisville, July 22, 1940.

DISTRIBUTION: Eastern states and Calif., Colo., Utah.

scurrus (Germar). Louisville, Aug. 20, 1947. On Lombardy poplar.

DISTRIBUTION: N. Y.

#### SUBFAMILY CICADELLINAE

Genus Alebra Fieber

albostriella var. agresta McA.\* Louisville. June 19, 1948. June 25, 1948 (D.L.H. & G.H.), June 29, 1948, June 10, 1947. Taken on elm and sycamore. Distribution: Md., Kans., Va.

*albostriella* var. *fulveola* (Her.-Sch.). Murray, July 18, 1941 (L.S.); Louisville, June 7, 1941, June 10, 1947 on elm; Berea, June 30, 1941 (J.S.B.); Henderson, July 10, 1948.

DISTRIBUTION: D. C., Ill., Kans., Md., Minn., N. Y.

albostriella var. pallidula (Walsh).\* Louisville, June 10, 1947, July 9, 1948 (D.L.H. & G.H.).

DISTRIBUTION: III., Kans., Mass., Mo., N. Y.

albostriella var. rubrafrons DeL. Jefferson Co., June 25, 1940.

DISTRIBUTION: Ill., Tenn.

fumida Gillette. Louisville, Aug. 6, 1940, June 19, 1948, July 24, 1941.

DISTRIBUTION: Ill., Kans., Minn., Tenn.

Genus Alconeura Ball and DeLong

unipuncta (Gillette). Murray, July 28, 1941, July 29, 1941, Aug. 7, 1941, Aug. 8, 1941 (all L.S.).

DISTRIBUTION: Ala., Ariz., Calif., Fla., Miss., Ore.

Genus Dikraneura Hardy

abnormis (Walsh). Louisville, Apr. 24, 1941, May 15, 1941, May 22, 1941, Sept. 9, 1941; Rock Haven, June 8, 1941.

DISTRIBUTION: Conn., D. C., Ga., Ill., Ia., Kans., Mo., N. Y., Ohio, Pa., Wis., Tex. angustata Ball and DeL. Louisville, May 9, 1947, May 22, 1941, Sept. 9, 1941, Sept. 19, 1941; Rock Haven, June 8, 1941; Sept. 27, 1941; Brandenburg, June 1, 1941, Aug. 21, 1941, Sept. 14, 1941; Jefferson Co., May 10, 1941; Murray, Aug. 13, 1941 (L.S.); Middlesboro, July 3, 1948. DISTRIBUTION: Kans., S. C., Tenn., Tex.

*cruentata* Gillette. Rock Haven, Sept. 27, 1941; Louisville, July 30, 1940, Sept. 9, 1941, Sept. 19, 1941; Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: B. C., Calif., Colo., Kans., Me., Md., N. Y., Ohio, Tenn., Va.

maculata Gillette. Louisville, Sept. 9, 1941, Sept. 19, 1941; Berea, Oct. 6, 1941 (J.S.B.); Rock Haven, Sept. 27, 1941; Brandenburg, Sept. 14, 1941.

\* Previously reported in Ky. Nat. 3: 19. 1948.

DISTRIBUTION: La., Eastern U. S. (DeL. and Caldwell). Genus Emboasca Walsh bifurcata DeL. Middlesboro, July 3, 1948. DISTRIBUTION: Ala., Del., D.C., Fla., Kans., Mass., Miss., N. J., Pa., Wis. convergens DeL, and Davidson, Henderson, July 10, 1948. DISTRIBUTION: Can., Ohio. decurvata Day, and DeL. Louisville, Sept. 19, 1941. DISTRIBUTION: Kans., Tenn. fabae Harris, Henderson, July 10, 1948 (W.M.C.); Berea, June 25, 1941 (J.S.B.), Aug. 30, 1941 (J.S.B.); Louisville, July 25, 1940, July 24, 1940, Aug. 5, 1941, Aug. 20, 1940, Murray, July 31, 1941, Aug. 11, 1941, Aug. 14, 1941, Aug. 18, 1941 (all L.S.). DISTRIBUTION: Ala., Ark., D.C., Fla., Ill., La., Mass., Mich., Pa., Va. patula DeL. Louisville, June 7, 1941. DISTRIBUTION: Me., Pa., Tenn. bergandei Gillette, Rock Haven, May 24, 1941, July 17, 1940. DISTRIBUTION: Colo., Conn., Mass., Pa. trifasciata Gillette. Jefferson Co., June 25, 1940. DISTRIBUTION: Ill., Ia., Kans., Mass., Mo. Genus Ervthroneura Fitch aclys McA.\* Louisville, May 22, 1947, June 21, 1948, July 1, 1948; Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948. Several of the records from *Cercis*. DISTRIBUTION: Throughout U. S., east of the Rocky Mountains (Beamer). acuticephala Rob. Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Kans., Minn. (Beamer). affinis Fitch. Louisville, Sept. 9, 1941, Sept. 19, 1941; Henderson, July 10, 1948. DISTRIBUTION: Kans., Ohio. albescens Beamer. Louisville, Sept. 9, 1941, Sept. 19, 1941. DISTRIBUTION: Ill., Kans., Okla., Ohio (Beamer and DeL.) atra Johnson. Murray, July 28, 1941 (L.S.); Louisville, Sept. 19, 1941; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Onio. beameri Rob. Louisville, Sept. 9, 1941, Sept. 19, 1941; Rock Haven, Sept. 27, 1941; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: U. S. east of the Rocky Mountains (Beamer). bella McA. Louisville, Sept. 9, 1941, Sept. 19, 1941; Rock Haven, Sept. 27, 1941; Brandenburg, Sept. 14, 1941. DISTRIBUTION: Md., Ohio. bicornis Beamer. Rock Haven, Sept. 27, 1941. DISTRIBUTION: III., Md. bidens McA. Henderson, July 10, 1948. DISTRIBUTION: Md., Va. bistrata var. stricta McA.\* Louisville, June 21, 1948 from Cercis; Henderson, Iuly 10, 1948. DISTRIBUTION: Colo., Ind., Ia., Kans., Md., Pa. brundusa Rob. Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Kans. (DeL. and Knull), Ohio (Johnson). calycula McA. Rock Haven, Sept. 27, 1941; Murray, July 31, 1941 (L.S.), Aug. 7, 1941 (L.S.); Louisville, Sept. 19, 1941, Feb. 17, 1948; Henderson, July 10, 1948. DISTRIBUTION: Throughout the eastern half of U.S. and Canada (Beamer). campora Rob.\* Louisville, Aug. 16, 1948 (D.L.H. and G.H.). DISTRIBUTION: Ark., Kans., Nebr., N. Y., Ohio, Ont.

<sup>\*</sup> Previously reported in Ky. Nat. 3: 19. 1948.

#### A Preliminary List of Kentucky Cicadellidae

comes (Say). Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Throughout U. S. east of the Rocky Mountains (Beamer). compta McA. Henderson, July 10, 1948 (author and W.M.C.). DISTRIBUTION: Ala., Ill., Ind., Kans., Mich., Miss., Ohio, Ont, corni Rob.\* Louisville, July 7, 1948, July 9, 1948 (both D.L.H. & G.H.), July 1, 1948. DISTRIBUTION: Kans., Nebr., Ohio, cuneata Beamer. Henderson, July 10, 1948. DISTRIBUTION: Okla. cymbium McA. Rock Haven, Sept. 27, 1941: Louisville, July 17, 1940; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Eastern half of the U.S. (Beamer). cymbium var. disjuncta McA. Henderson, July 10, 1948. DISTRIBUTION: Kans., Pa. (DeL. and Knull), La., Ill. (Beamer). delictata McA. Henderson, July 10, 1948. DISTRIBUTION: U. S. east of the Rocky Mountains (Beamer). delicata var. accepta McA. Henderson, July 10, 1948. DISTRIBUTION: As in delicata (Beamer). diffisa Beamer. Henderson, July 10, 1948. DISTRIBUTION: Kans., Ohio, Okla., Tenn. diva McA. Louisville, Aug. 4, 1940. DISTRIBUTION: Eastern half of U. S. (Beamer). elegans McA.\* Louisville, June 23, 1948 (D.L.H. & G.H.). DISTRIBUTION: Throughout most of U. S. (Beamer). eluta McA. Henderson, July 10, 1948. DISTRIBUTION: III., Ind., Va. festiva Beamer, Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: III., La., Kans., Ark., Tenn. (Beamer). fraxa Rob. Louisville, Sept. 19, 1941; Henderson, July 10, 1948. DISTRIBUTION: Kans., Ark., Ill. (Beamer). fulmina McA. Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Md., Ill., Kans. fulvocephala Rob.\* Louisville, Aug. 16, 1948 (D.L.H. & G.H.). DISTRIBUTION: Kans. (DeL. and Knull), Ohio (Johnson). gleditsia Beamer. Henderson, July 10, 1948. DISTRIBUTION: Ohio, Okla. harpax Beamer, Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: D. C., Ohio, Tenn. illinoiensis var. illinoiensis (Gillette). Louisville, Feb. 17, 1948, Sept. 8, 1941. Oct. 12, 1940; Henderson, July 10, 1948. DISTRIBUTION: III. illinoiensis var. spectra McA. Henderson, July 10, 1948. DISTRIBUTION: Md., Ohio, Va. infuscata (Gillette). Berea, June 27, 1941 (J.S.B.), June 30, 1941 (J.S.B.), Sept. 18, 1941 (J.S.B.); Henderson, July 10, 1948. DISTRIBUTION: Throughout U. S. east of the Rocky Mountains (Beamer). integra McA. Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Throughout eastern half of U. S. (Beamer). kansana var. kansana Baker.\* Louisville, Aug. 16, 1948 (D.L.H. & G.H.), Sept. 19, 1941, Oct. 12, 1940; Brandenburg, Apr. 14, 1941. DISTRIBUTION: Conn., Kans., Md., Mo., Ohio, Tenn., Va. \* Previously reported in Ky. Nat. 3: 19. 1948.

kanza Rob. Louisville, May 22, 1941, Sept. 9, 1941, Sept. 19, 1941; Rock Haven, Sept. 27, 1941.

DISTRIBUTION: Kans., Nebr., Ohio.

lawsoni Rob.\* Louisville, June 29, 1948 (D.L.H. & G. H.), July 15, 1948, July 26, 1948 (both D.L.H. & G.H.); Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Ark., D. C., Ill., Ia., Kans., Md., Ohio, Okla.

lawsoniana Baker. July 24, 1940, Aug. 2, 1940, Sept. 30, 1940.

DISTRIBUTION: Calif., Conn., Ill., Kans., Md., Minn., Mo., Nebr., N. C., Ont., Tenn., Va.

morgani DeL.\* Louisville, June 29, 1948, July 15, 1948 (both'D.L.H. & G.H.), Sept. 9, 1941, Sept. 19, 1941; Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Ohio. Tenn.

nigra Gillette. Rock Haven, Sept. 27, 1941; Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Colo., Conn., Ill., Ia., Kans., Md., Nebr., N. Y., Va., (DeL. and Knull), Ohio (Johnson).

nigra var. decora McA. Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Md. (DeL. and Knull), Ohio (Johnson).

nigerrima McA. Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Colo., Conn., Ill., Ia., Kans., Md., Nebr., N. Y., Va., (DeL. and Knull), Ohio (Johnson).

noeva (Gillette), Louisville, Apr. 24, 1941, July 17, 1940, July 22, 1940, Sept. 9, 1941.

DISTRIBUTION: Calif., Colo., Conn., Ill., Ind., Kans., Md., Nebr., Ont., Tenn. (DeL. and Knull), Ohio (Johnson).

nudata McA. Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Throughout the eastern half of the U.S. (Beamer).

obliqua (Say). Louisville, July 28, 1940, Sept. 9, 1941, Sept. 19, 1941; Boyle Co., Apr. 26, 1941; Rock Haven, Sept. 27, 1941.

DISTRIBUTION: Can., United States.

omaska Rob. Henderson, July 10, 1948. DISTRIBUTION: Throughout U. S. east of the Rocky Mountains (Beamer).

osborni (DeL.). Henderson, July 10, 1948.

DISTRIBUTION: Ark., Ill., Ohio, Tenn.

quadrata Beamer. Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Ill., Kans. (DeL. and Knull), Okla. (Beamer).

rubens Beamer.\* Louisville, June 25, 1948 (D.L.H. & G.H.); Brandenburg, Sept. 14, 1941.

DISTRIBUTION: III.

rubra (Gillette). Louisville, Sept. 19, 1941; Rock Haven, Sept. 27, 1941; Henderson, July 10, 1948.

DISTRIBUTION: Throughout the eastern two-thirds of U. S. and Canada (Beamer).

rufostigmosa var. subnubila Beamer. Brandenburg, Sept. 14, 1941.

DISTRIBUTION: Ill., Kans. (DeL. and Knull), Ohio (Johnson).

scissa Beamer. Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Ark., Ill.

stolata McA. Rock Haven, Sept. 27, 1941.

DISTRIBUTION: Kans., Ia., Md. (Beamer), Ohio (Johnson).

tenuispica Beamer. Henderson, July 10, 1948.

DISTRIBUTION: Kans. (Beamer), Öhio (Johnson).

<sup>\*</sup> Previously reported in Ky. Nat. 3: 19. 1948,

tricincta Fitch. Rock Haven, Sept. 27, 1941; Louisville, Feb. 17, 1948; Brandenburg, Sept. 14, 1941: Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Throughout the eastern half of U.S. and Canada (Beamer).

unicuspidis Beamer. Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Kans., Ill. (Beamer), Ohio (Johnson).

vaga Johnson, Henderson, July 10, 1948.

DISTRIBUTION: Ohio (Johnson), La., Ark., Ill., Kans. (Beamer).

vitis (Harris).\* Berea, July 3, 1941, Sept. 3, 1941, Sept. 28, 1941, Oct. 1, 1941, Oct. 6, 1941 (All J.S.B.); Louisville, Sept. 19, 1941, June 23, 1948 (D.L.H. & G.H.), May 22, 1947; Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Throughout U. S. east of the Rocky Mountains (Beamer).

vitis var. corona McA.\* Louisville, June 23, 1948 (D.L.H. & G.H.), Sept. 9, 1941; Berea, Oct. 4, 1941 (J.S.B.); Henderson, July 10, 1948.

DISTRIBUTION: As in vitis.

vulnerata Fitch.\* Louisville, June 23, 1948 (D.L.H. & G.H.), July 17, 1940, July 22, 1940, July 28, 1940, July 30, 1940, Aug. 6, 1940, Sept. 9, 1941; Berea, June 27, 1941, June 30, 1941, July 3, 1941, July 7, 1941, Sept. 7, 1941, Sept. 15, 1941, Sept. 20, 1941, Oct. 1, 1941, Oct. 6, 1941, Oct. 8, 1941, Oct. 28, 1941 (all I.S.B.); Murray, July 18, 1941 (L.S.); Brandenburg, Sept. 14, 1941; Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Canada and United States.

ziczac Walsh. Henderson, July 10, 1948 (W.M.C.). Distribution: Ill., Calif., Colo., Ia., Kans., Md., Mich., Miss, Nebr., Ont.

Genus Forcipata DeLong and Caldwell

loca DeL. and Caldwell. Louisville, May 15, 1941, May 16, 1941, May 22, 1941, Sept. 9, 1941, Sept. 19, 1941, July 17, 1940; Jefferson Co., May 10, 1941, Berea, June 27, 1941, July 7, 1941, Oct. 6, 1941 (all J.S.B.); Brandenburg, Aug. 21, 1941; Rock Haven, Sept. 27, 1941; Middlesboro, July 3, 1948; Henderson, July 10, 1948 (W.M.C. and author).

DISTRIBUTION: Eastern states and Canada.

Genus Hymetta McAtee

balteata var. balteata McA.\* Rock Haven, Sept. 27, 1941; Louisville, June 23, 1948, July 9, 1948 (both D.L.H. & G.H.). Henderson, July 10, 1948.

DISTRIBUTION: D. C., Kans., Md., Tex., Va.

balteata var. anthisma McA. Rock Haven, Sept. 27, 1941; Henderson, July 10, 1948.

DISTRIBUTION: Md., Tex.

distincta Fairbairn. Henderson, July 10, 1948.

**DISTRIBUTION:** United States.

Genus Typhlocyba German

arisnoe McA. Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Mass.

danae McA. Berea, June 28, 1941, July 3, 1941, June 14, 1941 (all J.S.B.); DISTRIBUTION: N. Y., Va.

gillettei var. apicata McA. Louisville, June 10, 1947.

DISTRIBUTION: D. C., Ill., Ia., Kans., Md., Ont., Va., Wisc. (McA.), Ohio (Johnson).

gillettei var. casta McA. Berea, May 31, 1941, June 19, 1941, June 27, 1941 (all I.S.B.).

DISTRIBUTION: Ill., Ia., Kans., Md., Mass., Mich., N. Y., Ont., Wis., Va. (McAtee), Ohio (Johnson).

hockingensis Knull. Louisville, June 7, 1941, July 28, 1940. DISTRIBUTION: Ohio. Tenn.

\* Previously reported in Ky. Nat. 3: 19. 1948.

modesta Gibson. Louisville, June 27, 1940.

DISTRIBUTION: Ill., Ia., La., Mo., Va. (McAtee), Ohio (Johnson).

piscator McA. Brandenburg, Sept. 14, 1941.

DISTRIBUTION: Ill., Ia. (McAtee).

pomaria McAtee. Louisville, Oct. 12, 1940.

DISTRIBUTION: Eastern states and Ark., Colo., Kans.

#### SUBFAMILY COELIDIINAE

Genus Coelidia Germar

olitoria (Say). Louisville. Sept. 9, 1941; Sept. 19, 1941; Rock Haven, Sept. 27, 1941; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Ariz., Eastern and Kans., Mo.

#### SUBFAMILY JASSINAE

Genus Gybonana Ball

octolineata (Say). Louisville, July 24, 1940. DISTRIBUTION: N. Y., Pa. vincula DeL. Henderson, July 10, 1948; Louisville, July 22, 1940.

DISTRIBUTION: Conn., Kans., Nebr., Pa., Tex., Utah, Wis.

Genus Ponana Ball

limonea Ball and Reeves. Berea, May 31, 1941 (J.S.B.). DISTRIBUTION: Ohio.

quadralaba DeL. Louisville, Aug. 22, 1947.

DISTBIBUTION: Ariz., Nebr., N. J., Ohio, Tenn., Tex.

Genus Rugosana DeLong

querci DeL. Berea, Sept. 21, 1941 (J.S.B.).

DISTRIBUTION: Ariz., Fla., Md., Mich., Miss., Ohio, Pa., Tex., Utah.

#### SUBFAMILY EUSCELINAE

Genus Aligia Ball

modesia (Osborn and Ball). Murray, July 18, 1941 (L.S.), July 21, 1941 (L.S.). DISTRIBUTION: D.C., Ia., N. C., Pa.

Genus Amblysellus Sleesman curtisii (Fitch). Louisville, Sept. 19, 1941; Brandenburg, June 1, 1941. DISTRIBUTION: Northeastern states and Ia., Mo., Tenn.

Genus Amplicephalus DeLong estacadus (Ball). Louisville, Sept. 9, 1941, Sept. 19, 1941. DISTRIBUTION: Tenn., Tex.

Genus Chlorotettix Van Duzee

borealis Sanders and DeL. Pineville, July 3, 1948.

DISTRIBUTION: Wis.

tunicatus Ball. Rock Haven, Sept. 21, 1940.

DISTRIBUTION: Ark., Fla., Kans., La., Mo., N. C., Tenn., Tex.

viridius Van Duzee. Murray, July 18, 1941, July 29, 1941, Aug. 7, 1941, (all L.S.); Louisville, Aug. 4, 1940: Berea, Oct. 1, 1941 (J.S.B.); Brandenburg, Aug. 21,

1941; Rock Haven, June 8, 1941, Sept. 21, 1940.

DISTRIBUTION: Ark., Mich., and N. Y. to Fla., and west to Kans. and Tex.

vacunus Crumb. Rock Haven, Sept. 21, 1940.

DISTRIBUTION: Tenn.

lusorius (Osb. and Ball). Louisville, Sept. 9, 1941.

DISTRIBUTION: Northeastern states and Colo., Ia., Utah.

necopinus Van Duzee. Louisville, Sept. 19, 1941; Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: Southeastern states,

rugicollis Ball. Louisville, July 27, 1940. DISTRIBUTION: Fla., N. J., Tex.

galbanatus Van Duzee. Brandenburg, June 1, 1941, Aug. 21, 1941; Berea, Oct. 6, 1941 (J.S.B.); Louisville, July 22, 1940, July 27, 1940, Sept. 9, 1941, Sept. 19, 1941, Sept. 30, 1940, Oct. 14, 1942; Rock Haven, Sept. 21, 1940, Sept. 27, 1941; Kuttawa, July 25, 1948: Grayson, Aug. 14, 1948: Pactolus, Aug. 14, 1948; Henderson, July 10, 1948; Middlesboro, July 3, 1948. DISTRIBUTION: Eastern and Ia., Mont., N. D.

balli Osborn. Louisville, Sept. 9, 1941.

DISTRIBUTION: Ia., Ohio, Tenn.

Genus Colladonus Ball

clitellarius (Say). Berea, May 20, 1941, Aug. 30, 1941, Oct. 8, 1941, Oct. 22, 1941 (all J.S.B.); Louisville, May 22, 1941, June 7, 1941, July 24, 1940, July 30, 1940, Aug. 4, 1940, Aug. 20, 1940; Rock Haven Sept. 21, 1940. DISTRIBUTION: Colo., Kans., eastern. Mo.

Genus Deltocephalus Burmeister

balli Van Duzee, Murray, Aug. 11-13 incl., 1941, Aug. 15, 1941 (all L.S.); Louis-ville, June 7, 1941, July 22-24 incl., 1940, Aug. 4, 1940, Aug. 20, 1940, Aug. 27, 1940; Rock Haven, May 24, 1941 (F.H.B.), Sept. 21, 1940; Brandenburg, Aug. 21, 1941; Henderson, July 10, 1948. DISTRIBUTION: Ia., Ohio, Pa., Wis.

flavicosta Stal. Murray, July 28, 1941 (L.S.), Aug. 19, 1941 (L.S.); Brandenburg, Aug. 21, 1941; Louisville, June 7, 1941, July 27, 1940, July 30, 1940; Berea, June 28, 1911 (J.S.B.): Kuttawa, July 25, 1948; Dawson Springs, July 24, 1948; Pactolus, Aug. 14. 1948; Grayson, Aug. 14, 1948; Henderson, July 10, 1948 (W.M.C.); Middlesboro, July 3, 1948.

DISTRIBUTION: Eastern and Ia., southern and Kans., Mo.

melsheimerii (Fitch). Rock Haven, June 8, 1941.

DISTRIBUTION: Colo., Ia., Kans., and Me. to Gulf Coast,

sonorus Ball. Murray, July 31, 1941, Aug. 4, 1941, Aug. 6, 1941, Aug. 8, 1941, Aug. 14, 1941, Aug. 15, 1941 (all L.S.); Brandenburg Aug. 21, 1941; Rock Haven, June 8, 1941, Sept. 27, 1941.

DISTRIBUTION: Ariz., Calif., Fla., Kans., Miss., N. Mex., N. C., S. D., Tenn., Tex. sylvestris Osborn and Ball. (Determined in part by Dr. P. W. Oman). Bran-denburg, June 1, 1941, Aug. 21, 1941; Rock Haven, May 24, 1941 (F.H.B.); Louisville, May 22, 1941, May 30, 1941, Sept. 9, 1941; Middlesboro, July 3, 1948. DISTRIBUTION: Ia., Me., and Gr. Lakes to Gulf Coast.

uhleri Oman, Louisville, May 15, 1941.

DISTRIBUTION: Colo., Ia., Kans., Mc., Mo., N. Y., N. H., Ont., Pa., Tenn.

Genus Doleranus Ball

vividus (Crumb). Berea, June 30, 1941 (J.S.B.), July 7, 1941 (J.S.B.); Murray, July 31, 1941 (L.S.).

DISTRIBUTION: Kans., Ohio, S. C., Tenn.

longulus (Gill. and Baker). Jefferson Co., May 10, 1941; Rock Haven. Sept. 27. 1941; Louisville, May 22, 1941.

DISTRIBUTION: Colo., Ia., Kans., Pa., Tenn.

Genus Driotura Osb. and Ball

gammaroides (Van D.). Dawson Springs, July 24, 1948; Pineville, July 3, 1948. DISTRIBUTION: East of Rockies.

gammaroides var. fulva Ball. Dawson Springs, July 24, 1948; Pineville, July 3. 1948.

DISTRIBUTION: Colo., Ill., Kans., Tenn., Tex., Utah.

Genus Exitianus Ball

obscurinervis (Stal.). Rock Haven. Sept. 21, 1940; Berea, June 27, 1941 (I.S.B.), June 30, 1941 (J.S.B.), July 7, 1941 (J.S.B.); Murray, July 30, 1941 (L.S.), July

31, 1941, Aug. 1, 1941, Aug. 4, 1941, Aug. 11, 1941, Aug. 18, 1941, Aug. 19, 1941 (all L.S.); Louisville, Aug. 6, 1940; Brandenburg, Aug. 21, 1941. DISTRIBUTION: Throughout U. S., Haiti, Mex. Genus Fieberiella Signoret florii (Stal.). Louisville, July 24, 1940, Aug. 20, 1947. DISTRIBUTION: Conn., Ill. Genus Flexamia DeLong areolata Ball. Louisville, Sept. 9, 1941. DISTRIBUTION: Ariz., Kans., Mo., N. Y., S. C., to Miss. sandersi (Osborn). Rock Haven, June 8, 1941; Pineville, July 3, 1948. DISTRIBUTION: Conn., Miss, to Gulf, Ohio, Pa., Tenn. stylata (Ball). Brandenburg, June 1, 1941. DISTRIBUTION: Ia., Neb. bicta (Osborn), Rock Haven, June 8, 1941; Brandenburg, June 9, 1938; Dawson Springs, July 24, 1948. DISIRIBUTION: Kans., Md., Miss., N. Y., Ohio, Pa., Tenn., Va. Genus Graminella DeLong fitchii (Van D.). Pactolus, Aug. 14, 1948; Middlesboro, July 3, 1948. DISTRIBUTION: Eastern and Ia., Kans. nigrifrons (Forbes) (determined in part by Dr. P. W. Oman). Murray, Aug. 11, 1941, Aug. 12, 1941, Aug. 15, 1941 (all L.S.); Louisville, July 17, 1940, July 24, 1940, Aug. 4, 1940, Aug. 20, 1940; Brandenburg, June 1, 1941; Berea, June 25, 1941 (I.S.B.); Grayson, Aug. 14, 1948; Pactolus, Aug. 14, 1948; Henderson, July 10, 1948 (W.M.C.); Middlesboro, July 3, 1948. DISTRIBUTION: Eastern and Colo., Ia. pallidula (Osborn). Louisville, July 22, 1940. DISTRIBUTION: Ia., Pa. Genus Idiodonus Ball subcupraeus (Provancher). Louisville, June 7, 1941. DISTRIBUTION: East coast. kennicottii (Uhler). Rock Haven, May 24, 1941 (F.H.B.). DISTRIBUTION: Eastern states and Br. Col., Colo. Genus Iowanus Ball majestus (Osb. and Ball). Louisville, Sept. 19, 1941. DISTRIBUTION: Ia., N. J., N. C., Ohio, Tex. Genus Latalus DeLong and Sleesman sayi (Fitch). Louisville, May 15, 1941, May 30, 1941, Sept. 9, 1941 Brandenburg, June 1, 1941; Rock Haven, Sept. 27, 1941. DISTRIBUTION: Colo., Dak., Ia., Kans., Ky., Me., Mass., Miss., Mo., N. H., N. J., N. C., Ohio, Ont., Pa., Que., Tenn. Genus Menosoma Ball cincta (Osb. and Ball). Louisville, Aug. 4, 1940, Sept. 20, 1940, July 6, 1948; Rock Haven, Sept. 21, 1940; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Eastern and Colo., Ia., Tex. Genus Norvellina Ball helenae Ball. Louisville, June 7, 1941, July 24, 1940; Rock Haven, May 22, 1941 (F.H.B.), May 24, 1941. Distribution: Fla., Ky., Mo., Tex. seminuda (Say). Jefferson Co., June 25, 1940; Louisville, July 24, 1940, July 30, 1940, Aug. 6, 1940, Aug. 20, 1940, Sept. 30, 1940, Oct. 12, 1940; Rock Haven, May 24, 1941 (F.H.B.); Berea, May 29, 1941 (J.S.B.), June 12, 1941, Oct. 6, 1941 (both J.S.B.); Brandenburg, May 26, 1941; Henderson, July 10, 1948. DISTRIBUTION: Eastern and Ia., Kans., Mo., Tex. Genus Opsius Fieber stactogalus Fieber. Louisville, May 5, 1941, June 7, 1941, Oct. 12, 1940. DISTRIBUTION: Coast to coast.

Genus Paraphlepsius Baker

slossonae (Ball). Rock Haven, Sept. 21, 1940.

DISTRIBUTION: Fla., N. C., S. C.

fuscipennis (Van D.). Louisville, July 24, 1940, July 30, 1940.

DISTRIBUTION: N. Y., eastern to Fla.

humidus (Van D.). Louisville, July 17, 1940; Kuttawa, July 25, 1948.

DISTRIBUTION: CONN., Me., Md., N. H., N. Y., Ohio, Pa., Tenn.

*collitus* (Ball). Louisville, June 7, 1941, July 24, 1940, July 30, 1940, Aug. 20, 1940; Berea. May 20, 1941 (J.S.B.), May 28, 1941. June 21, 1941 (both J.S.B.); Rock Haven, May 24, 1941 (F.H.B.), Sept. 21, 1940; Brandenburg, June 1, 1941; Henderson, July 10, 1948. Distribution: Me. to Fla. and west to Ia.

irroratus (Say). Berea, May 20, 1941, May 23, 1941, May 29, 1941, June 25, 1941, June 27, 1941, Sept. 7, 1941 (all J.S.B.); Murray, Aug. 1, 1941, Aug. 6, 1941 (both L.S.); Louisville, May 15, 1941, July 22, 1940, July 24, 1940, Aug. 4, 1940; Rock Haven, Sept. 21, 1940; Brandenburg, Aug. 21, 1941; Princeton, July 25, 1948: Kuttawa, July 25, 1948; Dawson Springs, July 24, 1948.

DISTRIBUTION: Coast to coast.

pusillus (Baker). Dawson Springs, July 24, 1948.

DISTRIBUTION: D. C., Md., N. C.

rossi (?) (DeL.). Louisville, Sept. 9, 1941.

DISTRIBUTION: CONN., III.

tenessus (DeL.). Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: D.C., N. C., Ohio.

Genus Polyamia DeLong

interrupta DeL. Jefferson Co., June 25, 1940.

DISTRIBUTION: III., Mass., N. Y., N. C., Ohio, Pa., Tenn.

inimica (Say). Louisville, July 24, 1940; Berea, May 31, 1941, June 27, 1941 (both J.S.B.); Murray, July 30, 1941, July 31, 1941, Aug. 14, 1941, Aug. 19, 1941 (all L.S.); Kuttawa, July 25, 1948; Henderson, July 10, 1948. Distribution: Coast to coast.

apicalis (Osb.). Rock Haven, June 8, 1941; Henderson, July 10, 1948.

DISTRIBUTION: Eastern and Md., Vt.

compacta (Osb. and Ball). Brandenburg, June 1, 1941; Rock Haven, June 8, 1941; Gravson, Aug. 14, 1948; Kuttawa, July 25, 1948.

DISTRIBUTION: Eastern and Ia., Kans., Wis.

obtecta (Osb. and Ball). Brandenburg, June 1, 1941, Aug. 21, 1941; Murray, July 18, 1941, Aug. 11, 1941, Aug. 15, 1911 (all L.S.); Pineville, July 3, 1948.

DISTRIBUTION: Eastern and Ia., Kans., Mo.

similaris DeL. and Davidson. Dawson Springs, July 24, 1948.

DISTRIBUTION: III., Tenn.

weedi (Van Duzee). Murray, July 18, 1941, July 28, 1941, July 29, 1941, July 30. 1941, Aug. 1, 1941, Aug. 4-8 incl., 1941, Aug. 11, 1941, Aug. 13. 1941, Aug. 19, 1941 (all L.S.); Brandenburg, June 1, 1941, Aug. 21, 1941; Rock Haven, June 8, 1941; Kuttawa, July 25, 1948; Dawson Springs, July 24, 1948; Middlesboro, July 3, 1948. DISTRIBUTION: Eastern and Ia., Kans., Miss.

Genus Psammotettix Haupt

striatus (L.). Louisville, May 22, 1941; Berca, June 27, 1941 (J.S.B.); Rock Haven, Sept. 27, 1941.

DISTRIBUTION: Coast to coast.

Genus Scleroracus Van Duzee anthracina (Van Duzee). Rock Haven, June 8, 1941. DISTRIBUTION: Northeastern states and Colo., Ia., Kans.

Genus Stirellus Osborn and Ball bicolor (Van Duzee). Brandenburg, Aug. 21, 1941; Murray, Aug. 11, 1941 (L.S.),

Aug. 15, 1941 (L.S.); Dawson Springs, July 24, 1948; Pineville, July 3, 1948. DISTRIBUTION: Kans., Miss., N. L. and Md. to Ia, and Nebr. and south. dixianus var. acutus Thomas. Louisville. Sept. 9. 1941. DISTRIBUTION: Ala., Fla., Miss. obtutus (Van Duzee). Brandenburg, Aug. 21, 1941, Sept. 14, 1941; Louisville, May 15, 1941, Sept. 9, 1941, Sept. 19, 1941; Jefferson Co., May 10, 1941; Rock Haven, Sept. 27, 1941. DISTRIBUTION: Miss., throughout the South and Southwest. Genus Texananus Ball decorus (Osb. and Ball). Pineville, July 3, 1948. DISTRIBUTION: Fla., Ill., Ia., Me., N. C., Ohio, Tenn. Genus Unerus DeLong colonus (Uhler). Rock Haven. Sept. 27, 1941; Louisville, Sept. 19, 1941; Murray, July 18, 1941 (L.S.): Aug. 6, 1941, Aug. 7, 1941, Aug. 11, 1941 (all L.S.); Berea, Sept. 7, 1941 (J.S.B.); Brandenburg, Sept. 14, 1941. DISTRIBUTION: Fla., Tenn. Genus Acurhinus Osborn pyrops (Crumb). Dawson Springs, July 24, 1948. DISTRIBUTION: Md., N. C., Ohio, Pa., Tenn., Va. Genus Cloanthanus Ball scriptus (Ball). Berea, May 27, 1941 (I.S.B.). DISTRIBUTION: Kans., Tenn. fulvus (?) (Osborn). Brandenburg, June 1, 1941; Rock Haven, Sept. 21, 1940. DISTRIBUTION: N. Y., Ohio, Pa. acutus (Say). Rock Haven, June 8, 1941, Sept. 21, 1940; Louisville, Sept. 9, 1941. DISTRIBUTION: Eastern states and Br. Col., Calif., Colo., Mo., Kans., Utah. cuprescens (Osborn). Rock Haven, Sept. 21, 1941, Sept. 27, 1941. DISTRIBUTION: Colo., Me., N. Y., N. C., Ont., Que., Tenn. frontalis (Van Duzee). Rock Haven, May 24, 1941 (F.H.B.), June 8, 1941, Sept. 21, 1940 Brandenburg, June 1, 1941, Aug. 21, 1941; Berea, Sept. 14, 1941 (J.S.B.): Louisville, June 7, 1941; Kuttawa, July 25, 1948; Grayson, Aug. 14, 1948; Pactolus, Aug. 14, 1948: Pineville, July 3, 1948. DISTRIBUTION: Eastern and Calif., Ia., Kans., Mo. cinereus (Osborn and Ball). Murray, July 29, 1941 (L.S.); Louisville, June 7, Distribution: Ariz., Fla., Ia., Kans., Nebr., N. C., Tenn. Genus Japananus Ball hyalinus Osborn. Murray, July 28, 1941, July 30, 1941, July 31, 1941, Aug. 11, 1941, Aug. 14, 1941, Aug. 18, 1941 (all L.S.); Louisville, June 25, 1940, July 17, 1940, July 22, 1940, July 24, 1942, July 27, 1940, Sept. 30, 1940. Distribution: D. C., Ill., Ohio, Pa. Genus Mesamia Osborn nigridorsum Ball. Louisville, June 2, 1948 (H. L. Bockman). DISTRIBUTION: Eastern states and Colo., Dak., Ia., Kans., Utah. Genus Osbornellus Bali auronitens (Uhler). Louisville, Sept. 19, 1941; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Eastern states only. consors (Uhler). Berea, July 4, 1941 (J.S.B.); Louisville, May 20, 1940; Henderson, July 10, 1948 (W.M.C.). DISTRIBUTION: Eastern and Colo., Ill., Tex., Utah. clarus Beamer. Rock Haven, Sept. 27, 1941. DISTRIBUTION: Ala., Ariz., D. C., Fla., Ga., Kans., Ky., La., Md., Miss., S. C.

rotundus Beamer. Henderson, July 10, 1948 (W.M.C.). DSITRIBUTION: Ala., Conn., D. C., Fla., Ga., Miss., S. C. Genus Sanctanus Ball

sanctus (Say). Previously reported from Ky., but not seen by author.

Genus Scabhoideus Uhler

dilatus DeL. and Mohr. Louisville, July 22, 1940. July 23, 1940, July 24, 1940. July 27, 1940, July 28, 1940, July 30, 1940. DISTRIBUTION: Pa.

diutius DeL, and Mohr. Henderson, July 10, 1948 (W.M.C.).

DISTRIBUTION: III., Pa.

immistus (Say). Louisville, June 17, 1940, July 23, 1940; Berea, June 25, 1941 (I.S.B.): Brandenburg, Sept. 14, 1941.

DISTRIBUTION: Eastern and Calif., Colo., Ia., Kans., Mo., Tex.

productus Osborn. Previously taken in Ky. Not seen by author.

Genus Xestocephalus Van Duzee

pulicarius Van D. Rock Haven, Sept. 9, 1941, Sept. 27, 1941; Louisville, Jan. 22, 1940, July 17, 1940, Sept. 9, 1941; Murray, Aug. 14, 1941, Aug. 15, 1941 (both L.S.); Berea, June 27, 1941, July 3, 1941, Oct. 28, 1941 (all J.S.B.); Henderson, July 10, 1948.

DISTRIBUTION: Eastern and Ia., Kans., Mo., Utah.

Genus Balclutha Kirkaldy

punctata (Thunberg). Rock Haven, June 8, 1941; Louisville, Sept. 9, 1941; Boyle Co., Apr. 26, 1941.

DISTRIBUTION: Br. Col., Colo., Eastern, Mo.

impicta (Van Duzee). Boyle Co., Apr. 26, 1941; Rock Haven, Sept. 27, 1941; Pactolus, Aug. 14, 1948; Dawson Springs, July 24, 1948. DISTRIBUTION: Eastern and Calif., Kans., Mo., Wash.

impicta var. maculata DeL. and Davidson. Brandenburg, Apr. 17, 1941; Madison Co., Apr. 26, 1941; Boyle Co., Apr. 26, 1941.

DISTRIBUTION: CONN., D. C. Pa., Tenn., Wis.

abdominalis (Van Duzee). Madison Co., Apr. 26, 1941; Brandenburg, Aug. 21, 1941; Boyle Co., Apr. 26, 1941; Louisville, Apr. 24, 1941, May 9, 1947, May 15, 1941; July 24, 1940, Aug. 4, 1940, Aug. 5, 1940, Sept. 9, 1941; Pactolus, Aug. 14, 1948; Dawson Springs, July 24, 1948; Pineville, July 3, 1948.

DISTRIBUTION: Br. Col., Eastern and Calif., Colo.

neglecta (DeL. and Dav.). Murray, July 30, 1941, July 31, 1941, Aug. 7, 1941, Aug. 8, 1941, Aug. 11, 1941, Aug. 15, 1941, Aug. 19, 1941 (all L.S.); Louisville, July 30, 1940; Brandenburg, Aug. 21, 1941; Middlesboro, July 3, 1948. DISTRIBUTION: U. S.

Genus Davisonia Dorst

delongi Dorst. Louisville. June 7, 1941; Jefferson Co., June 25, 1940.

DISTRIBUTION: Canada, Ill., Ia., Md., Mass., N. Mex., N. Y., Ohio, Pa., Va., Wis. Genus Macrosteles Fieber

lepidus (Van Duzee). Jefferson Co., June 25, 1940; Rock Haven, Sept. 27, 1941. Distribution: Kans., N. Y., Ohio, Tenn., Wis.

divisus (Uhler). Rock Haven, May 24, 1941 (F.H.B.), Sept. 21, 1940; Louisville, May 10, 1941, July 17, 1940, July 24, 1940, Aug. 4, 1940, Aug. 5, 1940; Murray, July 29, 1941 (L.S.), July 30, 1941 (L.S.), throughout August 1941 (L.S.); Berea. May 23, 1941 (J.S.B.); Brandenburg, Apr. 17, 1941; Princeton, July 25, 1948; Dawson Springs, July 24, 1948.

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variatus (Fall.). Henderson, July 10, 1948.

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wilburi Dorst. Louisville, July 17, 1940, July 30, 1940, Aug. 21, 1941. DISTRIBUTION: Kans.

## ACADEMY HOLDS SPRING MEETING

The Kentucky Academy of Science held its Spring meeting at Cumberland Falls State Park on Friday afternoon and Saturday morning, April 29 and 30, 1949. Main feature of the Friday afternoon program was a symposium on "Fish and Streams". The following speakers participated in the program:

Mr. Hudson Biery, Chairman of the Ohio River Valley Water Sanitation Commission. Subject: "Ohio Valley States Undertake Pollution Abatement".

Dr. Peter Doudorff, Environmental Health Center, Cincinnati. Subject: "Standardization of Toxicity Bio-assays in Relation to Waste Disposal Control".

Mr. Earl Wallace, Director of the Division of Fish and Game, Frankfort. Subject: "How You Can Use Wildlife Resources".

Mr. Glen Gentry, Aquatic Biologist, Paris, Tennessee. Subject: "The Fisheries Program of the Tennessee Department of Conservation".

Dr. A. H. Wiebe, Chief of the Fish and Game Branch, Division of Forestry Relations, T. V. A. Subject: "Density Currents in Norris Reservoir".

Following the dinner meeting Friday evening, Mr. Ben East, Field Editor of *Outdoor Life*, spoke on the subject of "Conservation Education". A short business meeting was held following Mr. East's address.

The schedule for Saturday morning included an early morning bird hike, mid-morning field trips to points of interest in Cumberland Falls State Park and a late morning trip to the fish hatcheries a short distance from the Falls. Main feature of this latter trip was a demonstration of an electric seine by Mr. Minor Clark, Superintendent of Fisheries.

The outdoor meeting at Cumberland Falls was an experiment in response to a long felt need for a type of Academy meeting which provided our biologists and geologists with greater opportunity for field trips. The number and enthusiasm of those participating in this meeting provide ample evidence that the experiment was a success. It must be remembered, however, that this outdoor meeting was undertaken to complement, not to replace, our annual meeting which this year will be held on the Campus of Eastern State College, Richmond, Kentucky, October 21 and 22.

# NOTICE TO CONTRIBUTORS

The TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE is a medium for the publication of original investigations in science. In addition, as the official organ of the Kentucky Academy of Science, it publishes programs of the meetings of the Academy, abstracts of papers presented before the annual meetings, reports of the Academy's officers and committees, as well as news and announcements of interest to the membership.

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Papers should be submitted typewritten, double-spaced, with wide margins, in an original and 1 carbon copy, on substantial quality paper. Articles are accepted for publication with the understanding that they are to be published exclusively in the TRANSACTIONS. Each paper will be reviewed by one or more persons qualified in the field covered by the article in addition to the editors before a contribution is accepted for publication.

Bibliographic citations should follow textual material (except in Research Notes, see later). Abbreviations for the names of periodicals should follow the current system employed by either Chemical Abstracts or Biological Abstracts. Bibliographic citations in Research Notes should be in the same form as for longer papers but enclosed in parentheses within the text of the note.

Footnotes should be avoided. Titles must be clear and concise, and provide for precise and accurate cataloguing.

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#### CONTENTS

| Effect of Commercial Malt Sprouts on the Anaerobic Growth of<br>of Distillers' Yeast. R. E. Scalf and T. J. B. Stier           | 69  |
|--|-----|
| Preparation of Ketones by the Sommelet Reaction. M. I. Bowman,<br>Irving B. Joffe, W. W. Rinne and James C. Wilkes             | 78  |
| Economic Status of Lespedeza Seed Oil. Richard H. Wiley  | 80  |
| Performance of an Earth Heat Pump on Intermittent Operation.<br>E. B. Penrod, E. L. Dunning, and H. H. Thompson                | 82  |
| The Effects of Small Amounts of Glycine and Ethyl Glycine on Food<br>Ingestion in the Dog. J. W. Archdeacon and A. B. Carreiro | 100 |
| The Precision and Accuracy of Meter Sticks. Sigfred Peterson   | 102 |
| The Effects of Composition on the Specific Gravity of Binary Wax<br>Mixtures. John R. Koch and Sister M. Concetta              | 104 |
| Chromosome Behavior in a Second Gasteria-Aloe Hybrid.  |     |
| Herbert Parkes Riley   | 111 |
| Academy Affairs  | 110 |

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# EFFECT OF COMMERCIAL MALT SPROUTS ON THE ANAEROBIC GROWTH OF DISTILLERS' YEAST<sup>1</sup>

R. E. Scalf<sup>2</sup> and T. J. B. Stier Department of Physiology, Indiana University Bloomington, Indiana

Acceleration of lactic acid fermentation in a glucose or molasses medium by the addition of commercial malt sprouts was attributed to the presence of accessory substances for growth as well as fermention in this material (Pan, *et al*, 1940). Euler (1924) found that water extracts of malt sprouts stimulated cell multiplication and  $CO_2$  production of yeast and that water extracts of fresh barley sprouts gave higher rates of  $CO_2$  production than water extracts of the dried material. We will present evidence showing that, when the anaerobic growth of a distillery type of yeast is increased by the addition of malt sprouts to a medium which is apparently complete with respect to the water soluble growth factors. lipid substances in the malt sprouts themselves account for the larger crops.

