House Design, Construction and Equipment

PLANNING, BUILDING
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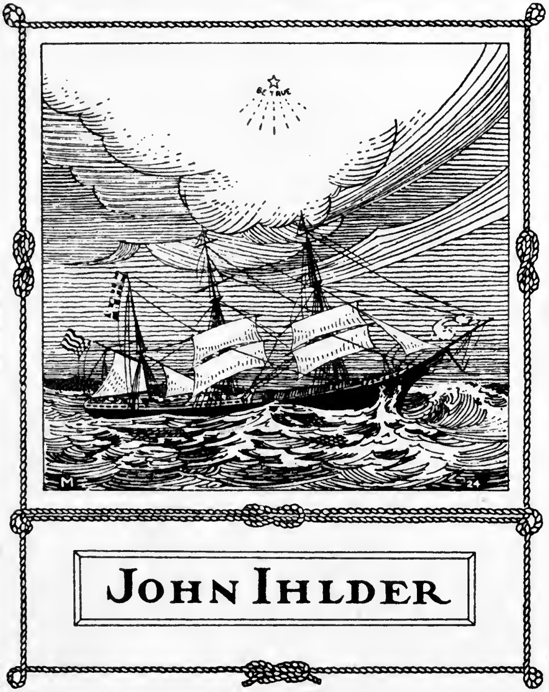
OF DWELLINGS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THE PRESIDENT'S CONFERENCE ON HOME BUILDING AND HOME OWNERSHIP

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FINAL REPORTS OF COMMITTEES

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Edited by
JOHN M. GRIES and JAMES FORD

THE PRESIDENT'S CONFERENCE ON HOME
BUILDING AND HOME OWNERSHIP
WASHINGTON, D. C.

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* The Committee on Construction was assisted in its research by F. K. Metzger, Research Engineer, and H. E. Foreman, Engineer, Associated General Contractors of America.

† Mr. McDonough dissents from the report of the Committee on Construction for reasons stated at the end of that report, page 97.

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* Mr. E. C. Commery represented Mr. Luckiesh at several meetings of the committee and assisted in the preparation of the committee's report.

FOREWORD

Faulty design, uneconomic planning, defective construction and imperfect equipment have characterized in greater or less degree the majority of dwellings constructed in the years of our greatest prosperity. They should not characterize the building of the future. For each new dwelling which must serve its occupants for perhaps two generations or even more should incorporate the best knowledge and skill, the best quality of design and construction, the most serviceable equipment that it is possible to provide at the price range which that house represents. No public servant, builder, producer or workman should be content with second-rate performance. No family, neighborhood or community should be required to put up with dwellings that are an economic or social liability or a detriment to neighboring property. Each dwelling should be the best that can be built for the price that can be paid.

Leadership in the building industry for the coming generation will fall to the persons who consider the errors in planning, organization and practice of the past and who devise a perfected policy for the future. The more deeply they can penetrate to the fundamental causes of past mistakes and the more effectively they can develop the fundamental principles of good housing, the greater will be the certainty of their active direction of their branch of the construction industry locally or nationally when the building revival begins.

The three committees which have contributed their reports and studies to this volume were composed of persons who have been recognized leaders in their respective fields. They have brought together much of the best thought and experience of recent years in a deliberate attempt to discover the insufficiencies of the past and the way out. Their reports represent the points upon which all committee members can agree. Individual thinkers may carry their conclusions further or may invent new devices for improving upon existing practices.

There is a wealth of valuable material in these pages which it will pay every architect, contractor or producer of building materials and equipment to study. In conjunction with the reports of other committees of the conference, contained in other volumes of this series, this book provides a large part of the ground work that is essential to the type of building enterprise which will best serve the future home buyer and his community.

In the past, houses have been built too largely with a quick turnover of builders' capital primarily in mind. Superficially the houses because new, appeared sound; but they have too often had a needlessly rapid rate of depreciation. The services of skilled architects have been employed ordinarily, only by the well-to-do. The economies of standardization of parts have been too largely neglected. Materials and equipment that are inferior or ill-adapted to their uses have been employed because of the ignorance of the buyer and often of the builder as well. The means of overcoming these and many other defects are outlined with much skill by the committees represented in this volume. Further research should develop ways of reducing costs of construction—not by the elimination of conveniences, such as cellars, backstairs and fireplaces but by the discovery and popularization of new and more efficient materials or processes. It remains for trade associations, scientists and professional men, economists, architects and engineers, builders and representatives of the building trades, to make it their prerogative to raise the minimum standards of future dwelling construction.

ROBERT P. LAMONT.

June 4, 1932.

INTRODUCTION

Dollars and cents reductions in building costs and better adaptation of design, construction and equipment to the needs and wishes of home owning families are necessary if we are to bring new houses of high standards within the reach of families of modest means, and particularly the wage-earning group of our population. Earlier volumes in this series have shown the contributions that improved city planning and zoning, subdivision layout, home financing and taxation, and large-scale operations can make. Nevertheless, the chief burden of effecting lower costs must be assumed by architects, builders and the manufacturers and distributors of building materials and equipment. Even in the absence of the measures described in other volumes, these groups can help, step by step, to bring better design and more efficient housing down to the families of low income.

Each hundred dollars taken off the cost of a good house enlarges the potential market. Outside of the rural districts and the South and some industrial villages, only occasional members of our wage-earning population have opportunity to live in new houses with modern equipment. Even where such opportunity exists the houses are seldom as well designed and well built as they should be in view of existing knowledge of small house architecture, and of the principles of construction and equipment.

The problems of the designer—to distinguish essentials from nonessentials, to plan efficiently for the most economical use of materials, to find means of rendering small homes attractive in their mass as well as in proportions and detail—can not be solved by the architects alone. They, as well as speculative or operative builders, contractors, and manufacturers of building materials and the equipment that is used in houses, need to join forces, not only with one another but with home economists and other groups, in finding out more about the ways in which families live and what features they require in their houses. Each of the groups must realize that it has much to learn and much to contribute, and recognize the tremendous advantage of working together to help educate the public in appreciating and demanding the features that make for usefulness, enduring beauty and sound value, and in not being misled by fashions that have only a passing utility.

Architects as individuals and as a profession can do much along these directions, one of their tasks being to bring competent architectural service within the reach of potential home builders and home buyers, irrespective of income, and to help develop on the part of the public and home building industry an understanding of what constitutes good taste in architecture and ability to distinguish competent from incompetent planning.

The Committee on Construction emphasized three general lines of thought in its report. First, a more widespread use of the best building practices known today; second, helps to protect the home buying public against "jerry" building; and third, intensified search and research for new and better materials and methods.

Within the first category the committee pointed out that designers and builders could reduce costs by eliminating nonessentials and by better use of existing materials and processes that are now available. More advanced fabrication of materials before they come to the site, more efficient storage of materials, better routing of labor, and improved handling of materials were listed as fields in which great advances have been made, but not as generally applied in practice as they should be. At the same time, they constitute promising fields for continued study and research.

Ignorance of materials that are now available on the market, the employment of traditional and outworn processes, carelessness and irresponsibility are all too common in the home building industry. Improved quality of construction and protection against substandard structure depend largely upon the general esteem in which high quality is held by builders and building trades workers and probably can be furthered by impartial organizations which would certify homes that meet certain standards.

At the same time, the adaptation of contemporary building codes to permit and encourage the use of new materials and methods as they come upon the market, promotes economies and helps to maintain certain minimum standards. More sound, qualified, professional judgment in the framing and revision of building codes, and improved inspection service are indicated as needs in hundreds of our cities and towns.

In the field of research, each year and each decade should see progress made through carefully planned studies of new materials, and methods of construction and equipment. Building material producers, trade associations, technical schools and others, may all contribute to the subject until mass-produced houses preserving individuality, in those details in which individuality deserves to be expressed, may be brought in a wide variety of designs, like the automobile, within the reach of virtually every family.

The best houses of the present day are distinguished from those of the past more by changes in fundamental equipment than by any other characteristic. Built-in devices for heating, lighting, plumbing, refrigeration and, more recently, air conditioning and ventilation have undergone a remarkable development within a comparatively few years. Although the United States leads the world in the number, quality and distribution of such devices, it still has a large portion of its population, in urban and suburban areas as well as in towns and villages, who are not provided with such equipment as should be within their means and appropriate to their needs.

The committee on this subject considered standards, location and installation of such equipment. It has brought together a summary of information of immediate use to every builder, owner or renter of a house, and its studies throw much light on relative values and on the best uses for equipment now on the market. Besides recommending technical research and invention in this field, it suggests study of means for organizing distribution along lines that will help to bring the right equipment to the family that needs it.

The reports of the three committees presented in this volume should be of great and direct value to everyone connected with designing, building, renting or owning a home, or in furnishing the materials that go into it.

JOHN M. GRIES,
JAMES FORD.

June 14, 1932.

CONTENTS

Courtesy Dwight James Baum, Architect *Photograph by Samuel H. Gottscho*

A well designed single-family house which received honorable mention in the Small House Architectural Competition conducted by Better Homes in America. Secretary Wilbur has stated that "Beauty is not a veneer to be applied at added cost, but lies rather in the lines of a house, its proportions, the relations of its parts one to another, and of the whole to its setting. It is demonstrable that quality pays, both by endearing the home to the family and by the enhancement of property and community values."

PART I

CHAPTER I

DESIGN OF THE DWELLING

Statement of Problem and General Conclusions

Is the design of the average American dwelling defective? If so, to what extent has any shortcoming in design been responsible for the failure of the building industry in recent years to produce good standard dwellings that sell or rent on a basis of $5,000 or less, which is all that approximately seventy families out of one hundred in cities can afford? These questions the Committee on Design has sought to answer in an exhaustive investigation.

In general, the committee believes that the design of the average small American dwelling is seriously defective. This refers to the dwelling of six rooms or less, with or without garage, whether of the single-family, two-family or multi-family types, produced for the lower-income groups of the population. In most cases these dwellings are produced by builders and retailed to the public.

As to the second question—to what extent defective design has contributed to the high cost of the average home—the answer is not clear since other factors than design, such as unit costs of construction and cost of land and finance, figure as principal elements in costs. However, the committee believes that a much higher standard of design is possible in the average residence; and that this higher standard need not increase costs and should tend to reduce them.

Design Includes Social and Economic Factors

At the outset, the committee wishes to make clear what is meant by design. Design includes or touches upon all the factors that create a dwelling—economic, social and financial, as well as physical. Design is not limited to the aesthetic factor, important as that is. The true basis of design is the plan and the three-dimensional form that develops from the plan. The artistic element, where it exists, is a natural growth out of the three-dimensional form; and is thus an effect, not the cause, of design.

Furthermore, design extends beyond the walls of the individual dwelling, into the lot, and it covers the relation of the house to the lot and to its planting and appurtenant structures; it deals with the relation of the house to adjacent houses, to the street, to the block and to the neighborhood and city. Therefore such dwellings should be treated primarily as related, instead of as *isolated* units. In fact the true unit of design is the group, not the dwelling, as will be pointed out specifically later.

In this report the committee points to the lack of group design, the chief cause of the failure in the design of the current product of small dwellings in the United States. Our observations leave no doubt as to this conclusion. Throughout the country houses are produced in stereotyped fashion, on uniform lots, using generally an identical dwelling plan for each of several houses located together. There is little organization of the group as a whole.

Unfortunately, the necessity of group design is not fully understood. By some it is looked upon as a mechanical conception, an attempt so to institutionalize a group of dwellings and families that the individual is in danger of being stifled and regimented. Others conceive of group design merely as an architect's desire to be picturesque.

On the contrary, group design is solidly based on the structure of human society in residence areas. A collection of families occupying houses in a given area, if unhindered, in course of time gradually becomes an entity. This process takes place in a multitude of ways that are familiar. The collection of families forms a neighborhood, a community, a village. Group design is simply the physical form of this design of human society. The physical design reacts upon the human pattern; each makes the other possible. Conversely, failure in one injures the other.

It may be objected that today the traditional organization of the neighborhood is weakening. Life is complex, heterogeneous, changing. It is said that the individual's ties to society are slighter, and that he and his family feel a lessened security in their position in the neighborhood. Thus their group loyalty wanes. The population tends to become nomad. And even if it were possible to restore the neighborhood, it is claimed that people would not want it, because the individual wishes to be free.

The answer to this objection is easily made. The most natural, the most stable and the strongest position for the individual in this complex world is to become a member of a strong, successful residence group—one which has become welded into a true neighborhood, and in which the human functions have adequate social and physical expression. This organization gives to the individual a sense of security that is a liberating influence. The organization can easily avoid institutional tendencies.

Home ownership—or anything akin to it—is possible only on such a basis. The very idea of home ownership means permanence, stability, security. The best security for home ownership is a high-standard dwelling, located in a desirable neighborhood, protected against deteriorating influences. It is futile to expect the individual to maintain a stable position in society in a home in one of a number of depreciated dwellings which have not been welded into a true neighborhood. This is true in direct proportion to the size of the community.

Practical examples of the right type of neighborhood are many. Group organization is found in well-developed form in finer residence districts. In what is called the "country club district" one sees more highly perfected neighborhoods, integrated in many ways both socially and physically. Great efforts are made to give the neighborhood every possible value, both material and intangible. Moreover, these finer neighborhoods are carefully *protected* from every form of encroachment or deteriorating influence. People desire them to be fit places for children to grow up in.

As one descends the economic scale, the neighborhood structure, both human and physical, has been weakened or disrupted by the speculative production of substandard homes that are poor social assets and bad financial risks.

The committee believes that low-priced dwellings can have the same advantage and supporting values of sound, permanent, highly developed neighborhood design as higher-priced ones. In fact, it is even more essential, since the smaller homes are grouped so closely together, with a much higher concentration of families to the acre. As a matter of economy, group design is necessary, since considerable waste results from its absence, beginning with the subdivision of the land and continuing through the design of the individual houses.

The almost universal defect of the speculative method is the mechanical repetition of a single "standard" dwelling type along a street or throughout a district. This standard plan is in itself too inflexible to meet the varying needs of families. There is almost no sound relationship of dwelling to adjacent dwellings or to the group. The interior arrangement of the individual unit may be fundamentally well devised but when built between two immediately adjacent houses it may be entirely unsatisfactory.

In proposing better standards for small dwelling design, including neighborhood amenities, we should no longer feel limited by the restriction of a low standard of living which was established during an earlier period when immigrant and other low-wage elements constituted a more predominant factor in the population. Now higher standards can and should be provided. The speculative builder attempts to supply this need in terms of what he can most readily understand or interpret as "what the public demands." Usually this means added mechanical conveniences rather than more fundamental improvements. We believe that failure to expand the market on low-priced dwellings, as well as some of the recent widespread mortgage foreclosures, have been the result of the builders' incapacity to follow a sound policy of good design and better neighborhood protection. It is hoped that as a result of this Conference the better methods here proposed may lead to action by responsible building agencies who will apply fundamental rather than surface improvements in the low-price field.

The committee has not gone extensively into ways and means of improving the details of the individual dwelling. Most of these are being studied by other committees of the Conference. But no matter how good the dwelling may be in itself, it is a defective house if it is not properly related to the group. The committee feels that with proper group design, the difficulties with individual house plans will be overcome.

As a general result of its investigation the committee finds that a serious situation confronts the nation in the need for rehabilitating the design of the small house which has gradually departed far from fundamental human requirements. The committee has not contented itself with indicating technical failure in design and suggesting remedies, but has gone further. It has endeavored to fix responsibility for the failure. It suggests ways and means by which all interests active in the production of homes may collaborate to establish the right standards and to maintain them. This is the only sure way to restore the falling social and financial value of the average small American home.

Conclusions

The committee's conclusions are as follows:

1. Fundamental Defects Are Widespread. The deficiencies in design of the average dwelling, noted above, are to be observed in the small single-family house, the two-family house and the multi-family house. These are the dwellings, generally containing 6 rooms or less, with or without garage, that are built for the lower-income groups. Comparatively few dwellings now being constructed, even above the range of the cheapest types, provide as fully as possible many of those fundamental amenities—privacy, quiet, repose, roominess, security, convenience, comfort, efficiency, light and air, permanent value, cheerfulness, beauty—that constitute the *home*. These attributes have been increasingly difficult to preserve in recent years. They are too often lost through carelessness and through lack of that integrity and organization which are expressed in design.

This defective design was found in most of the larger cities of the country and in a number of smaller ones that were investigated. Apparently this records a widespread condition, one that is the more sharply indicated by comparison with the occasional farsighted and competently designed development.

2. The Values Resulting from Higher Standards. A higher standard of design, consistent with economy, exerts a powerful influence for the better on family life. It opens up new vistas in domestic living, contributes towards increased pleasure and happiness, and furnishes a strong incentive towards home ownership. By providing a permanent, finer, and more convenient environment, better design helps to relieve the pressure of life in our towns and cities, rendered discordant as so many of them are by the complexities of industrial activity. In particular we must plan our districts of low-priced residences properly to take care of the automobile, with regard to both its storage and its movement, as is being done already in a few developments.

Improved design not only makes our neighborhoods less deadly monotonous and mechanical, but it makes them more convenient and more beautiful. In addition, they are better investments and superior mortgage risks.

3. Unvarying Repetition of Houses on Too Narrow Lots. An obvious major defect in the design of the average dwelling product offered to the public by builders, is the common practice, in our larger cities, of practically unvarying repetition of a single "standard" plan, on uniform lots that are too narrow. This produces a depressing appearance, a deadening environment; and it causes a cramped, monotonous arrangement of house plan, of lot, street and group. It impairs the character of our towns and cities and injures their appearance. Thus it contributes to rapid neighborhood obsolescence. Even in those cases where the builder provides a choice of several plans in his group development, as observed in one case in Cincinnati, the same cramped planning of the houses is apparent.

Nor does the repetition of a single plan meet the varying needs of the group of families to be housed in a given neighborhood—either the differences in size and in wants of the families in the group at any one time, or the variation of the individual family in its history. Undoubtedly this defect is a deterrent to home ownership. It may explain in some measure the popularity of the larger apartment house, which usually offers a wide choice of suites of varying character and sizes.

The practice of repeating the same plan on uniform narrow lots, regardless of exposure, fails to provide for the requirements of orientation of the dwelling and of the layout of the lot; or to take advantage of differences in topography or in other site conditions which are often a welcome asset to the skilled designer. It usually fails to create pleasing outlooks from the dwellings over open spaces, or efficient and beautiful relationships of the house to garden, to recreation and other open spaces, either private or public.

The committee noted the case of a builder in Buffalo, who, after taking over a group of lots that were too shallow to accommodate typical bungalows designed for narrow lots, found that he could use a superior plan for a broad-front type dwelling with appreciable economies. The same situation might obtain in the case of a small two-family house. Why not view such problems rationally by not fixing permanent lot lines until the building plans are

An example of a small home of simplicity and charm in which landscape planning plays an important part.

An example of the undesirable repetition of a single type of Buffalo house on a series of too narrow lots.

Photograph by Alexander E. Piaget

The house of simple design on the right was built in an effort to establish a standard of design for the development. The house on the left, of an over elaborated type of design, was built later by a speculative builder.

Courtesy of Shannon and Luchs, Realtors *Photograph by Leet Brothers*

A row house development of more than usual dignity and distinctiveness. Burleith, Washington, D. C.

known? We then would say: "Here is so much space in land and so much space in the homes that are to be placed on that land. The whole thing must be designed before it is put into production." A builder who expects to build up a certain piece of land with houses of a given size and general arrangement will naturally subdivide open land somewhat in advance of his immediate needs, but the presubdivision of land for open market sale lies at the bottom of extravagant costs of land for small houses.

The committee does not wish to be understood as condemning the "standard" or "stock" plan, or the sale of a ready-made house to the public. On the contrary, it is sure that there is a necessary and valuable field of usefulness for the stock plan. It is the unintelligent use of the stock plan that is to be condemned.

The mere fact that this stereotyped dwelling product sells, does not prove that it fully meets the popular need. People generally must accept the dwellings offered them by builders. The public evidently does not know that a finer product is possible, at no additional cost. Even if there are localities where people understand this fact, they may be obliged to reside in a district where no such product has been made available.

4. Defects of Exterior Architectural Treatment. The standard of decorative design is deplorably low. The committee observed many instances, amounting to a common tendency, of the use of decorative features that are unrelated to the underlying structures. An enumeration of the many technical errors of this kind is impossible in this report, and therefore certain illustrations must suffice. Motives such as faked gables that have no relation to the roof behind them are frequent, and even chimneys without fireplaces or fireplaces without chimneys have been observed. The lack of relation of the side and rear elevations of the house to the front is frequently seen. A common defect is the use of too many varieties of materials in a small home. This produces discordant effects of form, color and texture, as well as complicating the structure and weatherproofing.

Another specific defect is the type of roof line by which the gable end of a two-storied dwelling is given a false and clumsy effect of dormers, so as to make the building appear as a story and a half structure. The unintelligent use of the "Dutch Colonial" type for single-family detached dwellings is another case of the same sort. The house is framed as a two-story house, and is one in fact, with both floors of equal area. The gable rakes are falsely applied to this two-story structure in order to give it the appearance of a story-and-a-half house with dormers. The rake mouldings represent no roof slopes and are therefore a false motive. These exotic practices and styles have only a temporary aspect and they are apt to go out of fashion in a very few years, endangering the permanent value of a home.

Another fault is the misconception that a small dwelling should be a reduced copy of a large residence. The committee observed frequent instances where enough motives—gables, angles, dormers, colors—to decorate a millionaire's mansion were jammed onto a tiny cottage. Sometimes this was an unintelligent attempt to copy a well-designed expensive house in the locality. Cases were noted where a big front entrance proportionate to the large mass of the expensive house dwarfed a small house.

These common defects emphasize the desirability and the financial value of good design, its ornamental features determined by structural forms, its elements simple and appropriate to small structures, and in general avoiding unduly crude or exotic motives. Good design in small dwellings, as in any other houses, can be expected only when produced by skilled designers. This can be accomplished in the case of small operations by the use of stock plans prepared by skilled designers and professionally supervised; and in the cases of large group developments by the employment of complete professional services, the cost of which is spread over the whole operation at a comparatively low cost per unit.

5. New Accent on Block Interior. Another defect is the popular idea that a row of dwellings should provide a theatrical set for the street. This practice fails to recognize the evolution—or revolution—that has taken place in the typical street in residence neighborhoods. In older, more spacious days the streets had little traffic, and that slow-moving; land was inexpensive, and houses could be spaced well apart and set well back from the sidewalk, allowing room for planting. The result was that a residence street partook somewhat of the nature of a park or garden. Nor was it altogether a bad playground in many cases. Today the reverse is true. Homes are crowded shoulder to shoulder close to the sidewalk; trees and other planting and lawns are squeezed out;

and the street is now dangerous for both adults and children. The street thus tends to become a mere service alley.

The changed character of the street emphasizes the interior of the block as the logical center of social and landscape interest, the common meeting ground. The planning of fine residence neighborhoods, and of some garden apartment groups for low-income as well as high-income groups, recognizes this principle. There is no conclusive reason why it should not be carried out in residence districts of the lower-income groups, especially in congested centers where the area per family must be reduced to a minimum.

6. Necessity for Group Planning. Group planning, with adjustment of the relation of each house to its neighbors, at the sides, at the rear and across the street; the relation of the houses to street and to block, with recognition of the recent evolution of the street from a crude neighborhood, social and landscape center into a dangerous service alley; the development of the center of the block to replace the defunct social usefulness of the street, as is being done in expensive developments—this is the type of design that endows dwellings with the full attributes of homes. As to cost, the elimination of expensive spurious decorative effects, both exterior and interior, together with the important economy that should result in land utilization from intelligent group planning, would not only not increase the cost but would doubtless somewhat reduce it.

These principles relate chiefly to the physical side of home organization. But, as we pointed out at the beginning of this report, they are the expression of the fundamental organization of individual families into groups. The neighborhood is the true unit of design, from every point of view—architectual, financial, social, civic, city planning, slum prevention, layout of public utilities, etc. This is true whether dwellings are rented or owned. Also, under capable group management, it is possible to give much of the permanent value of home ownership to rental properties.

From a practical point of view, the Committee on Design believes that group design is logical, since it has observed (and has checked its observations with reports from many authorities) that today in the larger cities the large majority of houses are being produced in groups, by builders, for sale to the public. From 25 to 100 dwellings or even more are being built in a single group. In some cities the proportion of houses built in this way runs as high as 80 to 90 per cent. The production of dwellings in groups should make it easier to give them the benefit of group design.

It is true, however, that the possible extent of group design depends upon the local demand for housing. As we reach the small cities and towns and the outlying districts of larger cities, the density of population is reduced, and the new housing units are scattered over a wide area. Under such conditions they will continue to be built singly or in small groups, and they must look chiefly to the community for the protection of their environment. This should take the form of sound subdivision practice, zoning laws and other measures.

In the design of larger apartment houses there have been successful attempts at grouping units having a variety of suites of different size and capacity. This progressive design of the apartment house may be a factor both in its increasing popularity and in the reduction of home buying in the single-family types, which do not present these characteristics.

In order to provide the needed variety in dwelling designs for differing family needs, several standard dwelling types may be used in a single group together with several different stock plans of each type.

This variety should not be repeated mechanically, nor is an indiscriminate mingling of types and varieties of a single type desirable. The Seaside Village group of the Bridgeport Housing Company meets most of these requirements for good homes. In this group a one-and-a-half and two-story row single-family type and a two-family type, with variants, are logically combined. In "Sunnyside" single-family, two-family, and, in certain cases, three-family types are combined in groups, so distributed that each group and each type has the advantage of a particular exposure and location that is best suited to it and to the group plan and appearance. The two-family type has four and five rooms, and in the single-family house there are usually six or seven rooms. Apartments at "Sunnyside" have generally four rooms. In "Sunnyside" it is important to note that twenty families are housed to the acre instead of the usual fifteen. Further economies should be possible with the readjustment of block sizes and the elimination of superfluous street area in the conventional street system.

Such economy refutes the idea that in order to provide sufficient land around dwellings, it is necessary to expand the plot, thus increasing land cost.

Many of the war housing projects and such later community developments as Mariemont, Ohio, also provide excellent illustrations of group design in practice. They offer most of the requirements of a home to a remarkable degree. The committee calls attention to them as guide posts pointing towards even finer residence developments of the future for the mass of the population.

The necessity for group design is not affected by any change in the type or character of the dwellings. Particularly is this true of methods of construction. There is discussion of the "fabricated house"—a house built as far as practicable in the factory, by new and revolutionary processes. If the fabricated house proves commercially practical, it will not reach its full value if it is to be mechanically repeated on uniform lots, following the usual practice. The more permanent the new construction, the more need will there be to combine it intelligently into groupings of permanent character.

Nor should existing methods of financing be permitted to remain an obstacle to sound design. This aspect will be dealt with later, in pointing out the failure of real estate financing interests to recognize the value of sound design. Here, however, the committee takes the position that when the support of neighborhood value, as contributed by sound group design, is withheld from the American small house, it cannot be expected to prove a good financial investment.

7. Subdivision as an Obstacle to Efficient Planning. The convenient, harmonious and economical planning of dwellings is seriously handicapped by the practice of making the subdividing of land for closely related dwelling units a separate process from the construction of dwellings upon it. Small houses must be set close together and their "huddled" position makes group planning necessary. Usually the forms and dimensions of lots are fixed before the plans of the actual structures have been determined. The result is that the boundary lines of the lots cut arbitrarily and disastrously across any sound group plan of the dwellings, thus cramping and distorting the plan of the individual dwelling and emasculating the plan of the group.

Also, when group planning is attempted in an area that has been subdivided and in which the lots have been sold, it meets the obstacle of reassembling the plots by that time in different ownership, and of obliterating these lot lines, so as to form a large plottage. Also, the sewers and other public utilities may need to be rearranged, and in some cases the streets repaved. In other cases, regrading must be done. There is also duplication of sales expense when a plot is sold separately from the house. All this waste causes unnecessary expense. Residence land, therefore, should be handled in large plots, suitable for group planning, with the most efficient layout of streets and of public utilities.

8. Popular Types of Dwellings — Characteristics and Trends. The committee has investigated popular trends in the production of the various dwelling types, both through observations of committee members in their localities and through studies of reports of government and other research authorities. It is difficult to determine exactly what leads to the preference for particular dwelling types in a locality at any one time, on account of the many factors involved, some of which are intangible.

The cost of land is one of the determining factors in the choice of dwelling types. Generally, high-priced land calls for multifamily types. Nevertheless, the committee noticed a regrettable tendency among builders to reproduce intensive metropolitan multifamily types on extremely cheap land in outlying sections of cities and in small towns.

In single-family houses, the two-story six-room house has been the prevalent standard; although it is accompanied in varying degrees by one, one-and-a-half and two-story five-room houses, four- to six-room bungalows and an occasional three-room bungalow. In many western cities the bungalow has long been the popular type of dwelling. In other areas (particularly in the Mississippi Valley) where the two-story house was formerly characteristic, the use of the bungalow has increased markedly in recent years.

The bungalow, with its spread plan, is particularly unsuited to the typical long, narrow lot. When a garage is added, there is but little of the lot left uncovered by building or by concrete pavement. In a St. Louis bungalow, one of the two bedrooms was placed, as usual, in the center of the house facing on a narrow side yard, and was ventilated to the outside only by one casement window four feet above the floor. It would be almost impossible to sleep in such a room during the summer in the St. Louis climate.

The two-story single-family detached house, although more compact than the bungalow, is nevertheless emasculated by squeezing it to fit into a narrow lot. Its land requirement and its higher construction cost in many cases make it appreciably more expensive than the properly designed group row-house. This makes it less economical for the lower-income groups. Unfortunately builders adopt the two-family and multi-family types, without considering the possibility of producing the single-family group row-house which, in its more compact form, is economical in land use without undue sacrifice of openness and light and air.

The single-family house occurs either as individual detached buildings, or in row form, attached by party walls. The detached form prevails in the western part of the country, whereas the row house is limited chiefly to the Atlantic seaboard, where it has existed since colonial times. In Philadelphia and Baltimore small houses are almost universally of this type. The committee calls attention to the merits of the single-family row house planned in "groups," because of its economy and plan desirability; this applies to dwellings with a broad-front plan, two rooms deep. In respect to economy, the group row-house is definitely less expensive than is the free-standing house of equal size and similar good standard, due to certain economies in the party wall and the use of less land. We believe that a compact plan of the single-family group row-house can be produced just about as cheaply in most cases as similar accommodations in the two-family house.

The comparison of the cost of the single-family row type with the multi-family types is more complex. It is a matter largely to be decided on its merits in each particular case. The multi-family types are, of course, more efficient in the utilization of land, and this differential increases as land cost mounts. The subject is too technical for generalizing, but the committee points out that a careful analysis of the comparative costs of group and smaller types of multi-family dwellings of the same standard show that they are almost equal in cost. Both types will prove economical on land that is low in value but not too low to bear the cost of a full complement of streets and utilities.

The defects of the two-family house have been pointed out.

This type has been extensively built in Chicago, St. Louis, Buffalo and elsewhere. Sometimes it evolves out of the bungalow by expansion vertically. A case of this type was noted in Buffalo, where there is a modified form of bungalow, called "investment bungalow," on account of having a room above the ground floor, in the roof, for renting. The "investment bungalow" evolved into a two-family house, but without being planned anew for so radical a change. The design of the two-family house, even more than the single-family house, suffers from the custom of forcing such a dwelling into a deep, narrow lot.

The two-family house, however, may be a valuable type, if used as a variant type in a grouping with single-family row houses, as in the case of the Seaside Village of the Bridgeport Housing Company. In that development, the usual defects of the two-family house are eliminated by good design.

The committee calls attention to the "shoebox" houses of New Orleans as one of the most undesirable dwelling types that is now being produced. This type consists of two single-family dwellings, divided by a party wall, the houses built closely together on unusually deep narrow lots. Each dwelling consists of four to six rooms, placed in a line one directly behind the other, usually without communicating halls, so that access to front and rear rooms is had only by passing through the interior rooms, which are usually bedrooms. Each room has a single window about six feet distant from the neighboring house, and overhanging eaves leave only the narrowest strip open to the sky. Often a high board fence restricts still further the circulation of air, if any. In many cases, this double bungalow type has been elevated into a two-storied dwelling with still greater restriction of light and air. The injurious effect of the New Orleans "shoebox" dwelling upon the working population of that city must be appreciable. The future production of this form should be forbidden by legislation, as was done with the "railroad" and "dumb-bell" tenements of New York City and the New England "three-decker" of Boston.

The committee points out that there is a large difference in the character and standard of design of the multi-family types. These are the flat, the large high-coverage apartment house and the large "garden" apartment. They constitute a very large part of new low-cost housing in our larger cities.

The flat, so-called, is likely to be built on a narrow frontage, with the result that each suite runs deep back into the lot. Whatever be the combinations of this narrow-front type—detached, or a dwelling for four or six families with party wall division in the center—it is usually seriously defective in light, air and privacy at the sides, in the plan of the suites, and in respect to fire risks, if it is of wood construction.

The large apartment house of high land coverage—that is 60 to 70 per cent or more—is in most cases no improvement on the old flat, except that, as noted, it may offer a wider choice of suites. However, in recent years, the large apartment has undergone a revolution at the hands of architects, who have greatly improved its plan, introducing the principle of low coverage, with consequent beneficial effect on light, air, and openness. This improved type is known as the "garden apartment." Unfortunately, comparatively few large apartments are designed on the garden principle.

The committee noted a marked similarity in the building product of each type in many cities, extending often to details. This uniformity indicates that local variation in design often is not great, except in certain instances like the New Orleans "shoebox" mentioned. In these cases there is blind adherence to obsolete design. There is thus a certain standardization followed by builders all over the country, indicating that it is practicable to establsh standards. Every effort should be made to raise this standard.

In some cities a given type is popularized for a few years, and then a change made to another type. The choice of dwelling type should be based on fundamental analysis of the needs of design as indicated, and not on the vogue of a few years.

The committee believes that statistics on dwelling production would be more valuable if more emphasis could be placed on the type of design. The lack of distinction between the various multi-family types, as noted previously, is serious. Also there is a tendency to underestimate the influence of the two-family and multi-family types, on the ground that the single-family house is the predominant type, taking the country as a whole. The fact is overlooked that the two-family and multi-family types together form the majority, or are close to being a majority, of the dwellings in the cities. There they have produced huge areas of defectively designed homes. The rapid growth of the great cities and the influence of their standards on the country, together make these intensive dwelling types more important than the figures indicate.

9. Observations from Research and Cost Data. Accurate itemized costs of dwellings were furnished to the committee by responsible builders in ten larger and a number of smaller cities. The most valuable of these were for typical two-story six-room houses of closely corresponding size and construction in three widely separated cities, and for other houses and five-room bungalows in some of the same cities and elsewhere. These offered an opportunity for comparative study, leading to certain approximate deductions in regard to costs and other matters.

1. The most typical moderate priced houses in the suburbs of northern and eastern cities are detached two-story frame dwellings about 24 x 26 feet, with the broader dimension to the street, the living-room across the front, and three bedrooms and bath on the second story. Breakfast-nooks are often included. Good hot-air or steam heaters are used. Present sales prices range generally from $6,000 to $8,000.

2. In the central west and upper Mississippi Valley the trend is strongly toward the bungalow of five-room plan (two bedrooms), frequently with extra rooms or sleeping porches in the roof. Ground floor plans of bungalows more or less universally typical in each of three cities studied also corresponded closely in all three cities. The plan presented the uniform defect of having one of the two bedrooms "pocketed" in the middle of the house, with exposure only on the narrow side yard. Elaboration of kitchen details and gaudy interior finish was generally more marked in bungalows than in the two-story types.

In Appendix III to this report, material from the periodical *The Small Home* shows that a house built from the same plan may increase in cost from a base of 100 to 143 per cent by reason of changes in specifications involving differences in finish, equipment, etc., as well as in qualities of basic construction materials and workmanship. These differences should be taken into account in any study of costs. They are further discussed in the appendix mentioned, i.e., Appendix III, "Quality of Small Houses in Relation to Their Cost, with Classification Tables," found on page 37.

However, the more typical builders' houses, in which there is strong competition to furnish a maximum of mechanical comforts, tend to correspond rather closely in construction methods, and do not vary greatly in quality among more responsible builders in different cities. While not entirely of the standard which might be desired, they are sufficiently satisfactory and typical to permit a few general statements of comparison. (*Note:* All of these statements refer to five- or six-room detached frame dwellings of one, one-and-one-half, or two stories.)

(1) The structure and interior finish comprise from about 65 to 75 per cent of the construction cost. Plumbing, heating, electric wiring, etc., range from 20 to 30 per cent; fixtures, kitchen equipment and decoration from 7 to 12 per cent.

(2) The major structural costs—stone work, lumber and framing, brickwork and roofing—tend toward uniformity in different cities over reasonable periods of time. Mechanical equipment costs (for plumbing, etc.) vary from place to place, particularly in the pipe trades. This is due both to a wider variation in the quality of the installation and to differing requirements of building codes or of union regulations.

(3) The tendency is definitely toward an increase in the relative costs of mechanical and other equipment in proportion to the structural costs. This is due to greater completeness, added complexity of the equipment, and overemphasis on nonessential equipment. Good equipment deserves a sound structural envelope, and expensive equipment cannot be wisely introduced to the detriment of structural quality and permanence.

(4) In smaller cities the cost of labor in relation to that of materials is measurably less than in larger cities. This seems to be due to greater freedom in adjusting the small units of work in different trades, as well as to lower wage scales.

(5) The bungalow is distinctly more costly for the amount of space enclosed than the compact two-story house. In the case of dwellings produced by a certain quantity builder in South Bend, Indiana, a bungalow with 65 per cent of the floor area of a two-story house cost 80 per cent as much as the latter for construction. These dwellings were of corresponding construction, finish, and equipment, and were built at the same time. (Space occupied by stairs is omitted in stating proportionate areas.)

As previously suggested, these findings are subject to some inexactitude, and perhaps involve some arbitrary interpretation. It should be noted, however, that these figures, while representing a limited number of samples, also indicate conditions of quality and cost which were selected in each case by local builders, architects, or building officials as being typical of the current local situation. In addition, most of the dwellings considered were actually inspected by the secretary of this committee in an extended tour of investigation. For this reason it is believed that the factor of judgment supplies validity to the conclusions reached.

However, much more accurate and reliable cost information was available in regard to group row-dwellings, both single-family, two-family, and smaller multi-family, as constructed by large-scale building organizations. These data represent experience extending over a period of seven years, with almost identical plan types and construction methods and in three different communities, two in the New York City region and one in Pittsburgh. The conclusions drawn from this material are particularly valuable as demonstrating the advantages of the well-designed row house. Also the opportunity, offered by continuous large-scale operation, to obtain and analyze accurate cost records, indicates that adequate cost-accounting can be of cardinal importance in reducing the costs of small dwellings, since a real knowledge of the costs of every element of construction and equipment will assist in determining standards and in directing design practices within the economic limitations necessary to reach the lower-income groups.

Some of the most valuable data show very accurately the relation of cost between equivalent free-standing, semi-detached, and row houses, all of brick construction. A six-room house, well planned with broad front and desirable in any of the three forms, which costs approximately $7,500 in a free-standing position (including land at about $40 per front foot), will cost in semi-detached form or at the end of a row only 89 per cent of that amount, and in the interior of a row only about 76 per cent. In other words, there is a saving of $1,780 merely by efficient planning, with the cheaper house preserving a satisfactory standard of openness, light, and good planning which are frequently absent from the typical builders' free-standing house on the usually inadequate city lot.

These matters are more fully presented in Appendix IV to this report, page 41. A principle there set forth as to the segregation of the elements in cost accounting is offered as one of the more significant contributions of the research work of the committee.

On the costs of the usual commercial type of two-family houses the data available are not specific enough for useful analysis, on account of the wide variety in these types, as noted. There is great need for exhaustive research in this field.

The committee has studied the costs of apartments of the specialized garden apartment type, as developed in New York and Chicago, but the data are limited in quantity. The annual reports of the New York State Board of Housing are valuable as an indication of the determining factors in large apartment-house costs, as well as of the cost levels which can be obtained under large-scale operation.

The committee cautions against taking dwelling construction costs of $2,000 to $3,000 as typical. Sometimes these figures reported represent dwellings of a few rooms. For example, the lowest price encountered was in Denver and stood at $3,400, for a four-room bungalow. Also, similar low costs may represent a summer cottage type, of impermanent construction and lacking complete mechanical equipment. In certain cities building permits may not include costs attributable to the mechanical trades.

An important part of the committee's survey of costs is the outlining of improved methods of compiling and of appraising costs. These include the classification of factors of cost of construction and equipment details as—(1) essentials, (2) conveniences, (3) luxuries. If a standard of this kind prevailed in the building industry, it would aid in regulating the tendency towards over-elaboration of details.

Regardless of the fluctuations of material and labor costs there has been a tendency in the last few years for builders to elaborate features, finish, details, mechanical equipment, and decorative effects. Some of this, where it is intelligently handled, is laudable, as representing increase in the standard of living, but it has its unfortunate side. This complexity is added often at the expense of sound structure and adequate space. Moreover, the sound, standard, $5,000 house (land, building and other costs) is being built less and less, so that most houses produced now are too expensive for all but 30 families out of every 100. Only the small apartment suite of 3 or 4 rooms and small bungalows in rural or semi-rural districts, particularly in the southern states, can be produced under this figure. No account has been taken of the recent fluctuations in prices, since it is not yet clear that stabilized levels of costs and of incomes have been reached.

The committee desires to point out that firm control of design, based on accurate knowledge of costs, is essential to the industry of dwelling production. The lack of a uniform system of cost-accounting among builders and of complete statistics—both in regard to national and local phases—relating to figures of production, family incomes, and other necessary data—is a serious obstacle to the restoration of prosperity in the industry. It is difficult, if not impossible, for the designer to develop the most efficient design without accurate and detailed knowledge of costs and economic conditions. In designing, he must figure closely on total cost, and he must also keep track of the proportionate cost of site, of construction, of finance and overhead. In respect to construction costs, he must strike a balance between the expense of the various trades and various other factors that are carefully considered by experienced architects in the design of other classes of structures.

10. Need for Cooperation of All Producing Elements. There should be organized, effective action among all interests engaged in the production of homes, to secure the full benefit of efficient design. In the main, this means taking full advantage of the highest architectural skill, at the same time securing the cooperation of engineers and other design experts in producing the highest possible standard of home consonant with economy. If impetus is given to the principle of large-scale operations, the interest of competent architects will everywhere be enlisted. The combined efforts of architect, contractor, manufacturer and financial agencies should result in vast improvement in residence building, making it better and cheaper.

In making this recommendation, the committee recognizes the merits of the builders and their important contributions to the business of producing and marketing homes, particularly their efforts to understand the public's need. Nevertheless, the serious defects in design of the small home and the alarming decline in home ownership should stimulate the builders to improve their product—

to make it more efficient, more attractive, and, if possible, lower in price. Builders should make fullest use of competent design in all departments of the home, ranging from the layout of subdivisions and group design to the special details of kitchen and bathroom equipment. In order to make effective use of the designer's skill, the builders must themselves appreciate the value of design, and they must learn to cooperate with the designer not as a minor employee but as a principal. They must also be prepared to furnish the designer with accurate cost and statistical data in order to give him the needed economic foundation. The fact that design has wrought a revolution in practically all classes of American buildings—except the small dwelling—in the past three generations makes it certain that the low-priced home could benefit from the services of the skilled designer.

The architect should interest himself more actively in the design of the small dwelling as he has in that of larger buildings. Unfortunately, architects have not paid enough attention to this important field. If builders are to secure competent design and advice on the preparation of designs for individual homes and for grouping them effectively, certainly architects should organize their services so as to provide standardized units of service to be economically available to large and small operators. The architect should master the intricacies of costs and the statistical knowledge necessary to an understanding of the economic foundation of this work. Good stock plans are an essential, and architects might well give their attention to developing stock designs suitable for the local market. They should then be ready to give competent advice on a reasonable economic basis in the selection of plans, particularly with regard to site conditions, orientation, etc.; in grouping the houses; in subdivision; and in altering defective subdivisions.

The professional schools of architecture should actively support the technical improvement in design of the small dwelling. The architects' societies should also take leadership in developing this field.

Cooperation to secure good design should go further in the building industry. Realtors should insist on sound design in the full sense of the term. As salesmen of homes to the public, they should see that the public gets full value. Through their powerful organization of real estate boards, they should be able to exercise a decisive influence against low standards and in favor of high standards. Through insistence on intelligent subdivision, on efficient street layout, and on neighborhood and town and city planning, they can do much to secure to the individual home or group plan the needed protection against rapid depreciation from substandard surroundings. They should cooperate with the local architects' organizations to this end.

A decisive step toward improvement in design would be taken if the mortgage and building loan companies would finance only sound designs. Indeed, some authorities hold that this is the key to the situation.

Generally, the policy of most lending institutions with regard to design is extremely crude. They take slight interest in the quality of the design of the product on which they loan; they approve a type which is supposed to meet with local popular favor and which sells at a price that is supposed to create a strong demand. The country-wide overproduction of dwellings of all types, with consequent endangering of mortgage values, and resulting frozen loans, indicates that this policy has not been profitable. Staggering losses have resulted. A more thorough and more comprehensive concern with design, on the lines advocated in this report, and extending particularly to group design, is therefore suggested.

Such control of design is sound economics and sound finance. It recognizes the fundamental economic principle that homes are capital goods, articles of individual and personal service, whose value must endure for many years. The existing rather perfunctory policy is based to some extent on the economic fallacy that the dwellings are consumption goods, rather rigidly standardized, and of momentary, speculative value. It is obvious that real improvement in design, which assumes that the dwelling has enduring personal value, is impossible if it is financed on the contrary hypothesis.

We believe that there is growing among lending interests recognition of this unfortunate condition. There should be no difficulty in developing an efficient organization in each locality, composed of building and real estate interests, architects and representatives of mortgage companies and building loan associations, to set standards of design and to maintain them. The operation of such an organization should cost extremely little per family housed, if spread over many hundreds of houses, and would be repaid many times. As a guide in the evaluation of residence properties, the committee has formulated a score card, in which the attributes to be sought are outlined, with weighted values. This score card will be found in Appendix V, page 49.

Building material producers and distributors should interest themselves actively in design. The material manufacturer has a vital interest in seeing that the house has added value and that it costs less. His is almost the only interest in the building industry that operates on a large-scale, national basis. The material interests, therefore, can do immensely valuable work in improving the design of the average dwelling by (1) supporting research in design and publicity, (2) more intelligent advertising, emphasizing the dwelling as an entity, not as a collection of unrelated parts, and (3) active leadership in the building industry, cooperating with architects, builders, realtors and lending interests in the maintenance of high standards.

Outside the building industry there should be effective aid in the work of teaching the public the essentials of high standard homes, in which sound design is basic. Educational agencies, including press, magazines and radio, are necessary to this end.

Civic authorities and social workers should promote recognition of the neighborhood as the true unit of design.

The United States Government should by all means continue to expand its useful support of higher standards of design. The Division of Building and Housing in the Department of Commerce has already laid an excellent foundation in educational work relating to the small home. The Division of Building and Housing, in cooperation with this committee, is publishing a manual on home planning for the guidance of the home builder or purchaser. The Department of Commerce should promote in the building industry higher standards of design somewhat on the precedent of its useful work in the standardization of building materials. Also, the United States Government should compile more thorough statistics covering the production and marketing of homes.

The final recommendation of this committee is that some powerful and effective permanent agency be organized to carry on the work of this Conference after its adjournment. As far as possible, this agency should be supported by the cooperative effort of all interests in the building industry, and by educational and governmental authorities.

Committee Program in General

In deciding its program of work this committee has tried to develop carefully that portion of the problem of design which lies between the more detailed considerations covered by the Committees on Kitchens and Household Management on the one hand, and, on the other hand, the field of complete community organization and regulation which falls under the work of the Committee on City Planning and Zoning. The province of land subdivision is so directly related to the actual plan of the dwelling, that the Committee on Design has called attention to the serious damage that is caused by the more common existing subdivision methods, in many cases making good design impossible.

Thus the committee's work covered, not only the improvement of the design and plan arrangement of the individual dwelling, but extended to group planning, i. e., the relationship of dwellings, whether single-family houses, two-family houses, or multi-family houses, one to another; to the group, to the street, and with regard to the efficient use of land.

The personnel of the committee has been distributed throughout the various regional centers of the United States. Each member of the committee has contributed to the study of conditions typical of his center and of the region which it serves. The limitations of this report have made it necessary to generalize the results of these individual studies in order to reveal the more significant factors in the problem and to suggest solutions.

Finally, the committee suggests that a lack of appreciation of the economic value of good design is the chief obstacle to raising the standard of design of the average American small home of six rooms or less. The fact is that design is the one great asset for better quality and better value that has not yet been drawn upon to the full.

The following cities and towns have furnished information from the sources indicated:

LEGEND: (1) Member's report. (2) Visit of secretary on tour of research investigation. (3) Detailed information by city building department or other official source. (4) Detailed information by local architects or builders.

Chicago, Ill. (1) (2) (3) (4)
New York City (1) (2) (3)
Kansas City, Mo. (1) (2) (3) (4)
Denver, Colo. (1) (3) (4)
Philadelphia, Pa. (1) (4)
Cincinnati, O. (1) (2) (3) (4)
San Antonio, Texas (1) (2)
Seattle, Wash. (1) (4)
Buffalo, N. Y. (1) (2) (4)
Washington, D. C. (1) (4)
Pittsburgh, Pa. (1) (2) (3) (4)
Minneapolis } Minn. (1) (2) (3) (4)
St. Paul }
Fort Myers, Fla. (1)
Los Angeles, Cal. (1)
Detroit, Mich. (1) (2) (3) (4)
St. Louis, Mo. (1) (2) (3) (4)

Boston, Mass. and suburban area (1) (3) (4). Also Massachusetts general data, from State Division of Housing & Town Planning.

Cleveland, O. (1)
New Orleans, La. (1) (2) (4)
Portsmouth, O. (4)
Richmond, Ind. (3)
Xenia, O. (4)
Marietta, O. (4)
Findlay, O. (4)
Marion, O. (3)
South Bend, Ind. (4)
Bridgeport, Conn. (2) (4)

APPENDIX I

TRENDS IN KINDS AND NUMBER OF DWELLINGS BUILT IN RECENT YEARS

In the recently published study, *Neighborhoods of Small Homes* by Whitten and Adams (Harvard University Press) the following approximate distribution of dwellings occupied is shown as of 1930 for 73 cities of 30,000 to 1,000,000 population (with the one larger exception of metropolitan Boston): 47.1 per cent of families live in single-family dwellings, 47.7 per cent in two-family or small multi-family dwellings (flats), and 5.2 per cent in heated apartments.

Very complete statistical studies of the changes which have been taking place in the post-war period are to be found in recent issues of the *Journal of Land and Public Utility Economics.* These indicate an accelerating increase in the proportion of two-family and multi-family types in most cities during the period, reaching at least 60 per cent of the total production in many cities and almost 80 per cent in Chicago. These same studies show also a marked change in regard to the proportion of two-family and larger multi-family dwellings, particularly in the period from 1925 to 1929, during which the proportion of two-family dwellings fell off rapidly, with other multi-family types increasing so as to more than make up the difference.

Two tables are appended here, showing these trends in St. Louis and Cincinnati. These are typical in a number of ways of the larger cities during the period. The peak of building was reached in most cities during 1926, 1927, or 1928, followed by a rapid falling-off in volume in subsequent years. In St. Louis the peak was reached in 1925, with a more gradual decline following.

During the rapid general decline in building since 1929, the proportion of single-family dwellings has gradually increased in various cities, including particularly Boston and St. Louis. This tendency parallels a similar shift in the period of underbuilding immediately following the war. Since in each period the total amount of building was relatively small, the net result has not materially affected the general upward trend of multi-family types as related to single-family dwellings in cities of 50,000 or more throughout the central and eastern industrial regions. Moreover,

Table 1. Dwelling Construction, St. Louis, 1921-1930 Inclusive

(Data from St. Louis Building Commissioner)

Year	Total families provided for	Percentage of families in		
		One-family dwellings	Two-family dwellings	Multi-family dwellings
1921	1,689	61.0	19.0	20.0
1922	3,056	48.0	39.0	13.0
1923	4,586	42.5	38.5	19.0
1924	3,979	49.0	38.0	13.0
1925	6,642	38.0	43.5	18.5
1926	4,900	39.5	45.5	15.0
1927	4,078	39.0	40.0	21.0
1928	4,845	35.0	42.5	22.5
1929	3,056	41.0	28.5	30.5
1930	1,372	61.0	19.0	20.0

Table 2. Dwelling Construction, Cincinnati, 1921 and 1925-30 Inclusive

(Data from Cincinnati Department of Building)

Year	Total families provided for	Percentage of families in		
		One-family dwellings	Two-family dwellings	Multi-family dwellings
1921	1,161	92.9	1.3	5.8
1925	2,526	62.5	20.5	17.0
1926	2,530	58.5	19.2	22.3
1927	3,212	52.0	18.0	30.0
1928	3,562	51.2	10.1	38.7
1929	1,971	64.0	9.5	26.5
1930	1,697	59.0	7.0	34.0

it would seem unwise to interpret as a change in trend this periodical increase in the proportionate number of single-family houses built during periods of general decline in the total production of dwellings. It should be interpreted rather as a quality of persistence of the single-family house during the period in which the timidity of investment capital causes a natural shrinkage in the number of rental buildings produced.

It is impossible to avoid the conclusion, from the above examination of trends, that the multi-family house has become a very large and permanent factor in the housing situation throughout the country. In relation to its statistical importance, it has not received the attention which it merits at the hands of students of the housing problem. Its importance is increased because, as shown in the Whitten-Adams study, the multi-family house provides a very large proportion of the lower-cost or rental dwellings occupied by those whose housing facilities need the most careful consideration and guidance by disinterested agencies. Very little is known in regard to the general trends within the multi-family field. These are by no means fully revealed by mere statistics as to the number of families housed. There is a wide variation as to methods in vogue with respect to both the form and the methods of owning, renting, and servicing multi-family dwellings, and even in the more simple considerations of the two-family dwelling there is a wide difference in the quality of plan and completeness of services offered, as built in various cities and at various periods. It is reported that a large number of the more recent two-family dwellings in one of our largest cities depend on individual stove heat in place of basement heating units for each of the two dwellings. The latter are quite inefficient in fuel cost, but the change to stove heat reintroduces all the problems of a primitive period which many had thought to have been permanently superseded by more modern methods.

On the other hand, the two-family dwelling, when well planned, provides a fairly desirable and low-cost property for the resident owner who applies the rental from the upper floor against his purchase payments. Where, in return for this, he performs such services as providing heat from a common efficient heating plant, the rental dwellings thus provided are both desirable and appropriate for families not in a position to own, and not requiring the individual yard accommodations of the single-family dwelling.

One of the most significant observations of this committee in regard to the two-family dwelling concerns the so-called "Investment Bungalow," popular in such cities as Buffalo and Detroit. Here can be traced a complete evolution, taking place within a few recent years, from the one-story bungalow, first to the authentic investment bungalow with only two or three rooms added in the attic space for rental purposes, and finally to the complete two-story two-family dwelling, still masquerading as a bungalow, but providing complete and independent facilities for an approximately equal amount of living space on each floor. Unfortunately, this evolution starts with an undesirable type of bungalow plan fitted to a narrow lot. The building, already deep and narrow, is still further deepened to accommodate the additional stairs, etc., required for two families, and the increase to full two-story height, usually on the original lot width, further darkens the first-floor rooms with side-yard exposure. If this were an occasional tendency, it might be ignored, but in one city visited, more than 300 buildings of this type, providing for 600 families, were under construction in 1931, constituting more than two-thirds of the current building, and all embodying the defects herein noted.

APPENDIX II

RESEARCH INTO COSTS OF RECENT DWELLINGS AND METHODS USED BY COMMERCIAL BUILDERS

This committee devoted a very considerable amount of time and work on the part of its members as well as its research secretary, in observing and collecting data as to the more typical forms of dwellings recently produced in a large number of cities. The committee represents in its personnel 19 cities in almost as many distinct regions of the country. The secretary visited many of these, and other cities in which there were no committee members. As shown by the report, various types of investigation were made in 28 cities altogether. A large amount of factual material, typical plans, etc., was collected and carefully studied. The material is, however, of a character which, because of wide variations, cannot be tabulated as exact comparative data. We have endeavored to place a fair and reasonable interpretation on what has been generally observed in reaching the following general conclusions.