## MATERIALS AND METHODS

Yeast strain. All experiments were conducted with a distillery type yeast obtained from Joseph E. Seagram & Sons, Inc., Louisville, Kentucky, under the identification, *Saccharomyces cerevisiae*, strain DCL. This strain is included in the culture collection of the Northern Regional Research Laboratory, Peoria, Illinois.

Medium. A medium containing 10 gm glucose, 0.5 gm  $\rm KH_2PO_4$ and various amounts of Difco yeast extract (see below) per 100 ml was used throughout these experiments.

Seed yeast. The yeast for the inocula were grown under initially aerobic conditions, according to the method of Brockmann and Stier (1947) and, after dilution to 10 million cells/ml with the growth medium, were rendered oxygen-free by purging with Linde High Purity Nitrogen. The purging was carried out in a flask of special design from which an inoculating syringe could be loaded under strict anaerobic conditions.

This syringe loading unit consisted of a 50 ml boiling flask (Corning 4100) with a special side tube assembly for inserting the

<sup>1</sup> This work was aided by a grant from Joseph E. Seagram & Sons, Inc.

<sup>2</sup> Formerly Seagram Research Associate at the Laboratory of Cell Physology, Indiana University. Present address: Joseph E. Seagram & Sons, Inc., Louisville 1, Kentucky.

3 inch needle of the syringe and a ground glass head carrying both a center gas inlet tube (7 mm OD) extending to the bottom of the flask and a 1 mm capillary vent tube sealed into the dome of the head. The syringe loading sidearm consisted of a  $25 \times 5$  mm tube sealed at a 60° angle near the neck of the flask, a short piece of rubber tubing for inserting the hypodermic needle and ended with a piece of 1 mm capillary tubing for the escape of nitrogen gas, thus ensuring the removal of any oxygen brought into the sidearm with the needle. The 3 inch needle of the 10 ml Luer-Lok syringe was inserted into the flask above the liquid level by perforating the rubber tubing of the sidearm connection, and nitrogen was alternately drawn into the syringe and discharged back into the flask several times in order to remove any entraped oxygen. The nitrogen purge rate through the inoculum was maintained at 80 ml/min for 30 minutes before the syringe was loaded for inoculation of the all-glass culture flasks described below.

Experimental culture flasks. The growth studies were conducted in all-glass units similar in design to those described by Stier, Scalf and Brockmann (1950, Fig. 1) except that they were fabricated from 250 ml wash bottles with standard taper stopper (Corning 1660). A straight bore stopcock was attached to the original water outlet tube of the stopper, and a mercury trap was attached to the original air inlet tube. A short length of heavy walled rubber tubing connected the stopcock of the center tube of each flask to a manifold which was attached by copper tubing to the cylinder of purified nitrogen. Anaerobic conditions were established by purging the rubber tubing and the attached flasks, with their experimental growth medium (25 ml), with Linde High Purity Nitrogen at a rate of 80 ml/min for 40 minutes. The flasks were then inoculated with 1 ml of seed yeast, which had been treated as described above, by inserting the needle of the syringe through the rubber tubing and allowing the stream of nitrogen to carry the volume of inoculum into the flask. Purging with nitrogen was continued for an additional 20 minutes in order to remove any oxygen which may have been introduced during the inoculating procedure. The trap on the gas outlet tube was then filled with mercury to a height of 2 cm and the stopcock was closed.

Malt sprouts. The malt sprouts employed in these studies were obtained from Joseph E. Seagram and Sons, Inc., and were ground

70
#### Lipid Anaerobic Growth Factors In Malt Sprouts

fine in a Wiley mill before being used. In the experiments reported below, the dry malt sprouts were added to the basal growth medium (see legend, Fig. 2) and autoclaved together at  $120^{\circ}$  C for 12 minutes.

Yeast population. The number of yeast cells in a known dilution of medium was determined, after cessation of cell multiplication (circa 40 hours at  $30^{\circ}$  C), by direct count in a Neubauer counting chamber. Interference with the counting of the yeast cells by particles of malt sprouts was eliminated by filtering the entire contents of each flask at the end of the growth period through four thicknesses of cheese cloth and washing the residue free of yeast cells with sufficient water to make a final volume of 200 ml.

Various extraction procedures employed for determining the gross nature of the anaerobic growth stimulating material in the malt sprouts will be given in the following section.

#### **Results and Conclusions**

In order to set up nutritional conditions which would reveal the presence of any unusual growth factors in the added malt sprouts, we first studied the relation between the Difco yeast extract concentration of the medium and the resultant crops produced under anaerobic conditions. Figure 1 shows that the final crops increased in cell number as the yeast concentration was increased in the range 0 to 7% and that no further increase in crop production resulted beyond the 7% yeast extract concentration.

The final crops reported in these experiments were obtained after 42 hours at 30° C. Periodic sampling at low and high yeast extract concentrations established this period of time as being sufficient for the complete development of maximum crop. Additional experiments, not reported, showed that the dextrose concentration of the medium did not limit the development of the maximum crops.

On the basis of the findings reported in Fig. 1, a basal medium consisting of 7% yeast extract, 0.5% KH<sub>2</sub>PO<sub>4</sub> and 10% dextrose

was chosen for subsequent studies of the relation between malt sprouts concentration and magnitude of the final crop. These results are given in Fig. 2. Note that the addition of malt sprouts to the basal medium resulted in an increase in the size of the final crop. It was found that 5% malt sprouts was the maximum concentration which could be handled satisfactorily for these growth studies.

To determine the nature of the stimulatory substance in the added malt sprouts, we first made extracts of the water-soluble materials and the fat solvent soluble substances. An outline of the fractionation procedure and results from a typical experiment are given in Figure 3. The procedure employed was as follows: 10 gm of malt sprouts in 100 ml of distilled water, adjusted to pH 4.8, was autoclaved in a 200 ml centrifuge bottle at 120° C for 12 minutes, and the solids were removed and washed with three 100 ml portions of distilled water by centrifugation. The combined liquids containing the water extractable substances were evaporated under reduced pressure at 50° C to a final volume of 100 ml and assayed in the 7% yeast extract medium.

The washed solids, obtained above, were dried at 60°C in a vacuum oven for 24 hours and their weight determined. Triplicate portions of this residue, each equivalent to 1.25 gm of the original sprouts material, were assaved under sterile conditions in 25 ml of basal medium for their anaerobic growth promoting activity. The remainder of the solids was extracted with three 100 ml portions of absolute alcohol by refluxing for 30 minutes over a steam bath. This treatment of the solids was followed by a similar extraction with absolute ethyl ether. The two extracts were then combined by evaporating the ether and redissolving the residue from the ether extract in the alcohol extract. This fraction called the "alcohol-ether extract", was assayed in triplicate by measuring an aliquot, representing the fat solvent soluble material in 1.25 gm of the original malt sprouts, into a sterile culture flask and evaporating the alcohol under reduced pressure at 60° C. Sterile medium was then added to the material deposited on the bottom of the flask, and the whole culture unit was prepared for inoculation with oxygen-free seed yeast as described above. The alcohol-ether extracted solids were dryed at 60° C in a vacuum oven for 24 hours, weighed and assaved in the same manner as the water extracted solids

#### Lipid Anaerobic Growth Factors In Malt Sprouts

The results given in Figure 3 indicate that it was the lipid materials in the malt sprouts which had induced the extra anaerobic growth. The material in the alcohol-ether extract was then fractionated by saponification. An aliquot of the alcohol-ether extract was saponified by refluxing 4 hours with KOH on a steam bath, followed by extraction with ethyl ether and washing the ether extract with water. The final washed ether fraction which contained the non-saponifiable substances was then tested for its anaerobic growth promoting properties by the same procedure described above for the alcoholether extractives<sup>3</sup>.

Additions of the non-saponifiable material (11.2 mg), obtained from 1.25 gm malt sprouts, to 25 ml of basal yeast extract medium gave yeast crops with values within  $\pm 10$  per cent of those obtained with the alcohol-ether extracts. Therefore, it is concluded that the lipid anaerobic growth stimulating material of malt sprouts belongs to the non-saponifiable class of substances. We have reported a similar finding for the lipids extracted from distillers' dried solubles (Stier and Scalf, 1949). The work of Devloo (1938), on the stimulation of cell multiplication of yeast by various sterols, suggests that the sterol fraction of malt sprouts might contain the material which stimulates the anaerobic growth of our distillers' yeast.

The manner in which the lipid growth stimulating substances of malt sprouts are absorbed and metabolically utilized by the yeast cell has not been investigated as yet. In some recent experiments (unpublished) with oils from plants and animals, we have found that these oils will form stable emulsions in the yeast extract medium itself. The possibility that this process also takes in the case of the lipids of finely ground malt sprouts, or that some process of solubilization takes place whereby the growth stimulating fat-soluble substances couple with certain water-soluble substances in the medium (for example, see Wald, 1949), will be considered in future investigations.

<sup>3</sup> The average yields of the various extractives from the malt sprouts were as follows: water-soluble substances, 27%; alcohol-ether extractives, 8.4%; non-saponifiable substances, 0.9%.







The growth medium consisted of 0.5%  $\text{KH}_2\text{PO}_4$  (Merk, reagent), 10% dextrose (Merck, reagent) and varying concentrations of Difco yeast extract (Control # 395778). The Difco yeast extract employed in this laboratory has generally given final anaerobic crops of 90-100 x 10<sup>6</sup> cells/ml at a concentration of 7%. However, some shipments of Difco yeast extract gave maximum crops in the range 15-25 x 10<sup>6</sup> cells/ml and therefore were not suitable for the experiments reported in this paper.





Figure 2. Relation of concentration of malt sprouts to magnitude of the final anaerobic yeast crop.

The basal medium consisted of 7% Difco yeast extract, 0.5%  $\rm KH_2$ -PO<sub>4</sub> and 10% dextrose and produced anaerobic crops of 90 x 10<sup>6</sup> cells/ml. The basal medium was apparently complete with respect to water-soluble growth factors since additions of water extracts of malt sprouts (Fig. 3), or of liver (unpublished) or higher concentrations of yeast extract (Fig. 1) did not increase the final yeast crops.



Figure 3. Anaerobic growth promoting activity of the water and fat solvent soluble fractions of malt sprouts.

Note that the water extracted residue gave approximately the same anaerobic yeast crop as the untreated malt sprouts. Extraction with absolute alcohol followed by ethyl ether gave a residue producing no extra anaerobic growth when added to the basal 7% yeast extract medium. Addition of the materials in the water extract also gave no significant increase in anaerobic growth; addition of the alcohol-ether extractives from 5 gm of malt sprouts per 100 ml of basal medium, however, gave an average crop of  $175 \times 10^6$  cells/ml. We have not been able, so far, to produce larger crops by extracting the lipid material with other fat solvents.

Lipid Anaerobic Growth Factors In Malt Sprouts

#### SUMMARY

The production of anaerobic crops of a distillery type of yeast was increased from 100 to  $195 \times 10^6$  cells/ml by the addition of commercial malt sprouts to a basal medium which was apparently complete with respect to the water-soluble growth factors. Water extracts of the malt sprouts were shown not to contain the substances which produced the larger anaerobic yeast crops. The anaerobic growth stimulating material was extracted by alcohol and ether and all of the active lipid substance (or substances) was shown to be present in the unsaponifiable fraction.

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#### PREPARATION OF KETONES BY THE SOMMELET REACTION

M. I. Bowman, Irving B. Joffe, W. W. Rinne and James C. Wilkes\* University of Louisville

The Sommelet reaction involves reacting a halogen compound with hexamethylene tetramine to give a salt of the quaternary amine type. This is then decomposed by steam distillation to give the aldehyde. Little or no work has been done in preparing ketones by this method and it appears likely that secondary halides do not ordinarily undergo this reaction to any great extent. In the cases discussed here, it is possible that the fact that the halogen is adjacent to the double bond activates this reaction.

A possible mechanism for the Sommelet reaction has been suggested by Graymore and Davis (1945).

Two procedures are commonly used, one involving actual isolation of the quaternary salt and the other steam distillation of the reaction mixture without isolating the salt. We have found the latter to give better results in the cases studied.

#### *Experimental*

2-Methyl-2-cycloheren-1-one. 1-Methylcyclohexene (30 g.) was brominated with N-bromosuccinimide in carbon tetrachloride in the usual manner (Ziegler, 1942). Two fractions were obtained (A) b.p. 53-60/10mm (20 g.) and (B) b.p. 60-90/10mm. (11 g.). Both fractions were subject to the Sommelet procedure as described by Weygand (1945).

Both of these products were analyzed by treatment of aliquot portions with dinitrophenylhydrazine. The dinitrphenylhydrazones were not pure but could be recrystallized from benzene-ethanol and glacial acetic acid to bring the melting point up to 204-6°. Chromatography gave somewhat better results. Two bands were formed with either chloroform or benzene on alumina, a top band about 1/5 of the total, m.p. above 300°, and a lower band m.p. 208°, about 4/5 of the total. According to Butz (1947) the dinitrophenyl hydrazone of

<sup>\*</sup> This work was carried out under contract N8onr76201 between the Navy Department, Office of Naval Research, and the University of Louisville.

#### Preparation Of Ketones By The Sommelet Reaction

2-methyl-2-cyclohexen-1-one melts at 207-10°. From the quantities obtained it appeared that the yield of ketone from (A) was only 3% wrereas from (B) it was 18%.

The identity of the 208° m.p. derivative was checked by mixed melting point with that from several samples of 2-methyl-2-cyclohexen-1-one prepared by other methods. Also mixed chromatograms were run using many different solvents and no separation of bands could be produced.

An attempt to prepare this ketone from the bromo derivative by the oxidative hydrolysis method of Mousseron (1947) gave only traces of the desired product. However, refluxing with potassium carbonate gave a 15% yield of 2-methyl-2-cyclohexen-1-ol, (Urion, 1934) readily converted to the phenyl urethane m.p. 209-10°. 6-Methyl-2-cyclohexen-1-one. Starting with 4-methylcyclohexene  $\dagger$  and

6-Methyl-2-cyclohexen-1-one. Starting with 4-methylcyclohexene † and subjecting it to the same procedure as above, there was obtained a small amount of ketone yielding a dinitrophenylhydrazone m.p. 158°. This corresponds to the 6-methyl derivative as indicated by Birch (1946) rather than the 5-methyl which Mousseron obtained by oxidative hydrolysis of the bromo compound obtained in the same manner as ours. Our bromo derivative differs slightly from Mousseron's in physical properties. Further investigation of this reaction is being made.

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† Kindly supplied by the Phillips Petroleum Company, Bartlesville, Okla.

# ECONOMIC STATUS OF LESPEDEZA SEED OIL

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A preliminary report on the isolation and characterization of lespedeza seed oil has occasioned a general interest in the economic possibilities involved in the production and utilization of lespedeza seed oil. This discussion summarizes some of the pertinent information on this topic.

Lespedeza is rapidly becoming a major agricultural crop in Southern states. It is widely and readily accepted as a forage crop of the legume family. Its acceptance is due to its excellent growth during hot months (July and August) when other forage crops do not provide good pastures and to its value as a legume in rebuilding exhausted soils. Lespedeza seed is harvested for replanting on a fairly large scale. An estimated (2) 250,000,000 pounds was harvested in the United States in 1948. The oil from the seed has not been studied prior to our work. Neither has the possibility of cultivating the plant as a seed crop other than for replanting been examined.

Preliminary studies (1) of its unsaturation and drying propetries indicate that the oil has properties that will make it of value as a drying oil for the paint and varnish industry. If the oil is of commercial value, the Southern farmers have available, without now realizing it, an oil seed crop which may be as valuable to them as the soy bean crop has been to Middle Western farmers. Such use of lespedeza as a seed crop is of obvious value in developing a diversification of Southern agriculture.

The potential cost of lespedeza seed oil is determined by the yield per acre of seed. Current yields of the Korean strain average 200 pounds per acre but "yields of 500 pounds of cleaned Korean seed per acre are not unusual." (3) Yields of Sericea seed of up to 1200 pounds per acre have been reported (4). Using 500 pounds as an average yield of seed, \$10 per acre as minimum costs for harvesting by combine, and a 10% yield of oil from seed, the estimated cost of the oil not including costs of extraction is \$0.20 per

#### Economic Status Of Lespedeza Seed Oil

pound. This might well be halved by developments in increasing seed yield per acre. Current quotations on linseed oil are \$0.18 per pound and reflect a decrease of 30% in the last year. This is regarted as unusually favorable for this development when it is remembered that current oil prices are low and that lespedeza culture as a seed crop has received little if any development.

If Southern lespedeza seed oil, based on a crop readily accepted by the Southern farmer, can replace Northern linseed oil, based on a crop which must be subsidized to find acceptance by farmers who are loath to grow it, the Southern agricultural leaders should know about it and plan and work accordingly for the benefit of the region. Such developments take many years during which short range economic factors—particularly market values—will undoubtedly go through many fluctuations in the \$0.10 to \$0.40 range.

The most important problems facing this development at present are: (1) to relate oil yields from seed to seed production particularly with strains giving high seed yields and (2) to complete a thorough characterization of the oil. Both are receiving active, although limited, attention in our laboratories.

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# PERFORMANCE OF AN EARTH HEAT PUMP ON INTERMITTENT OPERATION

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#### INTRODUCTION

From October 31, 1949 to May 1, 1950 the earth heat pump at the University of Kentucky operated intermittently on the heating cycle  $(1)^1$ . By the use of an electric clock, the plant was set in operation at 6 p.m. and stopped at 6 a.m. daily. While the plant was in operation heat was extracted from the earth, thereby lowering the temperature of the soil surrounding the earth heat exchanger  $(2,3,4)^2$ . The heat absorbed from the earth at a low temperature level was discharged at a higher temperature level to the air stream going to the space to be air conditioned. During the twelve hour period in which the heat pump was idle, heat flowed from the more remote soil into that surrounding the earth heat exchanger, thereby restoring its temperature wholly, or partially to its original value.

## THE HEAT PUMP INSTILATION

The earth heat pump system installed in the mechanical engineering laboratory consists of a Marvair package unit manufactured by the Muncie Gear Works, Muncie, Indiana, an instrument panel, and an earth heat exchanger (Fig. 1) buried at an average depth of

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<sup>1</sup> Numbers in parentheses refer to references in the Bibliography.

<sup>&</sup>lt;sup>2</sup> For a description of an earth heat pump and how it functions, see pages 47-58, reference (2); pages 506-513, reference (3); and pages 24-30, reference (4).



Earth Heat Pump On Intermittent Operation

Figure 1. The earth heat exchanger or ground coil.

about 4.5 ft. in the soil nearby (1, 5). The essential parts of the package unit are two heat exchangers; a 4-cylinder, single stage, aircooled, refrigeration compressor manufactured by Servel, Inc., Evansville, Indiana; a 5-hp, single phase, electric motor used to drive the compressor<sup>1</sup>; a fan driven by a  $\frac{1}{2}$ -hp, single phase, electric motor; and a circulating pump driven by a  $\frac{1}{2}$ -hp, single phase, electric motor<sup>2</sup>.

The earth heat exchanger (Fig. 1) consists of an effective length of 489 ft. of one inch copper tubing through which an antifreeze solution is circulated. Thermocouples were installed so temperatures could be measured at the center of the antifreeze line at stations 1 to 8 inclusive. The line heat source is 171.9 ft. long and consists of the portion of the earth heat exchanger from stations 2 to 5, and from stations 7 to 8, except the length of tubing which is thermally insulated as shown in Fig 1. The grid has a length of 317.1 ft., and is that portion of the earth heat exchanger between stations 5 and  $7^3$ . Thermocouples (Fig. 2) were installed so that the temperature of the soil at stations 3 and 6 could be measured.

#### Definitions

It has been shown that a heat pump system should have a heating energy ratio of about 3.33 to deliver as much heat energy as a pound of coal burned in stoker-fired furnace<sup>4</sup>. If the heat pump is to replace conventional heating equipment for the sake of economy its efficiency must be improved considerably.

The French use the term coefficient of amplification as a measure of the efficiency of a refrigeration plant, while Davies and Watts use the term performance energy ratio (6, 7). In the United

<sup>1</sup> For the tests during the heating season of 1949-1950 a 5-hp motor was used instead of the 3-hp motor which was originally installed in the Marvair package unit.

<sup>2</sup> For a description of the heat pump installation used in this research, see pages 8-21, reference (1).

<sup>&</sup>lt;sup>3</sup> In this paper the heat source will be considered as the entire effective length of copper tubing in the earth heat exchanger, namely 489 ft. In a future Engineering Experiment Station Bulletin a more detailed analysis will be given in which the earth heat exchanger will be considered as a line heat source of 171.9 ft. and a grid heat source of 317.1 ft. of copper tubing.

<sup>4</sup> See page 58, reference (2); and page 521, reference (3).



STATION 6



Figure 2. Schematic diagram showing the location of thermocouples used to determine the soil temperatures at stations 3 and 6.

States the term coefficient of performance (COP) is generally used as a measure of the efficiency of a refrigeration plant<sup>1</sup>. In heat pump engineering these terms are somewhat misleading since the energy ratio for heating exceeds, theoretically, that for cooling by unity<sup>2</sup>. In this paper the term coefficient of performance will be replaced by the term heating energy ratio.

The object of this research is to determine the factors responsible for the low performance energy ratios, and to find out if the earth is a suitable heat source. In order to make a careful analysis of data taken, the following definitions were used:

- 1. A Carnot heat pump is a highly idealized machine which removes heat reversibly from a cold body at a constant temperature, and discharges heat reversibly to a hot body at a constant temperature; it operates on a cycle consisting of two isothermal and two isentropic processes.
- 2. A vapor compression refrigeration plant is a system consisting of an evaporator, condenser, precooler, expansion valve (or capillary tube), and a compressor.
- 3. A heat pump is a refrigeration plant and the electric motor used to drive the compressor.
- 4. A heat pump system is defined as a heat pump plus the necessary auxiliary equipment (which consumes electric energy) needed for air conditioning.
- 5. The heating energy ratio (HER) of a Carnot heat pump is the ratio of the heat absorbed by the hot body to the heat equivalent of the net work of the cycle.
- 6. The heating energy ratio (HER) of a refrigeration plant is the ratio of the heat absorbed by the condenser to the heat equivalent of the work of compression.
- 7. The heating energy ratio (HER) of a heat pump is the heat absorbed by the fluid which removes heat from the condenser to the heat equivalent of the electric energy supplied to the motor used to drive the refrigeration compressor.
- 8. The heating energy ratio (HER) of a heat pump system is

<sup>1</sup> For two years the senior author has been using the team heating energy ratio (HER), in his classes in thermodynamics and refrigeration, as a measure of the efficiency of the heat pump when it operates on the heating cycle, and the term cooling energy ratio (CER) when it operates on the cooling cycle.

<sup>2</sup> See page 506, reference (3); and page 2, reference (4).

## Earth Heat Pump On Intermittent Operation

the ratio of the heat absorbed by the fluid which removes heat from the condenser to the heat equivalent of the electric energy supplied to the entire system<sup>1</sup>.

# Performance Tests of Short Duration

During the summer of 1949, four heating tests of short duration were made to determine the efficiency of the Marvair package heat pump unit, and the general operating performance of the entire installation<sup>2</sup>. For the sake of comparison with the six-month heating test considered here, the average values obtained from these four tests are listed in Table I<sup>3</sup>. Items 19 and 20, clearly indicate that a very inefficient refrigeration compressor was installed in the Marvair package unit<sup>4</sup>. From item 5, it can be seen that 25,650 B of heat were discharged to the air stream per hour. In reference (2), it was shown in an 8-hour heating test made on June 24, 1949, that 6,670 B of heat were absorbed from the air stream by the evaporator and connecting pipes each hour, thereby reducing the useful heat power to the air stream from 31,420 to 24,750 B/hr. This shows clearly that the evaporator (and pipes leading to and from it) should have been either more thoroughly insulated, or should have been placed in a separate compartment through which the air steam did not pass during the heating cycle. As shown in item 14, 14,630 B of heat per hour were absorbed by the antifreeze from the earth, which is one indication that the evaporator in the package unit is an inefficient heat exchanger. From items 21 and 22 it can be seen that the heating energy ratio of the refrigeration cycle is 5.6 or 87.5% of that for the Carnot heat pump. The actual HER for the heat pump is 2.3 or 41% of that for the refrigeration plant; this reduction in the heating energy ratio is due to taking the single phase compressor motor into consideration, and to insufficient insulation on the evaporator and connecting pipes. By including the single phase fan and pump motors, there is a further reduction in the HER, and it can be seen that the heating energy ratio of the heat pump system is 1.7, or about 74% of that for the heat pump. This fur-

<sup>1</sup> See reference (5).

<sup>2</sup> See pages 35-46, reference (1) and 24-30, reference (4).

<sup>3</sup> Pages 55-64, reference (1).

<sup>4</sup> By reducing the compressor speed from about 1130 to 700 rpm, the capacity of the refrigeration plant was reduced from 2.0 to 1.6 tons although the volumetric efficiency increased from about 52.7 to about 71.5%.

ther reduction is due to the additional energy consumed by the fan motor and circulating pump motor. From the above it can be seen that the package heat pump under consideration is very inefficient.

# TABLE I. AVERAGE VALUES OBTAINED FROM FOUR HEATING TESTS OF SHORT DURATION DURING THE SUMMER OF 1949.

|  | 07.0              |
|--|-------------------|
| 2. Inlet temp. of air stream, ○F                         | 85.8              |
| 3. Outlet temp. of air stream, $\circ F$                 | 104.9             |
| 4. Increase in temp, of air stream, OF                   | 19.1              |
| 5. Heat power to air stream, B/hr.                       | 25,650            |
| 6. Inlet temp. of antifreeze, ○F                         | 36.0              |
| 7. Outlet temp. of antifreeze, OF                        | 39.6              |
| 8. Increase in temp. of antifreeze, °F                   | 3.6               |
| 9. Temp. of antifreeze in earth heat exchanger, OF       | 37.7              |
| 10. Soil temp. 6 in. below center of antifreeze line, O  | F 60.2            |
| 11. Soil temp. 12 in. below center of antifreeze line,   | ◦F 61.0           |
| 12. Soil temp. 18 in. below center of antifreeze line,   | of 61.5           |
| 13. Strength of heat source (entire earth heat exchanges | r), B/hr/ft. 27.4 |
| 14. Heat power from soil, B/hr                           | 14,630            |
| 15. Electric power input to compressor motor, kw         | 3.632             |
| 16. Electric power input to fan motor, kw                | 0.484             |
| 17. Electric power input to pump motor, kw               | 0.810             |
| 18. Total electric power to heat pump system, kw         | 4.926             |
| 19. Volumetric efficiency of refrigeration compressor,   | % 52.7            |
| 20. Compression efficiency of refrigeration compressor   | ., % 66.7         |
| 21. HER for Carnot heat pump                             | 6.4               |
| 22. HER for refrigeration plant                          | 5.6               |
| 23. HER for heat pump (actual)                           | 2.3               |
| 24. HER for heat pump system (actual)                    | 1.7               |
| 25. Heating cost, kwhr/therm                             | 18.1              |
| 26. Actual capacity of refrigeration plant, tons         | 2.0               |

The heating energy ratios determined in the tests of short duration are in line with those calculated from a hypothetical earth-to-air heat pump installation<sup>1</sup>. It is hoped that designers of new heat pump installations will take cognizance of the various factors which are responsible for the reduction in the heating energy ratio (i. e., from 5.6 to 1.7 in the case under consideration).

<sup>1</sup> Page 29, reference (4).

#### Earth Heat Pump On Intermittent Operation

#### HEATING TEST FROM OCTOBER 31, 1949 TO MAY 1, 1950

A great deal of information concerning the performance of an earth heat pump system has been obtained through tests of short duration. However, such tests give little or no information as to the actual quantity of heat that is available, in the earth, for heating a building during the entire season. A long-term heating test in which the heat pump operates continuously throughout the entire season will not give the true performance because actual plants generally operate on a demand basis.

During the heating test of 1949–1950, the heat pump system operated intermittently, extracting heat from the earth daily from 6 p.m. to 6 a.m. It was recognized, however, that by operating the plant in this manner, more heat would be absorbed from the earth during the first and last parts of the heating season than would be required normally to heat a house on the demand basis. Nevertheless, this procedure simulates actual operation much better than where the heat pump system is kept operating continuously.

The chief results obtained from the test made during the heating season of 1949–1950 are listed in Table II. The total degreedays<sup>1</sup> during the test period were about 92% of normal for 43 seasons. From Table III, however, it can be seen that the average outdoor temperature for the season<sup>2</sup> was  $42^{\circ}$  F and the normal temperature for the same period was  $41.1^{\circ}$  F. The rain fall was 36.48 inches as compared with 22.33 inches which is the normal for the same period.

The average heat power supplied to the air stream for the season considered was 92.36 therms per month, and the average electric power input to the heat pump system was 1893 kwhr per month. Hence the average monthly heating cost

<sup>1</sup> The degree-day is a term based on the idea that heat is not required in a building maintained at 70°F when the average outdoor air temperature, represented by the mean of the maximum and minimum outdoor air temperatures for the day, does not fall below 65°F (8). If the average outdoor air temperature is 64°F, there is one degree-day, and if the average outdoor air temperature is 40°F, there are 25 degree-days.

<sup>2</sup> The actual average outdoor air temperatures reported in this paper are the average hourly temperatures instead of averages of the maximum and minimum temperatures.

 $= \frac{1893 \text{ kwhr/month}}{92.36 \text{ therm/month,}}$ = 20.5 kwhr/therm

Whence, the average heating cost from October 31, 1949 to May 1, 1950 was found to be 20.5 kwhr/therm for cold wet soil <sup>1</sup> (average soil temperature 6" below the center of the antifreeze line for the season was  $43^{\circ}$ F). For the four tests of short duration, the average heating cost was found to be 18.1 kwhr/therm for warm dry soil (average soil temperature 6" below the center of the antifreeze line was  $60.2^{\circ}$ F).

By the strength of the heat source is meant the heat absorbed per unit time per unit length of the earth heat exchanger. The average strength of the heat source (Table III) was 27.5 B/hr/ft for the season of 1949-1950, and that obtained from the four tests of short duration was 27.4 B/hr/ft for the summer of 1949. Curve E, Figure 3b shows the variation of the strength of the total heat source (489 ft of pipe) versus time. From Fig. 3a and 3b it can be seen that the maximum value of the strength of the heat source occurs at the time of maximum rainfall.

For the season under consideration the average temperature of antifreeze solution in the earth heat exchanger was  $28.1^{\circ}$ F for November and  $17.5^{\circ}$ F in April. The average temperature of the antifreeze in the earth heat exchanger was  $23.3^{\circ}$ F for the entire season.

TABLE II. AVERAGE MONTHLY VALUES OBTAINED DURING AN IN-TERMITTENT HEATING TEST FROM 6 P.M., OCTOBER 31, 1949 TO 6 A.M., MAY 1, 1950.

|    |                              | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. |
|----|------------------------------|------|------|------|------|------|------|
| 1. | Outdoor air temp., °F        | 43.4 | 40.0 | 40.0 | 37.9 | 40.6 | 49.9 |
| 2. | Normal outdoor air temp., °F | 44.8 | 35.8 | 32.9 | 35.4 | 43.7 | 54.3 |
| 3. | Air temp. in Mech.           |      |      |      |      |      |      |
|    | Engr. Lab., °F               | 72.4 | 69.9 | 71.5 | 70.5 | 72.2 | 75.7 |
| 4. | Inlet temp. of air           |      |      |      |      |      |      |
|    | stream, °F                   | 76.5 | 75.1 | 76.7 | 75.2 | 77.0 | 80.4 |
| 5. | Outlet temp. of air          |      |      |      |      |      |      |
|    | stream, °F                   | 97.9 | 95.2 | 97.4 | 94.7 | 96.6 | 99.9 |
|    |                              |      |      |      |      |      |      |

<sup>1</sup> In Fig. 3(a) the actual and normal monthly rainfalls are shown graphically for the season.

# Earth Heat Pump On Intermittent Operation

| 6           | Increase in terms of                 |        |                |                |         |        |               |
|-------------|--------------------------------------|--------|----------------|----------------|---------|--------|---------------|
| 0.          | oir stream OF                        | 21.4   | 20.1           | 20.7           | 19.5    | 19.6   | 19.5          |
| 7           | Heat nower to air                    |        | 2001           | 2000           | 2.71.7  | 10.0   |               |
| •••         | stream. B/hr                         | 27.265 | 25.620         | 26.590         | 24.900  | 24.440 | 24,230        |
| . 8.        | Total heat nower to                  | ,      |                |                | ,       | ,      |               |
|             | air stream, therms/mo.               | 98.15° | 95.31°         | 98.91°         | 83.66°  | 90.92° | 87.23°        |
| 9.          | Temp, of antifreeze                  |        |                |                |         |        |               |
|             | entering line, °F                    | 28.1   | 26.4           | 23.7           | 19.2    | 17.8   | 17.5          |
| 10.         | Temp. of antifreeze                  |        |                |                |         |        |               |
|             | leaving line, °F                     | 31.4   | 29.4           | 27.4           | 22.7    | 21.4   | 20.7          |
| 11.         | Increase in temp.                    |        |                |                |         |        |               |
|             | of antifreeze, $\circ F$             | 3.3    | 3.0            | 3.7            | 3.5     | 3.6    | 3.2           |
| 12.         | Temp. at center of                   |        |                |                |         |        |               |
|             | antifreeze line, ○F                  | 28.7   | 27.6           | 25.7           | 20.5    | 19.0   | -18.4         |
| 13.         | Soil temp. 6 in. below               |        |                |                |         |        |               |
|             | center of antifreeze line, $\circ F$ | 51.9   | 45.1           | 40.2           | 41.0    | 39.3   | 40.9          |
| 14.         | Soil temp. 12 in. below              |        |                |                |         |        |               |
|             | center of antifreeze line, ○F        | 56.4   | 49.2           | 41.0           | 43.0    | 43.1   | 43.9          |
| 15.         | Soil temp. 18 in. below              |        |                |                |         |        |               |
|             | center of antifreeze line, $\circ F$ | 55.4   | 48.6           | 43.2           | 43.7    | 42.2   | 43.0          |
| 16.         | Strength of heat source              |        |                |                |         |        |               |
|             | (for 489 ft), B/hr/ft                | 27.8   | 23.8           | 30.5           | 28.9    | 28.0   | 26.2          |
| 17.         | Heat power from earth to             |        |                |                |         |        |               |
|             | antitreeze, B/hr                     | 13,560 | 11,840         | 14,890         | 14,150  | 13,700 | 12,800        |
| 18.         | Total heat power from                | 10.00* |                |                |         |        | 10.000        |
| 10          | earth to antifreeze, therms/mo       | 48.80° | 44.15 <b>*</b> | 54.39 <b>°</b> | 47.60*  | 50.90* | 46.10°        |
| 19.         | Elect. power to                      | 1 201  | 1 1 2 0        |                |         | 2 5 10 |               |
| 20          | compressor motor, kw                 | 4,391  | 4.430          | 3.780          | 3.560   | 3.540  | 3.540         |
| 20.         | Elect. power to fan                  | 0 500  | 0 500          | 0 503          | 0 501   | 0.400  | 0.400         |
| 0.1         | motor, KW                            | 0.503  | 0.500          | 0.502          | 0.501   | 0.489  | 0.482         |
| 21.         | Elect. power to                      | 0.000  | 0.949          | 0.075          | 0.971   | 0.960  | 0.050         |
| 00          | Floot power to host                  | 0.652  | 0.042          | 0.075          | 0.071   | 0.000  | 0.000         |
| <i>4</i> 4. | pump system kw                       | 5 726  | 5 779          | 5 157          | 1 0 2 2 | 1 880  | 1 880         |
| 93          | Fleet energy supplied                | 0,120  | <u>ش</u> ،،،،  | 0.107          | 4.504   | 4.005  | 4.000         |
| 20.         | to heat nump system kwhr             | 2061*  | 2147*          | 1018*          | 1657*   | 1810*  | 17579         |
| 24          | HEB for heat nump                    | 1.82   | 1.82           | 2.06           | 2.05    | 2 02   | 2.00          |
| 25          | HER for heat rump                    | 1.02   | 1.02           |                | 2.00    | 2.02   | 2.00          |
| <i></i>     | system                               | 1.39   | 1.30           | 1.50           | 1.48    | 1.16   | 1.45          |
| 26.         | Bainfall, inches                     | 2.40°  | 7.25*          | 15.63*         | 4.09*   | 3.62*  | 3.52°         |
| 27          | Normal rainfall.                     |        |                | 20100          | 1.00    | 0.0    | · · · · · · · |
|             | inches                               | 3.34°  | 3.37°          | 4.18°          | 3.62°   | 4.32°  | 3.50°         |
| 28.         | Degree days                          | 625°   | 775°           | 654°           | 751°    | 743°   | 441 °         |
| 29.         | Normal degree days                   | 601*   | 916°           | 964°           | 862°    | 650°   | 352°          |
|             | ~ /                                  |        |                |                |         |        |               |

\* Total values--not average values.

# RAINFALL AND STRENGTH OF HEAT SOURCE VS TIME FROM NOV.I, 1949 TO MAYI, 1950

- A. ACTUAL RAINFALL
- B. NORMAL RAINFALL
- C. STRENGTH OF LINE HEAT SOURCE
- D. STRENGTH OF GRID HEAT SOURCE
- E. STRENGTH OF TOTAL HEAT SOURCE







#### Earth Heat Pump On Intermittent Operation

TABLE III. AVERAGE VALUES OBTAINED FOR THE SIX-MONTH HEAT-ING TEST. HEAT WAS ABSTRACTED FROM THE EARTH TWELVE HOURS EACH DAY.

| 1.  | Outdoor air temperature, °F                                 | 42.0   |
|-----|---|--------|
| 2.  | Normal outdoor air temperature, °F                          | 41.1   |
| 3.  | Inlet air temperature, °F                                   | 76.8   |
| 4.  | Outlet air temperature, °F                                  | 97.0   |
| 5.  | Heat power to air stream, B/hr <sup>1</sup>                 | 25,510 |
| 6.  | Heat power to air stream, therm/mo <sup>2</sup>             | 92.36  |
| 7.  | Heat power from earth, B/hr                                 | 13,490 |
| 8.  | Heat power from earth, therm/mo                             | 48.66  |
| 9.  | Temperature at center of antifreeze line, $\circ F$         | 23.3   |
| 10. | Soil temperature 6 in. below center of antifreeze line, °F  | 43.0   |
| 11. | Soil temperature 12 in. below center of antifreeze line, OF | 46.1   |
| 12. | Soil temperature 18 in. below center of antifreeze line, °F | 46.0   |
| 13. | Strength of heat source (489 ft.), B/hr/ft                  | 27.5   |
| 14. | Electric energy to heat pump system, kwhr                   | 1893   |
| 15. | HER for heat pump   | 1.96   |
| 16. | HER for heat pump system                                    | 1.43   |
| 17. | Heating cost, kwhr/therm                                    | 20.5   |
|     |   |        |

The average value of the soil temperature 6 in. below the center of the antifreeze line was  $43^{\circ}$  F for the season<sup>3</sup>. The average soil temperatures for the season were  $46.1^{\circ}$  F and  $46.0^{\circ}$  F at distances of 12 and 18 inches below the center of the antifreeze line, respectively.

The average heating energy ratios for the heat pump and the heat pump system are 1.96 and 1.43, respectively, while those reported for the four tests of short duration were 2.3 and 1.7, respectively.

The performance of the actual earth-to-air heat pump system for the test season is shown graphically in Fig. 4. The effect of heavy rainfall upon the temperature of the antifreeze in the earth heat exchanger, the soil temperatures, and the rate of absorbing heat is quite apparent. It should be pointed out that the intermittent opera-

<sup>1</sup> B/hr means British thermal units per hour.

<sup>2</sup> Therms/mo means 100,000 British thermal units per month.

<sup>3</sup> It may be more than passing interest to not that the average outdoor air temperature for the season was  $42^{\circ}$  F.

GRAPHICAL PRESENTATI

STATION 3, ANTIFREEZE LINE 5.6 FT. BELOW GF

- A. TEMPERATURE AT CENTER OF ANTIFREEZE LIN
- B. TEMPERATURE 6" BELOW CENTER OF ANTIFRE
- C. TEMPERATURE 12" BELOW CENTER OF ANTIFRE
- D. TEMPERATURE 18" BELOW CENTER OF ANTIFRE







ata during the heating season of 1949-1950.





tion, also, is responsible for the irregularities in the graphs. From curve F. Fig. 4, and item 17 of Table II it can be seen that the time rate of absorbing heat from the earth is nearly constant for the test season<sup>1</sup>. Professor Coogan reports a gradual decrease in the strength of the heat source and the heat absorbed for continuous operation of 700 and 900 hours (9, 10). It should be pointed out that on comparing curves F and A (Fig. 4), that apparently there is no correlation between the variation in the outdoor air temperature and the rate of absorbing heat from the earth. According to Ingersoll and Plass (Problem 6, page 121) there should be a periodic variation of the soil temperature in the vicinity of the earth heat exchanger due to the variation in the solar energy absorbed at the earth's surface (11, 12). Neglecting the effect produced on the soil by extracting heat from it and that due to rainfall, the soil temperature should have decreased (somewhat in a sinusoidal manner) from, say, the middle of October to the middle of April. The decrease in the soil temperatures (items 13, 14, 15 in Table II) from October 31, 1949 to May 1, 1950 is partly due to the extraction of heat from the soil and partly due to the periodic reception of solar radiation. Graphs A, B, C, and D show that considerable heat was carried to the soil in the vicinity of the earth heat exchanger (due to moisture migration) on December 10-14 and 18, January 3-6, 10-14 and 29-31, February 1, and March 11-13.

# Conclusions

1. Some of the average results from the six-month heating test compare favorably with those obtained from tests of short duration using the same installation; namely,

|   | SIX-MONTH | TESTS OF |
|---|-----------|----------|
| Outlet air temp., °F                      | 97.0      | 104.9    |
| Heat power to air stream, B/hr            | 25,510    | 25,650   |
| Heat power from earth, B/hr               | 13,910    | 14,630   |
| Elect. input to entire system, kw         | 5.259     | 4.926    |
| Strength of heat source (489 ft), B/hr/ft | 27.5      | 27.4     |
| HER for heat pump                         | 1.96      | 2.3      |
| HER for heat pump system                  | 1.43      | 1.7      |
| Heating cost, kwhr/therm                  | 20.5      | 18.1     |

<sup>1</sup> The time rate of absorbing heat from the soil probably would have decreased from November to May if the ratio of the refrigeration capacity to ground coil length had been 5 tons to 489 ft. instead of about 2 tons to 489 ft.

## Earth Heat Pump On Intermittent Operation

2. The heating energy ratios obtained from tests of short duration show clearly where the reduction in efficiency takes place; to wit,

| HER for the Carnot heat pump    | 6.4 |
|---------------------------------|-----|
| HER for the refrigeration plant | 5.6 |
| HER for the heat pump           | 2.3 |
| HER for the heat pump system    | 1.7 |

3. The heating energy ratio of the refrigeration plant can be increased by producing better heat exchangers and refrigeration compressors. A more efficient heat exchanger can be manufactured by decreasing the pressure drop through it and its connecting pipes, and by increasing the amount of heat transfer surface. Professor Budenholzer has shown that the HER of a refrigeration plant can be improved by decreasing compressor losses, low side pressure drop losses, and high side pressure drop losses (13). Through research and development it ought to be possible to produce an axial-flow vapor refrigeration compressor with a volumetric efficiency of 88% (or better) and with a very high mechanical efficiency. In using the axial-flow vapor compressor, the above high and low side pressure drops will be reduced greatly. It has been observed that there was very little loss in efficiency due to departure from isentropic compression in the four tests of short duration<sup>1</sup>. Also, the HER of the refrigeration plant can be increased by using a heat pump of the direct expansion type, thereby eliminating one heat exchanger, the circulating pump and its driving motor. By doing this, the initial cost of the earth heat pump system could be decreased considerably, and the operating cost would be decreased by about 17%.

4. It is probably possible to manufacture electric motors in the low capacity bracket having an efficiency of about  $85^{\circ}_{\circ}$ . without increasing the cost of production, assuming wages and the cost of raw materials remain the same.

5. The evaporator of the package unit should not be in the air stream during the heating cycle, and the condenser should not be in the air stream during the cooling cycle.

<sup>1</sup> The average increase in entropy during compression for the four heating tests was 0.0043 B/lb/deg. Rankine. In two cooling tests of short duration, the entropy increased by 0.0089 in one test, and decreased by 0.0007 B/lb/deg. Rankine in the other.

6. From October 31, 1949 to May 1, 1950, the rainfall was in excess of the normal for that period by 64.4%. Therefore, the performance of the earth heat exchanger should be interpreted accordingly. Additional heat was carried to the ground coil by moisture migration so that the time rate of absorbing heat from the soil did not decrease appreciably with time. If the rainfall had been normal, the soil temperature in the vicinity of the earth heat exchanger would have decreased with time as the heating test progressed, thereby reducing the capacity of the refrigeration plant<sup>1</sup>.

7. The demand, particularly, for domestic heat pumps will probably increase in direct proportion to improvements in the design and methods of manufacturing refrigeration equipment. The cost of production will naturally decrease as the volume of sales is increased.

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## Earth Heat Pump On Intermittent Operation

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# THE EFFECTS OF SMALL AMOUNTS OF GLYCINE AND ETHYL GLYCINE ON FOOD INGESTION IN THE DOG

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One of the unsolved problems in the physiology of the mammal is the urge to eat. In general investigators have attempted to elucidate the role of mechanical and/or metabolic factors in the regulation of food ingestion. The rat and the dog have been used often as experimental subjects. Brobeck (1) has reported data to substantiate the importance of the metabolic factor in food ingestion regulation. In this study with rats he concluded that food intake appears to be controlled is if it is a mechanism of temperature regulation, and that the amount of food eaten appears to be determined partly by the organism's ability to dissipate the heat of food metabolism (Rubner's "Specific Dynamic Action").