The committee's study and research has been directed and interpreted in the interest of finding, if possible, reasons for the present high costs of dwelling construction and methods by which they might be reasonably reduced. The committee has been able to observe closely in many cities the production methods of the best local building agencies, which have endeavored to operate efficiently and on close margins in respect to both building and financing. Such agencies have offered very genuine cooperation, providing the committee with exact details of the itemized costs of their typical houses and of other dwellings which they have built in considerable numbers in the recent past. As noted in the committee's report, the most typical houses in the moderate priced field found in the suburbs of eastern cities have been free-standing, six-room, one-bath houses, usually of frame construction, while in the mid-western cities the five-room bungalow has largely predominated.

While in both classes of dwellings the size and plan arrangement has varied to some degree, there has been a remarkable similarity among the product of builders competing at the popular price level in each city, while similar plans extended throughout many cities. For instance, in the three Mississippi Valley cities studied in detail, Minneapolis, Kansas City and St. Louis, the popular type of bungalow is characterized by almost identical arrangement on the first floor, the principal variation being the placement of the breakfast-room either between the dining-room and kitchen, or on the rear of the house, separated from the dining-room by the kitchen. The plan almost universally provides two ground-floor bedrooms with bath between, occupying half of the width of the house opposite the kitchen and dining-room. Various methods were observed of adding an extra room or rooms in the attic, while in Kansas City the general practice is to "erect" a sleeping porch across the ridge of the bungalow at the rear of the building. A new tendency of design, to be measured almost in months, was noted in all three cities, having been only just introduced into St. Louis. This was the result of roofing the living-room which, with vestibule, occupied the entire front of the house, at right angles to the main ridge of the building, thus attempting to mask the awkward length of these deep narrow-lot buildings. Few important functional improvements were to be observed, but a rapid evolution was taking place through the addition of "competitive" features in the form of elaborate plaster decorations, arched recesses, sunken bath tubs, wrought iron stair rails, etc. Even in the better quality dwellings, these features left much to be desired in the way of good taste, while in the poorer quality imitations there was evidenced a definite backward swing toward mid-Victorian precedents. The extent and gaudiness of such selling features was least manifested in New England, and increased proportionately as one proceeded westward, reaching its greatest flower in the bungalows of the Mississippi Valley. No corresponding data as to cheaper construction in the far-west have been available to the committee.

Unquestionably the high cost of dwellings in recent years may be largely attributed to the increased standards in regard to conveniences and equipment. In so far as these represent added comforts, they should be provided to the greatest extent possible, but in many of these recent examples comforts have been interpreted in terms of unnecessary elaboration and features which constitute useless "gadgets" of questionable value for use or as an investment. The studies of the committee have endeavored to reveal the general proportionate costs of the simple, sound structure in which cost reduction should be sought only through the economies of new methods of building or quantity construction, and not through sacrifice of quality. The amount of cost in this respect will represent an irreducible minimum to provide ample spaciousness and number of rooms essential to the needs of the family.

The experienced builder has discovered that the cost of fairly generous standards in regard to room sizes is relatively small in contrast to that of "tight" plans and pinched room sizes, although he has tended to cramp the lot, partly by reason of his generosity in size of the building. On the other hand, the builder has definitely fallen into error through following what he considers "the public demand," which has become, however, a question of matching every new "feature" which his competitor chances to introduce. That there is definite danger in carrying such competition further may be demonstrated in the tendency of many present building agencies to gradually advance their necessary selling price to cover these endless additions, which removes the product continually further above an average selling price which can be afforded by any but a very small part of those needing new dwellings.

Table 1 gives a breakdown of the itemized construction costs of typical single-family dwellings from different cities. Nine of these are one-and-one-half or two-story houses, with six rooms unless otherwise noted, with full basements, of frame construction, having one bathroom, usually tiled, and in most cases a gravity warm-air heating system. All of these houses are approximately square in plan (about 25 feet in each dimension), with a gross ground-floor area (not including projecting porches or vestibules) of from 650 to 750 square feet.

The 3 bungalows included in the table have five rooms, are of approximately the same grade of construction and equipment, and measure from 24 x 34 to 30 x 40 feet.

The costs in Table 1 were furnished by active builders and represent actual costs in recent building in all but one case. In one example estimates of complete plans, made especially for the committee by a builder, have been used. Construction costs in all cases were furnished sufficiently well classified to permit of equitable comparison with only minor adjustments of specific items. They are shown here as construction costs only, without builders' overhead or profit, site costs, financing or selling expense, all of which varied so greatly in their indication as to permit of no conclusive comparisons. In general, however, selling prices of this grade of dwellings will average 20 to 25 per cent above the net construction cost, of which amount the lot cost will range from about $500 to $1,000.

The conclusions which have been made from these tabulations are included in the body of the report at page 17.

In the case of the Minneapolis bungalow, the plan was typical of almost all the dwelling construction throughout the city in 1931. The tendency here seemed to be to repeat not only a typical plan, but to reach an almost uniform selling price for all areas of the city, whether previous dwellings in each area had been more or less expensive than the type now being produced. The Minneapolis two-story house and bungalow costs are not sufficiently well related for comparison. However, in the case of South Bend, the two-story six-room house and five-room bungalow were built by the same agency at the same time, and in approximately the same form of construction, quality of finish and equipment, throughout. They form a basis for conclusion 5 on page 17. The two-story house last referred to is also the house used in the next summary, showing the distribution of cost as between materials and labor in two two-story houses of approximately equal floor area.

It will be seen from Table 1 that from 50 per cent to 60 per cent of the actual construction cost is all that is definitely affected by the size of the building, although certain additional items are increased in accordance with the number of windows and doors. An increasingly large amount of house cost is going into the items of mechanical and other equipment—plumbing, heating, electric wiring, fixtures, kitchen equipment, bathroom tiling, etc.—which have very little relation to either the size or the plan of the house. For instance, plumbing consists of one complete kitchen and bath room, water heater and laundry-tubs outfit. This may be more extensive and elaborate in a given small house than in another larger one, and no small part of the plumbing costs is in the utility connections, which relate to the size of the lot, depth of sewer, etc. In heating, and to some extent in electricity, the important cost lies in the central installation rather than in the individual room outlets.

Table 2 is not susceptible of definite conclusions but indicates that, through a more extensive knowledge of the distribution of costs in dwellings, some progress might be made toward preserving a sane balance of costs, as well as toward effecting economies.

Table 2 is the result of a limited amount of reliable information with regard to the distribution of materials and job labor costs

Table 1. Itemized Costs of Typical Builders' Houses in Various Cities

City or suburb	Total construction cost without overhead	I Structural shell—(excavation, foundation, masonry, iron, rough lumber and carpentry, roof, sheet metal, windows and exterior doors)		II General finish—(plastering, painting, glass, mill work, stairs, finish, interior doors, wood floors)		Total of structure and finish:	III Basic mechanical installation—(plumbing, heating, electric wiring, hot water heater)		IV Equipment, decoration—(fixtures except plumbing, cases, hardware, screens, shades, etc., tile work)	
Houses: 2 or 1½ stories		Amount	Per cent	Amount	Per cent	Per cent	Amount	Per cent	Amount	Per cent
1. Boston, (suburb) 7-room frame, 20 x 35 feet..	$7,202	$4,045	56.0	$1,510	21.0	77	$1,192	16.5	$455	6.5
2. Minneapolis 6-room frame, 25 x 25 feet..	5,988	2,777	46.0	1,773	30.0	76	926	15.5	511	8.5
3. Denver 1½-story 6-room stucco on frame..................	5,682	2,761	49.0	1,278	22.0	71	1,134	20.0	507	9.0
4. Boston, (suburb) 5-room, 1½-story frame, approx. 26 x 30 feet.....	5,675	3,283	58.0	1,012	18.0	76	1,000	17.0	380	7.0
5. Detroit 6-room brick veneer, 25 x 25 feet.................	5,580	2,515	45.0	1,325	24.0	69	965	17.0	775	14.0
6. Bridgeport 6-room frame, 23 x 26 feet, fireplace, closed porch....	4,514	2,111	47.0	1,135	25.0	72	895	20.0	373	8.0

7. South Bend, Ind. 6-room frame, 28 x 24 feet. .	4,250	2,460	58.0	850	20.0	78	687	16.0	252	6.0
8. Bridgeport 6-room frame, 24 x 24 feet. .	4,130	1,913	46.0	991	24.0	70	1,025	25.0	201	5.0
9. Buffalo 6-room frame, 22 x 26 feet. .	3,462	1,654	48.0	799	23.0	71	714	20.5	294	8.5
Bungalows										
10. Minneapolis 5-room stucco, 29 x 40 feet. .	5,728	2,632	46.0	1,531	27.0	73	910	16.0	655	11.0
11. Minneapolis 5-room stucco, 30 x 40 feet.	5,001	2,201	44.0	1,412	28.0	72	927	18.5	460	9.5
12. South Bend, Ind. 5-room frame, 24 x 34 feet. .	3,451	1,989	57.5	606	17.5	75	620	18.0	235	7.0
Range from lowest to highest. . .			44.0 to 58.0 (note *)		17.5 to 30.0 (note †)	69 to 78 (note ‡)		15.5 to 25.0 (note §)		5.0 to 14.0 (note ¶)

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* Except in 7 and 12, where building code permits very cheap plumbing installation, and 1 and 4 (See note †), the structural-shell cost varies only from 44 per cent to 49 per cent, and the total of I and II from 69 per cent to 76 per cent.

† 1 and 4 compensate for high percentage in I by correspondingly low percentages in II, bringing their totals for I plus II within the normal range. Allocation of items between I and II was in some cases difficult, with the result that the percentage total of I plus II is more significant than either percentage alone.

‡ Of all examples listed, 5 was least clearly "broken down" by the builder. It is suspected, from the plan and description furnished, that a more accurate analysis would transfer an appreciable sum from IV to II. This house now furnishes the maximum percentage in IV.

§ 8 had a steam heating plant.

¶ Totals of less than $255 in IV for 7, 8 and 12 reflect the desire of two smaller-city builders to keep their cheap houses simple. 1 has low percentage in IV because of relatively simple equipment in the most expensive house.

Except for 5 (See Note ‡), the range in IV is from 5 per cent to 11 per cent.

in two two-story houses, one in a large and the other in a smaller city.

Table 2. Itemized Cost and Subdivision of Cost of Job Labor for 6-Room Free-Standing Houses of Approximately 21,000 Cubic Feet Each *

	New York* and Pittsburgh*	Labor only	South Bend, Ind.	Labor only
Excavation, foundation and cellar work	$ 615	$ 285	$ 325	$ 131
Brick, steel and stone	1,285	630	210	60
Lumber, millwork, carpentry, stairs, roofing	2,305	965	2,510	675
Plastering	660	405	280	215
Painting and decorating	410	315	220	125
Plumbing and utilities	715	220	425	170
Heating—steam, except in South Bend —hot air	495	185	210	60
Floors, tile, hardware, electric wiring, fixtures and equipment	735	310	325	175
	$7,220	$3,315	$4,505	$1,611

* Actual costs in New York region and estimated costs at Pittsburgh (1930) varied but slightly; labor costs taken from Pittsburgh, estimates. South Bend labor costs are actual.

Unfortunately, the value of the above comparison is somewhat qualified by the fact that the higher priced house was of brick veneer construction, while the other was of painted frame. The difference in cost, amounting to about 60 per cent increase in the larger city, would probably have been 10 per cent less if frame construction had been used. However, the very much larger difference, amounting to 100 per cent, in the job labor is unquestionably a direct reflection of the size of the city, which results in added restrictions in regard to jurisdictional trade regulations, etc. Building code restrictions were also a factor. Greater freedom is permitted the builder in the smaller city to purchase practically all materials direct and pay labor by the day or on the basis of unit quantities. This observation is not intended as a criticism of methods so much as to bring out the fact that dwelling construction suffers through reflected costs and methods which originate from and are scaled to the magnitude of commercial and other larger structures in the same city.

APPENDIX III

QUALITY OF SMALL HOUSES IN RELATION TO THEIR COST, WITH CLASSIFICATION TABLES

The committee recognized from the outset the wide variation in the quality and completeness of houses in the same or different cities, and the following table was prepared for the guidance of its members in adjusting these factors as typical builders' houses were studied for and reported to the committee. In general, the dwellings used in the foregoing studies lie approximately within class "B" of the table, although individual items occasionally fall within either "A" or "C."

Table 1. Classification of Houses by Kind and Quality of Materials and Equipment

House	Class "A"	Class "B"*	Class "C"
Foundations	Concrete, or equal	Concrete blocks, hard	Concrete or cinder blocks
Walls	Brick or brick veneer	Brick, or brick veneer or good frame	Frame siding or stained shingles
Roof	Slate or thick asbestos	Thin asbestos or heavy asphalt	Thin asphalt or wood shingles
Plaster	3 coats on better than wood lath	2 coats on wood lath	1 coat trowelled on wood lath
Framing {Joists, Girders}	Heavy steel	Medium, steel or wood	Light, wood
Floors	Double, all oak	Double, all or part oak	Single, all or part pine
Fireplace	Usual wood burning	Wood or gas	Gas or fake
Plumbing	Full bath, extra toilet, best fixtures	Tub and shower, good fixtures	Same or less, cheaper fixtures
Hot water	Automatic	Automatic storage	Gas coil
Bathroom	Tile floor and walls, or equal	Tile floor, often walls	Magnesite or wood floor
Heating	Return steam or hot water	One pipe steam or good hot air	Pipeless hot air
Painting, hardware, screens, weather-strips, electric fixtures, kitchen equipment	Complete, and general good quality	Fairly complete, fair quality	Incomplete, fair to poor quality

* Special considerations might rate any house generally in class "B" as "B+" or "B−" etc., because of special features or equipment.

The above classification is similar to but not identical with one quoted later in this appendix, page 40, from *The Small Home*. The latter is based upon the recommendations of a disinterested agency whose standards in the matter of structural soundness, etc., even in the cheapest grade of dwellings, are appreciably above those of the average commercial builder. The committee's table, on the other hand, was prepared for the classification of commercially produced houses, and necessarily indicates certain practices and standards which the committee would not recommend.

As an indication of the committee's policy with reference to quality and necessary compromises, suggestions are offered below as to choices in materials and equipment, under the headings of: "Necessities," "Desirable Features," and "Luxuries." This brief statement is an indication of principles rather than an attempt to list in detail the choices which must be made.

Choice of Materials and Equipment

Necessities. Substantial construction with good quality materials and workmanship, particularly in all concealed work, including fire-stopping, good quality piping, etc. Substantial footings, precautions against dampness, and insulation. Reasonably ample space provision. Economies may safely be obtained through use of:

1. Good non-curling composition roofing material;
2. Single flooring, at least on upper floors;
3. Linoleum or magnesite bathroom floor with hard plaster wall finish, and similar lower-cost surface finishes, which are for the most part both durable and satisfactory and susceptible to replacement if later desired.

Space provision for, but omission of, kitchen equipment, closet fittings, etc.

Desirable Features. Better quality materials may be substituted for some of the previous items as, for instance, fire-proof roofing material, double floors, additional kitchen and bathroom conveniences, including built-in fixtures, tile walls and shower in restrained taste. More complete original equipment, as rustless screens, weatherstripping, etc. Consideration should be given to the economy in maintenance of the use of masonry rather than painted frame exterior walls. Where the first cost can be assumed, the carrying charge on such expenditure will often be no more than the annual cost of repairs, painting, etc.

Luxuries. The exact line at which any particular feature becomes a luxury depends upon the needs of the family or its ability to assume the additional first cost of conveniences or quality materials which are not essential to a reasonably durable and satisfactory dwelling.

Slate or tile roofs are both durable and pleasing in proper design and color combinations. Attractive wood-burning fireplaces add to the comfort and pleasure of any home. A second bathroom, frequently with tiled shower stall instead of tub, may be desired, as well as first-floor or basement toilet, breakfast-nooks, completely tiled bathrooms, tiled kitchen walls, elaborate built-in cabinets, etc. Numerous mechanical devices, such as automatic storage water heaters, vapor, steam or hot-water house heaters, with thermostatically controlled oil burners, mechanical refrigeration, and incinerators, should be considered more or less in the field of luxuries, and certainly not obtained at the sacrifice of either construction quality or reasonably ample living space. Any or all of these may be considered desirable, rather than luxuries if they can be secured without sacrifice either of space requirements, construction quality, or the less expensive desirable features previously listed.

Choice of Quality in Specifications

The above does not undertake either to offer a complete list or to go into all the alternatives in types of finish, kinds of heating, etc. It is merely suggested that the family whose expenditure is limited should seek a house that may be produced within the cost that can conveniently be assumed, and in which whatever may be included will give satisfaction without undue repairs or deterioration. The temptation will be to add this or that apparently inexpensive additional improvement or feature. The total cost of the house rapidly increases through this process, as will be seen from Table 2, in which exactly the same five-room bungalow has been estimated with three different qualities of materials and equipment. Built with the least expensive specifications at about $5,700, the house would be a thoroughly satisfactory and well-constructed dwelling. The "A" specifications, which add nearly 50 per cent to the cost, are made up of a large number of details, any one of which might be considered desirable, but which in their cumulative effect will bring the cost of the house entirely outside the range of most house owners. The following table of comparative costs under different specifications was taken from *The Small Home* for April, 1931.

Table 2. Classification of Houses by Kind and Quality of Materials and Equipment *

Specifications	Class "A"	Class "B"	Class "C"
Footings	Reinforced	Not reinforced	Same
Beam fill	Best	Same	Same
Basement floor	4-inch	4-inch	4-inch
Basement waterproofing	Cement plaster	Asphalt	None
Framing lumber	#1 Kiln	#1 Air	#1 and #2
Insulation	Rock fibre	Same	Quilt and rigid sheets
Glass	Plate	Single strength	Same
Screens	Bronze	Bronze	Black wire
Medicine cabinet	Metal	Metal	Wood
Plaster	3 coats	2 coats	2 coats
Lath	Metal	Wall board and metal.	Wood and insulating board
Weatherstrips	All exterior openings.	Same, cheaper	Doors only
Plumbing	$675	$600	$525
Heating	Vapor vacuum, oil: $770	Hot water pressure: $425	Moist air gravity: $225
Decorating	$575	$510	$425
Wiring	60 outlets	53 outlets	45 outlets
TOTAL CONSTRUCTION COST	$8,182.10	$6,709.50	$5,728.85
Without profit or architect's fee	143%	117%	100%

* From *The Small Home*, April, 1931.

APPENDIX IV

RESEARCH IN COMPARATIVE COSTS AND USE-VALUES OF BASIC TYPES OF SMALL SINGLE-FAMILY AND MULTI-FAMILY DWELLINGS

In undertaking the following research, the committee had access to an important and accurate source of factual material which is practically uniform for these various types of dwellings, and which is the accumulation of knowledge of uniform continuous building for the past seven years. This source includes large operations in Long Island City, N. Y., and near Paterson, N. J., and estimated costs for a similar project in the city of Pittsburgh. The latter has proved to be so nearly the same, both in detailed items and total cost per dwelling, that it is included in the basic data used for the present study.

Lot Costs

In attempting a comparison of various types of dwellings, it is first necessary to set up an equitable basis of comparative costs for lots of various sizes, which again has been done with the use of known factors in the New York and Pittsburgh areas. In Table 1 the various factors have been given first on the basis of

Table 1. Site Costs * for Normal Lots of Varying Widths

Lots 100 feet deep by	30 feet	35 feet	40 feet	20 feet
Land at 10 cents sq. ft. net*	$ 300	$ 350	$ 400	$200
Grading at 5 cents	150	175	200	100
Public improvements	445	520	595	300
Yard work	300†	330†	360†	165
Contingencies and maintenance	100	100	100	75
TOTAL COST	$1,295	$1,475	$1,655	$840‡

* Cost items are given in full at a land value of 10 cents per square foot net within the lot (unimproved), including all improvements except water and gas mains and lateral utility connections for normal street frontage allotments on minor residential streets. (See Table 2 for costs at higher land values.)

† Deduct $25 for saving in side-yard improvements if semi-detached or row house.

‡ Row house only.

land at 10 cents per square foot net within the lot (unimproved), and in Table 2, the total costs at 20 cents and 40 cents. It may be explained that land at 10 cents net within the lot area would be approximately 7 cents per square foot, or $3,000 per acre, for the gross area before the streets have been deducted. The acreage price in the other cases is stated in the note to Table 2. Lot improvements include both public improvements and private yard improvements; in other words, all costs necessary to complete the property for either sale or rental, except public water and gas mains which are usually provided at the expense of the city and are not directly chargeable to the building operation.

Table 2. Effect on Total Lot Cost of Land at Twice and Four Times the Cost Shown in Table 1

Lots 100 feet deep by	30 feet	35 feet	40 feet	20 feet
Total Cost:				
Land at 20 cents sq. ft. net*........	$1,595	$1,825	$2,055	$1,040
Land at 40 cents sq. ft. net.........	2,195	2,525	2,855	1,440

* The price of land per square foot net may be converted into cost per acre where 31 per cent is allowed for streets as follows: 10 cents net = $3,000 per acre; 20 cents net = $6,000 per acre; 40 cents net = $12,000 per acre.

Building Costs—A Method of Analysis

It is fortunate that in the developments under construction, practically all of the types of dwellings considered have been built of uniform depth of 28 feet 4 inches from front to back. In addition to those types presented in Table 2, three-story apartment houses were also built with plans practically identical in arrangement and in the same building depth as the two-family dwelling here used. From very complete cost accounting we are able first, to suggest a convenient form of cost comparison between these dwellings, and then to check it against actual costs of the completed building, which assures us that the basis assumed is within 1 or 2 per cent of accuracy in all cases. It will be noted, then, that for these various types of dwellings, it is possible to assume a factor of cost of net cubage (item 5—20 cents in this case) and another factor of cost of one complete outfit (item 8) of bathroom, plumbing, kitchen equipment, etc., which may be carried as *uniform through all types* built within the same building depth and form of construction. These two items, except for the addition of the porch, become, then, the complete cost of the interior row house. To this may be added uniformly for semi-detached or free-standing houses or flats, *uniform items for the end walls* (items 6 and 7) and in the case of the two-family house, items 9 and 10 represent the additional number or amount of bathroom, kitchen equipment, etc. In this way, by using the relative lot costs established in Table 1 we arrive at a very accurate knowledge of the relative cost and its component parts for all of the types here considered.

From further knowledge of actual costs, it is known that for the same building depth and type of construction, it will be possible to add to or subtract from the width of any of these types from 1 to 5 feet at a cost of about $100 per foot for building only. This means that no more partitions, doors or windows, etc., are added, and indicates that where the general cubage cost of structure only is 20 cents a cubic foot, additional space may be added without plan changes at about 12 cents a cubic foot. The land cost could be taken proportionately on whatever basis is assumed. Thus, the 20-foot row house, if built 18 feet 6 inches wide, would cost approximately $150 less for building, and in this case $65 less for land, or vice versa if increased to 21 feet 6 inches. It will be noted that the increased cost (for building only) of the semi-detached house over that of the row house is less than the increase from the semi-detached to the detached house by 2 per cent, due not only to the need for an individual chimney in the latter, but to the greater amount of detailed work in forming the roof, cornice, etc., and the difference between a single and double porch. On the other hand, when the site cost is added, the increase is more rapid from the row house to the semi-detached than from the semi-detached to the detached house, due to the fact that in the case of these developments, detached houses may be arranged in pairs with their stairway walls adjacent and spaced 10 feet on the stair side, as compared with 18 feet or 19 feet on the living side. This difference would be reduced if the houses were placed only 10 feet apart on the living side, but semi-detached or free-standing houses less than 15 or 18 feet apart, are generally less

Table 3. **Comparative Production Costs of Two-Rooms-Deep Brick Dwellings *—28 Feet 4 Inches Deep by Various Widths.**

	"A" Free-standing house—6 rooms	"B" Semi-detached or end house	"C" Interior row house	"E" 2-family flat—8 rooms	"F" 2-family flat—9 rooms
1. Overall size	21′ x 28′ 4″	20′ 6″ x 28′ 4″	20′ x 28′ 4″	25′ x 28′ 4″	30′ x 28′ 4″
2. Net Floor Area (except outside walls and halls)	950 sq. ft.	950 sq. ft.	950 sq. ft.	1,200 sq. ft.	1,450 sq. ft.
3. Cubage 30′ high	17,900 cu. ft.	17,425 cu. ft.	17,000 cu. ft.	21,240 cu. ft.	25,500 cu. ft.
4. Lot size	35′ x 100′	30′ x 100′	20′ x 100′	25′ x 100′	30′ x 100′
5. Net cubage at 20 cents	$3,580	$3,485	$3,400	$4,248	$5,100
6. One 28′ 4″ end wall	$ 450	$ 450			
7. One 28′ 4″ end wall and extra ½ heater flue	$ 515				
8. Plumbing, tiling, 1 bath, electric wiring, stair, chimney, kitchen equipment, heater (excl. radiation)	$1,420	$1,420	$1,420	$1,420	$1,420
9. Second bath (same stack) = kitchen equipment, etc. (a) extra stair				$ 675	(a) $ 750
10. (a) = Extra size boiler; (b) = 2 heating and hot water outfits, extra flue				(a) $ 100	(b) $ 450
11. Porch (a) = single wood post, (b) = double brick, (c) = porch with balcony, entry stoop	(a) $ 313	(b) $ 265	(b) $ 265	(c) $ 425	(c) $ 425
COST OF BUILDING	$6,278 100%	$5,620 89½%	$5,085 81%	$6,868†	$8,145†
LOT COST (Table 1)	$1,475	$1,270	$ 840	$1,050	$1,260
TOTAL PHYSICAL COST PER FAMILY	$7,753 100%	$6,890 89%	$5,925 76.4%	$7,928 51%‡	$9,405 60.7%‡

* 6-room houses, detached, semi-detached, and row. 4-and 4½-room row flats. All with brick or brick-veneer walls and slate roofs.

Based upon accurate costs for two actual projects in the New York metropolitan region, and one proposed in Pittsburgh. Including complete new public and yard improvements. Land taken uniformly at 10 cents per square foot net. See Table 1 for lot costs.

Dwellings are of approximately Class "B" specifications (See Appendix III, page 37.) The smaller flat, 25 feet by 28 feet 4 inches, has a single stair, and heating plant serviced by first floor owner. Flat 30 feet by 28 feet 4 inches has internal private stair access from second floor to basement, with two heating plants.

† In the case of flats, costs are for two suites.

‡ Per family.

desirable and less private than (and therefore not comparable to) well-planned row houses with a similar amount of living space.

Observations from Tables 1, 2 and 3

In the case of houses shown in Table 3 all but "A" have been built in almost the exact form listed. In the table, only slight modifications have been made for uniformity, and the costs given check closely with actual costs. "A" has not been built in this exact form, but the basic items are sufficiently constant, and correspond to such items where actually built, that we need have no hesitancy in assuming their accuracy within close limits.

We have, therefore, more reliable data than any heretofore produced to show the actual comparative cost where the same house plan and identical floor area are built in detached, semi-detached, and row forms. The results are shown by the percentages at the bottom of Table 3 and are considered to be very significant.

The variation in cost between the free-standing and interior row house of identical living area is from 100 per cent to 76.4 per cent where land is taken at only 10 cents per square foot. On 40-cent land the difference is further increased so that the row house will cost only 74 per cent as much as the free-standing. This very considerable difference clearly indicates the superiority of the row house for substantial low-cost dwellings. The cost advantage applies not only to first cost, but is even more important with respect to low upkeep cost in such items as heating, repairs, painting, etc.

Row versus Free-Standing House: A Striking Comparison. To compare the advantages of the row house with those of the free-standing house, let us take from Table 3 the interior row house, in which the net construction cost (without porch) is $4,820 and the lot $840, or a total of $5,660. Without complicating the problem by the addition of overhead, financing and selling costs, we will assume that a purchaser can afford $6,500 worth of dwelling instead of $5,660. He may desire a larger house, or he may fancy a fully detached house. How would the necessary changes affect his cost; how can he spend the extra $840 to best advantage?

If the 20-foot house (widened to 21 feet to provide the extra thickness of exposed walls) is built free-standing on a lot only 30 feet wide, his cost will be increased by $102 for additional cubage, $450 and $515 for exposed end walls in place of party walls, and $455 for added lot width. This increases his total cost from $5,660 to $7,182, or $682 more than he is prepared to pay. He has only gained a few windows on side yard exposures of 9 feet on each side, and a larger yard.

Let us say, on the other hand, that he accepts instead a row house 5 feet wider, with 25 per cent more space on each floor and 25 per cent more frontage than the original house (although narrower than the 30-foot lot for the free-standing house). If no changes are made in plan arrangement (as they need not be, all of the additional space being thrown into the width of living-room, dining-room, and two bedrooms), the extra 5 feet of house will cost him $500 for extra cubage, and $210 for the added 5 feet of land, or a total of $6,370, leaving him still $130 to spend on more windows in the two walls which will look out upon the ample front yard and garden spaces.

Efficiency of the Various Types. In order to carry the comparison further, two other types of dwellings have been added to those of Table 3, and costs taken correspondingly as follows:

"D." 4½-room 2-story row house, 16 feet by 28 feet 4 inches, with 735 square feet of usable area. Construction cost: $5,085 (type "C") minus $400 ($100 per foot) for diminished width, minus $265 for porch, or $4,420 total. Lot Cost: $840 minus 20 per cent or $672. Total house and lot cost $5,092.

"G." Double or semi-detached 4½-room flats in 2-story buildings 30 feet 6 inches by 28 feet 4 inches, with 725 square feet of usable area. Construction cost: $8,145 (type "F") plus 425 cubic feet additional @ 12 cents ($51), plus $450 for end wall, or total cost, including porches, of $8,646. (Recently built with 475 cubic feet additional ($95), for $8,750, showing how closely theoretical figures check). Lot cost: 40-foot lot (Table 1) $1,655, minus $25 for semi-detached use, ($1,630). Total construction and lot cost for one-half of four-family building (including porches) $10,276; without porches $9,851; per family without porches $4,926.

Efficiency of All Types

In order to compare the efficiency of all the types, the usable floor area has been figured for each type, and Table 4 shows the costs of the types and their respective areas compared in various ways.

Table 4. Comparative Costs for Usable Space in Various Type Houses

Type*	Number of rooms	Usable area, sq. ft.	Areas		Costs§	Costs		Room costs		Sq. ft.‡‡
			Per cent†	Per cent‡		Per cent¶	Per cent‖	Note**	Note ǂ	
"A"	6	950	100	129.0	$7,440	131	146	$1,240	$1,415	$6.28
"B"	6	950	100	129.0	6,625	117	130	1,104	1,254	5.63
"C"	6	950	100	129.0	5,660	100	111	943	1,045	5.07
"D"	4½	735	77	100.0	5,092	90	100	1,131	1,238	6.01
"E"	4	600	63	81.6	3,751	66	73	938	1,030	5.37
"F"	4½	725	76	98.6	4,490	79	88	998	1,098	5.32
"G"	4½	725	76	98.6	4,943	87	97	1,098	1,228	5.66

* "A", detached; "B", semi-detached; "C", 6-room row; "D", 4½-room row; "E", 4-room row flat; "F", 4½-room row flat; "G", 4½-room semi-detached flat.

† Per cent usable area in terms of "C."

‡ Per cent usable area in terms of "D."

§ Full cost per family, building and lot (10 cent land) without porches.

¶ Per cent full cost on basis of "C."

‖ Per cent of full cost on basis of "D."

** Cost per room, building and lot, on basis of land at 10 cents net.

ǂ Cost per room, building and lot, on basis of land at 40 cents net.

‡‡ Cost of building only (without porches) per square foot of usable area.

Conclusion

Although the foregoing has been based on very definite reliable data, and has been checked and rechecked against actual results, we hesitate to draw hard and fast conclusions, or to enter upon the many problems which would arise in order to apply them under the widely varying conditions which pertain to different cities, and particularly to cities of various sizes or degrees of customary intensity in the use of land.

We believe that the material which has been available to the committee, and the deductions which have come about through its careful study and interpretation, constitute a record which is unique and not duplicable from other sources. The findings, which establish more carefully than heretofore the important relation of actual costs in terms of use area for detached, semi-detached, and row single-family houses, and for well planned flats embodying the two most customary methods of building and servicing them, are in themselves of great significance to those interested in the problem of reducing the costs and improving the character and quality of low-cost dwellings. However, quite aside from the actual results of this research, we wish to call attention to the methods here pursued to reach an understanding of the actual facts in regard to many questions of the desirability and effectiveness of various types of dwellings which should replace the present uncertain theoretical or frequently unsupported assumptions which have in the past too frequently interfered with real progress toward the goal of better housing for the masses in the United States.

APPENDIX V

A SCORE CARD FOR APPRAISING A HOUSE

The elements on which one must base an opinion of the quality of a house as a place in which to develop a home are many and diverse. The lack of any standard measuring rod by which to appraise their relative values makes difficult the establishment of any agreed rating for individual houses.

The Committee on Design decided that it would be helpful if an acceptable standard *score card* could be devised that would indicate the various basic elements involved and establish approximately accurate relative values for these elements, so that a final composite rating could be calculated that would indicate the quality of the house as a whole.

Tentative drafts were considered by the committee, and the difficulties involved in the design and practical use of a score card were made clear, but its value was equally clearly indicated. It was therefore decided to include in an appendix to the committee's report, a tentative draft of a score card with a brief explanation of its construction and use, in the hope that it might later be perfected into a form generally acceptable and capable of helpful use.

The committee desires to emphasize the fairly obvious fact that impartial appraisers are essential if the use of a score card is to develop a dependable rating. The judgment of the owner of the house would generally be prejudiced on certain points and inexpert on others. The judgment of a real estate operator about a house he was trying to sell, or of an architect about a house he had designed and supervised, would be equally and inevitably prejudiced.

Both architectural and real estate values are involved as well as financial judgment. It is suggested that an appraisal should therefore be based upon the united judgment of an architect and a realtor, and that possibly to these should be added a banking agency official.

In one community it is already proposed to create within the local building congress an appraisal committee to appoint appraisers and to review appraisals, thus creating official standards for the community which would tend automatically to eliminate the substandard product.

The following tentative draft of a score card is presented as a first step, and in no sense as a final conclusion. It is hoped that serious study of it will be given by architects, realtors and bankers in many different communities with a view to perfecting it into a practicable instrument that will be helpful by creating that standard measuring rod which today is clearly lacking.

Attention is called particularly to the footnote to the score card which states that, to be entitled to a final composite rating, a house must have a rating of at least 60 per cent on each of the six main items. This seems a desirable rule to apply in some way. A person contemplating building or buying a house is solely interested in the result as a whole. He desires assurance that the design and the construction of his house are adequate, but these will be of small consolation to him if he finds he has built his house in a depreciating or unprotected district that makes his house valueless as a home in a few years.

Serious deficiency in any one of these six underlying factors may outweigh a perfect score on all the other items. We have suggested 60 per cent as the low limit of safety. This is a sure assumption and we are not prepared to say that 75 per cent or even 80 per cent is not a better percentage to adopt for this purpose. Perhaps only practical experience in the use of such a score card can determine this question which is one of many questions concerning the score card on which comments are desired.

SCORE CARD*

A. *Surrounding Community Conditions* 1,000
   (1) General character of occupancy;
   (2) Trend of character of occupancy;
   (3) Service by public utilities;
   (4) Transportation facilities;
   (5) Recreational facilities;
   (6) Health conditions.

B. *Obsolescence* 1,000
   (1) Character of property in relation to current type of construction;
   (2) Character of property in relation to current types of equipment;
   (3) Character of property in relation to modern living habits and economies.

C. *Physical Depreciation*		1,000
(1) General structure;		
(2) Exterior finish;		
(3) Interior finish;		
(4) Heating plant;		
(5) Plumbing;		
(6) Wiring;		
(7) Equipment;		
(8) Appurtenances;		
(9) Planting.		
D. *Relation of House to Surroundings*		1,000
(1) Outlook and orientation	240	
(2) Relation to adjacent property uses	240	
(3) Adequacy of lot	200	
(4) Location on the lot—privacy	160	
(5) Garage and services	80	
(6) Planting	80	
E. *Design;*		
(1) Plan		600
(a) Adequacy and proportions of room sizes	120	
(b) Interrelationship of rooms	120	
(c) Economy of space (halls versus rooms)	120	
(d) Work spaces and equipment (heat and plumbing) adequacy, arrangement	80	
(e) Light and ventilation	80	
(f) Closets—size and equipment	40	
(g) Usable wall spaces	40	
(2) Appearance		400
(a) Exterior; Total 240		
(1) Use of materials Simplicity, Good combination of materials, Logical use of materials, Texture, Character of details,	40	
(2) Character of decorative motives	40	
(3) Relation to adjacent designs	40	
(4) General mass	40	
(5) Proportions of openings	30	
(6) Relation of openings to wall surfaces	30	
(7) Color	20	
(b) Interior; Total 160		
(1) Treatment of stairs	40	
(2) Relation of openings to wall surfaces	20	
(3) Treatment of fireplace	20	
(4) Standing finish	20	
(5) Treatment of wall surfaces	20	

(6) Electric fixtures and hardware	20	
(7) Color	20	
F. Construction		1,000
(1) Quality of materials	500	
(a) Foundations;		
(b) Walls, floors and partitions;		
(c) Roofing;		
(d) Exterior finish;		
(e) Interior finish;		
(f) Flooring;		
(g) Heating plant;		
(h) Plumbing;		
(i) Wiring.		
(2) Quality of Workmanship	500	
(a) Foundations;		
(b) Walls, floors and partitions;		
(c) Roofing;		
(d) Exterior finish;		
(e) Interior finish;		
(f) Flooring;		
(g) Heating plant;		
(h) Plumbing;		
(i) Wiring.		

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* If the rating of any one of the six main factors is less than 60 per cent serious question would be raised as to the value of the property and no final percentage rating should be allowed.

PART II

CHAPTER II

DWELLING CONSTRUCTION

Introduction

In order that certain construction information and recommendations may be conveniently available in the United States, as a result of the President's Conference on Home Building and Home Ownership, the Committee on Construction has conducted a comprehensive survey of existing conditions in the home building field. The data obtained have enabled the committee to make certain recommendations with respect to improved construction of new dwellings involving the principles of economy, quality, and quantity.

The building industry is, next to agriculture, the most important industry in the United States, and the building of homes for the men, women, and children of our country constitutes a very large part of that industry.

House construction, however, presents such a variation in both type and cost, as well as method, that it is impossible to do more than generalize in the subsequent statements.

It is hoped that the suggestions contained in this report may be of some value to home owners, investors, builders, material interests, building trades workers, and others concerned in dwelling construction.

Purpose

The purpose of the committee was to determine in what directions new dwelling construction can best be improved with respect to economy, quality and quantity, in order that families may obtain a better return for their money, and in order that investors, builders, material interests, building trades workers and others concerned in dwelling construction may be likewise benefited.

Scope of Work

I. Building Practice. Consider: Details of sound, durable, and economical construction with a view to assuring a more satisfactory structure at lower cost; labor conserving methods; means by which good standards of workmanship may find more general acceptance; means of informing builders, foremen and mechanics as to the best and most economical practices.

II. Building Materials. Study the possibilities of standardization and simplification; of economies through more advanced and more extended fabrication by the producer, dealer, or builder; elimination of waste in distribution; elimination of waste in cutting and fitting; storage and handling of materials at the site; consider means by which new and practical ideas in design and use of materials can be employed in building operations.

III. Building Codes. Study formulation, adaptation and keeping up-to-date of modern codes relating to the structure and its fundamental equipment which protect the public interest, and at the same time do not stand in the way of economical, progressive developments in building.

IV. Construction Organization. Analyze: The size and number of home building concerns of various types, such as subdividers, operative builders, and individual home builders; business relationships between various groups, such as contractors and subcontractors; study: Instability in production and possible remedies through periodic vacancy surveys; need of cost accounting data; the organization, or lack of organized facilities, for personal and professional contact among builders, and between builders and other groups, such as architects and material dealers; the possibility of establishing better defined standards of sound construction which will aid home buyers and lending institutions, with a view to developing suggestions as to various proposed methods of assistance, such as inspection bureaus maintained by financing institutions, real estate boards or other agencies.

Program

(As adopted at the committee's first meeting, May 6, 1931.)

1. **Can Group Construction Operations be More Economical per House than Single Operations?**
    (a) If so, in what way? (Central heating plant for example.)
    (b) If not, what measures are advisable?

2. **What Would be the Effect on Construction Policies if the Tendency toward Two- or Multi-family Houses Increases?**
    - (a) Decreased square feet per capita.
    - (b) Central heating, garage and service.

3. **Operative Building versus Owner Client** (construction policy)
    - (a) Minimum requirements.
    - (b) Marketability and style.
    - (c) Selectivity—custom made.

4. **Choosing the Constructor**
    - (a) Competition—skill, integrity, responsibility and experience.
    - (b) Selection—one good job deserves another.

5. **Contract**
    - (a) Standard form—revised A.I.A. 4th edition.
    - (b) Is special simplified form advisable?
    - (c) Lump sum versus sliding fee.
    - (d) Service fee.

6. **Construction Payments**
    - (a) Monthly or semi-monthly.
    - (b) Retained percentage.
    - (c) Interest during construction.
    - (d) Semi-final payment upon use or occupancy.
    - (e) Final payment when due.
    - (f) Guarantee of payments.
    - (g) Financing by construction group.

7. **Scheduling**
    - (a) Sequence of work.
    - (b) Maintaining the schedule.

8. **Purchasing**
    - (a) Quantity discounts.
    - (b) Monthly discounts—pass on to owner if payments are made by owner to contractor by 10th of month following purchase.
    - (c) Credit bureaus.

9. **Inspection**
    - (a) Architectural and engineering.
    - (b) Certified construction.
    - (c) Service by central bureaus.
    - (d) Minimize public and public utility inspection costs.
10. **Twelve Month Construction** (custom, not climate)
    - (a) Seasonal discounts of materials.
    - (b) Seasonal discounts of labor rates.
    - (c) Diversity of leasing dates.
    - (d) Winter protection—fingers and mortar.
11. **Effect of Building Codes and Regulations upon Construction Costs**
    - (a) Urban.
    - (b) Suburban.
    - (c) Fire area limits for frame structures.
    - (d) Zoning—value insurance.
    - (e) Permit charges on value or area basis.
    - (f) New materials.
    - (g) Not to unnecessarily increase cost of construction.
    - (h) Adoption of recommended uniform codes in every community where possible.
12. **Insurance Classification**
    - (a) Liability and compensation.
    - (b) Fire, tornado, earthquake—(proposed new combination policy).
13. **Responsibility of Builder**
    - (a) Prequalification of bidder.
    - (b) Lien law—new model State act.
    - (c) Surety bond for performance and payments by one or both parties to the contract.
14. **Foundation Construction**
    - (a) Bearing value of soils (solid and filled ground).
    - (b) Insuring against uneven settlement.
    - (c) Basement walls, as to thickness and interior finish.
    - (d) Piers versus wall footings.
    - (e) Depth of frost.
    - (f) Waterproofing.
    - (g) Areaways.
    - (h) Concrete form-board marks.

15. Efficiency of Power Construction Equipment

- (a) Possibility of increasing its use at the site.
- (b) Possibility of increasing its use away from the site.

16. Workmanship and Materials

- (a) Classification—grade marking.
- (b) Identification—brand of material.
- (c) Simplification of materials.
- (d) Pride and reputation of builder.
- (e) Craftsmanship of artisans—apprenticeship and trade schools.
- (f) Testing and specifications.

17. Fireproof Construction

- (a) Comparative cost of partial fireproof construction.
- (b) Comparative cost of total fireproof construction.

18. Framework

- (a) Ironwork and metal spandrels.
- (b) Use of miscellaneous and odd length lumber.
- (c) Exterior materials and framing—stucco.
- (d) Interior materials.
- (e) Minimizing first floor partitions due to central heating.

19. Framing Details

- (a) Fire stops.
- (b) Bridging and wind bracing.
- (c) No studs on top of joists.
- (d) Well-seasoned lumber.

20. Lath and Plaster

- (a) Color.
- (b) Finish.
- (c) Number of coats.
- (d) Cracks.

21. Interior Finish

- (a) Wall board.
- (b) Paper.
- (c) Curtain partitions.
- (d) Interior finish.

22. Prefabrication
- (a) Shop fabrication of certain units.
- (b) Shop fabrication of whole houses.

23. Overhead
- (a) Job or field superintendence.
- (b) General—office and coordination.
- (c) Sales and distribution.

24. Margin for Contingencies
- (a) Fair amount.
- (b) Definite and clear specification.
- (c) Quantity survey.
- (d) Cash allowances.

25. Profit
- (a) Commensurate with risk and service.
- (b) Unwarranted.

I. Building Practice

(a) Sound and Durable Construction. As a result of its investigations, the Committee on Construction feels that the cost of dwelling house construction in a great many cases can be materially reduced if the builder will follow the many good practice recommendations which are already available through publications, and take advantage of every approved method which has been developed through scientific research. It is quite evident that the best practices are not being followed in every case, as is illustrated by the continuous use of methods which years ago were found to be obsolete. Fortunately, however, there are many builders today of the more progressive type, who take advantage of every opportunity to produce sound and durable construction, which has been found by experience to be the most economical in the long run.

It is the opinion of some prominent builders that often considerable time, and therefore money, may be saved by those in charge of the preparation of plans and specifications, in the selection of builders and the awarding of contracts, especially after the improvement has been determined upon. With a little more concentrated effort these details could be accomplished in less time than is usually taken, and the dwelling made available for occupancy at an earlier period.

The members of the committee believe that in order to obtain more widespread confidence in the soundness of home building in general, the builders must strive to produce a structure which will embody all of the desirable features of good construction that have been developed to date. The district in which a house is located, as well as the house itself, should be well planned, and in these matters attention is directed to the reports of the Committee on City Planning and Zoning and the Committee on Design, constituting Chapter I of Volume I of this series and Chapter I of this volume, respectively.

The committee feels that for the building industry to function better, there should be proper coordination between the various groups represented in it. This result might be accomplished through weekly or monthly conferences, which would stimulate interest in the development of new ideas. It is apparent that these several groups have been thinking too much of their own interests instead of working together for the good of all. It is essential that an attempt should be made to bring all home building groups closer together in order to stabilize home construction.

The committee realizes that, at present, houses are not produced so efficiently as automobiles, and the members are of the opinion that the building industry may learn a lesson in the reorganization of its processes by a study of the automotive industry. However, in quantity production of homes, due consideration must be given to variety and individuality, as is done in the automobile industry. If automobiles had been built in the past with the same lack of coordinated effort as is still practiced in some home building operations, the automobile industry would long ago have had to confine itself to the limits of a luxury product or abandon its efforts. The same is true of every other successful large-scale producing organization.

In the matter of construction details, the committee has not had sufficient opportunity to conduct extensive research. Houses that are built improperly often show evidences of failure, such as wet basements, bulging walls, squeaking stairs, creaking and sagging floors, shrunken trim, cracked plaster, draughty or rattling windows and doors, leaky roofs, and other defects too numerous to mention. It has been found that such failures can be traced to one or more of the following causes:

Insufficient footings.
Poorly constructed foundations.
Lack of drainage facilities.
Poor mortar joints.
Inadequate sizes and wide spacing of joists or rafters.
Improper nailing throughout.
Failure to provide full bearing areas.
Lack of proper bridging and bracing.
Omission of fire stops.
Lack of, or improper, flashings around openings.
Frail construction over openings.
Careless nailing of floors.
Unseasoned lumber.
Inaccurate cutting and improper fitting.
Faulty construction around chimneys.
Improperly designed roofs.
Poorly designed gutters.
Wrong kind of nails for roofing.
Use of building papers of inferior quality.

There are many splendid publications already available pertaining to good construction practice. The Building Code Committee of the Department of Commerce has performed a very valuable service during the past ten years in formulating recommendations for sound building construction. Seven reports have been published to date, four of which have a direct bearing on dwelling house construction, particularly the one entitled "Recommended Minimum Requirements for Small Dwelling Construction." In this report the most desirable methods of framing for stairways, over door and window openings, around chimneys, etc., are described and illustrated. Good practice recommendations, such as diagonal sheathing and subflooring, bridging and bracing, fire-stopping and correct methods of attaching joists and rafters to various types of walls, are also described. The committee is confident that if the recommendations set forth regarding methods and workmanship are carefully practiced, satisfactory results will be obtained.

Builders should remember that local building codes are legal *minimum* requirements from the viewpoint only of public safety. Good business practice proves that good construction builds reputations as well as structures.

Other publications which have come to the attention of the committee and which contain suggestions for first class construction are:

"Light Frame House Construction," containing technical information for the use of apprentice and journeyman carpenters, issued by the Federal Board for Vocational Education in cooperation with the National Committee on Wood Utilization of the Department of Commerce.

"Building and Loan Construction Standards," containing specifications for residence building, by John M. Wyman, Associate Editor of the American Building Association News, and a member of this committee.

"Good Practice Specifications for Building Construction," described as an authoritative guide for the protection of the builder or purchaser of a home, and prepared by the Construction Industries Division of the Better Business Bureau of St. Louis.

"The High Cost of Cheap Construction," published by Weyerhaeuser Forest Products, a well known lumber organization, which explains in detail the importance of right construction in house building.

"Standard Pocket Guide to Good Construction," by Arthur C. Holden, A.I.A., 670 Fifth Avenue, New York, N. Y., a member of this committee.

"Wood Construction," prepared by National Committee on Wood Utilization of the Department of Commerce, McGraw-Hill Book Company, Inc., New York, N. Y.

Many of the national material trade associations have published much helpful and interesting information relating to the proper uses of their products, which should be consulted when building a house. The Division of Building and Housing of the Bureau of Standards has compiled a list of such publications, known as Letter Circular 287, which is intended to be of assistance to home owners, home builders, and others interested in materials, equipment, and practices employed in dwelling construction. The list in question is entitled "List of Published Material Relating to Home Building and Maintenance."

(b) Estimating, Contracts, Cost Accounting, and Scheduling of Work. The committee finds that comparatively few builders use regular standardized forms for detailed estimating, contracts, cost accounting, and job scheduling.

It is recommended that complete standardized forms should be used to record original estimates and actual detailed costs in order to arrive at a definite comparison. This information, combined with past experience, enables the builder to establish an intelligent sale price. It is also advisable to use a good standard form of contract. As a suggestion, the revised form of the American Institute of Architects, 4th edition, is one which has been recognized by the courts. The "lump sum" contract basis is usually preferable to the "sliding fee," but the "service fee" is considered by many builders as the most equitable. Specifications should be clear and definite so that the margin allowed for contingencies need not be excessive. The changing of certain details in plans from the original, during the course of construction, often adds considerable overhead to the cost, and should be avoided where possible. A profit commensurate with the risk involved and service performed should be added to the estimate.

Among those who have compiled comprehensive form data relative to the above are: L. Brandt, Housing Engineer, Pittsburgh, Pa.; The Associated General Contractors of America; the American Institute of Architects; and other organizations.

Many job superintendents arrange the work as it progresses. On individual structures this method may be satisfactory, but in group operations it is necessary to plan in advance and to maintain a definite schedule in order to complete the work on time and to control costs.

The various trades should move along in sequence without interruption, and all necessary materials should be on hand at the proper time to avoid delays. All concealed features, such as piping and wiring, should be placed at the proper time so as to avoid subsequent cutting and fitting. Each trade should complete its work, if possible, the first time on the job in order to avoid disrupting the schedule and to save the expense of returning. Work planned and executed carefully in accordance with these suggestions will effect considerable saving in time of completion and in ultimate cost. It has been suggested that a job might be carried on more continuously if it could be so arranged that the various labor groups could stagger their weekly "day off," so that the entire job, including equipment, need not be idle on Saturday.

(c) Reducing Construction Costs. Costs of construction can be materially reduced as new developments are adopted. Uneconomical practices and customs in building must be avoided if progress is to be made and construction costs cut. It is impractical to expect to follow obsolete methods and produce a modern home at moderate cost. *Comfort and custom* are not synonymous.

The elimination of certain sections of the house, and particularly of needless parts, might be effected and result in savings. The basement and the attic are two parts which might reasonably be omitted. It is evident that many of the original needs for these portions no longer exist or are rapidly disappearing. The introduction of improved types of heating, laundry facilities, and insulating materials has made it possible to install such equipment in a smaller space, adjacent to the house, and to provide proper temperatures in the upper parts of the house by employing scientific insulation methods. Back stairs, a number of interior partitions and doors, which were necessary in the days of individual stove heat, may now be omitted as unwarranted expense.

Cellars may or may not be wholly or partially eliminated. In either case the foundation walls may be built of good quality building units, monolithic concrete, or stone masonry. In any case the outside wall should be waterproofed. The depth of foundations and footings depends upon the depth of frost penetration, which varies throughout the country. On filled ground, piers and reinforced girders may be used instead of carrying footings to solid ground. The use of precast foundation building units eliminates form building and wastage of materials and is, therefore, an important saving. Good ready-mixed concrete may also offer opportunities for saving.

Group construction operations in which good architecture is featured have been shown to be more economical per house than single operations. In this case the operative builder can effect savings in the development of site, quantity purchases, and architectural services and supervision. As a result, many operative builders feel that they have an advantage in costs and quality over an individual.

In the selection of a building lot it is important to consider its advantages and disadvantages. Some of the items to be considered are: Whether or not the ground has been newly filled and not compacted; what the conditions regarding grading may be; and whether or not provision has been made to take care of ground water, street widening, sewers, water and gas, sidewalks, street and alley paving, public utility power lines, transit facilities; zoning; private restrictions; etc.

The first item in actual construction is excavation. The use of power excavators in group house construction saves considerable expense over single unit construction.

Stock sizes of lumber and the amount of cutting necessary should be considered in determining room dimensions. This consideration applies also to framing, doors and windows. The use of short length lumber should be investigated as well as the use of standard brands and grades.

Consideration should be given to location of bathrooms and kitchens with a view to reducing length of piping as much as possible. The same principle applies to the location of heating units.

Where lath and plaster costs are excessive, substitutions may be made by using high grade wall boards, well applied and covered with a colored finish plaster, applied direct and textured. This treatment may produce a permanent and sanitary wall surface, saving the cost of papering or painting at frequent intervals. Spray painting of walls will grow in favor as equipment and painting materials are perfected. Plywood panels, which are made in wall-board or larger sizes, which can be stained or papered over, may also be used for finishing walls where strength and economy are desired.

Prefabricated kitchen units for which space has been accurately designed, and standardized bathroom fixtures, are also available.

The central heating plant, by which a group of houses or possibly a whole block may be heated, is now being more commonly used than ever before. It is possible that a central heating plant may some day be as common as sewers, water facilities, and other group-serving conveniences with a considerable saving in cost. It has been pointed out that the piping of such plants could be installed in a common trench with other pipes, thus reducing the cost of original excavation and subsequent repairs. Air conditioning for homes is likely to grow in favor as the costs of installation are reduced.

In large operations it has been found highly profitable to segregate labor and material costs. Contracts can be made with craftsmen for labor only, and the builder himself can buy all materials on a quantity basis. This purchase eliminates all subcontractors' profits on materials furnished, and the builder, buying direct from manufacturers or jobbers and taking discounts, can save money. This method, of course, requires closer supervision if the advantages mentioned are to be secured.

If it were possible to get away from custom and tradition with regard to many features of house building which under present-day conditions are of little value, and to adopt methods which have proved to be more satisfactory, the cost of production could be materially reduced and the completed house turned over to the owner in at least one-third less time than has formerly been required. As more low-priced quality homes are built, sales will increase.

(d) Labor-conserving Methods. The use of labor-saving equipment and devices is more practicable on large-scale operations than on small ones. Power excavators, when used on large-volume jobs, effect a saving of 50 to 75 per cent, but are not as yet generally used on small jobs. In individual dwelling construction, it has been found that the various types of equipment are used by few builders. However, floor sanding machines are used extensively, and at a saving of 10 to 50 per cent over sanding by other methods. Contrary to the general opinion of many outside the building field, portable forms, ready-mixed concrete, plaster mixers, power drills and paint-spraying equipment are used comparatively little, even on large-scale building operations. Many builders have stated that they can mix concrete on the job at less cost than they would pay for ready-mixed concrete. It has been found that power saws have been used in about one-half the cases investigated, and at a saving of 10 to 50 per cent. Those not using such equipment have stated that lumber may now be procured cut to any required length, which, of course, results in conservation of labor on the job. The smaller types of labor-saving equipment are found most advantageous when the work is so planned or is of such a nature that the equipment is almost constantly in use.

(e) Promoting Good Standards of Workmanship. The home buying public should be better acquainted with the details of good construction in order better to judge the product which is being purchased. It is evident that few people examine the quality of a house in the same manner that they would investigate an automobile, in spite of the fact that a house represents a much larger investment and is often the largest purchase of a lifetime. The building industry should carry on more extensive educational campaigns in which the qualities of construction are particularly stressed.