It is known that certain amino acids exert the specific dynamic action effect more than others. One of these amino acids is glycine. In the following experiments glycine and its ethyl derivative were injected intraperitoneally into the dog. The assumption was that if body heat production was raised the ingestion of food might be inhibited. The experiments in which one and two grams of glycine and ethyl glycine were injected are reported here.

Data were collected on three adult dogs and are presented in Table I. The figures represent average values, and each was obtained from at least three days' experiments. The days were "scattered" in order that eating cycles be avoided. The amino acid was injected in a 0.3% sodium chloride solution, and the total volume injected was twenty milliliters. As a control, a similar volume of .9% sodium chloride solution was injected. The animals were exposed to food (block Purina) forty-five minutes after the injection of the amino acid. They were then allowed to eat as much food as they desired in a half hour interval. The quanity of food eaten was determined. The animals received food at no other time during the day. They were kept separately in metabolism cages each of which was large enough for the animal to move about freely.

# The Effects of Glycine and Ethyl Glycine On Food Ingestion

It may be seen from Table I that glycine in the amounts of one and two grams exerted no constant inhibitory effect on food ingestion. In fact, dog 5 ate more food when two grams of glycine were injected than when the animal received the control saline solution. However, an interesting effect was obtained with the ethyl derivative of glycine. It may be seen from Table I that there was an inhibition of food ingestion both with one and with two grams of ethyl glycine. Dogs 4, 5, and 6 ate only 41%, 10%, and 23%respectively of the food eaten in the saline interval when one gram of ethyl glycine was injected. With two grams of ethyl glycine the inhibition was quite marked. Only dogs 4 and 6 ate, the former 18 grams and latter 1 gram.

The data in these experiments seem to indicate that the ethyl group on the glycine molecule exerted an inhibitory effect on food ingestion, at least when the compound was used in the quanity of two grams. The mechanism of probable inhibition is not clear. Meites (2) has reported on the effects of administration of natural and artificial estrogens on the food intakes of rats. It was concluded that diethylistilbestrol decreases growth and food and water intakes. The substance was administered in comparatively small amounts. Again the presence of an ethyl group in a food intake depressing compound is to be noted. This, in conjunction with the present experiment, indicates that the ethyl group may have been the responsible factor of food intake inhibition which occurred in these experiments.

|       | Average | Average Quantity of Food Ingested (Grams) |                    |                            |                             |  |
|-------|---------|---|--------------------|----------------------------|-----------------------------|--|
|       | Na Cl   | 1 Gram<br>Glycine                         | 2 Grams<br>Glycine | l Gram<br>Ethyl<br>Glycine | 2 Grams<br>Glycine<br>Ethyl |  |
| Dog 4 | 148     | 113                                       | 81                 | 61                         | 18                          |  |
| Dog 5 | 135     | 108                                       | 196                | 13                         | 0                           |  |
| Dog 6 | 207     | 171                                       | 127                | 47                         | 1                           |  |

TABLE I

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#### THE PRECISION AND ACCURACY OF METER STICKS

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It seems unusual to think of an ordinary laboratory meter stick as a precise or accurate instrument. Yet a successful student experiment illustrating the statistical laws governing precision has been based on the meter stick as an instrument (1). By application of statistical formulas to 100 measurements of the same length with randomly chosen portions of the same meter stick, the probable error of *a single measurement* is frequently found to be as low as 0.01cm. or less, and seldom greater than 0.02 cm. This means that the average of 100 measurements with the same meter stick is *precise* to 0.01 millimeter!

A sufficiently large number of classes have now performed this experiment measuring the same specimens so that it now becomes possible to compare measurements of the same length with several different meter sticks. Table I gives typical sets of results, each result the average of about 100 measurements with the same meter stick. Since there were about 12 meter sticks available for the experiment, it is possible that some pairs of results on the same specimen used the same stick, but the variations must be due to differences between different meter sticks.

For each specimen studied at least five times, Table II gives the average of the average lengths, the difference between the highest and the lowest values, and the average deviation from the average. It appears that different meter sticks can differ by as much as 0.10 cm. when used very carefully to measure the same length. However, if one can assume that the errors of different meter sticks are random, it can be concluded that the average of several measurements with the same meter stick is certainly accurate to within a few hundredths of a centimeter and is probably within 0.02 cm. of the truth. The Precision and Accuracy of Meter Sticks

# Table I

Typical Average Measurements of Rods

| 38.80 | cm. | 60.23 cm. | 46.725 cm. |
|-------|-----|-----------|------------|
| 38.81 |     | 60.24     | 46.75      |
| 38.82 |     | 60.26     | 46.765     |
| 38.86 |     | 60.32     | 46.77      |
| 38.87 |     | 60.32     | 46.79      |
| 38.87 |     |           | 46.80      |
| 38.89 |     |           | 46.80      |
|       |     |           | 46.80      |
|       |     |           | 46.81      |

# Table II

# Spread of Values

| Number of | Average   | Maximum  | Average   |
|-----------|-----------|----------|-----------|
| Values    | Length    | Spread   | Deviation |
| 5         | 36.87 cm. | 0.03 cm. | 0.014 cm. |
| 7         | 38.85     | 0.09     | 0.03      |
| 5         | 43.75     | 0.10     | 0.03      |
| 9         | 46.78     | 0.09     | 0.025     |
| 7         | 47.38     | 0.05     | 0.02      |
| 6         | 58.16     | 0.08     | 0.02      |
| 5         | 60.27     | 0.09     | 0.04      |
| 7         | 61.43     | 0.07     | 0.02      |

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# THE EFFECT OF COMPOSITION ON THE SPECIFIC GRAVITY OF BINABY WAX MIXTURES

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Commercial waxes when used in binary mixtures show some interesting expansion results with increase of temperature. In the present study these results were observed over a temperature range of  $25^{\circ}$  C to  $80^{\circ}$  C. In some mixtures this expansion proved to be regular no matter what the percentages of the binary composition. With some other mixtures this was definitely not the case.

Because of the very many theoretical and practical applications and because of the accuracy with which the values can be determined, it was thought best to work out the problem by specific gravity or density determinations. The density of the wax mixtures at  $25^{\circ}$  was determined by the pycnometer method using a Hubbard pycnometer, and at higher temperatures it was determined by the dilatometer method.

The density of the commercial waxes at  $25^{\circ}$  C was determined in the following manner. Twenty grams of the wax were placed in a 50 milliliter beaker and heated on a steam bath until the wax melted. The melted wax was carefully poured in a petri dish to cool. This required from two to three hours for complete shrinkage. Small slabs of approximately one and a half by three centimeters were cut; the edges were smoothed, and the corners rounded. These were weighed. The Hubbard pycnometer was cleaned, dried, and weighed. It was filled with recently boiled and cooled distilled water, and again dried and weighed. The pycnometer stopper was removed. A weighed wax slab was lowered into the distilled water as carefully as possible to avoid the adherence of air bubbles. The stopper was replaced and the pynometer and contents were weighed. The density or specific gravity could be calculated at  $25/25^{\circ}$  C from the following equation.
# Specific Gravity Of Binary Wax Mixtures

Weight of the wax

Specific Gravity =  $-\frac{2}{A-B+Weight of the wax}$ 

where A = weight of the pycnometer filled with water, and B = the weight of the pycnometer, water, and wax sample. Results were reproducible to 0.001.

The specific gravity of the waxes at higher temperatures was determined by the dilatometer method. Ten milliliter graduated cylinders were cut off at the four milliliter mark, and the edges were fire polished. One milliliter Mohr pipettes graduated in hundredths were cut off, polished, and placed in rubber stoppers so that the ends were just even with the ends of the stoppers. The empty dilatometer was weighed, then the dilatometer and wax, and finally, the dilatometer, wax, and water were weighed. After these weighings were made the cut off Mohr pipette was inserted carefully so as not to trap any air bubbles, and the water rose to some constant level. This was taken as the initial reading. The dilatometer was placed in the water bath and the temperature was increased about cne degree per minute. Readings on the pipette were made at the desired temperatures. (Fig. 1).



Figure 1.



The volume of the wax was determined by dividing the weight of the wax sample by the specific gravity as calculated at  $25^{\circ}$  C. The volume of the water used was determined by dividing the weight of the water by the specific gravity of water at  $25^{\circ}$  C, which value can be obtained from a hand book. The total volume of wax and water used was obtained by adding these two volumes together.

The volume of water at the elevated temperatures was calculated. The total volume minus the volume of water equaled the volume of wax at the higher temperatures.

The specific gravity of the wax sample at the desired temperature was obtained from the equation

Specific Gravity =  $\frac{\text{Weight of wax}}{\text{Volume of wax}}$ 

The values at the higher temperatures agree to 0.01 or 0.02. In some cases the agreement is less than this. The volume of the dilatometer was read to the third place. but this third place was necessarily an estimation. A difference of 0.001 milliliters in volume makes a difference of about 0.01 in the specific gravity value, depending upon the wax used.

From the calculated specific gavity values at  $25^{\circ}$  C to  $80^{\circ}$  C the volume increase of the waxes were as follows:

| Mineral       | Waxes |       |
|---------------|-------|-------|
| Paraffin Wax  |       | 20.7% |
| Ozocerite Wax |       | 25.9% |
| Montan Wax    |       | 11.8% |

# Specific Gravity Of Binary Wax Mixtures

| Vegetable Waxes    |       |
|--------------------|-------|
| Carnauba Wax       | 12.0% |
| Candelilla Wax     | 18.7% |
| Japan Wax          | 15.1% |
| Ouricury Wax       | 11.0% |
| Animal Waxes       |       |
| Refined Beeswax    | 15.8% |
| Yellow Beeswax     | 15.1% |
| Chinese Insect Wax | 8.9%  |

It will be seen that the mineral waxes expand the most and animal waxes the least. The hard, microcrystalline, tough, high melting waxes show less expansion than those which are soft and have low melting points, and Chinese Insect Wax. which is a fairly hard, crystalline wax, shows the least expansion.

It was found that there is an interesting relation of the melting point to the extent of expansion. Usually where the melting point curve follows the normal pattern the expansion curve will likewise do so.

When the beeswax curves are studied certain similarities are noticed. The expansion between  $25^{\circ}$  C and  $30^{\circ}$  C is very slight. The greatest amount of expansion is between  $50^{\circ}$  C and  $60^{\circ}$  C. Mixtures of waxes with melting points lower than  $70^{\circ}$  C show very little expansion between  $70^{\circ}$  C and  $80^{\circ}$  C.

The most striking graph in this group is presented by the mixture of refined beeswax with yellow beeswax. (Fig. 2). Refined beeswax has a specific gravity at  $25^{\circ}$  C of 0.957 and yellow beeswax one of 0.953. Mixtures of these two waxes show an average value of 0.974 which means that the two waxes shrink in mixtures at  $25^{\circ}$  C. This change is equally observable at  $30^{\circ}$  C, less so at  $40^{\circ}$  C, still less at  $50^{\circ}$  C, and at  $60^{\circ}$  C,  $70^{\circ}$  C, and  $80^{\circ}$  C the average value is the same for the mixtures as it is for the individual waxes.

The greatest amount of expansion in the beeswax occurs with the largest percentages of beeswax except in the case of paraffin and ozocerite (Fig. 3). The  $25^{\circ}$  C and  $30^{\circ}$  C curves are regular. We see the increase of expansion toward the middle of the curve in the  $40^{\circ}$  C,  $50^{\circ}$  C, and  $60^{\circ}$  C curves.

The candelilla wax mixtures at 25° C give normal curves and the individual specific gravity values could be calculated from the values of the original waxes within the limits of experimental

error. The candelilla mixtures with vegetable waxes, with refined beeswax and with ozocerite wax show a decreased volume at  $30^{\circ}$  C. In most of the candelilla mixtures we see that between 30% and 70% of candelilla there is almost no increase in the amount of expansion.

The most interesting sets of curves are obtained with the carnauba mixture. The greatest amount of expansion with increase of temperature occurs where the percentage of carnauba is small. The specific gravity values of the wax mixture at  $25^{\circ}$  C can be calculated within the limits of experimental error from the values of the original waxes. A study of the carnauba wax-montan wax curves will point out this regularity in the  $25^{\circ}$  C curve. (Fig. 4).

This same graph can be used to point out that the 50-50% mixtures with carnauba call for special attention. The greatest percentage of expansion is found in these mixtures when carnauba is studied with refined beeswax, yellow beeswax, candelilla, Japan wax, montan, paraffin, and ozocerite. On the other hand, the greatest amount of shrinkage is found when equal amounts of carnauba and Chinese Insect wax are mixed. (Fig. 5).

The most regular sets of curves are obtained with the paraffin wax mixtures. The paraffin wax—montan wax curves serve as an example. (Fig. 6). The 25°, 30°, and 40° curves are very regular. There are only slight deviations in the 50°, 60°, and 70° curves. The 80° curve again follows the regular pattern. The experimental specific gravity values for the mixtures at 25° C agree very accurately with the calculated values in all the mixtures except those with carnauba (where the difference is more marked). The greatest amount of expansion occurs between 40° C and 50° C. In most cases the amount of expansion increases with the increase of the percentage of paraffin.

A careful study of the graphs and a check with mathematical calculations show that in most cases the values for the specific gravity of the wax mixtures at  $25^{\circ}$  C can be calculated from the values of the components and that the experimental values agree very well with the calculated values, except in the cases pointed out. Most of the calculated values for higher temperatures have been found to agree with the experimental values by 0.01, and rarely have the differences been more than 0.02.



Specific Gravity Of Binary Wax Mixtures

Figure 3, top left Figure 4, top right Figure 5, bottom left Figure 6, bottom right

One other set of observations may be made. The mixture of a soft low melting wax with another soft low melting wax exhibits a very normal expansion between the  $30^{\circ}$  and  $40^{\circ}$  curves. Past this temperature the mixtures show more expansion than do the original components.

The mixture of a soft low melting wax with a hard micro crystalline high melting wax or with a hard crystalline wax also give normal curves.

When hard high melting waxes are mixed together their curves exhibit marked abnormalities as was pointed out in the carnaubamontan mixtures. When these same waxes are mixed with hard crystalline waxes marked volume changes are noticed at the different temperatures. The carnauba-Chinese Insect wax mixtures illustrate this point.

We may summarize our conclusions as follows:

- 1. Various waxes exert different effects upon the expansion of any individual wax.
- 2. The greatest amount of expansion occurs just before the melting point of the wax mixture.
- 3. Paraffin wax mixtures give the most normal sets of curves.
- 4. Carnauba wax exerts the most marked effect in expansion values. The 50 - 50 mixtures show the greatest deviations.
- 5. Candelilla wax mixtures tend to shrink most in the neighborhood of 30° C.
- 6. Hard, microcrystalline, high melting waxes show less expansion in the  $80^{\circ}$  range.
- 7. Chinese Insect wax which is a fairly hard, crystalline, high melting wax shows the least expansion.
- 8. Mixtures of soft low melting waxes with each other or with other waxes, at temperatures higher than 40° C expand more than do the original wax components.
- 9. When hard high melting waxes are mixed together, or are mixed with high melting crystalline waxes their curves show marked abnormalities. Examples: carnauba-montan, carnauba-Chinese Insect wax.
- 10. Care should be taken in calculating the specific gravity of a wax mixture unless the specific gravity versus composition curve at the desired temperature is known to be a straight line.

# CHROMOSOME BEHAVIOR IN A SECOND GASTERIA-ALOE HYBRID

# Herbert Parkes Riley University of Kentucky

The author (Riley, 1948) has recently described the behavior of the chromosomes in a putative hybrid between *Gasteria* and *Aloe*, found among a collection of succulents growing at the University of Kentucky. More recently, a second putative hybrid has been studied from the same collection. Both plants had been obtained from



Figure 1

Mr. Charles Cass of Pacific Grove, California, but are considerably different in general appearance.

The second plant is herbaceous and has a very short stem. The leaves form a rosette but lack the prominent spines so often present on the margins of *Aloc* leaves (Fig. 1). The leaves are pale

green, approximately the color of those of *Gasteria sulcata* and they are not covered with white dots. The flowers resemble those of *Aloe*, being straight at the end and not swollen at the base, but the racemes are lax and not dense and, except for a tendency to be not secund, are like those of *Gasteria* (Fig. 2). The inflorescences and flowers of the two putative hybrids are much alike.

Observations – Pairing at the first meiotic metaphase was much more frequent than it was in the hybrid reported previously, al-



Figure 2

# Chromosome Behavior In A Second Gasteria-Aloe Hybrid.

though not so frequent as has been observed in plants of either genus. As Table I shows, there was a large proportion of cells with three or four bivalents among the eight long chromosomes. The chiasma frequency was 1.40 per bivalent and 0.51 per chromosome, and about 45 per cent of the chiasmata were terminalized. The six short chromosomes showed a greater tendency to pair than did the long ones, and no cell showed a complete failure of pairing among the short chromosomes. The chiasma frequency was apparently 1.00 per bivalent and 0.43 per chromosome, and all the chiasmata were terminalized.

| Table 1 | Т | able | I |
|---------|---|------|---|
|---------|---|------|---|

Frequency of bivalents at first meiotic metaphase in a Gasteria-Aloe hybrid.

| of Eight long chromosomes |  | Six short ch  | romosomes   |
|---------------------------|--|---|---|
| No. of cells              | Per cent   | No. of cells  | Per cent  |
| 35                        | 28.93  |   |   |
| 55                        | 45.45  | 74  | 67.27   |
| 18                        | 14.88  | 29  | 26.36   |
| 10                        | 8.26   | 7   | 6.36  |
| 3                         | 2.48   | 0   | 0.00.   |
| 121                       | 100.00   | 110   | 99.99   |
|                           | Eight long chi<br>No. of cells<br>35<br>55<br>18<br>10<br>3<br><br>121 | Eight long chromosomes           No. of cells         Per cent $35$ $28.93$ $55$ $45.45$ $18$ $14.88$ $10$ $8.26$ $3$ $2.48$ $$ $$ $121$ $100.00$ | $\begin{array}{c ccccc} Eight long chromosomes & Six short ch \\ No. of cells & Per cent & No. of cells \\ 35 & 28.93 \\ 55 & 45.45 & 74 \\ 18 & 14.88 & 29 \\ 10 & 8.26 & 7 \\ 3 & 2.48 & 0 \\ \hline 121 & 100.00 & 110 \\ \end{array}$ |

There were a number of irregularities at first anaphase and only 48 of the 87 cells which were examined showed a 4-4 distribution of the long chromosomes. In four cells the distribution was 4-3 with one chromosome lagging on the equator and in one cell was 4-2 with two laggards. In 24 cells there was an equational separation of one or more chromosomes at the first division. In nine cells the distribution was 5-3 and in one cell it was 6-2. Six cells had chromatid bridges with fragments. For the short chromosomes, 90 per cent of the cells were normal. In one cell there was a 4-2 distribution and a few cells had lagging chromosomes or the equational separation of chromatids. A chromatid bridge between the short chromosomes was present in one cell.

Of 320 cells in first telophase, 190 appeared normal. In 115 cells there was one micronucleus and in 15 cells two micronuclei were found.

Thirty-eight cells were examined in anaphase of the second meiotic division. In 26, four long chromosomes were going to each pole on both spindles, but the other twelve cells showed various abnormalities including lagging chromosomes. The loss of chromosomes or of chromatids at the first meiotic division was clearly reflected in some of the cells at second anaphase. In two figures chromatid bridges connected the two daughter nuclei on one spindle, and in one figure a bridge appeared to connect one nucleus of each spindle.

Second telophase did not appear so abnormal as in the hybrid previously reported. The tetrad consisted of four daughter cells in about 74 per cent of the figures, and all four nuclei always appeared to be about the same size. "Tetrads" of five cells were found in about 24 per cent of the figures, groups of six cells in two per cent, and a group of seven cells was found once. When the "tetrad"

# Table II

Stages of successive buds on the main raceme of a *Gasteria*-Aloe plant. The buds with the lowest numbers are the smallest.

Bud

Stage

- 1 Early prophase of first meiotic division (leptotene and zygotene).
- 2 Zygotene through diplotene.
- 3 First metaphase through second telophase.
- 4-8 Tetrads; microspores together.
- 9-16 Microspores separated; nuclei generally central; in later buds some nuclei towards one side of cells which are somewhat more elliptical; in buds 15 and 16, some cells shrunken.
  - 17 Same but an occasional prophase of the microspore division.
  - 18 Some cells empty; cytoplasm becoming very oily in most cells; an occasional dividing cell, chiefly in prophase.
- 19-20 More cells appear empty; only a few have nuclei.
- 21-40 All but a very small per cent empty and shriveled; none with two nuclei.

Chromosome Behavior In A Second Gasteria-Aloe Hybrid.

consisted of more than four cells, one or two were frequently smaller than the others.

In spite of the normal appearance of well over half the te-trads, the mature pollen appeared to be 100 per cent inviable. As Table II shows, development proceeds normally until the tetrad stage. The microspores separate from one another normally and begin to take on a mature shape and to develop a pollen grain wall, but very few develop so far as the nuclear division. Most of them remain in interkinesis. Their cytoplasm becomes very oily and sooner or later the nucleus and cytoplasm disappear and the cells appear to be merely shrunken pollen grain walls. No microspore metaphases or anaphases were observed, but a few cells were found in prophase. When cells were studied from buds of various sizes, about four per cent appeared to be shrunken and empty shortely after meiosis. About one per cent was unusually large and probably was a diploid microspore, and about two per cent were unusually small but ap-parently contained cytoplasm and a nucleus. About four per cent of the cells that seemed to be otherwise normal contained one or two micronuclei. On the other hand, in one of the largest unopened buds there were 497 shrunken and empty cells, four large cells without nuclei, and 27 cells that were unusually small but which appeared to contain cytoplasm but no visible nucleus; no cell appeared to be normal in the largest buds.

Meiotic pairing in this plant was considerably more frequent than in the plant previously described, which would indicate a greater homology between the genomes of its parents. However, both plants appear to be 100 per cent pollen sterile. The high percentage of bivalents would suggest that some mature pollen grains would be found. It is possible that the failure to find any fertile grains is in part due to a disharmony between chromosomes and cytoplasm in an intergeneric cross.

# LITERATURE CITED

Riley, H. P. 1948. Chromosome studies in a hybrid between Gasteria and Aloe. Amer. J. Bot. 35: 645-650.

# ACADEMY AFFAIRS

# THE 1949 FALL MEETING

The thirty-fifth annual meeting of the Kentucky Academy of Science was held at Eastern State College, Richmond, Kentucky on Friday afternoon and Saturday morning, October 21 and 22, 1949.

Main feature of the Friday afternoon program was a symposium on "Recent Scientific Developments." Participating in this program were:

- Dr. J. M. Schreyer, University of Kentucky. "Recent Developments in Chemistry."
- Dr. D. M. Bennett, University of Louisville. "Recent Developments in Physics."
- Dr. W. R. Jillson, Transylvania College, "Recent Developments in Geology."
- Dr. J. S. Bangson, Berea College. "Recent Developments in Biology."
- Mr. J. Stephen Watkins, President of the Kentucky Chamber of Commerce. "Recent Industrial Development in Kentucky."

Following the annual dinner of the Academy Friday evening there was held a symposium on "Research Facilities in Kentucky". Speaking on this symposium were:

- Dean R. C. Ernest, Dean of the Speed Scientific School, University of Louisville. "Research Facilities at the University of Louisville."
- Dr. Leo Chamberlain, Vice-President of the University of Kentucky. "Research Facilities at the University of Kentucky."
- Mr. Ervin Kaufman, Chief-Chemist, Hirsch Bro. & Co., Louisville. "Research Facilities in Kentucky Industries."

At the business meeting Saturday morning officers were elected for the Academy year, 1949-1950.

President: W. E. Blackburn, Murray State College, Murray
Vice-President: E. B. Penrod, University of Kentucky, Lexington.
Secretary: C. B. Hamann, Asbury College, Wilmore.
Treasurer: R. H. Weaver, University of Kentucky, Lexington.
Representitive to the Council of the A.A.A.S.: Austin R. Middleton, University of Louisville, Louisville.

William Moore and Mary E. Wharton were elected to serve on the Board of Directors until 1953.

Following the Saturday morning business meeting the various Divisions of the Academy met for the presentation of specialized papers and for the transaction of divisional business. The programs of the various Divisions are recorded as follows:

# Academy Affairs

Medical Technology and Bacteriology

Miss Mary Benedict Clark, Presiding.

"A comparison of methods of giving blood transfusions". L. C. Harrison, Good Samaritan Hospital and University of Kentucky, Lexington.

"Rh-Hr classification and antibody determination". Mary Benedict Clark, Louisville.

"Techniques of Huggins thermal coagulation test for carcinoma". Oscar M. Alton, Norton Infirmary, Louisville.

"Quick microtenchniques for bacteriological work". R. H. Weaver, University of Kentucky, Lexington.

"Mycological techniques in clinical diagnosis". Margaret Hotchkiss, University of Kentucky, Lexington.

"A weekly mold survey of air and dust in Lexington". M. Elizabeth Wallace, R. H. Weaver and M. Scherago, University of Kentucky, Lexington.

"Problems in the standardization of allergenic extracts". Morris Scherago, University of Kentucky, Lexington.

"The laboratory production of penicillin". Robert Blair, University of Kentucky, Lexington.

Marcus Allen, Howard Clinic, Glasgow, Kentucky, was elected Chairman of the Division of Medical Technology and Bacteriology for the coming year. *Biology Division* 

Dr. Joe Neel, Presiding.

"Observations on the life history of *Cyclops bicuspidatus thomasi*". Gerald A. Cole, University of Louisville, Louisville.

"Biographical data on the life of Sadie F. Price, Kentucky naturalist." Harvey B. Lovell, University of Louisville, Louisville.

William M. Clay, University of Louisville was elected Chairman of the Biology Division for the coming year.

Engineering.

Prof. E. B. Penrod, Presiding.

"Finishing steels for decorative and corrosion resistance purposes". Reid Kenvon, Armco Steel Co.

"Research in highway engineering". William B. Drake, Kentucky Department of Highways.

"The heat pump from a home owner's viewpoint". O. G. Petersen, Somerset, Kentucky.

"Teaching electronics at the junior college level". H. Alex Romanowitz, University of Kentucky, Lexington.

"Physiological aspects of flight". W. F. Savage, University of Kentucky, Lexington.

"Hydrogen manufacture". Robert Reed, Girdler Corporation, Louisville.

"Chemical colors". J. D. Todd, Kentucky Color and Chemical Co., Louisville.

"Aluminum in the petroleum industry". William B. Moore, Reynolds Metals Co., Louisville.

"Manufactured tobacco products". Jesse Simpson, Brown and Williamson Tobacco Corp., Louisville.

E. B. Penrod, University of Kentucky was reelected Chairman of the Engineering Division for the coming year.

#### Chemistry.

#### Dr. G. L. Corley, Presiding.

"The banding of silver chromate and silicic acid gel". Miss Cooper, Centre College, Danville.

"Increase in dissolved solids and acidic components during the aging of whisky". M. C. Brockmann, Joesph E. Seagram & Sons, Inc., Louisville.

"A preliminary characterization of lespedeza seed oil". Richard H. Wiley and A. W. Cagle, University of Louisville.

"Soil iodine". Forrest G. Houston, Kentucky Agricultural Experiment Station, Lexington.

"Determining sugars in plant material". J. H. Hamilton, Ivan Stewart and M. E. Weeks, Kentucky Agricultural Experiment Station, Lexington.

"Comparative rates of growth and calcification of the humeri of male and female New Hampshire chickens having crooked keels". G. Davis Buckner, W. M. Insko, Amanda H. Henry and Elizabeth F. Wachs, Kentucky Agricultural Experiment Station, Lexington.

"Comparative rates of growth and calcification of the femur, tibia and metatarsus bones of male and female New Hampshire chickens having crooked keels". G. Davis Buckner, W. M. Insko, Amanda H. Henry and Elizabeth F. Wachs, Kentucky Agricultural Experiment Station, Lexington.

"The catalase activity of normal tissues". Sister Mary Julitta, Donna Keller and Richard Klare, Villa Madonna College, Covington.

"Effects of *Staphylococcus aureus* on blood and liver catalase in mice". Sister Rose Agnes, Sister Mary Adeline and Cornelius W. Kreke, Nazareth College Unit of Institutum Divi Thomas, Louisville.

"Some observations on tidal disturbances in the atmosphere". G. C. Mance, Union College, Barbourville.

"The effect of composition on the specific gravity of binary wax mixtures". John R. Koch, Marquette University, and Sister M. Concetta, Ursuline College, Louisville.

"Pigment derived from dioximes". Max I. Bowman, Carl E. Moore, Leonard Viola and Shelden Weinstein, University of Louisville.

"Cyclo octa tetraine". Norman O. Long, University of Kentucky, Lexington. Dr. T. C. Herndon, Eastern State College was elected Chairman of the Chemistry Division for the coming year.

The final event of the Richmond meeting was an address by the Hon. Charles Farnsley, Mayor of Louisville. Mayor Farnsley spoke on "The Role of Scientists in City Government" at a Saturday luncheon in the Student Union Building.

The following faculty members of Eastern State College served as the Committee on Arrangements for the Richmond meeting: Anna A. Schnieb (Chairman), T. C. Herndon, Meredity Cox J. G. Black, L. G. Kennamer and Smith Park.

# Academy Affairs

### THE 1950 SPRING MEETING

Murray State College was host to the Kentucky Academy of Science at its spring meeting held on Friday and Saturday, April 28 and 29, 1950. It is the intent of the Academy that these spring meetings, which were inaugarated last year at Cumberland Falls State Park, should provide the maximum opportunity for field trips in regions of the Commonwealth which are of special interest to outdoor scientists.

Following registration Friday afternoon provision was made for an inspection of the new science building at Murray State College. President of the Academy, W. E. Blackburn of Murray State College presided at the Friday afternoon program. The following papers were presented:

"Geological sketch of the Jackson Purchase". E. B. Wood, Kentucky Geological Survey.

"A look at Kentucky Woodlands". Eugene Cypert, U. S. Fish and Wildlife Service.

"Wild turkey in Kentucky Woodlands". John DeLime, Kentucky Division of Fish and Game.

At the dinner Saturday evening, Dr. R. H. Woods, President of Murray State College gave a short address of welcome. Following dinner, members and guests reconvened for a general program consisting of addresses on:

"Research and development activities at the T.V.A. chemical works, Wilson Dam, Ala.", Ralph Stitzer, Tennessee Valley Authority.

"Recent advances in medical science". Hugh L. Houston, Kentucky State Medical Association.

"Indian corn in Old America". Paul Weatherwax, Indiana University, Bloomington.

The program for Saturday was intended to provide members an opportunity to participate in a variety of field trips or to pursue special outdoor interests. The schedule provided for a trip to Kentucky Woodlands, a sightseeing tour of Kentucky Lake, an inspection of the Kentucky Dam and Generating Station and a conducted tour through the plant of the Pennsylvania Salt & Manufacturing Co. which produces hydrofluoric and sulfuric acids. Facilities were provided for small fishing parties.

Arrangements were made for a Saturday noon luncheon. In the evening the membership of the Academy was invited to a social and informal dance sponsored jointly by the honory biological sciences fraternity and the American Chemical Society student affiliate chapter of Murray State College.

Preparations for the meeting were in the hands of the following committees which were drawn from the faculty of Murray State College:

Program-A. M. Wolfson (Chairman), Grace Wyatt and Peter Panzera. Dinner-Mrs. A. M. Wolfson.

Arrangements-C. W. Kemper (Chairman), Collus Johnson, William G. Reed, Paul Bryant and R. A. Johnston.

Registration–Liza Spann (Chairman), Roberta Whitnah, A. G. Canon, and R. E. Goodgion.

# THE 1950 FALL MEETING

The thirty-sixth annual meeting of the Academy will be held at the University of Louisville on October 27 and 28, 1950. All sessions will meet in the main building of the Speed Scientific School, located on the south side of Eastern Parkway near South Third Street.

The program of Friday afternoon will consist of conducted tours to certain industrial plants in Louisville. These tours will leave the University of Louisville at 2:30 p.m., and will return in time for the annual dinner at the Seelbach Hotel at 5:30. The guest speaker at the dinner is to be Dr. Anton J. Carlson, of the University of Chicago, who will address the Academy on "Science and Society". It is necessary to meet promptly for the dinner, inasmuch as Dr. Carlson must leave Louisville at 8:00 o'clock for another engagement. A business session will conclude Friday's activities.

Saturday morning will be allotted to scientific sessions, held in the Speed Scientific School, and to any remaining matters of business.

#### CALL FOR PAPERS

A third number of the TRANSACTIONS can be published before the end of the present calendar year if a sufficient number of manuscripts are submitted to the editors in the near future.

# NOTICE TO CONTRIBUTORS

The TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE is a medium for publication of original investigations in science. In addition, as the official organ of the Kentucky Academy of Science, it publishes programs of the meetings of the Academy, abstracts of papers presented before the annual meetings, reports of the Academy's officers and committees, as well as news and announcements of interest to the membership.

Manuscripts may be submitted at any time to the co-editors:

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Bibliographic citations should follow textual material (except in Research Notes, see later). Abbreviations for the names of periodicals should follow the current system employed by either Chemical Abstracts or Biological Abstracts. Bibliographic citations in Research Notes should be in the same form as for longer papers but enclosed in parentheses within the text of the note.

Footnotes should be avoided. Titles must be clear and concise, and provide for precise and accurate cataloguing.

Tables and illustrations are expensive, and should be included in an article only to give effective presentation of the data. Articles with an excessive number of tables or illustrations, or with poorly arranged or executed tables or illustrations may be returned to the author for modification.

Textual material should be in clear, brief and condensed form in order for a maximum amount of material to be published.

Reprints must be ordered at the time galley proof is returned.

The following individuals, educational institutions and industrial organizations have subscribed to one or more sustaining memberships in the KENTUCKY ACADEMY OF SCIENCE.

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# TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

Official Organ

KENTUCKY ACADEMY OF SCIENCE

#### CONTENTS

| Bibliography of Sarah F. Price, Kentucky Naturalist.<br>Harvey B. Lovell   | 121        |
|--|------------|
| The Electrical Conductance of Solutions of Ferric Chloride in<br>Acetone at 20° and 40° C. Lyle R. Dawson and Ralph<br>L. Belcher  | 129        |
| The Distribution of Alkali Iodides Between Ethylene Glycol<br>and Ethyl Acetate. Lyle R. Dawson and Edward J.<br>Griffith  | 137        |
| The Free Energy of Copper Chromate. Sigfred Peterson and<br>Orland W. Cooper   | 146        |
| Emissivities of Protective Coatings. W. R. Barnes and N. P. Shah<br>Performance of an Earth Heat Pump Operating Intermittently on  | 149        |
| the Cooling Cycle. E. B. Penrod and R. C. Thornton<br>Effects of Staphylococcus aureus Infections on Blood and Liver<br>Catalase in Mice. I. Titrimetric Method. Sister Mary<br>Adeline O'Leary, S.C.N., Sister Virginia Heines, S.C.N.,<br>Sister Roderick Juhasz, S.C.N., Sister Rose Agnes Green-<br>well, S.C.N., and Corenlius W. Kreke | 156<br>173 |
| Effects of Staphylococcus aureus Infections on Blood and Liver<br>Catalase in Mice. II. Gasometric Method. Sister Mary<br>Adeline O'Leary, S.C.N., Sister Virginia Heines, S.C.N.,<br>Sister Roderick Juhasz, S.C.N., Sister Rose Agnes Green-<br>well, S.C.N., and Corenlius W. Kreke   | 178        |
| Antibotic-Producing Species of <i>Bacillus</i> from Well Water.<br>R. H. Weaver and Theodore Boiter  | 183        |
| Subsurface Earth Exploration By Electrical Resistivity Method.<br>L. C. Pendley  | 189        |
| Mailing List   | 201        |
| Academy Affairs  | 208        |

# KENTUCKY ACADEMY OF SCIENCE

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Correspondence concerning membership in the Academy, subscriptions or other business matters should be addressed to the secretary. Manuscripts and other material for publication should be addressed to the editors.

# BIBLIOGRAPHY OF SARAH F. PRICE, KENTUCKY NATURALIST

By Harvey B. Lovell Biology Department, University of Louisville

Louisville, Kentucky

# INTRODUCTION

Sarah Frances Price was born in Evansville, Indiana, in 1849, the daughter of Alexander and Maria Morehouse Price. The family moved to Bowling Green, Kentucky, while she was still quite young. She was educated at a church school in Terra Haute, Indiana, An injury to her back invalided her for many years but after six months' treatment by Dr. Weir Mitchell of Philadelphia, she was sufficiently improved to follow her interests in natural history. Miss Price first taught a class painting but later gave a course in nature study. From 1889 to 1893 she prepared an exhibit of water-color sketches of the native plants and birds of Warren County, Kentucky, for an exhibit at the Chicago World's Fair; this exhibit took first place in it class. She had previously published two compilations, Songs from the Southland in 1890, and Shakespeare's Twilights in 1892. The list of plants which she had made while preparing her plant exhibit for the fair she privately published as the Flora of Warren County, Kentucky in 1893. It contained 714 species of vascular plants. In several copies of this list which I have seen, Miss Price has written in 255 additional species, the number which she found during the next ten years.

Miss Price now began to subscribe to several botanical journals and published many short articles on her discoveries. Many of these are quotations from letters which she wrote to the editors. Several contain questions which are answered then or later. Her earliest contributions were to GARDEN AND FOREST, the ASA GRAY BULLETIN, and the LINNAEAN FERN BULLETIN (later called the FERN BULLETIN). She also wrote for the PLANT WORLD. Her most extensive botanical work was *The Fern Collectors' Handbook* published by Henry Holt and Co. in 1897, which contained drawings of the ferns of northeastern United States. In 1898 she printed privately the *Trees and Shrubs of Kentucky*, which contained a list of 255 species of woody plants.

Miss Sadie was an all round naturalist and made observations in several other fields. Many of these were published, such as her

articles on A Peculiar Stone Mound, Kentucky Folk Lore, and the Mollusca of Southern Kentucky, the latter containing a list of 151 species of mollusks which she wrote that she had collected "while engaged in botanical work." She also wrote several articles on birds, although most of her bird observations were never published. Her drawings of birds are mounted in a large book which was deposited in the library of the Missouri Botanic Garden by her sister in 1908. There is also a portfolio of water-color sketches of moths and butterflies in the same library. The majority of these include the caterpillar on the host plant, the chrysalis, and the mature insect. She had evidently reared these from caterpillars to the adult stages.

Her sudden death (from dysentery) on July 3, 1903, at the age of 54 left much unpublished material and many projects unfinished. Several of her unpublished manuscripts were submitted for publication by her sister and life long companion, Mary Price. Miss Sadie had been earlier commissioned by Willard N. Clute, editor of the FERN BULLETIN, to prepare an article on the fern flora of Kentucky. This appeared in the July, 1904, issue with the comment that it had been complied from her notes. Other posthumous contributions were her illustrated manuscript on Kentucky Oaks published in the PLANT WORLD in February, 1904, and two bird articles in the AMERICAN ORNITHOLOGIST also in 1904. An autobiographical article describing in detail one of her longer field trips was entitled "Perusin" the "Pennyrile" County. It appeared in two parts in the AMERICAN BOTANIST for December, 1906, and January, 1907. In this paper Miss Price describes her visits with one companion to the back country along the Green and Nolin rivers in search of rare plants.

Much of Miss Price's fame rests on her discovery of several new species of plants, five of which were named in her honor. These were *Cornus Priceae* Small, *Oxalis Priceae* Small, *Viola Priceana* Pollard, *Apios Priceana* Robinson, and *Aster Priceae* Britton. Other species discovered by her include *Clematis flaccida* Small, *Lycopodium porophilum* Lloyd and Underwood, *Polyporus juniperus* Schrenk, and *Ganoderma sessile* Schrenk. A sketch of her life appeared in *Who's Who in America* (1903-1905). The FERN BUL- LETIN published a brief biography of her life in the January, 1904, issue which contains the only known picture of Miss Sadie.

Miss Price's nature class at Bowling Green continued to meet regularly for nearly thirty years after her death. The members called themselves the Sadie Price Nature Class and continued to explore and collect in Warren County, the locale of her labors.

# The Bibliography

- 1890. Songs from the Southland, selected by S. F. Price. D. Lothrop and Company, Boston. 32 pages, illus.
- 1892. Shakespeare's Twilights. D. Lothrop and Company, Boston. Illus. Part I. Shakespeare's mornings. Part II. Shakespeare's sunsets.
- 1893a. Flora of Warren County, Kentucky. C. F. Carr, Printer, New London, Wisconsin. 31 pages.

A list of 714 species of vascular plants. In addition to the scientific name and common name, a local name is occasionally added. The copies in the Missiouri Botanic Garden, the Filson Club, and the Louisville Public Library have 255 additional species written in, bringing the list to 969.

- 1893b. Cave plants. Garden and Forest, vol. 6, no. 292, p. 403. "A different growth of plants is to be found in the cave entrances and large sink holes than along the banks of streams." She describes Wolf's Sink and Lost River.
- 1893c. A rare fern. Garden and Forest, vol. 6, no. 262, pp. 99-100. Asplenium Bradleyi was found September 10, 1892 in a very wild spot 13 miles from Bowling Green.
- 1894a. The buck bush. *Garden and Forest*, vol. 7, no. 438, p. 429. Deer formerly fed on the bush.
- 1894b. The ferns of Warren County, Kentucky, Part I. Illustrated Kentuckian, vol. 2, no. 11, March.
- 1894c. The ferns of Warren County, Kentucky, Part II. Illustrated Kentuckian, vol. 2, no. 12, p. 277, April.

- 1894d. The ferns of Warren County, Kentucky, Part III. Illustrated Kentuckian, vol. 3, no. 1, p. 291 and pp. 294-295. May.
- 1895. Queer misfortunes of birds. American Naturalist, vol. 29, p. 341.

A crow blackbird died from entanglement in string and a hairy woodpecker was found dead with its bill stuck in a tree.

1896a. A plea for the trees. Bowling Green Courier, March 6, Friday. She states that trees are being trimmmed so badly that

many die. Article is signed P. F. S. (In scrapbook).

- 1896b. Kentucky birds. Bowling Green Courier, May 31, Sunday. "I have frequently been asked to give a list of Kentucky song birds." She then lists by families the species which she considers songsters.
- 1896c. Two rare ferns-Asplenium Bradleyi and Trichomanes radicans. Garden and Forest, vol. 9, no. 451, p. 418.

In a letter to editor she describes the finding of these ferns on a trip to Edmonson County. She noted many changes in the flora since Professor Shaler had camped there in 1875.

- 1896d. A few Kentucky plants. Asa Gray Bulletin, vol. 4, no. 6, p. 66. Miscellaneous notes on albino blackberries, Solanum rostratum, and the spider lily ("the most fragrant flower").
- 1896e. Trichomanes radicans. The Linnaean Fern Bulletin, vol. 4, no. 4, pp. 57-59.
- 1896f. Ophioglossum vulgatum. The Linnaean Fern Bulletin, vol. 4, no. 4, pp. 61-62.
- 1896g. (No title; in: Our Miscellany). The Linnaean Fern Bulletin, vol. 4, no. 4, p. 66. A note on a forked frond of *Trichomanes radicans.*
- 1897a. The fern-collector's handbook and herbarium. Henry Holt

and Company, New York. 72 drawings.

Opposite each drawing there is a blank page to be used for mounting ferns. There are no descriptions but a guide in front is arranged in part as a key.

1897b. Albino plants. Asa Gray Bulletin, vol. 5, no. 3, p. 47. Signed S. F. Rice but was pasted in her scrapbook.

- 1897c. A peculiar stone mound. The Antiquarian, vol. 1, p. 107. An oblong knob named "Indian Fort" in Warren County has a group of limestone slabs, set endwise at regular distances.
- 1898a. Trees and shrubs of Kentucky. Privately printed. 6 pages. A list of 255 woody plants based on work of several botanists including her own. The list contains 145 trees and 110 shrubs and woody climbers. Seven additional species have been added in writing to the copy in the Filson Club library.
- 1898b. (No title; in: Our Miscellany). The Fern Bulletin, vol. 6, no. 2, p. 30.She describes the growing of ferns indoors in winter.
- 1898c. (No title; in: Our Miscellany). The Fern Bulletin, vol. 6, no. 2, p. 31.

She asks about a crested form of Aspidium marginale.

1899a. (No title; in: Notes and News). Plant World, vol. 2, No. 10, p. 175.

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This is a plea for the protection of the plants of the eastern mountains.

The heaven tree. Louisville Times

Miss Price states that if the tree is prevented from flowering by cutting back the branches every second year, the bad odors are eliminated.

No title. Louisville Post. Not signed but S. F. Price

An article about the need for bird protection. written at the bottom of the copy in the scrapbook.

# THE ELECTRICAL CONDUCTANCE OF SOLUTIONS OF FERRIC CHLORIDE IN ACETONE AT 20° AND 40°C

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A study of the conductance of solutions of ferric chloride in acetone was undertaken with a view toward obtaining evidence concerning the nature and extent of dissociation of a tri-univalent salt in a solvent having a relatively low dielectric constant. Generally, it is assumed that no strong electrolytes exist in non-aqueous solutions where the dielectric constant of the solvent is less than 40 (1). Therefore it seemed of interest to study the influence of temperature on the primary dissociation of a 3-1 electrolyte and investigate the extent to which secondary dissociation occurs.

Anhydrous ferric chloride dissolves readily in acetone with the liberation of considerable heat. In dilute solutions, the heat effect may be caused by solvation or it may result from neutralization in the Lewis sense. Timmermans (2) reported that in more concentrated solutions the yellow color produced at first deepens rapidly and evidence of extensive reaction appears; however, de Coninck (3) found that dilute solutions of ferric chloride in acetone are stable.

Rabinowitch and Stockmayer (4) have reported evidence that aqueous solutions of ferric chloride contain a variety of forms of ions including Fe  $(OH)^{++}$ , Fe  $(OH)_{2}^{+}$ , FeCl<sup>++</sup>, and FeCl<sub>2</sub><sup>+</sup>. No report of extensive studies of the molecular or ionic species occurring in solutions of ferric chloride in acetone has appeared.

# EXPERIMENTAL PROCEDURES

Commercial anhydrous ferric chloride, which analysis by the Mohr method and titration with standard dichromate showed to

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be better than 99.5% pure, was used without further purification.