If every potential home buyer knew as much about house construction as he knows about the other products he buys, the standards in building practice would automatically rise.

Too many buyers are attracted by "appearances" and pay little attention to what lies beneath. Attractive bathrooms and kitchens will in many cases do more to sell a house than construction of good quality, because they are the features which the sales organization demands of the builder.

In present-day real estate advertising, great stress is usually laid on the location of the property, the character of the neighborhood, the exterior appearance of the house, and the many built-in features. While these are necessary features for a home buyer to consider, it is exceptional to find any reference made to the equally important matters of character of construction, the quality of materials, or the length of time for which the builder is willing to guarantee his product.

In connection with the matter of educating the buyer, governmental and other agencies have been striving during recent years to point out the desirable features of house construction. The Department of Commerce, through the Division of Building and Housing and the National Committee on Wood Utilization, has issued various pamphlets designed to guide the prospective home owner in selecting and judging a house. Many national trade associations have also contributed largely to the campaign. Better Homes in America, with local representatives throughout the country, has done much to promote home ownership on a sound basis. Better business bureaus in various communities and inspection bureaus sponsored by lending agencies are awake to the fact that more education in home buying is necessary and are doing their part in encouraging better standards in both workmanship and materials.

(f) Informing Builders, Foremen, and Mechanics on Modern Methods. In order to obtain first class construction it is essential that all engaged in the business of building houses should be currently well informed regarding the best principles and current practices in their field. It becomes evident, after examining the workmanship in many cases, that those responsible have not kept abreast of the times and have followed methods which experience has shown are not the best.

Some of the leading trade associations have done admirable work in educating foremen and mechanics in the properties and uses of certain materials. One association in particular has, during the past ten years, been active in presenting to those who use their material, the best information on how to obtain satisfactory results. Their program included a series of conferences to which those interested were invited. Meetings were held in the principal building centers and were timed to reach builders when they were least busy. Through lantern slides, motion pictures, large photographs and drawings, the construction details of a house were shown. Booklets giving construction details, specifications, and other information based on approved construction methods were furnished and further information was mailed upon request.

Another effective plan used was to send around an expert mechanic to demonstrate to gatherings of mechanics and foremen the latest recommended practices in applying a certain kind of material.

As a result of these meetings it is reported there was a decided awakening of interest, especially on the part of the mechanics, in the importance of doing quality work. The demonstrations helped a movement that was under way, designed to encourage mechanics to exert a definite effort to see that each job used satisfactory materials and was constructed in accordance with approved specifications. The fact was emphasized that pride of workmanship is vital. Every craftsman should perform his job to the best of his ability. When he does so, his work is appreciated and he is more steadily employed.

Many national organizations have prepared handbooks and other publications which should be more extensively used, including the publications listed under the discussion of sound and durable construction, page 61.

To encourage better craftsmanship the committee suggests that some form of recognition be given to workers on the job. It may be in the form of a prize or a bonus. This practice is being followed rather extensively in the construction of large buildings and, where used, the results have justified the effort.

It has been found that the men prize such awards very highly and are grateful for any recognition of their ability. The introduction of competition between workers not only produced better construction but resulted in greater output. It is thought that, as the men themselves are the best judges of good workmanship, they should be represented on award committees.

The New York Building Congress, which has been sponsoring such a movement in connection with the erection of important buildings in metropolitan New York, in its pamphlet, "Recognition of Craftsmanship," says:

> "The first step in the revival of the spirit of artisanship is to single out and to honor the workmen who excel in the various trades. The craftsman is distinguished by his love of good work for its own sake and for the character-molding values of integrity, thoroughness, intelligence, reliability, loyalty and cooperation. Men with these attributes are still to be found in the building industry. They are entitled to public recognition and to the satisfaction of knowing the building industry appreciates those who carry on the best traditions of the trade; moreover, they are good citizens."

Apprenticeship training is also suggested as a means of insuring future good workmanship. In one large city apprentices must take a four-year course of training, which requires attendance in evening school two nights per week, two hours per night. The work in these schools includes a definite training program for the following trades—bricklaying, carpentry, electrical, painting and decorating, plastering, and plumbing. Seven hundred to eight hundred young men each year are graduated into the ranks of journeymen from this training. In some instances representative advisory committees of employers, labor and the public trade schools are utilized by public boards of education to furnish practical suggestions concerning the local apprenticeship program.

(g) Winter Construction. With present-day methods, modern facilities, and heating appliances, cold weather construction can be carried on without much interruption or serious delay. The expense involved in protecting winter work against the weather is comparatively small and is in part offset by lower prices of materials and labor.

Some of the leading national trade associations have done considerable research work in connection with winter construction and have carried on extensive educational campaigns in an effort to point out the advantages of year-round operations. Efforts to induce the prospective home owner to build when he is ready rather than when everyone else is ready, have been effective. In 1924, a committee of The President's Conference on Unemployment made a study of the subject of year-round construction and published an interesting report entitled "Seasonal Operation in the Construction Industries." As a result of its investigations this committee found that the stoppage of winter work was due to *"custom rather than climate."*

Many builders who had been obliged to complete their work during winter weather discovered methods of a simple nature which helped them to overcome the physical obstacles. The use of mechanical heaters (for water and aggregates), salamanders, and simple chemical compounds allows the safe pouring of concrete even in zero weather. If the heating system in a house is installed as soon as possible, interior work can be carried on more efficiently during cold weather. These methods have become fairly standardized and the expense involved is comparatively small. Other suitable means of protection to labor and material are inexpensive and allow the work to continue with little interruption.

In some sections of the country where it is the custom to have only one renting or leasing date in the year, we find that operations are more seasonal. In these cases it would be advisable to change the system to have at least two or more dates, so that builders would be encouraged to extend their operations to conform to these various dates.

Construction work is always considered a very important phase in the industrial life of any community and all attempts possible should be made to eliminate seasonal fluctuations, and thus benefit not only the home building industry but the country as a whole.

Recommendations

(a) Sound and Durable Construction. The committee recommends that in order to insure a well-built structure and to avoid construction detail failures, such approved practices as are previously mentioned should be strictly adhered to. There are many publications available, pertaining to good construction practice, which should be used. Much wider application should be made of the more standardized existing data which are available through manufacturers, government and educational organizations, relating to use of new construction materials and methods.

Intensive educational work is required to bring these facts to both builders and prospective owners. Continued research on construction standards by an impartial group is eminently desirable.

(b) Estimating, Cost Accounting, and Scheduling of Work. Quality construction results are accomplished through intelligent cost information. It is therefore recommended that complete standardized estimating and cost accounting forms similar to those previously mentioned in this report should be used. A reasonable profit is necessary to the builder and 100 per cent value is due the owner.

It is also recommended that the work of all crafts be scheduled and coordinated so that the particular job of each may be completed in as short a time as is practical.

(c) Reducing Construction Costs. The reduction of construction costs is foremost in the minds of all who are interested in the building of homes in the lower-price range. The committee therefore recommends that particular attention be directed to the elimination of uneconomical practices and customs and to the acceptance of new developments in materials and methods when they have proved worthy. The following topics should be especially considered from the point of view of effecting economies: The simple plan *versus* the complicated plan or design, coordinated with materials; elimination of cellars and attics; type of foundation; room dimension to meet stock sizes of lumber; standard framing, doors and windows; location of bath and kitchen so that short length of pipe may be used; efficient placing of heater;

lath and plaster *versus* wall board; spray painting; prefabricated construction units and interior fixtures; elimination of back stairs; a smaller number of interior partitions; possibilities provided by central heating plants; elimination of false appurtenances including false fireplaces and gables; and the use of well-seasoned lumber throughout.

Builders should emphasize the statement "comfort and custom are not synonymous." "Taking the walking out of cooking" saves initial expenditures and energy thereafter.

(d) Labor-conserving Methods. Although there are many kinds of labor-saving equipment available, many builders do not make use of them, partly because they are considered impractical for their particular job and partly because of insufficient knowledge of the results to be obtained. The committee recommends that builders study costs and results of the use of such equipment, especially for large group operations. It is important to have efficient coordination between trades and trade processes. The necessity of cutting and patching should be reduced to a minimum.

(e) Promoting Good Standards of Workmanship. Through educational work the home buyer may become more familiar with good construction and should not be guided in the purchase of a house by consideration of the accessory equipment alone. The committee recommends that impartial home information centers be encouraged in all communities, where reliable information can be obtained locally. In this connection attention is directed to the report of the Committee on Home Information Centers.[1] Local home shows and exhibits, not highly commercialized, should be arranged by civic groups to specialize on education in quality as well as style and comfort.

(f) Informing Builders, Foremen, and Mechanics on Modern Methods. Builders and architects should cooperate in disseminating information relative to community and home planning. In order to familiarize builders and craftsmen with the most modern methods of construction and the use and application of new materials, the committee recommends that educational

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[1] See "Homemaking, Home Furnishing and Information Services," *Publications of the President's Conference on Home Building and Home Ownership,* Washington, 1932, Vol. X.

movements sponsored by manufacturers and associations be continued and extended to include all kinds and types of materials and processes. Trade schools under the jurisdiction of labor groups should be established in every community, where interesting courses on best trade practices would be given. It is also recommended that home building courses be included in the curricula of architectural, engineering, and cooperative technical schools.

(g) Winter Construction. In view of modern methods, considerable economies are possible by the universal adoption of twelve month construction operations. The committee believes that "winter work is worth while" and recommends that it be given careful consideration in each building operation. It also suggests that the promotional work of various manufacturers and trade organizations be continued and extended; and that the matter of leasing dates be investigated by local authorities with the view of encouraging such changes as will be most beneficial to the community.

II. Building Materials

(a) Identification, Standardization, and Simplification. Grade-marking, trade-marking, and other means of identifying good grades of materials are of commercial value to both buyers and sellers. Much progress has been made during recent years in developing standards of quality and quantity. When they are more widely adopted, they will constitute an important factor in insuring quality construction at reduced cost. The use of nationally known material and equipment increases the prestige of homes and is an outstanding factor in promoting their sale. Many products and installations are identified by licensed trade marks which are either stamped on the material itself or attached to the structure in which installations are made.

These products include lumber, brick, hollow tile, and wall-paper, also such installations as electrical wiring, and piping. Certificates are furnished by recognized organizations indicating that the installation conforms to standard specifications. The Bureau of Standards of the Department of Commerce, through its Divisions of Simplified Practice, Specifications, and Trade Standards, has contributed largely to the progress in these fields. This bureau should have the active cooperation of all research groups in the building industry.

The Division of Simplified Practice cooperates with industrial and commercial groups to reduce waste, usually through eliminating unnecessary variety of product, method, or practice. An address by Edwin W. Ely, Chief of the Division, given before an annual convention of the National Association of Builders' Exchanges, describes what simplified practice has done for the construction industry, and what the possibilities are for future activity along these lines.[2] Specific recommendations, covering building materials, appliances and equipment and items of occasional interest in connection with building, have been published by the division from which information thereon may be obtained.[3]

The Division of Specifications is engaged in promoting and facilitating the use and unification of specifications. In doing so, it carries on activities involving cooperation with technical societies, trade associations, Federal, state and municipal agencies, producers, distributors, and consumers, and testing and research laboratories. It compiles and distributes lists of sources of supply of materials guaranteed to comply with the standards and specifications. It shows both the buyers and the sellers the benefits of handling nationally specified, certified and labeled commodities. Many materials and various equipment used in building construction are now covered by standard specifications, and it is hoped that eventually all such items will be included. Information regarding the methods and accomplishments of these activities may be obtained from the division, including a description of the certification plan, its application to Federal specifications and commercial standards, and comments regarding the adoption of the use of quality labels by national associations.

The Division of Trade Standards, on request, assists industrial and commercial groups in the voluntary establishment of standards covering grades, quality, dimensional interchangeability, or other acceptance criteria as a national basis for marketing manufactured commodities. Industries are encouraged to apply self-certifying

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[2] "What Simplified Practice Has Done for the Construction Industry up to This Time," 1931. (Mimeographed.) Division of Simplified Practice, U. S. Bureau of Standards.

[3] Inquire Division of Simplified Practice, U. S. Bureau of Standards.

labels to products meeting the commercial standard requirements, as a means of protecting the consumer and the scrupulous seller from misrepresentation. Many commodities used by the building industry are included in the list of available commercial standards published by this division. A pamphlet entitled "The Commercial Standards Service and its Value to Business" is also available.[4]

As an added protection to the owner, and for future public information, title companies should add to their service a complete history of the house. There should accompany every title report to a new house, copies of the plans and specifications; the names of the architect or designer, general contractor and subcontractors, and material dealers. In case the title company should prefer to keep this file, a certificate thereof should be issued. Knowledge of the foregoing data enables the owner to satisfy himself as to whether or not he has received full value for his money.

(b) Economies of Prefabrication. That much manufacturing is still being done on the job, which could now be done more advantageously in a mill or factory at less cost, seems obvious. During recent years, considerable progress has been made in the fabrication of parts of a house away from the site. In connection with prefabrication the question of standardization is of vital importance. In order to establish prefabrication on a paying basis, the dimensions of parts of the house where such units are to be used will have to be standardized, in order that the manufacturer may confine himself to as few stock sizes as possible and be assured of a market for his products.

A number of builders were consulted regarding the possibility of using prefabricated windows set in frames completely fitted, weather-stripped, screened, and with window brackets attached; doors fitted to frames, with hardware in place; and stairs in complete units. In answer to these inquiries most of those consulted said that they were not using such units and many were of the opinion that under present conditions such procedure is not feasible.

A few builders, however, stated they were using prefabricated windows, doors, and stairs, and in so doing were able to save labor

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[4] Commercial Standard CSo-30, Washington, Government Printing Office, 1930, price 10 cents.

and complete the job in reduced time. These builders added that the factories were more efficient in producing these parts and that better workmanship was assured at the mills. On the other hand, many claimed that each of these items required special attention on the job. A number agreed that material of this kind is too costly at present, but thought that under mass production it might be turned out at a lower figure.

A few contended that prefabricated fitted windows set in frames were not as yet entirely satisfactory, as often they did not fit properly, especially during changing weather conditions. Attention was called to the use in some instances of metal frame and sash, especially that of the casement type. These types can be had completely screened.[5]

In regard to doors completely fitted, some contended that the openings not being standardized, they could not be produced in mass until standards had been set, and that a proper selection could not be made from such doors as are produced at present.

The prefabrication of stairs seems to be a difficult problem according to most of the builders consulted. Owing to the difference in plan layout encountered at the present time, it was thought that few standard stair sets as now manufactured could be used. In all the foregoing units well-seasoned lumber should be insisted upon.

From a number of builders consulted it has been learned that the sale of their houses has been noticeably affected by the installation of an increased proportion of prefabricated interior furnishings. They are produced more satisfactorily and economically at the mill. This same practice might well be applied to other parts of the house through standardization. When every possible unit is produced in mass, the cost of building a house will be substantially reduced.

Shop fabrication of whole houses is now being studied extensively, but apparently no definite practical units have been developed as yet. The present tendency toward individuality would limit the sale of shop fabricated houses, except in industrial centers. Some of the factors which might tend to control the extent

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[5] Mr. Homer W. Ballinger, a member of the committee, dissents on the grounds that "cheap steel casement sash frames and screens are not satisfactory on account of cost of upkeep, painting and replacement."

to which the method will be developed are design, production, and distribution.

(c) Elimination of Waste in Distribution, Cutting and Fitting. Where manufacturing of building units is done on a large scale, materials can be purchased in car load lots or similar large quantities. The finished product can then be delivered to the site, instead of being produced on the site from different kinds of materials all hauled separately to the site and there combined, as at present. It is possible to effect a considerable saving in the cost of construction by the former methods. Ready-mixed concrete is one example of how all materials might be assembled at and delivered from a central plant. Ready-mixed mortar for masonry and premixed hard wall plaster have also proved feasible and economical in many cities where these plants are available.

During recent years a large proportion of the former waste in cutting and fitting lumber has been eliminated through adoption by the lumber industry of standard dimensions of length, width, and thickness. The use of standard sized lumber, squared on all sides and ends with guide lines, has made it possible to construct houses with a minimum amount of sawing. End-matched (tongued and grooved) lumber is also produced. Short and odd length lumber can be procured at lower prices, but it has been found that many builders prefer standard length lumber in order to reduce labor in handling, placing, and cutting on the job, unless the various lengths are classified, handled, and marked separately.

Many builders experience great annoyance in construction due to their inability to obtain properly seasoned lumber. This material is obtainable at a slightly increased price from the mills, but material dealers have not made a general practice of carrying it in stock, because of insufficient demand on the part of the contractors.

The National Committee on Wood Utilization and the National Lumber Manufacturers' Association, together with the Commercial Standards group of the Department of Commerce, have accomplished commendable results in reducing waste in the use of lumber.

Other materials, especially masonry building units, are being standardized as to size, and wall boards and other finishing materials may now be had in sizes to fit stud and joist spacing.

In the design of buildings these facts should be borne in mind in order that full advantage may be taken of adopted sizes which have proved practical.

(d) Purchase and Discount of Materials. Many material dealers, as a result of losses caused by the failure of certain purchasers to settle their accounts promptly, are forced to add a certain percentage to the average price of materials to cover such losses. Thus the reliable builder who pays his bills regularly is often obliged to bear a share of the added cost burden.[6]

Fairly successful credit bureaus have already been established in many of the larger cities. It is evident that in many cases material men are too lenient with credit to irresponsible builders, or sponsor financial assistance themselves, and that it would be desirable to regulate this practice. Credit should be given to builders only when it is commensurate with their moral and financial responsibility. It has been found that the loss to material dealers through unpaid accounts is in excess of 1 per cent, with ratios up to 5 per cent not uncommon.[7]

Many reliable builders, when operating on a percentage or fee basis, pass on the saving obtained through discounts on material purchases to the owner. This is a commendable practice and one which should increase confidence in the industry.

Seasonal discounts on material are not so much a factor as they might be in many localities, but it has been found that in some sections supply and demand cause certain material producers to

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[6] Mr. W. W. Campbell, a member of the committee, believes this statement carries a false impression and protests its inclusion here. He states that a thorough canvass of the leaders of the building supply industry, who handle many of the large accounts with many of the large contractors over the country, fails to reveal knowledge of a single case where the price of any commodities has been raised a certain percentage to cover previous losses.

[7] Mr. H. C. Thomson, Executive Secretary, The Lime and Cement Exchange, Baltimore, Md., also objects to the statements in the two foregoing paragraphs regarding the practice of raising the prices of material, and the loss from unpaid accounts. He further states that a survey conducted by the Bureau of Business Research, Harvard University, revealed that bad debt losses of building material dealers did not average more than 1.1 per cent.

give discounts to dealers in an effort to keep their labor employed throughout the year.

If a higher percentage of construction could be carried on during a twelve-month period, material manufacturers and dealers could operate more economically and as a result could sell their supplies at lower average prices. Several prominent educational associations have helped to increase winter construction through their various publications.

(e) Storage and Handling of Material at the Site. Of the builders consulted it was found that the great majority order their material to be delivered as needed. One large operative builder, however, reported that he ordered some material and stored it on the job for periods ranging from ten to thirty days. A few others stated they stored some material from two or three days to a week before using it. It was found that the loss of materials from the job was negligible, owing in most cases to the employment of a watchman.

Responsible builders generally take advantage of the discount on materials, but do not always allow for it when they are considering costs. Some still find it advisable to take advantage of the improved facilities for prompt deliveries and have the material delivered just prior to the time it is to be used.

For a large operation it is often practicable to have certain materials delivered in large quantities, but for a single dwelling job the quantity must necessarily be controlled more definitely. If plenty of space is available, rough materials might be delivered when the supply dealer finds it most convenient, thus insuring against delays. It is important that when materials are received at the job, they be piled and arranged in proper sequence of use in order to minimize rehandling and the distance they are to be carried.

(f) New Materials and Methods. Coordinated research in regard to the adaptation and production of new materials for use in the building industry is of utmost importance. This should be carried out not only in isolated fields involving particular materials, but full consideration should be given to the relation of one material to the other, and to their functional value. In the simplification of the process of building, methods of production both in the shop and at the job should be carefully studied with a view to their improvement. The building industry should learn its lesson from the automotive industry through the reduction of the cost of its product and its continual improvement through modern methods of production organization. All elements in the building industry should cooperate to this end and should keep each other informed. The marketing processes of operative builders should be improved so that the public may enjoy the full benefits of those methods of quantity production which are already in operation.

(g) New Types of Houses. The design of houses should be carefully studied and research carried on so as to adapt the latest materials and methods and coordinate these with the production of more efficient and more desirable homes. New methods of fabrication will undoubtedly have their effect upon the cost of the home as well as upon its appearance. The committee is not prepared to prophesy whether or not the completely shop fabricated house will be evolved to take the place of the present type of house. The purpose of efficient design should be the production of desirable neighborhoods and communities. Efficient design will be ineffective if limited to the consideration of the individual house.

(h) Fireproof Construction. In recent years, increased attention has been directed by architects, contractors, material manufacturers, and insurance companies toward fireproof and fire-resistant construction. Developments of detached, and especially row houses, are now built wholly or in part of masonry. Building code requirements demand certain general practices to insure against fires.

Concrete, steel, brick, tile and other masonry materials perform certain functions in house construction. For example, it may occasionally be found that in the type of houses here being considered, the first floor consists of a four-inch reinforced concrete slab.[8] Upon this wooden sleepers are used, to which the finished

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[8] Mr. Homer W. Ballinger, a member of the committee, states that the concrete slab costs a great deal more than wood joists and causes delay in construction. He also believes that practically the same fireproofing results can be obtained by the use of metal lath and plaster over the joists in the basement ceiling.

floor is nailed. Masonry side and party walls of brick, tile, concrete, cinder block, etc., are more generally used in constructing row houses.

Plastering direct on properly prepared masonry walls, or a good metal lath or plaster job where the lath is practically imbedded in mortar to other incombustible base is considered by some as fire-resistive construction, although for other reasons it is generally considered better practice to fur such walls. In the type of house to which major consideration is here directed, wood floor beams are usually used, but recently there have been introduced for residential construction steel and reinforced concrete beams. There are also available on the market for use in residential construction, should the home owner desire to obtain them, metal sash frames and windows.[9]

In some styles of architecture exposed wood is eliminated at cornices and eaves and a suitably designed low parapet of incombustible materials carries the run-off from the roof. Slate, tile, and cement asbestos roofs add materially to fire protection. However, there are some high quality composition roofings which are considered fire-resistant.

For the interior construction, an incombustible felt between the two board layers of a floor adds appreciably to fire resistance and smoke tightness. Floor members above the furnace should be protected with some fire-resistant plaster boards or asbestos board to prevent fires resulting from overheated or defective pipes. This application may be extended over the entire ceiling of the cellar where a wooden first floor is used. Walls, ceilings, and floor finishes are the first to receive the attack of fire from interior origins. Wood and combustible fiber board finishes can be made

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[9] One member of the committee, Mr. Ballinger, believes that the use of steel columns and beams for floor supports increases expense out of proportion to the results obtained. He states that wood timbers are very slow burning and, when only partly burned, can be repaired. He believes the application of fireproof paint, which is now available, to wood columns and beams would eliminate any dangerous fire hazard. As regards metal sash and frames, he states that those which compare favorably with wood in lasting qualities are much more expensive than wood, and their use entails architectural considerations. He considers windows are not a serious fire hazard except where a fire is confined to the inside of a building, and glass set in wood is not subject to breakage because of expansion of the frame.

less flammable by application of fire-retardant paint, whitewash, or calcimine.

The Building Code Committee of the Department of Commerce has recently issued a report entitled "Recommended Minimum Requirements for Fire Resistance in Buildings" which should be of interest to all builders. A pamphlet entitled "Fire Resistant Dwelling Construction" by Mr. S. H. Ingberg, Chief, Fire Resistance Section of the United States Bureau of Standards, gives results of many tests which are of commercial value.[10] There are many interesting reports issued by various manufacturers covering the fire-resistant qualities of their materials.

(i) Insurance. In the construction of a house it is important and desirable to adhere to specific requirements of the local board of fire underwriters. Certificates of guarantee and approval covering electric, heating, and gas installations should be insisted upon from the builder. If this practice could be made a general requirement in large communities and cities, more favorable insurance rates might be obtained.

It is also to the owner's advantage to be covered by a combination "all-risk" insurance policy including fire, tornado, earthquake, explosion, and similar protection covering loss or damage however caused. This should be arranged for as soon as the stage of construction is reached where such protection is needed.

The builder should at all times satisfy himself that he has met state requirements with reference to workmen's compensation insurance and any other liability insurance required in order to afford complete protection to the owner.

(j) Corrosion. Corrosion depends on two conditions, one being the corrodent and the other the material corroded. The nature of the corrodent is a widely varying factor throughout the country. In the use of metals in house construction special attention must be given to the different locations and conditions involved.

Roofing materials that give satisfactory service under suburban conditions may be very short lived under industrial or seashore conditions. Copper, zinc, and aluminum are the common nonferrous materials used as shingles and as sheets in gutters, valleys,

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[10] See *Journal of American Insurance,* July, 1929.

flashings, etc. In heavy industrial atmospheres, zinc and aluminum would be attacked, and copper has been reported as having failed where a combination of marine and sulphurous atmosphere prevailed. The life of these metals can be materially improved by painting or, in the case of copper, by lead coating. The life of galvanized metal is determined by the weight of zinc coating and the gage of the sheet and it should therefore be kept well painted.

Metal window casements are becoming more popular even in low-priced houses. Those being made of iron and steel should be painted with special corrosive-resistant paint to insure satisfactory service. For weatherstripping, zinc, bronze and aluminum are commonly used. For finishing hardware, brass and brass-plated steel may be used without increasing costs. Plated hardware is not to be recommended for outdoor or other places where exposure to the weather subjects the metal to corrosive conditions.

The character of the water supply should be the final determining factor in the selection of the kind of piping to install. The choice between a ferrous pipe and copper, brass or some other nonferrous pipe depends upon the degree of corrosion resistance required.

In the nonferrous class of building materials, aluminum is fast becoming a real competitor with copper, zinc, and other materials. Since all ferrous materials corrode they must be protected by metallic coatings or paint. Corrosion-resistant or stainless steels are still too expensive to be considered for ordinary house construction except in very limited amounts. However, labor costs should be approximately the same regardless of the grade of material used.

Recommendations

(a) Identification, Standardization, and Simplification. The first step in obtaining quality construction is to make use of quality materials. The committee recommends that all products used in house construction be identified by means of approved grade-marking or trade-marking and that such identification should designate basic materials, species in lumber, and finish in other materials. It therefore urges that all branches of the construction industry cooperate with government groups and all other agencies engaged in this work. The committee also recommends that specifications covering materials be standardized and made uniform in order to reduce waste. Complete cooperation of all research groups in the building industry should be utilized to eliminate unnecessary variety of products and methods through simplified practice. In the matter of credentials to accompany a title report, the committee suggests that a responsible architects' organization should cooperate with builders and title companies to draft necessary standardized documents.

(b) Economies of Prefabrication. There is little doubt that the use of prefabricated units of construction, even up to a complete house, will increase as standardized methods are introduced and mass production becomes better appreciated. Interior units are also included in this class. The committee recommends that further attention and study be given this subject by all concerned in the hope that prefabrication may become more practical and more economical to the builder. It is also recommended that joint group investigations by manufacturers, involving combinations of materials, be conducted with the advice of a body of architects.

(c) Elimination of Waste in Distribution, Cutting and Fitting. There is a distinct and economical advantage in quantity purchase of raw materials as well as the use of pre-prepared products, such as ready-mixed concrete, mortar, and plaster. Highly standardized types and dimensions of lumber eliminate waste in cutting and fitting on the job. Many finishing materials are also available, which require no extra preparation before they are put in place. The committee recommends that in the design of houses these materials should be investigated by architects and builders and full advantage taken of economies to be effected by using them wherever possible.

(d) Purchase and Discount of Materials. As a means of protection to the reliable builder, the material supply dealer, and the manufacturer, certain credit principles should be enforced. The committee recommends that material credit bureaus be promptly established for the building industry in all communities, in order to eliminate unnecessary losses now being sustained.

The practice of allowing larger seasonal discounts is commended and should be continued. This would naturally reflect in lower average prices throughout the year.

(e) Storage and Handling of Material at the Site. Since each project presents its own individual problems, the committee recommends that proper consideration be given by the builder and dealer in each case to the matter of material delivery, storage, and handling.

(f) New Materials and Methods. The committee recommends that coordinated research and cooperation among all elements of the building industry be continued and extended, in order to obtain maximum practical benefits from new materials and methods.

(g) New Types of Houses. The increased demand by the public for modern improvements has made it necessary for the home builder to change and improve the types and styles of house construction. The committee recommends that the public remain open-minded and alert to the possible advantages of improved methods of fabrication for the complete house as well as for the individual parts thereof.

(h) Fireproof Construction. In view of the enormous annual losses in lives and property as a result of fire, the committee recommends that in the design of dwellings due consideration be given such construction details and fire-resistant materials as may be practicable in an effort to minimize fire hazards and reduce insurance premiums.[11]

(i) Insurance. To protect the owner's interests the committee recommends that all requirements of the local board of fire underwriters be complied with, and that various hazards such as mentioned in this report be covered by adequate insurance.

(j) Corrosion. The committee recommends that noncorrosive materials be used wherever practicable. If corrosive materials

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[11] Mr. George F. Lindsay, a member of the committee, believes this statement regarding fire-resistant materials should have reference only to houses in the higher-cost range. Such materials, he states, are prohibitive in cost for use in the more isolated communities and on the farm, are unnecessary for reasonable safety from fire, and finally, are not conducive to economy.

Mr. Homer W. Ballinger, also a member of the committee, believes this discussion is inadequate in that it fails to explain how suitable protection may be secured by the proper use of materials that are not incombustible.

are used, however, it is suggested that they be protected with a corrosive-resistant paint.

III. Building Codes

Although uniformity in building requirements is highly desirable, both from the standpoint of safety and economy, it does not necessarily follow that all requirements can be stated in the same terms throughout the country. Minor variations of necessity must persist because of peculiar local conditions. However, in the main, uniformity is both desirable and possible.

Perhaps the most important application of uniformity, from the standpoint of the architect and contractor doing business on a nation-wide scale, is the manner of presenting code requirements. A uniform method of doing this would save many hours of groping for complete information and would tend to greater observance of regulations because of better familiarity with them.

New materials and processes are being developed daily, and it should be the purpose of good building regulations to recognize such developments when they prove themselves desirable. Unless these worthy new materials are introduced, upon satisfactory proof to the building officials that they are capable of performing the function for which they are intended, the public will be deprived of the economy which would result from their use.

Building regulations can be a hampering influence upon architectural and engineering design, through the perpetuation of requirements which have lagged behind developments in engineering knowledge. This delay in progress involves an unnecessary cost to the public.

Fortunately there have grown up great bodies of professional and scientific men and manufacturers of building materials who have worked earnestly toward producing sound standards for utilizing the various materials that enter into construction. Testing of materials has assumed ever growing importance with the passing years, and the accumulation of data has furnished a basis on which many structural requirements may be determined.

When President Hoover was Secretary of Commerce, he saw the need for greater uniformity in building laws and appointed a committee of eminent architects and engineers, representing a number of professional groups, which became known as the Building Code Committee of the Department of Commerce. This committee and its subcommittee on plumbing have been hard at work since their organization ten years ago and, to date, have published the following seven reports, which should be of value to all interested in construction problems:

Recommended Minimum Requirements for Small Dwelling Construction.
Recommended Minimum Requirements for Plumbing.
Recommended Minimum Requirements for Masonry Wall Construction.
Minimum Live Loads Allowable for Use in Design of Buildings.
Recommended Practice for Arrangement of Building Codes.
Recommended Building Code Requirements for Working Stresses in Building Materials.
Recommended Minimum Requirements for Fire Resistance in Buildings.

These reports are available to local building code committees and others interested in safe and economical requirements. A recent survey shows that they have been used in revisions now complete or going on by 281 municipalities in building code work and by 183 in plumbing code work. They have also been used by several states in connection with legislative matters relating to building regulations.

Reports on other subjects will be issued from time to time and the older reports are being revised as occasion requires. The first three and the last named reports are particularly adapted for use in connection with small dwelling construction and contain many useful suggestions for home builders.

Recommendations

Uniformity of Arrangement. Uniformity of arrangement of building codes, as a matter of convenience and economy in time for those who use them, is desirable, and it is recommended that the arrangement prepared by the Building Code Committee of the Department of Commerce be followed.

Uniformity of Requirements. So far as practicable and not contrary to local building needs, the provisions of building codes should be made uniform, keeping in mind the differences in quality and strength of materials available in various localities.

Public Safety. Keeping in mind that building codes are remedial statutes under the police power, whose object is public safety, their provisions should be sufficiently broad to permit of any materials or methods of construction that will attain that end, and should not compel practices that entail expenditures not necessary to secure safety. It is not the province of the building code to specify best methods of construction.

Freedom in Design. Within the limits of safety, the greatest possible freedom of design should be permitted and the least practicable interference with new developments, especially when they tend to effect economies in construction, maintenance, and operation of the completed structure, should be imposed.

Avoidance of Detail. Provisions of building codes should prescribe the purposes to be attained rather than specific methods of attaining them; that is, they should not be hard and fast specifications.

Permits. Consistent with the necessity for care and for accurate and adequate records, the procedure to be followed to secure official approvals should be made as simple as practicable, and permits issued should be inclusive, avoiding the necessity of application to several separate agencies to make a lawful building operation possible. Permit fees, when required, should be on an area basis, not on a cost basis.

Certificate of Occupancy. Through the medium of a certificate of occupancy upon the completion of a building operation, assurance should be given the owner of quiet, undisturbed occupancy, so long as he makes no unauthorized alterations and makes no unlawful changes in occupancy.

Administration. The administration of the building code should be entrusted only to technically qualified persons with years of experience, with good judgment and ample authority to accomplish the purposes of the code, whose tenure of office is dependent only on good behavior and satisfactory service.

The committee recommends that attention be directed to the published reports of the Building Code Committee of the Department of Commerce, previously listed under this subject.

IV. Construction Organization

(a) Contracting, Operative and Speculative Builders. Home building operations are usually carried on under one of three general methods of procedure.

In one case the house is built directly for the owner by an independent contractor according to the owner's plans and specifications. The results should be an individually created home embodying all of the special desires of the owner with respect to environment, layout, conveniences, and quality of materials and workmanship. The extent of ultimate satisfaction, however, depends largely on the selection of a competent architect to draw up the plans and specifications and an experienced and reliable builder to do the work.

The operative builder usually purchases a tract of land and develops it by grading and laying out streets, installing sewers, water lines, and other public utilities. Houses are built, varying in number according to the size of the tract. The prospective owner has the choice of selecting a house designed and constructed according to the ideas of the builder, or one meeting his own ideas, but conforming to certain general requirements of the development.

The speculative builder usually constructs a number of houses as finished products. In this case the buyer must accept all of the ideas of the builder, with the possible exception of the selection of a portion of the interior decoration.

When both operative and speculative builders produce for a general market, the purchaser has the advantage of seeing the completed house before he buys it. In most large cities a great proportion of houses are constructed by operative and speculative builders.

Each of the systems mentioned above has its advantages and disadvantages, and each has a place in the home building field.

The so called "jerry builder" who produces inferior structures and takes advantage of the home buying public should be avoided.

(b) Builders' Relations with Subcontractors and Other Groups. From replies received to a questionnaire the committee finds that practically every builder has some form of organization either directly under his control or closely associated with him.

An analysis of actual conditions indicates that the larger contractors have rather close cooperation and contact with many of their subcontractors. If the general contractor is financially strong, he surrounds himself with a responsible group of subcontractors who continue to do his work over a long period of years. In this way he practically develops his own organization without carrying all the burden of overhead and credit necessary to finance jobs during construction. A balanced budget for each year and each house is evidence of good building practice as well as the best assurance of remaining in business.

In some cases large operative builders make yearly contracts for labor only with various subcontractors, guaranteeing them steady work from year to year. In this way they develop a strong and efficient craftsman organization because of their desire to have steady work, and the builder himself obtains lower prices than if each job were subcontracted. In this case the builder also purchases all materials and relieves subcontractors of financial responsibilities.

In some instances builders own or are interested in the building supply business, and thus are able to take advantage of lower prices. Material supply companies finance some builders in order to sell their materials. Some builders handle financing in their own organization.

Many progressive builders benefit by following constructive information furnished them by manufacturers of special materials and trade educational associations.

In fairness to the contracting business and its best interests, a general contractor should not be engaged in any other business which will give him an unfair advantage. When a price on any construction is determined, it should remain fixed so that the custom of "shopping" bids may be eliminated. Secret arrangements and agreements of any nature arouse suspicion and should be avoided in the interest of the owner. Material distributors should render their best service to builders and thereby secure sufficient volume to return a profit. Price discrimination by manufacturers, even on quantity purchases, is not the best practice and tends to create an unstable market for building. Duplication of sales effort on the part of manufacturers and distributors adds to general overhead, and should, therefore, be minimized as much as possible, without conflicting with the fundamental business policies of either group.

The present methods used by some surety companies in bonding contractors does not insure against irresponsible ones securing jobs. The character, experience and responsibility of the builder are the best criteria of performance. These qualifications should be carefully analyzed before awarding a contract.

The subject of advertising in connection with selling is an individual problem for every builder. The general tendency is to feature the many specialties offered in houses instead of calling more attention to the various qualities of construction. Competition presumably obliges all builders to do this in order to attract prospective owners.

The whole problem of the marketing of construction should receive the earnest and immediate attention of not only all the various constituent elements of construction groups but the whole integrated industry. Construction, as such, necessarily competes with all other industries for the consumer's dollar. It therefore behooves the progressive groups and leaders with vision to initiate research into adequate markets, publicity, and finance.

(c) Need of Cost Accounting Data. Further information secured through the questionnaire indicated that in very few instances has there been any attempt on the part of builders to make use of any standard form of estimating or cost accounting systems which will give them data for future jobs. Various items of construction are "lumped" together in a general way and exact detailed costs are unknown. Careful preliminary estimates of cost of labor and materials are not made, and many contractors claim that their years of experience enable them to use a general figure to cover the cost of estimating a particular item. It is here that the feature of uncertainty enters to a marked degree. As a result of this uncertainty many jobs are cheapened when it appears that costs are exceeding estimates.

Every cost sheet should include job overhead items, such as plant rental, permits, insurance, weather protection, and superintendence. It should also include general expense, such as interest during construction, lost time, cost of getting business, publicity, office expense, and transportation.

The committee has obtained a comprehensive form for estimating and cost accounting by a rather simple method, one which can be used and kept up to date by any intelligent bookkeeper or contractor's office man. At any interval a definite comparison can be made between the estimated cost and the cost to date. At the end of the job each unit item shows whether costs exceeded or were less than the original estimate and the comparison of totals indicates whether there has been a profit or loss.

Among other complete forms available covering this subject are those prepared by the American Institute of Architects, the Associated General Contractors of America, and L. Brandt, Housing Engineer, of Pittsburgh, Pa. Information is also found in these publications regarding the selection of a contractor and means of determining his responsibility, contract forms, lien laws, bonds, payments from owner, and completion and satisfaction of bills by contractor.

(d) Home Building Agencies. Although the building industry, next to agriculture, is the most important industry in the United States, yet the committee finds that, taken as a whole, it is very weak in its system of organization.

In many of the larger cities there are real estate boards whose membership includes the progressive and prominent builders. Certain business principles, ethics, and standards are maintained which tend to eliminate unscrupulous dealings with the public. It is also the aim of these groups to promote and establish a higher set of standards for construction. However, the activities of these organizations are somewhat limited, and many of the smaller builders are not members. With these conditions prevailing, there exists a large and varied type of construction, meeting only certain local building code and climatic requirements.

Many attempts have been made to establish a closer relationship between the builders and the architects, with a view to securing more favorable designs; but they have been only partially successful. It is quite usual for those builders constructing a considerable number of row houses to give little or no consideration to the architects' services. The responsibility for this condition is divided.

Best ultimate results can be obtained only when there is an honest and earnest effort put forth by every interested group to contribute its best advice, services, material and workmanship.

(e) Central Inspection Bureaus. During the past decade steady progress has been made in the development and use of good standards of construction, but the committee feels that there is still room for further improvement and extension in this direction. The more progressive type of builder, especially in the large cities, is availing himself of every opportunity to produce improved houses at decreased costs.

The home buying public, as a result of nation-wide advertising campaigns conducted by material manufacturers, and through increased publicity in home magazines, daily newspapers, and other mediums, is being awakened to the advantages of sound, durable, and pleasing construction, and in general is demanding better quality in workmanship and materials. Wherever good architects are employed and inspection and supervision are under their jurisdiction, excellent results should be secured.

Several years ago a building and loan association in one of the southern states, in an effort to stamp out shoddy construction and assure home owners of that measure of quality and ultimate satisfaction to which they were entitled, began to supervise the construction of all houses on which it loaned money. The experiment was evidently successful, inasmuch as similar inspection and supervising services have been established in other communities. In Oklahoma City, the building and loan associations, operating through a central bureau, are supervising the construction of all residential building erected in that community. An architects' supervisory service has been operating for several years in New York City, under the jurisdiction of a railroad cooperative building and loan association.

The building and loan associations of New Jersey are now perfecting an organization to provide inspection service for their clients. Several national associations have recently planned to inaugurate at Cincinnati, Ohio, a "certified construction" service which would unite the interests and requirements of public authorities, public utilities and insurance companies. It is hoped that by using one inspector for this work many duplications can be avoided, and public utility inspection costs can be minimized.

The Architects' Small House Service Bureau, a nonprofit-making organization, provides not only plans and working drawings, but complete specifications, bills of material or quantity surveys, and contract forms, and gives advice on questions which may arise during construction.

The committee finds that a large percentage of homes are constructed without supervision and, as a result, many are so poorly built that expenditures of considerable sums for repairs are necessary after a few years.

Some of the advantages to lending institutions and home owners, which should be gained as a result of properly supervised construction, follow:

Better security to lending agencies in case of foreclosure and repossession of property.

Guarantee to the home buyer of a well-built house of good quality materials.

Better-built communities, reduced fire hazards and protection from blighted districts.

Increased salability of homes and assurance of a ready market for such property.

Better prices for the property because of its sound character.

Good will and restoration of the confidence of all interested in home building and buying, and a resultant increased activity in the building field.

Higher percentage of lending for senior and junior financing for longer periods.

As a basis for setting up good standards of construction, the publications listed under the heading "Building Practice," page 61, are of value.

(f) Construction Payments. Most contractors and builders when performing individual contracts receive monthly payments unless it is agreed that they shall be made upon reaching certain stages of completion. Subcontractors are entitled to proportionate monthly payments for their respective work as it progresses and to final payment not later than thirty days after completion. General contractors should also receive a "semi-final" payment when the structure is ready for use or occupancy, and the final payment, including the retained percentage, within thirty days after full completion.

When financing is done through an established, reputable, financial institution, guarantee of payments is not necessary; otherwise a payment bond may be desirable.

(g) Guarantees. The quality of all materials and workmanship used in constructing a house should be of such grades that the builder and the manufacturer can guarantee them for a definite period of time. In most cases where a manufacturer values the business of the builder, any faulty mechanical equipment is readily replaced or repaired. Material and workmanship on foundations, roofs, plastering, painting, etc., are usually guaranteed for a period of at least one year. Some builders, however, often make necessary corrections without charge within a longer period. This is especially true if the builder holds one of the mortgages on the home. Prospective home owners are often influenced in their selection of a builder by the reputation he has established in guaranteeing quality.

Recommendations

(a) Contracting, Operative and Speculative Builders. The committee recommends that more careful attention be given by builders and architects to the subdivision of land and group planning of houses, and suggests that the reports of the Committee on City Planning and Zoning and the Committee on Subdivision Layout of this Conference be referred to.[12]

Since each of the three types of builders mentioned in this report has a place in the home building field, it is important that the prospective home owner thoroughly investigate the merits of each, in order to decide which type he may best utilize.

The committee feels that fair dealing and honest values on the part of the builder are essential requisites of successful operations, and that "one good job deserves another."

(b) Builders' Relations with Subcontractors and Other Groups. Successful results are often dependent upon the character of the contractor's organization. The committee recommends that there should be complete cooperation between the builder and all those who are in any way associated with him in his work. Periodical conferences of all or various groups promote interest and better efficiency. The committee urges that a closer

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[12] "Planning for Residential Districts," *Publications of the President's Conference on Home Building and Home Ownership,* Washington, 1932, Vol. I, Chs. I and II, respectively.

relationship be established between builders and architects in order to give the home owner the benefits of the knowledge of each. Best ultimate results can be obtained only when there is an honest and earnest effort put forth on the part of every interested group to contribute its best advice, material, and workmanship.

(c) Need of Cost Accounting Data. The introduction of new materials and methods makes it impossible to depend on past experience alone, as a basis of establishing accurate cost data for the various items of work. The committee recommends that detailed records be made of each job and the subjects of overhead, profit, superintendence, and contingencies, be analyzed in order to arrive at an intelligent sale price for any house.

(d) Home Building Agencies. The committee recommends that more interest be taken in higher standards of construction by home building agencies which now exist, and that others be formed, to establish and promote such standards. The committee believes that the various individuals and elements in the building industry should more generally commend and support unprejudiced local and national organizations and cooperating magazines. It is suggested that excellent results might be obtained by the establishment of a home building division as part of some national organization, with local chapters which might serve as focal points for practical construction information.

(e) Central Inspection Bureaus. Better defined standards of sound construction should be established for every community, as an aid not only to home buyers but to the lending institutions as well. The committee recognizes the value of supervision of construction and recommends that local central inspection bureaus be established and supported by financial agencies. These bureaus should include representatives from the various groups concerned with financing, designing, and construction of homes. in order that a well-balanced organization may be obtained.

(f) Construction Payments. In order to avoid misunderstanding, to promote uninterrupted progress of the work, and to minimize interest charges during construction, the committee recommends that definite payments at certain periods be agreed upon in advance by the builder and the owner and made a part of the contract, and that the obligations thereafter be promptly fulfilled.

(g) Guarantees. Misunderstandings between builders and buyers often result from oral statements. In order to eliminate this possibility the committee recommends that guarantees for all material, workmanship, and equipment for definite periods of time be included as a part of the contract of sale of every house. This feature of protection will tend to eliminate the irresponsible builder and create confidence and an increased desire in a greater number of people to own their own homes.

Summary

The committee believes that the following important facts described in the foregoing paragraphs should be especially emphasized:

1. Sound and durable construction may be obtained by using current valuable information available in various publications covering recommended building practice.
2. Reduction of cost may be effected by accurate estimating and cost accounting, best methods in the use of standardized quality materials, proper use of labor saving devices and equipment, and proper job organization.
3. A more extensive development of group construction of houses with better arrangement is advocated in order to appeal to a greater number of prospective home buyers.
4. More prefabricated units of construction may be obtained by a continued investigation of the possibilities of standardization.
5. Best possible results may be secured only through cooperation between construction groups, architects, and manufacturers.
6. Quality construction, as well as the special features of attractive house equipment, may be secured only by education of the home buyer regarding fundamentals.
7. Modern merchandising methods now used to create a public demand for home equipment and furnishings should be studied and applied to the sale of houses as a whole, and should be coupled with scientific research.

General Conclusions

As a result of the committee's investigation it concludes:

1. That there are too few home building organizations which give much needed attention to the construction of homes for families whose annual income is approximately $2,000 or less per year. Further study and re-

search work should be extended to meet the demand for homes costing $5,000 and less, including land.

2. That cooperative supervision and inspection bureaus be established in order to insure the proper use of quality materials and quality construction in return for money spent; these bureaus to be within the industry and located in all large cities, and in smaller cities as the need presents itself.

3. That the importance of further education on modern substantial construction is vital, and that available data be compiled by the committee staff or other competent body, in a pamphlet entitled, "How to Construct a House." This should be in two sections, one describing, "What a Home Buyer Should Know Regarding Construction," and the second, "What a Home Builder Should Know about Modern Construction Practices." Present and new information regarding construction should be made available through libraries and national and local headquarters of all branches of the construction industry.

4. That the subject of finance is one of the most definite problems of both the builder and buyer, and their attention is therefore directed to the report of the Finance Committee of this Conference on this subject.[13]

5. That credit bureaus be established for the protection of all interested parties in the home building industry and to eliminate liens or double payments against a home owner's property.

6. That more uniformity in building ordinances be established, and that building codes be so formulated as to permit the inclusion of modern methods and uses of nationally accepted quality materials.

7. All possible attention and cooperation should be given publicly and privately to the problems of providing the best quality homes at the lowest possible cost, for the greatest number of people. It is universally recognized that increasing the number of home owners in any community or nation increases the calibre of its citizenship.

DISSENTING STATEMENT OF MR. M. J. McDONOUGH

I am opposed to too much standardization in home building, as it takes the individuality out of the construction of homes, and is a means of adding to our already large number of unemployed building tradesmen.

I am opposed to the advocacy of the use of the spray machine for painting, as it is a menace to the health of the operator.

I am opposed to the use of wall board as a substitute for plastering. Plastering, well done, is an insurance against fire, a

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[13] See "Home Finance and Taxation," *Publications of the President's Conference on Home Building and Home Ownership,* Washington, 1932, Vol. II, Ch. I.

sanitary protection, and the possibilities for decoration and ornamentation are limitless.

I am not in favor of erecting homes in the same manner as automobiles are built.

The report savors too much of a machine-made home and, as a practical building trades mechanic, I know that the reforms as advocated in this report are not practical; hence, I am opposed to the report in full.

APPENDIX

SMALL HOUSE SURVEY[1]

In order to present some idea of the various types of small houses which are built and sold at prices below $10,000, information is herewith submitted which describes 20 houses located in 19 cities in the United States. The price range is from $1,950 to $9,850. This paper describes in detail bungalows, detached and row houses which are considered as representative types for the cities in which they are built. The general features of each house are given; floor plans are shown in all instances and photographs in some. The average room sizes of all houses inspected in the survey are shown on page 110.

The types of construction are frame and masonry; the style of architecture varies widely. No attempt has been made to state what prices these houses would sell for in other cities, but the data indicate the kind of house which can be bought in the respective cities for the amount of money mentioned.

In the houses visited during the survey, made early in 1929, it was found that kitchens were more nearly alike in size than any other room. Most of them contained about 100 square feet, with the width about three-quarters of the length, so that 8 feet 10 inches by 11 feet 8 inches would be typical. Living-rooms from 11 to 15 feet wide and 15 to 22 feet long, with the width commonly about two-thirds the length, were most frequent. Dining-rooms tended to have the width about three-quarters of the length, with about half again as large an area as the kitchens. Bedroom sizes ran distinctly larger in two-story than in one-story houses. The owner's bedroom in many two-story houses was over the living-room and of about the same size.

Ceiling heights were usually greater in the South than in the North, presumably because they are more comfortable in warmer climates, and on account of custom. In houses above the lowest-price range there was an increasing tendency to obtain a higher ceiling in the living-room by keeping its floor one or two steps lower than the rest of the first floor.

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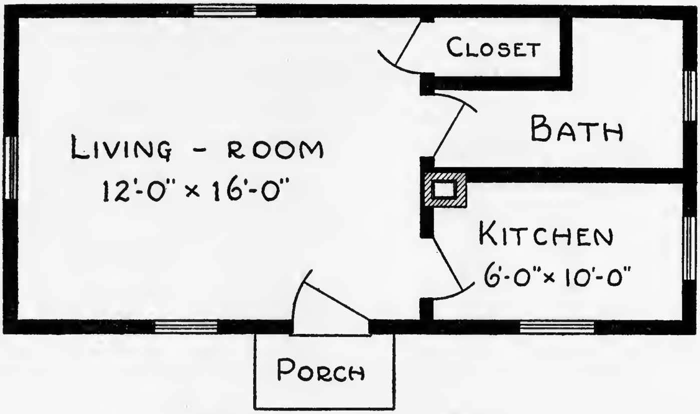
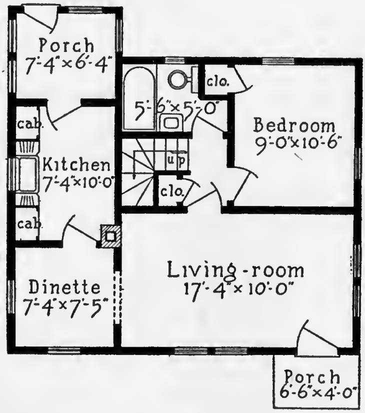
[1] The material from which these data were selected was collected during a survey conducted by the Division of Building and Housing of the U. S. Department of Commerce. The survey included visits to 31 cities where local builders were interviewed and houses were inspected by staff members.



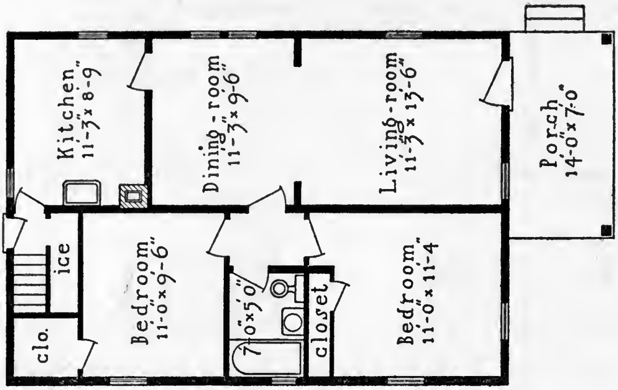
House No. 1, Dallas, Texas.

Selling price	$1,950	Floor space	rear porch, living-room, kitchenette, bathroom
House price	1,550		
Lot price	400	Heating	none—piped for gas
Lot size	50′ x 125′	Garage	frame, detached, 1-car
Description	bungalow, frame		



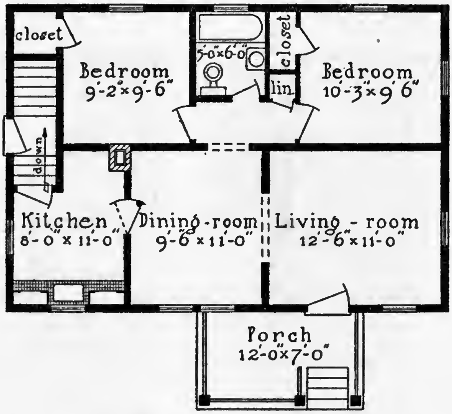
House No. 2, Seattle, Washington.

Selling price	$2,750	Floor space	rear open porch, living-room, dinette, kitchen, 1 bedroom, 1 bath
House price	2,350		
Lot price	400		
Lot size	60′ x 120′	Heating	individual coal stoves
Description	bungalow, 4 rooms, siding	Garage	frame, detached, 1-car



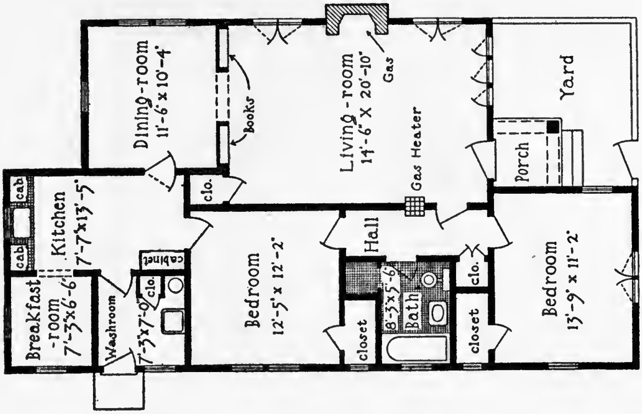
House No. 5, Indianapolis, Indiana.

Selling price	$3,950	Floor space	front open porch, living-room, dining-room, kitchen, 2 bedrooms, 1 bath
House price	3,350		
Lot price	600		
Lot size	35′ x 135′		
Description	bungalow, 5 rooms, siding	Heating	warm air
		Garage	frame, detached, 1-car



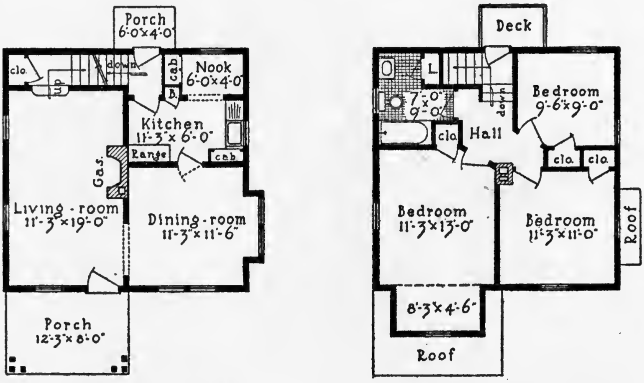
House No. 20, Flint, Michigan.

Selling price	$5,400	Floor space	front open porch, living-room, dining-room, kitchen, 2 bedrooms, 1 bath
House price	3,900		
Lot price	1,500		
Lot size	50′ x 100′		
Description	bungalow, 5 rooms, siding	Heating	warm air
		Garage	none



House No. 31, Los Angeles, California.

Selling price	$6,350	Floor space	no porch, living-room, dining-room, breakfast-room, kitchen, 2 bedrooms, 1 bath
House price	4,450		
Lot price	1,900		
Lot size	45′ x 120′		
Description	bungalow, 5½ rooms, stucco on frame	Heating	warm air
		Garage	frame, detached, 2-car

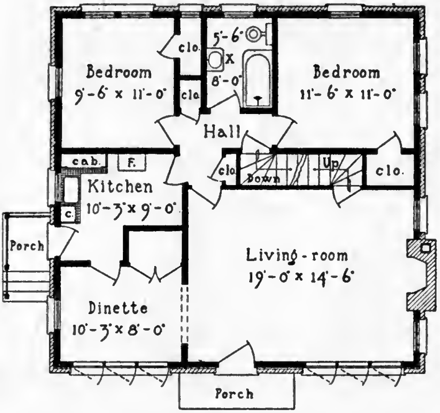


First-floor Plan

Second-floor Plan

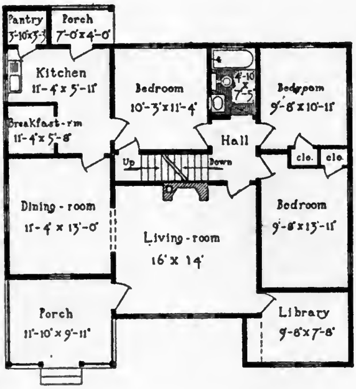
House No. 32, Toledo, Ohio.

Selling price	$6,350	Floor space	front open porch, living-room, dining-room, breakfast-nook, kitchen, 3 bedrooms, 1 bath
House price	5,600		
Lot price	750		
Lot size	35′ x 100′		
Description	2-story, 6 rooms, siding	Heating	warm air
		Garage	frame, detached, 1-car



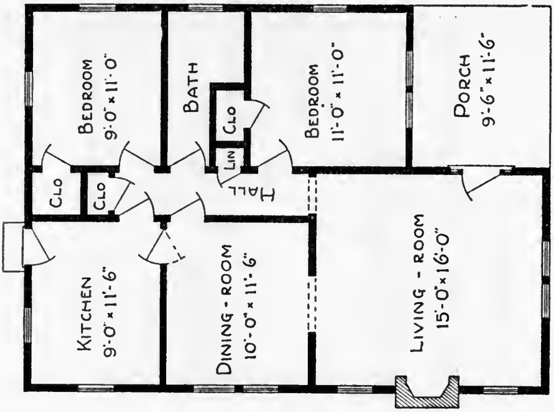
House No. 34, Seattle, Washington.

Selling price	$6,500	Floor space	no porch, living-room, dining-room, kitchen, 2 bedrooms, 1 bath
House price	5,300		
Lot price	1,200		
Lot size	43½′ x 108′	Heating	vapor heat
Description	bungalow, 5 rooms, brick veneer	Garage	built-in, 1-car



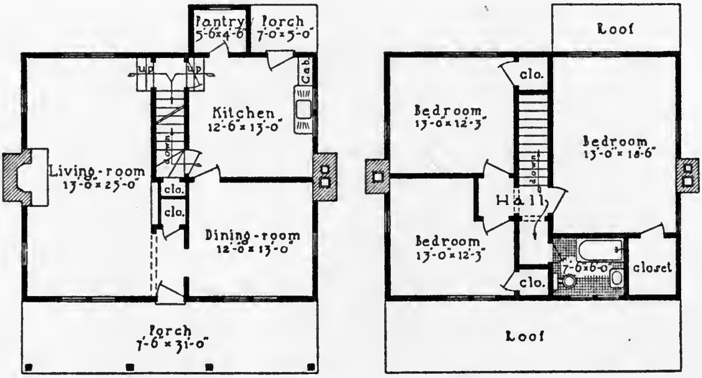
House No. 36, Winston-Salem, North Carolina.

Selling price	$6,500	Floor space	front open porch, living-room, library, dining-room, breakfast-nook, kitchen, 3 bedrooms, 1 bath
House price	5,000		
Lot price	1,500		
Lot size	55′ x 135′		
Description	bungalow, 7 rooms, siding	Heating	warm air
		Garage	frame, detached, 2-car



House No. 42, Trenton, New Jersey.

Selling price	$6,800	Floor space	front open porch, living-room, dining-room, breakfast-nook, kitchen, 2 bedrooms, 1 bath
House price	5,900		
Lot price	900		
Lot size	50′ x 150′		
Description	bungalow, 5 rooms, siding	Heating	steam
		Garage	frame, detached, 1-car



First-floor Plan Second-floor Plan

House No. 44, Birmingham, Alabama.

Selling price	$7,200	Floor space	front and rear open porches, living-room, dining-room, kitchen, 3 bedrooms, 1 bath
House price	6,000		
Lot price	1,200		
Lot size	50′ x 150′		
Description	2-story, 6 rooms, siding	Heating	warm air
		Garage	frame, detached, 1-car

House No. 1

House No. 31

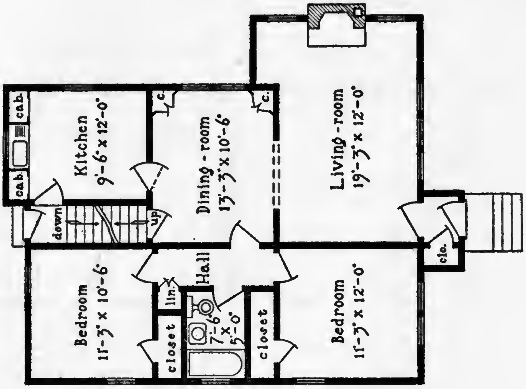
House No. 34

House No. 42

House No. 57

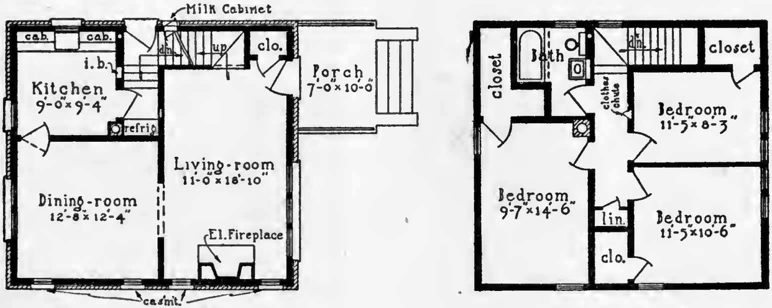
House No. 59

House No. 63



House No. 45, Minneapolis, Minnesota.

Selling price	$7,350	Floor space	no porch, living-room, dining-room, kitchen, 2 bedrooms, 1 bath
House price	6,100		
Lot price	1,250		
Lot size	50′ x 128′	Heating	warm air
Description	bungalow, 5 rooms, stucco on frame	Garage	frame, detached, 1-car

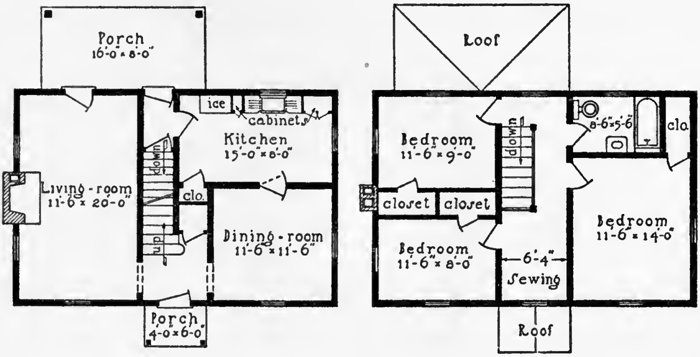


First-floor Plan

Second-floor Plan

House No. 56, Detroit, Michigan.

Selling price	$8,640 (approximately)	Floor space	front open porch, living-room, dining-room, kitchen, 3 bedrooms, 1 bath
House price	6,140		
Lot price	2,500 (approximately)		
Lot size	45′ x 110′		
Description	2-story, 6 rooms, brick veneer and shingles	Heating	warm air
		Garage	none

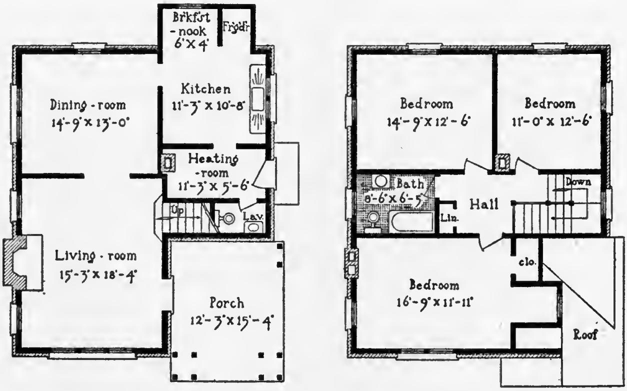


First-floor Plan

Second-floor Plan

House No. 57, Fort Wayne, Indiana.

Selling price	$8,950	Floor space	rear porch, living-room, dining-room, kitchen, 3 bedrooms, 1 bath
House price	6,950		
Lot price	2,000		
Lot size	45′ x 122′	Heating	steam, coal
Description	2-story, 6 rooms, siding	Garage	none

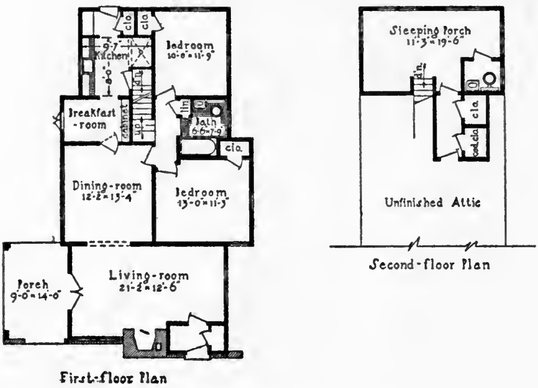


First-floor Plan

Second-floor Plan

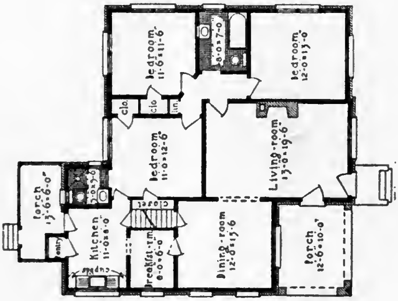
House No. 59, Jacksonville, Florida.

Selling price	$9,200	Floor space	front open porch, living-room, dining-room, kitchen, 3 bedrooms, 1 bath, extra toilet
House price	7,200		
Lot price	2,000		
Lot size	50′ x 120′		
Description	2-story, 6 rooms, brick veneer	Heating	1-pipe warm air
		Garage	frame, detached, 2-car



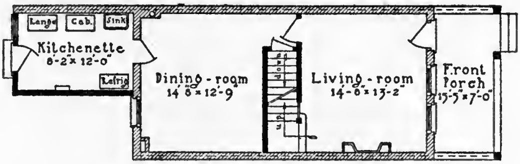
House No. 63, Kansas City, Missouri.

Selling price	$9,500	Floor space	side open porch, living-room, dining-room, breakfast-room, kitchen, 3 bedrooms, 1 bath, extra toilet
House price	7,500		
Lot price	2,000		
Lot size	45′ x 112′		
Description	bungalow, 6½ rooms, brick veneer and stucco on frame	Heating	warm air
		Garage	frame, detached, 1-car

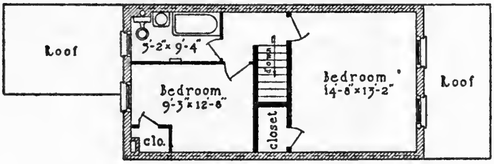


House No. 65, Atlanta, Georgia.

Selling price	$9,850	Floor space	front and rear open porches, living-room, dining-room, breakfast-room, kitchen, 3 bedrooms, 2 baths
House price	7,850		
Lot price	2,000		
Lot size	50′ x 150′		
Description	bungalow, 6½ rooms, brick veneer and stucco	Heating	steam
		Garage	built-in, 1-car



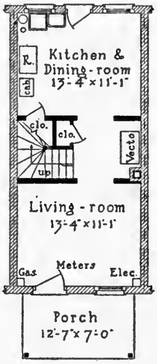
First-floor Plan



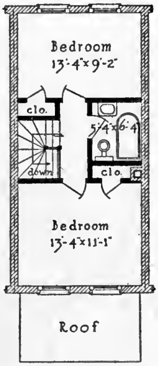
Second-floor Plan

House No. R-8, (row) Baltimore, Maryland.

Selling price	$4,916	Floor space	living-room, dining-room, kitchen, 2 bedrooms, 1 bath
House price	3,850		
Lot price	1,066 (capitalized on ground rent basis)	Heating	hot water, coal
Lot size	15′ x 75′	Garage	none
Description	2-story, 5 rooms, masonry		



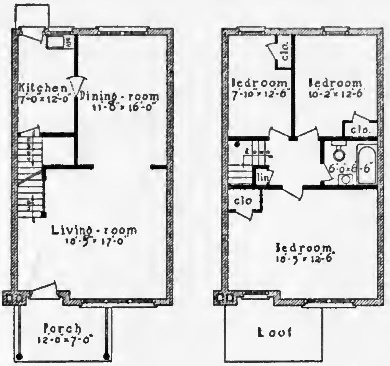
First-floor Plan



Second-floor Plan

House No. R-10, (row) Washington, D. C.

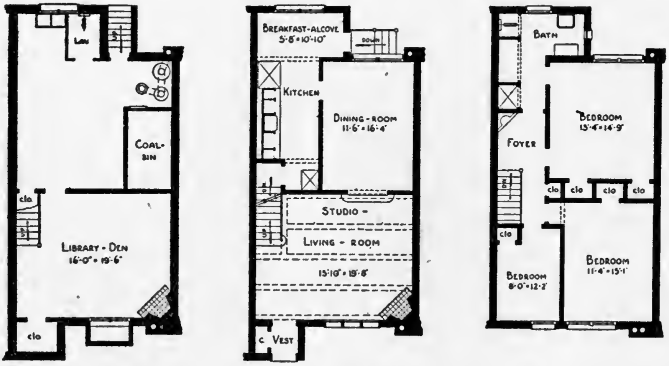
Selling price	$5,375		
House price	4,875		
Lot price	500		
Lot size	14′ x 91′	Heating	"parlor" hot-water heater in small room on first floor
Description	2-story, 4 rooms, solid brick		
Floor space	front open porch, living-room, combination dining-room and kitchen, 2 bedrooms, 1 bath	Garage	none



First-floor Plan Second floor Plan

House No. R-12, (row) Camden, New Jersey.

Selling price	$5,500	Floor space	front open porch, living-room, dining-room, kitchen, 3 bedrooms, 1 bath
House price	4,000 (approximately)		
Lot price	1,500 (approximately)		
Lot size	19′ 2″ x 100′		
Description	2-story, 6 rooms, solid brick	Heating	hot water
		Garage	brick, detached, 1-car

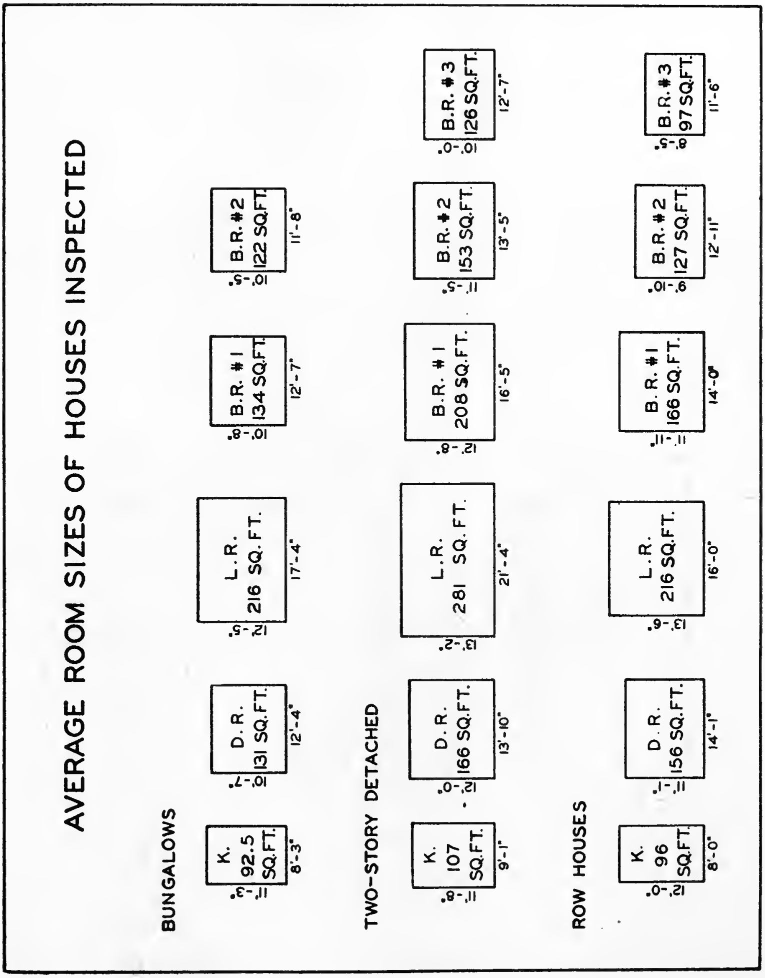


Basement Plan First-floor Plan Second-floor Plan

House No. R-100, (row) Laurelton, Long Island.

Selling price	$7,190	Floor space	vestibule, studio - living-room, basement library - den, dining-room, breakfast-alcove, kitchen, 3 bedrooms, 1 bath
House price	6,390		
Lot price	800		
Lot size	20′ x 75′		
Description	2-story, 6 rooms, masonry		
		Heating	steam
		Garage	detached, 1-car

The diagram shown below gives the average room dimensions for the three types of houses as indicated, viz.: Bungalows, two-story detached, and row houses.



PART III

FUNDAMENTAL EQUIPMENT

Introduction[1]

The work of this committee has been intensively done, starting immediately after its formation during the middle of the past summer. Its scope seemed to fall logically under four heads in the matter of equipment for the home, viz.:

1. Heating, Ventilating and Air Conditioning.
2. Plumbing and Sanitation.
3. Electric Lighting and Wiring.
4. Refrigeration.

When one thinks of a house as a structure being built for the purpose of becoming somebody's home, does it become such when the outer shell is completed, even with beauty of outline and surface made possible by effective architectural design? We do not wish to claim for a committee on fundamental equipment in a conference on home building an all important position, but we do feel that what goes into a house to make it healthy, convenient, and economical to live in is that which changes it from a house into a home. Therefore, what this committee has been chiefly concerned with is how to make a *"home"* of every "house."

Standards of living and the ideals of home life are unquestionably affected by our environment in the home as represented by the physical conveniences surrounding us. Living conditions in some of the more remote yet civilized parts of the world are sometimes such that people won't work there, because the things are lacking to protect health, to afford conveniences necessary to reasonable comfort, and to make it possible for a man and his wife to perform their daily tasks without anxiety lest water-borne diseases attack the family, extremes of heat or cold lower its vitality, and food supplies prove a menace instead of a blessing because their proper preservation is impossible.

It is frequently said that even the introduction of water into dwellings is in itself one of the greatest steps yet taken toward making houses into homes and homes into the health centers science ordains them to be.

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[1] By Collins P. Bliss, Chairman of the Committee on Fundamental Equipment.

Certainly sanitation and plumbing have made the modern city possible. Indeed the vast systems that bring pure water to city dwellers and the equally vital but less celebrated systems that carry their wastes away have been likened to the blood system of the human body.

And hardly less important are the present-day necessities in nearly all rural and city housing classed as heating, gas, electricity and refrigeration.

With all the equipment, fundamental and otherwise, that is available today for the home builder and for the home owner who perhaps has already built, it is the hope of this committee that its report may prove somewhat of a guide and perhaps also stimulate the desire to absorb some of the overproduction which we have lately been hearing so much about. It is obviously beyond the function of this committee to designate the products of any manufacturer as being good or bad, suitable or unsuitable for any given condition, but rather to describe for the home owner the fundamental requirements which should govern his selection of equipment for his particular house, with due regard for geographical location.

Furthermore, the committee felt that some range of cost for the house, exclusive of the land, should be set up, because in a house of very moderate cost it would be entirely impossible to consider certain types of equipment, which for houses of higher price might be recommended.

We therefore established the cost range as between $2,000 and $10,000, feeling that houses costing $12,000 and up would be turned over to an architect, whose professional skill would guide the owner in the selection of proper equipment.

Before presenting the summary of the committee's report on fundamental equipment, we wish to call special attention to the authorities constituting the personnel of this committee and publicly to thank them for the great amount of time and the conscientious effort which each member, including our efficient secretary, Mr. George N. Thompson of the Bureau of Standards, has given to this task.

Professor A. C. Willard, of the University of Illinois, as chairman of the group on Heating and Ventilating; Mr. A. E. Hansen, Consulting Engineer of New York City, on Plumbing and Sanitation; Mr. E. W. Commery of Nela Park, Cleveland, Ohio, acting for Dr. Matthew Luckiesh on Electric Lighting and Wiring; and Dr. Louise Stanley, Chief of the Bureau of Home Economics, U. S. Department of Agriculture, on Refrigeration, have all been responsible for the invaluable and definitive reports on each respective division of the committee's program.

CHAPTER III

HEATING, VENTILATING AND AIR CONDITIONING[1]

Section I. General Statement

1. Definition of Small House. Since the heating, ventilation and air conditioning of a home depend to a greater or less degree on the type, location, size and construction of the home in question, it becomes necessary to define the limits of the problem before undertaking its solution. Therefore, for the purposes of this report, it will be assumed that the homes in question range between $2,000 and $10,000 in actual cost, exclusive of the site on which they stand as isolated or detached structures. The size and construction of such houses, within any particular cost range, will vary somewhat and the heating equipment will vary considerably, according to locations. The heating in any particular locality will vary according to construction and especially as between insulated and uninsulated conditions. Homes in this cost bracket represent a large percentage of all the homes in this country and, while much of the material to be presented will apply equally well to far more expensive homes, it is with the equipment of the small home that this report is primarily concerned.

2. Purpose. The purpose of this report is to give the buyers and builders of small homes disinterested information as to the relative installation and operation costs, and the operating characteristics and limitations of available equipment for heating, ventilation and air conditioning of such structures. Factors concerning health as affected by indoor atmospheric environment are also discussed.

Section II. Types of Available Equipment and Systems

It is essential to establish in the mind of the home owner, whether he be buyer or builder, the importance of the relation between the house as a structure, and the heating, ventilating and air conditioning equipment best adapted to that house. This rela-

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[1] This chapter was drafted for the committee by the following members: Messrs. Arthur C. Willard, Philip Drinker, W. H. Driscoll, and Perry West.

tionship is especially important when considering the type of heating plant to be installed, and is discussed in detail in Section IV.

The cost of a house will vary considerably with location, due to differences in costs of labor and materials and the requirements for heating; also appreciably, according to whether the construction is of wood or masonry. Greater variations in costs are due to exterior and interior embellishments, special equipment, features of design; also as to whether constructed in quantities according to stock plans or individually according to higher class plans and specifications. The figures submitted later in Section IV are self-explanatory as to these variations.

In the case of well-built homes, almost any modern well-designed and properly installed system will be satisfactory, while in the case of poorly built homes no heating system will prove satisfactory. It is amazing how completely the home owners of this country regard the heating plant as something entirely separate and distinct from the house in which it is to be placed and of which it is to become a part.

It is equally surprising to discover just what the home owners mean by "best" type of heating system. One thinks largely in terms of first cost, another of operating expense (of which fuel is only a part), another of simplicity and freedom from service calls, another of convenience, cleanliness, and automatic operation, another of more uniform temperatures from floor to ceiling and of reasonable humidities.

1. Heating Equipment. Any critical consideration of types of heating equipment or systems involves a knowledge of the general classification of modern methods of heating buildings.

There are three general types of heating systems in use today known as the direct, the indirect, and the concealed heater. The first, or direct system, includes ordinary fireplaces, coal, oil and gas stoves, and those using familiar direct steam and hot-water radiators as well as gas and electric heaters located right in the space or spaces to be heated. Such systems not only warm up the air in the room but also give off more or less heat by radiation to the walls, the furniture and the occupant.

The second, or indirect system, has no heating surfaces in the space or spaces to be heated, but instead supplies heated air through one or more registers. This air mixes with and warms the air in the space or spaces to be heated to the desired temperature. Furnaces placed in the basement, both of the "pipeless" and the more satisfactory piped type, as well as "indirect" steam and hot-water radiators and gas heaters and radiators, are used in such systems.

Fans are not necessary in any of these indirect systems in the average home, but may be used to accelerate the air flow over the indirect heating surfaces. When fans are used, somewhat lower temperatures of the air entering the rooms are sufficient, since more air is circulated than with a gravity flow system. There is no radiation effect in the actual rooms of the house when indirect systems are used, but some people require a slightly higher air temperature where there are no direct heating surfaces.

The third, or concealed heater system, includes those making use of the newer types of nonferrous fin or extended surface type of steam and hot-water heating elements for concealment in recesses in the building walls or in furniture steel cabinets set out in the rooms or other spaces to be heated. This system partakes of the principles of both the direct and the indirect systems, but is essentially different from both.

As in the indirect system, the heaters deliver most of their heat to the room by heating the air, which is circulated by gravity from the room to intakes at the base of the flues, and after passing over the heaters is delivered back to the room through outlets at the top of these flues. The heaters, being set in shallow recesses in the walls or in cabinets within the space to be heated, give off a certain amount of heat by direct radiation to the walls and objects within the room. This type of heater is essentially a convection heater, however, and delivers most of its heat indirectly by heating the air which is circulated over it.

The great difference between this system and the other two is that the primary heating surface is comparatively small, but is augmented to the required capacity by extended surfaces and in addition has its heating effect materially increased by an increase in the velocity of air passing over it, as caused by the flue action of the recessed or cabinet type enclosures. The comparatively small amount of space occupied by the heaters for the heating capacity obtained and the prompt responsiveness of the heaters in heating up and in cooling off, as the steam, hot water or other heating medium within them is raised or lowered in temperature, are great advantages in some cases.

Recently some newer types of ferrous heaters have come out for similar use in recesses or in cabinets which occupy comparatively small space, but do not have such quick responsiveness in the matter of heating or, especially, of cooling with changes in the temperature of the heating medium.

The concealed type of system generally gives good results so far as uniformity of temperatures between floor and ceiling is concerned and tends to remove the cold strata of air from the floors.

2. Ventilation and Air Conditioning Equipment. The ordinary detached house has enough natural air leakage to give sufficient air change for the house as a whole and does not necessarily require any additional provisions for general ventilation. Warm air furnace systems may be arranged to take either all or a portion of their air supply from out-of-doors and in this way furnish additional air to the rooms, but it is generally found expedient from an economical standpoint and quite satisfactory from the standpoints of health and comfort to recirculate most or all of the air within the building and to take little or none from the outside. The cost of fuel for heating will run about twice as much for a system taking all of its air supply from the outside as for one recirculating all of the air within the building.

The use of mechanical ventilating apparatus for certain rooms and spaces in a home may be quite desirable, however, depending somewhat upon the physical layout and natural aeration of these rooms and the desires and reactions of the occupants. Kitchens may be relieved of odors, smoke and excessive heat by electric fans, usually built into one of the outside walls near the ceiling, preferably as near the range as possible and with automatic louvers to close against back drafts, rain or snow when the unit is not running, and equipped with speed control for operating at low and less noisy speeds whenever higher speeds are not required. Toilets may be equipped with similar units for eliminating odors and excessive heat. Laundries may require such units for eliminating steam and heat. Basement play rooms or recreation rooms may be equipped with similar units; or, in order to overcome the disadvantages of overhead direct heat in such rooms, small unit heaters with electric fans attached may be used for heating in winter and ventilating in summer.

The subject of air conditioning and cooling for homes is treated under Section VII entitled "Factors Affecting Health and Comfort," but it may be briefly stated here that air conditioning and cooling will generally be found too expensive for the entire house, within the price range covered in this report. Humidification may and should be employed, however, and where warm-air furnace heating is used, this as well as the filtering of the air may be accomplished reasonably.

Reasonable cooling for summer may be applied to one or more rooms; i.e., to a first-floor basement sitting-room or to one of the bedrooms.

In this way a health, recreation or rest room may be established where at least one or more of the members of a family may find refuge from the excessive heat in times of sickness, exhaustion or after a hard day's work.

Section III. Performance Standards

1. Human Comfort the First Objective. Just what should be expected of the available types of heating equipment when installed and operated in an actual house is seldom defined or understood by the home owner, who thinks in rather general terms of only one result—human comfort. On the other hand, the installer of the heating system has a much more limited and concrete idea of performance, usually stated in his contract as "Guarantees to heat the house to 70 degrees Fahrenheit in coldest weather." At precisely what level in the rooms of the house the temperature of 70 degrees is to be measured is seldom stated, and no reference is ever made to temperatures at other levels.

2. Proper Basis for Heating Guarantees. The trend of recent standards is towards a guarantee based on the measurement of the room temperature at a distance of not more than 30″ above the floor—a distance of 18″ has even been suggested.

3. Variation in Air Temperatures, Floor to Ceiling. Any of the systems indicated in the preceding sections is capable of heating a house to 70° F. at the "breathing line" (an arbitrary level 5 feet above the floor), at which level temperatures are now usually taken in checking up a heating guarantee. There may, however, be a great difference between the "breathing line" temperature and the air temperature at other levels in the room. Tests in actual rooms, with zero outside and 70° at the "breathing line," may show temperatures as low as 60° near the floor and 85° near the ceiling. Even worse conditions may exist with stoves and "pipeless" furnaces, although the "breathing line" temperature is maintained at 70° in all cases.

Modern warm-air furnace heating systems and "indirect" steam and hot-water systems, as well as concealed radiator systems and direct steam and hot-water systems using long, low, narrow radiators, will maintain air temperatures at floor and ceiling much nearer the "breathing line" temperature than those quoted at 60 and 85°, respectively.

Such extreme conditions are intolerable, and the home owner will avoid much dissatisfaction and argument, as well as much personal discomfort, by giving thoughtful consideration to the effect of type of heating system and heating units on the room air temperatures at floor and ceiling, regardless of the fact that the system may maintain a "breathing line" air temperature of 70°.

4. Proper Temperatures of Heating Media. (a) For indirect systems, the air supplied to the rooms for heating should enter at a relatively low temperature even in coldest weather. When it is zero outside this temperature should never be above 175° at any register face, and better be 160°. The air supply from a "pipeless" furnace is usually heated far above these temperatures.

(b) For direct systems, the heating surface should not be highly heated as is often the case with stoves. Even with direct steam radiators which are usually somewhat above 212°, much better results will be secured with long, low, narrow radiators than with high radiators. Hot-water radiators are seldom operated at water temperatures above 170° with an open tank system, and maintain somewhat better room air temperatures at floor and ceiling than steam systems using radiators of the same type. With pressure systems of hot-water heating, water temperatures may run to 220°.

Experience has shown that the cheaper the heating system of any given type, the greater the air temperature difference between floor and ceiling, and therefore the greater the discomfort or waste of heat.

Section IV. Installation Factors as Affected by House Structure and Location

Since the size of the heating plant for any given house varies with the heating load, which in turn depends upon the climate in the given locality, it becomes necessary to consider the district in which the house is located, both for thermal and economic reasons. Fifteen such districts have been set up in which climate, habits and practices of the people and cost factors are considered fairly uniform for the territory indicated. (See Table 1 in the appendix, page 310.

Various other factors, such as kind and cost of available fuels, kind and cost of available apparatus and the usual care and attention given to installation and operation will influence the kind of heating apparatus to be used. For instance, in a district like California, where the cost of coal is high and the cost of oil and natural gas is low, oil and gas burning apparatus is used. This favors boilers and furnaces, as well as gas space and floor heaters, particularly adapted to these fuels. In districts along the eastern seaboard anthracite is the principal coal, while in the central states bituminous and semi-bituminous coals are more common. In some districts where manufactured gas is available at special rates for heating, its use may prove attractive and should be considered. In certain districts, where the cost of electric current is low and the heating requirements are mild, electric heating may be used profitably.

1. Cost of Equipment as Affected by District and Climate, also by Urban or Rural Location. About the first thing a prospective home builder or owner wishes to know is the comparative cost of the various kinds of heating systems. Definite figures for these comparative costs cannot be determined for any particular house in any particular district except by submitting definite plans and specifications to several reputable contractors for estimates. In the process of budgeting a home before this state is reached it is very helpful to have some idea of what these comparative costs may run.

The following general observations regarding the relative costs of various types of heating systems may be of value. The ordinary one-pipe steam system is made the basis of comparison and the subject is treated in some greater detail in Table 2 of the appendix, page 312.

The costs of one-pipe steam systems in the colder climates range from 15 per cent for $2,000 homes to 10 per cent for $9,000 homes and in the milder climates from 10 per cent for the $1,500 homes to 5 per cent for the $7,000 homes. The costs of other systems in percentage of the cost of one-pipe steam systems will range about as follows:

Two-pipe vapor	125%
Two-pipe hot water	125%
Piped furnace	65%
Pipeless furnace	35%
Convection heaters or stoves	15%
Air conditioning gas or oil-fired furnaces	150%
Air conditioning furnaces with summer cooling	250%

Heating systems costing more than 10 per cent of the total cost of the home are out of normal proportion in the budget and for this reason stoves, convection heaters or grates are recommended for houses costing $2,500 or less.

2. Operating Costs. After analyzing the cost of equipment, the next important question is the economy of operation. Tables 3 and 4 in the appendix, pages 312 and 313, give essentials from which this may be figured, but the following general observations may be made in this connection. Almost any kind of system with almost any kind of fuel may be operated more economically in the colder than in the milder climates in the matters of heating done per unit of fuel used. This is true for the reason that the load factor in the colder climates is more uniform and therefore requires less regulation, banking and "on" and "off" operation.

The cost of oil in cents per gallon multiplied by 1.4 for hard coal and by 1.5 for soft coal will give the equivalent cost of coal in dollars per ton.

The cost of manufactured gas in dollars per 1,000 cubic feet multiplied by 24 for hard coal and by 26 for soft coal will give the equivalent cost of coal in dollars per ton.

These figures are general averages for hand-fired coal and may vary widely with various fuels, systems and methods of control and operation.

3. Personal Preferences. The further important questions are concerned with comfort, cleanliness, noise, odors, space occupied, general appearance of apparatus, labor and care of operation, control and uniformity of results and the carrying charges and upkeep of apparatus.

These are all questions which must be decided by each individual owner in accordance with his desires and requirements.

4. Effects of Building Construction. The following general points may be observed regarding the effects of different types of building construction on the heating of a home:

Standard wood construction is taken as a basis and shall be understood to consist of the following:

Walls—of 2″ x 4″ studs spaced not over 18″ on centers, 25/32″ wood sheathing on outside, building paper over this and bevel siding, drop siding or shingles over this; inside wall—wood laths and plaster.

Roof—wood shingles on slat deck on wood rafters, no underfinish. Attic floor—wood joists, no attic flooring, under finish of wood laths and plaster forming the top floor ceiling.

Walls of other constructions will have the following general effects on an average six-room house:

The addition of an extra wood sheathing under the plaster will have about the same effect as the substitution of the ordinary ½″ board form of insulating base and will add about $100 to the cost of the house, save about $75 in the cost of hot-water heating system and about $15 in the cost of coal in the colder climates. In milder climates these may reduce to a saving of $40 in the cost of a hot-water heating system and less than $5 in the saving of fuel.

The addition of lumber construction consisting of 25/32″ wood sheathing and ⅞″ x 2″ furring strips under the wood laths and plaster and similar furring strips between the outside sheathing and the siding or shingles will add about $250 to the cost of the house, save about $180 in the cost of a hot-water heating system and about $30 in the cost of coal in the colder climates. In milder climates these may reduce to $75 and $5 respectively.

Lumber construction with stucco outside instead of the siding or shingles will cost about $100 less, but may cost slightly more for heating system and coal.

An 8″ common brick wall furred and plastered on the inside will cost about $600 more and will require about the same heating.

A 12″ brick wall furred and plastered on the inside will cost about $900 more and require slightly less heating.

An 8″ hollow clay tile wall with stucco outside and plaster inside on the masonry will cost about $675 more and will require more heat.

A 12″ tile wall of the same character will cost about $1,200 more and require slightly less heat.

In the matter of roofs, the addition of a 25/32″ wood attic floor will add about $60 to the cost of the house and save about $75 in the cost of hot-water heating equipment and $10 in cost of coal in the colder climates, reducing to $30 and practically nothing respectively for milder climates.

Tile roof instead of shingles will cost about $275 more and require slightly more heating.

The addition of a tight deck to a shingle roof will add about $50 to the cost of the house and save about $10 in cost of fuel in cold climates.

The addition of an under finish of wall board or plaster to the underside of roof joists will cost about $125, save $100 in cost of heating equipment, $15 in coal in colder climates, reducing to $50 and $3 respectively in milder climates.

In connection with the above figures hot-water heating has been used and the relative saving in costs for other systems will be in proportion to their relative costs. The stated saving in cost of coal is per season.

5. Effects of Building Insulation and Weatherstripping. Regarding the effects of different kinds of insulation on the heating of a house the following general observation may be noted:

The value of insulating or weather-stripping a home, as far as the cost of heating is concerned, depends upon the amount that can be saved in the way of interest and depreciation on the cost of the heating systems, plus the saving in the cost of fuel, as compared with the interest on the added cost of the insulation or/and weatherstripping. The heat losses from the average home, without insulation or weatherstrips, is divided into about 35 per cent through walls, 20 per cent through ceilings and roofs, 20 per cent through glass and 25 per cent through air leakage. Of these losses about half of the loss through walls, ceilings, and roofs can be prevented by good insulation and about 50 per cent of the losses through air leakage can be prevented by good weatherstripping.

This means that the preventable losses, based on the amount of fuel required for the same house without insulation or weatherstrips, are as follows:

1. Through walls by insulation	15 to 20%
2. Through roofs by insulation	5 to 10%
3. Through air leakage by weatherstripping	10 to 25%
4. Total by insulation and weatherstrips	30 to 45%

Good insulation in the colder climates will save about 30 per cent of the cost of the heating system and from 20 to 30 per cent of the cost of fuel. In a house with rooms of average size the added cost of insulation for walls and roof will amount to about $350, the saving in cost of the heating system will be about $200 and the yearly saving in fuel will be about $45. These conditions vary with climatic conditions, so that in the milder climates the saving in cost of the heating system may amount to not over $100 and the saving in fuel to less than $10 per year. These figures are based on wood construction and hot-water heat. The saving in the cost of the heating system will vary as the comparative cost of different types varies.

In all instances of insulation it should be remembered that the substitution of many of the ½″ commercial insulations for plaster base instead of wood lath and for sheathing instead of wood does not constitute the kind of insulation referred to above.

Also, masonry walls up to 12″ thick, while more durable and more costly than wood, require better insulation.

Heavier masonry walls may require the same or even less insulations than wood walls and in addition may produce much warmer conditions in winter and cooler conditions in summer on account of their added capacity for heat, which, by causing a lag in the time of transmission, will prevent escape of some heat in winter or exclude some in summer except during protracted periods of either hot or cold weather. Thin masonry walls (12″ or less) may give the opposite results of a cold house in winter and a warm one in summer.

In addition to the economic consideration, good insulation tends to prevent cold walls which produce a disagreeable sense of chilliness to persons near them although the surrounding air within the room may otherwise be at the comfort temperature. It also tends to produce more uniform temperature between floor and ceiling, to prevent cold floors, and air leakage and disagreeable drafts. In the summer, it tends to prevent sweating of walls and excessive air change or replacement of the conditioned air where cooling is employed.

Generally speaking, flexible and blanket forms of house insulation have high insulating values, but some types may be subject to deterioration or infestation.

In the colder climates the cost of weatherstripping is usually paid for by the reduction in the cost of the heating system and a saving in fuel of about 20 per cent of this amount is made per year. This condition varies, according to climatic conditions, so that in the warmer districts the saving in the cost of the heating system reduces to about 25 per cent of the cost of weatherstrips and the saving in fuel to about 5 per cent. Weatherstrips tend to prevent disagreeable drafts and cold floors in winter and to prevent excessive air change where summer time cooling is employed. They are also very effective in excluding dirt and dust.

6. Fire Hazards and Fire Protection. The greatest sources of fire hazards in heating systems are the chimney, the smoke flue, the boiler, furnace, or other main heating unit, and any piping, ducts, or flues carrying high temperature steam, water or air.

The chimney should be constructed and tested in accordance with the latest "Chimney Ordinance" of the National Board of Fire Underwriters, which is approved by the American Society of Heating and Ventilating Engineers. It should have tight flue lining and there should be no timbers extending into the chimney walls. The smoke flue should be at least 24″ from any wood or other inflammable materials, or if closer, should be properly insulated and have any such adjacent materials properly protected with a sheet metal or asbestos board shield set at least 1″ from such materials.

Boilers should be installed on concrete or other masonry floors or be surrounded with a masonry hearth extending out at least 6′ 0″ all around the boiler. They should be insulated with at least 1″ of magnesia or its equivalent both for the purpose of economy and fire prevention. Steam and hot-water pipes passing through or near wood or other inflammable materials should be protected by sheet metal sleeves set at least 1″ from any such materials and allowing space around the pipes for expansion and contraction.

Warm-air furnaces should be installed in accordance with the latest code of the National Warm Air Heating Association, including the construction and insulation of furnace bonnet and air ducts. Warm-air ducts should not be run nearer than 1″ to wood or other inflammable materials unless such materials are properly protected with metal or asbestos board.

It should be remembered that the basement or cellar of any home is the most frequent source of fire and should be kept free of accumulations of rubbish or inflammable materials of all kinds.

Wherever feasible, the installation of a few automatic sprinkler heads in this area should be considered, and their cost, together with the reduction in insurance rates, should be investigated.

The overheating of boilers and furnaces or other parts of heating systems is also a possible source of fires in homes and should be carefully guarded against. This particular hazard occurs most frequently when the system is first started in the fall, especially if the building is chilled and the chimney flue is cold, by trying to force the boiler or furnace to heat the building in too short a time. Frequently a burned out smoke flue or some other worn out part of the system may cause a fire at this time and the apparatus should be carefully gone over by an experienced person before the fire is started.

Another danger period occurs in extremely cold weather and during sudden "cold snaps" if the firing is too heavy and drafts are opened too wide in an endeavor to heat up too quickly. A furnace system should never be pushed so as to give over 175° F. air at the registers; steam heating systems should never be pushed so as to raise steam within less than thirty minutes after the water is hot, or to give over 2 pounds of pressure on the gauge; hot-water systems should never be run with water temperatures over 180° F. for open systems, or 225° F. for closed systems.

Proper cleaning and inspection of heating systems before starting up, and regular operation during the heating season, will not only greatly reduce fire hazards but will also pay good dividends in economy of operation.

7. Best Procedure and Sequence for Installing Equipment in Cooperation with Other Work. The heating system should be planned, and the necessary space requirements—such as recesses, chimney, fuel storage, and ash removal facilities and all ducts and flues—should be provided for at the time plans for the general construction are prepared.

The boiler, furnace, or other main heating unit should be installed in time to provide temporary heat if required during the construction period. Permanent radiators, registers, valves, return traps and finishing plates should not be installed until the plastering and other rough work within the building are completed.

Openings with pipe sleeves built into them should be left in all masonry walls for the passage of pipes. All exposed risers and other exposed pipes should be run before finished floors are built and sheet metal sleeves extending entirely through the floor or wall construction should be installed around these pipes so that the finished floors and plaster may be built around these sleeves instead of around the pipes themselves.

All concealed piping should be installed in time to prevent delays in the work of other contractors and avoid unnecessary cutting of wall or floor construction. All such concealed risers should be tested and made tight under city water pressure before being closed in. Ducts and flues should be installed as the building construction proceeds.

Openings for the admission of boilers, furnaces, or other large items of the equipment for the building must be provided for in the plans. Supports for radiators or other heating elements, if necessary, should be installed before plastering is done. Recesses for radiator enclosures should be provided, if required, and the linings for them installed as the work progresses.

Wiring or piping for automatic control apparatus and wiring for motors should be installed before the plastering is done.

Water supply connections and boiler blow-off drainage should be provided for in the plumbing work.

Section V-a. Fuels for Domestic Heating

1. Solid, Liquid and Gaseous Fuels, as well as electricity, are used in this country today for domestic heating. The selection of a medium of household heating is affected by the locality in which it is to be used, and is determined largely by economic considerations, although other factors are receiving far more consideration than in the past.

Fuels may also be classified as either natural or manufactured. Wood, coal, crude oil, and natural gas are examples of the former class, and charcoal, coke, coal briquets, oil distillates or residues, artificial gas, and electricity are examples of the latter class. Usually the second class of fuels costs more in a given locality, than the natural or "raw" fuels from which they are made, but they also have certain operating advantages over the first class.

The time when only those fuels which were native to a given locality could or should be considered is past, although it is well to investigate thoroughly all the possibilities of the native or local fuels before deciding upon an imported fuel, which must carry heavy transportation charges and the supply of which may be interrupted without warning.

2. Operating Characteristics. From an operative standpoint, it is essential that the fuel be adapted to the heating unit in which it is to be burned. If electricity is applied directly in domestic heating service by the use of radiant heaters placed in the rooms heated, we may consider it perfectly adaptable and 100 per cent efficient. This is not true of other fuels, which must be burned in some sort of a device such as a fireplace, stove, warm-air furnace, steam boiler, or hot-water heater. In *all cases it is essential to burn the fuel, whatever it may be, completely in the device in which the combustion takes place.* The importance of this is not generally appreciated by the public who use and pay for these fuels. Comparisons of fuels on the basis of their heating value, as determined by a laboratory, as so many B.t.u. per pound, gallon, or cubic foot, *may mean very little and prove very misleading* unless we know just how efficiently the fuel *can and will be burned by the home owner in his particular fuel burning device.* For example, if fuel A costs twice as much per pound or cubic foot as fuel B, but the householder can burn it with twice the efficiency that he can fuel B, then it costs no more, although both fuels have exactly the same "laboratory heat value." However, if the home owner must install a more expensive fuel burning device to handle fuel A than fuel B, he must give consideration to the added interest, depreciation, and servicing on his more expensive investment, which may be partially or wholly offset in his particular opinion by certain operating advantages such as greater convenience, cleanliness, and possibly space requirements.

3. Factors Affecting Fuel Selection. The matter of proper fuel selection, it will be seen from the preceding, is very complicated, tied up, as it always is, with the fuel burning device which has been or, as in the case of a new house or replacement in an old house, is to be installed. A detailed statement of the more important factors involved may help in solving the problem, or at least in its more intelligent consideration. These factors are:

(a) *Availability in your locality.* Can one get the fuel he wants when he wants it, which means any time and all the time?

(b) *Dependability or uniformity, and adaptability.* The fuel may be available, but to one's surprise he may find there are many grades, some of which are much better suited to his fuel burning device than others, so that deliveries whether by truck, tank, or pipe line, may exhibit widely varying combustion characteristics. Such variability may require decided changes in methods of firing, or readjustment of burners for proper and efficient combustion.

(c) *Composition.* The valuable constituents of all fuels are carbon and hydrogen which, at a sufficiently high temperature and when intimately mixed with the oxygen of the air, will burn completely to form carbon dioxide and water vapor.

If the temperature of the fuel and air is not sufficiently high or if the fuel and air are not intimately mixed, or both conditions exist, then *incomplete* combustion takes place, and the highly dangerous gas, carbon monoxide, may be produced, free carbon or lamp black may be formed along with various volatile hydrocarbons (compounds of hydrogen and carbon), all of which not only represent valuable heating values lost but also, except for carbon monoxide, all are readily deposited on the heating surfaces and chimney flues and contaminate the atmosphere. The nonvaluable constituents are moisture, sulphur, and ash, with some oxygen and nitrogen.

The ideal fuel would contain none of the latter group of constituents, especially sulphur and ash, but any such fuels are naturally expensive to buy and invariably require special burners if not complete furnaces, boilers, or heaters for their proper combustion. It is also true that almost any fuel may be burned completely if the fuel is properly prepared and the proper fuel burning devices are used, as in the case of certain hard and soft coals when used with automatic mechanical stokers, or when the latter coals are pulverized and burned in a highly heated jet of air. Unless special methods or devices are used or available, solid fuels with a high "fixed carbon" content, which means they contain relatively less of the volatile hydrocarbons, are preferable for hand firing in domestic heating service, where infrequent attention to the fire is the rule. While it is desirable and helpful to know the composition of the fuel one is considering, *the final test is, how completely can one burn it in his particular fuel burning device, under his conditions of operation.*

(d) *Heat value and efficiency.* Since these values are determined by laboratory test, they must always be modified by the fuel burning efficiency of one's plant. Efficiency as here used means combustion efficiency, that is, the per cent of the "laboratory heat value" which is made available in the fuel burning device as it would be operated in the house using the fuel under consideration. At one extreme, we have radiant electric heaters with an efficiency of 100 per cent, and at the other the open fireplace, the efficiency of which, as a heating plant, may run as low as 10 per cent. The gaseous, liquid, and solid fuels range all the way between, depending fully as much upon the fuel burning equipment, its proper adjustment, and the care and attention which it receives, as upon the fuel. As already stated, *it is quite impossible to separate the fuel from the equipment in which it is burned* when considering what fuel to select. It is at this point that so many mistakes have been made and so much misleading information presented in comparative studies of various fuels for heating purposes.

(e) *Costs.* The home owner naturally thinks of the local market price of any particular fuel as its cost, but he also considers this cost as his cost of heating. So long as every one used stoves for heating and each man took care of his own firing and ash removal, such a basis of cost was valid. Today the problem is much more involved, largely as a result of the development of mechanical coal stokers, oil and gas burners and, in fact, complete automatic fuel burning devices or units of all types. Costs of fuel are no longer synonymous with costs of heating. Comparisons of the costs of different fuels or different methods of burning the same fuel may and usually do involve such items as:

(a) Price of fuel for heating season.
(b) Labor costs for operation of heating device during the heating season.
(c) The installation cost of the fuel burning device.
(d) Cost of power for electric motors attached to the fuel burning device.
(e) Interest on the installation cost.
(f) Depreciation allowance (based on probable life of the device).
(g) Servicing and repairs for the device.

Comparisons of various operating advantages or benefits to be gained should also be carefully considered as well as the monetary costs when making a selection of fuel and fuel burning equipment. Unfortunately, such items are not easily evaluated in dollars.

Section V-b. Fuel Burning Equipment

In considering any type of fuel burning equipment for heating purposes, it is essential for the home owner to keep two basic principles constantly in mind. These are: (1) Complete combustion of the fuel within the unit so that no combustible products can escape into the chimney, and (2) effective heat transfer so that all the heat generated by the combustion of the fuel (except the small amount necessary for draft purposes) will be transferred to the air or water which is being heated. We do not heat steam, we heat the water until it turns into steam.

1. Complete Combustion the First Objective. To realize the first objective with hand firing is very difficult, especially with highly volatile solid fuels, under domestic service conditions in which the attention given the fire is very infrequent, and hence fairly large quantities of fuel are added at a time. As a result, the fuel is not properly supplied and mixed with air at the proper temperature during a considerable period after firing, and we have a gas-producer effect resulting in the loss by distillation, of valuable combustible products. As these products pass through the flues of the device and into the chimney, some of them are usually condensed as soot, seriously reducing the heat transfer and choking the draft. After a while the fuel burns down and holes begin to form in the fire, and, as a consequence, there is likely to be too much air passing through the fuel bed. This unnecessary air lowers the temperature of the combustion chamber and cools off the heating surfaces and, worst of all, carries away valuable heat which is practically a total loss to the home owner. Hence, to accomplish the first objective, it is necessary to maintain a uniform fuel bed, burning the fuel at a constant rate, so that the air supply will not have to be readjusted radically from time to time.

2. Effective Heat Transfer the Second Objective. To realize the second objective is also difficult unless there is a sufficient amount or area of clean heating surface always exposed to the hot gases *to absorb all the heat generated at any time or at any rate of burning.* The heating device may have enough heating surface, provided the heat of the fuel is liberated at a uniform rate hour after hour. Fuels are seldom burned at a uniform rate, however, when they are hand fired, or in mechanical firing for that matter. As a result, the heating unit is usually driven hard intermittently, and then remains more or less quiescent during the intervening periods, so that we may have many times as much heat generated in one hour as in the next, depending upon the interest of the fireman or the operation of the thermostat. During the "rush period," the heating surface (adequate for a steady uniform rate of heat production) is "burned up" more or less literally, and the hot gases go roaring up the chimney at high temperature and in large volume, practically a total loss after they leave the heating unit. Thus, to accomplish the second objective, we should fire more frequently in small quantities, maintaining a more uniform rate and condition of combustion hour after hour, whether a manually or mechanically operated unit is installed. Obviously, all heating surfaces should always be kept clean and free from soot and ashes.

3. Factors Affecting Efficient Performance. It will be apparent from the preceding discussion that both objectives depend largely for their successful accomplishment on almost exactly the same procedure in firing and air supply regardless of the fuel used. Hence, efficient fuel burning equipment of any kind must provide in its design, construction and operation for carrying out this procedure either manually or mechanically. There are certain solid fuels which are so rich in highly "volatile" combustible material that it is extremely difficult to burn them efficiently in manually operated fuel burning equipment of the domestic type unless equipped with special devices and given special attention when in operation. On the other hand, solid fuels which are not so rich in highly "volatile" combustible material but carry a large percentage of "fixed carbon" not easily distilled may be burned fairly efficiently in manually operated fuel burning equipment without special devices, and with reasonable attention.

Briefly stated, the efficient performance of successful fuel burning equipment, whether manually or mechanically fired, depends on:

(a) Thorough mixing of the fuel and air at the point where combustion takes place.

(b) The air and fuel must be at the proper combustion temperature for the particular fuel in use.

(c) Proper adjustment of the amount of air supplied to completely burn the particular fuel in use at whatever rate of fuel feed is demanded. Any excess air results in a distinct loss, which may be very serious. This requires a chimney of proper design and proper controls for the draft.

(d) The fuel should be fed at a uniform rate, depending on the heating demands.

(e) The heating surface must be adequate in amount and so placed or arranged as to absorb practically all of the heat generated *at the maximum rate* at which the fuel is fed or burned.

4. Commercial Types of Fuel Burning Equipment. Commercial fuel burning equipment is usually designed to burn a certain particular class or type of fuel. For example, satisfactory wood burning stoves and furnaces would not prove successful in burning coal, which requires quite a different arrangement of grates to take care of the much greater amount of ash contained in most coals. Oil is often burned by installing "burners" in equipment designed primarily for coal, but better results are secured when the entire fuel burning unit is designed for oil, which burns with a very hot flame. Such equipment, to be efficient, should have more indirect heating surface than is usually provided for solid fuels. Gas also can be burned more efficiently in specially designed gas burning units than by installing "burners" in furnaces and boilers intended for solid fuels.

It will be apparent that fuels such as oil and gas can be more intimately and readily mixed with air and the mixture kept under proper control better than is possible with manually fired solid fuels, although mechanical coal stokers are now readily available on the market, for both hard and soft coal, even of a grade not suitable for hand firing, with many of the desirable operating characteristics of oil and gas burning units. Even in a fully automatic mechanically fired plant burning solid, liquid or gaseous fuels it is difficult to meet all of the five conditions previously listed. Most manufacturers prefer to design their equipment for a fixed rate of fuel feed in excess of the heating demands, and then adjust the air supply to satisfy this rate. This results in an intermittent or "on" and "off" operating cycle. In very severe winter weather, the fuel burning equipment is "on" most of the time, but in mild weather it is "off" most of the time, and the bad effects of intermittent operation for solid fuel have still to be overcome. The bad effects of intermittent operation may be reduced in the case of gas by a draft hood, which breaks the draft so that the "off" period loss is not as serious as in the case of direct flue connection with no draft hood.

5. Comparisons of Cost of Equipment. All such oil and gas and mechanical units are more expensive to install than hand fired equipment and it becomes a matter of great importance to the house owner or builder to find some basis for making valid comparisons and a proper selection between these various units. Since the home owner or builder must pay for both the fuel and the device in which it is burned, he cannot make comparisons of either fuel or fuel burning equipment independently of each other. The monetary items involved in such a comparison have all been listed under "Costs of Fuels" and are repeated here for the convenience of the reader.