Samples of acetone having a specific conductance as low as  $4 \times 10^{-8}$  ohm<sup>-1</sup> cm.<sup>-1</sup> were prepared by successive distillations from argentic oxide, sodium hydroxide, and anhydrous calcium oxide collecting only the middle fractions each time. However, solvent of this purity was very hygroscopic and seemed to offer no particular advantage. Every sample used in this investigation had a specific conductance of  $3.8 \times 10^{-7}$  ohm<sup>-1</sup> cm.<sup>-1</sup> or less.

A shielded bridge similar to that described by Shedlovsky (5) was used for the resistance measurements, the null-point being determined by use of headphones. The conductivity cell was of the Freas type having a constant of approximately 0.4, which was determined by the method of Jones and Bradshaw (6). Between  $20^{\circ}$  and  $40^{\circ}$  the change in cell constant was negligible.

A water-bath which maintained the temperature constant to within  $\pm 0.01^{\circ}$  held the conductivity cell and the viscometer. Viscosity data obtained for the solvent used were in good agreement with the values reported in the literature (7).

All dilutions were made in a dry atmosphere and the solutions were prepared on a volumetric basis directly in the conductivity cell. In these dilute solutions, the molar concentrations were assumed to be equal to the product of the density of the solvent and the molal concentration.

The conductances of solutions of ferric chloride in acetone were determined over the concentration range 0.00266 M to 0.00025 M at  $20^{\circ}$  and  $40^{\circ}$ , with some additional values being obtained at higher concentrations. Averages of duplicate or triplicate determinations comprise the data presented.

Electrical Conductance of Solutions of Ferric Chloride

# Results

# TABLE ISolutions of Ferric Chloride in Acetone at 20°C

|                             |             |             |                      |              | Thermodynamic       |
|-----------------------------|-------------|-------------|----------------------|--------------|---------------------|
|                             |             | Mean        | Dissociation         | Degree of    | Dissociation        |
| Concentration               | Equivalent  | Activity    | Function             | Dissociation | Constant            |
| (Molar; x 10 <sup>3</sup> ) | Conductance | Coofficient | (Ostwald; x $10^3$ ) | (Fuoss)      | (x10 <sup>3</sup> ) |
| 0.00                        | 109.9       |             |                      |              |                     |
| 0.2603                      | 95.2        | 0.877       | 1.49                 | 0.934        | 1.15                |
| 0.7101                      | 84.2        | 0.812       | 1.80                 | 0.864        | 1.19                |
| 0.8115                      | 82.7        | 0.801       | 1.88                 | 0.856        | 1.20                |
| 0.8739                      | 82.3        | 0.795       | 1.98                 | 0.856        | 1.25                |
| 0.9467                      | 80.0        | 0.790       | 1.88                 | 0.836        | 1.17                |
| 1.033                       | 79.2        | 0.782       | 1.95                 | 0.832        | 1.19                |
| 1.136                       | 78.0        | 0.777       | 2.01                 | 0.826        | 1.20                |
| 2.271                       | 67.3        | 0.706       | 2.22                 | 0.755        | 1.11                |
|                             |             |             |                      |              |                     |

# TABLE II

# Solutions of Ferric Chloride in Acetone at $40^{\circ}C$

|             |  |  |  | Thermodynamic   |
|-------------|--|--|--|---|
|             | Mean   | Dissociation   | Degree of  | Dissoclation  |
| Equivalent  | Activity   | Function   | Dissociation   | Constant  |
| Conductance | Coefficient  | (Ostwald; x $10^3$ )   | (Fuoss)  | (x10 <sup>3</sup> )   |
| 116.2       |  |  |  |   |
| 102.1       | 0.829  | 3.01   | 0.982  | 2.07  |
| 100.8       | 0.815  | 3.21   | 0.980  | 2.12  |
| 99.6        | 0.802  | 3.42   | 0.977  | 2.19  |
| 96.4        | 0.788  | 3.22   | 0.960  | 1.99  |
| 90.4        | 0.711  | 4.33   | 0.963  | 2.19  |
| 82.1        | 0.644  | 4.55   | 0.937  | 1.89  |
|             | Equivalent<br>Conductance<br>116.2<br>102.1<br>100.8<br>99.6<br>96.4<br>90.4<br>82.1 | Mean           Equivalent         Activity           Conductance         Coefficient           116.2         0.829           100.8         0.815           99.6         0.802           96.4         0.788           90.4         0.711           82.1         0.644 | Mean         Dissociation           Equivalent         Activity         Function           Conductance         Coefficient         (Ostwald; x 10 <sup>3</sup> )           116.2 | Mean         Dissociation         Degree of           Equivalent         Activity         Function         Dissociation           Conductance         Coefficient         (Ostwald; x 10 <sup>3</sup> )         (Fuoss)           116.2 |

# TABLE III

# Conductance Data for Higher Concentrations of Ferric Chloride in Acetone

| $20^{\circ}$  |             | $40^{\circ}$  |             |
|---------------|-------------|---------------|-------------|
| Concentration | Equivalent  | Concentration | Equivalent  |
| (Molar)       | Conductance | (Miolar)      | Conductance |
| 0.0149        | 49.2        | 0.0145        | 56.1        |
| 0.0236        | 48.2        | 0.0719        | 53.9        |
| 0.0406        | 48.7        | 0.0753        | 52.9        |
| 0.0738        | 46.5        | 0.2060        | 50.9        |
| 0.0775        | 44.3        |               |             |
| 0.2101        | 39.9        |               |             |

Ferric chloride in acetone was treated as a uni-univalent electrolyte which dissociates as follows:  $FeCl_3 \hookrightarrow FeCl_2^+ + Cl^-$ 

Application of the Ostwald dilution law results in the following equation,

$$1/\Lambda = \Lambda C/K^{1}\Lambda_{\circ}^{2} + 1/\Lambda_{\circ} \qquad [1]$$

This is the equation for a straight line in which  $1/K^1 \Lambda_{\circ}^2$  is the slope and  $1/\Lambda_{\circ}$  is the intercept. From conductance data, values of  $1/\Lambda$  and  $\Lambda C$  were plotted, and by the method of least squares the intercept and slop of the line were obtained.



In order to obtain more nearly accurate values for the limiting equivalent conductances and to permit calculation of the thermodynamic dissociation constants in which corrections for interionic effects were introduced, the Fuoss method of calculation was employed. Using the value of  $\Lambda_{\circ}$  obtained as described above, a variable Z was calculated from the equations,

$${
m Z} = \left[ ( heta \Lambda_{\circ} + \sigma) / {\Lambda_{\circ}}^{3/2} 
ight] \ (10^3 {
m L})^{1/2} \ [2]$$

 $\theta = 8.147 \text{ x } 10^5 / (\text{DT})^{3/2}$ 

 $\sigma = 81.86/\eta \, ({
m DT})^{1/2}$ 

The value of the function of Z, F(Z) as defined in the Fuoss treatment, was obtained from the Fuoss table (8). The apparent degree of dissociation, which was calculated from the relation  $a = \Lambda/\Lambda_{\circ}F(Z)$ , was substituted in the following equation to obtain the molar activity coefficient:  $-\log f^2 = 2A(Ca)^{1/2}[3]$  where  $A = (1.812 \times 10^6)/(DT)^{3/2}$ .

These values permitted use of the Fuoss equation  $F(Z)/\Lambda = (1/K\Lambda_\circ{}^2) (C\Lambda f^2/F(Z) + 1/\Lambda_\circ[4]$ . Plots of  $F(Z)/\Lambda$  versus  $C\Lambda f^2/F(Z)$  resulted in straight lines with, in each case, the intercept equal to  $1/\Lambda_\circ$  and the slope equal to  $1/K\Lambda_\circ{}^2$ . By the method of least squares a value for the limiting equivalent conductance was obtained. Then this value was improved by substituting in equation [2] and calculating another value for the limiting conductance. This process was repeated until a constant value was obtained.



Fig. 2. Plots of equation [1] for solutions of ferric chloride in acetone.



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Electrical Conductance of Solutions of Ferric Chloride

# DISCUSSION

The plots of conductance versus the square root of concentration and of equation [1] are typical of those obtained for weak electrolytes.

Cryoscopic data (2) for this system furnish additional evidence that the solute behaves as a weak uni-univalent electrolyte for at no concentration is the molecular weight found to be as low as 81, which would be the case if the first ionization were complete.

According to Murray-Rust and Hartley (9) the limiting ionic conductance of the chloride ion is about 25 in ethanol having a viscosity of approximately 1.2 centipoises. In acetone, with a viscosity of 0.3 centipoise, the value would be expected to be three or four times as large. The conductance of the large  $\text{FeCl}_{2^{-+}}$  ion would be much smaller than that of the chloride. Therefore a value of 109 for ferric chloride in acetone seems to be reasonable on the assumption that it behaves as a uni-univalent electrolyte. No break appears in the plot of equation [1] which seems to indicate that the second dissociation does not occur at obtainable concentrations; or if it does occur in dilute solutions at these temepratures, its effects must be almost entirely counterbalenced by interionic effects.

The degree of dissociation increases with temperature in going from  $20^{\circ}$  to  $40^{\circ}$ . This produces a greater number of ions per unit volume resulting in a decrease in the mean activity coefficient. As would be expected, the molar activity coefficient increases with a decrease in concentration at both temperatures.

In Fig. 4, the broken lines are plots in which the slopes have the theoretical values of the constant "A" in the equation for the Debye-Hückel limiting law (equation [3]). It may be observed that at both temperatures the limiting law is obeyed at lower concentrations. Deviations from ideality become more pronounced at higher concentrations at  $20^{\circ}$  than at  $40^{\circ}$ .

Conductance data for several higher concentrations are presented in Table III, although at present there is available no satisfactory theoretical treatment for such solutions.

#### SUMMARY

- 1. Conductances of solutions of ferric chloride in acetone have been determined at  $20^{\circ}$  and  $40^{\circ}$  over the concentration range  $0.26 \times 10^{-3}$ M to  $200 \times 10^{-3}$ M.
- 2. The Fuoss method has been used to calculate the thermodynamic degree of dissociation and this has been compared to the Ostwald dissociation function over the concentration range studied.
- 3. It has been shown that ferric chloride in acetone behaves as an incompletely dissociated uni-univalent electrolyte at attainable concentrations at  $20^{\circ}$  and  $40^{\circ}$ .
- 4. Conformity of the solutions to the Debye-Hückel limiting law at low concentrations has been demonstrated.

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## THE DISTRIBUTION OF ALKALI IODIDES BETWEEN ETHYLENE GLYCOL AND ETHYL ACETATE

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It is well known that the distribution rate for a solute between two immiscible solvents remains constant for varying concentrations only where it represents the ratio between the activities of the solute in the two phases (1). The activity may be considered as the product of the activity coefficient and the concentration, or  $a = \gamma e \cdot C$ . Therefore, for a solution which exists in the same state of aggregation in both phases, the exact form of the equation for the distribution ratio is

$$\frac{a_{A}}{a_{B}} = K$$
or
$$\frac{\gamma e_{A} \cdot C_{A}}{\gamma e_{B} \cdot C_{A}} = K$$
[1]

Where  $\gamma_c$  refers to the stoichiometrical activity coefficient as defined by Brönsted (2). If the state of aggregation of the solute is different in the two phases, a suitable exponent must be used with one of the terms in equation [2] (3).

In sufficiently dilute solution where the activity coefficients approach unity, the ratio of the concentrations becomes practically constant. Similarly, if two relatively immiscible solvents are chosen so that the solute to be studied is sparingly soluble in one giving a solution of low concentration in which the activity coefficient may be considered to be unity, equation [2] may be used to calculate the activity coefficients of the solute in the more concentrated phase at various concentrations (4).

The purpose of this investigation was to determine the distribution ratio for the iodides of ammonium, sodium, potassium, and lithium between the two slightly miscible solvents ethylene glycol and ethyl acetate. It was desired also to determine the

variations in activity coefficients of the pure iodides in ethylene glycol solution with changes in concentration and to study the resulting effects when mixtures of these salts were used.

#### Reagents

Best grade, "anhydrous," salts which were carried through a final re-drying operation immediately prior to use, were employed throughout the investigation. The cthylene glycol was dried over anhydrous sodium sulfate and distilled under reduced pressure. The ethyl acetate was tested for water with anhydrous copper sulfate and its purity confirmed by measurement of its refractive index.

#### EXPERIMENTAL PROCEDURE

One hundred ml. of glycol solution of the salt and three hundred ml. of pure ethyl acetate were mixed in a one-liter flask and stoppered with paraffin-sealed corks. The flask was supported in a thermostat at  $30^{\circ}$ C. and thoroughly agitated for twenty hours. Upon being removed from the thermostat, the greater part of the acetate solution was poured off and a 10-ml. sample of the glycol layer was removed by means of a pipet.

Then the two solutions were analyzed for iodide by the Mohr method. Titration of the glycol solution directly with a water solution of silver nitrate gave consistently satisfactory results, but analysis of the acetate layer was more difficult. The ethyl acetate was removed by carefully controlled high temperature evaporation, and the iodide redissolved in about 10 ml. of water. The iodide concentration was then determined by titration with standard silver nitrate solution.

#### Results

The results are presented in Tables I to VII and in Figures 1 to 3. All data were obtained at 30°C. The activity coefficient,  $\gamma_{c}$ , is a relative value based on the activity coefficient of ammonium iodide taken as a unity.

# The Distribution of Alkali Iodides

## TABLE I

Distribution Ratios of Ammonium Iodide Between Ethylene Glycol and Ethyl Acetate at 30°C.



## TABLE II

Distribution Ratios and Activity Coefficients of Sodium Iodide



# The Distribution of Alkali Iodides

# TABLE III

Distribution Ratios and Activity Coefficients of Potassium Iodide

| Moles/1. | Moles/1. x 10 <sup>2</sup>    | K               | $\gamma_{c}$                       |
|----------|-------------------------------|-----------------|------------------------------------|
| KI in    | KI in                         |                 |                                    |
| Glycol   | Ethyl Acetate                 |                 |                                    |
| 0.0694   | 0.0358                        | 194             | 1.02                               |
| 0.1511   | 0.0822                        | 184             | 1.08                               |
| 0.1870   | 0.1020                        | 183             | 1.08                               |
| 0.2123   | 0.1172                        | 182             | 1.09                               |
| 0.2770   | 0.1590                        | 174             | 1.14                               |
|          | TABLE IV                      |                 |                                    |
| Dis      | tribution Ratios and Activity | Coefficients of |                                    |
|          | Lithium Iodide                |                 |                                    |
| Moles/1. | Moles/1. x $10^{2}$           | K               | $\boldsymbol{\gamma}_{\mathrm{e}}$ |
| LiI in   | LiI in                        |                 | <i>'</i>                           |
| Glycol   | Ethyl Acetate                 |                 |                                    |
| 0.1336   | 0.0320                        | 417             | 0.93                               |
| 0.1859   | 0.0430                        | 430             | 0.90                               |
| 0.2496   | 0.0568                        | 439             | 0.89                               |
| 0.3681   | 0.0782                        | 470             | 0.83                               |
| 0.4759   | 0.0975                        | 489             | 0.80                               |
|          | TABLE V                       |                 |                                    |

# Distribution Ratios and Activity Coefficients of Sodium Iodide-Ammonium Iodide Mixtures

|            | Ser             | ies One                  |     |                                    |
|------------|-----------------|--------------------------|-----|------------------------------------|
| Mole % NaI | Moles $I^-/1$ . | Moles $I^-/1$ . x $10^2$ | Κ   | $\boldsymbol{\gamma}_{\mathrm{c}}$ |
| to         | in              | in                       |     | ,                                  |
| $NH_4I$    | Glycol          | Ethyl Acetate            |     |                                    |
| 5          | 0.2683          | 0.0885                   | 304 | 0.96                               |
| 25         | 0.2739          | 0.0909                   | 301 | 0.96                               |
| 40         | 0.2621          | 0.0910                   | 288 | 1.02                               |
| 55         | 0.2681          | 0.0948                   | 283 | 1.03                               |
| 70         | 0.2668          | 0.0987                   | 270 | 1.08                               |
|            | Ser             | ies Two                  |     |                                    |
| 10         | 0.4138          | 0.1316                   |     | 0.93                               |
| 20         | 0.4244          | 0.1366                   |     | 0.94                               |
| 35         | 0.4231          | 0.1473                   |     | 1.02                               |
| 50         | 0.4148          | 0.1580                   |     | 1.07                               |
| 70         | 0.4125          | 0.1368                   |     | 1.09                               |



Fig. 3. Effect on activity coeffecient of solute of substituting alkali ions for part of the ammonium ions in ethylene glycol.

The Distribution of Alkali Iodides

#### TABLE VI

Distribution Ratios and Activity Coefficients of Potassium Iodide-Ammonium Iodide Mixtures

| Mole % KI                   | Moles $I^-/1$ . | Moles I <sup>-</sup> /1. x 10 <sup>2</sup> | K   | $\gamma_{\rm e}$ |
|-----------------------------|-----------------|--|-----|------------------|
| to                          | in              | in   |     | · ·              |
| $\mathbf{NH}_{4}\mathbf{I}$ | Glycol          | Ethyl Acetate                              |     |                  |
| 10                          | 0.2680          | 0.875                                      | 306 | 0.95             |
| 25                          | 0.2741          | 0.965                                      | 284 | 1.03             |
| 50                          | 0.2421          | 0.991                                      | 244 | 1.18             |
| 60                          | 0.2399          | 1.062                                      | 226 | 1.29             |
| 70                          | 0.2377          | 1.103                                      | 216 | 1.36             |

#### TABLE VII

Distribution Ratios and Activity Coefficients of Lithium Iodide-Ammonium Iodide Mixtures

| Mole % L:I                  | Moles $I^-/1$ . | Moles $I^{-}/1$ . x $10^{2}$ | K   | $\gamma_{\rm c}$ |
|-----------------------------|-----------------|------------------------------|-----|------------------|
| to                          | in              | in                           |     | ,                |
| $\mathrm{NH}_{4}\mathrm{I}$ | Glycol          | Ethyl Acetate                |     |                  |
| 10                          | 0.2296          | 0.0760                       | 310 | 0.97             |
| 25                          | 0.2315          | 0.0713                       | 325 | 0.90             |
| 40                          | 0.2261          | 0.0654                       | 346 | 0.83             |
| 60                          | 0.2095          | 0.1595                       | 381 | 0.76             |
| 70                          | 0.2176          | 0.1528                       | 396 | 0.71             |
| 80                          | 0.2261          | 0.1620                       | 413 | 0.70             |
|                             |                 |                              |     |                  |

#### DISCUSSION

Activity coefficients of solutes may be influenced by solvation or other solvent effects or, in the case of electrolytes in solvents having low dielectric constants, by changes in the degree of dissociation as the concentration is varied.

In the distribution of ammonium iodide between ethyl acetate and ethylene glycol it was found that the ratio did not vary with changes in concentration in the range from 0.1 M to 0.5 M with respect to the glycol layer (Fig. 1). This indicates that ammonium iodide exists in the same molecular form in both solvents, and that

its activity coefficient is not altered appreciably by concentration changes.

The activity coefficients,  $\gamma_{\rm c}$ , listed in the tables given above and shown in Fig. 3 are calculated from equation [2] and are stoichiometrical in nature in that they are based on the total iodide concentration in the two phases irrespective of its relationship to the cations. It may be assumed that the solute exists essentially as "molecules" or "ion-pairs" in ethyl acetate which has a low dielectric constant. Therefore, the activity coefficients calculated from the data obtained in this investigation, represent in each the ratio of the number of "molecules" or "ion-pairs" of a given solute in the glycol layer to the number of "ion-pairs" of ammonium iodide in the acetate layer at a given total electrolyte concentration.

The decrease in the distribution ratio as the concentration of sodium iodide or potassium iodide is increased is probably caused by an increase in the relative number of "ion-pairs" in the glycol layer, hence, a greater tendency to pass into the acetate layer. As would be expected, the equilibrium between "ion-pairs" and "free" ions is shifted to the left as the concentration is increased.

The opposite effect observed with pure lithium iodide, that is, an increase in the distribution ratio resulting from a decreased tendency to pass into the acetate layer, indicates that at higher concentrations there are relatively fewer of the species that cross the interface. It is difficult to conceive of increased dissociation at higher concentrations. However, it seems probable that, owing to the high charge density on the lithium ion, complex ions or "triple" ions of the type  $\operatorname{Lil}_2^-$ , or possibly others containing more iodide, would form in ever increasing numbers at higher concentrations. If these do not cross the interface, the distribution ratio would increase.

Graphs illustrating the effects of substituting varying quantities of foreign salts on the distribution of ammonium iodide are shown in Figure 2. Small amounts of sodium or potassium salts increase the partition ratio by shifting the equilibrium, "ion-pair"  $\Leftrightarrow$  "free" ion, to the right as the result of a decrease of the

#### The Distribution of Alkali Iodides

actual "ionic" activity of the free ions. At higher concentrations, greater solvation of the foreign cation in comparison to the ammonium ion causes the equilibrium to shift to the left, which results in a smaller distribution ratio. Potassium ion appears to exert a greater influence in this respect than does sodium ion.

Substitution of lithium ion for ammonium ion leads continually to larger distribution ratios, presumably because of complex ion formation, as mentioned above.

#### SUMMARY

1. Distribution ratios for lithium, sodium, potassium and ammonium iodides and mixtures of each lithium, sodium, and potassium iodides with ammon'um iodide between ethylene glycol and ethyl acetate have been determined at 30°C.

2. Stoichiometrical activity coefficients for the alkali iodides and for solutes in solutions of mixed iodides have been calculated using the constant distribution ratio of pure ammonium iodide as a basis of reference.

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#### THE FREE ENERGY OF COPPER CHROMATE\*

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As an aid in predicting the behavior of argentic oxide, AgO, it was desired to know the extent of conversion of copper oxide to chromate by reaction with dichromate:

(a)  $\operatorname{CuO} + \operatorname{Cr}_2 \operatorname{O}_7^- = \operatorname{CuCrO}_4^- + \operatorname{CrO}_4^-$ While a direct measurement of the equilibrium probably could be made by a series of spectrophotometric observations, it was decided to calculate the equilibrium constant from existing thermodynamic data and the solubility of copper chromate.

The early literature on copper chromate (4) reports a number of preparations of both normal and basic salts but little study of their properties. Basic salts usually result from precipitation at elevated temperatures or from alkaline solutions. The normal dihydrate was precipitated by Briggs (1) by adding sodium chromate to a copper dichromate solution; Pelletier, Cloutier, and Gagnon (5) find the normal salt precipitates when potassium chromate is added to cupric solutions.

The validity of our calculations requires that the copper chromate formed by reaction (a) be the same as that in equilibrium with solutions containing  $Cu^+$  and  $CrO_4^=$  and little else. This is reasonable since both conditions should give the normal salt and since the degree of hydration of copper chromate should not be appreciably affected by dichromate ion in the solution. Our calculations are based on the anhydrous formula  $CuCrO_4$  although the chromate is probably hydrated as found by Briggs. In that case, the free energy of formation of hydrated copper chromate is our value plus the proper multiple of the free energy of formation of water; the equilibrum constant for reaction (a) will be unaffected.

#### EXPERIMENTAL

An aqueous solution of reagent quality cupric chloride was added to a solution of sodium chromate (also of reagent quality). The precipitate was filtered, washed with water and with methanol

<sup>\*</sup> Presented before the Chemistry Section of the Kentucky Academy of Science, October 28, 1950.

(C. P. special acetone free), and dried in the air at room temperature.

The copper chromate obtained was left in contact with distilled water and the mixture occasionally shaken. No effort was made to thermostat the mixture; the experiment was performed at laboratory temperatures not far from 25°C. The close agreement between measurements in two seasons (August, October) show the temperature dependence of the solubility is not great.

Samples of the saturated solution were removed after 3 and 9 weeks of equilibration and analyzed by a standard method for chromate (6). Since both ions of copper chromate oxidize iodide, equivalence was determined from the equation

 $CuCrO_4 + 5 I^- + 8 H^+ = CuI + Cr^{+++} + 4 H_2O + 2 I_2$ The molarity found (x 10<sup>3</sup>) and average deviation were after three weeks,  $3.47 \pm 0.06$  (2 samples); after nine weeks,  $3.42 \pm 0.03$  (3 samples); average,  $3.44 \pm 0.04$ .

#### CALCULATIONS

Solubility Product of  $CuCrO_4$ : To calculate a solubility product from the measured solubility requires an estimate of the mean activity coefficient of copper chromate. The only available activity data for 2-2 electrolytes are for a number of sulfates—these data indicate that the activity coefficients depend far less upon the identity of the cation than those of other charge types (2), in fact, the extreme variation in values for different salts at the same concentration is only a few percent. Accordingly, it seems reasonable that chromates should not differ very greatly from sulfates. Thus we take as the mean activity coefficient of 0.00344 *M* copper chromate the value 0.55 graphically interpolated from the values (3) for copper, cadmium and zinc sulfates at molalities of 0.001, 0.002 and 0.005, neglecting the small differences between molality and molarity. This gives as the solubility product of copper chromate 3.6 x 10<sup>-6</sup> and the standard free energy of solution 7440 cal./mole.

*Free Energy of Copper Chromate*: For the dissolution of copper chromate we have

 $\begin{array}{l} \text{per chromate we have} \\ \text{CuCrO}_4 = \text{Cu}^{++} + \text{CrO}_4 \ ; \ \bigtriangleup \ \text{F}^\circ = \begin{array}{c} \text{F}^\circ \\ \text{Cu}^{++} \end{array} + \begin{array}{c} \text{F}^\circ \\ \text{CrO}_4 \end{array} = \begin{array}{c} \text{-F}^\circ \\ \text{CuCrO}_4 \end{array}$ 

Putting in the above value for the free energy of solution and literature values (3) of 15,910 and -171,400 for the standard free energies of copper ion and chromate ion respectively we find for copper chromate a standard free energy of -162,930 cal./mole.

Copper Oxide-Dichromate Reaction: For reaction (a) we have  $\triangle F^{\circ} = F^{\circ} + F^{\circ} - F^{\circ} - F^{\circ}$ 

 $CuCrO_4$   $CrO_4 = CuO Cr_2O_7 =$ 

Putting in the above values for copper chromate and chromate ion and the values -30,400 for copper oxide and -306,000 for dichromate ion (3) gives as the standard free energy of the reaction 2,070 cal. This corresponds to an equilibrium constant of 0.030. This is the ratio at equilibrium of the activities of chromate ion and dichromate ion in a solution saturated with both copper oxide and copper chromate. This corresponds to reaction (a) proceeding until the dichromate is about 3% converted to chromate, since the activity coefficients of two similarly charged ions in the same solution should not be greatly different.

#### SUMMARY

The solubility in water of copper chromate is found to be  $3.44 \times 10^{-3} M$  at about  $25^{\circ}$ C. From this it is calculated that the thermodynamic solubility product is  $3.6 \times 10^{-6}$ , the free energy of copper chromate is -162,930 cal./mole, and the equilibrium constant is 0.030 for

 $CuO + Cr_2O_7^{=} = CuCrO_4 + CrO_4^{=}.$ 

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### EMISSIVITIES OF PROTECTIVE COATINGS

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#### Abstract

A thermometer technique for the determination of surface emissivities of paints is described. The procedure involves the use of 1/10 degree thermometers coated with a paint and one reference thermometer to which has been applied a bright silver coating. Theoretical considerations, and experimental values of five differently colored paints, lamp black, and a mercury-glass thermometer are given.

Heat transfer is one of the important considerations in all branches of engineering and science. Traditionally, heat transfer mechanisms have been considered to be convenction, conduction and radiation. The mathematical and theoretical treatment of these mechanisms has been verified by thousands of experiments and in many cases the heat transfer may be anticipated without recourse to experimental investigation.

So frequently is heat transfer considered in many industrial operations that convection, conduction, radiation and appropriate combinations may be considered of major importance and the particular operation of secondary significance by comparison. On the other hand, there are many instances wherein there are several fundamental processes occurring simultaneously, e.g., heat and mass transfer together with fluid flow.

The continuing use of radiant heating in industrial and domestic installations has emphasized the importance of this mechanism. Many uses of radiant heating are such that it is difficult, if not impossible, to completely isolate the radiation from other phenomena. Nevertheless, the radiation is important, and appropriate constants and data for radiation calculations are required.

One application of radiant heat transmission which has been of interest is the so-called radiant drying or baking of protective coatings on various objects. The baking of finishes or protective coatings on automobile body parts is an example of this type of operation.

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The conventional relationship (1) for calculating the net transfer of heat by radiation from a hot body to a cooler body separated by a nonabsorbing medium is,

$$q_r = 0.173 F_e F_A \left[ \left( \frac{T_1}{100} \right)^4 - \left( \frac{T_2}{100} \right)^4 \right]$$

where  $q_r = net$  heat transfer by radiation, BTU/hr.

- ${\rm F_{_e}}$  = emissivity factor relating the emissivities of the surfaces of the two bodies.
- $F_A =$  geometric factor relating the areas of the surfaces of the two bodies.
- $T_1$  = temperature of the surface of the hot body, °R.
- $T_2$  = temperature of the surface of the colder body, °R.

An inspection of the above equation clearly indicates the need of emissivity values for the surfaces of objects to be subjected to radiant heat transmission if heat requinrements are to be calculated.

The emissivity of a surface is the ratio of the emissive power of the surface to that of a "black body". The "black body" has zero reflectivity, an absorptivity of unity, and is a perfect radiator, i.e., its emissivity is unity. Accordingly, the theoretical range of values of emissivity would be slightly above zero to unity. Then the closer the emissivity value is to unity the better the radiator, and the poorer the reflectivity.

In the following discussions and presentations the surface emissivities of several protective coatings are reported to illustrate the variations in values, and the experimental technique used in obtaining these emissivity values is described.

The technique employed in these measurements has been termed a static thermometer technique and requires little specialized apparatus. Essentially, the apparatus consisted of tenth-degree thermometers, a duct fabricated from 8 inch diameter galvanized sheet iron pipe, a blower for moving warm air through the duct, an anemometer for measuring the air velocity within the duct, and a portable poten-

#### Emissivities of Protective Coatings

tiometer for obtaining thermocouple readings of the pipe temperature. The simplicity of the apparatus is shown in the sketch of Figure 1 where thermometers are shown inserted through the pipe wall into the warm air stream.



In operation, warm air was passed through the duct with thermometers extending into the duct at right angles to the direction of air flow, and thermocouple in place as shown. When constant thermometer and thermocouple readings were obtained, the values were recorded and the air velocity determined with the anemometer.

One thermometer was designated as a reference thermometer and was coated with silver by Brashear's method (2). The second thermometer having dimensions substantially the same as those of the reference thermometer was coated with the paint and dried. This latter thermometer was called the material thermometer. Both thermometers were coated over the entire surface exposed to the warm air stream.

When constant temperature readings were obtained, an ap-

proximate heat balance was permissible,

 $\mathbf{q}_{c} = \mathbf{q}_{r}$ 

- where  $q_c$  = heat transfer by convection from warm air to thermometer, BTU/hr.
  - $q_r =$  net heat transfer by radiation between thermometer and surfaces in sight of thermometer, BTU/hr.

The simple heat transfer case of an air stream, with true air temperature  $t_a$  flowing through a duct of a diameter large compared to that of the reference thermometer at temperature  $t_r$  and the inner duct surface at temperature  $t_c$  can be described by the heat balance,

$$\mathbf{q}_{c} = \mathbf{q}_{r} \text{ or } \mathbf{h}_{c} \mathbf{A} (\mathbf{t}_{a} - \mathbf{t}_{r}) = \mathbf{h}_{r} \mathbf{A} (\mathbf{t}_{r} - \mathbf{t}_{s})$$

where  $h_{e} = \text{convection heat transfer coefficient, BTU/(hr) (sq.ft.)}$ (°F)

- h<sub>r</sub> = radiation heat transfer coefficient, BTU/(hr) (sq.ft.) (°F)
- A = thermometer area, sq.ft.

The heat balance may be written,

$$h_A (t_a - t_a) = 0.173 e A [(T_a / 100)^4 - (T_a / 100)^4]$$

where e = emissivity of the reference thermometer.

In this case of a small object, the thermometer, very nearly totally inclosed by the larger object, the duct,  $F_e = e$ , the emissivity of the small object. Similarly,  $F_A = A$ , the area of the small object, the thermometer

The heat balance may be arranged to

$$(t_{a} - t_{r}) = (h_{r}/h_{c}) (t_{r} - t_{s})$$

and a similar expression may be written for the coated material thermometer

$$(t_{a} - t_{m}) = (h_{r}'/h_{c}') (t_{m} - t_{s})$$

Under nearly identical conditions  $h_c = h_c$  since the two thermometers

#### Emissivities of Protective Coatings

have identical demensions and

$$(t_{a} - t_{m}) = (h_{r}^{2}/h_{c}^{2}) (t_{m} - t_{s})$$

where  $h_r'$  and  $h_o'$  refer to the material thermometer.

The value of  $h_c$  can be calculated from the air velocity and equations for convection transfer from air flowing at right angles to single cylinders (3),

 $h_c D/k_i = 0.32 + 0.43 \ (DG/\mu_i)^{0.52}$ 

for ranges of  $(DG/\mu_{\rm f})$  from 0.1 to 1000 and

$$h_c D/k_f = 0.24 \ (DG/\mu_f)^{0.6}$$

for ranges of  $(DG/\mu_{\rm f})$  from 100 to 50000. In this case D is the thermometer diameter in feet, G is the mass velocity—the product of the linear velocity and air density—in lb/(hr) (sq.ft.), k is the thermal conductily of the air at the film conditions in BTU/(hr.) (sq.ft.) (°F/ft.), and  $\mu_{\rm f}$  is the air viscosity at the film conditions in lb./(ft.) (hr.).

Values of  $h_r$  may then be obtained since the true air temperature can be calculated from the equation given above,

$$(t_{a} - t_{r}) = (h_{r}/h_{c}) (t_{m} - t_{s})$$

by solving for t

 $\mathbf{t}_{a} = (\mathbf{h}_{r}/\mathbf{h}_{c}) (\mathbf{t}_{m} - \mathbf{t}_{s}) + \mathbf{t}_{r}$ 

Obviously  $h_r$  for the silver coated reference thermometer must be obtained in order to solve for  $t_r$ . This evaluation of  $h_r$  is made using the equality,

$$h_r A(t_r - t_s) = 0.173 e A[(T_r/100)^4 - (T_s/100)^4]$$

For polished silver the emissivity, e, is 0.02 (1).

With a value of  $t_a$  the heat balance for the coated material thermometer can be used to calculate  $h_a$ ?

$$(t_{a} - t_{m}) = (h_{r}^{2}/h_{c}) (t_{m} - t_{s})$$
$$h_{r}^{2} = (h_{c}) (t_{a} - t_{m})/(t_{m} - t_{s})$$

and

The numerical value of  $h_r$  is then used to calculate the emissivity as follows,

$$e = \frac{h_{r}^{2} (t_{m} - t_{s})}{0.173 [(T_{m}/100)^{4} - (T_{s}/100)^{4}]}$$

Using the apparatus and calculation procedure described above, emissivities of six colored paints, lamp black and the uncoated thermometer were determined (4). The average numerical values of these emissivities are listed blow:

#### TABLE I

#### AVERAGE EMISSIVITY VALUES

For The Temperature Range 90°F to 140°

| Finish                    | Emissivity |
|---------------------------|------------|
| Lamp-Black                | 0.95       |
| Yellow                    | 0.46       |
| Orange                    | 0.60       |
| Red                       | 0.70       |
| Green                     | 0.74       |
| Phythalocyanine Blue      | 0.91       |
| Milori Blue               | 0.88       |
| Glass-Mercury Thermometer | 0.95       |

Obviously, the exact color and characteristic of the paint will influence the emissivity value. This fact is demonstrated in the range of values contributing to the averages listed above. The number of different paints of each color and the range of emissivity values are given in Table II.

#### TABLE II

RANGE OF EMISSIVITY VALUES FOR VARIOUS COLORS

| Number of      |                     |                  |
|----------------|---------------------|------------------|
| Colored Paints | Color               | Emissivity Range |
| 5              | Yellow              | 0.32 - 0.66      |
| 5              | Orange              | 0.32 - 0.74      |
| 5              | Red                 | 0.30 - 0.87      |
| 5              | Green               | 0.66 - 0.78      |
| 5              | Phthalocyanine Blue | 0.89 - 0.94      |
| 5              | Milori Blue         | 0.70 - 0.98      |

#### Emissivities of Protective Coatings

An inspection of the data of Table II shows the overlapping of emissivity values for the several colors even though repeated determinations with a given paint rarely gave deviations as great as 3.5 percent and in many cases less than 1.0 percent.

These ranges of emissivities for a given color strongly emphasize the need for an evalution of the emissivity of the particular surface if precise radiant heat transmission calculations are important. Frequently the determination of the emissivity of the coated surface has been considered such a time-consuming task that the measurement of the property has been neglected or average values estimated. However, this thermometer technique is straight forward and requires little or no equipment not in common use in the industrial laboratory. Accordingly, it is felt that the appropriate use of the procedure can provide information of immediate use in a number of radiant heating operations.

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# PERFORMANCE OF AN EARTH HEAT PUMP OPERATING INTERMITTENTLY ON THE COOLING CYCLE

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#### INTRODUCTION

The rate at which heat can be absorbed from, or discharged to the earth with a heat pump depends on the size and configuration of the ground coil as well as the physical properties of the soil. Some of the physical properties of the soil surrounding the earth heat exchanger are affected by rainfall, solar radiation and by altering the quantity of heat energy in the ground by artificial means. Therefore a brief history of the operation of the heat pump will be given here.

From October 31, 1949 to May 1, 1950, the heat pump operated intermittently on the heating cycle extracting heat from the earth from 6 p.m. to 6 a.m. daily  $(1)^1$ . During this period the rainfall was in excess of its normal value by 64.4%. The heat pump remained idle from May 1, 1950 to May 16, 1950 inorder to permit the temperature of the soil surrounding the earth heat exchanger to recover its normal value. The plant operated continuously<sup>\*</sup> on the heating cycle from May 16, 1950 to July 1, 1950 in order to obtain data from which the thermal diffusivity of the soil could be calculated if desired (2, 3). On June 9, 1950, data were taken, at two-hour intervals from 10 a.m. to 4 p.m. so that the calculated *results from a heating test* of short duration could be compared with the *average results of seven cooling tests* of short duration.

The earth heat exchanger, Fig. 1, was buried in soil at an average depth of about 4.5 ft. It consists of an effective length of 489 ft. of one inch copper tubing through which an antifreeze solution is circulated. Thermocouples were installed at the center of the antifreeze line at stations 1 to 8 inclusive. By use of thermocouples,

<sup>1</sup> Numbers in parenthesis refer to the Bibliography

<sup>\*</sup> From June 19 to July 1, the plant was stopped several times for making minor changes.



Figure 1. The earth heat exchanger or ground coil.

soil temperatures can be measured at depths of 6, 12, and 18 inches below the center of the antifreeze line at station 3, and also at 6 and 18 inches below the line at station 6.

The line heat sink is 171.9 ft. long and consists of the portion of the earth heat exchanger from station 2 to 5, and from station 7 to 8, except the length of tubing which is thermally insulated as shown in Fig. 1. The grid heat sink has a length of 317.1 ft. and is that portion of the earth heat exchanger between stations 5 and 7. The distances between the center of the grid pipes are 4.75 ft. The total heat sink includes the line and grid sections of the earth heat exchanger.

The soil surrounding the earth heat exchanger falls in the general Casagrande classification of lean clay. Analysis of a sample of the soil at station 3 showed that about 60% of its grains are in the size generally termed clay, and less than 30% of the sample is silt. The liquid limit of the sample is 43.4% and its corresponding plasticity index is 16.1%. The bulk density of the dry soil is 103.4 lb/cu. ft. (1).

## INTERMITTENT COOLING TESTS

From July 1, 1950 to October 1, 1950 the heat pump operated intermittently on the cooling cycle from 6 a.m. to 6 p.m. daily. When the plant was in operation, heat was absorbed from the air circulated throught the package unit (also from the compressor-motor and the fan-motor combinations), and discharged to the soil. The rainfall was 30.1% in excess of the normal rainfall for the same period.

In addition to the three month test, seven tests of short duration were made during the cooling season. In the tests of short duration, data were taken at two-hour intervals from 10 a.m. to 6 p.m., at the beginning and middle of each month. The results of the tests of short duration are listed in Table 1, and their average values are given in Table 2.

During the heating test of June 9, 1950, the refrigeration compressor was driven at a speed of 1180 rpm by a 5-hp, single phase, electric motor. Previous cooling tests clearly indicated that the heat

pump could not be operated at this speed during the entire cooling season under controlled conditions. Therefore, the plant was changed so that the compressor was driven at an average speed of about 680 rpm by a 3-hp, single phase, electric motor during the cooling season of 1950. By operating the refrigeration compressor at a speed much below its normal rating, its volumeric efficiency was increased from 61.2% for the heating test to 72.8% on the cooling tests.

## COOLING TESTS OF SHORT DURATION

From Table 1 it can be seen that the suction pressure remained nearly constant, (at about 35.6), but the discharge pressure increased from 143.1 to about 190 psia during three months of intermittent operation. The strength of the total heat sink (489 ft.) was practically constant, and its average value for the seven tests was 34.8 B/hr/ft. The temperature of the antifreeze entering the soil increased from 91.7°F to 124.5°F, and then decreased to 120.5°F. At station 3, the soil temperature 6 in. below the center of the antifreeze line increased from 56.2°F on July 1 to 73.4°F on September 30, while that at station 6 increased from 53.8°F to 77.7°F. The cooling cost remained nearly constant from July 15 to September 30°. The soil temperatures 18 in. below the center of the antifreeze line increased slightly from July 1 to September 30. These increases in soil temperature are due, in part, to the effect of solar radiation (4).