(a) Price of fuel for heating season.
(b) Labor costs for operation of heating device during the heating season.
(c) The installation cost of the fuel burning device.
(d) Cost of power for electric motors attached to the fuel burning device.
(e) Interest on the installation cost.
(f) Depreciation allowance (based on probable life of the device).
(g) Servicing and repairs for the device.

As indicated and enumerated under "Costs of Fuels," the monetary comparison must be supplemented by a further consideration of various operating advantages and benefits, which cannot be evaluated in dollars. At any rate, the specific items (a) to (g) can be determined or estimated in each case with a fair degree of accuracy for a given house in a given locality.

Section V-c. Electrical Heating Equipment

Reference has already been made to the use of electrical energy for heating buildings, and its high efficiency has been pointed out. There are no combustion or transmission losses with such a system of heating if the electric radiators are placed directly in the rooms or spaces heated. Moreover, the original installation cost (with radiant heaters) may be the lowest of any of our present-day systems of heating, but the operating cost is usually many times that of any other system of house heating.

There are a few notable exceptions to the last statement, and in those localities where the charges for electric current for house heating are less than 1 cent per kw. hr. the small home owner might at least investigate the possibilities. Even at this rate the house should be well insulated and the fluctuations in outside air temperatures during the heating season should not be very great, nor should these temperatures go very low.

Electric heating, aside from its high operating cost, has many advantages, such as elimination of all heating chimneys, smoke, and ash, as well as odorous and deleterious flue gases. The further elimination of all fuel storage space and equipment, as well as of fuel deliveries or ash removal in residential sections are very attractive features. Perfect and very simple regulation of the heat supply to exactly balance outside conditions so that neither overheating nor underheating occurs is readily provided. In the case of the all-electric system, the very minimum of space is required for the heating system, and the basement is absolutely clear of all boilers, heaters, furnaces and piping. Certain modified systems of electric heating make use of existing hot-water and warm-air systems and do not eliminate as much equipment as the all-electric system; in fact they often add equipment.

Electric heating at 1 cent per kw. hr. will about equal the cost of heating with coal at $30 per ton and the cost of apparatus will be somewhat greater for an electrically operated hot-water heating system with storage tanks and other necessary apparatus in the basement, the remainder of the apparatus throughout the house usually being an ordinary two-pipe hot-water job, or warm-air furnace system.

It is, of course, almost impossible to place a monetary value on convenience, automatic control and regulation, space saved or required, cleanliness, and other intangibles such as paying by meter after use, etc., all of which have widely different values to different people. However, even with liberal monetary allowances for all of these intangibles, electric heating must at present be regarded as a luxury for most sections of the United States.

Section V-d. Gas Heating

Reference has been made to the use of gas for heating buildings, and its great convenience has been pointed out. The operating cost of gas heating varies widely with the variations in the climate and the gas rate. However, wherever natural gas is available, it is likely that gas for house heating is not only attractive because of convenience, cleanliness and automatic operation, but also because of low operating cost. Where manufactured gas is available, the cost of operation, although somewhat higher, is nevertheless well within the limits of many budgets, especially if the house is well insulated and weather-stripped.

Gas heating, whether with natural or manufactured gas, can be perfectly regulated to exactly balance outside conditions, so that neither overheating nor underheating occurs. Refinements have gone far enough to use dual-type thermostats which anticipate changes in temperature by having one thermostat out of doors as well as one indoors. For gas systems a very minimum of space is required for the heating system. Here, again, the placing of a monetary value on convenience and other intangibles is difficult. It is certainly true that wherever natural gas is available, gas for house heating is going to be one of the most attractive methods, and where manufactured gas is available—although in the luxury class—gas heating is of growing importance.

Section V-e. Oil-burning Equipment

As the satisfactory operation of fuel burning equipment, such as oil burners, is equally dependent upon the quality of the burner and the perfection of its installation and adjustment, the purchaser of such equipment should:

1. Select a burner manufactured by a nationally known company of character, experience and financial responsibility.
2. Be sure that the local representative who makes the installation is financially responsible and mechanically competent.

This responsibility and competence is evidenced by a record of successful installations over a period of two years or more, with a burner listed as standard by the Underwriters' Laboratories or approved by other nationally recognized organizations such as the Oil Heating Institute.

Section VI. Operation, Care, and Repair of Equipment

Once a satisfactory heating system is installed, the results obtained, measured in human comfort and economy, will depend on the method of operation and the care which the system receives.

1. Manual and Automatic Control. The effect of type of heating system on regulation and control of air temperatures throughout the house, as well as on the flexibility and responsiveness of the system, is often given too little consideration. Certain systems may be controlled from a central point, such as the main heating unit, far better than others. Stoves, of course, which are individual units in themselves and must be dealt with separately, are hardly to be considered in this connection.

The ordinary one-pipe steam-heating system is simple in construction and low in first cost, but may prove very unsatisfactory from the standpoint of uniformity of heating and economy of operation if not properly designed, installed and operated. The inherent fact that the steam entering and the condensate leaving the individual heaters or radiators must pass, in opposite directions, through the same pipe, between the main and the heater, makes this a very difficult system to control. This is because the one-pipe connection to each radiator must be full open so long as it is in operation. This means that the relative quantity of steam going to each radiator must be governed solely by the pipe sizes and the rate of air elimination. In the same way the relative rate of cooling as steam goes down will be governed by the relative quantity of steam originally fed and the relative rates of air reentry to the radiators. Unless the system is nicely balanced, and the air elimination through the air valves on each individual radiator and at the ends of mains is commensurate with the size of the radiator, the time of heating up and the time of cooling off of the various radiators will be very uneven. This may cause a long interval between the time of heating up of the radiators closest to and those farthest from the boiler, and in the same way a long interval between the time of cooling of these radiators. This means that the tardy radiators receive their heat last and lose it first, as the steam pressure in the boiler is raised or lowered.

Where the control is by a thermostat, located usually in one of the down stairs rooms nearest the boiler, practically all of the radiators "go cold" every time the thermostat closes off the boiler. Under these conditions and unless the thermostat is set high enough to overheat the rooms nearest the boiler, the other rooms may not receive enough heat, so that the system will operate on an "all on" or an "all off" principle, causing the house to be alternately hot and cold with much waste of fuel. The same conditions will exist under hand control except that they may be exaggerated and depend considerably upon the skill and continuity of the attention given.

These difficulties may be substantially eliminated by the use of properly proportioned piping of ample size and proper air valves on radiators and mains, but the ordinary one-pipe steam system is so deficient in these respects that it usually operates on the "all on" or "all off" principle in a very unsatisfactory manner when dependent on hand control.

The use of a vacuum type of air valve on the radiators and mains of such a system will prevent the air from reentering the radiators and mains, thus eliminating much of the difficulty of the rapid and uneven cooling down of the radiators. With this type of valve and a substantially tight job, the pressure within the entire system may be reduced below atmospheric, as the fire is permitted to decline, thus maintaining more or less even distribution of vapor throughout all radiators, until the steam pressure is again raised.

Caution should be exercised in the use of modern extended-surface fin-type heaters or radiators with this type of system as the air and water elimination may prove unsatisfactory.

The simplicity and low cost of this system coupled with its possibilities, when properly designed, installed and operated, constitute the basis of a very satisfactory job.

Two-pipe vapor heating systems operate much the same as one-pipe steam systems equipped with vacuum air valves, except that they circulate much more freely, dispel air much more quickly and eliminate the noise, odors and leakage of air valves in the rooms by discharging all air in the basement.

This type of system is generally equipped with hand control valves or orifices at the inlet to each radiator so as to secure an even or any desired distribution of the steam or vapor throughout each radiator. The outlet of each radiator is also equipped with a thermostatic trap for passing the condensate and air to mains in the cellar, but prevents the passage of steam.

Neither the one-pipe nor the two-pipe vapor system can be run continuously for any length of time with subatmospheric pressure within the system. This is true for the reason that air leaks in, and can only be expelled by raising the pressure above atmosphere.

The tighter the system, the longer it can be run below atmospheric pressure, but in order to do this successfully the fire must be controlled accurately so as to produce vapor regularly and at the rate and pressure required by the weather conditions. The ordinary system is neither tight nor does it regulate the fire accurately, so that with the ordinary vapor system there is usually considerable lack of flexibility and temperature control, but the possibilities are much better than the ordinary performances.

The two-pipe fractional distribution steam-heating systems have great possibilities for control, flexibility and economy of operation, but are comparatively new in the house heating field. They operate on the principle of distributing the steam to the various radiators through orifices or/and fractional control valves in proportion to the weather requirements, thus either keeping a portion of the radiator filled with steam and the remainder of the radiator filled with air at atmospheric pressure or the whole radiator filled with a mixture of steam and air at or near the boiler pressure so as to give off the quantity of heat commensurate with the requirements. The former type operates with an open end vent in the boiler room for dispelling the air and the boiler pressure is maintained slightly above atmospheric pressure. A pump is required for returning the condensate to the boiler. The damper or other fire control on the boiler maintains a constant steam pressure. The latter type operates with an automatic air vent in the basement and may be operated periodically above and below atmospheric pressure much the same as a vapor system, with damper or fire control at the boiler for maintaining steam or vapor pressure according to weather requirements and operated from a central thermostat in one of the rooms.

Two-pipe subatmospheric vacuum steam-heating systems with full automatic control on the boiler drafts, oil burner or gas burners and on the vapor pressure within the system, operate on a more or less continuous temperature ranging from 140° F. to 212° F. in the radiators, depending upon the weather requirements. The success of the control of such a system depends greatly upon the proper and gradual control of the fire or the capacity of the steam generator to continue to furnish vapor after the fire is reduced or extinguished by its control. Best results cannot be gotten with an "all on" or "all off" fire control for this kind of a system, since all the vapor from the boiler is used soon after the fire is out and radiators "go cold" until the fire is again turned on. This type of system is expensive, but has great possibilities for control, flexibility, and economy of fuel. They usually require some power to operate.

Hot-water heating systems are usually designed to operate at lower temperatures in the radiators than exist in any of the steam systems, hence much larger radiators are required with such systems when operating with an "open" expansion tank placed above the highest radiator. In this country these "open" tank systems carry a maximum water temperature of about 180° F. and are designed for a temperature drop of 20° F. in the water passing through the radiators, giving an average water temperature in the radiator of 170° F. Unless these systems are properly designed by an experienced person, they may not circulate uniformly, and the drop in temperature of the water passing through some radiators may be very much greater than in other radiators. As a result, the water in these radiators may be much lower in temperature than in other radiators and the house will be heated unevenly. Small motor driven water circulating pumps are sometimes installed on the return main near the heater in order to improve the circulation in these systems and provide for a more positive and uniform circulation in the main piping system. Hot-water systems may be installed with a single flow and return main or with separate flow and return mains in the basement. Sometimes the flow main is carried overhead and run in the attic space, if available, which gives a more uniform operating head on all radiators, but this is, of course, a more expensive installation.

Hot-water systems may also be installed with a "closed" expansion tank in the basement. In this case. the maximum water temperatures in the radiators can be increased to steam temperatures of 215° F. or more, and no increase in the size of radiators over those used for an all-steam system is necessary. The "closed" tank prevents the water from boiling in the heater which would certainly occur in an "open" tank system with these higher water temperatures.

A direct hot-water heating system, as well as an indirect warm-air heating system, is extremely flexible and the house temperature may be controlled from the main unit by manual or automatic regulation of the drafts. In mild weather, very low water or air temperatures may be maintained, and in severe weather very much higher water or air temperatures, corresponding to the weather conditions, may be maintained. So long as there is any fire in the main unit, there is heat in the hot-water radiators or in the air entering at the registers.

The warm-air furnace system is most responsive, as a change in fire intensity in the main unit is immediately reflected in the temperature of the air passing through the system. These systems, when installed in residences, usually recirculate the air from the house through one or more return air registers located in the first floor of the house. The warm-air risers and registers must always be located in or along inside walls and never placed in cold outside walls.

It is neither necessary nor desirable to take the air supply from the outside since the normal air change in any residence is more than sufficient for ventilation and considerable economy results from not heating any unnecessary outside air. The air supply should never be taken directly from the basement. It is most important that these return registers and connections be as large and direct, that is, free from sharp turns, as possible. If these connections are made too small, too long or too tortuous, it will be necessary to overheat the furnace and the air passing through it in order to increase the motive head (similar to chimney draft) sufficiently to overcome the resistance of friction of these unsatisfactory return connections. Unfortunately, due to ignorance of this fact, many otherwise satisfactory *warm-air* systems become *hot-air* systems, and the furnace is overfired or "burned out" in a short time. Moreover, with such highly heated "hot air" entering the rooms at air temperatures above 175° F. serious stratification of air takes place in the rooms resulting in high air temperatures at the ceiling and low air temperature at the floor, even with the breathing-line air temperature at 70° F. Fuel waste and discomfort are the usual result in such a *hot-air* system, whereas with a properly designed *warm-air* system in which the air circulates freely with comparatively low entering air temperatures, never above 175° at any register, both economy and comfort are readily secured.

2. Overheating and Effect on Fuel Consumption and Life of Equipment. The maintenance of any heating system depends largely on the care and attention given to the system and varies over a wide range. No system is absolutely foolproof, but a warm-air furnace system is practically immune against freezing, which, of course, is not true of steam and hot-water systems. The fuel burning unit of any heating plant may be ruined in a comparatively short time by careless firing and indifferent control of drafts. An exactly similar unit and type of heating system may last a life time if carefully fired and properly regulated, so that the fire is never allowed to "run away" with drafts left wide open. Uniformity of operation, meaning a fairly constant house temperature day and night, means long life for the main unit, and more comfort for the occupants, and generally requires less fuel.

Throwing the drafts wide open and then allowing the plant to "run wild" every morning is about as perfect an illustration of "what *not* to do" with a heating plant as could possibly be found.

3. Reduced Temperatures at Night During Heating Season. The idea seems to be more or less prevalent among house owners that any fuel not burned at night is just so much fuel saved regardless of how much the house may have cooled off during the night. The justification for such an idea is very slight indeed provided it is necessary to bring the house back to a comfortable condition promptly the next morning. In fact, if there is any considerable drop in house temperature (more than 10° to 15° F. below daytime normal), there are several distinct disadvantages, and no saving in fuel is possible.

These disadvantages, which increase rapidly as the outside temperature drops, are: (a) A serious overload on the heating plant during the early morning recovery period, when the main unit is being forced to the utmost. Such daily forcing of any fuel burning unit materially shortens its life. (b) Fuel is often burned wastefully and in large quantities during these forcing periods, as all losses are usually aggravated, particularly the heat carried away in the very hot flue gases. (c) The house is not comfortable even after the air temperature has been brought back to the usual daily normal, because the walls and floors cool off as the inside air temperature drops during the night, and it may require several hours to warm them up to normal. In consequence, the inside air temperature has to be raised several degrees above normal at the very worst or coldest time out of doors. The home owner fails to realize that during the very time his house is cooling off the outside air temperature is also falling rapidly, and hence his heating plant has to pick up the load under the worst possible conditions.

It is, therefore, doubtful if any fuel economy results from any appreciably reduced temperature at night, and it is quite certain that both "wear and tear" on the heating unit and human discomfort are increased by this much too common practice. Sleeping room temperatures may be reduced as much as desired, but doors between these rooms and the rest of the house should be made as tight as possible by weatherstripping and kept closed at night, and radiators or registers in these rooms should be shut off or (in the case of hot-water systems) covered at night. Bedrooms with open windows may cause a serious waste of heat in small houses and greatly increase the cooling off of the rest of the house at night.

4. Factors Affecting Operating Costs. Since the principal item of operating cost in a heating plant is the cost of fuel, the efficient utilization of that fuel is the most important operating factor in the problem. There are three steps involved: (1) Efficient combustion of the fuel (complete combustion) in the fuel burning unit, (2) efficient transfer, in the same fuel burning unit, of the heat of the fuel to the medium, such as water, steam or air, which heats the house, and (3) efficient transmission of this heat to the individual rooms or heated spaces of the house. With the single exception of electricity, there are bound to be losses, often large losses, at each step in the process.

It is the house owner's objective so to operate his heating plant that each of these losses will be as small as possible. Detailed information on the first step in this process, efficient combustion of fuels, has been given in Sections V-a and V-b which deal with "Fuels" and "Fuel Burning Equipment." It should be evident that we can neither transfer the heat of the fuel to the heating medium nor transmit heat so transferred to the rooms unless we *burn the fuel completely* in the first place. Here is where the greatest loss usually occurs, and with fuels poorly adapted to the fuel burning unit and careless or ignorant operation of the fire, this loss in combustible can, with high volatile coal, easily amount to 25 per cent or more of the heat in the fuel. With properly selected fuels and careful and intelligent operation of the fire this loss in combustible in the flue gas should be kept well within 15 per cent of the heat in the fuel, even with hand firing. With properly adjusted mechanical fuel burners it should not exceed 10 per cent for either solid, liquid, or gaseous fuels. The best types of gas- and oil-burning units probably develop nearly 100 per cent of the heat in the fuel; in other words there is no unburned combustible escaping in the flue gas. Such efficient performance requires perfect adjustment of the burners to suit each particular grade of fuel and rate of feed.

In addition to the loss of combustible in the flue gases, there may be, in the case of certain solid fuels, a considerable loss of solid combustible material through the grates, resulting from excessive shaking of the grates or careless cleaning of the fire. Such losses are, to a large extent, under the control of the fireman, but even with average care and attention the combustible in the ash may amount to 25 per cent of the weight of ashes removed from the ash pit.

The second step in the process of efficient utilization of the fuel is the transfer of the heat liberated by the combustible of the fuel to the heating medium and also takes place in the fuel burning unit. The time available for this transfer is extremely brief, often only a few seconds elapse between the burning of the particles of fuel and the time they escape into the smoke pipe. If there is not enough clean heating surface, properly placed to absorb the heat and cool the hot gases to a reasonable temperature as they enter the smoke pipe, then the second step in the process may prove very wasteful and the efficiency may be very low. It is not practical to take out all the heat (that is, cool the gases down to room air temperature) since they must leave at least as hot as the heating medium. Moreover, with natural draft, some heat, possibly 15 per cent of the heat in the fuel, is required to keep the flue gas in the chimney hot enough to create and maintain a draft. The items which determine efficient heat transfer are:

(a) Clean heating surface, both that in contact with fire or hot flue gas on one side and with the heating medium on the other side.

(b) Sufficient area of surface to absorb the heat generated at the maximum rate of burning fuel.

(c) Proper location of heating surface. Solid fuels burning as an incandescent mass require a large amount of direct surface on which the "fuel shines" or which can "see" the fuel. Liquid and gaseous fuels usually require more indirect surface.

(d) A fairly uniform rate of burning fuel; seldom provided for or achieved in either manually or mechanically fired plants of the present day.

The third step in the process of efficient utilization of the fuel is the transmission of the heat absorbed by the heating medium from the fuel burning unit to the rooms or heated spaces of the house. This matter is not as important as the other two, as heat "losses" in transmission are not absolute losses, like losses in the combustible carried away in the flue gases. Such "losses" in heat transmission are really in the house somewhere, but they are not very effective in heating some distant room. Therefore, reasonable attention should be given to covering and protecting the heat transmission lines, such as pipes and ducts, so that as large a percentage as possible of the heat which leaves the main fuel burning unit will reach the individual rooms, especially the more distant ones. In fact, either extra capacity should be provided in these long runs or else *such distant rooms should be specially insulated.*

Operating costs should not vary greatly in the same house between the various types of systems, provided the same fuel is used and the same degree of temperature control is exercised, and we have a well-designed plant in each case. Small differences in the overall efficiency of the heating plant as a whole are of no great consequence in a small house since the only heat which should be really lost from the house is that left in the smoke gases at the top of the chimney, assuming an inside chimney. Of course, if there is much difference in the completeness with which a given fuel is burned, the efficiency of the main unit becomes important.

There is apt to be considerable difference in the quantity of fuel consumed with the different types of systems, however, due to the relative degree of overheating, the accuracy with which temperatures may be controlled, and the uniformity or lack of uniformity of temperature between floor and ceiling. Obviously a system which does not permit practical control of room temperatures will overheat the rooms and so consume excessive fuel on this account, other factors being equal. Likewise a system with which it is impractical to secure uniform temperatures between floor and ceiling must operate with a relatively high temperature near the ceiling in order to maintain comfortable temperatures near the floor and will, therefore, waste heat through the upper portion of the rooms. Generally speaking, systems which are the most flexible and which are capable of most nearly controlling the inside air temperature regardless of outside conditions are the most economical of fuel. As between the poorest and best systems in this respect there may be a variation of 25 per cent in the amount of fuel required.

5. Ash Removal. Practically all heating plants burning solid fuel develop more or less ash, which varies in amount with the kind and quantity of fuel burned. Small size anthracite coal runs high in ash while such a fuel as petroleum coke contains very little. In most cases, however, the proper and frequent removal of the ash from the firebox and the ash pit is an important matter, which, if neglected or incompletely accomplished, results in burned out grate bars and sluggish fires.

Grate bars are made of cast iron which will warp, soften, and melt at high temperature, and these bars may do all of these things with a very hot fire on the grate if ashes are allowed to accumulate *below* them in the ash pit so that no air can get to the back of the ash pit and keep the grate bars cool. One set of grate bars should last as long as the heating unit if the house owner will keep the ash pit clean *all the way back*. Some accumulation of ashes *above* the grate bars, especially when carrying a very hot fire, is desirable, in order to still further protect the grate bars from the intense heat of the incandescent fuel. With fuels running very low in ash content this latter precaution is very important.

Ashes and clinkers above the grates should also be removed, preferably by shaking them through the grates. Sometimes clinkers must be handled through the fire door, in which case every effort should be made to get the clinkers out with as little mixing of hot fuel and ashes as possible or still more clinkers will surely be formed. However, never disturb, shake or rake a nearly burned out fire until after a *little* fresh fuel has been added and ignited so that the fire can stand the disturbance without being completely extinguished.

Section VII. Factors Affecting Health and Comfort

The optimum conditions of temperature, humidity, and air motion vary with climatic conditions, with the age of the occupants of the house, and with the type of clothing worn. Of these three factors, climate or acclimatization is probably the most important. In winter we like an indoor temperature which we would consider uncomfortably cool on a hot summer's day; older persons and babies feel the cold more than children and young persons do; clothing, particularly underwear, worn in the United States varies with climatic conditions.

The combination of these three variables—temperature, humidity, and air motion—is the basis for the cooling or warming effect of any atmosphere, and an alteration in any one gives the impression of a change of temperature. Charts and tables are available by which these variations can be evaluated in terms of the heating or cooling effect, and the householder should realize that he can keep his home comfortable in winter and summer by the use of very simple, inexpensive means.

1. **Temperature**. During the months in which central heating is used, it is best to maintain with moderate humidity, an indoor temperature between 68 and 72° F., the lower temperatures applying roughly to the northern half of our states, and the higher range to the more southerly states. It is desirable that these temperatures represent average room conditions and that the differences between floor and ceiling temperatures be as small as possible. In homes with badly designed heating plants and improperly located radiators, differences of 15° between floor and ceiling temperatures are not uncommon. Hygienically and economically, such differences are very unwise. They should not, and need not, exceed 5°.

During summer weather the optimum indoor temperatures lie between 70 and 85° with a relative humidity not exceeding 50 per cent. It is not wise to maintain a temperature within as narrow a range as that advocated for the winter months. For example, on a 95° day, it is found that an indoor temperature of 80 to 85° is preferable to one of 75°. We are not adapted to such great changes of temperature in summer as in winter, nor does custom allow us to take off clothing to the extent represented in winter by the removal of a heavy overcoat, gloves, etc.

2. **Humidity.** Air contains a variable amount of moisture usually measured as a percentage of the maximum which could be present in a unit volume of air at any given temperature. The relative humidity of saturated air is 100 per cent, while that of chemically dried air is zero.

Air at 20°, when warmed to a comfortable room temperature, is very dry, and absorbs moisture from every available source, such as household furnishings or human skin. There is a fairly widespread feeling among competent physicians, supported by a certain amount of physiological evidence, that alternate exposure to dry warm air indoors, and cold wet air outdoors predisposes one towards colds. The arguments in favor of humidification are, therefore, the prevention of damage to household furnishings and the possible reduction in the likelihood of catching cold. Of the two, the former is indisputable, while the second is debatable.

With an inside temperature of 69° and a relative humidity of 50 per cent, condensation will occur on single glass windows when the outside temperature is only 43° but will not occur on double sash windows, of good construction, until the temperature is as low as 15°. Expressed another way, an outside temperature of 20° causes condensation on single windows when the relative humidity reaches 25 per cent, but on double sash, there is no condensation until 52 per cent is reached.

With humidifiers available today, the householder can easily maintain 30 to 40 per cent relative humidities in a home with weatherstripped doors and windows. There is then need for double windows only where the cold is extreme. The owner will probably experience difficulty in maintaining the desired humidities in cold weather unless he dispenses with open fires and closes the damper in the chimney openings. Otherwise, leakage of the humidified air through the chimneys is so great that the average humidifier is rendered ineffective.

The home owner can obtain a fair idea of the effect he can expect from a humidifier by watering either the cellar floor or (if he burns coal) the coal pile, and leaving open the door at the top of the cellar stairway. Flowers and plants growing in a room are also simple humidifiers.

Humidification permits the use of lower indoor temperatures than would otherwise be acceptable. From this it should not be inferred that fuel economy results from humidification as the opposite is true. Suppose we have a relative humidity of 60 per cent, and an outdoor temperature of 20°. By the time this air has been heated to make the room comfortable at about 74°, it will have been dried so much that the relative humidity will be only 9 per cent. By increasing the relative humidity to 50 per cent, we need only a 69½° temperature to get comparable warmth and comfort, but the heat required to evaporate the water practically offsets that gained by reducing the indoor temperature, and in most cases no actual saving in fuel consumption results.

In a house which has not been weather-stripped, we need about two gallons of water a day for the living room and about ten for the entire house. Weatherstripping, in spite of a reasonable opening of doors and windows, reduces this figure to about half. However, more water must be evaporated than purely theoretical considerations demand and unless a substantial margin of safety is allowed, the results of humidification are disappointing.

Humidifiers which are installed in the cellar and form an integral part of the heating system are generally the most satisfactory and best adapted to automatic control. They cost from $200 to $350.

Cabinet type humidifiers, piped with water and arranged with automatic humidity control, have been developed to the point where they may be used for humidifying in winter and dehumidifying and cooling in summer. They cost from $50 to $500, depending entirely upon their rated capacity and expected performance.

Evaporating pans placed upon the radiator generally have about a fourth the required capacity and are ineffective unless kept clean and filled with water. Cans or tanks connected with warm air furnaces are likely to present the same defects but can easily be made adequate and automatic.

3. Air Motion. In warm weather natural or artificial drafts serve as a substitute for lowered temperatures. Although this simple fact is known to all, the magnitude of the possible cooling effect is not fully appreciated. Suppose we have a temperature of 85° with a high humidity but with no perceptible breeze from the open window. The use of the ordinary electric fan will then produce a cooling effect equivalent to a drop in temperature of 7°, which is enough to make pleasant and stimulating an otherwise hot and humid room.

Stale air, which does not circulate is always unpleasant. Because houses are not air tight (and we do not attempt to make them tight) we have a certain slight but ever-present exchange taking place. This may mean a draft, too slight to be perceptible to the average person, but easily measurable with appropriate instruments. The absence of these slight air currents (amounting to 10–20 feet per minute) invariably causes a sensation of stuffiness.

4. Cooling and Dehumidifying. The atmosphere of a hot, sticky summer day can be improved artificially by lowering the temperature, by decreasing the humidity, or by increasing the air movement. A combination of the first two methods is commonly employed, and apparatus of both the central-system and unit types is available for this purpose and is becoming increasingly popular.

Dehumidification, by passing humid air through a chemical absorbent, like silica gel, has been applied successfully to large homes, but its application to these very small domestic installations has yet to be developed. Ice water sprays or ice-cooled surfaces may also be used for dehumidification purposes, but the very small domestic installation is still in process of development.

The central-system types may be separate, but are generally combined with a warm-air furnace for giving warm, filtered and properly humidified air in winter, and filtered, cooled and dehumidified air in summer, all under automatic control. Such a system may have a division of units and ducts so as to warm the entire house in winter, but cool only one or more rooms in summer, and thus reduce the first cost and expense of operation for cooling. In such an arrangement it is possible, for example, to cool a living-room by day and a bedroom at night.

Where the whole house is involved, the added first cost for cooling in such a system amounts to from $750 to $1,500 and the operating cost per season, with electric current at two cents, $75 in the cold climates to $175 in the warmer ones.

For the cooling of one room, the first cost ranges from $500 to $800 and the cost of operation from $20 to $50 per season. Unit coolers and dehumidifiers for one room are available also at somewhat lower prices.

Apparatus is now on the market in the form of gas, oil, or coal warm-air furnace systems which automatically clean, humidify, and warm the air in winter and may be arranged to clean, cool, and dehumidify the air in summer. A complete system of this kind costs from $1,500 to $2,500. The cost for manufactured gas at eighty cents is about 1½ times that of coal at $14 a ton. Oil is nearer the cost of coal. Both the central type and the unit type are made with water-coil precoolers which cost slightly more, but save refrigeration costs where cold water is available.

Air washers with recirculated spray water may provide some cooling of the air, but they always increase the relative humidity, and they can never cool below the wet-bulb temperature of the air entering the washer.

In cooling homes within the price range of this report, it is suggested that one room, such as the living-room or a bedroom be treated in preference to the whole house, so as to reduce the first cost and cost of operation. In selecting the room or rooms to be treated, it is advisable to choose those having the least exposure to sun and reflected heat, and the most shade or other natural advantages. A sitting-room in the cellar, if available, is comparatively easy to cool and to maintain so, since the heat intake from the outside is small. Vines on the outside walls, and plants, in the room to be cooled are helpful since the vines reduce the heat intake, and both give some cooling effect by the evaporation of moisture.

Insulation, which may be used to advantage, costs about $400 and saves about $250 in the first cost, on the basis of air conditioning for the entire house. For one room the cost is about $100 and the saving $150. The resultant savings in operation vary from $25 to $75 for an entire house, and from $5 to $15 for one room.

Small electric-fan units for setting in walls, with automatic weatherproof louvers and condenser-type speed-control motors, are recommended for cooling kitchens, laundries, and bathrooms.

The speed control may be omitted, but is valuable in reducing noise at such times as the higher and more noisy speeds of the fan are not required. The controls are bulky, and should be mounted in a box in the wall or in a closet. These units cost about $35 without, or $50 with, speed control.

Ventilators in the roof will also relieve some of the heat from the attic space, and they are inexpensive, but care must be exercised in seeing that they are not unsightly.

5. Effect of Atmospheric Impurities. The flue products from no oil or coal appliances, except kerosene and gasoline cookstoves, should be allowed to vent into the atmosphere of the house. Rules for the flue connection of gas appliances have been prepared under the auspices of the American Gas Association, in cooperation with the United States Bureau of Standards, United States Public Health Service and other national bodies, which should be strictly followed in so far as they do not conflict with local ordinances. Numerous accidents and fatalities throughout the United States have been caused by ignoring these simple and inexpensive precautions. The accidents have been due invariably to carbon monoxide gas, the poisonous ingredient formed by the incomplete combustion of all fuel. Architects should be careful to provide ample flues for various types of fuel-burning appliances in the design of new houses. The cost of chimney construction is much less at such time than if it has to be done after the house is built.

Accidents have resulted occasionally from leaks in various types of mechanical refrigerators. The householder will do far better to open the windows and call the proper repair man who understands the risk than to attempt the necessary repairs himself.

Soot and smoke, which damage furnishings and increase the work of cleaning, are not so much matters of health as of inconvenience. Modern vacuum cleaners have done much to reduce the routine work of cleaning, but in no way have they lessened the amount of dust and dirt which comes into the house. Weather-stripped doors and windows, making a tighter house, help in this respect.

The pollens of numerous flowers and weeds cause hay fever in a small percentage of the population. Pollen-free air can be had inexpensively in one or more rooms of any well-built house. The apparatus needed consists in a suction fan which draws air from outdoors, passes it through a dense filter to remove the pollen, and then blows it into the room. The entire apparatus is about the size and appearance of a radio cabinet and uses approximately the same amount of current as does a vacuum cleaner.

Gas and oil heating systems have the advantage over coal of being clean and eliminating dust from ashes. The gas-fired unit with complete air conditioning has perhaps the greatest possibilities in this connection. In this system, a large fraction of the total air in the house is brought back, washed, and circulated through the rooms again, thereby cleaning out a great deal of the dirt in the house. The advantages of a spotlessly clean house from the health standpoint are difficult to prove, but the clean and neat home is generally one with healthy occupants.

Section VIII. Inspection and Certification of Equipment and Systems

The heating plant in the home, contributing so much to the health and comfort of the people, receives little or no attention from public bodies charged with the duty of protecting the public in matters of health, comfort and safety.

Neither state laws, municipal ordinances, nor building codes, in so far as the committee has been able to find, provide in any comprehensive way for such inspection or certification as to insure to the home owner an installation of a system that will meet his expectations or properly serve his needs. The type, kind and adequacy of the heating system of the home seem to be considered in general as entirely outside the jurisdiction of the law and something that the home owner has the right and responsibility of determining without official aid, advice or interference.

Whatever protection he has must come from the heating contractor to whom he entrusts the installation. The ordinary heating plant installed in a home rarely warrants the employment of an expert engineer and, unfortunately, many men and firms, taking contracts for heating, are sadly lacking in a proper understanding of the scientific principles involved in the problem and many very unsatisfactory installations are made. The choice of a good contractor, however, is of far more importance than the saving of a few dollars by the selection of one whose bid may be low, but whose ability may be lower.

Educational activities of engineering societies and of manufacturers interested in the proper installation of their products, do not seem to cover the field with a thoroughness that offers much hope of relieving the situation, so far as inspection and certification are concerned. This situation has been one of grave concern to the heating industry and it would appear to the committee that the most promising attempts thus far made to protect the householder have been initiated and applied in a very effective way by the National Warm Air Heating Association and the Heating and Piping Contractors National Association.

In the field of warm-air furnace heating, the National Warm Air Heating Association has developed a "Standard Code Regulating the Installation of Gravity Warm Air Heating Systems in Residences," which is now in its eighth edition. This code is intended to provide the installer with all the necessary information for the correct design, layout and installation of such systems in residences of all kinds. The standards of good practice which are set forth in this code are based on the results of the research work which the association has been conducting for the past thirteen years. Ordinances based on this code have been adopted by a number of municipalities, but in general, outside of these municipalities, no certification or inspection of warm-air furnace heating plants for small homes is required by law, nor is such a service available, except as may be arranged for privately.

In the field of steam and hot-water heating, the Heating and Piping Contractors National Association has established their code or principles of "Certified Heat" which apply only to radiator heating. This association has spent much time and money in the development and setting up of definite standards of radiator, pipe and boiler sizes, etc., to meet the heating requirements of small buildings in all sections of the country, paying particular attention to the home.

Any member of the association, licensed in the sale of "Certified Heat," is compelled to install the work in accordance with the national standards. All plans are checked by one of the national association engineers who also inspects and checks the work during its installation, entirely independent of the contractor, and compels observance of, and adherence to, the national standards.

In the installation of such a system all guesswork has been eliminated. Every part of the installation is made in accordance with the best scientific data available, and carries not only the guarantee of the local contractor but that of the Heating and Piping Contractors National Association.

Both the American Gas Association and the American Oil Burner Association, as well as the various coal associations, such as the National Coal Association and the Anthracite Institute, will be glad to supply the home builder or home owner with information relative to the use of the respective fuels in which they are interested, and the equipment required for the combustion of such fuels.

Where fire insurance is carried on a home, inspection of the plant may be made by a representative of the Board of Fire Underwriters, but this has nothing to do with the adequacy of the plant. The Board of Fire Underwriters concerns itself only with the elimination of fire hazards in the location of the boiler, the setting of the smoke piping, and the running of heating pipes through partitions, etc.

Section IX. Group Heating from a Central Plant

In many of the larger cities, and in not a few smaller communities, steam or hot water for heating purposes is served to all classes of buildings through mains that start at a boiler plant, located generally at a remote point. These mains are run through the streets like gas and water mains, and service connections are taken from them to the buildings.

These plants are generally operated by a private company under a franchise granted by the governing body of the municipality. This franchise generally gives them the exclusive right to run such mains through the streets.

Where such systems are available they, of course, obviate the necessity of boilers, stacks, coal bins, etc., and eliminate dirt, smoke, and the inconvenience of ash removal. For the small home owner, however, the cost of such service is generally prohibitive and may be considered only as a luxury.

Some few attempts have been made in connection with group housing programs to eliminate the individual boiler plant and serve the group from a main boiler plant located at a convenient and nearby point. One of the best examples of such group heating is found in connection with a development owned by the Girard Estate in Philadelphia. This is a forced hot-water system in which approximately five hundred homes are heated by hot water pumped from the power plant through underground distributing mains to all of the buildings in the group. The temperature of the circulating water is regulated at the power house in accordance with the outdoor temperature so that, regardless of outside conditions, an even temperature of 70° F. will be maintained in all houses. This regulation of temperature makes for economy in operation, as well as for comfort in the home. There is another plant located near Cincinnati, Ohio, where a large group of residences is heated by a steam distributing system from a central power plant.

Whether steam or water is used, however, the cost of central heating, even where this distribution is concentrated and confined to a compact group, is likely to be greater than the cost of operation by individual boiler plants, both as to first cost as well as to operating cost.

The higher first cost is due to many things, not the least of which is the necessity for maintaining a separate power house and stack, whereas in the case of the individual plants, cellar space not otherwise occupied would be utilized for boiler purposes. Furthermore, there is the cost of distributing mains, tunnels, pumps, etc., as well as the fact that, although a limited number of boilers is used, the cost is likely to be greater than the combined cost of all the small individual boilers. In operating such a plant, there are line losses, or losses from distribution pipes between buildings, which does not occur in the case of the individual boiler. Furthermore, the entire plant has to be operated to suit the most exacting demands as to time of operation, and as to temperature carried.

Where the individual householder has control of his own plant, he operates it with a scrupulous regard for economy. Where he is served from a central plant, he is more likely to be very exacting in his requirements. Furthermore, the householder, as a rule, performs his own labor in the firing of his boiler, and the handling of his ashes, for which no charge is made against the operating cost; whereas, in a central plant, firemen and engineers are required throughout the twenty-four hours of the day.

Section X. Garage Heating

Any consideration of methods of heating garages for small homes involves the question of whether the garage is separate from, or attached to, the house structure. In the latter case, it may be practicable to heat it from the house heating plant, provided the plant has sufficient heating capacity, while in the former case this is seldom practicable. But in any case the garage should be made as nearly wind-tight as possible and should preferably have a tight ceiling forming an attic space, if such space is available. Attempts to heat loosely built sheds often little better than "packing boxes" are destined to failure. Naturally, the better and tighter the construction, the easier it will be to heat the garage, and the less heat it will need.

Under no circumstances should the garage be heated above 50° F., whether connected to the house heating plant or not. Great waste of fuel results if these poorly constructed buildings are overheated.

Separate heating plants, consisting of a fuel burning unit placed directly in a small garage, are more or less of a fire hazard, the risk varying with the degree of attention to, and control or regulation of, the fire. The ideal heating plant would be a low-temperature non-luminous electric unit, but in most cases operating costs would prove prohibitive. In case coal-, gas-, or oil-burning garage heaters are used, they should be approved by the fire insurance company concerned or by the Board of Fire Underwriters.

It would, therefore, seem that the only really practical solution of this problem, in the case of the small home owner, is to incorporate the garage as a part of the house structure, and then provide for sufficient additional capacity in the house heating plant to take care of the garage. This will involve the least expense both for installation and operation of the heating equipment of a small garage.

Section XI. Waste Disposal for Small Homes

The satisfactory disposal of waste, which includes garbage and miscellaneous household trash, confronts every home owner, and the problem becomes especially acute where no municipal or other organized waste-disposal service exists. In any case, it is desirable to dispose of all such waste material as promptly, conveniently and completely as possible, since these accumulations constitute either a health or a fire hazard or, more usually, both.

A large part of the waste accumulations of every household is combustible, and hence can readily be destroyed by incineration in the proper type of equipment, connected with a suitable chimney flue to provide the necessary draft. The house heating equipment should never be used for this purpose, especially in the summer time. Unnecessary corrosion and fouling of valuable heating surface will result if any such bad practice is permitted. The incinerator unit may be of the portable or built-in type and should be located in the basement for the greatest convenience. In fact, with the built-in type, the waste does not even have to be carried to the basement, but can be put into the incinerator through a hopper door in the kitchen that opens into the incinerator flue. This requires some forethought in planning the house so that this flue will be properly located in one of the kitchen walls.

In operation, it is essential that a considerable proportion of the charge consist of dry combustible trash or waste material mixed with the green or wet materials so that combustion will be rapid and reasonably complete; otherwise a smouldering fire may result. To incinerate such mixtures, the fire should burn *from the top down and an ample air passage should be maintained* either through or around the burning material. Such an air passage also assists materially in the drying out of the moisture between firings. Special gas-fired incinerators are available for use where gas service exists, in which case the combustion is not dependent on having a large proportion of dry combustible material mixed with the garbage. The small amount of ash from any properly operated incinerator, except for metal, tins and glass, can be used as fertilizer in the garden beds around the house.

The use of outdoor wire-basket trash burners for disposing of garbage and other wastes is not as satisfactory as the use of present-day commercial incinerators installed in the basement and connected to a chimney flue which creates a positive draft at all times. Such makeshifts are soaked with rain unless carefully covered and the smouldering fires which result pollute the atmosphere to leeward for long distances if there is any wind movement at all. If they are used, the charge should be well sprinkled with kerosene and then lighted *from the top,* after a careful observation indicates that the direction in which the resulting smoke will drift will not create a nuisance.

The cost of satisfactory incinerator equipment ranges from $50 to $200, depending on type and size of unit. These prices do not include the chimney, which, of course, must be provided, nor do they include the brick work for the built-in type which should be constructed by a brick mason. It is possible, with the portables, to make use of the kitchen range flue by extending it down to the basement, but this arrangement is not, by any means, considered the best practice.

The home owner should certainly give careful consideration to his waste-disposal problem at the time of planning a new house or remodeling an old one, and provide a separate flue for an incinerator of either the portable or built-in type.

CHAPTER IV

PLUMBING AND SANITATION[1]

Modern plumbing in the home is the factor which, more than any other, tends to create clean and sanitary conditions.

It is the intention that this discussion shall lead the home builder and the home owner to the installation of sanitary plumbing systems, and thereby safeguard the health of the nation.

Section I. Looking Backward

The span of a single life might well encompass the years in which sanitation has been developed from the crude practices of centuries into the classified knowledge and understanding of the laws and principles involved, which now stamp it with the dignity of a science.

The old drainage systems of half a century ago, consisting of brick, flag, or tile sewers, connected by leaky putty and cement joints, have gradually been replaced with pipes of substantial rust-resisting cast iron and steel, or wrought iron, screwed together, or made tight with caulked lead joints. Their tightness is now assured by tests made under water pressure, air pressure, and by filling them with smoke; so that, where a modern plumbing system is installed, the owner may be secure in the feeling that he and his family are not inhaling the foul stench which formerly issued from slime-covered drainage pipes.

Without the present-day venting system it is impossible to install a practical plumbing drainage system for any building exceeding one story in height.

The plumbing industry has taken advantage of the opportunities that the "Machine Age" has created and has utilized them to the fullest advantage in improving manufacturing methods, as well as the quality, the appearance, the sanitary aspects, and the efficiency of the fixtures and materials that go to make up a plumbing system.

Coloring has been added to pottery and enameled iron, so that all sorts of color schemes may be carried out to satisfy the most

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[1] This chapter of the report was prepared for the Committee on Fundamental Equipment by Messrs. A. E. Hansen, E. F. Carter, W. H. Driscoll and J. L. Murphy, members of the committee.

exacting tastes. Whether this most recent development will prove to be a passing fad or a continued trend remains to be seen. It will be found difficult to make replacements of colored fixtures, if such replacement is necessary, to exactly match the fixtures removed. It may be difficult to get an exact match between the tile walls of a bathroom, the plumbing accessories, and the fixtures.

The manufacturers have yielded to the demand for colors and have solved the problem in a highly satisfactory manner, but the home owner is cautioned to give careful thought to the subject before he indulges in the luxury of their use.

Modern fixtures are so designed that they can be quickly filled without splashing, and the waste water can be rapidly removed. The modern American demands a saving of moments, even when he is filling his plumbing fixtures.

It has been constantly in the minds of those connected with the plumbing industry to produce fixtures more and more sanitary. Even the nerves of the user have been taken into consideration in attempting to make fixture operations silent.

It stands to reason that progress in developing plumbing fixtures, plumbing design, and plumbing materials may not be so rapid in the future as it has been during the past fifty years.

It is the opinion of the committee that plumbing fixtures, and plumbing systems, purchased and installed according to modern practice, will be acceptable twenty years from today, although it must be borne in mind that fashions in clothing, in homes, and in plumbing fixtures will continue to change.

Section II. Sources of Water Supply for the Home

The sources of water supply which the individual householder can develop for himself may be divided as follows:

(a) Rain water;
(b) Springs;
(c) Shallow wells;
(d) Deep wells;
(e) Streams.

1. Rain Water. The evaporation of water from sea and land is condensed in the cloud strata, falls through the air to the earth and, in passing through the air, absorbs soluble gases and carries with it particles of dust. Although in its original condensed form it is probably distilled water, when it reaches the earth it has absorbed such gases as ammonia, carbon dioxide, sulphur oxides, and chlorine, and has brought down with it mineral and organic particles of dust.[2]

The usual method of collecting rain water for domestic purposes is by means of gutters on the roofs and downspouts that discharge into either exposed or underground tanks or reservoirs. Reservoirs of this kind should be covered to prevent access of sunlight, flies, mosquitoes, and vermin. Sunlight is necessary for the growth of plants; the green scum found in barrels of rain water could not exist if the barrels were covered.

Rain water is soft, excellent for washing, but in its natural form will rapidly corrode iron and steel; the purer the water, in popular language, the more likely it is to produce such corrosion. Rain water should not be carried through lead pipe; it attacks lead and may create serious lead poisoning if the water is used for drinking purposes.

The best method of storing rain water is in underground stone or concrete water-tight reservoirs, from which it may be pumped either by hand pumps or mechanical power pumps.

In regions where water is ordinarily hard and therefore unsuitable for washing, the house owner may find it advantageous to collect the rain water and use it for laundry purposes only.

Long drought periods in different regions of the country necessitate large storage reservoirs for rain water; in regions where the rainfall is evenly distributed throughout the year such reservoirs may be smaller. Assuming that the average family uses for washing purposes 100 gallons per week and that during the dry summer season no rainfall occurs for a period of three months, the storage capacity of the rain water reservoirs used for washing should be not less than 1,200 gallons, namely, 6 feet square and 5 feet deep, inside measurements. The cost of a reservoir of this size should not exceed $250.

2. Springs. When rain water falls on the ground, it strikes rocks, loose sandy soils, vegetation, and other materials and gives up to the vegetation its ammonia and takes on carbon dioxide and mineral salts;[3] it permeates the soil and rock crevices and continues to enrich itself by the further solution of mineral or organic compounds. When it falls on organic matter in roads or farm-

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[2] See Woodman, Alpheus G. and Norton, J. F., *Air, Water and Food from a Sanitary Standpoint,* New York, John Wiley and Sons, 1914.

[3] *Ibid.*

yards or when it permeates privies it becomes contaminated. It passes down through the ground until it encounters impervious materials, such as clay or solid ledge, flows underground along these impervious materials and breaks out, most frequently on the hillside, but sometimes in the plain, as a spring.

From this description it will be evident that the spring water issuing from the ground is entirely different from the original water which was precipitated from the clouds as rain water. If it is hard, it has absorbed lime and other hardening substances from limestone rocks and usually contains large quantities of carbon dioxide. If it is soft, such absorption has not taken place. If it is colored yellow or brown, it has dissolved coloring matter from decaying vegetation in swamps and the like, or it may even have leached out such coloring matter from manure piles. While the chemical properties of the water, as it issues from the spring, tell the history of its passage through underground regions, the bacteriological aspect of the water is equally, if not more, important, since the bacteriological analysis indicates its history in passing over or through contaminating materials. Every householder should know what the history of the spring water is, especially where the possibility of contaminating influences exist. Sometimes a sanitary (chemical and bacteriological) analysis, made by a competent laboratory tells this history. Such analyses of the water are frequently made without charge by the laboratories of the State Departments of Health. The owner of the spring should request such department to forward to him a sterile bottle for bacteriological analysis and a clean bottle for chemical analysis. Directions for collecting samples accompany the bottles as shipped by these departments, and they should be minutely followed.

Water analyses are not always conclusive as to the absence of contamination. During dry seasons of the year there may be no leaching of manure piles or of privy contents and cesspools, but during wet seasons there may be evidences in the analysis which show that such leaching actually exists.

If underground water has been seriously contaminated by any of the polluting sources above referred to, the bacteria may be filtered out by the water passing through long distances of sandy or earthy soil, but the chemical analysis will in that event show the presence of high quantities of chlorine, ammonia, and nitrogen; waters showing such an analysis should be watched with suspicion, Where springs are near the seashore, the chlorine content of the water is usually high because it is absorbed from the air. Such high chlorine content is not significant.

Soft spring water attacks lead pipe, and iron pipe, even though galvanized, quite readily. In the case of lead pipe it may cause lead poisoning; in the case of iron pipe, rapid corrosion. Red brass pipe is the proper kind of material to use for conveying waters of this kind.

Fairly hard waters create a coating of lime or gypsum salts on the interior walls of pipes; they are beneficial by preventing pipe corrosion. Very hard waters deposit these salts so rapidly that they plug the pipe lines. The best thing to do with such waters is to artificially soften them, by a process hereinafter explained.

The capacity of springs, that is, the quantity of water which may be obtained from them, depends on the watershed tributary to the spring and on the porosity of the soil or the area of the crevices in the rock, and also on the elevation of the tributary area above the spring.

Deep-seated springs are those where the water strata are at considerable depth below the surface. The watersheds of deep-seated springs are usually larger than those of shallow springs and may even be separated by hilly surface areas.

Shallow springs usually have a small watershed and dry up quickly during even short periods of drought.

Both deep-seated and shallow springs may be developed to produce larger quantities of water by deepening them artificially and by excavating trenches, usually along the contour lines, down to the gravel or sand strata, and placing agricultural tile in the bottoms of these trenches, leading them into the deepened spring hole. It must be borne in mind that while the rate of flow into the spring may be increased by such spring development, the probability is that, after protracted periods of drought, the flow of the spring will decrease more rapidly because of its development than it would have in its natural state. Under these conditions it is suggested that a reservoir be built for storing the water to tide over periods of drought.

Since spring waters are usually high in plant food, they should be stored in covered reservoirs, preferably underground, to keep the water cool. No ventilating shafts should be placed on their roofs since dust, pollen, and even vermin may find their way into the water. Reservoirs should be fed by the overflow from springs; they should not be made to drain the spring completely.

The cost of spring development varies with its depth, its area of development, and the length of its intercepting drains. The best method of developing a spring is to excavate an 8-foot or 10-foot square hole, vertically, to the depth at which the banks will maintain their vertical shape; thereafter to drive sheet piling all around the excavation, excavate inside of the piling, and remove the excavated material by buckets or otherwise, driving the sheet piling as the excavation proceeds. The sheet piling must, of course, be thoroughly braced with heavy timbers. The excavation should proceed until the source of the spring is found, which will usually be not over 20 feet in depth and in a bed of gravel. After the excavation is complete down to gravel, either concrete or masonry walls should be built inside of the sheet piling.

The water from the developed spring should be pumped or made to overflow into an underground masonry or concrete storage reservoir. Concrete is preferable, but it must be built without seams, that is, as a monolithic whole. This work can be done on small reservoirs by continuing the work until the entire concrete has been poured, and working with sufficient speed so that no concrete will set before the new concrete is deposited on it. On large reservoirs special precaution has to be taken.

It is preferable not to use the banks of the excavation to retain the concrete on the outside, but instead to use sheet piling or a wooden form to retain the outside faces of the concrete, for the reason that dirt may fall from the banks on the concrete while it is being poured and thereby destroy the bond. A concrete spring development without concrete bottom, built with 24-inch footings, 18-inch walls, and a 10-inch thick reinforced concrete roof covered with 12 inches of earth, 10 feet square on the inside and provided with a manhole, and having a total depth of 10 feet and a water depth of 6 feet should cost about $700. A concrete storage reservoir with 6-inch concrete bottom, 18-inch walls, 8-foot total depth, 6-foot water depth, 10-inch reinforced concrete roof, and cast iron manhole frame and cover should cost about $600. This reservoir will hold about 4,500 gallons of water and, at the rate of consumption of 50 gallons per person per day, will carry a family of three people over about a month's period of drought.

3. Shallow Wells. Shallow wells are usually known as dug wells, although they may be built with augers or other devices for digging small vertical holes in the ground into water-bearing strata. If they are bored, the earth, sand, or gravel walls will have to be cased with substantial iron pipe; to the bottom of this casing a well point and slotted pipe, with a copper strainer over the slots, may be attached. Dug wells are usually three or more feet in diameter, and are carried down to the water-bearing strata. They seldom exceed 30 feet or 40 feet in depth; their walls may be laid in stone masonry, either loose or cemented, or they may be built with 36-inch vitrified sewer pipe lengths.

The water level in shallow wells varies considerably; they react quickly to periods of drought and to periods of rainy weather. They, as well as springs, are dependent for the quantity of delivery on the tributary watershed and its elevation.

Springs have this advantage over shallow wells, that it is usually a simple matter to provide a storage reservoir into which the spring overflow discharges by gravity. Shallow wells usually have to be pumped.

What has been said about the quality of the water issuing from springs is equally true of shallow wells, and attention is again called to the danger of contamination of shallow-well water from near-by cesspools, manure piles, privies, and the like.

Shallow wells must be carefully protected at their top to prevent the admission of surface water. This is especially true where hand pumps are placed over them and where these hand pumps are used by men with boots coming from cow or horse stables or piggeries. The platform that covers a well should be a cement slab of not less than 4-inch thickness. At the outer edge of this slab a cement apron or flange should be set into the ground for about 6 inches, eliminating the possibility of surface water filtering through the soft top-soil to the casing of the well. The cement slab should be thoroughly cemented to the top of the casing whether it is of iron pipe, vitreous clay, cement blocks, or brick.

Shallow wells should never be placed in elevation below cesspools, manure piles, privies, pigsties, sewage disposal plants, or stables, if within 300 feet of them. This distance is usually assumed to be sufficient to provide satisfactory filtration and removal of disease-producing bacteria. It may be insufficient, however, on steep slopes, where polluted surface water may enter the well during heavy rain storms. For this reason, it is recommended that a surface-water intercepting trench be provided above the well which will divert any surface water from the well itself.

The same reasoning applies to springs.

Shallow wells, if built 36 inches in inside diameter, of either stone or tile pipe, and about 20 feet deep, should not cost more than $6 per average foot of depth; if 4 inches in diameter, the same depth, and bored by auger, not more than $3 per average foot.

4. Deep Wells. Deep wells are usually sunk by wash boring or drill boring. Wash boring is used where the material to be penetrated is soil, clay, sand, or gravel. The work is done by lowering a vertical pipe, usually galvanized iron or steel, into the ground by means of a water jet introduced at the bottom of the pipe in such a way that the pipe will sink either by its own weight or by driving as the earth removed by the jet is expelled through the pipe. This method is usual in regions where water-bearing gravel strata underlie the surface above solid rock.

The sinking of wells through solid rock is done by lowering the galvanized steel or wrought-iron drive pipe into the ground, inside of which a pounding drill is alternately raised and dropped and thereby grinds the rock to pieces, allowing the lowering of the pipe casing. It may also be done by drilling instead of pounding; in this case the rock core is drilled out, broken off, and removed. These rock cores then give a complete picture of the rock encountered, the seams therein, and any water-bearing veins which may penetrate the core of the removed rock.

In all of the usual rocks, except sandstone, it is necessary to penetrate water-bearing seams, fissures, veins or stratifications to obtain water from drilled wells. Sandstone, being porous, is naturally water-bearing; larger quantities of water can therefore usually be obtained from sandstone than from veins in other rocks. Shale and slate formations are the least promising water-bearing rocks because of the tightness of the stratifications through which water does not easily percolate. When gneiss or granite are penetrated to a depth much greater than 600 feet, the probability of encountering water-bearing seams becomes more remote as the depth increases, since the weight of the overlying rock is likely to close the seams tight.

Limestone formations offer considerable hope to the well driller as a source of water supply, but they are subject to the danger of pollution carried through many miles of underground veins and also to the danger of exhausting quickly if the source of the water should be an underground cave which has filled with water and has no large veins through which replacement water can enter rapidly.

As an instance of the danger of a limestone well, it may be cited that a village discharged its raw sewage into limestone crevices, through which the sewage disappeared rapidly; a typhoid epidemic developed three miles away in a university where water was pumped from wells drilled in limestone and where a direct underground connection was traced from the village sewage disposal to the water in the wells.

It is, therefore, very important in limestone regions, to keep track of the character of the water pumped from deep wells, by periodical water analyses.

When deep wells overflow at the surface they are known as artesian wells.

Surface contamination is kept out of deep wells by means of water-tight iron pipe casing, which penetrates the surface soil, sand or gravel, and is made to enter the bed rock. A water-tight joint must be made at this point. If possible, the casing should enter the rock for 20 feet, the rock hole being made 2 inches larger than the pipe, and the space between hole and pipe should be filled with cement grout.

The capacity of deep wells depends on the tributary watershed, on the character of the rock, the sizes of the water-bearing seams, the porosity of the sandstone, if any, and the pressure under which water enters the well. The latter is due to the relative elevations of the points at which the water enters the well and the point at which it originates. Wells drilled near the ocean or near lakes or streams, even through rock, may be contaminated by water entering from any of these sources.

Analyses of water derived from deep wells and collected immediately after the wells have been completed, usually show contamination due to the handling of the well casing, of the well drilling tools and other extraneous conditions which disappear with the conclusion of the well drilling and the installation of the pumps and pump piping. In such event the analyses should be repeated after the well has been in use for at least a month.

Drilled wells are commonly 4 inches, 6 inches, 8 inches, or 10 inches in diameter; their nominal size is that of the galvanized steel or wrought-iron casing used. Their price per foot drilled and tested is about $1 per inch diameter down to 300 feet; $1.25 per inch diameter from 300 to 450 feet; $1.50 per inch diameter from 450 to 600 feet depth. These prices include the casing, but not the brass screens, which cost from $8 to $15 additional per foot, and which are generally from 10 to 30 feet long, depending on the length of the water-bearing stratum.

In California so-called "stove-pipe" wells are sunk. They are 24 inches to 48 inches in diameter, or even larger. Their costs are usually materially higher than those stated above, but their yield is also materially greater. These wells have not been widely used in the East.[4]

Locating of wells by divining rods has not been successful in the experience of the members of this committee.

5. Streams and Lakes. The use of water from streams or lakes by the individual householder, except in very isolated regions, may involve considerable danger, unless there is assurance that no contaminating influences reach these bodies of water above the point where the householder derives his water supply. Sparkling brooks with waterfalls and rapids offer a beautiful idyllic picture, but there may be, lurking in their waters, death by typhoid germs that come from a privy used by a farmer's family on the banks above, or from campers on the shores. It is advisable for a householder, who derives his water supply from a stream or from a lake, to obtain advice from his State Department of Health as to the proper treatment of such water either by filtration or chemical disinfection. It is unfortunate that beautiful streams are being defiled by careless people, but it is impossible for the individual householder to protect himself against trespassers on the stream above and to assure himself that no disposal of faecal matter into the streams from privies and cesspools does occur. State Departments of Health are generally vigilant on this subject and will give their cooperation to any house owner to prevent pollution of streams.

The water from lakes is usually obtained by pumping directly from them. The extreme end of the suction pipe should be placed not less than 3 feet below the surface of the lake, and should be

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[4] See reports of U. S. Geological Survey for records of deep wells in various sections of the United States.

located in as deep water as possible, but not less than 3 feet above the bottom.

In the case of streams, the usual procedure is to build a small dam out into the stream, or to build an underground pipe connection to the stream. Sometimes an improvement of this method is made by digging a trench along the stream or lake bank, and allowing the water to filter into the trench, collecting it by means of agricultural tile draining into a storage reservoir.

The amount of water to be taken from any of these surface-water sources depends on the tributary area of the watershed, the degree of forestation, the rainfall, the run-off, and the evaporation.

Surface waters, like spring and well waters, vary in hardness; in addition they may receive considerably larger amounts of contamination both from sewage and industrial wastes. Many industrial wastes kill fish life in the streams and render waters impossible for human consumption. Domestic sewage, if not too concentrated, can usually be treated sufficiently to prevent serious danger to health, but such treatment requires everlasting vigilance.

Section III. Testing of Water Sources for Capacity

It is important for the householder to know approximately the amount of water upon which he can depend for his domestic and farm purposes. Measurements of this kind should naturally be made during a season of average flow when there has not been a prolonged season of rain. Measurements of the flow of springs located on hillsides can ordinarily be made by driving a ¾-inch iron pipe through the hillside into the spring, the lower end of the pipe being at such an elevation that a pail may be placed under it. A record should be kept of the time required to fill the pail, and on this basis a computation may be made of the flow in number of gallons per minute. Since there are 1,440 minutes in the day, the total yield of the spring can be easily computed.

Where the spring is located on level ground its water level should first be ascertained and thereafter lowered by means of a hand pump or a mechanically operated pump. When lowered to its water level, the pump should be operated at sufficient speed just to maintain this level, the water being measured into a barrel, or other convenient container of known capacity, and the time recorded. The rate of inflow into the spring may be determined from these measurements.

The test of the yield of the shallow well is made in a manner similar to that of a spring, by means of a pump.

The capacity of drilled wells is ordinarily determined before the well driver leaves the work, by means of a well machine or a mechanically operated pump. The pump is speeded up so that it begins to suck air and is maintained at this speed. Meanwhile, it discharges into a barrel of known capacity and the yield of the well is thereby determined. Since the sinking of drilled wells and the erection of pumping machinery for them involves considerable expense, it is advisable to make a pump test on such a well for a continuous period of not less than 24 hours, or preferably even 48 hours, day and night, in order to assure oneself that the yield does not decrease as the pumping continues.

Tests of the flow of smaller streams are made by damming them by means of a weir and measuring the rate of discharge over the weir.[5] A weir is a notched board; the stream flows through the notch, and the depth of flow over the notch together with the width of the notch determines the rate of flow.

The flow of larger streams is measured by gauging, and does not particularly enter into the problem of this committee since it is usually a matter for the consideration of municipalities.

Section IV. Public Water Supply

Usually, in our progressive states, the water consumers are safeguarded against impure public water supplies, but not infrequently the dangers of unexpected or unforeseen pollution of water supplies of municipalities are impressed on the public by typhoid epidemics traceable to carelessness. Indeed, both private water companies and municipalities have been held legally liable for deaths caused by typhoid fever epidemics traced to contaminated water supply.

The individual householder, once he becomes acquainted with the existence of typhoid fever or other serious widespread intestinal disturbances in his community, should at once begin to boil the water used for drinking and cooking purposes. He may thereby

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[5] Bulletins prepared by the U. S. Geological Survey in Washington describe the construction and installation of weirs.

save himself and his family against these illnesses. Fortunately, typhoid epidemics which are due to public water supplies are becoming more and more infrequent.

Given a safe public water supply, the consumer is interested particularly in the absence of color, tastes, and odors, the hardness, and the corrosive character of the water which he purchases.

Color, tastes, and odors do not necessarily mean unsafe water. Color is generally produced by peaty, swampy marshes, or by an excess of iron; tastes and odors, such as those of fish, geraniums or cucumbers, while unpleasant even to the degree of making the water unpalatable, are caused by microscopic organisms, such as diatoms, protozoa, synura, and the like. Often, experts of the water departments or the water company can control them only with great difficulty. The disinfection of water supplies by chlorine seems to increase the tastes and odors, even before the organisms can be detected by microscopic examinations. Their presence may sometimes indicate high nitrogen content and, therefore, possible sewage contamination, but this is by no means always the case.

Public water supplies may be bacterially pure, have no color, no taste, and no odors, but they may still be objectionable to the householder because of their hardness, which consumes soap, or because of their extreme softness, which tends to promote pipe corrosion. A water of medium hardness is usually the most desirable.

Color, tastes, odor, and corrosion of pipes are sometimes found in highly developed industrial and mining sections, where acids, alkalies, or salts are discharged into streams tributary to the watersheds. These are local conditions and often cannot be economically avoided. About the best thing the householder can do is to protect himself against pipe corrosion by installing red brass pipe or even copper pipe, although the use of the latter is still looked upon askance by some scientists because of much conflicting testimony on the danger of copper poisoning. Dr. Hugh S. Cumming, Surgeon General, United States Public Health Service, makes the following statement on this subject:

> "Although the literature is somewhat conflicting regarding the danger to health of copper dissolved from pipes, there is no direct reference to specific cases of poisoning from such source."

The drinking water standards adopted by the U. S. Treasury

Department for water used by common carriers in interstate commerce specify that copper shall not exceed 0.2 part per million in such water. Two-tenths part per million is equivalent to about one ounce of copper in 370,000 gallons of water.[6]

It has already been pointed out that soft waters tend to corrode pipes because they do not contain any substances which form deposits on the interior walls of the pipes; frequently they contain oxygen and carbon dioxide, the corrosive action of the former being accelerated by the presence of the latter. Hard waters, on the contrary, deposit a scale on the interior surface of the pipes which protects the pipe walls against corrosion by the oxygen.

Brass pipes are indicated for soft waters, both hot and cold. Brass pipes are manufactured which contain 60, 67, or 85 per cent copper. In general it may be said that the softer the water, the higher should be the copper content of the brass alloy. It is of interest to note that the United States Treasury Department generally prescribes grade "A" brass pipe for all hot- and cold-water

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[6] For further information on this matter, the following references are given which were furnished to the committee by Dr. Hugh S. Cumming, Surgeon General, United States Public Health Service:

Henstock, H., "Action of Natural Waters on Metallic Copper," *Chemistry and Industry,* May 8, 1925, Vol. 44, p. 219; *Journal of The American Water Works Association,* August, 1926, Vol. 16, p. 260. (Abstract.)

Ritter, W., "The Effect of Various Waters on Copper Containers and Pipes," *Apparatebau,* 1928, Vol. 40, pp. 57-9; *Chemical Abstracts,* May 20, 1928, Vol. 22, p. 1817. (Abstract.)

Mallory, J. B., "The Poisonous Effects of Copper," *Journal of The New England Water Works Association,* March, 1927, Vol. 41, p. 27; *Journal of The American Water Works Association,* April, 1928, Vol. 19, p. 463. (Abstract.)

"Copper and The Human Organism," *Journal of Experimental Medicine* (Rockefeller Institute), January 1, 1929; *Journal of The American Water Works Association,* February, 1929, Vol. 21, pp. 262-266; *Water Works Engineering,* February, 1929, Vol. 82, pp. 89-90. (This article reviews studies on effects of copper. The studies at Columbia University indicate that liver spots and cirrhosis of liver are not due to copper as suggested by Mallory, op. cit.)

Schneider, W. G., "Copper and Health," *Journal of The New England Water Works Association,* December, 1930, Vol. 44, p. 485; *Engineering News Record,* October 2, 1930, Vol. 105, p. 535. (Abstract.)

Schneider, W. G., "Copper and Brass Pipes and Tubes," *Journal of The American Water Works Association,* July, 1931, Vol. 23, pp. 974-992; *Canadian Engineer,* March 17, 1931, Vol. 60, pp. 90-93.

One of the most interesting discussions of the hydraulic service characters of small metallic pipes, based on actual experiments, has been written by Professors G. M. Fair and M. C. Whipple, and O. Y. Haiao, Research Fellow of the Harvard Engineering School, Cambridge, Mass. This discussion was reprinted in the *Journal of The New England Water Works Association,* Vol. 49, No. 4.

piping. This contains 83 to 86 per cent copper. The remainder is zinc, with a maximum allowable percentage of .08 per cent of lead and .05 per cent of iron.[7]

Lead pipe should never be used for soft waters because of danger of lead poisoning.

Black wrought-iron or steel pipe should not be used with soft waters because it will corrode rapidly and, for this reason, is uneconomical.

Galvanized wrought-iron or steel pipe will last longer than black pipe used with soft waters, but in many instances the cold water pipes are liable to fill up with rust in ten years or less, and the hot-water pipes to fill up in six years or less. For this reason it is more economical to install brass pipe in the beginning. The replacement of pipes is expensive and interferes with the comfort of the home. The experience of many house owners who have passed through the stages of colored water, yellow water, red water, rusty water, and plugging of pipe lines is a sad commentary on the absence of care taken in the selection of piping materials adapted to the particular kind of water which had to be carried.

For fairly hard waters the use of galvanized steel or wrought-iron pipe in the larger sizes is recommended, i.e., from 1-inch internal diameter upward. For ¾-inch and smaller sizes, brass pipe should be installed. For the hot-water supply pipe lines, brass pipe is most economical.

In the case of hard waters, it is necessary to determine whether the hardness is "temporary" or "permanent." Permanent hardness means that the water, when heated, will not deposit any heavy scale. Temporary hardness means that the hardening salts will be precipitated upon boiling. It is perfectly proper, therefore, to pass waters having a permanent hardness only, as well as cold waters having a temporary hardness, through galvanized-iron pipes. For water having both temporary and permanent hardness, brass pipe should certainly be used for hot water.

Where brass pipes are used, the installation should, of course, be accompanied by brass fittings, such as couplings, elbows, or tees. For galvanized wrought-iron or steel pipes malleable galvanized-iron fittings should be installed.

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[7] See Federal Specification, F. S. B. No. 342-A. (W-W-P.-351.)

Section V. Water Service Lines

The water supply connections from the street main to the building should be governed as to character of material by the foregoing remarks. For the average single- or two-family dwelling which has no flush valves for water-closets, but high or low flushing tanks, a ⅝-inch tap in the water main and a ¾-inch brass pipe (red brass preferred) will be found satisfactory with water pressures 30 pounds or over per square inch. If the water pressure is less, the service pipe should be enlarged to 1 inch. A brass service pipe should always be provided with a loop consisting of not less than four elbows to prevent breaking of the pipe in case of settlement of the overlying earth or heavy trucking.

Where flush valves are used on water-closets for a single- or two-family house it will be found necessary to install not less than a 1-inch tap in the water main and a service pipe into the building not less than 1¼ inches in size. Where the pressure is below 30 pounds per square inch it will be found advisable to increase the pipe size to 1½ inches. The expansion loops recommended for the smaller pipe are also recommended for the larger.

A corporation cock is usually placed on the service line next to the tap; some water departments require also that a curb cock should be placed on the service line at the curb, with a gate box and a gate rod so that the department may shut off the water from a house at any time without entering the premises. Inside of the cellar wall a main gate shut-off valve should be installed to control the entire water supply system in the building. Stop cocks of the plug and lever-handle or "T"-handle type should not be used since it is difficult to make or keep them tight.

Copper pipe, heretofore referred to, has the same thickness of walls and internal diameter as iron pipe; it is therefore known in the trade as copper pipe of iron-pipe size.

In more recent years copper service-pipe installations have been made of copper tubing, the wall thickness of which is considerably less than that of copper pipe of iron-pipe size. Its wall thickness varies from .049 inch for ⅜-inch tubing to .083 inch for 2-inch tubing, while the thickness of copper or brass pipe of iron-pipe size runs from .090 inch for ⅜-inch to .157 inch for 2-inch pipe. The test pressure of ⅜-inch tubing is 1,240 pounds; of 2-inch copper tubing 520 pounds per square inch. The test pressure of all brass and copper pipes of iron-pipe size is 1,000 pounds per square inch. Where copper tubing is used for water service lines from the city water main into the building, an expansion loop is advisable. These copper tubes are usually furnished, soft-annealed, and come in coils about 4 feet in diameter. The sizes from 1¼-inch to 2-inch pipe are furnished in straight lengths; they are limited to 20 feet for convenience in handling and shipping.

In the case of moderately hard waters, galvanized wrought-iron or steel pipe may be used for service lines. They should be one size larger than the brass pipes heretofore referred to because it is probable that gradual rust formations and lime deposits will roughen their interior surfaces.

Lead pipes for service lines are usually furnished in coils, the length of each coil running from about 90 feet for ⅜-inch to 15 feet for 2-inch pipe. Where the pressure averages from 30 to 50 pounds, "AA" lead pipe, or "extra strong" lead pipe, should be used. Its weight varies from 2 pounds per lineal foot for the ⅜-inch pipe to 9 pounds per lineal foot for the 2-inch pipe. Should the pressure exceed 50 pounds it is recommended that "AAA" pipe, also known as "double extra strong," should be installed. The weight of this pipe runs from 2 pounds, 10 ounces per lineal foot for the ⅜-inch pipe to 10½ pounds per lineal foot for 2-inch pipe. Expansion joints on lead service pipes are usually provided by means of goose-neck shaped bends.

The depth at which service lines should be laid is controlled in the northern part of the country by the depth to which frost penetrates and in the southern part by the depth to which the heat of the sun penetrates. In the North the depth at which they must be buried to protect against severe frosts, is as much as 5 feet; in the South, to keep the water cool, they should not be buried less than 3 feet deep.

Assuming that the depth of the excavation is the same where galvanized wrought-iron or steel pipes, brass or copper pipes, copper tubing or lead pipe is used, the cost per foot of furnishing and laying these service lines in trenches provided by the owner should be about as follows:

¾-inch grade "A" brass pipe..........	$ .97 per foot, including expansion joints
¾-inch copper pipe....................	1.01 per foot, including expansion joints
¾-inch copper tubing.................	.90 per foot

¾-inch galvanized steel pipe..........	.81 per foot, including expansion joints
¾-inch galvanized wrought-iron pipe..	.88 per foot
¾-inch "AA" lead pipe...............	1,07 per foot, including expansion bend.

The above prices are inclusive of tapping the main, the corporation cock, the curb cock and curb box, and the main shut-off valve in the cellar, and are based on a service-pipe length of about 30 feet; they include the furnishing of the pipe and the labor of laying it, but do not include excavation and backfilling.

Service lines should always be laid on a substantial trench bottom. Where soggy ground is encountered it is best to lay them on 2-inch by 8-inch planks laid longitudinally in the trench bottom. These planks should be creosoted. Where the service lines enter the cellar through the foundation wall a galvanized-iron pipe sleeve should be provided through the wall so that the weight of the wall will not crush the pipe, if it is of copper, brass, or lead.

Cinders should never be used for backfilling around any of the service lines. Frequently cinders contain sulphuric acid compounds; the acid constituents may be leached out of the cinders and will certainly attack and corrode any of the metals herein described. All backfill within 12 inches of the service pipe should be clean earth or sand, free from stones 6 inches or more in size. This will safeguard the pipe against damage by crushing. Upon this earth or sand fill the regular backfilling material may be used, but no voids should be left between stones. Stones resting against each other will quickly allow frost to penetrate so that all stones of larger sizes should be completely surrounded with dirt, clay, or other backfill, free from organic matter. All backfilling should be thoroughly tamped or settled by puddling with water. The tamping is best, and will usually allow all of the excavated earth to be replaced in the excavation without forming any mound on top of the trench.

Attic Tanks. Where the city pressure is insufficient to reach and give satisfactory service at the plumbing fixtures on the upper floor during the day time, it is advisable to construct a tank in the attic. Usually the day time water pressures are considerably less than those at night, so that the attic tank will fill itself during the night by the higher pressure. The inlet pipe to such a tank should be provided with a ball float, which will automatically close when the tank is full. An overflow pipe should be provided from the tank to the roof.

Attic tanks of this kind are usually constructed of wood, lined with tinned sheet copper or with sheet lead. Bearing in mind that the average water consumption per person per day in average city dwellings is not over 100 gallons, the capacity of the tank can easily be figured to give one day's supply; i.e., for a family of five people, the water consumption should not exceed 500 gallons per day, hence an attic tank of 500 gallons capacity (5 feet square and 3 feet deep) will answer the purpose for this condition.

Where the street pressure does not give satisfactory service for the upper floor fixtures it is usually advisable to feed the tank direct from the city main through the ball cock, and then to have all of the water fed from the attic tank downward to the plumbing fixtures, both for hot and cold water. This system is simpler than one in which an attempt would be made to supply part of the fixtures under street pressure and part under tank pressure. The cost of an attic tank of the size described above, including the lumber, 16-ounce copper tank lining, and ball cock, should not exceed $275.

Section VI. Safe and Potable Water

1. History of Water. Since an analysis of water indicates only its condition at the time of collection of the sample, it is most important to know the history of the water, meaning thereby its associations since it fell on the ground as rain. As one may know the character of the man by the character of his associates, so one can tell nearly, and with almost equal positiveness, the character of the water from the objects with which it has come in close contact from the time it fell. It has previously been stated that water which has been contaminated by manure, privies, cesspools, faecal matter, or other human wastes, is subject to suspicion. On its way to the source of water supply this contaminating material may have filtered out or may have been sterilized by the sun's rays, or may have become oxidized by the oxygen in the air; but still, having been polluted once, it is only natural that it should be watched.

The larger the watershed and the greater its development, the more likely is the water to be contaminated; the more rugged and steep its surface areas, the more likelihood there is of surface contamination being washed by heavy rains to the source of water supply. This is especially true in the spring of the year, after the winter frosts, and when the spring thaws begin, since then all organic decomposing materials become part of the spring floods and are carried by them to great distances. Surface waters are usually collected and stored in reservoirs. Small reservoirs are usually built underground, and of concrete; large municipal reservoirs are usually impounded by dams and may cover many acres, even several square miles.

In order to remove tastes, smells, and odors, which may make the water unpalatable, and to remove excess carbon dioxide, it is customary to aerate waters containing them; this may even be necessary where the water also contains considerable iron in solution. The aerating treatment is quite often successful in the removal of tastes, odors, and carbon dioxide; it will also frequently oxidize the dissolved iron, which will precipitate as iron rust after the treatment. No large financial expenditures should be made, however, for the building of an aerating plant, until it has been demonstrated by laboratory experiments that these conditions yield to aeration. Under certain circumstances this particular type of treatment will be unsuccessful.

A good deal has been said in the preceding pages on the subject of hardness of water. Medium hardness is desirable. A high degree of hardness causes trouble by the depositing of hardening salts and clogging of pipe lines; absence of hardness increases the danger of pipe corrosion. The hardness of the water is usually due to its association with lime or gypsum, which it may encounter either underground or on the surface.

Knowing the history of a water is of the utmost importance. It will be readily realized that the history of any water may change overnight by new associations which it may encounter on its way to the consumer. It is for this reason that water analyses are most desirable witnesses as to the conduct of the water. Mineral analyses of water are usually made only to determine whether they are suitable for power and heating plants; these analyses, therefore, do not have any place in a plumbing report. A sanitary (chemical and bacteriological) analysis is, however, of the greatest importance in plumbing work. Where a water is not above suspicion, such analysis should be frequently repeated, at least once in the spring and once in high summer.

2. Water Analyses. Sanitary chemical analyses require a sample of about six quarts. It is the usual procedure for chemical laboratories specializing in water analyses to send to their clients in wooden boxes, specially made for shipping, a 6-quart bottle for chemical analysis and a 6-ounce bottle for bacteriological analysis. The chemical bottle has been thoroughly washed and the bacteriological bottle thoroughly sterilized before they leave the laboratory. The person collecting the water for analysis should, before filling the chemical bottle, properly wash and rinse it with the water which is to be analyzed. He should never, however, rinse the sterile bacteriological bottle because of the danger of infecting it.

With the container sent by the laboratories there is usually shipped a complete set of directions for collecting the samples and an information card on which the collector should note any surrounding possible sources of contamination of the water and the general directions of downward slope with the distances that may appear necessary. The larger laboratories, specializing in water analyses, make so many analyses and have so many records on hand that the interpretation of any water analysis may be made in the light of other previous analyses on file in the laboratory and located near the source which is under consideration.

The shortcoming of any water analysis is that it is merely transient; it indicates what is here today but fails to give any clue as to what may be there tomorrow, unless today's analysis already arouses suspicion. In that event, tomorrow's analysis is likely to be at least equally bad or worse.

In bacteriological analyses, the laboratories usually determine the number of bacteria per cubic centimeter that grow on gelatin and agar, also the number of colon bacilli found present in one-tenth cubic centimeter, one cubic centimeter, and ten cubic centimeters. The latter are bacilli from the intestines of warm-blooded animals; they are merely indicative of the fact that intestinal germs are present in the water. They are not necessarily in themselves harmful, but show that typhoid bacilli might be present, since they, like colon bacilli, are bacteria found in the intestinal or urinary tracts of warm-blooded animals, such as man.

Water analyses have been fairly well standardized as to methods of procedure and report; the United States Treasury Department has certain definite requirements on the purity of drinking water served by interstate carriers. Copies of these requirements may be obtained direct from the United States Public Health Service or the United States Treasury Department. Water used for drinking should measure-up, in purity, at least to the requirements of drinking water furnished on railroad trains or steam ships in interstate traffic.

3. Metal Analyses. State Departments of Health usually maintain laboratories for making chemical and bacteriological water analyses. They should be approached by householders if any suspicion attaches to the water supply on their properties. Frequently, the state laboratories will analyze, free of charge, waters used for drinking purposes.

Unless specifically requested, no laboratory will make a test of the water for presence of lead, zinc, or copper. The United States Public Health Service prescribes maximum contents of these minerals as follows:

Lead—0.1 part per million
Zinc—0.5 part per million
Copper—0.2 part per million

4. Removal of Turbidity. The removal of turbidity is accomplished by sedimentation or by filtration, or by both, depending on the amount of turbidity in the water. Very finely divided particles cannot usually be removed by settling without the addition of chemicals, generally basic sulphate of alumina. The chemical should not be introduced, however, without knowing something about the alkalinity of the water. Waters with low alkalinity, say up to 18 parts per million, do not give proper reaction with alum treatment, and require an increase of the alkalinity by the artificial addition of soda-ash or lime. The assistance of a chemist should be sought in the treatment of such waters, to advise the house owner on the amount of lime or soda-ash, if any, required and the rate at which they should be fed to the water.

Where very finely divided matters are contained in water, so fine that they cannot be removed by ordinary settling without the addition of alum, soda-ash, or lime, they may be passed through filters. Filters for this purpose usually have sand, underlaid with gravel, as a filtering medium. The water, after settling in a settling basin, may be made to overflow on a body of sand and allowed to filter through, collected in the gravel underlying the sand and then be carried by a pipe line to an underground reservoir. Such water may also be pumped, either with or without preliminary settling, through pressure filters, which are cylinders of cast iron or steel, filled with sand.

Gravity filters, in the northerly regions of the country, have to be housed-in to prevent freezing. They require some attention in cleaning. The area of sand required for such gravity filters (technically known as slow sand filters) is very much greater than that of pressure, or rapid sand filters. Each individual case has to be judged by itself; sometimes it is cheaper to build the larger slow sand filters and save pumping; sometimes it is preferable to pump through the pressure filters.

Slow sand filters are limited to treatment of water of low turbidity, relatively low in color, and free from excessive sewage pollution. They are usually built to provide a rate of filtration of .02 to .2 gallons per square foot of filter area per minute. The greater the turbidity of the water, the lower will have to be the rate of filtration to avoid premature clogging of the filter bed.

No reason exists why slow sand filters may not be used in the South where they are not likely to freeze, or in the North if they are properly protected against freezing. If all of the water, not too turbid, and with not too high color and free from excessive sewage pollution, is to be filtered through a slow sand filter for the domestic use of a family of six people, consuming about 50 gallons per person per day, and if all of this water has to be filtered during about three hours of the day, the area of the filter would have to be 9 square feet, i.e., 3 feet on each side. Such a filter can easily be deep enough, however, to allow not less than a 4-foot depth of water on top of the sand. The depth of the sand should be about 30 inches; the sand should be underlaid with about 3 inches of gravel, about pea size, and this gravel should be underlaid with coarser gravel, from ½ to 2 inches in size, about 6 inches in depth. An outlet pipe should be connected to a point just above the bottom of the box, with a valve by which the rate of filtration can be controlled. The pipe and the valve need not be over ¾ of an inch in size.

The sand for the filter should be fairly coarse and as nearly as possible of uniform grains. Fine sand should never be used because it will clog very rapidly; neither should fine sand be mixed with coarse.

The filter usually becomes clogged at the top of the sand, and it is perfectly feasible to take a hoe or similar instrument and carefully remove the top dirty layer of sand. When 6 inches or 8 inches of the upper sand layer has been taken out, it should be replaced with fresh sand. The process of removing the dirty sand should be one of skimming off the surface, the sand should not be dug into. Of course, all of the water should be drained through the filter and the inflow should be closed while the sand is being removed.

Precautions should be taken to keep the inflowing water from jetting the top of the filter sand. This can be done by placing splash plates below the incoming water stream, which should always enter the filter above its high-water level, that is, not less than 4 feet above the top of the sand.

The best way to test a small home filter of this kind for rate of discharge is by closing the outlet valve almost completely just so that a small stream will trickle through, then time the filling of a 10-quart pail. The correct time for filling this pail at the proper rate of filtration would be 1½ minutes. If the pail fills in less time, the valve will have to be closed down more; if it takes longer to fill it, the valve will have to be opened more until the proper rate of discharge is obtained.

It will be noticed during the filter operation that the rate of discharge gradually decreases as the filter surface becomes fouled; when this happens, open the valve further, and repeat until it is finally wide open. Gradually the house owner will become accustomed to the number of turns which the valve has to be turned after definite periods of filter use. When the filter refuses to pass a 10-quart pail of water in 1½ minutes, it is time to clean the filter by skimming the dirt from the surface of the sand together with a thin top layer of the sand itself.

The slow sand filter becomes more efficient, as to removal of bacteria, the longer it is used.

Square wooden filter boxes are not easily made tight. It is preferable to make them circular. In the example above described, a circular filter tank having an inside diameter of about 2 feet 6 inches would have a somewhat larger area than the tank 3 feet square.

Where fairly coarse sand is available, even though it requires washing (and all dirt must be removed from the sand before it is used for filter purposes), a filter of this kind for a family of six people should not cost more than $75.

Pressure filters for domestic use are usually vertical cast-iron or steel cylinders, equipped with small pots in which alum and lime or soda-ash are stored. These pots are connected to the water main as it enters the pressure filter, and small quantities of one or both chemicals are discharged into the water main before the water enters the filters. The control of these pots is, however, very crude, since it is brought about by needle valves, and the user never knows how much or how little chemical he has put into the water. Too much alum is likely to create pipe corrosion. The cost of a pressure filter for the ordinary home is about $200. These filters have the advantage that the city pressure forces the water through them without pumping. When dirty, they lose about 8 to 10 pounds pressure by friction, and then require cleaning, which is done by simple valve control. Pressure filters have to be washed by reversal of flow until the water runs over. Without alum they merely act as coarse strainers.

The rate of filtration through pressure or rapid sand filters is from 2 to 8 gallons per square foot per minute. This rate is from 40 to 100 times greater than that of slow sand filtration; in other words, the area required for rapid sand or pressure filters is from 1/40 to 1/100 that required for slow sand filters.

5. Water Softening. The softening of water is usually done by one of two processes, either the lime-soda-ash process or by the zeolite process. The former is principally used by manufacturing plants or by municipalities or water companies; the latter, while also used for mills and public water supply plants, is particularly adaptable to homes.

> "There are certain limitations to . . . the lime-soda-ash method . . . it is not possible to reduce the hardness to less than two grains per gallon . . . extremely hard waters are . . . more difficult to soften than water of moderate hardness. Water high in non-carbonate hardness is more difficult to soften than water with an equivalent amount of hardness, but low in non-carbonate hardness. . . .
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> ". . . Zeolites are silicates containing sodium which may be replaced with other bases, such as calcium and magnesium. . . . When hard water is passed through a bed of zeolite, the calcium and magnesium are removed from their compounds in the water and are replaced with sodium. The sodium compounds do not cause hardness, so that as a result the water is softened.
>
> "The capacity of zeolite for softening water is, therefore, limited by the

amount of replaceable sodium it contains. When all of this replaceable sodium has been exchanged for calcium and magnesium from hard water, the zeolite must be regenerated. This is accomplished in practice by treating the material with a solution of common salt, sodium chloride. . . . The sodium of the salt drives out the calcium and magnesium from the zeolite and replaces them with a fresh supply of replaceable sodium. After regenerating, the salt solution is washed out and zeolite is again in condition to soften water."[8]

The general design and construction of a zeolite softener resembles that of the well-known pressure water filter, in which the bed of zeolite takes the place of the sand. Provision is made for the introduction and removal of the salt solution used in the regenerating process. In the operation of the softener, the water may be passed in at the top and out at the bottom, or in the reverse direction. Each system has its advantages and disadvantages.

The size and type of softener unit required for a home depends upon the chemical composition of the water, particularly its hardness and the quantity to be treated within a given period of time, and the maximum flow rate required to satisfy the demands of the household. The units for domestic service usually range in size from 9 inches to 30 inches in diameter, are approximately 6 feet high, and are equipped in most cases with either a salt pot, or a salt tank known as the "saturator." They range in price from $109 to $650 at the factory; the average installed price would be approximately $250 per unit.

The only operating cost is that of the salt, which may be purchased through local grocers. It is commonly purchased in 100-pound or 200-pound bags. The salt consumption is equivalent to approximately 0.7 of a pound of salt per 1,000 grains of removable hardness, for household size units.

It is common practice to install a softener unit sufficiently large to take care of the requirements of a household over a period of one week, and to compute the water requirements at the rate of 50 gallons per person per day occupying the home, including servants, irrespective of the number of plumbing fixtures in the home.

Zeolite softeners cannot be used successfully to soften waters with excessive content of sodium salts, nor when waters contain free acid or large amounts of iron, without previous purification.[9]

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[8] *Water Works Practice* (Manual of the American Water Works Association), Baltimore, Williams and Wilkins, 1925, pp. 257, 262.

[9] See *Ibid.*, p. 263.

6. Sterilization. Sterilization by chlorine is the popular method today of producing a water free from germs. Chlorine is so intensely effective and its quantity so infinitesimally small that it is difficult, in the average household, to introduce small enough doses into the water supply without at the same time overchlorinating and thereby producing unpleasant odors and tastes.

It is possible to satisfactorily chlorinate water by mixing a chlorine solution made from bleaching powder. Ordinary bleaching powder contains about 35 per cent of available chlorine. To make a chlorine solution, it is necessary to first prepare a paste by mixing the contents of ½ pound of chloride of lime with a small amount of water; if too much water is used the chloride of lime particles will repel the water and cannot be properly mixed with it. After the paste is made, water should be gradually added and the mixture stirred into a 10-quart pail, the pail covered, and the lime allowed to settle to the bottom. The liquid will then become clear and will be a chlorine solution containing about 0.17 pound of available chlorine, which is sufficient to sterilize from 7,000 to 20,000 gallons of water.

If this chlorine solution is now kept in a glass stoppered bottle it will retain its strength for some time, so that a proportionate amount of it may be mixed and stirred into a tank containing the water supply. The proper amount required can be definitely determined, but for ordinary household purposes sterile water will be produced when the water begins to have a slight indication of the taste of chlorine.[10]

The application of chlorinated water to the suction line of a pump offers the simplest method of introducing chlorine into a water supply. Under such conditions it is perfectly possible to construct an acid-resisting tank from an inverted length of vitrified salt-glazed sewer pipe, the bottom of which is formed with concrete. This tank may be filled from the concentrated chlorine solution heretofore referred to and water added as required. A small pipe may be connected to the pump suction line and extended into the chlorine solution storage tank to within a few inches of its bottom; a valve may be placed on this small pipe for control-

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[10] See *Water Works Practice* (Manual of the American Water Works Association), Baltimore, Williams and Wilkins, 1925, in which a simplified method of chlorine control is described, together with the apparatus required therefor.

ling the amount of chlorine solution which will be sucked into the pump suction line when the pump is operated. Repeated tests will show how far the valve will have to be opened so that the pump will deliver water in which the chlorine may be barely tasted.

There has been considerable agitation in recent years on the subject of treating water with iodine in an effort to prevent endemic water. For the individual householder the introduction of iodine into his water supply system would be out of the question; he would have to depend on iodized salt or other chemicals prescribed by his physician.

7. Algae. The growth of algae is, in general, most troublesome in lakes and ponds of municipal water supply systems. Where a house owner derives his water supply from a lake infested with these growths, and desires to rid the lake of them, he is advised to use the most common method of today, namely, the application of copper sulphate. The amount of copper sulphate required for different kinds of algae growths varies from one part in ten million parts of water to ten, twenty, or even fifty times that amount.

The application of copper sulphate to lakes is well described in the manual of the American Water Works Association.[11] It is made by placing about 50 pounds of commercial copper sulphate (blue vitriol) in a burlap sack and towing it behind a row-boat or beside a small launch.

In shallow portions of lakes, which are inaccessible by boat, the copper sulphate may be made into a solution and applied by sprayers, such as are used for spraying fruit trees.

Fortunately, those algae which grow most frequently and give most trouble are more susceptible to copper sulphate than are fish.

Where water in shallow wells and springs is exposed to sunlight algae growth may appear. If the wells or springs cannot be covered, they should be treated by copper sulphate in small amounts, which will destroy the algae, but they should then be thoroughly pumped out several times to remove any of the copper salt.

8. Cleaning Shallow Wells. The cleaning of shallow wells is a matter which should be regularly attended to. The water should be pumped out and the walls of the wells should be scrubbed with a chlorine solution prepared as previously de-

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[11] See *Ibid.*, p. 167.

scribed. Some of the diluted chlorine solution should be put into the well, and the well be allowed to fill and, thereafter, the well should be pumped dry several times and allowed to refill until no chlorine can be tasted.

Section VII. Devices for Delivering Water

1. Hand Pumps. The old oaken bucket has given way to hand pumps placed on concrete protected covers over the wells. These hand pumps are now made of the anti-freezing type and also as combination lift and force pumps. They have adjustable bases, and their pumping cylinders may be placed at any desired depth. Where they have no cylinders, they are limited to the suction lift of not over 25, and usually about 22, feet. Where they have a cylinder it may be placed at any desired depth, but not too deep for hand operation.

Pump cylinders preferably should be placed under water; if the cylinder is not submerged, a foot valve should be used on the bottom of the suction pipe. Pump cylinders should be of brass; the rod going from the pump handle to the piston in the cylinder should be of steel.

Force pumps which are intended to pump water to elevated tanks should have cock spouts or other connection for the discharge line to the tank.

There are so many different manufacturers of good, substantial hand force pumps that the average house owner cannot go very far wrong in purchasing any of the well-known makes. Hand force pumps are now sold as a part of small air-pressure water supply systems; the tank is usually a vertical steel tank; the pump is a double-acting force pump which will raise water by suction 15 feet from a cistern, spring, lake, or well, and force it into the pressure tank for distribution through pipes to any part of the house or premises. Pumps used for this purpose are provided with air-valve attachments for pumping a small amount of air with the water. Small hand-operated pumping outfits of this kind, with steel pressure tanks 18 inches in diameter by 60 inches long, may be bought for as little as $40. At a 20 stroke per minute operating rate, they will pump 4 to 5 gallons of water per minute into the pressure tank.

2. Mechanical Motive Power. Passing now from hand pumps to mechanically operated pumps, the purchaser has a choice between electric, gasoline-engine, oil-engine, hot-air, and steam motive power. Steam motive power is seldom available, except in large developments; the oil-engine is generally used only for fairly good-sized country estates; hence the home builder is particularly interested in hot-air engines, gasoline engines, and electric motors.

3. Hot-air Engines. Hot-air engines are limited in power; hence the capacity of pumps, both as to quantity of water and as to pressure, is limited when such pumps are driven by hot-air engines. In general, these engines are made for the export trade, or for places where wood, coal, or kerosene fuel is cheap, and electric power and gasoline is not readily available or is expensive. They are made in sizes capable of pumping from about 150 to 6,000 gallons per hour against a head of 10 feet to 670 feet. They are easy to start and simple in construction and operation; therein, they have the advantage over gasoline engines. They may be used in connection with air-pressure tanks or elevated tanks. Their cost is from $180 to $700.

4. Gasoline Engines. Gasoline engines are used more extensively for operating pumps in isolated locations than are hot-air engines. Almost every one knows the principles of operation and methods of repairing gasoline engines; for those who do not, there is usually a garage repairman handy. These engines can be bought from 1 horsepower up to almost any size within reasonable limits. The average stationary gasoline engine uses about one pint of gasoline per horsepower per hour, so that it is an easy matter to compute the probable amount of gasoline used for pumping purposes. The less-expensive stationary gasoline engines purchased today are mostly of the horizontal type. In the smaller sizes, many of them have small gasoline tanks attached to their base and water-cooling reservoirs cast on their bodies. The speed of these engines is about 250 to 500 revolutions per minute, running up to about 800.

High-speed stationary gasoline engines which are exceedingly smooth running, the less-expensive ones horizontal, the most-costly ones vertical, can be obtained, but they are used mostly for generating electricity for lighting and power purposes. Their speeds run from 800 to 1,600 revolutions per minute.

The ordinary low-speed gasoline engine is started by a crank and is equipped with a magneto which frequently gives trouble after some years' use, and which is usually the cause of difficult starting. It is desirable to provide what is known electrically as a "hot spot" battery for starting the engine, which, after starting, runs on the magneto.

Gasoline engines are connected to pumps either by belt, rope, or chain drive, or they may be directly connected by an extended shaft, or they may be geared to the pumps. Gearing is the most positive but also the most noisy. Raw-hide pinions are made to reduce this noise. Belts have a way of slipping off and of stretching; the rope drive is uncommon; the silent chain is highly desirable, but somewhat more expensive than the belt drive.

The pumps to which these engines are attached may be suction, suction and force, deep-well, rotary, or centrifugal pumps. The layman may compute the approximate theoretical horsepower required by his pump by multiplying the total suction lift plus the total discharge lift, in feet, by the number of gallons per minute to be pumped, by 8⅓, and dividing the product by 33,000. The average combination of gasoline engine and pump can be estimated to be not less than 33 per cent efficient; the theoretical horsepower should, therefore, be multiplied by 3, which will give approximately the actual horsepower required for pumping. There is always some additional load on the engine due to the friction of water in the pipes, which increases the total "head" against which the pump has to operate. If the pipes are designed so that the velocity of the water passing through them will not exceed about 1 foot 3 inches per second, this "friction head" is not very material and would ordinarily be compensated for by adding 5 per cent to the calculated actual horsepower. For larger installations the advice of an engineer should be obtained.

5. Electric Motors. Electric motors form the most desirable power for driving pumps where electric current is available at reasonable power rates. It is frequently desirable to install a gasoline-engine driven motor generator for lighting and for electrically driving the pump and such other machinery as may call for mechanical operation. These electric outfits are built for voltages of about 32 or of 110. Both have their advantages, but where pumping by electric motor is intended, it would be better to purchase the 110-volt gasoline-engine driven electric equipment since 110-volt electric motors are standard. Unfortunately, these generators produce direct current so that the motors will have to be designed for direct current use.

Ordinarily the 110-volt generator equipment has a starting battery instead of storage batteries. This requires that the equipment be kept running whenever there is a demand for power or light. They have the advantage, however, of eliminating the storage batteries. This is of especial importance for camps, because the transportation, care, and storage of storage batteries is a material expense to the camp owner, whereas the starting battery is a very simple equipment similar to the starting battery on an automobile.

6. Power Pumps. In the smaller municipalities, where high buildings are few in number, the city pressure is generally sufficient to force the water to the plumbing fixtures on the top floors, so that no pump is required. Where homes are isolated, however, and do not enjoy a public water supply, or in the cities where tall buildings are numerous, and where the city pressure is insufficient to reach the upper stories, it is necessary to pump.

For isolated homes the selection of the pumps depends on the source of the supply.

For shallow wells, lakes, streams, spring reservoirs, and the like, the owner should select, preferably, a piston pump which has a suction lift up to 25 feet, unless the pump is placed below the source of supply, in which event he should consider the use of a centrifugal pump or a rotary pump. Rotary pumps are quiet in operation, but have the weakness of leaking at the glands, which have to be constantly tightened; therefore, they have largely given way to centrifugal pumps.

Centrifugal pumps might also deserve some consideration where they are located not more than 10 feet above the water level of the source, but in such a case it will be necessary to install an automatic priming device. These devices are quite successful if properly installed. The reason that centrifugal pumps should receive some consideration under these conditions is that they are so simple in maintenance and operation. Where the amount of water to be pumped is less than 20 gallons per minute, however, it will hardly pay to give them any thought; the piston pumps should be used in such cases.

Piston pumps may be either single-acting, double-acting, simplex, duplex, or triplex. The single-acting pump merely draws water on one stroke from the source of supply and on the next stroke pumps it to the tank, reservoir, or other point of discharge; a double-acting pump draws and delivers on the same stroke; a simplex pump is one that has one cylinder; a duplex pump is one with two cylinders; a triplex pump has three cylinders. For the average low-priced home the double-acting simplex pump is in favor because of its medium cost, although in many instances, single-acting simplex pumps are effectively used for small houses. For the same number of revolutions, the rate of discharge from a single-acting pump is, of course, only about ½ that of the double-acting pump.

Triplex pumps are usually more substantial than simplex or duplex; their cylinders are vertical and they are built so that the rate of discharge is practically continuous, since the three pistons do not operate in unison, but successively. For suction and force pumps, they are the most desirable and efficient type and are particularly recommended for the most expensive homes in cases where centrifugal pumps are not desirable because of high-suction lifts, or because the head against which the pump has to operate varies materially. They can be obtained in capacities running up to 1,700 gallons per minute, and against pressures ranging up to 6,000 pounds per square inch. They usually occupy considerably more floor space than centrifugal pumps. Triplex pumps are usually built in only the single-acting type.

Electrically driven pumps, like those operated by gasoline engines, may have a direct, a belt, a rope, a silent-chain, or gear drive. The direct drive is usually the best for centrifugal pumps, since the motor shaft and the pump shaft are each extended, one toward the other, and are connected at the meeting point by a flexible coupling, thereby making the speed of the motor and the speed of the pump identical.

Usually motors ½ horsepower or less in size can be thrown directly across-the-line with a switch; for larger sizes it is advisable to have a rheostat, either manually or automatically operated.

In the larger cities the street pressure varies, sometimes as much as 15 pounds to 20 pounds between high and low; the high occurring during the middle of the night when practically no water is being drawn, the low occurring particularly on Mondays—that is, on washdays. It is difficult to design centrifugal pumps to operate efficiently under such varying heads, and without overloading the motor when the street pressure is high. For this reason it is recommended that such pumps take their suction from a steel or concrete suction or surge tank which is maintained full by street pressure through an automatic ball float.

7. Air-lift System. Lifting water by the so-called "air-lift system" has of late years become more popular in cases where the water requirements are large. The greater popularity is probably due to the greater efficiency in the development of the science; especially in the greater efficiency of air compression. In this system, a water delivery pipe is inserted in the well and an air discharge pipe is inserted either inside or outside of it. The air is compressed by means of an air compressor and discharged into the air pipe in the well; the air pipe, if outside of the water pipe, is connected to the water pipe, near its lower end, by a tee or other fitting; if inside of the water delivery pipe, it terminates above its bottom. As the compressed air emerges from the orifice of the air pipe into the water delivery pipe, it expands and forms large air bubbles which mix with the water, thereby reducing the weight of the column of water in the delivery pipe. The column of the water outside of the delivery pipe, being free of air, is heavier and this excess weight forces the mixed air and water in the delivery pipe up through the latter to the surface. Water continues to enter the well and maintains the water level in it. Since the air is continuously supplied from the air compressor, the delivery action is also continuous, provided the water level in the well outside of the delivery pipe remains sufficiently high to force the mixed water and air out of the well. It is for this reason that wells which are to be fitted with an air lift must be drilled considerably deeper so that there shall always be a minimum ratio between the submergence of the air orifice and the lift. Manufacturers specializing in air-lift systems can furnish the required information on air compressors, sizes of wells, depth of wells required, and percentage of submergence required.

It is probable that the air-lift system will produce more water from a well than any other method. This type of system is free from moving parts in the well and is, therefore, practically free from repair charges. Deep-well pumps sometimes are troubled by sand getting into the well; the air lift system does not have this defect. It should be borne in mind that the air which enters the well through the air compressor is not necessarily sterile and may contain germs of all kinds which may or may not be killed by the heat in the compressor chamber.

Air lifts are not well adapted for small deliveries; they are usually not over 35 per cent efficient, and they do not raise the water to a height much greater than the surface around the top of the well. For large quantities of water they can be made to discharge into reservoirs at the surface from which a centrifugal, rotary, or piston pump may lift the water into an elevated tank or reservoir. Since water from deep wells is likely to contain carbonic acid, it, together with the oxygen of the air, is likely to corrode iron or steel pipes quite readily, if air lifts are used.

8. Water Wheels. The use of water wheels of any kind for isolated domestic water supply systems presupposes the existence of a large body of water at sufficient elevation to furnish the necessary power and the required amount of water for driving the water wheel.

Water wheels are classified as gravity wheels, reaction wheels, and impulse wheels.[12]

Gravity wheels are those wheels driven by the weight of the water. In this class are the undershot, half-breast, high-breast, and overshot wheels. Their efficiency varies from about 75 per cent for overshot to about 25 per cent for undershot wheels.

Reaction wheels are not much used. Impulse wheels, as their name implies, "are driven by the impulse due to the weight of water acting through its velocity."[13] Among these may be mentioned the common paddle wheel and the Poncelet wheel.

The installation and design of all such water-wheel developments should be made with the assistance of competent engineers specializing in this work. Frequently the manufacturers of this equipment will be of material assistance and will be glad to furnish information on request.

"Turbines consist of a wheel to which buckets are attached and which is arranged to revolve in a fixed case having attached to it a nozzle, guide or series of guides. The guide passages or nozzles direct the water onto the buckets of the wheel."[14]

The development of water power for turbine use requires expert engineering advice.

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[12] See Mead, Daniel W., *Water Power Engineering,* New York, McGraw-Hill Book Company, 1915, p. 237.

[13] *Ibid.*

[14] *Ibid.*

9. Windmills. Present-day windmills, sometimes called air-motors, are constructed of galvanized steel and should be self-oiling. They supply the many needs of the country home, the farm, ranch, and plantation. There is no power so economical or reliable as the air-motor. Aside from the installation cost, there is practically no operating or maintenance expense. Designed to operate in light winds, and requiring little or no attention, the modern windmill offers many advantages not to be had with engines or motor-driven pumps. No attendance is necessary; there is no fuel expense, no costly overhauling jobs, and no wiring or motor charges.

The air-motor windmill will operate day and night throughout the year with but a single oiling. The working parts are completely enclosed in a bath of oil; therefore, the wear on bearings is practically negligible. The average life of a windmill installation is from 20 to 30 years. Engine-operated pumps have to be overhauled at least every two years, and replaced about every 8 to 10 years. They can only be permitted to operate safely for a few hours a day, and require fuel, water, lubrication, and attendance—these items being nonexistent with a windmill.

Records of the United States Weather Bureau, over a long period of years, show that in practically all localities the wind blows at a rate of 8 to 10 miles per hour, for many hours of the day. A modern windmill will pump water in good volume operating in this wind velocity; it reaches its maximum capacity in winds ranging between 15 and 18 miles per hour, which velocity exists for a great part of the year, at some period of the day or night.

Windmills can be used for pumping from wells, cisterns, springs, lakes, or streams at a depth from 10 to 1,000 feet, in capacities from 150 gallons to 5,000 gallons per hour, depending upon the conditions of the installation. A windmill pumping system consisting of the mill, tower, pump, and accessories, but not including tank and piping, will range from $100 to $1,000, depending upon the requirements of the user. The only shortcoming of the automatically oiled windmill for water supply would be where the user failed to install sufficient storage capacity.

Despite the fact that there are thousands of modern farms equipped with electricity and gasoline engines, windmills are preferred for pumping water on account of their reliability, long life, and freedom from breakdowns.

10. Hydraulic Rams. Hydraulic rams are used less, perhaps, for the water supply of isolated homes than conditions would warrant. They are the least troublesome and yet most highly efficient machines of any power plants used for delivering water to elevated tanks or reservoirs. The cost of power is nil; there is no lubrication; the repairs are inexpensive. Their field of usefulness, while limited, does not seem to be sufficiently exploited by the manufacturers nor taken advantage of by the owner.

Where the home owner has a stream, or pond, lake or large spring available from which he may obtain water and pressure on a ram located below, he should certainly give thought to pumping his water supply by this device. If the source of water is a polluted one, unfit for domestic water supply, he should investigate the use of a double-acting ram, which receives its water for power from the contaminated source, but its water for domestic purposes from an adjacent clean source, such as a spring.

In order to determine the suitability of a ram, the owner should ascertain the difference in elevation between the source and the ram, the distance between them, the approximate dry weather flow of the stream or spring or, if a pond or lake is used as a source, the dry weather flow of the outlet from them, or if this is not available, the approximate area of the lake or pond and their differences between high and low water level. He should determine, also, the height above the ram to which the water is to be raised, the length of the delivery pipe, and the number of gallons per day which he expects to consume. He should then transmit this information to one of the well-known ram manufacturers for recommendations as to pipe sizes.

Where the owner is considering the use of polluted water as a motive power of the ram for delivery of clean water, he should so state. The manufacturer will usually cooperate with the owner and give him the benefit of advice on the installation details.

Rams are constructed which will deliver from as low as 2 to as high as 700 gallons per minute; and with as a low as a 3-foot head to operate them. A ram of well-known make will, for instance, with a supply at the source of 12 gallons per minute and a fall of 10 feet, discharge a total of about 2,300 gallons per day against a 50-foot head.

Section VIII. Devices for Maintaining Pressure

1. Desirability. The desirability of maintaining adequate and continuous pressure is almost a necessity to the house owner. Numerous cases are on record for instance where people have been scalded, in some instances fatally, as a result of excessive hot-water temperatures at the shower bath. Almost invariably such serious results can be traced back to the insufficiency of the cold-water pressure. Convenience to the user also dictates that the water pressure should not be low at one time and high at another, because he or she becomes accustomed to a certain stream issuing from a sink faucet and opens the faucet sufficiently wide to produce that stream. Should the pressure be materially increased the result will be splashing or possible serious scalding of the hands. Beautiful clothes can be damaged in the twinkling of an eye by serious splashing from lavatory faucets.

Feeble streams trickling from a faucet, because of lack of pressure, would spoil any person's good temper, but it is equally provoking to encounter the splash of a too-voluminous rush from the faucet. Serious damage may be done to the entire plumbing system, especially faucets and ball cocks, if the water pressure is too high; this equipment is not ordinarily constructed to withstand unusual pressures, such as 80 or 100 pounds per square inch.

Water hammer is the result of suddenly bringing to rest a fast moving column of water in the piping system; it may cause rupture of the pipe lines, fittings, and appurtenances. It is referred to in more detail hereinafter.

The maintenance of equal pressures on both hot and cold water supplies is especially important for all fixtures having one common outlet, such as the combination faucets for kitchen and pantry sinks, lavatories, bathtubs, and showers.

Since the pressures in the hot and cold water lines, which supply these combination faucets, constantly vary because of the draft at other fixtures elsewhere in building, it is necessary for the designer of the piping system to provide for this condition. Should he fail to do so, serious consequences may result.

The most desirable pressures for domestic service are between 20 and 40 pounds per square inch.

2. Friction. Assuming that we have a 1-inch horizontal pipe 10 feet long and another horizontal pipe 1,000 feet long, and that water is introduced under the same pressure at the inlet to the end of each pipe, more water will issue in a given time from the 10-foot pipe than will from the 1,000-foot pipe. The reason for this is that the water passing through the 10-foot length has to overcome less resistance in the pipe than does the water passing through the pipe 1,000 feet long. This resistance to the flow is called friction. Friction increases proportionately with the length of pipe; it is 100 times as great in a pipe 1,000 feet long as it is in a pipe 10 feet long. It increases also with the decrease in diameter of the pipe; the smaller the pipe the greater will be the friction for the same amount of water passing through it. For instance, if it requires pressure of 11.1 pounds per square inch to force 100 gallons of water per minute through 100 feet of a new 2-inch iron pipe, it requires 307 pounds per square inch to force the same amount of water through a new 1-inch iron pipe; in other words, by reducing the pipe diameter ½ and the pipe area ¼, nearly 28 times as much pressure will have to be applied to get 100 gallons of water through the pipe. This is due entirely to friction created by the flow of water through pipes.

Pipes of different materials have, of course, different degrees of friction. Brass and copper pipes have the least friction of any metal pipes ordinarily used. Unless there is dezincification, or dissolution of the copper, or deposition of lime or gypsum salts left by the water on the interior walls of the pipe, these pipes retain their smooth bore almost permanently. There are many instances where iron or steel pipes, even though galvanized, corrode so badly in 3 to 10 years, that they are practically filled with rust and pass little, if any, water.