Table 1. Results obtained from seven cooling tests of eight hour duration.

|                           | 7/1/50 | 7/15/50    | 8/1/50 | 8/15/50 | 9/1/50 | 9/15/50 | 9/30/50 |
|---------------------------|--------|------------|--------|---------|--------|---------|---------|
| Room temp., °F            | 77.6   | 79.0       | 85.5   | 79.2    | 80.5   | 72.8    | 74.2    |
| Air temp. at entrance, °F | 77.6   | 81.1       | 87.9   | 79.1    | 80.8   | 73.0    | 75.7    |
| Air temp. at exit, °F     | 69.3   | 76.2       | 82.4   | 74.9    | 77.2   | 68.9    | 70.5    |
| R.H. of Room Air, %       | 50.5   | 79.0       | 58.2   | 74.0    | 75.0   | 55.0    | 72.0    |
| Air circulated, lb/hr     | 5,320  | 5,240      | 5.125  | 5,340   | 5,060  | 5,340   | 5,130   |
| Air circulated, cfm       | 1,214  | 1,233      | 1,205  | 1,230   | 1,180  | 1,220   | 1,170   |
| Heat power from air, B/hr | 5,320  | 7,280      | 7,720  | 7,850   | 6,990  | 6,660   | 7,550   |
| Heat power to evaporator, |        |            |        |         |        |         |         |
| B/hr                      | 20,250 | $18,\!940$ | 18,760 | 18,650  | 18,600 | 18,600  | 18,710  |
| Heat power to condenser,  |        |            |        |         |        |         |         |
| B/hr                      | 18,800 | 16,500     | 16,400 | 16,020  | 15,880 | 16,010  | 16,220  |

<sup>•</sup> In reference (1) it was shown that the package unit heat pump was very inefficient.

|                                | 7/1/50 | 7/15/50 | 8/1/50 | 8/15/50  | 9/1/50 | 9/15/50  | 9/30/50  |
|--------------------------------|--------|---------|--------|----------|--------|----------|----------|
| Suction press, psia            | 34.0   | 35.3    | 35.9   | 35.9     | 36.6   | 36.4     | 35.4     |
| Discharge press, psia          | 143.1  | 181.5   | 191.0  | 190.1    | 198.2  | 191.7    | 188.1    |
| F-12 circulated, lb/hr         | 315.2  | 300.3   | 298.6  | 299.6    | 300.0  | 303.0    | $302\ 0$ |
| Capacity of refrig. plant,     |        |         |        |          |        |          |          |
| tons                           | 1.69   | 1.58    | 1.56   | 1.55     | 1.55   | 1.55     | 1.56     |
| Vol. eff., %                   | 71.5   | 67.8    | 70.1   | 69.2     | 68.1   | 68.7     | 73.7     |
| Comp. eff., %                  | 74.8   | 77.0    | 85.0   | 79.8     | 78.4   | 78.5     | 77.7     |
| Comp. speed, rpm               | 704    | 701     | 673    | 677      | 675    | 680      | 651      |
| Comp. motor, kw                | 2.5    | 2.58    | 2.64   | 2.60     | 2.66   | 2.65     | 2.63     |
| Fan motor, kw                  | 0.50   | 0.49    | 0.49   | 0.50     | 0.47   | 0.49     | 0.49     |
| Pump motor, kw                 | 7 000  | 0.88    | 0.91   | 0.73     | 0.75   | 0.75     | 0.74     |
| Heat power to earth, B/nr I    | .7,000 | 10,550  | 10,780 | 10,310 . | 10,120 | 16,000 . | 16,510   |
| ainly P /by /ft                | 94.9   | 24.0    | 25 1   | 00.0     | 22.0   | 99 A     | 000      |
| Antifraeze circulated lb/hr    | 5 880  | 5 890   | 5 910  | 5.840    | 5 850  | 5 690    | 5 600    |
| Temp of antifreeze             | 0,000  | 0,000   | 0,010  | 5,040    | 0,000  | 5,030    | 5,000    |
| entering soil, °F              | 91.7   | 116.5   | 119.7  | 120.6    | 124.5  | 122.6    | 120.5    |
| Temp. of antifreeze            |        |         |        |          |        |          |          |
| leaving soil, °F               | 88.6   | 113.1   | 116.2  | 117.6    | 121.7  | 119.8    | 117.5    |
|                                | 2      | Station | 3      |          |        |          |          |
| Temp. of antifreeze, °F        | 93.0   | 116.3   | 119.5  | 120.2    | 124.0  | 122.5    | 118.1    |
| Soil temp. 6 in. below center  |        |         |        |          |        |          |          |
| of line, °F                    | 56.2   | 68.2    | 72.5   | 72.4     | 73.7   | 74.4     | 73.4     |
| Soil temp. 12 in. below center |        |         |        |          |        |          |          |
| of line, °F                    | 55.9   | 65.2    | 69.2   | 69.3     | 71.0   | 71.5     | 71.0     |
| Soil temp. 18 in. below center |        |         |        |          |        |          |          |
| of line, °F                    | 56.1   | 64.0    | 68.1   | 68.0     | 69.5   | 68.4     | 66.7     |
| Approximate temp. grad.,       |        |         |        |          |        |          |          |
| °F/ft                          | 73.6   | 96.2    | 94.0   | 95.6     | 100.6  | 96.2     | 89.4     |
|                                | 9      | Station | 6      |          |        |          |          |
| Temp. of antifreeze, °F        | 90.1   | 114.4   | 117.6  | 118.7    | 122.6  | 121.2    | 119.8    |
| Soil temp. 6 in. below center  |        |         |        |          |        |          |          |
| of line, °F                    | 53.8   | 67.0    | 73.3   | 74.9     | 77.7   | 78.0     | 77.7     |
| Soil temp. 18 in. below center |        |         |        |          |        |          |          |
| of line. °F                    | 51.6   | 60.7    | 67.9   | 70 5     | 797    | 72.0     | 744      |
| Approvimate temp grad          | 01.0   | 00.1    | 01.0   | 10.0     | 14.1   | 10.9     | 14.4     |
| or the                         | 70.0   | 04.0    | 00.0   |          |        |          |          |
| F/It                           | 72.6   | 94.2    | 88.6   | 87.6     | 89.8   | 86.4     | 84.2     |
| CER, Carnot                    | 5.38   | 5.02    | 4.43   | 4.43     | 4.35   | 4.44     | 4.46     |
| CER, refrig. plant             | 4.89   | 4.19    | 3.65   | 3.93     | 3.84   | 3.92     | 3.98     |
| CER, Heat pump                 | 0.62   | 0.83    | 0.86   | 0.89     | 0.77   | 0.74     | 0.84     |
| CER, Heat pump sys.            | 0.40   | 0.54    | 0.56   | 0.60     | 0.53   | 0.50     | 0.57     |
| Cooling cost, kwhr/therm       | 74.0   | 54.1    | 52.3   | 48.7     | 55.5   | 58.4     | 51.0     |

Table 2. Average results obtained from seven cooling tests while the heatpump operated intermittently from July 1, 1950 to October 1, 1950.

| Air temp. at entrance, °F                               | 79.3   |
|---|--------|
| Air temp. at exit, °F                                   | 74.2   |
| Heat power from air, B/hr                               | 7,050  |
| Heat power to earth, B/hr                               | 16,500 |
| Suction press., psia                                    | 35.6   |
| Discharge press., psia                                  | 183.4  |
| Capacity of refrigeration plant, tons                   | 1.58   |
| Compressor speed, rpm                                   | 680    |
| Volumetric efficiency, %                                | 72.8   |
| Compression efficiency, %                               | 78.7   |
| Input to heat pump system, kw                           | 3.91   |
| Total strength of heat sink (489 ft), B/hr/ft           | 34.8   |
| Temp. of antifreeze entering soil, °F                   | 116.6  |
| Temp. of antifreeze leaving soil, °F                    | 113.5  |
| Temp. of antifreeze at station 3, °F                    | 116.2  |
| Soil temp. 6 in. below center of line at station 3, °F  | 70.1   |
| Soil temp. 12 in. below center of line at station 3, °F | 67.6   |
| Soil temp. 18 in. below center of line at station 3, °F | 65.8   |
| Temp. of antifreeze at station 6, °F                    | 114.9  |
| Soil temp. 6 in. below center of line at station 6, °F  | 71.8   |
| Soil temp. 18 in. below center of line at station 6, °F | 67.4   |
| CER, Carnot   | 4.64   |
| CER, refrigeration plant                                | 4.06   |
| CER, heat pump  | 0.79   |
| CER, heat pump system                                   | 0.53   |
| Cooling cost, (sensible) kwhr/therm                     | 56.3   |

Fig. 2a is a diagram which shows the relation between the temperature of the antifreeze and soil 6 in. below (at station 3). as the antifreeze passes through the earth heat exchanger, and Fig. 2b shows the average temperature difference between the antifreeze and the condensing temperature of the Freon-12 in the condenser. Fig. 3 shows the change in temperature of the antifreeze as it passes through the earth heat exchanger for three cooling tests of short duration, and for the six-hour heating test.



Figure 2. (a) Graph showing the temperature difference between the antifreeze in the earth heat exchanger and the soil 6 in. below. (b) Graph showing the temperature difference between the antifreeze and the Freon-12 in the condenser.



Figure 3. Antifreeze temperature versus length of earth heat exchanger.

### COMPARISON OF HEATING AND COOLING TESTS

The results of the heating test made on June 9 are listed in Table 3. During this test the refrigeration compressor was driven at a speed of 1180 rpm by a 5-hp motor. However, the compressor was driven at an average speed of 680 rpm by a 3-hp motor during all cooling tests reported in this paper. All tests were made during the summer of 1950.

Comparative results of the cooling and heating tests of short duration are listed in Table 4. From Fig. 2a and 4a it can be seen that the difference in temperature between the antifreeze in the earth heat exchanger and the soil 6 in. below for the cooling and heating tests are  $46.7^{\circ}$ F and  $17.2^{\circ}$ F respectively. Similarly, from Fig. 2b and 4b the difference between the temperature of the antifreeze and Freon-12 for the cooling and heating tests are  $9.4^{\circ}$ F and  $25.5^{\circ}$ F respectively.

## COOLING TESTS OF LONG DURATION

The average of the daily results obtained from the cooling tests made during July, August, and September of 1950 are listed for each month in Table 5. On August 13, the antifreeze line connecting the expansion tank and the heat pump broke, so that nearly all of the antifreeze was lost. The line was repaired and *the earth heat exchanger was filled with water*. From September 15th to the 30th, the water was circulated counter clockwise instead of clockwise through the earth heat exchanger.

Table 3. Results obtained from an eight hour heating test made on June 9, 1950.

| Air town at antronce OF               | 70 0   |
|---------------------------------------|--------|
| Air temp. at entrance, <sup>-</sup> r | 10.8   |
| Air temp. at exit, °F                 | 99.6   |
| Heat power to air, B/hr               | 28,600 |
| Heat power from earth, B/hr           | 15,870 |
| Suction press., psia                  | 26.0   |
| Discharge press., psia                | 142.0  |
| Capacity of refrigeration plant, tons | 1.72   |
| Compressor speed, rpm                 | 1180   |
| Volumetric efficiency, %              | 61.2   |
| Compression efficiency, %             | 64.6   |
|                                       |        |

| Input to heat pump system, kw                           | 5.17  |
|---|-------|
| Total strength of heat source (489 ft), B/hr/ft         | 32.5  |
| Temp. of antifreeze entering soil, °F                   | 27.5  |
| Temp. of antifreeze leaving soil, °F                    | 31.4  |
| Temp. of antifreeze at station 3, °F                    | 28.0  |
| Soil temp. 6 in. below center of line at station 3, °F  | 46.7  |
| Soil temp. 12 in. below center of line at Station 3, °F | 49.8  |
| Soil temp. 18 in. below center of line at Station 3, °F | 51.5  |
| Temp. of antifreeze at station 6, °F                    | 29.5  |
| Soil temp. 6 in. below center of line at station 6, °F  | 42.7  |
| Soil temp. 18 in. below center of line at Station 6, °F | 47.0  |
| HER, Carnot   | 5.57  |
| HER, refrigeration plant                                | 4.99  |
| HER, heat pump  | 2.19  |
| HER, heat pump system                                   | 1.59  |
| Heating cost, kwhr/therm                                | 18.41 |
|   |       |

Table 4. Average results of seven cooling tests versus those for a single heating

---Summer of 1950.

|   |      | Cooling | ]    | Heating |
|---|------|---------|------|---------|
| Room temp., °F  |      | 78.4    |      | 78.3    |
| Air temp. at entrance, °F                                     |      | 79.3    |      | 76.8    |
| Air temp. at exit, °F   |      | 74.3    |      | 99.6    |
| Suction press., psia  |      | 35.6    |      | 26.0    |
| Discharge press., psia  | ]    | 183.4   |      | 142.0   |
| Nominal power of comp. motor, hp                              |      | 3       |      | 5       |
| Compressor speed, rpm   | (    | 680     |      | 1180    |
| Volumetric efficiency, %                                      |      | 72.8    |      | 61.2    |
| Compression efficiency, %                                     |      | 78.7    |      | 64.6    |
| Power input to system ,kw                                     |      | 3.91    |      | 5.17    |
| Total strength heat sink or source, B/hr/ft                   |      | 34.8    |      | 32.5    |
| Temp. of antifreeze entering soil, °F                         |      | 116.7   |      | 27.5    |
| Temp. of antifreeze leaving soil, $^{\circ}F$                 |      | 113.6   |      | 31.4    |
| Temp. of antifreeze at station 3, °F                          |      | 116.3   |      | 28.0    |
| Soil temp. 6 in. below line at station 3, $^\circ\mathrm{F}$  |      | 70.1    |      | 46.7    |
| Soil temp. 12 in. below line at station 3, $^\circ\mathrm{F}$ |      | 67.6    |      | 49.8    |
| Soil temp. 18 in. below line at station 3, $^\circ\mathrm{F}$ |      | 65.8    |      | 51.5    |
| Carnot  | CER, | 4.64    | HER, | 5.57    |
| Refrigeration plant   | CER, | 4.06    | HER, | 4.99    |
| Heat pump   | CER, | 0.79    | HER, | 2.19    |
| Heat pump system  | CER, | 0.53    | HER, | 1.59    |
| Operating cost, kwhr/therm                                    |      | 56.3    |      | 18.41   |



Figure 4. (a) Graph showing the temperature difference between the antifreeze in the earth heat exchanger and the soil 6 in. below. (b) Graph showing the temperature difference between the antifreeze and the Freon-12 in the evaporator.

Table 5. Monthly average of daily results obtained from cooling tests made in July, August, and September, 1950. The heat pump operated intermittently from 6 a.m. to 6 p.m. daily.

|  | July   | August | Septemł  | per 1950  |
|--|--------|--------|----------|-----------|
|  | 1950   | 1950   | lst-15th | 16th-30th |
| Rainfall, 43 year average, inches                    | 3.65   | 3.45   | 3.07     |           |
| Rainfall, 1950, inches                               | 6.24   | 2.70   | 4.28     |           |
| *Outdoor air temp., °F                               | 72.2   | 71.0   | 65       |           |
| Room, temp., °F                                      | 79.9   | 77.6   | 72.9     |           |
| R. H. at entrance, %                                 | 59.3   | 59.1   | 61.8     |           |
| R. H. at exit, %                                     | 69.2   | 67.5   | 69.7     |           |
| Inlet air temp., °F                                  | 81.1   | 78.6   | 73.6     |           |
| Outlet air temp., °F                                 | 75.3   | 74.0   | 69.3     |           |
| Air circulated, lb/hr                                | 5,280  | 5,280  | 5,250    |           |
| Sensible heat absorbed from air, B/hr                | 7,320  | 5,970  | 6,1-     | 40        |
| Total heat absorbed from air, B/hr                   | 8,530  | 8,243  | 6,770    | 7,800     |
| Temp. of antifreeze entering soil, °F                | 115.9  | 121.8  | 123.6    | 121.2     |
| Temp. of antifreeze leaving soil, °F                 | 112.5  | 118.8  | 120.9    | 118.0     |
| Antifreeze circulated, lb/hr                         | 5,950  | 5,780  | 5,720    | 5,660     |
| Heat power to the earth, B/hr                        | 17,010 | 15,950 | 15,850   | 22,760    |
| Strength of grid heat sink                           |        |        |          |           |
| (317.1 ft), B/hr/ft                                  | 41.5   | 39.9   | 39.5     | 28.1      |
| Total strength of heat sink                          |        |        |          | L         |
| (489 ft), B/hr/ft                                    | 34.8   | 32.6   | 32.4     | 46.6      |
| Temp. of antifreeze at station 3, $^\circ\mathrm{F}$ | 116.0  | 122.0  | 123.9    | 117.8     |
| Soil temp. 6 in. below center of line                |        |        |          |           |
| at station 3, °F                                     | 70.5   | 74.7   | 76.0     | 76.0      |
| Soil temp. 12 in. below center of line               |        |        |          |           |
| at station 3, °F                                     | 67.9   | 72.0   | 73.3     | 73.7      |
| Soil temp. 18 in. below center of line               |        |        |          |           |
| at station 3, °F                                     | 66.2   | 70.7   | 71.8     | 72.3      |
| Temp. of antifreeze at station 6, $^\circ F$         | 114.7  | 120.9  | 123.0    | 119.6     |
| Soil temp. 6 in. below center of line                |        |        |          |           |
| at station 6, °F                                     | 68.6   | 77.6   | 80.1     | 80.2      |
| Power input to heat pump system, kw                  | 3.946  | 3.956  | 3.928    | 3.848     |
| CER, heat pump (sensible)                            | 0.84   | 0.67   | 0.56     | 0.68      |
| CER, heat pump (total)                               | 0.97   | 0.92   | 0.75     | 0.85      |
| CER, heat pump system (sensible)                     | 0.54   | 0.45   | 0.38     | 0.46      |
| CER, heat pump system (total)                        | 0.63   | 0.61   | 0.51     | 0.59      |
| Cooling cost, kwhr/therm                             | 53.90  | 66.26  | 62.67    |           |

<sup>•</sup>Average of hourly readings.

The results of the three-month intermittent cooling test are shown graphically in Fig. 5. From curve A it can be seen that the temperature of the antifreeze in the earth heat exchanger increased from  $104^{\circ}$ F on July 1 to  $124^{\circ}$ F on September 1, after which it decreased as shown. The rise in antifreeze temperature would probably have been greater for a cooling season with normal rainfall, since wet soil has a high thermal conductivity as compared with dry soil.

Curves B, C, and D show soil temperatures at distances of 6, 12, and 18 inches below the center of the antifreeze line at station 3. The effect of heavy rainfalls on soil temperatures as well as the antifreeze temperature in the ground coil is quite apparent. It can also be seen that the soil temperatures beneath the ground coil increased slightly from July 1 to the latter part of September, after which they decreased. This drop in soil temperature is partly due to the excessive rainfall during the first three weeks of the month, and also to the decreasing effect of solar radiation on soil temperature at the depth under consideration, for this period of the year (4).

It is to be expected that the rate at which heat can be discharged to the earth would decrease with time. However with intermittent operation during July the rate of discharge increased due to exceessive rainfall. The precipitation in August was below normal, and it can be seen from curve F that the rate of discharging heat to the soil decreased until September 1. after which it increased.

### Conclusions

1. Valuable data for designing an earth heat pump are reported in this paper. These data, however, should be interpreted with the understanding that the rainfall was 30.1% in excess of the normal rainfall for the test period. In studying these data, it should be kept in mind that as previously reported, the heat pump package unit which is being used in this research, is not very efficient (1). The cooling comfort produced and the rate at which the soil dissipated the heat transferred to it depends upon the efficiency of the heat pump.

2. The performance of a heat pump is different when it is used for space heating than when used for space cooling. For this reason data from a three month cooling test and a six-month heating test are listed in Table 6. During the heating period the heat given



Figure 5. Graphical presentation of heat pump data during the cooling season of 1950. The earth heat pump operated daily from 6 a.m. to 6 p.m.

up by the compressor-motor and the fan-motor combinations is used to advantage to warm the air stream. However, during the cooling season the heat given up by the compressor-motor and the fan-motor combinations must be transferred to the earth, together with the heat removed from the air stream. This accounts for the small value (8,000 B/hr) of heat power taken from the air stream during the cooling cycle. The low value (25,510 B/hr of heat power to the air stream during the heating season is due to poor engineering practice in building the package unit (1). The heat power to the air stream is too low even though it includes the heat given to the air stream by the compressor-motor and the fan-motor combinations.

3. Low values are reported for the heat power to or from the earth (16,690 B/hr and 13,910 B/hr). These low results are due to the operation of an inefficient plant and are probably lower than they would have been under normal conditions as to rainfall.

4. The strength of the heat sink (35.6 B/hr/ft) was greater than the strength of the heat source as anticipated, and is due to the fact that the difference in temperature between the antifreeze in the ground coil and the soil was much greater during the cooling season than that during the heating period.

Table 6. Average results of a three month cooling test made during the summer of 1950 versus the average results of a six month heating test made from October 31, 1949 to May 1, 1950.

|  | 3-month      | 6-month      |
|--|--------------|--------------|
|  | cooling test | heating test |
| Outlet temp. of air stream, °F                 | 72.8         | 97.0         |
| Suction press., psia                           | 35.6         | 33.1         |
| Discharge press., psia                         | 183.4        | 149.9        |
| Heat power from or to air stream, B/hr         | 8,000        | 25,510       |
| Heat power to or from the earth, B/hr          | 16,690       | 13,910       |
| Power input to heat pump system, kw            | 3.93*        | 5.26**       |
| Total strength of heat sink or source, B/hr/ft | 35.6         | 27.5         |
| Antifreeze temp. at station 3, °F              | 119.6        | 23.1         |
| Soil temp. 6 in. below line at station 3, °F   | 73.7         | 43.1         |
| Energy ratios, heat pump                       | 0.90         | 1.96         |
| Energy ratios, heat pump system                | 0.60         | 1.43         |
| Operating cost, kwhr/therm                     | 62.9         | 20.5         |
| * 3-hp compressor motor                        |              |              |

\*\*5-hp compressor motor

5. The suction pressures during the cooling and heating periods are all right for good operating performance, but the discharge pressures are too high, particularly during the cooling period. The high discharge pressure are due to excessive pressure drops through the heat exchangers in the package unit.

6. From Table 5 it can be seen that the CER was much lower when the sensible heat only was taken into account, than when the removal of moisture from the air stream was considered.

7. There was no appreciable increase in the heat transfer from the ground coil to the soil when water replaced the prestone solution as the heat transfer medium.

8. During the last half of September the direction of flow through the earth heat exchanger was reversed so that the warm water entered the grid before passing through very much of the line. It was expected that the strength of the grid heat sink would be increased, since there was an increase in the difference between the temperature of the water in the ground coil and the soil. The strength of the grid heat sink was observed to drop from about 39.5 to 28.1 B/hr/ft. This apparent anomaly has not been fully accounted for. It may be due, in parts to the error resulting from taking the differences of temperatures of about the same value. The effect of reversing the direction of fluid flow through the ground coil will be investigated in the near future.

9. From this research it is believed that the earth is a suitable heat sink as well as a suitable heat source.

10. A more complete account of this investigation will be given in a future Engineering Experiment Station Bulletin of the University of Kentucky.

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# EFFECTS OF STAPHYLOCOCCU'S AUREU'S INFECTIONS ON BLOOD AND LIVER CATALASE IN MICE. I TITRIMETRIC METHOD

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In one of the earliest reports. Brahn observed low liver catalase activity in human beings who had died with different forms of cancer tumors. Later work revealed that the liver catalase of tumorbearing rats and mice is considerably more affected than many other individual enzyme systems studied (1). Within the last decade, intensive studies (2,3,4,5,6) have shown that this peroxide-splitting enzyme activity is considerably reduced in both the liver and kidney of these animals but not in the blood. The mechanism of action of catalase in these neoplastic conditions is not well understood, but as anemia generally accompanies tumor growth. it has been suggested that the progress of the tumor in some way interferes with the synthesis of the hemo-prosthetic group, which is possessed both by the hemoglobin and catalase (1).

It was the purpose of the present investigation to compare the enzymatic pattern of the catalase activity in the blood and liver of mice infected with *Staphylococcus aureus*, with that reported for mice bearing tumors, two quite different types of pathology.

#### EXPERIMENTAL

Normal female mice from Rockland Farm, N. Y., and a pathogenic strain of *S. aureus* from the General Biological Supply House, Chicago, Ill., were used in these determinations. The virulency of the microorganism was kept up by transfers to a blood agar medium. All reagents used were of the c.p. grade or of the highest purity obtainable.

About two dozen determinations were run to establish con-

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stant values for the enzyme activity, fahigkeit, of the blood and liver of normal animals. The permanganate titrimetric procedure, essentially the same as previously reported (7), showing the rate of decomposition of  $H_2O_2$  by catalase, was employed. This method was used in determining the fahigkeit of blood and liver of normal and infected animals.

In the preparation of the blood enzyme, the blood from the slit throat of the mouse was collected in a graduated certifuge tube and diluted. This dilution was made so as to contain the same weight of enzyme-containing material per ml. of blood to be used in the calculation of the fahigkeit from the K values at zero time.

The liver enzyme was prepared by placing the minced liver in 10 ml. of distilled water and allowing it to stand in the ice chest for 24 hours. Then it was diluted according to the original tissueweight and filtered. From these dilutions, samples were taken for analysis and further diluted according to the activity of the enzyme. After an equilibrium period of 10 minutes, which allowed the solution to come to  $0^{\circ}$ , 35 ml. of  $H_2O_2$  (0.9 ml. of 35% diluted to 1000 ml.) were mixed with 10 ml. of phosphate buffer (M/5 approximately pH 6.8) containing 1 ml. of the diluted enzyme. At three 5 minute intervals, 5 ml. of the reaction mixture were pipetted into 20 ml. of  $H_2SO_4$  (1:8) in order to stop the reaction, and the undecomposed peroxide titrated with 0.0140 N KMnO<sub>4</sub>. Blanks run for reaction of KMnO<sub>4</sub> with blood and liver enzyme activity showed almost negligible results.

#### Results

The analyses of the blood and liver catalase of 18 out of 24 normal mice are shown in Table I. The mean value for blood enzyme was found to be  $99 \pm 3.4$  and the liver enzyme to  $195 \pm 3.2$ . Ratios of blood fahigkeit values to liver fahigkeit is 1:1.8 showing the liver enzyme activity average about twice that of the blood activity.

Forty-eight animals were used in preliminary experiments to

## Effects of Staphylococcus Aureus Infections In Mice 1

determine the day best suitable for the analysis of the blood and liver of mice infected with Staphlococcus aureus. The 9th day showed the enzyme values to be the most consistent, and the day when the lesions had reached the peak of severity. Analyses were then made on 37 more infected mice to determine the fahigkeit of the blood and liver catalase. The mean value for blood catalase is  $81 \pm 4.7$ and  $216 \pm 18$  for the liver enzyme. The ratio of blood catalase to liver catalase in the infected animals varies from approximately 0.5 to 8, while in the normal animals the variation is from 1 to 2. From the data in Table II it can be seen that there is a wide variability in the enzyme values, particularly for liver, and no consistent pattern in the relationship between blood and liver catalase.

| TABLE I. | DETERMINATION | OF BLOOD | AND L | IVER | CATALASE |
|----------|---------------|----------|-------|------|----------|
|          | ACTIVITY I    | N NORMAL | MICE  |      |          |

| Det. | Mouse Wt. | Bi                 | ood Cata      | lase     | Liv                | er Catalas     | ė         | Kat. f.(liver) |
|------|-----------|--------------------|---------------|----------|--------------------|----------------|-----------|----------------|
| No.  | g.        | Zero time<br>Blank | K at<br>O tim | Kat.f.   | Zero time<br>Blank | K at<br>O time | Kat.f.    | Kat.f. (blood) |
| 1.   | 22        | 5.96               | 0.051         | 108      | 5.97               | 0.135          | 292       | 2.7            |
| 2.   | 21        |                    | 0.033         |          | "                  | 0.104          | 226       |                |
| 3.   | 21        |                    | 0.035         |          | "                  | 0.100          | 210       |                |
| 4.   | 26.1      | E.83               | 0.047         | 97       | 5.93               | 0.048          | 126       | 1.3            |
| 5.   | 24.5      |                    | 0.038         | 76       |                    | 0.068          | 176       | 2.3            |
| 6.   | 24.5      |                    | 0.055         | 86       | "                  | 0.059          | 166       | 1.9            |
| 7.   | 20.9      | 6.00               | 0.050         | 124      | 5.80               | 0.062          | 167       | 1.3            |
| 8.   | 23.8      |                    | 0.035         | 86       | "                  | 0.088          | 223       | 2.5            |
| 9.   | 24.6      |                    | 0.046         | 108      | **                 | 0.064          | 166       | 1.5            |
| 10.  | 23.0      | 5.85               | 0.041         | 90       | 5.85               | 0.074          | 224       | 2.48           |
| 11.  | 24.3      |                    | 0.056         | 119      |                    | 0.037          | 168       | 1.4            |
| 12.  | 21.3      | "                  | 0.057         | 98       | "                  | 0.084          | 271       | 2.76           |
| 13.  | 26.0      | 6.91               | 0.051         | 111      | 5.90               | 0.050          | 227       | 2.04           |
| 14.  | 23.7      | "                  | 0.051         | 118      |                    | 0.048          | 180       | 1.6            |
| 15.  | 20.9      | "                  | 0.058         | 116      | "                  | 0.058          | 222       | 1.9            |
| 16.  | 21.0      | 5.93               | 0.037         | 81       | 5.95               | 0.039          | 130       | 1.6            |
| 17.  | 23.8      | "                  | 0.039         | 95       |                    | 0.070          | 166       | 1.75           |
| 18.  | 21.2      | "                  | 0.032         | 80       | **                 | 0.062          | 167       | 2.02           |
|      |           |                    | AVE.          | 99 + 3.4 | AV                 | E. 195         | $\pm 3.2$ | AVE. 1.80      |

AVE.  $99 \pm 3.4$ 

175

# TABLE II. FAHIGKEIT VALUES OF BLOOD AND LIVER CATALASE OF MICE INFECTED WITH STAPHYLOCOCCUS AUREUS

| Det.      | Day of   | Mouse Wt. | Blood Kat.f.      | Liver Kat.f.      | Kat.f.(liver) |
|-----------|----------|-----------|-------------------|-------------------|---------------|
| No.       | Analysis | g.        |                   |                   | Kat.f.(blood) |
| 1.        | 6        | 19.6      | 128               | 308               | 2.4           |
| 2.        | 6        | 23.6      | 38                | 286               | 7.5           |
| 3.        | 7        | 18.2      | 91                | 398               | 4.37          |
| 4.        | 7        | 18.2      | 91                | 185               | 2.05          |
| 5.        | 7        | 20.4      | 96                | 196               | 2.04          |
| 6.        | 7        | 18.7      | 89                | 82                | 0.92          |
| 7.        | 9        | 18.0      | 32                | 110               | 3.4           |
| 8.        | 9        | 20.0      | 160               | 380               | 2.38          |
| 9.        | 9        | 18.4      | 106               | 284               | 2.68          |
| 10.       | 9        | 19.0      | 114               | 310               | 2.72          |
| 11.       | 9        | 18.2      | 114               | 270               | 2.37          |
| 12.       | 9        | 26.6      | 54                | 179               | 3.31          |
| 13.       | 9        | 22.2      | 118               | 63                | 0.557         |
| 14.       | 9        | 25.1      | 117               | 83                | 0.709         |
| 15.       | 9        | 24.0      | 55                | 444               | 8.07          |
| 16.       | 9        | 27.4      | 86                | 276               | 3.2           |
| 17.       | 9        | 22.4      | 69<br>E7          | 245               | . 3.55        |
| 10.       | 9        | 21.0      | 57                | 358               | 5.43<br>F 0   |
| 19.       | 9        | 22.0      | 02<br>65          | 271               | 5.2<br>9.57   |
| 20.<br>91 | 9        | 22.9      | 88                | 232               | 0.07          |
| 21.       | 9        | 23.9      | 66                | 411               | 6.23          |
| 23.       | 9        | 23.0      | 87                | 42                | 0.48          |
| 24.       | 9        | 24.8      | 82                | 175               | 2.13          |
| 25        | 9        | 19.9      | 61                | 110               | 0.85          |
| 26        | 9        | 22.5      | 118               | 173               | 1.47          |
| 20.       | 9        | 17.7      | 35                | 191               | 5.45          |
| 28        | 9        | 22.0      | 70                | 191               | 1.8           |
| 29        | 9        | 29.0      | 85                | 84                | 0.99          |
| 30        | 9        | 19.5      | 67                | 210               | 3.13          |
| 31        | 9        | 20.0      | 116               | 116               | 0.10          |
| 32        | 10       | 21.0      | 67                | 102               | 2.86          |
| 33        | 10       | 21.0      | 87                | 411               | 4.79          |
| 34        | 10       | 19.8      | 45                | 199               | 4.72          |
| 35        | 10       | 19.8      | 62                | 08                | 4.10          |
| 36        | 10       | 94.4      | 84                | 149               | 1.00          |
| 37        | 15       | 18.5      | 63                | 144               | 1.09          |
| 511       | 10       | 10.0      | AVE. $81 \pm 4.7$ | AVE. $216 \pm 18$ | AVE. 2.6      |

176

Effects of Staphylococcus Aureus Infections In Mice I

#### DISCUSSION

The data from the analyses of the infected animals indicates considerable variability in the catalase values of blood and particularly in the liver. The mean values of 81 and 216 for blood and liver catalase, respectively, point to the fact that on the average the blood enzyme in the infected animals was below normal, whereas the liver catalase, while slightly above normal, is less significantly so. Calculating the ratio of the normally distributed variant to its estimated standard error, (t) for blood is 15; for liver is 4.8. From these considerations it seems warranted to conclude that there tends to be a lowering of the blood catalase at the height of infection as revealed by the data on the 9th day.

This work is at present being repeated by other methods to attempt to eliminate some of the variations due to method in the blood and liver catalase of the infected animals.

#### SUMMARY

- 1. Normal blood catalase activity (Kat. fahigkeit) in mice was found to be  $99 \pm 3.4$ , and normal liver catalase  $195 \pm 3.2$ .
- 2. Mean values of blood and liver catalase of infected animals are  $81 \pm 4.7$  and  $216 \pm 18$ , respectively. The greatest variation was encountered in the liver catalase of infected animals.
- 3. Blood catalase tends to drop below the normal value at the height of infection without a consistent change in the liver catalase.

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# EFFECT OF STAPHYLOCOCCUS AUREUS INFECTIONS ON BLOOD AND LIVER CATALASE IN MICE. II. GASOMETRIC METHOD.

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Studies in this laboratory of the enzymatic pattern of the catalase activity in the blood and liver of mice infected with *Micrococcus pyogenes* var *aureus* have shown values of considerable variability. In a previous report (1) it was noted that on the average the blood enzyme in the infected animals was below normal, whereas the liver catalase, while slightly above normal, was less significantly so.

In order to attempt to reduce some of the variations possibly due to technique of the titrimetric method (2), the work was repeated using the gasometric procedure.

## Experimental

The procedure of White and Winternitz (3), extensively used by Greenstein in catalase studies in relation to cancer, is based upon the rapid evolution of oxygen after addition of  $H_2O_2$  to the enzyme mixture (Figure 1). The 100 ml. widemouth bottle moved through a distance of 10 cm. at the rate of 4 oscillations per second. The oxygen output was measured at constant pressure by the rate of displacement of a dilute solution of methylene blue from an inverted buret attached to the reaction bottle by means of a rubber tubing. Readings were taken at 5-second intervals over a period of 30 seconds.

In control experiments the wide-mouth bottle contained 5 ml. of M/5 prosphate buffer (pH 6.8), 2 ml. of distilled water, and 1 ml. of properly diluted enzyme, all kept at approximately 5°C. These were allowed to stand in contact 10 minutes at 5°C., at the end of which time a 1 ml. beaker containing 0.5 ml. of 30% H<sub>2</sub>O<sub>2</sub> was placed upright in the wide-mouth bottle before putting the bottle in the shaking machine. As shaking began, the beaker tipped

# Effects of Staphylococcus Aureus Infections In Mice II

over, allowing the  $H_2O_2$  to come in contact with the enzyme-buffermixture.



Figure 1.

#### PREPARATION OF ENZYME SOLUTION

A mouse liver is thoroughly ground in a glass mortar, diluted with cold distilled water, filtered through four thicknesses of cheescloth, and placed in an ice bath until ready for use. One ml. of the dilution added to the reaction mixture should give about 10 - 15 ml.  $O_2$  in 10 sec. Dry weights are determined and the ml.  $O_2$  per mg. dry weight is obtained.

The blood from the slit throat of the mouse is collected in a graduated centrifuge tube, diluted and kept in ice bath. As it is not possible to maintain a constant temperature in the reaction mixture during the course of the experiment, all ingredients are kept in an ice bath until ready for use. Under these conditions the enzyme does not deteriorate very rapidly and many experiments can be run with one preparation. Readings taken at the 10 second period are reported.

#### Results

Analyses of the blood and liver catalase of 12 control animais are shown in Table I. The mean value for the blood enzyme was found to be  $1.57 \pm 0.37$  and for the liver enzyme to be  $3.44 \pm 0.55$ . The ratio of the blood values to liver values is 1:2.1 showing the liver enzyme activity averages twice that of the blood activity.

Of the thirty-six animals infected with the organism, twentyfive animals gave mean values of  $1.37 \pm 0.32$  and  $3.88 \pm 1.18$  for blood and liver catalase respectively (Table II). The ratio of blood to liver enzyme is 1:2.8 or about 3 times that of the blood activity. Table III shows the comparison between the values obtained by the titrimetric and gasometric methods for both normal and infected animals.

TABLE I. BLOOD AND LIVER CATALASE ACTIVITY IN MICE. GASOMETRIC METHOD

#### CONTROLS

| Determination | Blood                       | Liver          |
|---------------|-----------------------------|----------------|
| Number        | ml/O <sub>2</sub> mg. dry w | t. extract     |
| 1.            | 1.75                        | 4.49           |
| 2.            | 1.36                        | 3.46           |
| 3.            | 1.72                        | 3.22           |
| 4.            | 1.78                        | 3.63           |
| 5.            | 1.34                        | 3.33           |
| 6.            | 1.68                        | 3.01           |
| 7.            | 2.54                        | 4.00           |
| 8.            | 1.26                        | 4.11           |
| 9.            | 1.31                        | 4.14           |
| 10.           | 1.77                        | 2.77           |
| 11.           | 1.10                        | 2.36           |
| 12.           | 1.30                        | 2.82           |
| Average       | $1.57 \pm .37$              | $344 \pm 0.55$ |

# Effects of Staphylococcus Aureus Infections In Mice II

# TABLE II. BLOOD AND LIVER CATALASE ACTIVITY IN MICE GASOMETRIC METHOD

## ANIMALS INFECTED WITH STAPHYLOCOCCUS AUREUS

| Days     | Blood                       | Liver           |
|----------|-----------------------------|-----------------|
| Infected | ml/O <sub>2</sub> mg dry wt | t. extract      |
| 8        | 1.50                        | 1.75            |
| 8        | 1.42                        | 2.90            |
| 8        | 1.45                        | 2.13            |
| 8        | 1.33                        | 2.63            |
| 9        | 1.43                        | 4.00            |
| 9        | 1.26                        | 3.72            |
| 9        | 1.36                        | 1.78            |
| 9        | 1.39                        | 3.87            |
| 9        | 0.82                        | 1.02            |
| 9        | 1.47                        | 1.96            |
| 9        | 1.52                        | 1.40            |
| 9        | 1.90                        | 3.33            |
| 9        | 1.23                        | 5.43            |
| 9        | 1.23                        | 3.61            |
| 9        | 1.54                        | 3.86            |
| 9        | 1.73                        | 4.22            |
| 9        | 1.52                        | 4.93            |
| 9        | 1.29                        | 5.52            |
| 11       | 1.17                        | 3.22            |
| 11       | .90                         | 4.03            |
| 13       | 1.02                        | 3.47            |
| 13       | 1.25                        | 3.40            |
| 13       | 1.89                        | 3.90            |
| 13       | 1.30                        | 3.87            |
| 13       | 1.48                        | 2.38            |
| Average  | $1.37 \pm 0.32$             | $3.88 \pm 1.18$ |

# TABLE III. CATALASE ACTIVITY IN MICE DETERMINEDBY TITRIMETRIC AND GASOMETRIC METHODS

|          | Blo             | bod             | Liver        |                           |  |
|----------|-----------------|-----------------|--------------|---------------------------|--|
|          | Titrimetric     | Gasometric      | Titrimetric  | Gasometric                |  |
|          | (ml. $O_2/mg$ . |                 |              | ( ml. O <sub>2</sub> /mg. |  |
|          | Kat. f.         | dry wt. extract | Kat. f.      | dry wt. extract           |  |
| Controls | $99\pm$ 3.4     | $1.57 \pm 0.37$ | $195\pm$ 3.2 | $3.44 \pm 0.55$           |  |
| Infected | $81\pm$ 4.7     | $1.37 \pm 0.32$ | $216\pm~18$  | $3.88 \pm 18$             |  |

#### DISCUSSION

The mean values of the blood and liver enzyme appear to show the same trend of activity by the gasometric as by the titrimetric method. Both procedures reveal a drop in the blood catalase and a rise in liver catalase of the infected animals. This increase of the liver enzyme activity shown by both methods may not be significant due to considerable variation in the liver values; however, calculating the ratio of the normally distributed variant to its estimated error, (t) for blood is 7.1 and 5.6 for the liver. From Fisher's table of t, P is 0.01 for a t value of 2.797. A t of 7.1 or of 5.6 is definitely significant.

#### SUMMARY

- 1. Catalase activity of blood and liver in normal mice by the gasometric method was found to be  $1.57 \pm 0.37$  and  $3.44 \pm 0.53$  respectively. The blood and liver values of animals infected by *Staphylococcus aureus* were found to be  $1.37 \pm 0.32$  and  $3.88 \pm 1.18$ respectively.
- 2. Both procedures (titrimetric and gasometric) revealed a drop in blood catalase during infection and an increase in the liver enzyme.
- 3. As there exists a wide variability in the enzyme values, particularly for the liver, no consistent pattern seems to exist between the relationship of the blood and liver catalase for individual animals, but the t and P values show that the results are significant for the groups.

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  - \* Vol. 13, no. 3, pp. 173-177.

# ANTIBIOTIC-PRODUCING SPECIES OF BACILLUS FROM WELL WATER

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The studies reported upon were carried out on triplicate samples that were collected from each of 32 Fayette County Kentucky wells. Of each set of samples, one was examined within two hours of the time of collection, another after storage for 24 hours at room temperature, and the third after storage for 48 hours. Plate counts, coliform determinations, and attempts to isolate antagonists for *Escherichia coli* were made on each sample. Attempts have been made to correlate the presence of antagonists with the presence of coliforms and with the decrease in number of coliforms during storage of the water samples. Antagonists isolated consisted chiefly of members of the actinomycetes, *Bacillus* and *Pseudomonas* groups. This paper deals only with the *Bacillus* strains.

The method used for the isoluation of the antagonists was essentially that of Kelner, 1948. Plates were prepared containing approximately 15 ml quantities of sterile nutrient agar. After the agar had solidified, a laver of 5 ml of nutrient agar containing an appropriate dilution of the water sample was spread over the surface of the plate. Quintuplicate plates for each of three dilutions were made from each water sample. After one week's incubation at room temperature all plates which contained a satisfactory number of colonies were tested for the presence of antagonists. For this purpose a 5 ml layer of nutrient agar containing 1:750,000 crystal violet and 1 ml per 50 ml of agar of a 24 hour nutrient broth culture of a freshly isolated strain of E. coli was poured over the surface of each plate. The plates were then incubated over night at 37 C and examination was made for zones of inhibition of growth of the E. coli above and around colonies of organisms that produced diffusable antibiotic substances. Attempts were made to isolate cultures from all types of colonies of antagonists that were found on the plates.

As the antibiotic substances produced by the *Bacillus* strains were apparently sufficiently bactericidal in almost all cases to kill the *E. coli* in the layer of agar above the colonies no difficulty was experienced in the isolation of pure cultures of these organisms.

Species of *Bacillus* that were antagonistic for the strain of E. coli used were isolated from 24 of the 32 sets of samples. In about two thirds of the cases only one or two colonies of the antagonists were present on the plates but in the other third of the cases the numbers of antagonists amounted to from several hundred to several thousand per ml of sample. Several types of antagonists were sometimes present on the same plate.

The Bacillus isolates were identified according to the procedure of Smith, Gordon and Clark, 1946. A total of 15 isolates of *B. subtilis*, 2 of *B. subtilis* var. *aterrimus*, 3 of *B. pumilis*, 13 of *B. cereus*, 1 of a *B. megatherium* - *B. cereus* intermediate, 1 of *B. circulans*, 1 of *B. macerans*, 1 of *B. brevis*, and 2 of *B. laterosporus* were identified.

After the purity of the cultures was established, they were stored in tubes of semi-solid agar in the refrigerator. Approximately 12 to 18 months later their antibiotic activities were studied. For this purpose a cross streak method similar to that used by Cervagal, 1947, Gilliver, 1949, and others, was employed. Each culture was streaked across one diameter of a nutrient agar plate. The plates were incubated at 32 C for 48 hours before cross streaking the other diameter of the plate with the test organisms. Test organisms used were Pseudomonas aeruginosa, Salmonella paratyphi, Salmonella typhosa, Shigella flexneri, Klebsiella pneumoniae, Aerobacter aerogenes, 3 strains of Escherichia coli including the one used in the isolations, a strain of Paracolobactrum, Micrococcus pyogenes var. aureus, Mycobacterium hominis, Mycobacterium phlei, Mycobacterium smegmatis, and Candida albicans. After a 24-hour period of incubation the zones of inhibition were measured. The plates were incubated for another 24-hour period and the zones of inhibition were rechecked. In no case did the zones increase or decrease during the second 24-hour period. All isolates were tested at least once against

#### Antibiotic-Producing Species of Bacillus from Well Water

each of the test organisms. Selected representative isolates were tested as many as six times.

As his been shown by many workers, *Bacillus* strains tend to lose their antibiotic activity upon cultivation on laboratory media. Many of the cultures were found to have lost their antibiotic ability against the strain of *E. coli* which had been used for their original detection, and many of the other isolates produced a smaller antibiotic zone than had been produced on the original plate.

It is evident that variations both in the antibiotic-producing abilities of the various isolates and in the resistance of the various test organisms occurred during the course of the tests. As examples of the former; On August 8, isolate 16 (*B. subtilis*) was antibiotic only to *S. typhosa* and *M. pyogenes*, although on July 26 it had also been antibiotic to *S. paratyphi*, *S. flexneri*, all 3 strains of *E. coli*, and the paracolon strain; On August 8, isolate 72 (*B. subtilis*) was antibiotic to *S. flexneri*, *S. typhosa*, one strain of *E. coli*, and *M. pyogenes*, although on July 26 it had been antibiotic only to *S. flexneri*. As an example of the latter, *S. paratyphi* gradually became resistant to all antibiotic action during the period of approximately four months during which the tests were being performed so that on August 8 none of 10 isolates showed any antibiotic action toward it although 9 of the 10 had showed such action on previous tests.

None of the *Bacillus* isolates showed antibiotic action against *P. aeruginosa*, *K. pneumoniae*, *A. aerogenes*, *C. albicans*, *M. phlei*, or *M. smegmatis*. The strongest antibiotic action was shown against *S. flexneri*, *S. typhosa* and *M. pyogenes*.

The best antibiotic action was produced by the *B. subtilis* isolates. On the original plates they had produced antibiotic zones of from 2 to 15 mm. In general, no loss in potency appears to have occurred during storage of the pure cultures before their antibiotic activities were tested. Some of the isolates produced larger zones than those on the original plates. Almost all the 15 isolates were antagonistic to *S. paratyphi*, *S. typhosa*, *S. flexneri*, the 3 strains of *E. coli*, and *M. pyogenes*. Four were antagonistic to the paracolon strain. Zones of inhibition varied from 2 to 18 mm, the largest being with *S. flexneri* (average 10 mm) and *M. pyogenes* (average 11 mm). The isolates of *B. subtilis* var. *aterrimus* were slightly less active.

The 3 isolates of *B. pumilis* produced zones of 8, 8, and 5 mm respectively against *E. coli* on the original plates. The ability to antagonize *E. coli* was lost completely during storage of the cultures. One of the isolates produced no antagonistic effects, one antagonized *S. flexneri* and *M. pyogenes*, and the third antagonized *S. flexneri*, *S. typhosa* and *M. pyogenes* when it was first tested but was entirely negative when it was retested 3 times from one to two months later.

The *B. cereus* isolates producted at least as large zones of inhibition against *E. coli* as did the *B. subtilis* isolates at the time of isolation but they almost completely lost their antibiotic powers before the tests for antibiotic activity were made. Eight of the 13 isolates had no antibiotic action, 2 produced a slight inhibition of *M. hominis* on one test, 1 produced a slight inhibition of the paracolon strain, and the other 2 inhibited *S. flexneri*, *S, typhosa*, one of the strains of *E. coli*, and *M. pyogenes* when they were first tested but were negative when they were retested a few days later.

The isolates of *B. brevis*, *B. macerans*, *B. circulans* and *B. laterosporus* produced zones of inhibition against *E. coli* of 15 mm, 20 mm, 2 mm, and 5 mm, respectively when they were isolated. All these isolates produced spreading types of growth so that reliable tests could not be made with the method that was employed in this study.

#### Comment

The data available thus far from this study are not adequate to determine the significance of *Bacillus* species in connection with the longevity of coliforms in water. Previous work has presented strong evidence that antagonistic organisms in water may significantly decrease the longevity of coliforms that are present along with them. Hutchison, Weaver and Scherago, 1943, isolated antagonists for *E. coli* from water samples and showed that if they were inoculated in fairly large numbers into water samples they would cause a rapid decrease in the number of coliforms present in the samples. Vaccaro, Briggs, Carey and Ketchum, 1950, have reviewed the question of viability of *E. coli* in sea water and have presented convincing evidence that microorganisms produce bactericidal substances in the water which affect the viability of the *E. coli*. The detection

#### Antibiotic-Producing Species of Bacillus from Well Water

of *Bacillus* strains in samples from 24 of 32 wells in this study is indicative that these organisms may have some signifiance. Samples from 29 of the wells yielded positive tests for coliform organisms. No direct correlation is evident between the number of coliforms and the number of antagonists present. Large numbers of *Bacillus* antagonists were found, however, only in heavily polluted water samples.

The most significant groups of *Bacillus* antagonists appear to be the *B. subtilis* and *B. cercus* groups. It is not surprising that the *B. subtilis* group should be one of the dominant ones in view of the large number of antibiotic substances that have been shown to be produced by members of this group. It should be noted, however, that the *B. cercus* isolates, on the average, produced slightly broader zones of antibiosis at the time of isolation than did the *B. subtilis* isolates. This antibiotic ability was largely lost upon cultivation. From these results, the possibility should be considered that the *B. cercus* strains are better suited to antibiotic formation under natural conditions whereas the *B. subtilis* strains are better suited to antibiotic formation on artificial media, and that the presence of *B. cercus* strains, in the water, therefore, may have greater signifi cance.

#### SUMMARY

Members of the genus *Bacillus* that are antagonistic for *Escherichia coli* were isolated from samples of water from 24 of 32 Fayette County, Kentucky, wells. Of 39 isolates that were identified, 15 were *B. subtilis* and 13 were *B. cercus*. The *B. cercus* isolates had slightly broader zones of inhibition for *E. coli* than did the *B. subtilis* isolates at the time of isolation. When they were tested 12 to 18 months later, however, they had almost completely lost their antibiotic-producing ability while the *B. subtilis* isolates had retained theirs. Almost all the *B. subtilis* isolates also produced antibiotic action against *Shigella flexneri*, *Salmonella typhosa*, *Salmonella paratyphi* and *Micrococcus pyogenes* var. *aurcus*. Although the data presented are inadequate to determine the significance of *Bacillus* species in connection with the longevity of coliforms in water, the demonstrated prevalence of potentially antagonistic strains indicates that they may have some significance.

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# SUBSURFACE EARTH EXPLORATION BY ELECTRICAL RESISTIVITY METHOD

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Throughout the ages men have erected innumerable structures and have performed a multitude of engineering feats directly upon the earth's crust or outer layer. In the planning for most of these projects, there has arisen the need for knowledge of the character and depth of the materials immediately below the surface at the site. On such occasions it has, until recently, been necessary to attack the problem by the direct, time-consuming, costly, and laborious method of digging by some means a pit or a hole in order to examine the underlying material. Even with up-to-date methods, this procedure is costly both in time and money. In recent years, however, two geophysical methods for securing information regarding subsurface conditions have attracted considerable attention. They are known as the Refraction Seismic method and Electrical Res'stivity method. Both of these methods have been used extensively in recent years by geologists, mining, and petroleum engineers for subsurface reconnaissance. In this paper, a brief discussion of the Electrical Resistivity method will be given. In addition, some results of a study now being made to attempt an evaluation of this method will be presented.

The basic theory underlying measurements of the earth's resistance to the flow of an electric current was set forth in 1915 by Wenner.<sup>(1)\*</sup> The method employed in this study is known as the four-electrode type. A schematic diagram of the four-electrode equipment as it is set up for use in the field is shown in Figure 1. In brief, the equipment used consists of a source of power such as "B" batteries, a milliameter to measure current passed, two current electrodes, two non-polarizing electrodes, a potentiometer to measure the drop in potential between the potential electrodes, and the necessary wiring to connect all parts of the equipment. This material is assembled in two independent circuits. The first or outer circuit includes the current source, the milliameter, and

• Numbers in parentheses refer to items in bibliography.

the two current electrodes. The current electrodes which are two copper-coated steel rods are driven into the ground a distance of "3a" apart. The power source is equipped with a reversible switch which allows the current to be transmitted in either direction along the circuit. The second or inner circuit consists of the potentiometer and the two non-polarizing electrodes. The non-polarizing electrodes consist essentially of a transparent plastic cartridge filled with a solution of copper sulfate and having a porous plug in one end to permit the solution to seep through in order to insure good electrical contact with the earth's surface. The non-polarizing electrodes are placed on a line between the two current electrodes dividing the distance 3a into three equal parts "a". A current "I" is then passed through the outer circuit and flows through the earth from one current electrode to the other. The drop in potential "E" between the intermediate potential electrodes is then measured. Current will flow from the current electrode in the usual pattern. Equipotential lines or equipotential surfaces normal to the current lines are also formed. Current is passed in one direction in the outer circuit and the drop E and voltage I are measured. In order



DIAGRAM OF FIELD SET-UP

Figure 1. Schematic Diagram of Equipment Used for Finding Resistivity of Soils by the Four-Electrode System.

to prevent polarization of the current electrodes and to eliminate or minimize the effect of stray currents present in the earth, the current direction is then reversed and the readings taken as before. The resistivity of the material between the potential electrodes may then be foud by use of the formula

$$ho = 2 \pi \,\mathrm{a} \frac{\mathrm{E}}{\mathrm{I}}$$

in which a is the electrode spacing in feet

E is the drop in potential, in millivolts

I is the current in milliamps flowing through the circuit and  $\rho$  = the resistivity of the soil between the potential electrodes in ohms-feet.

If the material is homogeneous, the resistivity found by this formula can be assumed to be the specific resistivity of the material between the equipotential lines or surfaces passing through the potential electrodes. If the material is not homogeneous and soil seldom is, then the resistivity found is called the apparent resistivity and represents the average specific resistivity of the material in the area between the potential electrodes.<sup>(2)</sup>

Various investigators have found that the value of resistivity is influenced largly by the material in the above area to a depth "a" and that materials at a depth greater than "a" apparently have a negligible effect on the flow of the current lines and therefore on  $\rho^{(3)}$ 

If the value of the electrode spacing "a" is increased through given increments, the current flow lines extend to deeper layers in the earth's crust and the resistivity found reflects the apparent resistivity of the material to greater depths corresponding to the increased electrode interval "a".

The resistivity of materials of the earth's surface has been found to depend largely upon the amount of moisture and ionized salts present in the material. Since the amount of these electrolytic salts will vary greatly with different types of material, the resistivities of layers of different materials may also be expected to vary greatly. For example, moist clay deposits may have a fair amount of these salts in their structure and as a result clays usually show very low resistivity value. Rock, on the other hand, is usually relatively dense and has few pores for the electrolytic solution to occupy and therefore shows correspondingly high resistivity values.

Several different methods of interpreting resistivity data have been used or proposed. The method of interpretation used in this study is known as the Gish-Rooney method.<sup>(4)</sup> By this system the resistivities found at each electrode spacing are plotted as ordinates against the electrode spacing as abscissae. If the curve plotted by this system is studied, it will usually show changes in slope at electrode spacings which correspond approximately with the depth at which changes in types of material occur.

For the electrical resistivity method to be of much value to the Highway Engineer, it is obvious that some quick method such as this must be used which will enable the readings to be placed in usable form as soon as possible.

One of the large problems of this study has been, therefore, to determine if depths of soil layers obtained by this method can be correlated with actual depths or thicknesses as obtained by direct methods. Also, if the correlation exists, is it close enough to allow the use of the data obtained in ordinary Highway work?

Several sites were selected where records of borings were available and resistivity measurements were made at these sites. Results from four of the principal sites investigated are presented here with typical resistivity curves obtained shown along with a plot of the drill borings at the same site.

#### TYRONE BRIDGE

One of our most detailed investigations was made at Tyrone Bridge on the Kentucky River near Lawrenceburg, Kentucky. Resistivity readings were taken in the flat space on the Versailles side of the river between piers four and five. The resistivity measurements were made along a line parallel to and seventy-five feet toward the river from the face of pier five and 149 feet from pier four. The right hand drill log shown in Figure 2 is from a boring at pier five and the left drill log is from a boring made at pier four.

Measurements were made on July 12 and 14. The weather



Subsurface Earth Exploration By Electrical Resistivity Method

Figure 2. Resistivity Measurements and Drill Cores along Line D at Tyrone Bridge.

was clear and ground was moist from previous rains.

The drill logs at this location show the upper layer of material to be a sandy clay. At pier five the log shows the sandy clay to be underlain at a depth of about twenty-five feet by sandy gravel which extends to bedrock (limestone) at a depth of about thirtytwo feet. At pier four the borings show sandy clay to a depth of twenty-one feet and sandy gravel extending to bedrock at a depth of 39.5 feet.

The resistivity curve at this location shows a marked increase in apparent resistivity at an electrode spacing corresponding to a depth of twenty-two feet. This increase would indicate the presence of a more resistant material such as a sand or gravel. The decrease in the rate of increase of the apparent resistivity of the sandy gravel between twenty-two feet and thirty-four feet probably reflects the increase in moisture content with depth as bedrock is approached. The next significant change in slope of the resistivity curve occurs at a spacing of thirty-four feet. The increase in slope at this point would point to the presence of a more dense material such as bedrock. This depth of thirty-four feet corresponds to a depth of about 34.5 feet to bedrock as predicted from the drill logs shown in Figure 2.

## BURNSIDE, KENTUCKY

Studies at this site were made in the vicinity of the Monticello, Pitman Creek and U. S. 27 Highway bridges. Data for resistivity Line A shown in Figure 3, were taken at the site of the new highway bridge on the Monticello-Burnside road. Measurements were taken on the north bank of the Cumberland River parallel to and 53.7 feet toward the river from pier five.

The drill logs shown in Figure 3 are located on the same line that the resistivity data were taken on and were spaced twenty-five feet each way from the center line of the bridge.

Data at this location were taken July 6, 1950. Adverse weather conditions consisting of intermittent showers were encountered.

As shown in Figure 3, the drill logs here show sandy loam to a depth of about four feet. This is underlain by a firm yellow clay to a depth of about thirty-seven feet. Below this is found a



Subsurface Earth Exploration By Electrical Resistivity Method

Figure 3. Resistivity Measurements and Drill Cores along Line A at Burnside, Kentucky.

layer of loose sand and gravel and bedrock is encountered at depths of forty-two to forty-four feet.

The low value for resistivity shown at four feet spacing undoubtedly was caused by the completely saturated condition of the topsoil at the time the readings were taken. With the above exception, this curve is practically ideal for the materials present at this location.

The ideal curve for the soil layers found here would start with high resistivity values in the loam strata and the resistivity values would decrease as the electrode spacings were increased, permitting a greater percentage of current lines to flow through the clay strata.

The resistivity values should decrease until an electrode spacing is reached which permits the major portion of the current lines to be flowing through the clay strata. At this point, the resistivity values should show a gradual increase with depth due to the combined effect of the overlying materials. This is the condition illustrated by Line A at Burnside as shown in Figure 3.

The first deviation from the above pattern may be noted at a spacing corresponding to a depth of thirty-six feet. The increase at this point is caused by the presence of the sandy gravel which is a more resistant material. Another change in slope is noted at forty-four feet indicating the possibility of a more resistant material at this depth. That this is the condition actually existing is shown by the drill logs which indicate bedrock at a depth from forty-two to forty-four feet.

#### BOONESBORO BRIDGE

Another location investigated was at Boonesboro Bridge on the Kentucky River. Resistivity readings were taken on the west bank of the river between piers eight and nine. The data were taken along a line parallel to and fifteen feet toward the river from pier nine. The right hand drill log shown in Figure 4a is from a boring at pier nine and the left hand drill log is from a boring made at pier eight.

The readings were taken June 26. Weather was clear and very warm. The river was falling.

Since the resistivity data were taken near the face of pier nine, it is believed that the drill log for the boring there presents a better picture than would the drill log at pier eight of the conditions to be expected at the point where the resistivity data were taken.

This drill log shows a firm clay to a depth of eighteen feet. This is underlain by a soft yellow clay stratum to a depth of twentysix feet. At this point, the material changes to a very soft blue clay which continues to a depth of forty-two feet. Below this is found gravel extending to bedrock at a depth of forty-six feet.

Down to a depth of twenty-six feet, the curve follows closely the ideal curve for a clay material. It is thought possible that the break in the curve at the electrode spacing corresponding to this depth can be attributed to a possible difference between the conductivity of the soft yellow clay and the very soft blue clay. The increase in the slope of the curve at thirty-six feet is believed to be caused by an extension of the sand strata into this area. A decrease in the slope of the curve is noted at forty to forty-two feet. This condition is contrary to what would normally be expected for the gravelly material shown on the drill log. Observations made at the time the resistivity data were taken indicate that this depth corresponded closely to the elevation of the water level of the river. In other words, it is thought probable that the decrease in resistivity values at this point was caused by a saturated condition of the sand and gravel strata. Forty feet could then be taken as the upper limit of the water table at this point. The increase in slope at fifty feet and beyond clearly indicates that the current flow lines have entered a more resistant material such as bedrock. This corresponds closely with the depth to bedrock shown on the drill logs.

#### CLAYS FERRY BRIDGE

A number of different investigations were made on the Lexington side of the Kentucky River at Clays Ferry Bridge. The line shown in Figure 4b was plotted from data taken between piers six and seven, twenty feet toward Lexington from the face of pier six, and along the line passing through the points where the cores shown in Figure 4b were taken.

Measurements were made May 16, 1950. Weather was clear and soil moist.

The center cores shown in the Figure were taken thirty feet apart. The outer cores were located fifteen feet on either side of the two center cores.



Figure 4a. Resistivity Measurements and Drill Core along Line A at Boonesboro Bridge, Ky.

Figure 4b. Resistivity Measurements and Drill Core along Line A at Clays Ferry Bridge.

The outer cores show eight to nine feet of sandy loam underlain by brown sand and yellow clay to a depth of twenty-four to thirty-six feet below which there is sand and blue clay to a depth of forty-six feet. A sandy gravel is then noted which gives way to bedrock at about forty-eight to forty-nine feet.

The center cores in Figure 4b show sixteen to eighteen feet of

## Subsurface Earth Exploration By Electrical Resistivity Method

sandy loam turning to a brown sand at about twenty-eight feet. This is underlain by blue clay and sand to about forty feet. Below this is coarse sand giving way to bedrock at forty-seven to fortynine feet.

This curve has been included to show some of the many problems that may be encountered in a study of this type. First, it should be noted that there is a pocket of sand in the area covered by the center drill holes. The exact size and shape of this deposit are unknown. It is believed possible that this deposit of sand could have caused the peak in apparent resistivity values shown at an electrode spacing corresponding to a depth of sixteen feet.

The erratic shape of this curve for electrode spacings from twenty-six to forty-two feet can possibly be attributed to the poor contact obtained with the current electrodes. At these electrode spacings, it was necessary to drive the current electrodes in an area which had been covered with rocky rubble used in backfilling around the pier.

Between forty-two and fifty feet, the curve follows the pattern expected for a granular material underlain by bedrock. The decrease in apparent resistivity values at this point is believed due to a solution channel. The presence of this channel is indicated by data from a core taken twenty feet toward the river on a line midway between the center cores shown in Figure 4b. The channel at that point was encountered at a depth of sixty-one feet. Drilling was discontinued at fifty feet on the cores shown on this figure which could explain why the channel is not shown.

An extensive study is being made at this location in an attempt to obtain better correlation between the resistivity data and the usual conditions shown by the drill logs.

#### Conclusions

Inasmuch as this study is not yet complete and the data taken has been only partially analyzed, no broad or sweeping conclusions can be attempted. More field data are being taken and some of the other methods available for analyzing these data are being investigated.

On the basis of the results to date, though, it is felt that the following conclusions are justified:

1. The amount of moisture present in the various soil strata encountered in this investigation was found to be the major factor influencing the resistivity of these materials.

2. The depth to bedrock can be ascertained with sufficient accuracy for general highway work.

3. By using this method in conjunction with properly located drill holes, it is possible to map the subsurface conditions of large areas at a saving of both time and money.

4. In the case of such a condition as illustrated in Figure 4b, this method can be used to direct core drilling operation in a manner that would insure drill holes being placed in the proper position to obtain the best survey of actual site conditions. For example, the resistivity data shown in Figure 4b indicate that another core should be taken midway between the two center cores in order to obtain a better idea of the shape of the sand pocket. Our data would also indicate that this core should be carried to a depth of at least sixty feet in order to investigate the possibility of a solution channel at this point.

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## ACADEMY AFFAIRS

#### THE 1950 FALL MEETING

The University of Louisville was host to the thirty-sixth annual meeting of the KENTUCKY ACADEMY OF SCIENCE on Friday afternoon and Saturday morning, October 27 and 28, 1950.

The program for Friday afternoon, October 27, provided for conducted tours through various industrial plants in the Louisville area. Arrangements for the tours were handled by Dr. M. I. Bowman of the University of Louisville.

The annual dinner of the ACADEMY was held Friday evening in the Seelbach hotel. High light of the dinner was an address delivered by Professor Anton J. Carlson of the University of Chicago on the subject, "Science and Society". Professor Carlson was introducted by Dr. Warren Rehm of the University of Louisville School of Medicine. Arrangments for the dinner and for the speaker were made by a committee, consisting of Dr. William Clay (Chairman), Dr. Paul Kolachov and Dr. Richard Wiley.

At the business meeting Saturday morning, October 28, officers were elected for the Academy year, 1950-1951.

President: E. B. Penrod, University of Kentucky, Lexington.

Vice President: M. C. Brockmann, Joseph E. Seagram & Sons, Inc., Louis-ville.

Secretary: C. B. Hamann, Asbury College, Wilmore.

Treasurer: R. H. Weaver, University of Kentucky, Lexington.

Representative to the Council of the A.A.A.S.: Austin R. Middleton, University of Louisville, Louisville.

W. E. Blackburn of Murray State College and Paul Kolachov of Joseph E. Seagram & Sons, Inc., were elected to serve on the Board of Directors until 1954.

Following the Saturday morning business meeting the various Divisions of the Academy met for the presentation of specialized papers and for the transaction of divisional business. The programs of the various Divisions are recorded as follows:

#### MEDICAL TECHNOLOGY AND BACTERIOLOGY

Mrs. Rose Conner, Presiding.

"Metabolism of sodium in health and disease with a photometric method for its determination in biological fluids". Mary Simonette, Nazareth College, Louisville.

"The use of the flame photometer". Jean Segar, Nichols General Hospital, Louisville.

"A mycological study of a case of histoplasmosis in a three month old in-
## Academy Affairs

fant from Jessamine County Kentucky". James T. McClellan, George H. Scherr and Margaret Hotchkiss, Lexington.

"Standardization of dust extracts by biological methods". Morton Reitman and Morris Scherago, University of Kentucky, Lexington.

Role of vitamins in the oxidation of glucose and glycerol by *Lactobacillus* casei". Mary M. Hardin, University of Kentucky, Lexington.

"Antibiotic producing species of bacillus from water". Theodore Bacter and R. H. Weaver, University of Kentucky, Lexington.

"Comparison of the bacterial count on home and commercially packed frozen foods". Leona Quigg and C. B. Hamann, Asbury College, Wilmore.

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"An ecological study of the microbenthic fauna of two Minnesota lakes". Gerald A. Cole, University of Louisville, Louisville.

"Notes on the vertical distribution of organisms in the profundal sediments of Douglas Lake, Michigan". Gerald A. Cole, University of Louisville. Louisville.

"An old case of gynandromorphism in *Boros discicollis*". T. J. Spilman, University of Louisville, Louisville.

"Reptiles of Bullitt County, Kentucky". Richard W. Allen, Louisville.

"Amphibians of Bullett County, Kentucky". Robert C. Cunningham, Louisville.

"Multiplication of *Bacterium tabacum* in leaves of *Nicotiana longiflora*". Stephen Diachum and Joseph Troutman, Kentucky Agricultural Experiment Station, Lexington.

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"Performance of an earth heat pump operating intermittently on the cool-

ing cycle". R. C. Thorton and E. B. Penrod, University of Kentucky, Lexington. "New tools for processing vegetable oils". Allen Bond, Votator Division, The Girdler Corporation, Louisville.

"New techniques in the study of soils for engineering purposes". James H. Havens, Kentucky Department of Highways, Lexington.

"Emissivities of protective coatings". W. R. Barnes, University of Louisville Institute of Industrial Research, Louisville.

"Subsurface earth exploration by electrical resistivity method". L. C. Pendley, University of Kentucky, Lexington.

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#### CHEMISTRY

#### T. C. Herndon, Presiding.

"3-Methyl-2-Cyclohexene-1-one and derivatives". M. I. Bowman and C. C. Ketterer, University of Louisville, Louisville,

"Chromatography of amino acids on cellulose columns". Forest G. Houston, Kentucky Agricultural Experiment Station, Lexington.

"The mechanism of action of certain sulfhydryl reagents on the cytochrome oxidase system". M. Angelice Seibert, Ursuline College, Louisville and Cornelius W. Kreke, Institutium Divi Thomae, Cincinnati.

"Effects of Staphlococcus aureus infections on blood and liver catalase in mice. II. Gasometric method". Mary Adeline O'Leary, Virginia Heines, Roderick Juhasz, Rose Agnes Greenwell and Cornelius W. Kreke, Nazareth College Unit of Institutium Divi Thomae, Louisville,

"The electrical conductance of solutions of ferric chloride in acetone at 20 and 40° C". Lyle R. Dawson and Ralph L. Belcher, University of Kentucky, Lexington.

"The distribution of alkali iodides between ethylene glycol and ethyl acetate". Lyle R. Dawson and Edward J. Griffith, University of Kentucky, Lexington.

The tetra-hydroxy cobalt (II) ion as a qualitative test for cobalt". Saul Gordon and James M. Schreyer, University of Kentucky, Lexington.

"The decomposition pH of the thio-anions of arsenic, antimony and tin".

# Academy Affairs

G. L. Corley and Norma M. Woodward, University of Louisville, Louisville.

"The free energy of copper chromate". Sigfred Peterson and Orland W. Cooper, University of Louisville, Louisville.

"Spectrophotometric studies of the composition of Lespedeza seed oil". Richard H. Wiley, A. W. Cagle and Phil H. Wilken, University of Louisville, Louisville.

"Improvement of soaps for GR-S polymerization. Retarding influence of multiple unsaturated acid soaps on the butadiene-styrene polymerization". C. S. Marvel, University, of Illinois, Urbana; W. E. Blackburn, Murry State College, Murray; D. A. Shepherd, The Upjohn Co., Kalamazoo, Michigan; and J. A. Dammann, American Safety Razor Corp., Brooklyn, N. Y.

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Chairman: Sister M. Virginia Heines, Nazareth College & Academy, Nazareth. Secretary: Mr. Gerrit Levey, Berea College, Berea.

#### THE 1951 SPRING MEETING

The spring meeting of the Academy was initiated several years ago to provide field trips in regions of the Commonwealth which are of special interest to botanists, zoologists, geologists and others. The 1951 spring meeting was held at Morehead State College, Morehead, Kentucky, Friday and Saturday, April 27 and 28. The Friday afternoon program provided for registration, refreshments served by the Home Economics Department, a conducted tour through the Lee Clay Products Company, and a short general meeting at which various field trips for Saturday were described.

At the dinner Friday evening, Dr. Warren C. Lappin, Dean and Acting President of Morehead State College gave a short address of welcome. Following dinner there were two addresses, "Related problems of water supply and sewage disposal" by Herman F. Dundberg, Chester Engineers, Pittsburgh, Pennsylvania and "The science of color as seen by the physicist and the artist" by Tom Young of the Morehead State College Art Department. After the addresses members of the Academy were invited to a dance in the college gymnasium.

The Saturday schedule provided for the following conducted tours and field trips:

Bird walk, tour of Lee Clay Products Company, tour of General Refractories at Olive Hill, trip to Carter Caves State Park, Forestry-Soil Conservation trip, scenic trip through Cumberland National Forest, trip to the Knob Licks area and a trip to Lochege.

Arrangements for the meeting at Morehead State College were directed by Professor Fenton T. West of the Division of Science and Mathematics.

#### THE 1951 FALL MEETING

The regular fall meeting of the Kentucky Academy of Science will be held on Friday and Saturday, October 26 and 27, 1951, at the University of Kentucky.

### OTHER NEWS

Dr. M. C. Brockmann has resigned from the editorial staff of the TRANS-ACTIONS. He assisted, however, in editing the present issue and prepared the preceding portion of the "Academy Affairs" section. The Academy is deeply indebted to Dr. Brockmann for his excellent services as editor.

William F. Savage, Assistant Professor of Mechanical Engineering at the University of Kentucky, has been appointed Associate Editor of the TRANS-ACTIONS. Manuscripts may be submitted either to Mr. Savage or to William M. Clay.

The printing of the present issue of the TRANSACTIONS was delayed by mechanical difficulties which could not be avoided. These are not expected to recur, and papers which are received now should receive prompt publication. It is our intention to publish two numbers per year, each volume to consist of four numbers. Number 4 of the present volume will go to press as soon as a few more manuscripts are received. If you are preparing a paper for the fall meeting, let us have the manuscript as soon as possible.

Dr. Arland Hotchkiss, Secretary of the Biology Section, will spend the Academic year of 1951-52 on the staff of Robert College, Instanbul, Turkey.

# NOTICE TO CONTRIBUTORS

The TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE is a medium for publication of original investigations in science. In addition, as the official organ of the Kentucky Academy of Science, it publishes programs of the meetings of the Academy, abstracts of papers presented before the annual meetings, reports of the Academy's officers and committees, as well as news and announcements of interest to the membership.

Manuscripts may be submitted at any time to the editor:

### WILLIAM M. CLAY.

Department of Biology, University of Louisville,

Louisville, Kentucky

Papers should be submitted typewritten, double-spaced, with wide margins, in an original and 1 carbon copy, on substantial quality paper. Articles are accepted for publication with the understanding that they are to be published exclusively in the TRANSACTIONS. Each paper will be reviewed by one or more persons qualified in the field covered by article in addition to the editors before a contribution is accepted for publication.

Bibliographic citations should follow textual material (except in Research Notes, see later). Abbreviations for the names of periodicals should follow the current system employed by either Chemical Abstracts or Biological Abstracts. Bibliographic citations in Research Notes should be in the same form as for longer papers but enclosed in parentheses within the text of the note.

Footnotes should be avoided. Titles must be clear and concise, and provide for precise and accurate cataloging.

Tables and illustrations are expensive, and should be included in an article only to give effective presentation of the data. Articles with an excessive number of tables or illustrations, or with poorly arranged or executed tables or illustrations may be returned to the author for modification.

'Textual material should be in clear, brief and condensed form in order for a maximum amount of material to be published.

Reprints must be ordered at the time galley proof is returned.

The following individuals, educational institutions and industrial organizations have subscribed to one or more sustaining memberships in the KENTUCKY ACADEMY OF SCIENCE.

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# TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

**Official** Organ

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## CONTENTS

| Preparation of Acylaminoacid Esters. Richard H. Wiley and<br>Olin H. Borum   | 213 |
|--|-----|
| Animal Habitats on Big Black Mountain in Kentucky. Roger<br>W. Barbour   | 215 |
| Electrical Conductances of Moderately Concentrated Solutions of<br>Several Salts in Dimethylformamide. L. R. Dawson, M.<br>Golben, G. R. Leader, and H. K. Zimmerman | 221 |
| Structure and Function of the Mature Glands on the Petals of<br>Frasera carolinensis. P. A. Davies   | 228 |
| Performance of a Domestic Heat Pump Water Heater. E. B.<br>Penrod  | 235 |
| Comparison of Electron and Optical Photomicrographs of a Cop-<br>per-beryllium Alloy. H. W. Maynor, Jr., C. J. McHargue,<br>and O. F. Edwards                        | 248 |
| Structural Settlement Computations. John E. Heer, Jr.  | 258 |
| Preparation of 1-xylyl-1, 3-butanediones using Diketene. Reedus<br>Ray Estes and Albert Tockman  | 265 |
| A Look at Kentucky Woodlands. Eugene Cypert, Jr.   | 270 |
| Geological Sketch of the Jackson Purchase. E. B. Wood  | 275 |
| Adsorption of Aliphatic Acids on a Weak Base Anion Exchanger.<br>Sigfred Peterson and Robert W. Jeffers  | 277 |
| Research Notes:<br>An Albino Snake (Elaphe obsoleta). William M. Clay  | 285 |
| Academy Affairs  | 286 |
| Index  | 288 |

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Correspondence concerning membership in the Academy, subscriptions or other business matters should be addressed to the secretary. Manuscripts and other material for publication should be addressed to the editors.

\* Resigned

# PREPARATION OF ACYLAMINOACID ESTERS

# Richard H. Wiley\* and Olin H. Borum

Ethyl esters of acetylglycille and acetylleucine are prepared by azeotropic distillation procedure

There are a variety of methods available for the preparation of a-acylaminoacid esters, RCONHCHR'CO<sub>2</sub>R". This report is based on a study of relative advantages of these methods and describes a preferred procedure for preparation of these esters.

A review of the literature has shown that acetylglycine ethyl ester has been prepared by the action of ethyl iodide on the silver salt of acetylglycine (1); by passing dry hydrogen chloride into an alcholic suspension of acetylglycine (2); by heating glycine ethyl ester hydrochloride on the water bath with acetic anhydride and sodium acetate with (3) or without (4) copper sulfate; by the action of acetyl chloride on a suspension of glycine ethyl ester hydrochloride in boiling benzene on the water bath (3); and by the action of ketene on glycine ethyl ester (5). Esters of other acylamino acids have been prepared by a simultaneous acetylation-esterification which takes place on treating the sodium salt of the amino acid in ethyl alcohol with acetic anhydride (6,7).

The method described in this report is an adaptation of the azeotropic distillation procedure used for other esterifications (8,9). It is preferred to esterification by the ethanol-hydrogen chloride method (2) which must be carefully controlled to prevent removal of the N-acyl radical.

Preparation of Acetylglycine ethyl ester (Aceturic acid ethyl ester). In a 1-l. round-bottomed flask are placed 58.5 g. (0.5 moles) of acetylglycine (10), 200 cc. of carbon tetrachloride (319 g., 2.08 moles), 200 cc. (157.8 g., 3.42 moles) of absolute alcohol and 2 g. of sulfosalicylic acid. Ordinary commercial absolute alcohol testing by specific gravity to be between 99.5 and 100% is used. During refluxing and distillation the system is protected from the atmosphere by means of a calcium chloride tube. The mixture is refluxed slowly for one hour and thirty minutes over an open-coil resistance heater. At the end of this time about 200 cc. of solvent are distilled slowly from the mixture through a 36-inch vertical column.

An apparatus similar to one previously described (9) is used, except that the arm provided for return of condensate to the reaction flask is omitted. A

 Present address: Department of Chemistry, University of Louisville, Louisville, Kentucky. This report is a contribution from the Venable Chemical Laboratory of the University of North Carolina. Inquiries may be addressed to this author.

36-inch condenser serves as a reflux condenser at first and later as a fractionating column. A thermometer at the top of the column shows that the mixture starts to distill at about  $63^{\circ}$  and the temperature then rises slowly to  $78^{\circ}$ . The round-bottomed flask is placed about one to two inches above the heating coil which is regulated by a variable transformer for the slow refluxing and distillation.

One hundred cc. each of carbon tetrachloride and absolute alcohol are added and the mixture refluxed again for one hour, after which about 175 cc. are slowly removed by distillation through the column as above. The same amount of solvent mixture is added again, refluxed, and finally distilled until about 200 cc. of solution remain. During this period all of the acetylglycine dissolves. Until this time the acetylglycine is suspended in the reaction mixture.

The clear remaining solution is then transferred to a 250-cc. Claisen distilling flask. The carbon tetrachloride and alcohol are removed at reduced pressure and then 62 g. (85%) of acetylglycine ethyl ester of b.p.  $124^{\circ}-130^{\circ}$  at 2-4 mm are collected with the oil bath at  $150^{\circ}-180^{\circ}$ . Toward the end of the distillation the bath is kept below  $180^{\circ}$  to prevent volatization of the catalyst. No attempt is made to remove the catalyst by washing prior to distillation because of difficulty in isolating the water soluble ester. The ester solidifies to hygroscopic solid, m.p.  $47^{\circ}-49^{\circ}$ .

Preparation of Acetylleucine ethyl ester. This ester is prepared by a similar procedure except that the heating period is lengthened to seven hours. From 60.3 g. of acetylleucine, prepared by the method of Karrer, Escher, and Widmer (11), there is obtained 61.5 g., 87.5%, of acetylleucine ethyl ester, b.p.  $113^{\circ}-120^{\circ}$  at 2.5-3.5 mm. with the bath at  $135^{\circ}-145^{\circ}$ . The ester solidifies to a solid, m.p.  $55.5^{\circ}-57.5^{\circ}$ .

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## ANIMAL HABITATS ON BIG BLACK MOUNTAIN IN KENTUCKY

## Roger W. Barbour

Department of Zoology, University of Kentucky, Lexington, Kentucky

Between 1939 and 1948 I camped over four months in Harlan County, Kentucky, making a study of the manimals, reptiles, and amphibians of Big Black Mountain. This mountain, the highest point in Kentucky, reaches a maximum elevation of 4150 feet above sea level. It lies largely in Harlan County, Kentucky, but occupies a portion of adjacent Wise County, Virginia.

The majority of data were collected within a four-mile radius of the summit of the mountain, centering at a point designated "Grassy Gap" on the United States Geological Survey Estillville sheet. Collections made elsewhere in the region are so indicated.

It is my purpose to herein present a classification of the animal habitats of the mountain, with notes on the occurrence of mammalian, reptilian, and amphibian species therein.

The area under consideration has been, and still is, subjected to intensive logging operations. The trees are being cut indiscriminately, with little apparent regard for young timber. In removing the timber, expediency rather than wise use seems to be the dominating factor. Such logging operations undoubtedly influence the fauna of the area and will continue to influence the animal population for years to come as the normal succession following logging operations takes place.

No intensive study of the habitats was undertaken, except as they influenced animal distribution. Braun (1940) made a thorough ecological study (from a botanical standpoint) of a transect of Black Mountain in adjacent Letcher County, Kentucky.

For my purposes, I have grouped the animal habitats of Big Black Mountain into six general categories, each with numerous subdivisions. A clear-cut delineation of the habitats of the area is impossible; frequently one habitat grades imperceptibly into another. More often a single habitat may be classified under two or more

divisions, depending on the individual point of view. These divisions and subdivisions are discussed below.

1. AQUATIC. Aquatic habitats of the area are divisible into two major groups: standing water, as rain pools, and running water. The latter may be further divided into springs and streams. The streams, on the basis of size, may be divided into brooks and creeks. The latter two classifications grade insensibly into each other.

Rain pools are common about the summit of the mountain: one puddle in a logging road was known to contain water continuously from June 4 to September 1, 1948. These puddles were extensively used as breeding pools by *Bufo americanus americanus*, *Bufo woodhousii fowleri*, *Hyla v. versicolor*, and *Pseudacris brachyphona*. A snapping turtle (*Chelydra s. serpentina*) was taken from one of them.

At least seven springs occur within a radius of two miles of the summit of the mountain; each of them that formed a pool supported one or more *Rana clamitans*. One could always find *Desmognathus fuscus welteri* about the springs. *Pseudacris brachyphona* was known to breed in the largest spring.

Nearly every cove about the summit of the mountain gave rise to a small but apparently permanent stream. These small, swift streams supported an abundance of salamanders, largely *Desmognathus fuscus welteri*, along their margins.

The creeks in the lower valleys were not so rich in salamanders as the brooks, but supported a considerable population of frogs and toads, largely *Rana catesbeiana*, *Rana clamitans*, *Bufo woodhousii fowleri*, and *Hyla v. versicolor*. *Natrix sipedon* was abundant in the larger streams, but rare in the smaller tributaries.

2. Low VEGETATION. This habitat comprises fields covered mostly with herbaceous vegetation. Extensive areas of this sort are found about the summit of the mountain. Some of these are largely in grass; others clothed with a mixture of *Lysimachia quadrifolia*, *Fragaria virginiana*, and *Potentilla simplex*; still others support practically pure stands of ferns, largely *Osmunda cinnamomea*, *Dryopteris noveboracensis*, and *Dennstaedtia punctilobula*.

The origin of these fields is obscure. They have been cultivated

# Animal Habitats On Big Black Mountain In Kentucky

in past years when the mountain top was inhabited by man. Old residents informed me the fields had been there when they were children. At the present time, trees are beginning to appear, although most are still small. Possibly, these areas are comparable to the "balds" in the Great Smokies.

As far as small mammals are concerned, these fields are practically deserts. The edges are fairly rich in species, largely of the genera *Peromyscus*, *Clethrionomys*, *Blarina*, and *Sorex*, but only *Synaptomys* was caught near the middle of the fields. Of the amphibians and reptiles, *Bufo americanus americanus*, *Bufo woodhousii fowleri*, *Diadophis punctatus edwardsii*, *Coluber c. constrictor*, and *Thamnophis s. sirtalis* occurred frequently in the fields.

In fields at lower elevations (obviously cleared), *Carphophis a. amoena, Diadophis punctatus edwardsii, Lampropeltis t. triangulum, Storeria occipitomaculata*, and *Thamnophis s. sirtalis* were taken as well as *Pseudotriton montanus diastictus, Bufo americanus americanus,* and *Bufo woodhousii fowleri.* All were taken from beneath stones with the exception of a large milk snake which was found in a weed patch near a pile of stones.

3. BRUSHLAND. This general habitat comprises areas in which the dominant species are shrubby. Areas of small individuals of tree species are treated under the subsequent divisions.

The brushland habitat, as defined above, may be subdivided into three groups, on the basis of the dominant species.

a. Crataegus - Vaccinium - Rhododendron cumberlandense. These three genera are dominant in several once-open areas about the summit of the mountain. These areas support a curious admixture of species from the beech - birch - maple and oak - hickory - chestnut associations treated below. This habitat is perhaps the least well defined on the mountain. Sorex cinercus, Sorex fumcus, Peromyscus maniculatus nubiterrae, Peromyscus leucopus noveboracensis, and Clethrionomys gapperi maurus, among others, were taken from this habitat. Amphibians and reptiles are scarce in this habitat. although one Hyla crucifer was taken here.

b. *Rhododendron maximum*. This species occupies extensive areas along the lower reaches of the mountain streams. In places, the

growth extends upward along the stream to an elevation of about 3600 feet.

c. *Kalmia*-*Vaccinium*. Some areas, where logging has been heavy, support practically pure stands of these two genera. In such areas, a few dead chestnuts remain standing; the ground is littered with decaying tree tops. According to natives, a little "red rabbit" is found only in such areas. A specimen of this "red rabbit" proved to be *Sylvilagus transitionalis*.

4. WOODLAND. Included in this habitat are those areas clothed with tree species; three subtypes are recognized, as follows:

a. *Beech - birch - maple*. This association is apparently the climax forest of the upper, more humid, slopes of the mountain. Although occupying extensive areas above 3000 feet on the northern exposures, on the south slopes this habitat extends no lower than 3500 feet, and reaches this elevation only in densely shaded valleys.

Few stands of virgin timber are left, and these seldom occupy more than a few acres. Here, the forest floor is relatively clean; there are few low woody plants, and the herbaceous plants are for the most part low. Humus ranges up to eight inches in depth, and is continually moist even in the dryest seasons. Here is to be found perhaps a greater assemblage of mammalian species than in any other area of the mountain.

When logged over, most of this area grew up again to the same woody species, with less beech and an admixture of oak and hickory. In places, these species, along with *Rubus canadensis*, *Smilax rotundifolia*, and *Pyrularia pubera* form an almost impenetrable thicket. With continuous logging operations over the years, practically every stage of growth is represented.

b. Oak - hickory - chestnut. This association clothes most of the lower slopes and extends up the drier areas to the very summit of the mountain. All the larger chestnuts have long since died, while most of the larger oaks have been removed. For a number of years, logging operations in the area were largely confined to removal of the dead chestnuts for mine timbers, but the remaining naked boles are still a conspicuous part of the landscape. In such areas, the woody species that have established themselves after logging are

# Animal Habitats On Big Black Mountain In Kentucky

predominantly oaks, hickories, and chestnut stump sprouts. Many other plants are abundant, among them Accr. Tilia, Rubus, Smilax, Kalmia, Vitis, and Vaccinium. These thickets form dense tangles. In some areas, logging has been remote enough for sufficient growth of the trees to occur to eliminate much of the rank undergrowth. In such areas, particularly at the lower elevations, there is a well marked growth of Liriodendron, Oxydendron, Robinia, and Cornus. From about 2400 to 3000 feet, particularly on southern exposures, a large part of this association supports a rank growth of Vitis. Along the highway on the Virginia (south) side of the mountain, these plants have vined vigorously into the tops of the trees and form a veritable canopy over the forest floor. Natives report that the opossum (Didelphis v. virginiana) is largely confined to this "grape belt." However, I took one specimen near the summit of the mountain, considerably above this region. In other areas at lower elevations, Smilax enters as a conspicuous part of the flora, vining 30 to 40 feet into the trees. In this habitat alone was *Peromuscus nuttalli* found.

c. Liriodendron. About the base of the mountain, at elevations ranging from 1800 to 2500 feet, regardless of exposure, are isolated areas consisting of practically pure stands of *Liriodendron tulipifera*. These areas have been logged over in the past, and the majority of the trees in the present stand vary from six to 14 inches in diameter breast high. Here the forest floor is relatively free of undergrowth. *Blarina* and *Peromyscus* are the most abundant mammalian genera in these areas.

5. ROCKLAND. Herein are grouped those regions where extensive areas of bedrock are exposed, and jumbles of rock occur. Such places are rare on Black Mountain; those that do occur support *Neotoma, Peromyscus, Clethrionomys, Sceloporus*, and *Crotalus*. On Pine Mountain, however, exposed bedrock is a very conspicuous part of the terrain. The little collecting done there, just north of Cumberland, Harlan County, Kentucky, revealed only *Neotoma* and *Aneides*.

6. MAN-MADE. In this category are grouped such works of man as buildings, roads, fences, orchards, and the like. Buildings sheltered *Rattus* and *Mus*, as well as various species of bats. Roads, especially little used ones, proved an extremely fertile field for collection

of amphibians and reptiles. Fences harbored *Sceloporus* and *Eumeces*. A single old orchard, located at the summit of the mountain, was examined briefly in 1939; at that time it proved to be a veritable desert, as far as amphibians, reptiles, and mammals were concerned.

## Conclusions

The two most extensive habitats on the mountain are the beech – birch - maple and oak - hickory - chestnut subdivisions of the woodland group. The majority of mammalian species occurring on the mountain may be found most abundantly in these two habitats. Qualitatively, there is little difference in the mammals of the two areas, but extensive trapping revealed that individuals were approximately three times as abundant in the beech - birch - maple regions as in the oak - hickory - chestnut habitat.

Reptiles were most abundant, both in number of species and number of individuals in habitats herein classed as man-made. The edges of little-used logging roads were the most fruitful collecting areas. This situation was undoubtedly due to several factors, among which might well be the exposing of rocks suitable for cover; the creation of woodland edges, affording two adjacent types of hunting territory; and the drying out of a narrow strip through an otherwise moist woodland.

Amphibians were most abundant, from the standpoint of individuals, along streams and about springs and puddles. However, as many species were found in the beech - birch - maple subdivision of the woodland habitat, as in areas classed as aquatic. Several species found only in wooded areas are known to breed in water, hence the occurrence of a given species in a certain habitat is dependent, among other things, upon the time of year.

At the present time, mining operations on the mountain are exposing extensive areas of bare soil. The effects of this wholesale destruction of the present-day habitats in the area are undoubtedly profound. Whether or not the operations will continue to the point of destroying the only known habitats in Kentucky for such animals as Sorex c. cinereus, Blarina brevicauda churchi, Mustela v. vision, Clethrionomys gapperi maurus, and Napaeozapus insignis roanensis, is a matter for the future.

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# ELECTRICAL CONDUCTANCES OF MODERATELY CONCENTRATED SOLUTIONS OF SEVERAL SALTS IN DIMETHYLFORMAMIDE\*

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Dimethylformamide combines the properties of a wide liquid range (1), good solvent power for inorganic salts, and fairly high dielectric constant (measurements in this laboratory have shown the dielectric constant to be 36.7 at 25). Consequently, it appears to have considerable promise as a solvent which may be used for electrolytic studies in the nonaqueous field. Reported here are the results of a study of the conducting properties of some solutions of magnesium and zinc iodides, magnesium, zinc and cadmium bromides, and silver perchlorate, all of which were found to be quite soluble in this solvent even at low temperatures.

## Experimental

Dimethylformamide supplied by the du Pont company was used after purification by fractional distillation under reduced pressure (specific conductance,  $1.83 \times 10^{-6}$  at  $25^{\circ}$ ). The salts used were the best available commercial anhydrous grade with the exception of the silver perchlorate, which was prepared from silver oxide and perchloric acid according to the method described by Hill (2) and dried at 110°C. Weighed amounts of each salt were added to weighed quantities of solvent, all transfers being made in a dry box. The final concentration of the perchlorate was confirmed by titration with standard thiocvanate solution.

Conductance measurements were made with a standard Wheatstone Bridge assembly, with temperatures being adjusted by means of a manually controlled bath consisting of a dry ice-acetone mixture contained in a one-gallon Dewar flask. Two Washburn-type conductance cells, having constants of 0.072 and 0.012 were used. The cell constants were determined by the Jones and Bradshaw (3) method. Because of the low specific conductance of the dimethylformamide no solvent correction was necessary.

Based on research performed under contract No. w36-039-sc-32265 for the U. S. Army Signal Corps.