The smoother the interior walls of the pipe, the less will be the loss in pressure by friction; the rougher, the greater will be the loss. Referring to the example cited above, if the 2-inch iron pipe is seriously rusted, about 400 pounds per square inch pressure would be required to force 100 gallons of water per minute through it instead of 11.1 pounds. This comparison is given merely as an example of the tremendous amount of waste in pressure that occurs when seriously rusted iron pipe is used.

In practical application to plumbing water supply systems, this means, for instance, that the motor of a pump connected to a 2-inch discharge line extended to a tank 100 feet above it will have to exert 36 times as much power to deliver 100 gallons per minute through a badly rusted 2-inch pipe as it would through a new 2-inch pipe. The necessity of maintaining the plumbing water supply pipes free of rust becomes evident at once from this example, as well as the importance of installing a piping system of corrosion-resisting material, such as brass or copper, in such instances where the water has corrosive qualities. The incidental nuisance of rusty water has already been referred to, but is of sufficient importance to repeat.

So far, reference has been made to friction caused only by straight pipes; other causes of friction are found in sudden increases or reduction of diameters of pipe lines or in sharp bends in the pipe lines. Sometimes in badly designed piping systems the velocity of the water through the pipe lines is also responsible for considerable loss of pressure.

Sudden increases or decreases in pipe sizes or sharp bends in pipe lines should be avoided.

3. Pressure by Gravity. Elevated tanks, standpipes, or elevated reservoirs are used in providing pressure by gravity to the home. While elevated tanks are sometimes built cheaply of wood, as are their towers, wood construction should be considered as a temporary expedient only. Permanent elevated tanks and their towers are best built of steel;[15] standpipes are also built of steel.

Reference has been made heretofore to wooden attic tanks, copper or lead lined. Wooden tanks are sometimes used as roof tanks on tall buildings. In such event they are built of staves encircled with steel hoops; they are built of cypress, red or white pine, or white cedar. The hoops should be of round, not flat, steel; flat hoops rust quickly. These roof tanks are covered with a flat roof and a conical roof above it.[16] Wooden-stave roof tanks when exposed to the weather are known to have lasted for 20 years or more if properly cared for.

The water consumption per person per day in large American

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[15] Steel-tower tanks are manufactured according to standards laid down by the National Board of Fire Underwriters and can be obtained in standard tank capacities from 5,000 to 500,000 gallons and in standard tower heights from 10 feet to over 180 feet. Complete detailed requirements for steel tanks and towers are issued by the National Board of Fire Underwriters, and can be obtained from the National Fire Protection Association.

[16] The National Board of Fire Underwriters has printed detailed requirements for wooden roof tanks up to 50,000 gallons capacity, a copy of which may be obtained by the interested reader.

cities varies tremendously. The following available statistics bring out this variation quite effectively:[17]

(Gallons per person per day)

Dallas, Texas	56
Oakland, California	63
San Francisco, California	81
Springfield, Massachusetts	91
New Orleans, Louisiana	100
Boston, Massachusetts	113
New York, New York	131
Baltimore, Maryland	132
Cleveland, Ohio	142
Philadelphia, Pennsylvania	168
Denver, Colorado	191
Buffalo, New York	213
Chicago, Illinois	275

It is not necessary to dwell here on the reasons for such tremendous variations, except to say that, in cases where very high water consumption occurs, the percentage of metered water is usually very low and vice versa, with the result that unmetered water consumption produces a great deal of water waste.

The required sizes of tanks for domestic service are controlled chiefly by the dependability of the source of water supply, and secondarily by the quantity of water which should be available under pressure per person per day for each day during which the source of water supply may be expected to be out of use.

As heretofore pointed out, the most satisfactory water pressures for domestic service range between 20 and 40 pounds per square inch. The piping system leading to the plumbing fixtures should be of sufficient size so that these pressures will not be materially reduced by friction.

4. Air-pressure Tanks. In some localities air-pressure tanks for domestic water service are preferred to elevated or roof gravity-pressure tanks. They do away with an unsightly tank on the roof or with an expensive ornamental tower enclosure for the tank; on the other hand, if placed in the basement of the building, they may occupy valuable income producing space. They require air compressors, which are either noisy or have to be silenced by artificial means, and deliver water to the faucets under slightly varying pressures, depending on the air pressure in the tanks. As the water leaves the tanks the air pressure is naturally reduced;

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[17] Taken from *Water Works Practice* (Manual of the American Water Works Association), Baltimore, Williams and Wilkins, 1925, pp. 428-429.

when a predetermined low-pressure point is reached, the air compressor, or the pump, or both, start automatically.

Pressure tanks are usually fitted with glass tube gauges on their heads which indicate the level of water in the tank; they should be fitted also with pressure gauges showing the pressure, and with safety valves to prevent damage to the tanks from excess pressures, also with generous-sized blow-off connections for emptying purposes.

5. Water Hammer. Water hammer is a phenomenon occurring in water supply systems when the flow of water is suddenly stopped or obstructed. Water flowing through a pipe has a certain mass and a certain velocity, therefore a certain momentum. When this momentum is suddenly checked, a series of shocks is felt through the entire system. These shocks may have devastating effects; pressures become momentarily enormous. Professor Cleverdon, of New York University, made some interesting tests in the hydraulic laboratory of New York University, to determine the magnitude of the pressures created by water hammer.[18] He found that by suddenly stopping a column of water flowing through a pipe under 40 pounds pressure, the water hammer produced would raise the pressure to as high as 600 pounds per square inch. By inserting an air chamber in the line close to the gate valve, which was used for suddenly stopping the flow, on its upstream side, it was found that the water hammer spent itself almost entirely in the air chamber and created practically no increase in pressure beyond the point where the air chamber had been inserted in the line. In the home or in apartment houses or in hotels where self-closing or quick-closing faucets are used, or where some types of water-closet flush valves are used, water hammer is likely to occur when such faucets or flush valves are closed. The banging noise which is heard in water lines under such conditions is due to this cause. The least damage that water hammer will do in time will be the loosening of pipe joints and of hangers with resultant leakage and possibly eventual displacement and breakage of pipe lines. Water hammer also damages faucets, ball cocks, flush valves and other mechanical equipment. Wher-

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[18] See Cleverdon, Walter S. L., "Solved 13 Plumbing Problems," *Domestic Engineering,* September 20, 1930, p. 72, and *Water Supply of Buildings and Rural Communities for Engineers, Architects, Plumbers, and Property Owners,* New York, D. Van Nostrand Company, 1925.

ever it occurs, it should be promptly cured by the insertion of an air chamber.

6. Choice between Gravity and Pressure-tank Systems. In homes which do not enjoy the benefits of city pressure, air-pressure systems should be used in preference to gravity systems, in spite of the fact that they are somewhat more mechanically complicated. These systems can be placed in the basement and are proof against freezing; they also keep the water temperature low in the summer.

Where no room is available to put pressure tanks in the basement of the building, they may be buried underground with their heads projecting into an underground pump house in which the pump and the air compressor are located.

Elevated tanks are frequently unsightly and are, therefore, objectionable in many instances.

Section IX. Service Pipes to the House

This subject of service pipes to the house has already been rather thoroughly covered, as to selection of materials, depths of trenches, backfilling of trenches, taps, corporation cocks, curb cocks, and main shut-off valves in buildings. It should be stated here, however, that protection against freezing is very necessary when rock is encountered in the excavating, the cost of removal of which would be prohibitive. In such instances it is possible to frost-proof the service pipe by placing it inside a covered wooden creosoted box 12 inches square, wrapping it with three thicknesses of tar paper and filling the box with mineral wool. The pipe should pass through the center of the box so that the mineral wool will be under, over and on both sides of the pipe. The box, including the ends, should be surrounded with three layers of tar paper.

Only clean earth, preferably sand, free of stones should be placed on top of the box.

Section X. Outside House Connections

The pipes leading to lawn and garden sprinklers should always be laid so that they will drain completely either to the sprinkler valves or to the main pipe in the building from which they branch; garden sprinklers should be used which are self-draining. Individual supply lines to each sprinkler should be not less than ½ inch in size if of brass, and not less than ¾ inch if of galvanized iron or steel and if not over 20 feet in length. For each additional 20 feet they should be increased one pipe size diameter up to 1½ inches. For two sprinklers they should be not less than 1 inch nor more than 2 inches in diameter.

If outside fire hydrants are installed, they should also be self-draining, and their piping connections should be laid so that they will completely drain.

Section XI. Interior Water Pipes

1. **Materials of Pipes.** The following materials are used extensively for interior water piping:[19]

Galvanized steel;
Galvanized wrought iron;
Brass pipe containing 60 per cent copper, 40 per cent zinc, called "Muntz Metal";
Brass pipe containing 67 per cent copper, 32½ per cent zinc, ½ per cent lead, called "Yellow Brass";
Brass pipe containing 85 per cent copper, 15 per cent zinc, called "Red Brass";
Brass pipe containing 70 per cent copper, 29 per cent zinc, 1 per cent tin, mostly used for condenser tubing, called "Admiralty Metal";
Copper pipe, 99.9 per cent copper.

2. **Materials of Fittings.** The commercial fittings on the market for water supply piping are:

Galvanized malleable iron, used with galvanized steel and wrought iron pipes; brass fittings (malleable pattern and steam-pipe pattern). For small dwellings a good grade of malleable-pattern brass fittings can be used with safety.[20]

3. **Sizes of Pipes to Individual Fixtures.** No galvanized wrought-iron or steel water pipes less than ¾-inch inside diameter should be used. Where brass pipes are used, the following sizes are recommended:

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[19] The owner will make no mistake, if he purchases water pipe by the following Federal Standard Specifications: Galvanized steel pipe—F. S. B. No. 162-A (W W-P.-431). Galvanized wrought-iron pipe—F. S. B. No. 242 (W W-P.-441). Brass pipe—F. S. B. No. 342-A (W W-P.-351). Copper pipe—F. S. B. No. 287 (W W-P.-378).

[20] F. S. B. No. 535 (W W-P.-471) and F. S. B. No. 448 (W W-P.-448) cover these materials adequately.

	Cold	Hot
Water-closet (flush valve)	1¼-inch	
Water-closet (tank)	½-inch	
Sinks	¾-inch	¾-inch
Bathtubs	¾-inch	¾-inch
Shower baths	¾-inch	¾-inch
Lavatories	½-inch	½-inch
Laundry trays	½-inch	½-inch

4. Sizes of Pipes to Combinations of Fixture Groups. To supply fixtures specified below, the following pipe sizes are recommended:

For a bathroom consisting of one water-closet supplied through a flush valve, one bathtub, with or without overhead shower, or with separate shower stall with 5-inch shower head in either case, and no rose sprays, one lavatory, 1½-inch cold, ¾-inch hot.

For the above group, except that the water-closet has a flush tank, ¾-inch cold, ¾-inch hot.

Kitchen—consisting of one sink and double compartment laundry tray, ¾-inch cold, ¾-inch hot.

One sink, alone, ¾-inch cold, ¾-inch hot.

Laundry—one two-compartment laundry tray, ¾-inch cold, ¾-inch hot.

5. Economical Aspect. The selection of the right pipe material for the water supply system of any building depends largely upon the results of an analysis of the water. In general, a soft water indicates short life for steel or wrought-iron pipe and a serious health problem (due to lead poisoning) with lead pipes. Brass pipes, with low lead content and high copper content, are preferable to lead. In a locality having hard water, galvanized pipes can be used with safety on cold water lines; they should be of ample size and installed exposed, to facilitate replacement. The hot-water pipes should be of brass, except that galvanized steel or iron may be used for medium hard waters, where these pipes are exposed and over 1 inch in diameter. Water-pipe materials should be selected that will not corrode under working conditions for which they are intended. In these days, modern plumbing requires that all pipes, where possible, be concealed within partitions or chases in walls, below tile floors, in furred ceilings, and various other places where they are not supposed to be seen; it is much more economical to install these pipes of a noncorrodible material than to go to the expense of replacement, with consequent damage to the structure, within a comparatively few years.

If the proper pipe is selected and the character of the water supply does not change, there is no reason why the pipes should not last as long as the structure.

6. Valve Control of Fixtures. In a small dwelling having a single bathroom, kitchen and laundry, individual fixture valves are not essential unless a fixture is isolated. They are, however, convenient. If any fixture gives trouble, it can be cut out of service without affecting the operation of the remainder of the group. Groups of fixtures should always be provided with valves, for the reason that a break or bad leak below a floor or in a partition can be controlled and repaired without interrupting the supply of the balance of the premises. Isolated fixtures should always be provided with separate valves.

7. Valve Control of Premises. The entire premises should always be provided with a control valve within the building. In small dwellings where the water main usually is of ¾-inch lead, galvanized-iron, steel, or brass pipe, ¾-inch gate valve should be placed on the water main just inside of the cellar wall, and adjacent to it a tee branch with a drip valve, through which the entire piping system in the building can be emptied. Whenever a bad leak or break occurs within the building, the owner will make an effort to shut the water off before he calls the plumber. Practically no home owners have a key for the extension rod in the curb box.

If the home owner desires to close his home for the winter, the entire plumbing system can be shut off at this valve and the entire water piping system, if properly installed, drained, and thereby serious damage due to freezing can be prevented.

8. Desirability of Drip Valves. Drip valves should be placed at the base of all risers and at low points in the water piping system. These valves should always be installed on the fixture side of all valves controlling the fixture or any fixture group. They facilitate repairs on any portion of the water supply system and eliminate the cost of blowing out the system if the building is not occupied during winter months.

9. Minimum Slopes. All water pipes should be given a minimum slope back to the riser or drip valves of about 6 inches in every 100 feet; this amounts to about 1/16 inch per foot. Cold- and hot-water branch lines should be pitched upward toward the fixtures.

10. Insulation of Water Pipes and Frost Protection. Cold-water pipes within a building are usually insulated to prevent sweating. If the air surrounding the pipes is warm and contains moisture, sudden and continued chilling of this air will cause condensation to form on the pipe, which drips to the floor, causing damp and musty smelling cellars, basements, or rooms through which such cold-water pipes may pass. To eliminate this dampness, the pipes are covered with sectional-moulded wool felt, or long cow-hair felt. By far the neater job is that in which moulded wool-felt covering is used.

Hair and wool felt, when new, are good heat retarding materials and, as such, are sometimes used in the covering of hot-water pipes, but they deteriorate with age and, unless they are covered with canvas and painted to seal all joints, they furnish a good breeding place for vermin; even mice or rats will tear them apart for the building of nests.

In selecting a pipe covering, consideration should be given to incombustible covering; it costs no more and is usually more effective, especially for the covering of hot-water pipes. Care should be taken to avoid coverings containing carbonates or sulphates, which may cause serious corrosion of the pipe metal against which it is placed.

The value of pipe coverings for heat insulation is not proportioned to its thickness. Good standard pipe coverings average about 1½ inches in thickness, and the reduction in loss by radiation, when such covering is employed, is about 90 per cent. Doubling the thickness of the pipe covering will increase the reduction in loss to about 95 per cent. Experience shows that a covering 1½ inches thick is both economical and efficient for heat insulation in dwellings.

Pipes to be protected against frost, are generally outside of the heated building, although in some houses a bathroom is located over an open porch. In such event the owner should insist that the architect adequately insulate the ceiling of the porch and, in addition, that the plumber should insulate the pipes.

Insulated pipes below ground or exposed to the atmosphere should be protected with a weather- and waterproof jacket; in addition, pipes below ground should be installed on a bed of broken stone of ample depth to provide drainage.

Sectional pipe covering is the neatest and cleanest. The most expensive and best is 85 per cent magnesia covering. Asbestos covering, asbestos air-cell covering, and wool-felt covering are less expensive, but not such good insulators. In ordinary work, asbestos air-cell covering is used. Pipe fittings can be insulated with moulded coverings, which are best although they are expensive, or with asbestos plastic cement, which is materially cheaper and is efficient.

11. Desirability of Access to Water Pipes. The present trend toward noncorrodible water pipes makes accessibility a thing of the past in small dwellings. The building and its drainage system are usually so designed that one stack serves the laundry in the basement, the kitchen on the first floor and the bathroom on the second floor. In modern plumbing, bathroom piping exposed on the ceiling of a modern kitchen can hardly be conceived. The only access provided now is to control valves and clean-outs.

12. Comparison of Costs of Various Piping Materials. Using galvanized-steel pipe as a base, the cost of other materials will compare at 1931 prices as follows:

Galvanized copper-bearing steel	8 per cent above galvanized steel
Lead pipe	33 per cent above galvanized steel
Galvanized wrought-iron pipe	83 per cent above galvanized steel
Copper pipe, iron-pipe size	2.5 per cent above galvanized steel
Brass pipe with 60 per cent copper and 40 per cent zinc	2.66 per cent above galvanized steel
Brass pipe with 67 per cent copper and 33 per cent zinc	2.80 per cent above galvanized steel
Brass pipe with 85 per cent copper and 15 per cent zinc	3.00 per cent above galvanized steel

The above comparison is based on small pipes up to 1 inch in size, such as would be used on small house installations.

There is a slight but almost negligible additional cost for labor to install lead, brass, and copper pipes, due to the fact that these materials have to be handled more carefully. Stillson wrenches should not, for instance, be used on brass pipes; they require strap wrenches, which leave no marks. Lead pipes require time consuming "wiped" solder joints.

Section XII. Hot-water Supply

1. Hot-water Demand. The importance of computing the hot-water requirements of a building is vastly greater than that of computing the cold-water supply. A safe rule to follow is that the minimum hot-water supply to the basin faucet should be 4 gallons per minute; to the bathtub and sink faucet, 6 gallons per minute; to a shower stall, 8 gallons per minute; to a shower and needle bath, 12 gallons per minute; and to laundry tubs, 5 gallons per minute. Slop sinks should have the same rate of hot-water supply as ordinary sinks.

Good judgment is required in estimating the number of minutes per hour during which hot water is required at these fixtures. The maximum hot-water consumption in the home occurs usually during one hour in the morning and one hour in the evening.

If there are four persons in a family and each person occupies the bathroom for 15 minutes, the hot-water consumption per person will be 10 gallons for the bath and 4 gallons for the basin, making a total hot-water consumption of 14 gallons per person, and for the four members of the family, 56 gallons of hot water per hour.

If, during the same hour, hot water is used at the kitchen sink for a total period of 1½ minutes, this will add 9 gallons of hot-water demand, making a total hot-water consumption during the morning hour of 65 gallons.

This estimate assumes that every person in every family takes a morning bath, which, of course, is not the case. Good judgment would seem to be that not more than 50 per cent of all people take baths in the morning.

2. Coal Heaters. Coal heaters have, up to recent years, been the principal means of producing hot water for domestic supply; either by means of a pipe coil placed in the fire pot, which would heat the water in the hot-water tank directly; or by means of an indirect heater, which utilizes the heat of a steam or hot-water heating plant; or by means of a steam coil placed in the hot-water tank. In numerous instances, separate coal, gas, oil, or electric heaters are used during the summer. The capacities of coal heaters for heating water are standardized by the manufacturers of steam or hot-water boilers and hot-water heaters so that the consumer cannot go wrong in accepting these standards, except that a warning is given to purchase a coal heater of a somewhat larger rating than its actual hot-water demand requires. It is much better to pay a few dollars more in the beginning and be on the safe side and avoid forcing a coal heater, than it is to replace a heater afterwards with a larger one. Attention is again called to the fact that soft water corrodes iron; for this reason, wherever it is encountered, the heating element—that is, the coil, waterback, or water jacket—should be of brass, or preferably of copper.

In small homes it is customary to heat the water by means of a waterback in the range; adjacent to the range is ordinarily placed a 30-gallon hot-water tank. These waterbacks should be of brass where soft water is used.

Where unusually hard water is encountered, the waterbacks, as well as the coils in the fire pots of boilers or hot-air furnaces, and water jackets in separate coal heaters, will eventually become encrusted with hard lime and gypsum deposits. When this occurs, dilute acid may be used for dissolving these encrustations, but, like automobile radiators, when they are encrusted, this is a delicate, and sometimes not successful, procedure. Eventually it will be the part of economy to replace encrusted waterbacks, coils, and water jackets with new ones.

Sometimes a pipe instead of a waterback is set into the fire pot of the kitchen range, or a pipe or coil is introduced into the fire pot of a boiler or furnace. Schemes of this kind are perfectly practical, but the pipes used in such coils should be of copper, which will withstand the heat of the fire much better than brass. In the ordinary kitchen-range fire pot, such a pipe might well be of ¾-inch size, and it may be laid directly on top of the fire brick; in the fire pots of boilers or furnaces, it is better also to use copper than brass, but the pipe should be of at least 1-inch internal diameter and should not be more than 8 inches long; otherwise, the water would become overheated, and would form steam. These coils should be placed at the level at which ordinarily the live coal is carried and should be at least 2 inches inside of the fire pot so as to avoid contact with the dead layer of ashes, which usually surrounds the live coal.

The average amount of anthracite coal used to raise the temperature of 100 gallons of water through 100 degrees Fahrenheit is about 10 to 12.5 pounds.

3. Fuel-oil Heaters. The same principles are followed in the use of fuel-oil heaters as for coal heaters, except that fuel oil is used instead of coal as the heat-producing agent. The difference between them is, however, that coal fires, even when banked, give off some heat, whereas oil burners are either on completely or off completely. This condition necessitates a thermostatic control of hot-water tanks, which starts and stops the oil burner automatically, depending on the temperature of the hot water in the tank. In cases of oil burners with hot-water or steam heating boilers, it is advisable to use an indirect heating unit for heating the hot water; where oil-fired heaters are used for heating the hot water only, the heaters may be provided with hot-water jackets and the jackets connected to the hot-water tanks, or they may have indirect heaters similar to those heretofore advised for steam or hot-water heating boilers.

Hot-water tanks may also be provided with steam coils, through which the steam generated by the oil burner in a steam boiler circulates. The temperature of the hot water in the hot-water tanks is easily controlled thermostatically with fuel-oil burners.

The average amount of fuel oil (grade 1 or 2) required to raise the temperature of 100 gallons of water through 100 degrees Fahrenheit is about 9/10 to 1 1/10 gallons.

4. **Gas Heaters.** The home owner or home builder has a large range of selection in types of gas water heaters. Nearly all responsible manufacturers of high-class gas heaters make instantaneous automatic water heaters, single- or multi-coil automatic storage heaters with hot-water storage tanks piped to the heaters, and with automatic storage systems in which the heater either is directly adjacent to, and connected to, the vertical hot-water tank, or where the hot-water tank is set over the heater.

The instantaneous heaters are those which begin to operate immediately when a hot-water faucet is turned on anywhere in the home. They are made to supply hot water for one bathroom and the kitchen sink only, or to supply up to three or four family bathrooms, a servant's bathroom, a kitchen and pantry, laundry, and lavatories.

The single- or multi-coil automatic storage systems consist of gas heaters as small as single coils for 24-gallon tanks to multi-coils for 700-gallon tanks. In the smaller sizes, the tanks are usually vertical and set in the kitchens with the gas heaters beside them and the tanks connected to the heaters by means of a ½-inch or ¾-inch brass pipe. The hot-water connection from the heating coil should be made into the tank on the side just below its top; the return or circulation connection should be made to the side or preferably to the bottom of heater.

The operation of these systems is entirely automatic, the gas being turned on automatically whenever the temperature of the water drops below that at which the thermostat is set. The gas continues to burn until the water in the tank is restored to the predetermined temperature, when the moment valve automatically shuts off the gas to the heater.

Automatic storage systems are furnished by the manufacturers in one unit, the storage tank and the heater being sold as one equipment. The water is maintained in the tank at a fixed temperature ready for any demand. The tanks are furnished properly insulated, ready for use.

In the case of the multi-coil automatic storage systems, the hot-water tanks may, or may not, be furnished with the heater, at the option of the owner or builder; the heaters may be purchased separately from the tanks. The purchaser is cautioned, however, to obtain tanks with tappings of proper size and location for connections to the heater.

Gas hot-water heaters must be provided with flues in accordance with the principles outlined in Chapter III, Heating, Ventilating and Air Conditioning, page 152, on the flue connection of automatic gas appliances.

The average amount of artificial gas required to raise 100 gallons of water through a temperature of 100 degrees Fahrenheit is 200 cubic feet.

5. Kerosene Heaters. Kerosene heaters have been developed during recent years, but are being built only for small heating requirements; they are rated at 20 to 60 gallons of hot water per hour. The manufacturers state that a two-burner kerosene water heater set underneath a multi-heating coil, will raise the temperature of one gallon of water 28 degrees Fahrenheit per minute, and that one gallon of kerosene is sufficient for 12 to 24 hours of operation per burner, depending upon the height of the flame used. Assuming that the average height of the flame (18 inches) is used, two gallons of kerosene would be sufficient to operate the two burners for 18 hours.

These kerosene heaters can be connected to hot-water tanks similar to the single- or multi-coil gas heaters. They require flues for the removal of odors and dangerous gases of combustion.

On the basis of these statements by the manufacturers, it is estimated that the average amount of kerosene required to raise the temperature of 100 gallons of water through 100 degrees Fahrenheit would be about 2/3 gallons.[21]

6. Electric Heaters. Much attention has recently been given to the faucet-type electric water heater. It appears that this type of heater is not at present acceptable to power companies because it necessitates too high a wiring cost for the home, and because of the high demand, the power company has to furnish too much investment to supply the faucet heater.

The power companies are apparently now promoting the electric tank-storage type heaters, which promise to be efficient. It is, of course, necessary to insulate thoroughly the hot-water tank, as well as the hot-water piping, and some attention should be given to the planning of the location of the hot-water pipes in inside walls instead of cold outside walls, if electricity is to compete successfully with other fuels.

In the view of this committee, electric heaters, not of the faucet type (which require excessive wiring) but of the storage type, have, when properly insulated, a promising field for homes where rates for electricty are under 2 cents per kilowatt hour. They are automatic, require no open flame, vents, nor flues. They are safe appliances when properly protected with a thermostat and a relief valve.

It is estimated by the electric water-heater department of an important corporation manufacturing electric appliances, that the efficiency of electric heaters will be developed shortly to such an extent that 26.3 kilowatt hours will be consumed by electric storage heaters to raise the temperature of 100 gallons of water through 100 degrees Fahrenheit.

7. Indirect Heaters. Indirect water heaters are placed between the hot-water or steam-heating boilers and the hot-water storage tanks. They utilize the heat in the water of these boilers for heating the water for domestic use. The two waters do not mix. The heaters may be either vertical or horizontal, the latter being more suitable for heavy demands. These heaters are usually built of cast-iron casings inside of which are placed copper coils. The domestic hot-water supply passes through copper coils, the water from the steam or hot-water boiler circulates through the casing. These heaters are very efficient, and are

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[21] See Sweet's Catalogue, New York. F. W. Dodge Corporation, 1931, Vol. C, p. 4802.

highly recommended for use during the winter when the house heating plant is in operation. They may be cross-connected to small coal or fuel-oil hot-water heaters or to gas or electric heaters for use during the summer when the heating plant is shut down.

In another type of indirect heater, a number of copper or brass tubes, which carry the domestic hot water, pass through the water in the steam or hot-water heating boiler. They have been on the market for over five years, and have proved themselves quite satisfactory and efficient. Care has to be taken, however, with this type of indirect heater, to proportion the tubing properly for the heating requirements, since heaters of this kind cannot be controlled automatically as to temperature. The manufacturers specializing in this particular equipment have had considerable experience, however, in making the tubes of the proper length and size for almost any particular requirements. Their cost is reasonable.

8. Hot-water Storage Tanks. Hot-water storage tanks are usually made of steel, wrought iron, copper, or of steel lined inside with copper. They may be had riveted, if of steel, wrought iron, copper, or copper-lined steel; welded, if of steel, wrought iron, or copper-lined steel; brazed, if of copper.

The most common type of hot-water storage tank is the old-fashioned "range boiler," made of galvanized steel, wrought iron or copper, and usually constructed for a water-working pressure of 85 pounds per square inch, but obtainable for higher pressures. With the modern trend toward heating every room of the house in cold weather, and the demand for gas, oil, or electric ranges in the up-to-date kitchen, the "range boiler" has lost its familiar place in the kitchen and been relocated as a "hot-water tank" instead of a "range boiler" in the basement or cellar, where it is connected to the house heating plant by a waterback, coil, or indirect heater, and perhaps cross-connected for summer use to an automatic gas, oil, or electric heater.

In the outlying districts where gas is not available, and in some tenement houses, range boilers are still extensively used and connected to the coal range in the kitchen.

In the larger buildings, owing to the necessarily large storage capacity, the hot-water storage tanks are generally located in basements. In selecting a hot-water storage tank, the same care and judgment should be exercised as one would use in selecting the piping material for any particular installation. In dwelling house work, one can seldom go wrong in selecting a good copper hot-water storage tank. The small domestic galvanized-steel hot-water storage tanks have a comparatively short life, especially with soft waters. The hotter the water, the more rapid the corrosion; the more rapid corrosion, the sooner will appear rust and red color, which will make the water unpalatable, unfit for bathing, and will ruin the washing; and the sooner pipes will become clogged with rust and leak at the joints.

In small dwellings the hot-water storage tank is usually installed in a vertical position. The bottom of the tank is concave and the rust particles that accumulate around the outer edges cannot be removed. A great improvement in domestic hot-water storage tanks could be effected by redesigning the tank and stand so that the bottom of the tank would be convex.

Galvanized-steel hot-water storage tanks should not be used with all-brass piping. The proximity of the copper and zinc causes an electrolytic action to take place, which induces rapid corrosion and the formation of a deposit at the point where the brass connects to the galvanized metal, and results in partial stoppages and poor circulation. A copper hot-water storage tank would eliminate all such trouble.

Hot-water storage tanks are used to store water heated by the heating element during periods when hot water is not being drawn. They thus provide a reservoir, which is drawn upon when hot water is used faster than it can be heated. A smaller heater can be used with one of these tanks than would be required if water were drawn directly from the heater and had to be heated as fast as needed.

The size of the hot-water storage tank should bear a certain relation both to the number of gallons of water used in a given time and the capacity of the hot-water heater. If the tank is too large for the heater, there will seldom be an adequate supply of hot water in the tank; if the tank is too small, the water will become too hot. It is possible that the temperature will rise to 212 degrees, or over, so that when a faucet is opened it will flash into steam.

Water is seldom used hotter than 130 degrees Fahrenheit, so that water of higher temperature, say 160 degrees, mixed with cold water, increases the volume of available hot water. The size of hot-water storage tank for the small dwelling is usually fixed at 30 or 35 gallons, and is found ample for the domestic needs of the average family.

Several good noncombustible materials are available for insulating hot-water storage tanks. They are usually covered with about 1½ inches of plastic asbestos trowelled to a hard finish over expanded metal, wired to the tank, or with 85 per cent magnesia blocks wired to the tank and then coated with plastic magnesia trowelled to a smooth finish.

9. Explosion Hazards. The greatest explosion hazard arises from the lack of proper control of the heating element, resulting in excessive steam pressures within the hot-water storage tank; this can be prevented in the first place by thermostatic control of the heater reinforced by a conveniently placed and easily read thermometer; in the second place by the installation of a first-class pressure relief valve set to a pressure about 25 pounds above the high water pressure; thirdly, by a regular inspection of the operation of the thermostatic and relief valves; fourth, by omitting all check valves on the cold-water supply to the hot-water tank, between the tank and the street main or the elevated or pressure tank.

Not only an explosion, but also the collapse of a hot-water tank has to be guarded against. Collapse is caused by the external atmospheric pressure on a tank from which the water has been siphoned out, while the cold-water supply was shut off. Since no air could enter the tank, it is in a partial vacuum state. An automatic vacuum valve placed on the cold-water line near the tank will prevent the collapse, but this valve also should be regularly inspected.

10. Hot-water Temperatures. The water temperatures required for various classes of service differ widely; for general domestic use 130 degrees to 160 degrees is ample. The average home has no way of heating the water separately for any service. It is usually heated to about 160 degrees in the tank and mixed with cold water to get the desired temperature. In the kitchen it is mixed by a combination faucet; in the bathtub it is mixed in a similar manner; in the laundry it is mixed in the tub.

With the showers, owing to the scalding hazard, the problem is different. The ordinary mixing valve on the market gives one a sense of false security. With this appliance it is impossible to mix thoroughly the water for a constant desired temperature at the shower head, unless a thermostatic valve is installed. If a water-closet is flushed while the shower is in operation, the pressure momentarily drops and the volume of cold water is decreased. If for any reason the temperature of the hot water in the tank should be near the boiling point, steam would flash from the shower head and rain scalding water upon the bather. The consequences would be serious. Experiments show that thermostatic valves are the only valves that will safely and surely deliver water at a constant temperature at the shower head. There is, however, another and cheaper valve on the market, which is very satisfactory; its operation depends on the differences of pressure between the hot and cold water; it will automatically reduce the hot-water quantity with the reduction in cold-water pressure, and will shut off the hot-water flow if the cold-water flow stops.

The cost of ordinary mixing valves is about $12; of thermostatically controlled valves, for one 5-inch shower head, about $60; and of pressure controlled valves, $40.[22]

Section XIII. Bathroom Fixtures

The subject of bathroom fixtures is one which should be of greater interest to the home owner than the selection of his car, his living-room furniture, or his radio. It used to be quite the reverse, with the result that the American bathroom of former years was probably the ugliest, most unsanitary room in the house. Within the last few years, however, extensive research work on the subject and elaborate advertising programs by fixture manufacturers have built up in the home owning public a plumbing fixture-mindedness. People realize that bathroom fixtures may be made things of beauty as well as instruments of sanitation. The bathroom should be sanitary and most comfortable.

It is a very important part of this committee's work to make a somewhat detailed report on modern bathroom fixtures, which the prospective home owner may be called upon to select.

1. Bathtub. The bathtub may be of several types. It may be a free-standing tub on legs, it may be of the built-in pattern, or it may even be sunken into the floor.

(*a*) *Free-standing Tub on Legs.* The free-standing tub is well-

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[22] F. S. B. No. 448, "Plumbing Fixtures for Land Use."

nigh extinct, for which the American housewife is truly grateful. It was a great dirt catcher and it was a very conscientious person who ever thoroughly cleaned the floor under the tub. Then, too, the under side of the rolled rim was a fine dust trap, which seldom got a good cleaning. The appearance of the tub was ugly and helped to make a homely room homelier.

(*b*) *The Built-in Tub.* The built-in tub has taken the fixture buying public by storm. In contrast to the old-fashioned tub on legs, there is no place on it which cannot be cleaned with ease and speed. It is built into the floor along its bottom edge and so leaves no space beneath to catch dust.

It may be of three types—corner, recess, or pier pattern. The corner type is built-in at the back, one end, and at the floor, leaving one corner finished off and free. The recess tub is one designed to fit into an alcove and is built-in at the back, both ends, and at the floor. This type of tub is especially good when used in combination with an overhead shower. The third, or pier pattern, type of tub is one which is built-in at the back and at the floor, leaving both corners rounded off and free.

(*c*) *The Sunken Tub.* The sunken bath is more or less of a luxury and would probably not be found in the moderately priced home, as it would entail quite an additional expense for special construction of the ceiling below to take care of the depth of the tub.

(*d*) *Selection.* The length of a bathtub is more or less a matter which will be decided by the home owner's individual taste. He has a selection of lengths between the extremes of 4 feet 6 inches and 6 feet. Tubs 5 feet and 5 feet 6 inches in length are most practical, however, for master bathrooms. The 4 foot 6 inch length is used mainly in servants' and children's baths.

To sum up the features which should be looked for in selecting a bathtub, the following should be noted:

It should be of the built-in type, and of the pattern especially adapted to the architecture of the particular bathroom.

It should be of ample length to accommodate the user.

Its bottom should be as flat as possible to obviate the danger of the user slipping on rounded slippery edges or corners while standing in the tub.

The brass supply- and shower-fittings for the bathtub will be discussed in a later paragraph.

2. Water-closet. The water-closet can be a menace to health.

for through it pass the excretions. Anything which increases this danger should be avoided. Among the factors which make a water-closet a menace are the following:

Tendency to stop up. This is usually caused by two small a waterway through the bowl. The minimum size should be not less than 2½ inches all the way through.

A large fouling surface. By this is meant a large uncovered area on the interior surface of the bowl on which material may fall and dry. In a well-designed bowl, the fouling surface is reduced to a minimum by having a large area of water always in the bowl.

A sluggish flush. The contents of the bowl are not entirely removed and may remain there until the bowl is again used. There should be a vigorous flush combining a strong scouring action and expelling force.

The bowl should not be too high. This fault tightens up the abdominal muscles, and hinders the peristaltic action of the intestines. A bowl between the heights of 14 inches and 15 inches is ideal and should be insisted upon.

The bowl should be impervious to moisture. The old porcelain bowls were subject to crazing, whereby moisture found its way under the glaze and caused noisome odors, as well as being very unsightly. A well-fired piece of vitreous ware will not craze and is nonabsorbent.

Water-closets may be classified into the following general classifications:

(*a*) *Siphon-jet Bowls.* These closets have one or two jets which set up a siphon action in the bowl, thus drawing the contents of the bowl out and on into the waste line. In addition, water is supplied through a flushing rim, which scours the interior surfaces of the fixture. This type has a very large water area and there is a minimum of fouling surface. It is also quiet in operation.

(*b*) *Wash-down or Reverse-trap Bowls.* This type of water-closet receives all its water through the flushing rim, and depends for its action on an accumulating head of water in the bowl, until the head becomes great enough to force the contents over the dam and into the waste line. This bowl has a greater fouling surface than those of the siphon-jet type and is also rather noisy. It is less costly than the siphon-jet bowl.

(*c*) *Blow-out Bowls.* This type of bowl depends for its action on a sudden discharge of water under high pressure. It is positive in action, but noisy. It can be used only in conjunction with a flush valve and is, for the most part, found only in public toilet rooms.

Water-closets may be flush valve operated or they may be supplied with water from a 6- or 8-gallon tank. The valve combination is about one-third less expensive than the tank combination, but makes it necessary to run at least a 1-inch water line to the closet. With a tank combination, a ½-inch line is all that is necessary.

3. Lavatory. The lavatory should be selected with as much care as the bathtub or water-closet, for this is the fixture which is used most often. It should be constructed of an impervious, nonabsorbent substance, such as vitreous china or enameled iron.

It may be of three types as far as general appearance is concerned:

(*a*) *Wall-hung.* As its name implies, the lavatory is hung on wall hangers.

(*b*) *Pedestal.* This type of lavatory rests upon a massive pedestal.

(*c*) *Leg.* This lavatory rests upon a slender leg, and is braced to the wall by brackets.

Any one of the three types is desirable, the appearance and the purchaser's pocketbook being the deciding factor as to its merits.

4. Shower. The shower is used more today than ever before. The general public has become used to taking showers, through a wider participation in athletics and the finishing-off shower.

At any rate, the shower is very popular and deserving of careful consideration. There are two general classes of showers, those of the mixing valve type and those having separate hot and cold valves.

(*a*) *Mixing Valve.* Three types of mixing valves are considered:

1. Hand-operated Mixing Valve. The ordinary hand-operated mixing valve is satisfactory if it works under ideal conditions, but it has absolutely no safeguard against shots of hot or cold water due to the sudden decrease in either of the two as a result of someone drawing either hot or cold water from some other outlet. It will not maintain a constant temperature.

2. The Pressure-regulating Mixing Valve. This will not compensate for any change in temperature of the hot or cold water. It is about one-third more expensive than the ordinary hand-operated mixing valve.

3. The Thermostatic Mixing Valve. This type valve gives certain protection against shots of hot or cold water. It is sensitive to changes in either temperature or pressure and responds quickly. It is, however, about twice as expensive as the pressure-equalizing mixing valve. It is well worth the difference, since it will actually prevent scalding.

(*b*) *Separate Valve.* This type of shower is awkward to operate and is just as bad as the ordinary mixing valve so far as sudden discharges of hot or cold water are concerned. It is the cheapest of any of the types mentioned.

5. Fittings. (*a*) *Bathtub and Shower.* As shower and bathtub fittings are often combined into a single unit, bathtub fittings are discussed next.

Four types of bath supply fittings are considered:

1. **The Bell Supply Fitting.** This consists of a bell, attached to the inside of the tub, through which water is supplied to the tub. The bell is often submerged, and dirty water may easily get into the supply lines. This type of supply fitting is very unsanitary and should be avoided.
2. **The Top-nozzle Fitting.** This fitting consists of a nozzle extending into the tub and coming through the inside shell of the tub. Although not so unsanitary as the bell supply, it may become submerged and permit dirty water to get back into the supply lines.
3. **The Over-rim Nozzle.** This nozzle is located in the wall above the tub and is absolutely free from any chance of being submerged in dirty water. It is the only truly sanitary supply fitting.
4. **Transfer Valve.** There is another type of fitting, known as the transfer valve, on the market. This fitting is used only when there is a shower located above the tub. The same hot and cold valves supply both tub and shower. Between these two valves and the tub and shower is located a diverting or transfer valve, which sends the water to the shower head or to the tub supply nozzle.

The principal merit this unit possesses is the opportunity that it gives the user to temper the water he intends using through the tub nozzle. After he has tempered the water to suit him, he can then divert the flow by means of the transfer valve to the shower head. If, however, he should be leaning over the tub and turn on the hot water, thinking that the transfer valve was going to divert the flow to the tub, and instead it diverted it to the shower, it would be very unpleasant for the user, if indeed not dangerous. For this reason, it would seem safer to have separate controls for shower and tub. This ever-present danger would seem to outweigh an advantage which this type of supply fitting may possess.

The waste fitting may be one of the following three types:

1. **Chain and Plug.** This type of fitting is the most reliable, the tightest fitting, and it is also sanitary.
2. **The Pop-up Waste.** This type of waste consists of a metal ground-joint plug, operated by means of a lifting knob. The pop-up waste when used on a bathtub is not, as it is on a lavatory, the most advantageous type to use. It has the disadvantage of not having a tight fit. Where it is only necessary to hold water in a lavatory for 5 minutes the fit is sufficiently tight. Where a matter of 20 minutes to a half hour is concerned the leakage

is too great. The pop-up waste, if draining, projects above the bottom of the tub and many a toe has been stubbed and badly cut on the waste plug.

3. **The Standing Waste.** This consists of a barrel with a ground seat, which, when lowered all the way into the waste chamber, makes a tight joint and holds the water in the tub. The overflow is taken care of by perforations in the barrel. The water rises around the barrel until it reaches the perforations and then goes on down the drain. Dirty water constantly surrounds this barrel making this type of waste unsanitary. It should be shunned.

(*b*) *Lavatory.* The lavatory may be equipped with either a combination faucet or single hot- and cold-water faucets. The combination fitting is preferable, as it is possible to secure tempered water through the one spout.

As in the case of the bathtub, the waste fitting may be one of three types:

1. **Chain and Plug.** This type of fitting is somewhat old-fashioned for lavatories and, while sanitary, it is not quite as desirable as the pop-up waste.
2. **The Pop-up Waste.** This operates mechanically by a lifting knob located on the slab of the lavatory. It is neat and sanitary and, for the lavatory, is the most desirable of the three types.
3. **The Standing Waste.** This has the same disadvantages here as on the bathtub, namely, that it is unsanitary.

There is a type of lavatory having what is known as an integral supply. The water is supplied through a hole bored into the ware itself. This is unsanitary, as the bowl may be so full that dirty water will get into this hole and thus get into the water lines. This type should be avoided.

In connection with a discussion of lavatories, it would seem an oversight not to mention the dental lavatory. It is an inexpensive fixture, but one which is designed especially for cleaning teeth. It has a combination fitting giving tempered water, together with a perforated rim through which water flows, keeping the side walls cleaned. It has this point of merit, that the user of the regular lavatory is not washing his face in a bowl over which another person has just finished cleaning his teeth.

6. Materials. The materials used in the manufacture of plumbing fixtures are as follows:

(a) Enameled Iron. This is the most economical material for the manufacture of plumbing fixtures. It is best adapted for bathtubs where its light weight makes it unnecessary to have a specially constructed floor to support it. Then, too, iron is a good conductor of heat and warms through easily. It has a disadvantage of chipping easily, if struck a sharp blow.

(b) Vitreous China. This material is best adapted to the manufacture of lavatories and water-closets. It is impervious and non-absorbent, it will not stain and will not chip with anything like the ease with which enameled iron will chip. It is too heavy to be used in the manufacture of bathtubs, as it would be necessary to greatly increase the supporting framework of the floor to stand the additional load. Also in a fixture as large as a bathtub, it would be impossible to get a straight enough piece of china because of the warping caused by the terrific heat that occurs during firing. A vitreous china fixture costs approximately three-fourths again as much as a similar fixture of enameled iron.

(c) Porcelain. This was formerly used extensively for plumbing fixtures, but has lost most of its popularity, because it crazes easily and is absorbent once the glaze has been broken. It is heavy and, when used for bathtubs, needs an exceptionally strong floor to support it. It remains cold to the touch for a long time. It should not be used by anyone desiring the utmost in cleanliness, appearance, and comfort.

(d) Finish of Fittings. There are several metal finishes for fittings on bathroom fixtures. Those most commonly used are nickel plate, chromium plate, and solid white metal.

Of these three, chromium plate is the most attractive and the most easily cleaned. It is very hard, resembles platinum, and merely requires a slight rubbing with a damp cloth to keep its luster spotless.

Nickel tarnishes and wears off under the constant rubbing necessary to keep it bright. White metal tarnishes, but does not lose its finish because the finish is not a plated one. In casting, however, it is very difficult to get a white metal free from minute pinholes which mar its appearance.

7. Outlet Sizes. The question of outlet sizes for various fixtures has long been a mooted one. From past experience and experiments it would seem that the following outlet sizes should be made standard:

Bathtubs	Full 2 inches
Water-closets	Full 3 inches
Lavatories	1½ inches

There has been a determined effort by the Federal Specifications Board to put through a standard specification for plumbing fixtures.[23] It had formerly been the practice of manufacturers to design special plumbing fixtures for a large operation and then to name the fixture after the job, as for example, the "Lincoln lavatory," the "Savoy water-closet," and so forth. These fixtures

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[23] For more detailed reference as to United States Government Specifications for plumbing fixtures, see F. S. B. No. 448.

would then be catalogued, further cluttering up a catalogue already full of superfluous material. This practice is gradually being abandoned by manufacturers, thanks to the efforts of the Federal Specifications Board.

8. Sanitary Features. As already stated, anything which causes a plumbing fixture to become a dirt catcher, or which is liable to cause a cross-connection between dirty water and the supply lines, is to be avoided. Below are listed the various sanitary features of bathroom fixtures, which should be sought, and the unsanitary features, which should be avoided:

(a) Water-closets

Sanitary or desirable	Unsanitary or undersirable
Large water area (minimum fouling surface);	Small water area (large fouling surface);
Large water way (less easily clogged);	Small water way (easily clogged);
Top supply if used with valve (no danger of contaminated water being syphoned back into water line);	Side supply if used with valve (danger of contaminated water being syphoned back into water line);
Height of 14 inches to 15 inches;	Porcelain.
Vitreous china.	

(b) Lavatories

Sanitary or desirable	Unsanitary or undesirable
Pop-up waste, or chain and plug;	Standing waste;
Separate metal spout;	Integral spout;
Combination supply fitting;	Separate hot and cold faucets;
Vitreous china or enameled iron;	Porcelain;
Chromium-plated trimmings.	Nickel-plated trimmings.

(c) Bathtubs

Sanitary or desirable	Unsanitary or undesirable
Over-rim spout supply;	Bell or top nozzle supply;
Chain and plug;	Standing or pop-up waste;
Flat bottom;	Rounded bottom;
Chromium-plated trimmings.	Nickel-plated trimmings.

(d) Showers

Sanitary or desirable	Unsanitary or undesirable
Pressure equalizing or thermostatic mixing valve;	Hand operated mixing valve or separate hot- and cold-water valves;
Chromium-plated metal.	Nickel-plated metal;
	Transfer valve.

9. Maintenance. The problem of maintenance of bathroom fixtures is considerably lightened by a selection of simple plumbing fixtures. Fixtures with rounded corners, no dirt pockets, and on which there are no inaccessible parts should be chosen. The materials of which they are constructed should be carefully considered, and only those of impervious, nonabsorbent materials should be used.

The problem of keeping the metal parts bright, with a minimum of effort is solved by selecting chromium plate as a finish for all metal fittings.

Plumbing fixture manufacturers have, in general, fixture-cleaning compounds for sale which greatly ease the task of keeping the bathroom looking well. These are intended for enameled-iron ware. No others should be used.

In general, the moderate-priced home may boast a bathroom which is a place of beauty as well as a model of cleanliness and practical utility. The home owner may even display his artistic feelings by the use of colored fixtures. They would cost approximately 50 per cent more than the ordinary white fixtures.

Where there is a little money and space left over, it is desirable to install an additional water-closet and lavatory on the first floor of the house. It will repay the additional cost by the added convenience it affords.

Section XIV. Kitchen Fixtures

1. Sink. The kitchen sink of today is a product of evolution. It is a far cry back to the days of the old sheet-metal sink, with its wooden frame and smelly, greasy drain boards, but from this humble beginning, the modern sanitary and attractive kitchen sink has developed.

In the latter part of the first decade of this century, fixture manufacturers brought out an enameled-iron sink made in two pieces. The sink itself comprised one part, the back the other. While this was a step in the right direction, it still left much to be desired. The joint between the two parts was an ideal depository of grease, moisture and dirt, and was extremely unsightly.

The next step forward was a "colonial" type sink which was cast all in one piece. This was a roll-rim sink, which, although undoubtedly more sanitary, was not a thing of beauty.

Finally, the modern apron sink was designed, with its drain boards, special double strainers, combination faucets, and all the refinements of which the housewife today has the use.

(*a*) *Materials: Advantages and Disadvantages.* The materials commonly used for kitchen sinks are:

1. **Enameled Iron.** The enameled-iron kitchen sink is probably the most largely used. It is the least costly, light in weight, as compared to sinks made of porcelain or china, and very durable. It has the disadvantage of being subject to damage by acids, such as are found in fruits and vegetables.

2. **Acid-resisting Enameled Iron.** As ordinary enamel loses its glaze when in contact with acid, fixture manufacturers have brought out an acid-resisting enamel. It is not affected by any acid except hydrofluoric, which, of course, will not be found in the average kitchen. It is a very hard enamel, and for this reason is especially well adapted to the hard knocks to which a kitchen sink is subject. It has no weak points and would seem to be the ideal finish for kitchen sinks. Its cost is about 25 per cent greater than ordinary enamel.

3. **Solid Porcelain.** Porcelain makes a very massive looking fixture but one which past experience has shown to be far from ideal. Porcelain is subject to crazing and developing fine hair cracks in the glaze, which gradually magnify until they are large enough so that moisture and grease find a way through to the porous material beneath. In time these cracks fill up with dirt and become smelly and unsightly. Porcelain is heavy and cumbersome, and costs about 8 to 10 per cent more than acid-resisting enamel.

4. **Vitreous China.** This material is used to some extent in the manufacture of kitchen sinks, but, for several reasons, it is not very practical. It is almost impossible to secure a perfect piece of vitreous china much larger than 24 by 30 inches because the material warps during the intense heat of firing. It would be very costly in sizes large enough to be practical for kitchen sinks, and though it is an ideal substance for any kind of plumbing fixtures, these factors would preclude its use to any great extent.

5. **Monel Metal and Stainless Steel.** Finally, kitchen sinks may be had of the rustless alloys, such as Monel and stainless steel of the chrome-nickel type, known as "18-8" or "KA2." They have the advantage over porcelain-enameled or solid porcelain sinks in that they cannot chip or craze. They will withstand the action of fruit or vegetable acids to the same reasonable degree as acid-resisting porcelain-enameled sinks.

These metal sinks, if made on large production scale and standardized as to sizes, integral backs and drain boards, and depths, could probably be produced at prices to compete for the individual home trade. The initial factory outlay of large sums of money for very expensive die, pressing, and automatic polishing equipment might then be warranted.

The committee recognizes the value of these metal sinks from the standpoint of quality, absence of chipping, reasonable resistance to damage by acid and fruit juices, design, and sanitation. From these standpoints they are an outstanding success. As to their relation to the home costing up to

$10,000 consideration must be given to the additional cost of the installation which the committee understands at present to be about $75.

(*b*) *Height of Sinks.* A report made by the "German Government Research Society for the Economical Conditions in the House Building Industry" in April, 1929, gives special consideration to question of height of sinks, with the recommendation that they be between 36 9/16 and 37 3/8 inches for work in standing. In this country, the greater number of sinks are now placed 36 inches high.

The report makes a plea for placing sinks so that work can be done sitting. Not only is less body strain (as when the work is done sitting comfortably) desirable for the average housewife, but it is especially important in the case of the aged, the pregnant, and the ill. Another reason is that the work time at the sink usually is at a period when sitting down is beneficial. There is considerable discussion of the adjustment of stools for the higher sinks, but the conclusion seems to be entirely in favor of the lower sink where the housewife can sit comfortably, and that the final figure should be based upon the average body size in different portions of the country, since it seems to vary.[24]

The subject gives much food for thought for the preservation of health of the American housewife.

(*c*) *Sink Sizes.* The kitchen sink of today may be had in a great variety of sizes, ranging from 16 inches square to 22 inches wide by 79 inches long, for enameled-iron sinks, and with approximately the same extremes for porcelain. The rustless alloy sinks may be had in practically any size, as they can be made up without the use of special moulds which cost anywhere from $500 up.

2. **Combination Sinks and Laundry Trays.** With the small house rapidly becoming popular, it has often been found necessary to combine the sink and laundry tray into one fixture. These fixtures may be had in lengths of 42 or 50 inches over all. Enameled iron or porcelain are the materials used, but enameled iron is by far the best for the reasons stated heretofore. As this fixture, besides being used for laundry work, is also used as a kitchen sink, it would be advisable to use acid-resisting enamel.

3. **The Laundry Trays.** The laundry tray may be had in

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[24] For this translated abstract of the report, the committee is obligated to Dr. Louise Stanley, Chief, Bureau of Home Economics, United States Department of Agriculture, Washington, D. C.

enameled iron, porcelain, alberene stone, and several other mineral compositions. Porcelain is objectionable owing to its tendency to craze. Alberene and the mineral composition laundry tubs are not especially good because they are composed of several pieces and the joints are grease and dirt catchers. Enameled iron is the best material of all and as it is not, in the laundry, liable to contact with vegetable or fruit acids, regular enamel has been found to be perfectly satisfactory. The average size laundry tray measures from 20 to 25 inches square per tub.

4. Drain Boards. The modern kitchen sink usually combines with the sink an integral drain board. These may be had on either the right or left hand side of the fixture, or on both sides. If there is only one drain board, it is most practical on the left side (as one faces the sink) as it makes it possible for the person using the sink to work from right to left.

There are, unfortunately, still in wide use, pantry sinks of sheet metal built into wooden dressers. The joints between the dresser and the sink and between the wall and the dresser form an ideal nesting and breeding place for croton-bugs and other vermin. The wooden drain boards become impregnated with greasy water and the whole thing becomes an eyesore after a few months' use. If this type of sink is to be used, it should be equipped with dressers and drain boards of the same material as the sink, with all joints welded or soldered into a moisture- and vermin-proof unit.

Drain boards of hexagonal tile backed up by wood are sometimes found in kitchens, but these are not desirable for the same reasons as those which make the wooden drain boards and dressers objectionable.

5. Rims. This feature of the kitchen fixture is one which shuld not be overlooked. The rim of the sink may be merely rolled over, leaving the rough under side of the sink exposed to view, or it may be carried down and form an apron around the sink hiding the rough part of the casting. This would seem to be the most satisfactory as well as the most sanitary method of treating the rim. A combination sink and laundry tray is manufactured with both types of rims, but here, too, the apron type is preferable. Laundry trays are made with only the roll-type rim, but as these are usually located in the basement, it is not of much importance to hide the rough parts of the fixture.

6. Outlet Sizes. Sinks and combination sink and laundry tubs should have outlets no less than 1½ inches and preferably 2 inches in diameter.

7. Costs. The comparative costs of kitchen and laundry fixtures when different materials are used in their manufacture have already been discussed, but in order to keep their relative costs clearly in mind, the following figures are given, based on regular enamel as the unit cost:

Regular enamel	1.000
Acid-resisting enamel	1.250
Alberene	.750
Porcelain	1.333
Vitreous china	1.750–2.000
Rustless alloy metals, etc.	2.500

8. Grease Traps. In small houses, it is usually unnecessary to resort to the use of grease traps. In restaurants, hotels, or homes with very large kitchens, it will be found that the greases and fats used in cooking will foul the traps and clog the waste lines. For this reason it is deemed advisable to insert a special trap into the waste line to remove grease and fat from the waste water. The accumulated grease may then be removed from time to time without breaking any of the connections.