# RESULTS AND DISCUSSION

Table 1. Conductance of Solutions of Various Salts in Dimethylformamide Conductances<sup>‡</sup> at the Temperatures:

| Molality  | 4  | 20°  |  | 0°  | -2   | 0°                                   | -4  | 0°                                   | 5   | )°                                   |
|---|--|--|--|---|--|--------------------------------------|---|--------------------------------------|---|--------------------------------------|
|   |  |  |  | Magnes  | ium Bi   | romide                               |   |                                      |   |                                      |
| $\begin{array}{c} 0.00725 \\ 0.0434 \\ 0.104 \\ 0.132 \end{array}$                  | 2.36<br>6.56<br>7.27<br>6.67                                 | (326)<br>(151)<br>(69.8)<br>(50.5)                     | $1.78 \\ 4.40 \\ 4.26 \\ 3.25$   | (246)<br>(102)<br>(40.9)<br>(24.6)                        | 1.29<br>2.86<br>2.19<br>1.57                                 | (178)<br>(65.9)<br>(21.0)<br>(10.9)  | $\begin{array}{c} 0.727 \\ 1.40 \\ 0.800 \\ 0.450 \end{array}$  | (100)<br>(32.2)<br>(7.68)<br>(3.41)  | $\begin{array}{c} 0.572 \\ 0.976 \\ 0.334 \\ 0.133 \end{array}$ | (79.1)<br>(22.6)<br>(3.20)<br>(1.01) |
|   |  |  |  | Magne   | sium I   | odide                                |   |                                      |   |                                      |
| $\begin{array}{c} 0.0103 \\ 0.0400 \\ 0.108 \\ 0.125 \\ 0.192 \\ 0.302 \end{array}$ | 3.73<br>9.04<br>10.6<br>6.25<br>5.12<br>7.60                 | (362)<br>(226)<br>(98.2)<br>(50.0)<br>(26.6)<br>(25.2) | $\begin{array}{c} 2.85 \\ 6.54 \\ 6.64 \\ 2.35 \\ 0.945 \\ 1.93 \end{array}$ | $(276) \\ (163) \\ (61.5) \\ (18.8) \\ (4.92) \\ (6.39) $ | 2.02<br>4.25<br>3.27<br>0.229<br>*                           | (196)<br>(106)<br>(30.3)<br>(1.83)   | 1.29<br>2.24<br>1.10<br>*                                       | (125)<br>(56.0)<br>(10.2)            | 0.86<br>1.42<br>0.532<br>*<br>*                                 | (83.5)<br>(35.4)<br>(4.93)           |
|   |  |  |  | Zinc  | Brom   | ide                                  |   |                                      |   |                                      |
| $0.0146 \\ 0.0588 \\ 0.107 \\ 0.144$  | $1.00 \\ 3.38 \\ 4.48 \\ 4.68$                               | (68.5)<br>(57.5)<br>(41.8)<br>(32.5)                   | 1.01<br>2.93<br>3.58<br>3.27   | (69.1) (49.8) (33.4) (22.7)                               | 0.871<br>2.20<br>2.30<br>1.87                                | (59.7) (37.4) (21.5) (13.0)          | 0.599<br>1.20<br>1.09<br>0.667                                  | (41.0)<br>(20.4)<br>(10.2)<br>(4:63) | $\begin{array}{c} 0.472 \\ 0.818 \\ 0.593 \\ 0.271 \end{array}$ | (32.4)<br>(13.9)<br>(5.54)<br>(1.88) |
|   |  |  |  | Zin   | e Iodio  | le                                   |   |                                      |   |                                      |
| $\begin{array}{c} 0.0120 \\ 0.0440 \\ 0.0789 \\ 0.110 \end{array}$                  | $1.54 \\ 3.64 \\ 4.76 \\ 5.00$                               | (128)<br>(82.9)<br>(60.4)<br>(45.4)                    | 1.68<br>3.28<br>3.81<br>3.84   | (140)<br>(74.6)<br>(48.3)<br>(34.9)                       | 1.72<br>2.72<br>2.72<br>2.35                                 | (143)<br>(61.9)<br>(34.5)<br>(21.4)  | $1.54 \\ 1.95 \\ 1.52 \\ 1.00$                                  | (128)<br>(44.4)<br>(19.3)<br>(9.09)  | $1.33 \\ 1.45 \\ 0.91 \\ 0.40$                                  | (111)<br>(33.0)<br>(11.5)<br>(3.64)  |
| Cadmium Bromide   |  |  |  |   |  |                                      |   |                                      |   |                                      |
| $\begin{array}{c} 0.00583 \\ 0.0408 \\ 0.0934 \\ 0.121 \end{array}$                 | $\begin{array}{c} 0.727 \\ 3.32 \\ 5.12 \\ 4.83 \end{array}$ | (125)<br>(81.4)<br>(54.8)<br>(39.9)                    | $\begin{array}{c} 0.532 \\ 2.46 \\ 3.54 \\ 3.19 \end{array}$                 | (91.4)<br>(60.3)<br>(37.9)<br>(26.4)                      | $\begin{array}{c} 0.367 \\ 1.54 \\ 1.99 \\ 1.55 \end{array}$ | (63.0)<br>(37.7)<br>(21.3)<br>(12.8) | $\begin{array}{c} 0.203 \\ 0.802 \\ 0.880 \\ 0.562 \end{array}$ | (34.8)<br>(19.6)<br>(9.42)<br>(4.65) | $\begin{array}{c} 0.148 \\ 0.625 \\ 0.506 \\ 0.304 \end{array}$ | (25.4)<br>(15.3)<br>(5.41)<br>(2.52) |
| Silver Perchlorate  |  |  |  |   |  |                                      |   |                                      |   |                                      |
| $\begin{array}{c} 0.208 \\ 0.530 \\ 0.945 \\ 1.10 \end{array}$                      | $11.6 \\ 20.5 \\ 24.1 \\ 23.9$                               | (55.8)<br>(38.7)<br>(25.5)<br>(21.7)                   | $8.67 \\ 14.4 \\ 15.6 \\ *$  | (41.7)<br>(27.2)<br>(16.5)                                | 5.57<br>8.53<br>8.53<br>*                                    | (26.8)<br>(16.1)<br>(9.01)           | 3.16<br>4.54<br>3.61<br>*                                       | (15.2)<br>(8.56)<br>(3.82)           | 2.15<br>3.28<br>1.89<br>*                                       | (10.3)<br>(6.19)<br>(2.00)           |

 $\ddagger Specific conductances (x 10^3)$  are given followed by "molal" conductances in parentheses.

\*Conductance not measured either because part of the solute precipitated or because of extremely high viscosity.











Since the nature of the dissociation of unsymmetrical salts in dimethylformamide is uncertain, "molal" conductances have been calculated and the conductance isotherms plotted in Figures 1 to 6. It may be observed that for magnesium bromide and silver perchlorate the conductance decreases uniformly with increasing concentration, the data showing no particular irregularities. The data for zinc iodide show similar behavior, but, in addition, there occurs a pronounced maximum in the conductance isosyst at 0.012 molal; thus there is a negative temperature coefficient of conductance over a part of the range studied. Evidence of the same type of behavior may be observed in the 0.0146 molal isosyst for zinc bromide also.

The molal conductance isotherms for magnesium iodide, zinc iodide and cadmium bromide all display departures from the smoothly dropping curves which were obtained for the first two salts. For magnesium iodide this break occurs at about 0.11 molal and is pronounced. Probably this phenomenon is due to a viscosity effect, since although magnesium iodide was found to be the most soluble of the salts in the halide group, its more concentrated solutions were extremely viscous. It is to be noted that for this salt, the effect appears to persist at all the temperatures studied, and therefore may be the result of a marked change in the nature of the particles participating in viscous flow. The irregularity for the zinc bromide solutions occurs at a much lower concentration (about 0.04 molal) and appears only at the higher temperatures. Thus, it would seem that its primary cause is not to be found in the viscosity influence. Similar behavior has been reported from this laboratory (4) for solutions for zinc chloride and bromide in methanol, which appears most likely to be the result of changes in the degree of complex formation between zinc and halide ions

It should be remarked also that silver perchlorate in dimethylformamide apparently is not a stable system as is shown by the appearance of a dark deposit in the solutions upon standing. The reaction was slow, however, and appeared not to influence appreciably the results of the measurements.

## SUMMARY

1. Conductances of solutions of silver perchlorate, magnesium, zinc and cadmium bromides, and magnesium and zinc iodides in dime-

# Electrical Conductances of Moderately Concentrated Solutions

thylformamide have been determined at concentrations ranging from 0.005 to 0.50 molal over the temperature range  $-50^{\circ}$  to  $20^{\circ}$ .

2. Evidences of unexpected changes in the nature of the solute particles at low concentrations and of behavior probably resulting from various solvent effects have been obtained.

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# STRUCTURE AND FUNCTION OF THE MATURE GLANDS ON THE PETALS OF FRASERA CAROLINENSIS

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On numerous occasions while on botanical field excursions, the writer has observed bumble bees actively working on the flowers of American Columbo, *Frasera* (*Swertia*) carolinensis. Although other insects were occasionally observed clinging to or resting upon the flowers, the bumble bee appears to be the only insect obtaining nectar from the flowers.

*Frasera carolinensis* is widely distributed in Kentucky. This biennial or triennial is usually found in oak-hickory habitats on dry hillsides. It can be easily identified during the winter by a basal rosette of large leaves. During the spring and early summer a single stem 9-21 dm. (3-7 ft.) high develops and produces at the apex during July and August a paniculate, many-flowered inflores-cence from 1.5 to 6 dm. long. The flowers range from 1.5 to 3 cm. broad and the floral parts, except for the two-carpillate ovary, are arranged in fours (fig. 1). On the mid-vein of each yellowish-white petal, about one-third the distance from its base, is a large oval, fringed nectariferous gland 3.3-3.9 mm. long, 3.0-3.3 mm. wide, and, including the wall processes, 3.2-4.2 mm. high. This is the gland visited by the bumble bees and is the subject of this paper.

A search through the literature has yielded but one reference on the floral morphology of *Frasera carolinensis*. McCoy (1940), in his studies on the floral organogenesis of this plant, has considered in detail the early structural development of the gland. He found that the glandular tissue arose in the adaxial subepidermal layer at the base of the petal. Periclinal divisions continue in this area until seven or eight cell layers are formed. This disk of adaxial derivatives forms the secretory tissue. Periclinal divisions in the glandular disk continue at its periphery to form the wall of the glandular cup. With periclinal divisions in the lower wall ceasing, and with divisions in different planes continuing in the upper part of the wall, the numerous wall processes are produced. These form the top of the gland

# Mature Glands On The Petals of Frasera Carolinensis

and cover the apical opening. Mature glands, which McCoy did not describe in detail, exhibit structures different from those usually found in entomophilous glands and so should be of interest to students of floral morphology.



FIG. I

Figure 1. Floral arrangement and the position of the glands.

External features of a gland (fig. 2) show that the basal portion of the gland wall is solid and extends 0.3-0.4 mm. above the surface of the petals. Above the solid portion the gland wall splits into numerous sections. Each section divides and re-divides frequently several times resulting in a mat of hair-like processes which plug the apical opening. The wall processes, as they mature, become sclerified and rigid. Bumble bees work along the sides of the glands, indicating that it is easier for the tongue to be pushed through the wall crevices than to penetrate the closely matted sclerenchymous wall processes which plug the apical opening.

Each gland is supplied by branches from the mid-vein and several small lateral ones. Vascular tissue extends into the base and walls of the gland but does not penetrate into the secreting area.



FIG. 2



# Mature Glands On The Petals of Frasera Carolinensis

Observations on the inner part of a gland (fig. 3) show that the solid lower walls and the nearly flat floor formed by the modified upper surface of the petal produce a large cavity or well. That part of the petal beneath the gland floor is slightly thickened and the secreting area is composed of modified epidermis and parenchyma tissue.



FIG. 3

Figure 3. View of the cavity or well of a gland showing its size, thickness of the secretory area and the extent of cell stretching.

The entire floor of the gland and the inner surface of the undivided wall area possesses secreting cells. Fig. 4 depicts a section through the floor of the gland and the upper part of the petal. It shows that in the upper seven layers of cells the cytoplasm is more dense, indicating greater cell activity. The maximum amount of cell activity is in the upper three layers. The basal tissue on which the



FIG 4

Figure 4. Section through the floor of a gland and the upper part of the petal showing the depth of the secretory area.

secreting cells rest is composed of the normal parenchyma cells of the petal. Covering the exposed surface of the upper layer of secreting cells and forming the floor layer of the gland is a mediumthick cuticle. Since no ducts or pores are present to carry the secretion through the surface layers and cuticle, the nectar must diffuse from cell to cell and then through the cuticle. Numerous mature glands were examined, and in each one only a thin film of liquid was present on the surface of the cuticle. Although the cuticle normally retards the flow of nectar, it does not inhibit it. Behrens (1879) and Bonnier (1879) found the same to be true for many other plant secretory surfaces.

While the flowers are in the bud, the walls of the glands are much reduced and the apical openings are large. As the buds open the floral parts expand, the walls extend upward and inward, forming conical-shaped glands. This reduces the size of the apical opening and brings the wall processes into a matted arrangement. A micro-

# Mature Glands On The Petals of Frasera Carolinensis

section through the lower part of the wall is shown in fig. 5. The secreting area, as indicated by cytoplasmic density, is confined to the two innermost layers of cells. The elongation of the walls, except



FIG. 5

Figure 5. Section through the lower wall of a gland illustrating the depth of the secretory area and the extent of cell stretching.

in the innermost layer and to some extent the next layer, is due to the stretching of the cells rather than to an increase in the number of cells. In the innermost layer the cells were able to divide rapidly

enough to keep pace with the stretching. The amount of stretching of the cells is indicated by the extent to which the nuclei are stretched.

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# PERFORMANCE OF A DOMESTIC HEAT PUMP WATER HEATER

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# INTRODUCTION

A study of a Master Kraft heat pump water heater was made during the last two weeks of June, 1951.\* Data were taken each day to obtain the operating performance of the hot water heat pump and the effect produced on the relative humidity of the air in the room containing the unit. The heating energy ratio of the plant was determined through tests of short duration.

# PRINCIPLE OF THE HOT WATER HEAT PUMP

The Master Kraft<sup>\*\*</sup> heat pump is designed to take heat, at a low temperature level, from the air in the basement (or utility room), containing the unit, and transfer the heat to the water in the tank at a higher temperature level (Fig. 1). When the heat pump is in operation the refrigerant (Freon-12) changes from the liquid phase to the vapor phase in the evaporator located in the air stream. In changing phase the refrigerant absorbs heat from the air reducing its temperature from, say, 73°F to 70°F. The temperature and pressure of the vapor are increased from about 62°F and 75 lbs. per sq. in. abs. to approximately 322°F and 177 lbs. per sq. in. abs. in passing through the refrigeration compressor.

The Freon-12 vapor is superheated during compression. As it passes through the condenser, located in the tank, it gives up heat to the water in cooling to the saturation temperature at the existing pressure, and then gives up additional heat while condensing. The liquid refrigerant then passes through the expansion valve, thus completing the refrigeration cycle. The primary purpose of the refrigeration compressor is to circulate the refrigerant and to main-

<sup>&</sup>lt;sup>o</sup>The Kentucky Utilities Company purchased a Master Kraft heat pump water heater and installed it together with the necessary instruments in the author's house. He is indebted to the Heat Pump Committee of this Company who sponsored the investigation.

<sup>\*\*</sup>The Master Kraft Heat Pump Water Heater is manufactured by Harvey-Whipple, Inc., Springfield, Mass.

tain a difference in pressure on the opposite sides of the expansion valve.

The heat given up by the refrigerant in cooling and condensing



Figure 1. A schematic diagram showing how a heat pump produces hot water for domestic purposes.

is absorbed by the water surrounding the condenser. The heat absorbed by the water while cooling the superheated Freon-12 vapor from  $322^{\circ}F$  to  $125^{\circ}F$  is about 40% of that required to raise the temperature of the water from  $80^{\circ}F$  to  $155^{\circ}F$ . The remainder of the heat transferred to the water is supplied while the refrigerant condenses at  $125^{\circ}F$ .

## Performance of A Domestic Heat Pump Water Heater

# HEAT PUMP WATER HEATER

The Master Kraft heat pump water heater shown in Fig. 2, is 26<sup>3</sup>/<sub>4</sub> inches in diameter and 70 inches high. It has a water capacity of 53 gallons and weights 680 lbs. empty. The circulating fan and refrigeration compressor are driven by 1/20-hp. and 1/3-hp., single phase motors. The circulating fan draws air through the evaporator coils and forces it out at the top of the unit. Fig. 3 is a photograph of the upper half of the unit showing the thermostat, refrigeration compressor, expansion valve, and the air coil or evaporator.

When the heat pump is in operation the refrigeration compressor circulates the refrigerant (Freon-12), through the condenser, expansion valve, and the evaporator. During the test period, the compressor maintained discharge and suction pressures of about 163 and 63 lbs. per sq. in. gage while the plant was in operation. The air temperature in the basement determines the suction pressure; and the thermostat setting, the rate of water consumption, and compressor capacity determine the discharge pressure.

# INSTRUMENTATION

A Bailey recording meter was used to measure the quantity of hot water used, and the inlet and outlet water temperatures. The thermometers were of the platinum resistance type, one being placed where the water enters and the other where it leaves the tank.

The relative humidity of the basement air was obtained by the use of a Bristol's wet and dry bulb recording thermometer and Taylor's relative humidity tables. The moisture taken from the air dropped in a trough beneath the evaporator coils. Provisions were made so that the condensed moisture could be piped to a suitable container and measured.

An Esterline-Angus recording meter was used to determine the operating time of the heat pump water heater and the power input to the fan and compressor motors. A General Electric single phase watthour demand meter was also used to determine the power input to the heat pump as well as the demand. A similar General Electric single phase watthour meter was used to determine the electric energy supplied to the house exclusive of that supplied to the hot water heat pump.

# DAILY OPERATING PERFORMANCE

During the test period the house was occupied by a family







Performance of A Domestic Heat Pump Water Heater

Figure 3. A photograph of the upper half of the heat pump water heater showing the thermostat, refrigeration compressor, and air coil or evaporator.

consisting of two adult persons. The following electrical appliances were in the house and were used when desired: electric lights, iron, refrigerator, washing machine, percolator, toaster, two clocks, radio, and a hot water heat pump. Performance data are listed in Table I. The daily average electric energy supplied to the hot water heat pump was about 54% of that supplied to the entire house. The hot water used per day varied from 30 to 55 gallons. The average cost of producing hot water was about 0.117 kwhr per gallon. The temperature of the water entering and leaving the tank were approximately  $80^{\circ}$ F and  $155^{\circ}$ F respectively.

The quantity of moisture removed from the basement air was, on the average, 2½ pints per day. The maximum amount of moisture was removed from the air on June 18th, 22nd, and 25th, the days that the washing machine was in operation, and laundry was hung in the basement to dry.

The average daily operating time of the hot water heat pump was 8.1 hours.

|        |                        | Electric<br>Supplied                     | Energy<br>i                     |                        |                      | Mositure<br>Removed     |                       |                     |
|--------|------------------------|--|---------------------------------|------------------------|----------------------|-------------------------|-----------------------|---------------------|
| Date   | Opera-<br>ting<br>Time | Total To<br>House<br>And<br>Heat<br>Pump | To Hot<br>Water<br>Heat<br>Pump | Heat<br>Pump<br>Demand | Hot<br>Water<br>Used | From<br>Basement<br>Air | Discharge<br>Pressure | Suction<br>Pressure |
|        | Hrs/Day                | kwhr.                                    | kwhr.                           | kw.                    | Gallons              | Pints                   | Psig.                 | Psig.               |
| 6-16   | 11.1                   | 9  | 5                               | 0.58                   | 50                   | 2                       | 148                   | 60                  |
| 6 - 17 | 6.2                    | 9  | 5                               | .58                    | 40                   | $1\frac{1}{2}$          | 152                   | 63                  |
| 6-18   | 8.6                    | 10                                       | 5                               | .58                    | 40                   | $3\frac{3}{4}$          | 163 ·                 | 63                  |
| 6-19   | 6.8                    | 8  | 4                               | .60                    | 35                   | $1\frac{1}{2}$          | 160                   | 62                  |
| 6-20   | 7.9                    | 8  | 4                               | .60                    | 30                   | $2\frac{1}{4}$          | 163                   | 62                  |
| 6 - 21 | 7.3                    | 9  | 5                               | .61                    | 35                   | $2\frac{1}{2}$          | 161                   | 63                  |
| 6-22   | 8.3                    | 9  | 5                               | .61                    | 45                   | 3¼                      | 158                   | 62                  |
| 6-23   | 9.3                    | 10                                       | 6                               | .61                    | 50                   | 3                       | 155                   | 62                  |
| 6-24   | 6.2                    | 8  | 4                               | .60                    | 35                   | $2\frac{1}{2}$          | 162                   | 62                  |
| 6-25   | 10.6                   | 10                                       | 6                               | .61                    | 55                   | $6^{1/}_{/4}$           | 162                   | 62                  |
| 6-26   | 6.8                    | 8  | 4                               | .59                    | 30                   | 2¾                      | 162                   | 62                  |
| 6-27*  |                        | 7  | 4                               | .60                    | 40                   | $2\frac{1}{2}$          | 163                   | 63                  |
| 6-28   |                        | 8  | 4                               | .60                    | 35                   | $2\frac{3}{4}$          | 157                   | 63                  |
| 6-29   |                        | 8  | 4                               | .60                    | 35                   | 2                       | 159                   | 63                  |
| 6-30   |                        | 7  | 4                               | .60                    | 35                   | $2\frac{3}{4}$          | 163                   | 63                  |
| Averag | es 8.1                 | 8.53                                     | 4.2                             | 0.598                  | 39.3                 | $2\frac{1}{2}$          | 159.2                 | 62.3                |

Table 1. Normal daily performance of a hot water heat pump from June 15, 1951 to July 1, 1951.

\*Difficulty with recording meter.
# Performance of A Domestic Heat Pump Water Heater

The actual operating time is shown graphically in Fig. 4, and the average electric power demand was approximately 0.60 kw. From



Figure 4. Graphical representation of the operation of the heat pump water heater, and the effect produced on the temperature and relative humidity of the basement air. Curve A gives the dry bulb temperatures. The plateaus of Curve B indicates the maximum electric power demand, and shows when the plant was in operation. Curve C gives the value of the relative humidity of the basement air.

Fig. 4 it can be seen that in general there was a slight decrease in the dry bulb temperature and a corresponding increase in the relative humidity of the basement air when the plant was in operation. On the whole the heat taken from the basement air did not reduce the dry bulb temperature to a great extent.

Fig. 5 is a photograph of the record of the wet and dry bulb temperature readings for a period of one week. The wet and dry bulb temperatures decreased simultaneously after the heat pump was set in operation. Shortly after the plant stopped the wet and dry bulb temperature readings returned to their previous values. The depressions in the two temperature graphs indicate clearly when the plant was in operation.

## Test Of Short Duration

During the normal intermittent operation of the domestic heat pump water heater it is virtually impossible to determine the heating energy ratio of the system because the water does not flow in a steady stream in and out of the tank. Hot water may be drawn out of the storage tank a great deal of the time when the unit is not in operation, and the cold water which enters merely mixes with the hot water, thereby reducing its temperature. In addition to this, hot water is generally drawn off at such a high rate that the heat pump did not have the capacity to maintain a constant temperature differential between the water at entrance to and exit from the storage tank.

During a short test of 52 minutes duration, hot water was drawn off at a steady rate of 0.37 gallons per minute. Test data are listed in Table 2. The air temperature dropped from  $76^{\circ}$ F to  $71^{\circ}$ F on passing through the evaporator coil. From the table it can be seen that the temperature of the air leaving the evaporator coil was  $1^{\circ}$ F below that of the wet bulb temperature.

Table 2. Results of a steady flow test of 52 minutes duration.

| Duration of test, hour                    | 0.866 |
|---|-------|
| Temp. of air entering evaporator coil, °F | 76    |
| Temp. of air leaving evaporator coil, °F  | 71    |
| Dry bulb temp. of basement air, °F        | 76    |
| Wet bulb temp. of basement air, °F        | 72    |
| Relative humidity of basement air, %      | 83    |
| Avg. hot water temp., °F                  | 116.8 |



Figure 5. A photograph of a weekly record made by Bristol's recording wet and dry bulb thermometers. (A) With the heat pump water heater and (B) without the heat pump water heater.

| Avg cold water temp., °F       | 88   |
|--------------------------------|------|
| Increase in temp. of water, °F | 28.8 |
| Water heated, *gallons         | 19.2 |
| Discharge press., psig.        | 136  |
| Suction press., psig.          | 61   |
| Theoretical H.E.R.             | 10.5 |
| Actual H.E.R.                  | 2.6  |

\*The hot water was discharged into a small tank and then weighed.

Energy supplied to heat pump system = 0.596 kw x 0.866 hr.

= 0.516 kwhr.Energy delivered to water  $= 28.8 \times 19.2 \times 8.3$  = 4580 Btu. = 1.341 kwhr.Actual H.E.R.  $= \frac{\text{energy delivered to the water}}{\text{energy supplied to the}}$   $= \frac{1.341 \text{ kwhr}}{0.516 \text{ kwhr}}$  = 2.6

The refrigeration cycle for the test of short duration is shown in Fig. 6. The theoretical heating energy ratio of the refrigeration cycle is given by the equation

Theoretical H.E.R.  $= \frac{h_4 - h_1}{h_4 - h_3}$  $= \frac{90.6 - 33.7}{90.6 - 85.2}$ = 10.5

The actual H.E.R. is just about one fourth of that for the refrigeration cycle. The reduction in the heating energy ratio from 10.5 to 2.6 is due to the inefficient single phase motors together with compressor and radiation losses.

From Fig. 6 it can be seen that the discharge and suction pressures are 150.7 and 75.7 lbs. per sq. in. abs., and the Freon-12 vapor



Figure 6. Refrigeration cycle of the heat pump water heater for a 52 minute test in which water flowed into and out of the storage tank at a constant rate. Isentropic compression was assumed. (a) Refrigeration cycle shown on the pressure-enthalpy plane. (b) Refrigeration cycle shown on the temperature-entropy plane.

was superheated only 7°F. In comparison, from Fig. 1 it can be seen that the discharge and suction pressures are 177 and 75 lbs. per sq. in abs.; and that the Freon-12 vapor was superheated  $197^{\circ}F$  $(322^{\circ} - 125^{\circ})$ . From an analysis of these data it can be shown that the actual heating energy ratio obtained from the test of short duration will exceed the heating energy ratio obtained if the plant could be tested under normal operating conditions as shown in Fig. 1.

### Conclusions

The following results give a good idea concerning the performance of the domestic heat pump water heater under actual operating conditions:

| Test period, days                                | 15    |
|--|-------|
| Operating time, hours/day                        | 8.1   |
| Elect. energy supplied to all appliances, kwhr.  | 128   |
| Elect. energy supplied to heat pump water, kwhr. | 69    |
| Demand, watts                                    | 598   |
| Hot water used, gallons                          | 590   |
| Hot water used, gallons/day                      | 39.3  |
| Hot water, gallons/kwhr                          | 8.54  |
| Moisture removed from basement air, pints/day    | 2.5   |
| Average basement air temp., F°                   | 76.3  |
| Average discharge press., psig.                  | 159.2 |
| Average suction press., psig.                    | 62.3  |

Freyder<sup>\*</sup> gives the following results from a similar study on a Harvey-Whipple pilot model:

| Test period, days                  |   | 91     |
|------------------------------------|---|--------|
| Water Consumption, gal.            |   | 5117.7 |
| Power Consumption, kwhr            |   | 427.0  |
| Gal/kwhr                           |   | 12.0   |
| Gal/day, avg.                      |   | 56.3   |
| Demand, watts                      |   | 560    |
| Basement air temperature, °F, avg. |   | 70     |
| Water inlet temperature, °F, avg.  |   | 67.9   |
| Water outlet temperature, °F, avg. |   | 140    |
| Load factor, %                     |   | 34.7   |
| Performance factor                 | e | 2.14   |
|                                    |   |        |

\*References are given in the Literature Cited

## Performance of A Domestic Heat Pump Water Heater

The results from the two studies compare favorably. For the test reported in this paper, hot water was supplied to a family of two, and for Freyder's test, to a family of four.

The following are some of the chief advantages of the heat pump water heater:

- 1. Provides a high load factor for the electric utility.
- 2. Operating costs at the regular residential rates are much lower for the heat pump water heater than for the electric resistance water heater operating under the same conditions.
- 3. Dehumidifies the air in the basement or utility room.
- 4. Laundry dries much faster in a room where the heat pump water heater operates.
- 5. It is not necessary to carry heavy wet laundry out of the house to dry.
- 6. Laundry hung out of doors to dry is subject to weather changes and dirt in the atmosphere.
- 7. The heat pump water heater can supply all the hot water needed and at the temperature desired.

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# COMPARISON OF ELECTRON AND OPTICAL PHOTOMICROGRAPHS OF A COPPER-BERYLLIUM ALLOY

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#### INTRODUCTION

It is conceivable that, (1) greater resolving power, (2) the process of replication of the surface and, (3) the shadowcasting technique may constitute factors which will be reflected in the appearance of electron photomicrographs, and differentiate them from optical photomicrographs. Also, it is possible that variations, by large amounts, in the magnification of electron photomicrographs may be accompanied by changes in the appearance of microstructures difficult to correlate. The objectives of this investigation (immediately following) were largely evolved from considerations of these possibilities.

a. To effect a visual comparison of photomicrographs of selected areas of polished and etched specimens of a copper-beryllium alloy (2.5% Be, 1.1% Ni, balance Cu) at magnifications within the range of both the electron and optical microscopes.

b. To further study the selected areas with the electron microscope: (1) by maintaining a nearly common geometric center of field as an orientation point for each individual series of photomicrographs and, (2) by varying the magnification in increments of approximately 12,000X.

c. To ascertain if certain structural features can be distinguished with the electron microscope that cannot be distinguished with the optical microscope.

#### EXPERIMENTAL PROCEDURE

The specimens were cut from copper-beryllium bar stock. All were solution treated at  $800^{\circ}$ C for one-half hour and quenched in water. Specimens A, B, and C were subsequently aged at 316-330°C for zero, one, and two hours re-

# Comparison of Electron and Optical Photomicrographs

spectively. The surface of each was polished and lightly etched after aging.

The production of a negative replica (1) of each specimen surface was carried out by dipping the specimen in ethylene dichloride containing one per cent by weight of Fornvar. When the film had dried and hardened, a 250mesh wire screen was placed in contact with the desired area and encircled by a scribed line. Then the replica was stripped by breathing upon it, covering it immediately with scotch tape, and gently pulling the tape with the attached replica away from the surface of the specimen. The time that elapsed between etching and stripping was never more than five minutes. This period of time appeared to be critical, and if exceeded, difficulty in stripping was encountered.

Shadow-casting of the specimens was carried out at a grazing angle of nine to eleven degrees with chromium. A thin alumium film was deposited vertically to strengthen the replica.

The electron photomicrographs were made with an EMU-2A, RCA electron microscope. The optical photomicrographs were made with a Bausch and Lomb research metallograph in the customary manner.

#### Results

# 1. Optical photomicrographs.

The light and dark areas in the optical photomicrographs corresponded directly with the apparently light and dark areas of the specimen surface which was illuminated by reflected light.

Figure 1 was an optical photomicrograph of specimen A (zero aging time) at a magnification of 3,000X. The appearance was typical of other areas of the same specimen. This photomicrograph showed annealing twins which characterize copper base alloys and which represent differences in orientation within grains. The small, white particles of a somewhat spheroidal shape comprised a precipitate generally thought to be of the formula CuBe (2). The presence of these particles in the specimen was due to the incomplete solution of the CuBe phase during the course of the solution treatment. Because this magnification was within the range of the optical microscope, the absence of very fine detail in this photomicrograph should be attributed to a lack of adequate resolving power rather than to insufficient magnification.

This fact was confirmed when the area within the circle was enlarged to give a magnification of 15,000X. Figure 2. The appear-



# Comparison of Electron and Optical Photomicrographs

ance of the surface showed that although the magnification had been increased here by photographic enlargement, no new detail was revealed.

Figure 3 was an optical photomicrograph of specimen C (two hours aging time) at 3,000X. As was shown in the optical photomicrographs of specimen A (zero aging time), Figure 1, the annealing twins and undissolved CuBe phase were readily revealed. The background presented a mottled appearance in which very little detail could be seen. This mottled appearance is common in age-hardenable alloys during the relatively early stages of precipitation and is probably due to very fine particles of unresolved precipitate. The presence of extensive areas of this unresolved structure indicated that precipitation occurred during heat treatment.

# 2. Electron photomicrographs.

The method used in preparing the replicas produced negatives of the surface, that is, depressions in the electron photomicrographs corresponded to raised places in the specimen surface. The black line in the various figures indicates a distance of one micron in the original specimen.

Figure 4 was an electron photomicrograph of specimen A (zero aging time) at a magnification of 3,000X. The variations in topography were more evident than in Figure 1, the optical photomicrograph of the same specimen at the same magnification, and were perhaps due to the use of the technique of shadow casting, which introduces artificial shadows, thus emphasizing contour differences. The apparent lack of depth and height in the optical photomicrograph was probably due to the method of preparation, or to the means of examination of the specimen, or to the absence of shadows, rather than to an actual lack of depth and height in the specimen surface. The wealth of detail contained in the photomicrograph was to a great extent hidden because of the use of the relatively low order of magnification. Inspection of the small, ringed area (containing the particle with the constricted central portion) at a higher magnification (see Figure 5), substantiated this statement. However, the resolution was better than that in Figure 1 as was evident when higher magnifications of each, Figure 5 and 2, respectively, were compared. New detail, in the form of small particles (smaller bits

of precipitate not dissolved during the solution treatment), were now seen (Figure 5) to accompany the larger particles of precipitate which were not dissolved during the solution treatment. No new smaller detail appeared in Figure 2.

Figure 5 was an electron photomicrograph of specimen A (zero aging time) at a magnification of 18,000X. Measurements indicated that the large, dark areas corresponded in size with the large, light, spheroidal particles such as were easily discernible in Figure 1. The size, shape and distribution of the smaller particles could now be ascertained for the first time in this series of electron photomicrographs, because here, both magnification and resolving power were sufficiently great.

The limit of resolution of the best optical microscopes is approximately equal to one-fifth of a micron. Consequently, any particle in this photomicrograph which is less than about one-fifth of the micron line cannot be resolved and hence cannot be seen with an optical microscope. Some of the structural features were less than one-fifth micron and ranged in size from 30 to 60 millimicrons.

It should be pointed out that it is extremely difficult, if not impossible, to interpret many electron photomicrographs solely upon the basis of their appearance. Among these difficulties is the optical illusion effect (3), which is apparent in this figure, inasmuch as the same portion of an image will sometimes appear as a raised area, and again as a depression. Only when the object-shadow relationship is known does it become possible to determine the true elevations of the different areas of the image. Since, logically, shadows are contained within depressions, but lie outside of raised areas, the orientation of the shadow with respect to the object serves to distinguish the hills from the valleys.

The crack-like lines were probably due to the deterioration of the Formvar membrane under the unavoidable handling to which the replica was subjected.

The presence of white particles in this photomicrograph was explained by any of the following reasons:

1. They may have been replicas of holes or depressions in the original specimen surface.

# Comparison of Electron and Optical Photomicrographs

- 2. They may have been pseudo structures produced by the stripping process and unintentionally implanted on the Formvar replica.
- 3. They may have been foreign matter deposited after stripping and prior to shadowing.
- 4. They may have been foreign matter (chromium) deposited during the shadow-casting operation.

Regardless of the reason for their existence in the photomicrograph, the white particles do not represent a part of what was believed to be the characteristic microstructure. In partial support of this contention, it could be stated that if they were indeed replicas of holes or depressions in the original specimen surface, then for each particle there must have been a hole in the original.

The presence of such a large number of depressions in the original would have been detected, since many of the particles were within the limit of resolution of the optical microscope, during microscopic examination of the specimen at the various stages of its preparation. Because such an examination failed to reveal the presence of holes, the first reason was untenable.

Evidence obtained by many workers in electron microscopy has indicated that Formvar is capable of producing faithful replicas. In view of this knowledge, the second possibility was believed to be remote.

The storage environment of the replicas, after preparation and prior to examination with the electron microscope, was so free of dust that it was relatively certain that such a great number of particles could not be attributed to dust which had settled on the replica surface.

It was possible that they were introduced during the shadowcasting process because rather concentrated quantities of metal have been observed over restricted areas of replicas (due to uneven increase of power input to heater filament) in other types of microscope preparations. The shapes and sizes of these particles were compatible with this viewpoint and not with the idea that they represented true structure, as they did not resemble any known structure of copper-beryllium alloys detectable in either optical or electron photomicrographs (3).

Figure 6 was an electron photomicrograph of specimen C (two hours aging time) at a magnification of 9,000X. It is considered at this point because of the large numbers of white particles that formed a pseudo structure and tended to mask the true structural features present. The interpretation of these particles was the same as for those in Figure 5. In addition, a careful examination of the shadows of the particles revealed that their orientation was incompatible with the shadows of the grain boundary, if it was assumed that the grain boundary was raised. Only when the assumption was made that a one sided, v-shaped boundary existed, could the orientation of the shadows of the particles be made compatible with the shadows of the grain boundary.

The depressions in this photomicrograph did correspond to precipitated particles on the copper-beryllium specimen surface.

Figure 7 was an electron photomicrograph of specimen A (zero aging time) at a magnification of 36,000X. The wrinkled area was produced by deterioration and collapse of the membrane. Since this photomicrograph did not contain any new, fine detail of structure heretofore unseen at lower magnifications, and since this magnification was concomitant with a reduced area of field, the working magnification for studies of this alloy should probably correspond more nearly to 18,000X than to 36,000X.

Figure 8 was an electron photomicrograph of specimen A (zero aging time) at a magnification of 50,000X. No new, structural detail could be seen in this photomicrograph, which indicated that lower magnifications were appropriate for this specimen.

Figure 9 was an electron photomicrograph of specimen C (two hours aging time) at a magnification of 3 000X. The large, dark areas corresponded to the undissolved precipitate seen in Figure 3. However, the magnification used did not permit revelation of the finest details, which higher magnification proved to be present in the specimen.

Figure 10 was an electron photomicrograph of specimen C (two hours aging time) at a magnification of 9,000X. The undissolved precipitate exhibited no new detail at this magnification, but the inComparison of Electron and Optical Photomicrographs



dividual particles of the newly formed precipitate were easily detected. They are not recognizable, as such, in optical photomicrographs after the elapse of periods of time of the order employed in this investigation. The doughnut-like appearance of some of these particles was explained on the basis of depressions resembling troughs, surrounding, and in contact with the precipitate. It was believed that this structure resulted from an accelerated rate of attack by the etchant at the CuBe-matrix interface.

Figure 11 was an electron photomicrograph of specimen C (two hours aging time) at a magnification of 18,000X. The precipitate, which was more plentiful in this photomicrograph than in Figure 5, showed the effect of aging on the process of precipitation in Cu-Be alloys.

Figure 12 was an electron photomicrograph of specimen C (two hours aging time) at a magnification of 36,000X. The doughnutshaped configuration of the precipitate was revealed in greater detail, here. Shadows with orientation both inside and outside confirmed the existence of the precipitate in this form.

Figure 13 was an electron photomicrograph of specimen C (two hours aging time) at a magnification of 50,000X. The increase in magnification definitely revealed no new, fine detail, which indicated the likelihood that all structural detail was large enough so that magnifications of a lesser degree were sufficient.

Figure 14 was an electron photomicrograph of specimen B (one hour aging time) at a magnification of 9,000X. The dark spots were not interpreted as being characteristic of the microstructure. Quite probably they were holes in the Formvar, negative replica. The white areas immediately surrounding the dark areas were just as probably due to the folding back of the replica around the holes. Since it was reasonable for the replica to deteriorate at points where it was relatively thin, it seemed probable that the holes were made by projections of precipitate on the original surface. As such, the holes did not describe the form of the precipitate, but did indicate that precipitation occurred rather extensively.

# Comparison of Electron and Optical Photomicrographs

## SUMMARY AND CONCLUSIONS

Optical and electron photomicrographs of nonidentical, but similar areas of sections of a Cu-Be alloy aged for zero, one, and two hours were compared, and the following conclusions drawn:

- 1. Electron photomicrographs of Formvar, negative replicas, shadowed with chromium, revealed topographic variations to a greater degree than reflection-type, optical photomicrographs.
- 2. The resolving power of the optical microscope did not permit the revelation of all detail present in the microstructure of the Cu-Be alloy.
- 3. It was possible to follow, with assurance, the changes in appearance of the microstructure of the specimens during the transition in magnification from the upper optical range to 50,000X, with electron photomicrographs of intermediate magnifications.
- 4. Certain structures which appeared in the electron photomicrographs were observed to be from 30 to 60 millimicrons in size. Obviously these were too small to be resolved with the optical microscope.
- 5. The presence of certain particles, foreign to the true microstructure, were attributed to defective shadowing.

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# STRUCTURAL SETTLEMENT COMPUTATIONS\*

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The Science of Soil Mechanics is one of the youngest of the Sciences, its entire history being within the past three decades.

Shortly before World War I, Civil Engineers had rather disastrous experiences with soils in three countries almost simultaneously. In Sweden there were catastrophic slides, resulting in the loss of many lives, on the State Railways. The German engineers were surprised many times with slides of the banks of the Kiel Canal. At the same time our own engineers were experiencing some of their most trying times with failures in the cuts of the Panama canal. Previously the study of the soil and its properties was a distasteful task, undertaken only as a last resort after all other experimentation with changes in the structural elements had failed to correct the difficulties encountered. With this attitude toward the problem it is small wonder that the data accummulated were hardly worthy of the term science.

Intensified experimentation from 1910 to 1930 led to the discovery of a whole series of vitally important physical factors which had escaped the attention of the investigators of the previous generations. Among these new found facts was one pertaining to the continued settlement, for many months, of structural foundations at a constant load. From the discovery of this and other just as important facts came a desire to rebuild the existing theories to conform with the increased knowledge of the physical properties of the soil.

As happens with the research program in many of the sciences, it is not always the oldest problem nor the one which is causing the maximum amount of real damage that receives the first attention of the scientist; it is usually that problem which is causing the most spectacular and newsworthy concern that gets first call on the time of those in the field. In soil mechanics, in spite of the fact that settlements had been causing structural damage and financial loss for many years, it was the lateral stability of earth slopes that received the primary consideration. This was probably as it

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## Structural Settlement Computations

should have been since seldom had settlements caused loss of life: and while settlements were probably causing more extensive damage, they were occurring in too many places with a correspondingly smaller loss per occurrence.

There is no complete theory of the settlement of foundations and probably there never will be, because of the non-homogeneity of the medium transmitting the forces. We have only theories which inform us by crude approximations of one or more of the aspects of the phenomena of soil behavior. At the present time, however, the theories that are available, while not exact, are adequate for a majority of the more serious cases, yet they are seldom given study until after the structure is built and the settlement begins to occur.

In view of the fact that the space allotted to this discussion is rather limited it would hardly be practicable to attempt to cover the settlement problem in its fullest details. I should like, therefore, to confine my discussion to just one phase of the problem, this phase being that which I consider one of the most important: the theory of the distribution of stress in the loaded soil mass.

In almost any recent text on Soil Mechanics can be found the development of an equation relating the physical properties of the soil mass, the loads on the soil, and the state of stress in the soil with the predicted settlement.

The equation will take a form somewhat as follows:

$$\mathrm{S}\,=\,\mathrm{H}\,\frac{\mathrm{C_{c}}}{1+\mathrm{e_{o}}}\mathrm{\log_{10}}\frac{\mathrm{p_{o}}+\Delta\,\mathrm{p}}{\mathrm{p_{o}}}$$

In this equation S is the predicted settlement. H is the thickness of the compressible layer,  $e_{o}$  the void ratio of the compressible layer,  $p_{o}$  and p the initial stress and increase in stress due to the superimposed load, and  $C_{e}$  is the coefficient of consolidation of the soil.

This equation has been developed from laboratory consolidation tests on both disturbed and undisturbed samples. The results of these tests have been extrapolated to give an equation which is proposed for use in computations involving virgin soil in a completely undisturbed state.

This paper is primarily concerned with the calculation of a reasonable value for  $\Delta p$ , or the increase in pressure on the compressible layer caused by the load of the structure. Since the compressible layer hardly ever is in direct contact with the footing, and may be many feet below the surface, the problem is presented in evaluating the amount by which the footing load is spread over adjoining area, thus reducting the unit stress as the load is transferred vertically into the ground.

The analysis of stresses in a loaded soil mass is a complex problem, the solution of which would be difficult even if we had a complete knowledge of the physical properties of the soil. The problem may be simplified by making various assumptions and accepting certain approximations.

If Soil Mechanics is to be applicable to engineering problems, it must be considered a part of the mathematical theory of elasticity and resistance of materials. The approach to solutions must be taken as special cases of that general theory.

The solution of any design problem can be broadly divided into three general steps:

- 1. The determination of the forces acting in terms of the basic properties
- 2. The basic properties of the materials under average conditions
- 3. The variation of the basic properties due to differences in assumption or non-homogeneity of the material.

Considering step one, if we assume that the stresses in the soil are the same as in an elastic, homogeneous and isotropic material, then the theory of elasticity can be applied to the solution. It is well known that this assumption is not valid; perhaps the only real excuse that can be offered for its use is that it leads to a convenient and generally a reasonable value for the stresses, and that the results, if accepted at their face value, are useful in estimating the probable settlement of a structure.

One of the first methods used to compute the increase in pressure on a compressible layer due to a building load was to break

# Structural Settlement Computations

the loaded area into small parts, considering the load on each piece to be concentrated at its center. On this basis, if we accept the theory of elasticity, the increase in stress due to each concentrated load could be computed. Then by the principle of superposition the results added to approximate the total increase in stress on the soil. This procedure, of course, amounts to a mechanical integration of the stress due to a differential force on a differential area.

If an external force acts on a very small area of a horizontal solid of semi-infinite dimensions, that is, one infinite in breadth only, the point load produces a state of stress with circular symmetry about a vertical line through the point of application of the load.

On account of the symmetrical nature of the stress the shearing stresses on vertical radial planes are zero. The intensity of the other stresses has been computed, by Bousenseq in 1885, by means of a stress function which strictly satisfies the boundary conditions.

The vertical stress at a point on a horizontal plane at depth z is expressed as

$$dp_{v} = \frac{3q}{2 \pi z^{2}} \left[ \frac{1}{1 + (r/z)^{2}} \right]^{5/2} dA$$

In this equation q is the point load on the differential area and r is the radial distance between the load and the point being stressed.

We can see from this equation and the variety of sizes and shapes of footings under a modern structure with combinations of individual, combined and continuous footings, and the further possibility of different unit loads on different footings, that a mechanical integration as such would require a tremendous amount of time and labor for a complete solution.

In order to reduce the amount of time involved in these calculations several alternate methods have been proposed for a solution of the problem.

One of the first proposed is a solution using the same differential load and area but using the calculus for the integration or summation. This method is satisfactory as long as the shape of the footing and hence the limits of integration are relatively simple, such as a

circular footing. Unfortunately, this is seldom the case in the practical structure.

A second method that has been suggested for use when the foundation consists of a large number of footings or footings of an irregular shape is a graphical solution developed by Newmark at the University of Illinois. If we take the basic equation and integrate it to find the pressure on a point at depth z and immediately below the center of the loaded area circular in shape with a radius R, we get

$$p_{v} = q \left[ 1 - \left( \frac{1}{1 + (R/z)^{2}} \right)^{3/2} \right]$$

This can be rewritten in the form

$$-\frac{\mathbf{p}_{\mathbf{v}}}{\mathbf{q}} = 1 - \left[ \begin{array}{c} 1 \\ 1 + (\mathbf{R/z})^2 \end{array} \right]^{3/2}$$

A study of this equation shows that when r equals infinity  $\frac{P_v}{q} = 1$ . Carrying this process further we can find values for the ratio of radius of loaded area to depth z for which the term  $\frac{P_v}{q}$  will be equal to 0.1, 0.2, 0.3, etc. As an example for  $\frac{P_v}{q}$  equal to 0.2 the ratio  $\frac{r}{z}$  will be equal to 0.401. This means in effect that if a loaded circular area has a radius equal to 0.401 times the depth z, the unit pressure at depth z will be 0.2 of that pressure being applied on the surface. If we proceed in this manner we can construct a chart showing the various circles to be loaded to give 0.7q, 0.8q, 0.9q as pressures at depth z. The first problem in the actual construction of the chart is to select a suitable scale. If we take any arbitrary length AB and let it be equal to the depth z we can use as radii of the

### Structural Settlement Computations



circles the proper fractional lengths of this scale to construct the chart.

From this chart we see that if p = 0.4g the area in the circle marked p = 0.5q p = 0.5g is loaded the pressure at depth z is one half the applied load. Similarily if the circle marked p = 0.4q is loaded, the pressure is four tenths the applied load; then from the principle of superposition if only the annular ring between the two circles is loaded, the increase in pressure is

0.5q minus 0.4q or 0.1q. We can further divide this annular ring into smaller areas by n equally spaced radial lines the smaller areas being included between two radii and the two circles, as shown cross-sectioned on the chart, the increase in pressure due to a load on this area being  $\frac{0.1q}{n}$ . Since all the areas are symmetrical about the center each will exert equal influence on the stresses in the soil; if n is equal to ten, the influence of each area is 0.01 q. This procedure was followed by Newmark in the construction of his charts published in 1942 by the University of Illinois Engineering Experiment Station Bulletin No. 338.

The method for using the chart is as follows: after the soil profile is throughly investigated, the depth to the center of the compressible layer is used as the depth z. Then to a scale such that z = AB from the chart a foundation plan is drawn showing the individual footings and their unit loads. This tracing is then laid over the chart in such a manner that the point on the foundation under which the stress is to be computed is directly over the center of the chart. The number of influence blocks covered is then counted, the increase in stress being equal to the product of the number of blocks, the influence stress per block, and the unit load on the footing area. If all the footings have the same unit load one calculation is sufficient; however, if there are footings of different unit loads, each unit load must be handled independently and the final stresses added to give the total increase in stress in the soil.

We have a notable example of the use of this theory in an

article published by Dr. Karl Trezaghi in his text. In this article he compares the predicted settlements with the actual measured settlements on the Charity Hospital in New Orleans. It is remarkable that in spite of the complexity of the problem the predicted and measured contours of equal settlement virtually coincide.

In closing I should like to call to your attention that while we are far from a complete solution, the problem is not as hopeless as some would lead us to believe. One of our most pressing needs today is to have more complete records from those people in the field who are having settlement problems. We must not only be told that the settlement is occurring, we must be given a complete description of the rate of its occurrence and the pattern of its occurrence throughout the building. Above all, it is necessary to have a detailed description of the soil profile and the results of laboratory tests of the soil.

# PREPARATION OF 1-XYLYL-1, 3-BUTANEDIONES USING DIKETENE°

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Hurd and Kelso (1) used diketene to prepare benzoyl acetone by three different methods in  $11-25\,^{\circ}_{\circ}$  yields. The preparation of benzoyl acetone in  $73\,^{\circ}_{\circ}$  yield by the reaction of diketene and excess benzene at  $50^{\circ}$  in the presence of aluminum chloride was reported by Boese (2). This appeared to be an attractive method for the preparation of the xyloyl acetones and for observation of the directive effects in the ring during this Friedel-Crafts type of reaction.

During preliminary experiments at 50° with diketene, excess p-xylene, and aluminum chloride it was noted that isomerization of p-xylene occurred. Re-use of the recovered p-xylene with diketene and aluminum chloride produced a non-separable mixture of d'ketones derived from m-xylene, p-xylene, and other substances which were not identified. (Isomerization of p-xylene to m-xylene at  $100^{\circ}$  by aluminum chloride (3) and at  $55^{\circ}$  by aluminum chloride and hydrogen chloride (4,5) has been reported.) Reaction of diketene and p-xylene in the presence of the milder catalysts, stannic chloride and boron trifluoride, did not produce any of the desired product. Boese found that the best vields of benzovl acetone were obtained by using two moles of aluminum chloride for each mole of diketene, because the diketone formed during the reaction complexes the aluminum chloride, making it less available for catalysis. The use of a lower reaction temperature made possible by the relatively greater ease of substitution of the xylenes, practically eliminated isomerization by aluminum chloride. The p-xvlene recovered from a typical run at 20° showed no appreciable change in index of refraction or freezing point. The viscous red complex formed by aluminum chloride and xylene (6) so decreased the efficiency of stirring that the vield was appreciably lowered unless xylene was present in large excess. This necessitated combination of the products of several batches to obtain enough material for purification by fractional distillation. The structure of each dike-

<sup>&</sup>lt;sup>o</sup> From the M.S. dissertation of Albert Tockman, University of Kentucky, April, 1950.

tone was determined by hypochlorite oxidation to the dimethyl benzoic acid, and conversion of the acid to the amide.

Only one monosubstitution product is possible from p-xylene (I). This gave upon hypochlorite oxidation 2, 5-dimethyl benzoic acid, corresponding to 1-(2, 5-dimethylphenyl)-1, 3-butanedione (II).



Three monosubtitution products are possible from m-xylene (III). The most probable position for the substituent is *ortho*- to one methyl group and *para*- to the other. A second possibility, *ortho*-to both methyl groups, is less probable because of the relatively weak *ortho*-directive influence of a methyl group and the likelihood of steric hindrance. The least probable position is *meta*- to both methyl groups. Hypochlorite oxidation of the product gave 2, 4-dimethyl benzoic acid, corresponding to 1-(2, 4-dimethylphenyl) -1, 3-butanedione (IV). Two monosubstitution products are pos-



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266

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# Preparation of 1-xylyl-1, 3-Butanediones Using Diketene

sible from o-xylene (V). The more probable position for the substituent is *para*- to one methyl group and *meta*- to the other. A slightly less probable position is *ortho*- to one methyl group and *meta*- to the other. The product which was obtained could not be purified by fractional distillation: the major component crystallized upon cooling. Hypochlorite oxidation gave 3.4-dimethyl benzoic acid, corresponding to 1-(3,4-dimethylphenyl)-1.3-butanedione (VI). Sufficient quantity for identification of the minor component (presumed to be 1-(2,3-dimethylphenyl)-1.3-butanedione (VII) could not be



VII

obtained. The 1-xylyl-1.3-butanediones gave a deep red coloration with ferric chloride. The copper complexes of the "para" and "meta" are useful derivatives of the diketones.

### Experimental

Melting points and boiling points are corrected. Analyses were made by the Clark Microanalytical Laboratory, Urbana, Illinois.

MATERIALS. Ortho-, meta-, and para-xylenes were obtained from The Matheson Co. Anhydrous aluminum chloride was Merck reagent grade. Diketene was kindly supplied by Carbide and Carbon Chemicals Co., at the South Charleston, West Virginia plant. It was purified by fractional distillation at 40 mm. pressure through a 48-inch helices-packed vacuum-jacketed column mount-

ed in a hood. The fraction boiling at  $50^{\circ}$  was collected and stored at  $-20^{\circ}$  until needed.

#### 1-(2, 5-Dimethylphenyl)-1, 3-butanedione (II).

Using a three-necked flask equiped with Walter dropping funnel, reflux condenser, and Hershberg stirrer, 16.8 g. (0.2 mole) of diketene dissolved in 63.7 g. (0.6 mole) of p-xylene was added dropwise over a period of 40 minutes to a stirred suspension of 54 g. (0.4 mole) of anhydrous aluminum chloride in 63.7 g. (0.6 mole) of p-xylene. The reaction temperature was  $20^{\circ}$ ; stirring was continued to give a total reaction time of one hour. The reaction mixture was decomposed by pouring onto 300 g. of ice and water containing 25 ml. of concentrated hydrochloric acid and was then gently refluxed for one hour. The unreacted p-xylene was recovered by steam distillation. About 100 ml. of acetone was added to the cool residue, the organic layer separated, and the acetone and any remaining p-xylene removed by distillation at 20 mm. pressure. The viscous red residue was then rapidly distilled at a pressure of 3 mm. leaving a considerable quantity of tars. Twenty-six grams of a pale yellow oil boiling at about 129° was obtained; the yield based on diketene was 68%. This material was combined with the products of other similiar runs and was fractionally distilled at a pressure of 10 mm. through a 10-inch helices-packed column, vielding a colorless oil boiling at 150.9-151.4°. Dielectric constant at 25.0° and 10 megacycles 14.15;  $d_4^{25}$  1.0512,  $n_p^{25}$  1.5702.

#### Anal. Caled. for C<sub>12</sub>H<sub>14</sub>O<sub>2</sub>: C, 75.76; H, 7.42. Found: C, 76.50; H, 7.52.

Two milliliters of the purified material was suspended in 10 ml. of 10% aqueous sodium hydroxide and added with stirring to 100 ml. of 5.2% sodium hypochlorite (Clorox) (7). After gentle warming for five minutes, 10 ml. of acetone was added cautiously and the mixture heated for 10 minutes. The solution was filtered and acidified with acetic acid. When cool, the precipitated white solid was separated by filtration and recrystallized twice from water-methanol mixture. The dried solid melted at 130.0-130.5° (literature for 2, 5-dimethyl benzoic acid, 132°). One gram of the dry acid was converted to the amide by treating with thionyl chloride and adding the resulting acid chloride to cold concentrated ammonia water. The amide was decolorized with charcoal and recrystallized twice from water-methanol mixture. The dry amide melted at 184-185° (literature (8) for 2, 5-dimethyl benzamide, 186°). A freshly filtered solution of 12 g. of copper acetate monohydrate in 150 ml. of hot water was added with stirring to 2 g. of the purified diketone. When the precipitate had crystallized (about two hours), it was collected by filtration and recrystallized from methanol. After three recrystallizations, the gray-green copper complex melted sharply at 122.0°

#### 1-(2, 4-Dimethylphenyl)-1, 3-butanedione (IV).

The apparatus and general procedure were the same as above except for the substitution of m-xylene for p-xylene. Twenty-four grams of a pale yellow oil, boiling at about  $135^{\circ}$  at 3 mm. was obtained; the yield based on diketene was 63%. The products of several runs were combined and purified as above,

giving a colorless oil boiling at 146.4-147.2° at 10 mm; dielectric constant at 25.0° and 10 megacycles 14.88;  $d_4^{25}$  1.0522;  $n_{\rm p}^{25}$  1.5754.

Anal. Caled. for C1.,H14O.; C, 75.76; H, 7.42. Found: C, 75.91; H, 7.19.

Hypochlorite oxidation as described above gave an acid which melted at  $125^{\circ}$  (literature (8) for 2, 4-dimethyl benzoic acid,  $126^{\circ}$ ). The amide melted at  $179^{\circ}$  (literature (8):  $179-181^{\circ}$ ). The blue-gray copper complex melted at  $156^{\circ}$ .

1-(3, 4-Dimethylphenyl)-1, 3-butanedione (VI).

The apparatus and general procedure were the same as above except that o-xylene was used. Twenty grams of a pale yellow oil, boiling at about  $160^{\circ}$  at a pressure of 7 mm. was obtained. The yield based on diketene was 79%. The products of three runs were combined and subjected to fractional distillation. No pure component could be isolated in this manner. Upon cooling, however, a solid separated and was recrystallized from Skellysolve B until its melting point became constant at  $48.8-49.0^{\circ}$ ;

Anal. Calcd. for C12H14O2: C, 75.76; H, 7.42. Found: C, 75.96; H, 7.25.

Hypochlorite oxidation gave an acid which melted at  $166^{\circ}$  (literature (8) for 3, 4-dimethyl benzoic acid,  $165\text{-}166^{\circ}$ ). The amide melted at  $130^{\circ}$  (literature (8):  $131^{\circ}$ ). The green copper complex decomposed without melting when heated.

#### Acknowledgements

Grateful acknowledgement is made of a grant-in-aid from The Research Corporation. The dielectric constants were determined by Mr. Frederick Gormley, using apparatus which has been described (9).

### SUMMARY

1-(2, 5-dimethylphenyl)-1, 3-butanedione, 1-(2, 4-dimethylphenyl)-1, 3-butanedione, and 1-(3, 4-dimethylphenyl)-1, 3-butanedione have been prepared from diketene and *para*—, *meta*—, and *ortho*-xylene respectively. Copper complexes of the first two compounds are useful derivatives.

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#### A LOOK AT KENTUCKY WOODLANDS

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Kentucky Woodlands National Wildlife Refuge is one of the system of some 280 Wildlife Refuges administered by the United States Fish and Wildlife Service. It is the only National Wildlife Refuge in Kentucky. It was established for the preservation and propagation of all forms of native wildlife, particularly the wild turkey, the white-tailed deer, and waterfowl.

#### HISTORICAL

The refuge, which contains approximately 65,000 acres, is located in Lyon and Trigg Counties between the Cumberland River and Kentucky Lake. This area, which was made a national wildlife refuge in 1938, has an interesting history. Most of the land included in it was formerly owned by the Hillman Land and Iron Company. Iron was mined and smelted here, intermittently, between 1841 and 1912. The ruins of one of the three iron furnaces, known as Center furnace, still stand. It was on this area, in 1845 or 1846, that the first Chinese labor was used on this continent. It was here, during the decade following the Civil War, that the so-called Bessemer process for making steel was developed. Here, also the famous Golden Pond moonshine whiskey was produced during, and just following, the prohibition era.

The area is, largely, rough hilly woodlands interspersed with cleared hollows which have been used, more or less, for some form of agriculture since an early day. The Cumberland River and Kentucky Lake extend parallel to each other about eight or nine miles apart along the east and west sides of the refuge. The Dividing Ridge, running between the two streams, has an elevation of about 520 feet. On the west side, the land slopes off rather sharply to Kentucky Lake. The general slope on the Cumberland river side is less abrupt and the hills gradually play out into the flat fertile Cumberland river bottom which averages about a mile across.

The timber on the wooded area has been cut heavily in the past. During the iron smelting day, it was clear cut. Everything

# A Look At Kentucky Woodlands

down to small trees, two inches in diameter, was used for making charcoal for smelting. Fortunately for the native wildlife, not more than 300 acres were clear cut in this way in any one year. After the cessation of iron mining and smelting, heavy timber cutting was carried on for the production of cross ties, until the land was purchased by the United States, through the Resettlement Administration, in 1936. During this long period, there was no attempt to control fires and the woods were burned over almost annually. Also, this country was without a stock law and free ranging livestock often severely stripped the woodlands of palatable vegetation and mast.

## GENERAL PROGRESS

Since the refuge was established, substantial progress has been made toward developing the area as wildlife habitat. Poaching, woods fires, and uncontrolled grazing have been practically eliminated through the vigilance of the refuge personnel. Three small lakes, Hematite Lake with an area of about 125 acres, Honker Lake with an area of about 130 acres, and Empire Lake with an area of about 60 acres, have been created on the eastern side of the refuge and waterfowl food plants have been established in them. Field crops, suitable for wildlife food, are planted and tended each year by refuge personnel and by neighboring farmers. When farmers tend this land, a share of the crop is left unharvested for wildlife as rent payment. Some of the land is rented as pasture for cattle. This is not incidental to wildlife management but is, rather, a part of it. While rental of pasture land fits in desirably with the local economy, I wish to emphasize that grazing is permitted primarily with the view of maintaining wildlife habitat. It is desirable, from the standpoint of certain species, to maintain clearings and the grazing of livestock is simply an economical way of doing this. In fact it appears that grazed clearings are actually more attractive to wild turkeys than clearings maintained in other ways.

## WILD TURKEY

Probably the most interesting form of wildlife on this refuge is the Eastern Wild Turkey. These birds are of the original wild stock and show no sign of being contaminated by domestic turkeys. Their spindle shaped bodies, small blue heads with practically no wattles. brown tipped tails and their nervous ever-alert manner all are characteristics peculiar to the pure strain wild turkey.

The wild turkey is truly a wary and resourceful bird. During the iron working days, and afterward, the area between the rivers was fairly thickly populated and the turkeys were hunted the year around. The fact that they were able to survive in spite of this uncurbed hunting and the disturbance and habitat destruction resulting from timber operations, fire, and uncontrolled grazing, speaks well for their adaptability.

These birds increased very satisfactorily for the first few years after the refuge was established and then there was a sharp decline in their numbers. This decrease was not due to poaching since the turkeys have been afforded good protection and the attitude of the local people toward turkey hunting has improved steadily. Apparently there is some factor, or factors, in the turkey's environment which tends to limit their density, that we have not yet determined. There are several factors which may contribute to this limitation of population:

- 1. The amount and availability of proper food and water at critical periods during the year.
- 2. The accessibility of the various types of conditions required by the turkey for feeding, nesting, and escape.
- 3. Competition with, and depredations by, other species of animals.
- 4. Disease and parasites.

It is the work of those concerned with wildlife management to discover the factors and inter-relations of factors that govern wildlife populations and to make practical applications of such findings.

## WHITE-TAILED DEER

The management of the white-tailed deer, on Kentucky Woodlands, has been simpler than the management of the turkey, and more successful. Given brushy growth, adequate water supply, and salt, the deer will ordinarily increase satisfactorily when protected. In 1915, the last of the native white-tailed deer were killed by

## A Look At Kentucky Woodlands

hunters. In 1919, Mr. J. N. Esselstyn, superintendent of the Hillman Land Company, introduced thirty white-tailed deer. These deer persisted through the years, in spite of a considerable amount of hunting, until the refuge was established. By 1948 the population appeared to be approaching the carrying capacity of the refuge. More than 350 deer were live trapped between 1946 and 1949 to restock wildlife areas managed by the state of Kentucky. In 1949, disease decimated the population so that trapping was discontinued. The remaining deer appear to be in good shape and it is expected that the population will build up again to its former density.

## WATERFOWL

In the future. Kentucky Woodlands may be looked upon as, primarily, a waterfowl refuge. The success of waterfowl management here has surpassed expectations and the refuge promises to be an important unit in the management of waterfowl of the Mississippi flyway. Prior to the establishment of the lakes, ducks and geese were almost unknown in this vicinity. Within four years after their flooding, as many as 10,000 ducks of several species could be seen on these lakes during the winter. The mallard and the black duck are the principal species. Pintails, ringnecks, lesser scaups, wood ducks, baldpatcs, gadwalls, goldeneyes. ruddy ducks, buffleheads, and mergansers are common.

The response of Canada geese to the refuge was not as immediate as that of the ducks but it is even more satisfactory. Large fields adjacent to Empire and Honker Lakes and to Kentucky Lake on the west side of the refuge have been cleared of brush and crops of small grain for winter green food and corn and milomaize are planted and are ready for the geese when they arrive in the fall.

In 1940, eight crippled geese from Horseshoe Lake in Illinois were placed on Hematite Lake as decoys. It was encouraging to refuge personnel that six Canada geese stopped and spent a day on Empire Lake. During the fall and winter of 1941 and 1942 three flocks of 28, 48, and 50 were observed on the refuge. And so each year there was a gradual increase in the number of Canada geese using the area. By the fall of 1945 there was a winter resident popu-

lation of about 250 geese. In the following spring 56 pinioned decoys from Carolina Sandhills Refuge were penned at Empire Lake. The following fall and winter there was a resident population of 475 geese. The following years showed a continued increase. During the winter of 1949-50, a peak of about 3,000 geese used the refuge and spent the winter there and nearby on Kentucky Lake and in neighboring grain fields.

Kentucky Woodlands is not considered as merely a kind of museum of native wildlife, but rather as a unit in a system of refuges and wildlife mangement areas whose object is the restoration of North American wildlife. It works in conjunction with a series of federal and state waterfowl refuges and managed hunting areas, extending along the system of T.V.A. lakes in Kentucky, Tennessee, and Alabama. This has resulted in a desirable eastward extension of the Mississippi waterfowl flyway.

## SUPERVISED HUNTING AND TRAPPING

Since 1946, the state of Kentucky has conducted a live trapping project for the purpose of restocking wildlife refuges and management areas throughout the state with turkeys, deer, and raccoons taken from Kentucky Woodlands Refuge.

Hunting and trapping are not entirely and forever excluded from this refuge. In fact, when a species becomes over-abundant, it may be good management to remove the surplus in this way. In years of a heavy squirrel crop, squirrel hunts, supervised by personnel of the refuge and the Kentucky Department of Conservation, are held. In the fall of 1949, a supervised coon hunt was conducted. The trapping of fur animals under permit is allowed at times when it is deemed desirable to reduce the fur animal population. It is entirely possible that, in the future, some regulated hunting of deer and turkeys may be conducted if these species build up a population that can safely stand such removal.

# GEOLOGICAL SKETCH OF THE JACKSON PURCHASE\*

# E. B. Wood Kentucky Geological Survey

Kentucky is divided into several physiographic provinces each with its own rather distinctive characteristics. The Cumberland Plateau of eastern Kentucky, with its rugged mountains, scenic beauty, widespread forests and vast coal deposits, is one example of these provinces. Another is the Bluegrass Region, famous the world over for its fertile farm and pasture land which supports the very important tobacco and horse industries. Still others are the Pennyroyal famous for the great Mammoth and associated caverns, good farm land and high calcium limestones, and the western Kentucky Coal Basin which produces most of Kentucky's petroleum and a considerable amount of coal. The Jackson Purchase is another province with its own peculiar characteristics.

The types of rocks present in outcrop and the influence of the elements (weathering) on them is an important factor in the formation of these various provinces. The outcrop pattern of the different systems of rocks shown in colors on the geologic map of Kentucky corresponds very closely to the physiographic provinces.

In the Jackson Purchase region some of the older rocks which outcrop in other parts of the state have been covered by younger formations consisting mainly of sands, gravels, and clays. This was accomplished by submergence of the area and the formation of a sort of glorified Gulf of Mexico which extended northward over what is now the Jackson Purchase region. These waters were responsible for the deposition of these younger sediments. Thus we find a different type of formation in the Jackson Purchase from that in any other section of the state.

It should be apparent from an east-west cross section through the state that one would not expect to find in the Purchase Region the coals of the western Kentucky Coal Basin or eastern Kentucky Coal Fields or the high calcium limestones of the Pennyroyal. Likewise, the Mississippian oil bearing formations of the western Kentucky Coal Basin which account for perhaps 75% of Kentucky's oil production would not be present.

So, while the Purchase lacks certain minerals found in other

Condensation of a talk presented at the 1950 Spring Meeting of the Kentucky Academy of Science at Murray State College.

parts of the state, it in turn possesses its own characteristic minerals. Probably the most important of these is its ball, sagger, wad and other high grade types of ceramic clay. In 1946 the value of ball clay alone totaled about one million dollars.

Other mineral resources include ground water, sand and gravel, chert and the possibility of oil or gas. Not a great deal is known concerning these mineral resources and more information must be compiled if they are to be efficiently developed.

At present, the Agricultural and Industrial Development Board through the Kentucky Geological Survey is carrying on mineral resource investigations in the vicinity of Henderson, Hopkinsville and Paintsville. Ground water investigations are also being carried on in close cooperation with the above program and in Louisville and Covington. Four inner Bluegrass counties have already been surveyed and water maps issued.

Also of vital importance to many state industries and agencies is the topographic mapping program under the sponsorship of the Agricultural and Industrial Development Board in cooperation with the U.S. Geological Survey. The goal of this program is to provide statewide coverage of modern up-to-date topographic maps on a scale of 1 inch = 2000 feet.

It is hoped that the mineral resource investigation will also be put on a statewide basis so that every section of Kentucky will know what mineral resources are present and how to develop them efficiently.
# ADSORPTION OF ALIPHATIC ACIDS ON A WEAK BASE ANION EXCHANGER\*

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Equilibrium isotherms have been measured at 30.3°C, for the reaction between Amberlite IR-4B and the acids chloracetic, formic, acetic, propionic, butyric, and isobutyric. Formic and chloracetic are more strongly taken up than the others from dilute solutions. A strong adsorption from high concentrations of butyric and isobutyric is probably due to true adsorption,

While considerable attention has been given in recent years to the factors influencing cation exchange equilibrium, little attention has been given to equilibria involving anion exchange resins. Kunin and Meyers (1) show graphically a variety of equilibria involving a weak-base resin, Bishop has correlated adsorption of a wide variety of acids by both weak base (2) and strong base (3) resins, and Robinson and Mills (4) show the adsorption by another weak base resin of normal aliphatic acids from water, acetone, and hydrocarbon solvent. Cleaver and Cassidy (5) show adsorption of glutamic acid by both anion and cation exchangers.

It is the purpose of this work to give a quantitative description of the adsorption of carboxylic acids by a weak base resin and to correlate the adsorption with other properties of the acids.

#### EXPERIMENTAL

Materials. – Amberlite IR-4B anion exchange resin (we are indebted to the Resinous Products Division, Rohm and Haas Company, for a generous supply of the resin) in 500 g, batches was left in contact with distilled water for a week, with water changed once or twice daily. The resin was then placed in a large Buchner funnel, washed with one liter of distilled water using gentle suction, and treated with a 5% solution of hydrochloric acid without suction until sufficient acid had been run through to convert the resin to the chloride form. The resin was then similarly treated with three one-liter portions of 5% sodium hydroxide, and washed with water. This washing with sodium hydroxide followed by washing with water used. Full suction was then applied for one hour. The resin was then removed from the funnel and dried in vacuo over calcium

'This work was reformed under a contract with the Atomic Energy Commission and also received some support from the College of Arts and Sciences Research Fund. The paper is based on the M.S. Thesis research of Mr. R. W. Jeffers.

chloride for three days. Resin was used soon after processing to avoid decomposition.

Laboratory distilled water was further demineralized by a mixed-bed ion exchange column.

C. P. Baker's analyzed formic and acetic acid, Coleman and Bell C. P. butyric acid and Dow specially purified chloracetic acid were used. Eimer and Amend C. P. propionic acid and Sapon Laboratories isobutyric acid were distilled, the fractions used boiling respectively at 141.0°C. (750 mm.) and 158.4°C. (760 mm.).

*Procedure.* — To weighed samples of resin (usually about 2 g.) in Pyrex glass stoppered bottles were added 100 ml. portions of acid of known concentration. The bottle was then agitated gently, sealed with paraffin wax and placed in a constant temperature bath at  $30.3^{\circ}$ C. for seventy-two hours, a time found to be quite sufficient for the system to reach equilibrium. The bottles were then removed and the concentration of the acid in the solution measured.

Acid concentrations were measured by titration with standardized sodium hydroxide. For acid concentrations below  $0.02 \ M$  conductometric titrations (6) were used.

# RESULTS AND DISCUSSION

From the decrease in acid concentration in the solution the concentration, y, of acid in the resin phase is calculated in millimoles per gram of dry resin. A number of graphical representations of the equilibrium data were plotted in order to find clues as to a suitable mathematical interpretation of the data. As illustrated in Fig. 1 for two of the acids, plots of y as a function of the equilibrium concentration, c, of the solution, as in typical adsorption isotherms, show slopes continuously decreasing from large values at low concentrations. While adsorption of strong mineral acids on a similar resin was found by Meyers, Eastes and Urguhart (7) to follow the Freundlich isotherm, graphs of  $\log y$  versus  $\log c$  for aliphatic acids on another similar resin were found by Robinson and Mills (4) to show slopes decreasing with increasing concentration, suggesting a saturation effect. Our data, as illustrated in Fig. 2 for chloracetic and acetic acids, show the same decreasing slope. This suggests fitting the data with the Langmuir isotherm which is derived for adsorbents of limited capacity, unquestionably a property of ion exchange resins if the "adsorption" is confined to the basic groups of the resin. In his report on the reaction between acids and weak base anion exchangers, Bishop (2) has derived the Langmuir isotherm in a form applicable to both weak and strong acids.



Adsorption of Aliphatic Acids On A Weak Base Anion Exchanger

279



280

Adsorption of Aliphatic Acids On A Weak Base Anion Exchanger

The Langmuir isotherm can be reduced to the linear form

$$c/y = Ac + B \quad (1)$$

in which A is theoretically the reciprocal of the capacity of the resin and B is inversely proportional to the "affinity" of the resin for the acid. Fig. 3 shows a test of this equation for propionic acid and butyric acid. Formic, acetic and chloracetic fit equation (1) as well



281

as propionic, giving fair agreement with the data to about 0.7 M. Isobutyric, like butyric, does not fit very well, showing important deviations above 0.25 M.

A careful examination of Fig. 3 shows also deviations from the straight lines at low concentrations, possibly indicating a difference in the nature of the "adsorbed" state at low concentrations. No other interpretation has occurred to us which permits the calculation of numerical quantities giving a measure of the equilibrium.

Lacking a satisfactory analytical comparison betwen the acids, we have read from smooth curves values of y for round concentrations. These are given in Table I along with the ionization constants compiled by Dippy (8). It can be seen that the stronger acids are more strongly adsorbed from dilute solutions, while the longer-chain acids are more strongly adsorbed from more concentrated solutions. Crossing of the isotherms in Fig. 1 also illustrates this.

| Acid        | $K_a \ge 10^5$ | $c \equiv 0.1$ | c = 0.3 | $c \equiv 0.6$ | $c \equiv 1.0$ |
|-------------|----------------|----------------|---------|----------------|----------------|
| Chloracetic | 137.8          | 5.9            | 6.8     | 7.5            |                |
| Formic      | 17.12          | 6.0            | 7.0     | 7.3            | 8.4            |
| Acetic      | 1.754          | 4.3            | 5.2     | 5.6            | 6.3            |
| Propionic   | 1.34           | 4.2            | 5.1     | 6.0            | 7.3            |
| Butyric     | 1.50           | 4.6            | 6.5     | 9.3            |                |
| Isobutyric  | 1.38           | 4.1            | 5.9     | 8.2            |                |

Table I. Adsorption (millimoles/g.) at round equilibrium molarities.

The increased adsorption at high concentrations (shown by the continued rise in Fig. 1 and the decreasing slope in Fig. 3) can be explained in a number of ways. Studies of cation-exchange (9) and strong base anion-exchange (10) equilibria have found that in some cases water taken up by the resin cannot be neglected in calculating compositions. If appreciable water is absorbed by the resin in our experiments, it can be shown that the error in y is proportional to the equilibrium acid concentration. This, however, is in the wrong direction unless we make the rather implausible assumption that the

# Adsorption of Aliphatic Acids On A Weak Base Anion Exchanger

resin carboxylate has a smaller affinity for water than does the resin base. There is no reason to believe that the resin phase is an ideal solution. Since one component of this phase is ionic, the other not, the activity coefficients should differ significantly from unity. This has been found (9, 11) to be true even when both components of the resin are ionic.

The process studied here is called adsorption only because it is measured and described like adsorption; it is in truth an acid-base reaction, the resin being a high molecular weight polyamine which is converted by the acid to a polycation resin which somewhere in its structure contains anions in quantity sufficient to keep the phase electrically neutral. That adsorption at high concentration is far greater for butyric acid and isobutyric suggests, however, that true adsorption is taking place in addition to neutralization of the resin base, since (12) increasing chain length increases adsorption of fatty acids on charcoal from aqueous solution. Also, the total concentration in the resin phase in equilibrium with high concentrations in solution is in the case of butyric acid greater than that calculated from the reported (1) nitrogen content of the resin with the assumption that all the nitrogen is in active amino groups. True adsorption has for some time been considered (2, 13) a source of error in equilibrium studies of this type. Recently evidence for true adsorption has been presented in studies of carboxylic acids with a strong base anion exchanger (14) and of weak bases with cation exchangers (15). Carboxylic acids are also apparently adsorbed by *cation* exchange resins (15) and by salt forms of strong base anion exchangers (16), and adsorption even of salts has recently been found (9) an important factor in cation exchange equilibrium.

To determine the temperature dependence of the equilibrium, parallel series of equilibrium measurements were made with the series of six acids at 24.4° and 30.4°C. The resin was older at the time of these experiments, and apparently less stable, since the solutions showed a vellow color due to resin decomposition products.

Nevertheless the equilibria found at either temperature fit the  $30.3^{\circ}$  isotherms about as well as do the points upon which the isotherms are based. This is illustrated for two of the acids in Fig. 1. From this we can conclude that the equilibrium does not depend

greatly upon temperature or upon age of the resin. The latter is reassuring to us since it was impossible to determine all points on six isotherms simultaneously.

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# RESEARCH NOTES

#### AN ALBINO SNAKE (ELAPHE OBSOLETA)

Inasmuch as reported instances of albinism in snakes are somewhat uncommon, it seems desirable to record that an albino *Elaphe obsoleta* (Say) was taken in Oldham County, Kentucky about the 12th of September, 1951. The living specimen was presented to the writer by Perry Farmer, a teacher at Anchorage, Kentucky, who in turn had received it from one of his students.

Description of specimen: This snake, a female 656 mm. in length, is essentially a "pure" albino in appearance. The general color is a light cream. The iris is of this same color, while the pupil is dark red and the tongue pink.

The skin is not entirely without pigment, however, and the blotched pattern characteristic of *Elaphe obsoleta confinis* (Cope) and of immature *E. o. obsoleta* (Say) is faintly discernible. Examination under a lens reveals the presence of small amounts of red and yellow pigments in most of the body scales. The unequal distribution of these pigments, particularly the erythrin, is responsible for the appearance, faint though it be, of the coloration pattern. A third pigment, a melanin, is present as small punctations on most of the head shields and on a few of the body scales. There is one obvious difference between the coloration of this snake and that of newly-born watersnakes (*Natrix sipedon sipedon* L.) described some years ago<sup>1</sup>. In the latter the areas corresponding to the dark blotches of normal individuals were of a deep flesh or pink color, a condition which resulted from the visibility of cutaneous blood. In the *Elaphe*, however, these areas as well as the spaces between are pervaded by the opaque cream which seemingly is due to structure rather than pigment.

The scutellation and size appear to be not unusual for this species: dorsal scale rows 25-24-26-19; ventrals 236 plus divided anal; caudals 74; supralabials 11; oculars 1, 2; temporals (left) 2 + 3 and (right) 2(+1)+3; total length 656 mm; tail length 102 mm; ratio of tail to total length 0.155.

*Remarks*: The present specimen provides further evidence (see *loc. cit.*) that albinism in snakes frequently or even generally is not complete but consists rather of the absence of a melanin which is abundant in normal individuals, while pigments normally present in small quantities are still present in albinos. It is logical to assume, therefore, that the different pigments are under the control of different genes. Albinism in its usual form (near or complete absence of melanin) appears to be inherited as a single factor Mendelian recessive, but little or nothing seems to have been published about the inheritance of the minor pigments.

A problem in the application of common names arises in connection with the albino discussed in this paper, since one cannot determine whether it is referable to *E. o. obsolcta* (the Pilot Black Snake) or *E. o. confinis* (sometimes called the Gray Rat Snake). These two forms are generally distinguished, of course, by the amount of pigmentation (particularly melanin) present in

l Clay, Copeia, 1935; 115-118

#### Research Notes

normally-colored individuals. Geography does not provide the answer, for *obsoleta* and *confinis* intergrade in this region.

Since individuals frequently cannot be determined reliably to subspecies, particularly among highly polymorphic species or in areas of intergradation, it is desirable to extend the practice of applying one common name to the entire population of such species with the addition of adjectives for the respective subspecies.

In this particular case, since the name "rat snake" is more firmly established for certain other species of *Elaphe*, and the term "black" is not descriptive of *E. o. confinis*, it would be appropriate to apply to the species *E. obsoleta* the common name of "Pilot Snake". The two forms under discussion may then be known as the Black Pilot (*E. o. obsoleta*) and the Gray Pilot Snake (*E. o. confinis*).

WILLIAM M. CLAY, DEPARTMENT OF BIOLOGY, UNIVERSITY OF LOUISVILLE, LOUISVILLE 8, KENTUCKY.

## ACADEMY AFFAIRS

#### THE 1952 SPRING MEETING

The 1952 spring meeting of the KENTUCKY ACADEMY OF SCIENCE was held at Mammoth Cave National Park, May 9 and 10, 1952. The committee on arrangements consisted of L. Y. Lancaster (Chairman), Ward Sumpter and Gordon Wilson. The program follows:

#### Friday afternoon, May 9

A symposium on Mammoth Cave and Mammoth Cave National Park.

"The history of Mammoth Cave and the Mammoth Cave Park." H. B. Lovell.

"The geology of Mammoth Cave and the Park." C. T. Reid, Park Naturalist. "The anatomy of the eyes of some cave animals." W. B. Owsley.

"The birds of Mammoth Cave National Park." Gordon Wilson.

"The flora of Mammoth Cave National Park." P. A. Davies,

#### Friday evening, May 9

"The National Parks." (illustrated) T. C. Miller, Superintendent of Mammoth Cave National Park.

Saturday morning, May 10

#### Field Trips:

- 1. Plants. Mary Wharton and P. A. Davies, leaders.
- 2. Birds. Gordon Wilson and Harvey Lovell, leaders.
- 3. Amphibians and reptiles. Roger Barbour, leader.
- 4. Geology. C. T. Reid, leader.

### Academy Affairs

Due to rain, only a few members attended the field trips. Many members, however, enjoyed going through the caves and noting the beautiful formations. In spite of the weather, a successful meeting was held.

#### 1952 CONFERENCE OF ACADEMIES OF SCIENCE

The next Conference of Academies of Science will be held on December 28, 1952, in St. Louis, Mo., as a part of the program of the A.A.A.S. The morning session will be a business meeting devoted to a number of vitally important questions concerning academy functions. Committees will report on "Cooperation among Academies of Science," "Cooperation of the Academies with the Academy Conference," and "The Committee to Sponsor the Junior Scientists' Assembly." Dr. C. L. Baker will give a brief history of the Academy Conference. The Resolutions Committee will make recommendations as to what action the Conference should take in reference to the above reports. The morning session will conclude with a roundtable discussion on "The Responsibilities of Academies of Science in Promoting Improvement of Science Teaching in the Public Schools."

The afternoon will be devoted to a second roundtable discussion of academy opportunities and should be of primary interest to all academy members. There topics will be discussed: "Relations of Academies to College Students," "Relations of Academies to the Public," and "Relations of Academies to the Press." The evening meeting will be a dinner for members of the Conference and their guests. At this time Dr. Paul Klopsteg will speak on "What, from the Standpoint of Geographic Distribution, the National Science Foundation is Doing in the Allocation of Awards."

> Conference of State Academies of Science. -Austin Ralph Middleton, President

It is with regret that we report the resignation of two associate editors, both of whom have accepted positions outside the state of Kentucky. Dr. Sigfred Peterson has joined the staff of the Atomic Energy Commission at Oak Ridge, Tennessee, and Mr. William R. Savage now is with an engineering firm in Cincinnati. Each assisted materially in the preparation of this issue. The Academy is grateful for their services.

Manuscripts for the next issue are now being processed. Additional papers received in the near future should obtain prompt publication. Short papers, of generally not more than two pages, will appear under "Research Notes."

Distribution of the TRANSACTIONS to other libraries and societies is now being handled by the University of Louisville General Library. Under an agreement with the Academy, materials received in exchange become the property of the University, but will be available to KAS members upon request. A list of these publications will be printed in a future issue of the TRANSACTIONS. For this exchange privilege, the University of Louisville contributes \$300 annually to the Academy.

# INDEX

Academy affairs, 68, 116, 208, 286 Acetone, conductance of ferric chloride solutions in, 129 Acylaminoacid esters, preparation of, 213 Air conditioners, heat pumps for, 1, 156 Albinism in snakes, 285 Aliphatic acids, adsorption on a weak base anion exchanger, 277 Alkali iodides: distribution between ethylene glycol and ethyl acetate, 137 Alloy, copper-beryllium, electron and optical photomicrographs of, 248 Aloe, 111 Andrews, B. S., 48 Archdeacon, J. W., 100 Barbour, Roger, 215 Barnes, W. R., 149 Belcher, Ralph L., 129 Borum, Olin H., 213 Bowman, M. I., 78 Carreiro, A. B., 100 Cartin, Rafael A., 38 Chapman Plate, comparison with Sherman Test for streptococci, 45 Chromosome behaviour in a Gasteria-Aloe hybrid, 111 Cicadellidae of Kentucky, 54 Clay, William M., 285 Concetta, Sister M., 104 Conductance, electrical ferric chloride solutions in acetone, 129 salts in dimethylformamide, 221 Copper, Orland W., 146 Copper-beryllium alloy, photomicrographs of, 248 Copper chromate, free energy of, 146 Cypert, Eugene, Jr., 270 Davies, P. A., 228 Dawson, L. R., 129, 137, 221 Deer, White-tailed, 272 Diketene: use in preparation of 1-xylyl-1, 3-butanediones, 265 Dimethylformamide, electrical conductances of solutions of salts in, 221 Distribution ratios of alkali iodides between ethylene glycol and ethyl acetate, 137 Dunning, E. L., 82 Edwards, O. F., 248 Electron photomicrographs, comparison with optical, 248 Emissivites of paints, 149

Esters, acylaminoacid, preparation of, 213

#### Index

Estes, Reedus Ray, 265 Ethyl acetate, 137 Ethyl glycine: effects on food ingestion, 100 Ethylene glycol, 137 Ferric chloride, conductance in acetone, 129 Formol titration, 48 Frasera carolinensis, structure and function of glands on the petals of, 228 Free energy, of copper chromate, 146 Gasteria, 111 Glands, of Frasera carolinensis, 228 Glycine: effects on food ingestion, 100 Golben, M., 221 Greenwell, Sister Rose Agnes, 173, 178 Griffith, Edward J., 137 Gruchalla, Frank I., 45 Habitats, animal, on Big Black Mountain in Kentucky, 215 Hamann, C. B., 45 Heat pump absorption type, 15 compression type, 16 earth: performance on cooling cycle, 156 earth: performance on heating cycle, 82 for air conditioning, 1 Peltier, 5 water heater, 235 Heat transfer: paints, 149 Heat transmission, radiant, 149 Heer, John E., Jr., 258 Heines, Sister Virginia, 173, 178 Homoptera: Cicadellidae of Kentucky, 54 Ingestion, food, 100 Jackson Purchase, geological sketch of, 275 Jeffers, Robert W., 277 Joffe, Irving B., 78 Juhasz, Sister Roderick, 173, 178 Kentucky Woodlands National Wildlife Refuge, 270 Ketones: preparation by the Sommelet reaction, 78 Koch, John R., 104 Kreke, Corenilus W., 173, 178

Leader, G. R., 221 Leaf hoppers, 54 Lespedeza seed oil, economic status of, 80 Lovell, Harvey B., 121

Mailing list, 201 Malt sprouts: effect on anaerobic growth of distillers' yeast, 69 Maynor, H. W., Jr., 248 McHargue, C. J., 248 Meter sticks, precision and accuracy of, 102 Middleton, A. R., 287

O'Leary, Sister Mary Adeline, 173, 178

Pendley, L. C., 189 Penrod, E. B., 1, 82, 156, 235 Peterson, Sigfred, 102, 146, 377 Photomicrographs, comparison of electron and optical, 248 Price, Sarah F., bibliography of, 121

Resistivity, electrical, in subsurface earth exploration, 189 Riley, Herbert Parkes, 111 Rinne, W. W., 78 Rosen, A. A., 48

Scalf, R. E., 69
Shah, N. P., 149
Sherman Test, comparison with Chapman Plate, 45
Snake, Albino, 285
Snakes (see "Habitats, animal")
Sommelet reaction in preparation of ketones, 78
Specific gravity of binary wax mixtures, 104
Staphylococcus aureus, effects on blood and liver catalase in mice, 173, 178
Stier, T. J. B., 69
Streptococci from teeth, comparison of Sherman tests with Chapman plate for identification, 45
Structural settlement computations, 258
Subsurface earth exploration, 189

Thompson, H. H., 82 Thornton, R. C., 156 Tockman, Albert, 265

Waterfowl: in Kentucky Woodlands National Wildlife Refuge, 271 Water heater, performance of a domestic heat pump, 235 Waters, bacteriological survey of well, 38

# Index

Waxes, binary: effects of composition on density, 104 Weaver, R. H., 38 Wiley, Richard H., 80, 213 Wild turkey in Kentucky Woodlands National Wildlife Refuge, 273 Wilkes, James C., 78 Wood, E. B., 275

Yeast, distillers, effect of malt sprouts on anaerobic growth of, 69 Young, D. A., Jr., 54

Zimmerman, H. K., Jr., 221

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Manuscripts may be submitted at any time to the editor:

WILLIAM M. CLAY, Department of Biology, University of Louisville, Louisville, Kentucky

Papers should be submitted typewritten, double-spaced, with wide margins, in an original and 1 carbon copy, on substantial quality paper. Articles are accepted for publication with the understanding that they are to be published exclusively in the TRANSACTIONS. Each paper will be reviewed by one or more persons qualified in the field covered by article in addition to the editors before a contribution is accepted for publication.

Bibliographic citations should be in one of the styles used in this issue. Abbreviations for the names of periodicals should follow the current system employed by either Chemical Abstracts or Biological Abstracts.

Footnotes should be avoided. Titles must be clear and concise, and provide for precise and accurate cataloging.

Tables and illustrations are expensive, and should be included in an article only to give effective presentation of the data. Articles with an excessive number of tables or illustrations, or with poorly arranged or executed tables or illustrations may be returned to the author for modification.

Textual material should be in clear, brief and condensed form in order for a maximum amount of material to be published.

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