9. Maintenance. The maintenance of kitchen fixtures is a point which should not be overlooked. With the recent advance in the use of materials which require little attention, it is possible to reduce maintenance problems to a minimum, if the purchaser will use enough discernment in his selections. It is recommended that an acid-resisting enamel be used in the kitchen whenever it is at all financially possible, and that regular enamel be used for the laundry tray. The use of chromium-plated fittings in both kitchen and laundry is also advised.

There is now on the market a double sink strainer which forms a basket-like receptacle, which will capture any particles of food or garbage thrown into the sink and prevent their going on into the trap. This strainer may be removed and the contents dumped out. It would seem advisable not to overlook this feature when contemplating the purchase of a sink.[25]

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[25] For United States Government requirements for kitchen sinks and laundry tubs, the reader is referred to pages 38, 39, 44, 45, and 46 of F. S. B. No. 448.

Section XV. Sanitary Principles and Their Application

1. Quick and Thorough Removal of Waste Water. Waste water, especially that which originates from the internal organs of man and that which contains the filth of his external ablutions, is charged with organic matter capable of rapid decomposition. Wherever decomposition of organic matter occurs, there will be myriads of bacteria multiplying with tremendous rapidity. The decomposition of organic matter is accompanied by the evolution of "stench." Wherever there is "stench" there is danger to health. Nature warns us against this danger by the feeling of nausea followed by vomiting. Nature would not give us this warning if there were no danger.

It, therefore, behooves man to dispose of his organic wastes in such a manner that they will not be harmful to himself nor to his neighbors. The quicker and more thorough this removal of human waste is accomplished, the safer will be the situation.

Modern plumbing provides the means for this removal by the materials and design of the plumbing fixtures as well as of the pipes used for carrying away the waste matters. Fixture material has been described. It is smooth, impervious, resistant to temperature changes and free from recesses or cracks in which waste water may lodge. Fixtures are so designed that they are self-cleansing as nearly as may be possible. They can be easily and completely cleaned, and they will thereafter leave no traces on or about them of decomposing wastes.

As to pipe materials and their design, they are made and designed with smooth surfaces and with tight joints. An important factor is that they shall be laid with sufficient grade to carry off the waste water without deposition of the solids.

Modern American life demands that the rate of discharge of the waste water from plumbing fixtures through the drainage system shall be as rapid as safety permits; the tendency, therefore, is for the plumbing fixture manufacturers to meet the public demand and increase the sizes of the waste outlets, and for the sanitary engineers to design plumbing drainage systems of larger sizes and with as great a fall as is obtainable in building construction.

Tests made by Dr. R. B. Hunter, Physicist for the Subcommittee on Plumbing of the Building Code Committee, Department of Commerce, at the Bureau of Standards, indicate, for instance, that a bathtub with a 1½-inch outlet, trap, and waste requires 1½ to 2 minutes to empty, whereas the same bathtub with a 2-inch outlet, trap, and waste requires only 1 to 1⅓ minutes to discharge.

The plumbing industry is wide-awake to this opportunity to serve the public, and is intensely interested in promoting it for the sake of convenience and health. It would be unfair to the American public to neglect to state that it has to pay for this convenience and this health factor through the installation of larger pipe lines.

2. Air Pressure in Soil, Waste, and Vent Lines. A variation in air pressure in soil, waste, and vent-pipe systems of over 2-inch water column deranges the proper working of the system; either the traps will lose their water seal into the drainage system, thereby allowing sewer air to enter the home, or they will lose their seal by repeated blowing if excess air pressure exists. This is equally bad. An equilibrium of air pressure in soil, waste, and vent lines must be maintained for a safe and satisfactorily operating plumbing drainage system.

3. Principle of Fixture Trap and Design. The waste pipe of every plumbing fixture in a building should be separately equipped with a device called a "trap." Some exceptions to this general rule are permissible, namely, where three laundry trays, or lavatories, or a set of two laundry trays and one sink are set close together, they may connect with a single trap, provided the trap is placed centrally and the branches connected into the trap seal at an angle of not more than 60 degrees to the vertical arm, and provided that the distance to any of the fixture outlets does not exceed 24 inches.

The ordinary plain fixture trap is a tube bent either in the P or S shape; the tube is of the same diameter as the waste pipe which it serves. This bent tube remains filled with waste water, and thereby excludes from the room the foul air of the plumbing drainage system. The P trap has its discharge outlet into the wall back of the fixture; the S trap has its discharge into the floor.

The seal of the trap—that is, the useful depth of its water column—should not be less than 2 inches nor more than 4 inches. The greater the depth of water column, the less likely the trap is to be self-cleaning. A trap should be self-cleaning, that is, it should not retain any solids that may be discharged from the fixture. Most of the traps used in large cities are traps with a 2-inch depth of seal.

It has been pointed out heretofore that the air pressures in a plumbing drainage system must be kept in equilibrium, and they can only be so maintained if the variation in air pressure does not exceed 2 inches in water column. No trap of the P or S type with 2-inch depth of water seal can withstand any greater variation. To protect it against such variation, the venting system is used. This is a separate system of air piping, having a branch connection to the sewer side of each trap, which either admits or emits air as may be needed to protect the water seal.

A great many attempts have been made by inventors to design traps which, without the venting system, would prevent trap siphonage. No such trap so far invented accomplishes this purpose in actual use. When they are clean they may be difficult to siphon (that is to make them lose their water seal), but when they are even only partially fouled, all of them can be siphoned without much effort.

The inventors of these so-called anti-siphon traps seem to lose sight also of two other very important factors which affect the seals of plumbing traps, namely, back pressure in the pipe line and corrosion of the pipe line by absence of air circulation. While they have built traps that have a tendency to resist siphonage, by making them hold large bodies of water, or by providing interior partitions or tortuous passageways in them, they have not built them so that they will withstand back pressure, and it is doubtful if this can be done without mechanically operated devices, such as check valves, flap valves, floating balls, or falling balls. Mechanical devices cannot, of course, be tolerated inside of plumbing waste pipes or traps since they are easily affected by grease, floating matter, pins, or the like.

4. Venting. Vent pipes in a plumbing drainage system are intended for two purposes: To maintain an equilibrium in the air pressure within the system, and to provide air circulation throughout the plumbing drainage system and thereby prevent corrosion of pipe lines by gases emanating from decomposing materials, such as slime which clings to the inside bottom of horizontal waste lines.

Pages upon pages on experimental work and the theories, sizes, and air-carrying capacities have been written on this subject. Of particular importance is the work done by the Subcommittee on Plumbing of the Building Code Committee of the United States

Department of Commerce, published in its report.[26] This book gives tables, illustrations, diagrams, and sizes of vent pipes and venting systems recognized for almost all needs, and is highly recommended. Any one interested in this phase of plumbing can obtain more value for 35 cents from this government publication, than from any other book known to the committee. It is being revised so that it will continue to be the outstanding report on the art of plumbing.

5. Dead Ends. Dead ends in drainage systems are waste and soil pipes in which there is no air circulation, except possibly that produced by the discharge of the fixture connected to the dead end. Dead ends of pipes are usually considered those unvented pieces of soil or waste pipes which exceed 7 feet in length, it having been determined by tests that no air circulation is induced in such lines if they exceed 7 feet in length.

The danger of dead ends is due to pipe corrosion, which may exist for many years without being noticed by pipe leakage. A horizontal sink waste pipe may continue to carry off the wastes from a sink because it is sound on the bottom, but it may be corroded through on the top and from the holes will issue sewer air unnoticed perhaps for years, especially if such pipe is concealed under sink closets. Air circulation prevents pipe corrosion in dead ends. Dead ends should never be tolerated and should be removed or connected at their upper ends to the venting system by proper vent lines.

6. Air Circulation in Drainage and Venting Systems. References have been made to the necessity of air circulation in drainage systems. Where venting systems are cross-connected to drainage systems on each floor and at each fixture on each floor, air circulation by natural means will occur throughout the drainage and venting systems as a result of temperature differences between the outside and inside air, and of fixture discharges.

Air circulation is as important to the plumbing drainage and venting system as it is to the human body, which could not exist without proper air circulation within and without.

Air circulation is important in plumbing work because the air oxidizes organic matters, destroys their anaerobic bacteria which decompose them, retards corrosion of the pipe lines, prevents trap

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[26] *Recommended Minimum Requirements for Plumbing*, Washington, Government Printing Office, 1929, price 35 cents.

siphonage and back pressure, and thereby protects the home against the invasion of foul stench, gases of decomposition of organic matter, and communication of vermin between the inside of the plumbing drains and the pantry or kitchen.

Section XVI. Drainage Piping

1. Sanitary and Combined Drainage Systems. A house drain should be large enough to carry off the greatest probable amount of water or sewage that will discharge into it, but also small enough to be self-cleaning. It should never be smaller than the largest fixture outlet discharging into it. The size of the house drain is determined by the amount of water or sewage it must conduct.

In drainage systems that receive the rain water from roofs, yards and areas, the amount of impervious surface to be drained and the rate of precipitation generally determine the size of the pipe.

2. Materials for Drainage Systems. When buried in the earth, house drains should be constructed of extra heavy cast-iron soil pipe. When located in ducts or chases, or suspended above floors, or from ceilings, they may be of galvanized wrought iron, galvanized mild steel, copper-bearing steel, or extra heavy cast iron. Fittings used on galvanized wrought iron and steel should be galvanized cast iron and recessed drainage fittings. The usual materials for the venting system are galvanized copper-bearing steel, mild steel and wrought iron.

3. Sizes of Individual-fixture Wastes.

Water-closets	3 inches
Bathtubs	1½ inches (but the trend of modern practice is to a 2-inch waste)
Lavatories	1½ inches
Kitchen sinks	2 inches
Slop sinks	3 inches
Laundry trays	2 inches
Showers	2 inches (but the trend of modern practice is to a 3-inch waste)

4. Sizes of Group-fixture Wastes.

1 water-closet	3 inches
1 bathtub	
1 lavatory	
1 kitchen sink	
1 set laundry trays	2 inches

5. Sizes of Soil and Waste Stacks. In small dwellings[27] where only one or two bathrooms are to be installed on a soil stack, a 3-inch soil pipe will be ample. For the waste stack a pipe no larger than the size of the fixture branch will serve the purpose.

6. Sizes of Inside and Outside Rain-water Leaders. Inside leaders are located within some part of the building secure from frost, and are installed by the plumber. They should be installed with pipe of material as given above for the drainage system. Outside leaders are usually made of sheet metal, with loose slip joints, and from a point about 2 feet or 3 feet above grade are installed by the sheet metal worker. Up to a point a few feet above grade, outside leaders should be of cast-iron pipe to withstand the rough usage they are likely to receive. Leaders should be trapped within the building if connected to the sanitary house drain. Leaders should be sized[28] to take care of the maximum rate of rainfall for their particular locality.

7. Slopes of Pipes. Soil, waste and leader lines, should be given a minimum slope of ⅛ inch per foot. Where possible, they should have a ¼ inch per foot fall. Vent pipes should be given a slope of about 1 inch in 10 feet, toward the trap which they vent.

8. Clean-outs. Clean-outs should be made easily accessible. They should be installed at the base of every soil or waste stack, at every change of direction and at every 50 feet on horizontal lines. Every trap should be provided with at least one clean-out.

9. Maintenance Problems. The reader is referred to the report of the Subcommittee on Plumbing of the Building Code Committee of the United States Department of Commerce.[29]

Section XVII. Costs of Plumbing Work

Plumbing plans and specifications were prepared by this committee for three types of homes and sent to ten responsible plumbing contractors for bids. Four estimates were received at the time this report was written. One came from a St. Louis, Missouri, firm; one from a Buffalo, New York, contractor; one from

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[27] For larger sized buildings, and for sizes of vent stacks in dwellings, the reader is referred to the report *Recommended Minimum Requirements for Plumbing,* previously cited.

[28] *Ibid.*

[29] *Ibid.*

an Atlanta, Georgia, firm; and the fourth from a Cincinnati, Ohio, firm.

The architectural plans were prepared by the Architects' Small House Service Bureau, and are known as Plan No. 3A-11-331, Plan No. 5A-52, and Plan No. 6A-64.

The following are the bids that were received:

Table 1. Bids for Plumbing for Small Houses

(Based on specifications drawn by this committee on three houses * planned by the Architects' Small House Service Bureau)

Bidder's location	Base price as per plans and specifications	Add for wrought iron	Add for yellow brass	Add for red brass	Add for copper	Add for two-valve shower	Add for Power's mixing valve
House 3A-11-331:							
St. Louis, Mo.	$1,175	$30.00	$55.00	$63.00	$65.00	$40.00	$75.00
Buffalo, N. Y.	678	15.00	32.50	37.25	43.50	43.00	75.00
Atlanta, Ga.	935	50.00	80.00	95.00	55.00	20.00	53.00
Cincinnati, Ohio	832	14.63	41.93	46.85	36.81	25.35	78.00
House 5A-52:							
St. Louis, Mo.	$1,145	$26.00	$50.00	$56.00	$58.00	$40.00	$75.00
Buffalo, N. Y.	695	24.00	49.00	58.00	67.00	43.00	75.00
Atlanta, Ga.	950	40.00	80.00	90.00	60.00	20.00	53.00
Cincinnati, Ohio	786	17.65	50.41	51.36	40.45	25.35	78.00
House 6A-64:							
St. Louis, Mo.	$1,130	$26.00	$50.00	$56.00	$58.00	$40.00	$75.00
Buffalo, N. Y.	712	24.00	49.00	58.00	67.00	43.00	75.00
Atlanta, Ga.	1,050	48.00	90.00	70.00	65.00	20.00	53.00
Cincinnati, Ohio	796	23.25	48.50	54.00	41.00	25.35	78.00

* The cost of these houses is estimated by Mr. Robert T. Jones, Architect, of the Architects' Small House Service Bureau, as follows: House 3A-11-331—$3,500; house 5A-52—$6,000; house 6A-64—$8,500.

The average of the four bids received for the plumbing work on the cash price was, respectively, $905, $894, and $922.

Section XVIII. Sewage Disposal [30]

1. Public Sewer Connection to Sanitary or Combined Sewer. Some municipalities have combined sewerage systems in which both storm water and sewage are carried. Others have

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[30] A very complete and carefully compiled booklet on the subject was published in Albany, New York, in 1928 by Mr. Henry Ryon, former Senior Assistant Sanitary Engineer to the New York State Department of Health. In it may be found complete tables for figuring capacities, rates of flow, and other valuable information. It is highly recommended to the house owner who has to build a sewage disposal plant.

separate systems for each. The connection between these municipal sewers and the house is known as the house sewer. It should be of extra heavy cast-iron soil pipe with caulked lead joints and, although vitrified pipe may be used, it is not so desirable because tree roots may find their way into the joints. The house sewer should be laid with a fall of ¼ inch per foot. If cast-iron pipe is to be used, the average home will require a house sewer[31] of 4 inches; if vitrified pipe is used a 6-inch house sewer is required. It may then be seen that the difference in price will not be appreciable, and cast-iron pipe is more desirable.

The home owner should confer with the sewer department, giving them the elevations of the lowest fixtures in the house. The sewer department can then, by checking up the elevation of the public sewer, determine whether there will be sufficient fall to permit fixtures at the desired elevation. They can also advise the home owner whether a back water valve or sewage ejector will be necessary.

2. Storm Water. Wherever either combined or storm-water sewers are accessible, rain water should be collected and discharged into them.[32] If not, leaders should discharge into vitrified tile pipe, with cemented joints, and carried under the sidewalk into the gutter.

3. Sewage Disposal by Septic Tanks, Cesspools, Subsurface Irrigation, and Sand Filters. Where it is necessary for the property owner to construct his own sewage disposal plant, he must be very careful to select the right means of disposing of his sewage.

He should first of all consider what natural means he has at hand to aid him in this problem. He should have a test of the soil made to determine its absorption qualities. A hole should be dug about 1 foot square and 2 feet deep. This hole should be filled with water to a depth of 6 or 8 inches. Care should be taken to moisten the soil thoroughly before making any tests. The time that it takes the water to drop 1 inch should be accurately recorded. Several such tests should be made and their average

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[31] For sizes for house sewers see *Recommended Minimum Requirements for Plumbing,* previously cited.

[32] For pipe sizes the reader is referred to *Recommended Minimum Requirements for Plumbing,* previously cited.

taken. It will be shown later how this will be of service in calculating the size of the sewage disposal plant.

The first step in the satisfactory disposal of sewage is the removal of solids. This is done by means of a settling or septic tank.

(*a*) *Septic Tanks.* While the septic tank removes about 60 per cent of the solids contained in domestic sewage, the gases generated by the anaerobic bacteria by the decomposition of the sludge at the bottom of the tank carry minute particles of this putrescible material into the sewage stream, which is passing through and from the septic tank. This effluent is still highly contaminated and should, therefore, under no circumstances, be allowed to flow onto the ground or into open ditches, streams, or lakes without further treatment, as hereinafter described under the headings of "Cesspools," page 238, and "Subsurface Irrigation," page 238, and "Sand Filters," page 239. The septic tank should never be used as the sole step in purification of sewage. When the septic tank is in use all the year round, it should be cleaned out at least twice a year. Where only in use during the summer months, cleaning once a year is necessary. In connection with septic tanks for homes, real estate developments, and the like, it is advisable to collect the effluent from the tank in a dosing tank. Here, by means of an automatic siphon, the sewage fields receive "doses" of effluent in sufficient quantities so that there is a good distribution over the whole field, as would not be the case if only a small, constant flow were coming from the septic tank.

The septic tank (as well as the dosing tank) is usually constructed of concrete, although almost any form of impervious masonry construction will be found to be satisfactory for small units.

The tank should be at least 5 feet deep and about two or three times as long as it is wide. It should be large enough to allow the sewage to remain in it about 24 hours. This length of time is required for the anaerobic bacteria to function properly. One hundred gallons per person per day may be considered as the basis for figuring the capacity of the settling tank. The inlet line to the tank should enter and then terminate in a tee having the run of the tee in a vertical position. The lower outlet of the tee fitting should be extended, if necessary, so that its end will come about

12 inches below the surface of the sewage. This will avoid disturbance of the scum which forms on the surface of the sewage. The upper outlet of the tee should be carried up through the roof of the tank as a clean-out. As the sewage is being decomposed by the bacteria, the solids will settle to the bottom.

It is wise to have the bottom slope sharply toward the inlet end, so that the solids, in settling, will collect near this point. They may then be washed down and into a sludge disposal bed, without the necessity of bailing out the tank.

The pipe outlet of the tank should be an elbow, facing down and extended so that the lower end comes about 18 inches below the surface of the sewage. No floating solids can then overflow into the discharge line and clog the siphon in the dosing tank or the tiles in the disposal fields.

(*b*) *Cesspools.* The cesspool is intended to act as an absorption area for the effluent from the septic tank. It will be found to be satisfactory where the surrounding soil is sandy or porous and where the underground water table is not so high as to interfere with the action of the cesspool.

The cesspool is generally constructed of ordinary field-stone without bonding mortar of any sort. The sandy or porous soil forms the bottom of the cesspool. The top is formed by laying the upper tiers in mortar, converging to form a manhole of sufficient size for a man to enter and perform a periodic cleaning. The area of the floor and the working area of the walls should average approximately 15 square feet per person where there is a good absorption soil, which should increase as the absorptive properties of the soil decrease. The cesspool must be cleaned often enough to prevent clogging by the solid materials deposited in it. The septic tank will prolong the useful life of a cesspool manifold.

(*c*) *Subsurface Irrigation.* This is a very satisfactory way of disposing of the effluent from the septic tank without any resultant nuisance from odor or unsightliness. There are several variations in the construction of a subsurface irrigation system.

In the simplest form of subsurface irrigation, the subsurface soil is absorptive and makes a natural filter. In this case, the sewerage tile is laid in trenches, 12 inches wide by 18 inches deep spaced about 3 feet to 4 feet apart. About 2 inches of gravel should be laid in the bottom of the trench, on top of this the tile, and gravel should then be placed on both sides of the tile for the width of the trench and 3 inches above the tile. No underground drainage is necessary below the sewage tiles, as the entire subsoil surrounding these distributing lines acts as a filter and allows the water to seep away. Several inches of loam is spread over the entire field and seeded.

When conditions are not so ideal as in the first case, it may become necessary to elaborate on the simple subsurface irrigation scheme as outlined above.

Trenches about 4 feet deep are dug about 20 inches wide and spaced 10 to 12 feet apart. At the bottom of these trenches are laid collection tiles 4 inches to 6 inches in diameter (or horseshoe tiles on terra-cotta blocks), embedded in gravel. On top of this is laid a 2-foot to 2½-foot layer of medium sand, which is the actual filtering agent. At right angles to these trenches are laid the distributing tiles. These should be 4-inch to 6-inch unglazed tiles (or horseshoe tile on terra-cotta blocks). They are embedded in gravel to prevent clogging due to earth washing in and filling up the joints. They should be spaced from 3 feet to 4 feet apart. Where they cross the collection trenches, they should be supported by 2-inch planks, lest they get out of alignment as the sand in the collection trenches settles. Loam is then spread over the entire field and sown with grass.

A more satisfactory, but more costly, subsurface irrigation system is constructed in the following manner: A suitable area is excavated to a depth of 4 feet and collection tiles are laid diagonally to the direction of the distributing tiles. The collection tiles should be embedded in from 6 inches to 8 inches of graduated gravel. The excavation is then backfilled to a depth of 2 feet with medium sand. Above this are laid the distributing tiles, also embedded in graduated gravel. On top of all this a layer of loam or topsoil is spread, and the whole area is then seeded. Where graduated gravel underlies the sand, the coarser gravel should be on the bottom, the finer at the top, to prevent the sand from getting into the coarser gravel below; where it overlies the sand, the graduation should be the reverse.

(*d*) *Sand Filters.* Finally there is the open sand filter which is used where entirely unfavorable conditions of soil exist. It is constructed as follows:

The soil is excavated to a depth of about 4 feet forming a level floor, and collecting tiles are laid, embedded in gravel, in the same way as previously described for subsurface irrigation systems. On top of this is laid a stratum of sand 2½ feet deep, medium coarse, and uniform in texture. There are no distribution tiles, but the "dose" from the dosing tank is allowed to flow onto the filter bed, covering it to a depth of 2 to 3 inches. Care should be taken not to allow the "dose" to flow onto the field with such force that it furrows and washes away the sand of the bed. It has been found expedient to allow the "dose" to flow into slotted rectangular wooden gutters, which check the velocity of the flow and allow the effluent to flow gradually onto the sewage field. An open sand filter bed should provide ½ to 1 square foot of filtering area for each gallon of sewage; the number of gallons of sewage should be based on 100 gallons per person per day.

Cesspools, subsurface sewage disposal fields, and open sand filters should be laid out in two units with a diverting gate, so that the sewage flow may be diverted daily from one unit to the other and so that one unit may rest while the other is in operation.

(*e*) *Considerations Governing Choice of Field.* When selecting a site for a sewage disposal plant the following studies should be made:

1. Character of soil. This will govern the type and size of disposal fields to be used.
2. Slope of ground. It is always desirable to be able to allow the sewage to flow by gravity through the various stages of purification. Without a good, natural slope this may be done but at a greatly increased cost, due to a larger amount of excavation or pumping.
3. A site should be selected, particularly if an open sand filter is to be used, which will be out of the way or sufficiently screened so that it will not become a nuisance and an eyesore.
4. A site should be selected which will be below and as far as possible from wells or springs from which water for human consumption is obtained.
5. The area for the subsurface irrigation fields or the sand filter should be as level as is possible to obtain.
6. There should be some method of disposing of the final sand-filtered effluent of the underdrained irrigation fields or the open sand filters, without reaching a potable water supply source.

(*f*) *Relative Cost.* The cheapest practical system of sewage disposal is a settling tank discharging to two cesspools. Next in economy to this is a settling tank in conjunction with a subsurface irrigation system in which filtration is achieved by passage through the subsoil which is of sufficient porosity. A subsurface system embodying the use of trenches filled with sand comes next in the order of cost. Then comes the open sand filter bed. Finally there is the subsurface irrigation field consisting of an entire field backfilled with sand with both collection and distribution tile lines. This is seeded over and gives no hint to the casual observer of the processes going on beneath.

(*g*) *Relative Effectiveness.* Where the subsurface soil is porous and absorptive, either cesspool or the natural subsurface irrigation field is effective. Where the soil is impervious and nonabsorptive, only the artificial subsurface irrigation bed or the open sand filter is effective.

(*h*) *Maintenance Problems.* From the very nature of the work, which any sewage disposal system performs, it is obvious that the maintenance is deserving of close attention.

The septic tank must be cleaned out at least twice a year if it is in operation throughout the year. Once annually is sufficient if used only during the summer months. If this is not done, solids will begin to pass into the sewage fields and serious clogging will result.

Cesspools must be periodically cleaned, as they are quite prone to stopping up and clogging.

Subsurface irrigation fields are used mainly in connection with small developments, and do not require very frequent cleaning. When they do, however, the only method is to dig up the fields and tiles, clean the latter and replace them.

With an open sand filter bed, cleaning also is necessary. The process of cleaning consists of removing only the top inch or two of the sand with a hoe or spade, when the sewage refuses to percolate. This can be repeated until the depth of sand is no more than 18 inches. When this point is reached more sand must be laid on the bed. The frequency with which the necessity of cleaning occurs depends on three factors, namely, the frequency of cleaning the septic tank, the coarseness of the sand, and the rate of filtration.

In our northern climate sand filters have to be trenched so that the sewage will flow in the trenches underneath the ice or snow crust.

(*i*) *Sludge Disposal.* Every septic tank must be cleaned periodically as heretofore stated.

If possible, it should be drained through an 8-inch valved pipe from its bottom to a "sludge bed"; otherwise, the sludge has to be bailed out by pailfuls, which is an unpleasant and sickening task.

When sludge has to be disposed of, plenty of chlorine water should be used, made as previously described.

When bailed out, it should be chlorinated and buried in trenches located so that their drainage cannot reach sources of potable water supplies.

When drained by gravity flow, a pit should be provided, large enough to hold the entire septic tank contents. When filled, chlorine water should be freely applied, and the pit filled with earth. Sludge contains about 95 per cent water. If the soil is at all porous, the sludge liquor will soak away. The solids will be disposed of by worms. The pit may be opened and reused after about 6 months.

Care should be exercised to locate the pit so that it cannot pollute wells, springs, or streams.

(*j*) *Principles of Operation.* The principles of operation of a modern and safe sewage disposal plant consist of the following:

1. No sewage disposal plant must be overloaded.
2. Grease must be kept out of the sewage disposal plant, if possible; separate grease traps should be provided.
3. The sedimentation period in the septic tank must be of sufficient length so that all settleable solids will settle.
4. The septic tank must be cleaned sufficiently often so that there will be no gas bubbles rising from the sludge which will carry with them solid particles that are carried along with the sewage into the dosing tank.
5. Septic tanks should be so designed that there will not be a narrow path of sewage flowing from inlet to outlet.
6. While settling tanks should have sufficient satisfactory means of access, light and air should be excluded from them.
7. Anaerobic bacteria, which cause decomposition of sewage, are present in sewage; they need not be artificially introduced into septic tanks.
8. No domestic sewage disposal plants should be constructed without preliminary sedimentation in septic (or settling) tanks.
9. The effluent from septic tanks, being still highly infected, should not be discharged on the ground nor into open trenches.
10. Means of disposal of the effluent from settling tanks should always be provided in duplicate.
11. Since treatment applied to septic tank effluents is dependent upon oxygen, oxygen should be admitted by natural means to any plants which dispose of septic tank effluents.
12. The reason for building in duplicate those portions of sewage disposal plants which receive and treat septic tank effluents, is that one-half of such portions should be at rest while the other half is receiving sewage. Only in this way can air be admitted artificially without expensive machinery, to those portions of the plant which require oxygen.
13. Means will have to be provided to alternate from one half to the other.
14. Nature's way of introducing air into the pores of the soil is the replacement by air of the voids left in the earth by the disappearing sewage.

4. Dangers of Pollution. Pollution of waters used for human consumption can result in the most widespread epidemics of typhoid, cholera, dysentery, and other water-borne diseases.

Bathing beaches, where the surrounding waters are polluted, are often sources of disease. Pollution of shellfish beds is another cause of epidemics.

Every citizen has a duty to perform in preventing pollution of this sort. He can see to it that he himself is not guilty of this offense by observing the principles of correct sewage disposal already mentioned, and by notifying the proper state, county, or municipal authorities of any violations by others, resulting in the pollution of such waters.

5. State Department of Health Regulations. State Departments of Health of the various states publish rules and regulations for the design of sewerage systems and sewage disposal plants. In them are usually described the minimum sanitary requirements for such systems, which will meet with the department's approval.

The following Federal boards and departments also publish literature covering this subject:

(a) The Board of Excreta Disposal of the United States Public Health Service.
(b) The United States Public Health Service.
(c) The United States Department of Agriculture.

Section XIX. Fire Protection

1. Outside Fire Hydrants. Outside fire hydrants should be placed about 50 feet from the building. They are of no particular service unless the water pressure is sufficient to throw an effective fire stream over the roof of the building, or unless they are within easy reach of the municipal fire department which can connect its pumper to the hydrant, sucking the water through it from the street main, boosting the pressure in the pump and connecting the fire hose to the pump delivery pipe. One outside fire hydrant with two nozzles should have a pipe connection of not less than 6 inches; two fire hydrants, not less than 8 inches; the pressure should be not less than 30 pounds. These fire hydrants should be provided with separate valves and should be self-draining.

2. Sprinklers. Since fires frequently have their origin in the cellar or in the kitchen of a home, the committee suggests that automatic sprinklers, with fusible link or plug, be placed in the furnace room, and the storeroom, if any, and in the cellar; and one or more might be placed in the kitchen. These sprinklers should be connected to the main water supply line which, together with the service line, should be not less than 1 inch to provide sufficient water supply for the sprinkler.

While it is conceded that no credit for this fire protection will be given by reduction of insurance premiums, the committee is of the opinion that much property, and perhaps life, may be saved by these simple precautionary measures.

3. **Inside Fire Hose.** If possible, and if the budget will permit it, it is suggested that a reel on which 50 feet of ¾-inch garden hose are maintained, with a garden hose nozzle at the end, might be provided near the cellar or kitchen entrance off the back hall, if any, or at some other convenient place and permanently connected to the main water supply line in the house; this hose could be used in a further effort to fight fire. Such equipment would be relatively useless unless every member of the household has had experience in handling it.

4. **Fire Extinguishers.** Fire extinguishers are so perfected today and are in such common use that everyone should be acquainted with them and with the method of using them. One fire extinguisher placed where conveniently accessible on each floor will frequently prevent the complete destruction of a house by fire, if used when the fire is in its incipient stages. These extinguishers are portable, easily handled, and will work wonders. All types are not of equal value; some are suitable only for certain kinds of fires.[33] Dependable types are labeled by Underwriters Laboratories, Inc.

Section XX. Gas Supply

1. **Gas Service.** The main gas supply in the modern home should be of sufficient size to provide not only gas for the kitchen range and gas water heater, but also for a possible eventual heating of the home by gas. The gas companies are making strenuous efforts to compete in this field against coal, fuel oil, and electricity.

2. **Pipe Sizes.** In the average home, the gas service pipe

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[33] For further particulars see *First Aid Fire Appliances,* Boston, National Fire Protection Association.

should be not less than 1¼ inches; the branch to a four-burner gas range not less than ¾ inch; to a six-burner gas range 1¼ inches and to the gas water heater from ½ inch to 1 inch, depending on the size of the heater.

If gas heating of the house is intended, the service pipe for low-pressure gas should be not less than 2½ inches.

Gas pipes in buildings should be of black steel; their fittings should be of galvanized malleable iron. The pipes should be painted with asphalt before installation to prevent corrosion.

All gas pipes should be dripped to remove condensation; the pipes should slope downward to the drips. No unions or bushings should be used on gas piping; the reductions from one size to another should be made by reducing fittings.

The entire gas piping system should be tested under air pressure of 12 inches of mercury, and should show no leaks whatever under this pressure.

3. Canned Gas. In many sections of the country, compressed or liquefied gas is now furnished in cylinders. Two cylinders usually are supplied with each installation, one being a reserve, while the other is in use. The gas in the cylinders is under moderate pressure. A pressure-reducing device is furnished by the manufacturers to reduce this pressure to that required at the gas range and other appliances. Cylinders and the pressure-reducing valve and controls are placed in a steel cabinet in which is also contained a mercury seal, which is a safety valve automatically preventing the building up of high gas pressure inside of the house. One of the best known gas appliances is listed as "Standard" by the Underwriters Laboratories and does not increase the insurance rate.[34] The regulations of the National Fire Protection Association regarding installation of gas piping and appliances are a valuable source of reference.

4. Gas Machines. Gas machines, which manufacture gas from gasoline, are widely used sources of a private gas supply. There are a number of large responsible corporations which make these machines.

The machines have an air pump or meter, which is usually

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[34] For further information on canned gas see *Letter Circular No. 292*, U. S. Bureau of Standards.

placed in the cellar of the building and operated by a suspended weight, or water wheel if preferred. It is partly filled with water, the balance of its contents being air. It can be placed next to a furnace. No gas ever enters this part of the machine. It produces a constant pressure to generate the gas and to send it back to the pipes. The machine operated by a suspended weight requires no more effort than is necessary to wind an ordinary clock. The water wheel operates automatically by water, using water only in proportion to the quantity of gas consumed.

The other part of the gas machine is a gas generator, which is buried in the ground, about 30 feet from the building, and which contains all the gasoline. The generator requires no vault of any kind. Inside of the generator is the carburetor which floats on top of the gasoline. The carburetor mixes the air with the gasoline vapor and thus makes the gas.

Over the generator, the mixer is buried in the ground. Its function is to take the gasoline vapor from the generator and thoroughly mix or "equalize" it with a given quantity of air, thus insuring that all gas drawn from it for consumption at the burners will be smokeless, uniform, and of standard quality. The mixer requires no attention.

Gas machines are made in standard sizes from 15 to 1,000 light capacity. Generators are made to hold from 3 to 50 barrels of gasoline.

Gas machines built by responsible manufacturers do not increase insurance rates if they are properly installed, and they have the approval of the National Board of Fire Underwriters.

5. Pressure Control. Some of the progressive gas companies, especially those who have to pipe gas for long distances, carry gas in their pipe lines under pressures up to 25 or 50 pounds. Gas cannot be used in the house under such pressure. The public service corporations furnishing the gas usually provide a pressure-regulating valve to be placed on the gas main as it enters the building.

There should be a separate gas control shut-off valve on the main gas line just inside of the building on the street side of the pressure-reducing valve and one on the house side of the valve, so that the valve can be taken out for repairs or replaced with a new one. Stop-cock controls should be provided at every fixture, including lighting, heating, and cooking appliances.

Section XXI. Garage Plumbing

The garage for the average small home is not usually provided with a floor drain or a sink. If a floor drain is installed, there is usually also a plain, small galvanized sink.

A floor drain connected to the city sewer or to a private sewage disposal plant should have its 3-inch waste outlet connected to the sewer through an oil separator, which is a cast-iron pot provided with baffles or other device permitting the oil and gasoline to rise to the top, where it accumulates and can be skimmed or pumped off.

If vitrified sewer-drain lines are used from a garage floor drain, they should not have their joints made with bituminous compounds, which are soluble in gasoline or oil. Such joints should be of Portland cement.

The water supply line to a garage should be capable of being completely drained.

CHAPTER V

ELECTRIC WIRING AND LIGHTING[1]

The most outstanding convenience- and comfort-producing features which make for true modernity in the home of today are provided through pipe and wire. Both of these items were practically unknown in the house of but a few generations ago. In fact, if these two items were entirely removed from the most modern of houses, only a single day of occupancy of such a house would conclusively convince us that we had lost a large part of the modern comforts and conveniences to which we are so thoroughly accustomed. The house without electric wiring and without gas, water and heating pipes would indeed be a dismal failure, and its shortcomings would need no mention when placed upon the real estate market, for every prospective buyer would turn away from it almost automatically.

Inasmuch as both wire for electricity and pipe for supplying water, gas, heat, etc., came into more general use at about the same time, one might assume that the same degree of completeness of these two classes of service would be found in homes at the present time. As for the pipe service, it is probably safe to say that we have gone beyond installing bathrooms, kitchens, heating systems, etc., which are just passable, but unfortunately this cannot be said for the wiring installations, electrical equipment and lighting equipment in general usage.

Most people are fascinated by the wonders of electricity and the accomplishments performed by it, and from the increasingly important role it is playing in our civilization, it would be natural to assume that every new home would not only contain a wiring and lighting installation that was more satisfactory than that which is just passable, but would also, in so far as reasonably possible, anticipate the future.

This lack of appreciation of the well-lighted home and of the value of electrical labor-saving devices cannot be placed entirely upon cost. Obviously anything appears to be expensive for which we lack a "measuring stick" for determining its value. The cost

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[1] This chapter was drafted for the committee by the following: Messrs. M. Luckiesh, R. T. Jones, M. L. Nichols, and R. A. Palmer, members of the committee, and E. W. Commery, adviser to the committee.

of daylight indoors in our homes has never concerned us, because we most naturally think it is free. Contrary to the general belief that daylight indoors is obtained at no cost, the daylighting in a good many houses costs as much as the artificial lighting when it is quite adequately provided. An analysis of the added costs of building due to windows instead of unbroken walls, both interior and exterior, added costs for additional heating plant and fuel consumed to compensate for the heat loss through window openings, costs for cleaning the windows, and greater depreciation of many materials in the house due to added infiltration of outside dirt, definitely proves that the daylight in our homes is not free. When this kind of reasoning is applied to the reasonableness of the cost of electric lighting, there is little room for the feeling that an abundance of light in the home is expensive. Good electric lighting does more than provide light to proceed from place to place at night; it can extend our day for almost anything we may wish to do, for now it is completely controllable as to direction, quantity, harshness or softness, and color. It can conserve our eyesight and it can add charm and beauty. Furthermore, lighting can create somberness, and gayness, and, accordingly, restful or stimulating interiors. No other medium possesses these attributes to the same degree and also under such direct control. Paint, textiles and furniture all play a part in creating a given room, but they need not be altered or moved when we call upon light to make the sweeping change.

In turning our thoughts to the conserving of our vision and particularly to the vision of children, we find we must attach even greater importance to the lighting of our homes. When 23 per cent of the people under twenty years of age have defective vision; when 39 per cent of the people under thirty years of age have defective vision; when 48 per cent of the people under forty years of age, and when 82 per cent of the people under sixty years of age have defective vision, we must turn to better lighting for help. Seeing is, after all, a partnership of light and vision, and every step ahead in the progress of mankind has imposed new and added burdens upon this partnership. It is only in relatively recent years that practically all individuals began to use their eyes for serious visual tasks indoors. Almost everyone in this country can read, so that practically everyone, from school children to grandparents, uses his eyes under indoor lighting for some portion of the day or night. Two great factors responsible for defective eyesight arose from the artificial indoor world. Eyes which were adapted to the very high intensities of illumination outdoors were obliged to work at severe tasks under greatly restricted daylight indoors, for only a small percentage of daylight is admitted to most interiors. This combination of greatly restricted lighting and greatly increased severity of visual tasks alone can account for much of the defectiveness of vision which is so prevalent.

Until recently artificial light-sources were very feeble, so that they did little more than emphasize the darkness after daylight had waned. Furthermore, the providing of anything like adequate amounts of artificial light indoors was expensive. Today, artificial light-sources are powerful and the cost of light has diminished to but a fraction of what it was in the past. Only forty-five years ago light from incandescent-filament electric lamps cost eighteen times as much as it costs today.

While the cost of electric lighting in its infancy may account, in part, for the indifference and abuse to which we have subjected our eyes in the past, it does not account for the continuance of this indifference or lack of consciousness of lighting and vision. Few people, even today, distinguish between mere light and adequate light. They are even further from recognizing the refinements of proper lighting, as distinguished from the crudity of improper lighting. In the school, office and factory, there has been an awakening to the importance of proper lighting and the conservation of vision, but proper lighting and the conservation of vision have scarcely caught the attention of the homemaker. A great improvement can be made merely by increasing the amount of light used, by placing the lighting equipment in proper positions with respect to the work areas and by eliminating unshaded lamps, for they are the chief causes of glare. Additional refinements for the improvement of seeing are omitted, for space does not permit the presentation of the necessary details. Proper consideration to the placing of wiring outlets, sufficient electrical capacity for supplying the necessary amounts of light, and a true appreciation of the services which the proper lighting equipment will perform, precede these refinements in making the first steps toward the possibilities of modern artificial light in the home.

Charm, beauty, convenience, comfort, and conservation of vision are all obtainable with properly planned lighting. It also can play its part in providing safety. Stairways unlighted or poorly lighted are potential sources of hazard, particularly where older people with dimmed eyesight and uncertain steps are involved. Stairways are probably the cause of more painful and even serious injuries than any other one source of injury in the home. The well-lighted stairway is a very different thing to traverse from the dimly or improperly lighted stairway. Personal safety is also enhanced with lighting placed at the entrances to the house and on the exterior of the garage, for the thief or night prowler is soon discouraged if he has to face light on the exterior of the house, and particularly at the rear of the house.

Electricity's first use in the home was that of supplying light, and this single function continued for many years. In the first instance, a lamp was hung from the ceiling in a few of the principal rooms of the home. Then more rooms came in for consideration. The inconvenience of grasping in the dark for the pendent light led to the installation of the wall switch. Outlets for bracket lights came into use, and next the advent of the portable lamp introduced the idea of placing outlets in the baseboards, for the unsightliness and inconvenience of dangling cords from both ceiling and wall lighting fixtures soon became obvious. Then, as electric appliances were introduced, the lack of outlets for their specific usage was felt. Again, lighting fixtures and the few baseboard outlets (now termed convenience outlets) for portable lamps were disrupted and often overloaded, for the wiring installation was not planned for the arrival of labor-saving electrical appliances. While a multitude and an ever-growing number of electrical appliances have been available for some years, only a relatively few houses have been built in which the complete electrification of the home has been considered. The usual faulty procedure is to consider the wiring installation for only its lighting requirements, and then, after the house is occupied, an immediate overloading of certain circuits, as witnessed by a multitude of plugs in a single receptacle, or a patching of cords, begins. Next, the vacuum cleaner cord must be strung through several rooms or up and down an entire length of stairs, or the electric refrigerator, the washing machine, the percolator, the electric mangle, the dishwasher, the bathroom heater and a host of other real homemaking modernizers, try to find a place for themselves but there is no place to connect them. Electricity is daily proving itself to be an increasingly important servant, one which performs its duties day or night and at continually diminishing costs. In planning the wiring installation, the outlets for electricity should not be limited to just those electrical devices which one possesses at the time of building, or even to those devices which may be under contemplation, for the home of the future will not only contain practically all of the electrical devices which we now know, but a host of others.

The electric range provides not only an excellence of prepared food which is unique, but it also does it automatically and without constant vigilance. When the family wishes to take a day's outing together, or the housewife wishes to be away for an afternoon, it can be done, for meals placed in the ovens of the electric range in the morning are ready to be placed on the table in the evening. The electric range in itself provides a freedom for the homemaker which was unheard of but a few years ago. Yet how few have availed themselves of this new freedom!

The washing of dishes has undoubtedly been one of the most irksome tasks of housekeeping. The homemaker is rewarded for her painstaking care in the preparation of the meal by the smiling faces surrounding the dining table, and the zest of the family in partaking of the meal. At the conclusion of breakfast the smiling faces depart for school or work, and in the evening they depart to parts of the house other than the kitchen for the book, the magazine, the newspaper or homework. When every other member is free to relax for the day, dishwashing confronts the homemaker, and this uninteresting chore must be performed just as it was yesterday, the day before, and on back through generations and generations. Electricity and modern invention, in joining hands, completely change this irksome duty, for the electric dishwasher, with but very little work, both washes and dries the dishes, making them ready for the next meal.

The electric refrigerator, electric iron, the washing machine, the electric mangle, mixing machines, and other devices to come, all afford the homemaker more time for pursuing such cultural or social tendencies as she may wish to cultivate.

The demands of the homemaker's time, and her justified increasing desire to grow beyond the four walls of her home, must be met, and electricity appears to be her chief emancipator. Not only is it her apparent emancipator but it also affords her opportunities to give her family better living conditions and at costs which are continually decreasing.

When this broader point of view is taken of the part that electricity can play in modern homemaking, we find that the planning of the wiring system of a house takes on an entirely different aspect from that which it generally possesses today. The houses which were considered quite adequately provided for but a few years ago have already been found lacking; while the house having only the usual and inadequate attention to its wiring details needs so much revision that it can scarcely be thought of as being a product of this age of electrical development. Only the lack of a true appraisal of modern homemaking, with electricity doing its part, can account for the thought that a complete instead of a just passable electrical wiring and lighting installation is expensive. To meet the changing conditions of our times, industry has turned to electricity again and again, and to its betterment. The home in its functioning carries on a great number of the operations which are to be found in the industrial and commercial world. If, then, the home is to be placed upon anything like a comparable basis of economy and effectiveness, and is to be a place in which our lives may be devoted to obtaining the greatest freedom, we should at least keep pace with the industrial and commercial world in which we live.

Local Sources of Information

Houses having an adequate number of properly placed lighting, switching, and appliance outlets may be found, but they are limited. Since, then, good examples are not common, the often practiced method of observing arrangements and details in newly built houses cannot be depended upon for electric wiring and lighting. Decisions involving the number of outlets and their placement must be made, and made with all the possibilities of furniture locations, with the positions of the work centers, with the travel to and fro through the various rooms, and with the habits of the family in mind. The time spent in studying the exact positioning of all outlets is indeed well spent, for it not only insures lasting satisfaction when living in the home, but it obtains this satisfaction for the minimum expenditure. As with the many elements entering the house, additions and alterations, especially when they become extensive, almost always cost more than though they had been included at the time the house was completely open and therefore easy to work in.

Similarly, the lighting fixtures for the house should be considered well in advance; in fact, the most ideal time is before the plastering of the house is applied. Position and height of wall outlets is often very dependent upon the specific fixture selected, and unless this order of procedure is adopted, unsatisfactory compromises often follow. Last minute decisions often limit the home owner's choice of lighting equipment, for local dealers, when allowed time, are often in a position to supply equipment from the respective manufacturers which they may not happen to have on hand at the moment. When the intimate part lighting plays in making a house a home is fully appreciated, this method of procedure will be found to be the only one to pursue.

After the home builder has given his own best thoughts to the problem, an experienced and competent electrical contractor should be sought, for his familiarity with what may be needed and what is new often reveals many important changes or additions. Too often the contractor is considered as one to consult on price only, whereas he can be looked to for competent guidance in providing a thoroughly satisfactory electrical installation. More recently there have come into existence local electrical associations and electrical leagues. The services of their specialists are generally available at no charge. The complete design of the wiring installation of a house is usually obtainable from these groups. The Red Seal Wiring Specifications as developed by the Society for Electrical Development, Inc., represent a good standard of modern wiring practice and as such may be referred to for planning the wiring of a house or may be used to appraise the worthiness of the wiring of a completed house. In addition, the local company furnishing electricity usually has individuals on its staff from whom this information may be readily obtained. These companies in larger cities have specialists devoting their entire time to all phases of the uses of electricity in the home and are entirely competent to answer questions regardless of whether they are on lighting fixtures, portable lamps, wiring, refrigerators, ranges or vacuum cleaners, etc.

The Local Electric Light and Power Company Service

Before placing the contract for the wiring system, it is always advisable to ascertain the kind of services which are available from the light and power company, and the prevailing rates. In those communities where, for example, two meters are used, one for lighting and small appliances and the other for heavier appliances such as the electric range, hot-water heater, dishwasher, etc., it is very advantageous to have the convenience outlets, such as the ones in the kitchen, bathroom and laundry, connected to the heavier appliance meter. Obviously, the time devoted to getting this information is usually well spent, for it can make a material difference in the money spent for electricity after the house is occupied; that is, where two meters are supplied. In those places where all the electricity is supplied through one meter (and there appears to be a greater number of companies furnishing services this way), the user of the larger appliances usually obtains the advantages of the low power rates offered where the separate power meter is supplied, for a "sliding scale" rate is offered. In this case the first units of electrical energy carry a higher charge per unit, but the additional successive units used bring the lower rates into play, for the users of larger appliances use a sufficient amount of electricity to bring these lower rates into effect.

Some companies are able to offer what are termed "promotional rates." In this case these rates usually apply to houses having a number of the heavier appliances installed and in use. In the vast majority of locations lower rates are offered, for the greater usage of electricity often makes it advisable to consider the use of electricity for a great many more services than the home owner now realizes.

It is usually advisable to take the wiring plans of a house which is to be built, along with a list of the appliances, particularly the larger ones, to the local light and power company before proceeding, for the company may find it necessary to supply the house, due to its particular demands, with three-wire service instead of two-wire service. The contractor usually knows these requirements, but if there is any question about this point, the question should be definitely determined with the light and power company before the installation starts. This will avoid later delay and may also eliminate expense for changes that may be incurred.

Wiring Methods, Wiring Costs, and Inspection

While there are many methods and materials employed in the wiring of homes, the final decision on the choice in any particular case will be largely determined by local practice, local ordinances and inspection, and cost. The most common methods employed are termed knob-and-tube wiring, wiring with flexible armored cable, often referred to as "BX," and wiring in rigid conduit. Conduit, while used almost exclusively in public buildings, has not come into usage, except in certain localities, for residential building. In addition to these three types of wiring methods, several others are employed, although not so extensively as the three previously mentioned. Among this latter group are found nonmetallic sheathed cable, surface metal raceways, and electrical metallic tubing.

Knob-and-tube wiring employs single, rubber-covered wire, the rubber being covered with a sheath of fibrous material braided onto its surface. This wire is concealed between partitions and floors and is supported on porcelain knobs. Porcelain tubes are used where it is necessary to "tunnel" through wooden joists, beams, or studding. The wires are kept separated from each other by at least 5 inches and are kept at least 1 inch away from the surface on which they are mounted. At those places where it is impossible to keep the wires separated by 5 inches, each wire is encased in an unbroken length of flexible tubing of fibrous material known as loom. Metallic boxes are provided for outlets and switches.

The armored cable assembly consists of a wound flexible metal cover over rubber insulated wires. This assembly is run from outlet to outlet in continuous lengths. The cable is fastened with straps similar to those used for water pipe, and when it is necessary for it to pass through wood joists, studs, etc., holes are bored in the center of the members, and the armored cable is passed, without cover, through them. The armored covering of the assembly is both mechanically and electrically connected to all outlet boxes and fittings.

Rigid conduit wiring involves using a specially made metal pipe coated on the inside and outside, exclusive of threads at joints, with zinc, enamel or combinations of both. In practice, the entire assembly of conduit is built up in place and then the wire is drawn into it. From the order of procedure in the original installation, it is obvious that any or all lengths of wire may be withdrawn from the conduit at any time and accordingly replaced. This method involves the use of a variety of fittings usually termed outlet boxes. These are placed flush with the plaster or the baseboards in the house. In turn they contain the necessary wall-switch mechanisms and the receptacle part of the convenience outlets, also the wire and supporting devices for lighting fixtures.

Nonmetallic sheathed cable involves the use of two conductors, each separately insulated with rubber and other insulating materials but contained in an outer sheathing of braided fibrous material. This assembly is also made up with a third wire, but in this type the third wire does not carry individual insulation. This third wire is for grounding purposes. The assembly of nonmetallic sheathed cable is run from outlet to outlet in continuous lengths without joints or spliced-in connections. The cable itself is fastened directly to wood joists, studs, etc., by means of metal straps similar to those used for supporting water pipe to joists and beams. Where grounding wire is required the encased ground wire is connected to the outlet boxes or fittings into which the cable is supplied and also to a suitable ground connection thereby grounding all outlet boxes and fittings.

Surface metal raceways in houses are used primarily for making extensions along baseboards, ceilings, walls, etc., in older houses. Since it may not be concealed, with but few exceptions, its use would scarcely ever be considered in new house construction. The materials coming under this classification for house wiring generally consist of a shallow metal channel with a second piece for a cover, the cover being driven on. It also takes on the form of flat rectangular or nearly rectangular shapes either in one piece or two pieces. When made in two pieces with one of the pieces removable it is possible to place the wires inside of the metal duct or raceway and then drive on the removable piece. With one-piece types the wires have to be pulled into it just as wire would be pulled into conduit. An extensive assortment of fittings, outlet boxes, etc., are made for the various makes of this class of material.

Electrical metallic tubing is similar to rigid metal conduit, and the details of its type and usage are quite similar to the latter. The chief difference between it and rigid metal conduit are found in its lesser wall thickness and its lack of pipe threads. Threadless outlet boxes and fittings have been developed for its use.

The brief discussions in the foregoing paragraphs on some of the principal wiring methods are based principally upon material contained in the "National Electrical Code" of the National Board of Fire Underwriters. For complete installation information and regulations on these wiring methods this code or local codes should be referred to.

Knob-and-tube wiring and wiring with flexible armored cable appear to cost about the same amount, while conduit wiring is higher in price. Actually, one might find a considerable difference in the cost of wiring between the knob-and-tube and armored flexible cable methods, but there are reasons to believe that this is due primarily to the familiarity the workmen have with the material used. Workmen who have never done knob-and-tube work but are daily doing flexible armored cable work would require more time to do knob-and-tube work at first than they would require to do flexible armored cable work, and vice versa. Similarly, contractors who do little or no conduit work might not be able to submit a bid on this class of work that would be comparable with the contractor whose workmen are highly skilled in conduit work. From these considerations it is apparent that the best work and the most economical work will very likely be done with one of the methods which is most commonly practiced in the community in which the house is located.

The general inadequacy of the numbers of convenience outlets, lighting outlets and switch outlets is in no small measure due to lack of knowing even approximately how much should be allowed for the wiring installation or what an average outlet costs. Such figures as have appeared may differ from those given here, for there are various degrees of adequacy, and figures obtained in different parts of the country also differ due to varying material and labor costs. A survey conducted for the purpose of this report, one which brought in figures from cities located on the Atlantic and Pacific Coasts, and in the South and the Central States, again reveals this variation; but the figures obtained permit the establishment of approximate average figures.

It is to be particularly noted that wiring specifications submitted for houses representative of the three price classes studied were reduced to the minimum of adequacy in the numbers of outlets employed. Accordingly, it might be said that allowances less than those given should never be entertained. A study of the principal figures reveals a very pertinent point; namely, that the fewer outlets in an installation the greater the cost per outlet. The increased cost per outlet when the conduit system is employed is also brought out. The slight increase in cost incurred by the use of larger wire in both the branch circuits and the main supply is of particular interest. A discussion of this point follows:

For many years nearly all houses have been wired with a size of wire known as No. 14, American Wire Gauge ("A W G"). In the earlier days of electricity in homes, lighting constituted the entire load, for appliances were undeveloped and the amount of light used was very limited. As time has gone on, more and more electric appliances have come into use and more and more lighting is being employed. This, of course, is in keeping with our improving standards of living. Possibly an equally great factor is that of the continually lowered rates for electricity itself. Today, for example, due to the lowered rates for electric service, improvement and lowered prices of incandescent lamps, we are able to buy over eighteen times as much light for a dollar as we were able to buy forty-five years ago. At the same time this has been taking place we have been placing greater demands on our wiring systems. Studies which have been made indicate the desirability of using a larger size of wire for the usual circuits of the house. With this in mind the cost of wiring houses with a larger size wire (No. 12, A W G) was included in this survey. Table 1 which carries the various wiring costs also lists the cost of wiring with No. 12 wire. The increases due to the use of this size of wire are so small both in actual amount, and particularly in per cent, over that required for No. 14, A W G wire that the question of using the larger size wire deserves real consideration in the construction of new homes.

Table 1. Average Residential Wiring Costs *
(Minimum)

Approximate House Value	$3,500	$6,000	$8,500
Knob-and-Tube Installation. No. 14 wire branch circuits	$ 79.15	$136.68	$217.94
Knob-and-Tube Installation. No. 12 wire branch circuits with three No. 6 service wires	$ 87.68	$148.56	$235.28
Conduit Installation. No. 14 wire branch circuits	$121.28	$225.05	$361.85
Conduit Installation. No. 12 wire branch circuits	$131.56	$246.17	$380.02
Additional cost for electric range wiring	$ 26.75	$ 33.19	$ 33.45

* The wiring specifications used in obtaining these figures were the very least that should ever be utilized. Bids submitted by contractors varied from the amounts given but the majority of bids received were with a few exceptions fairly close to the average values shown in the table. These values, then, approximate the least amount that should be appropriated for the wiring installation. The amounts given include the necessary wiring and equipment for electric doorbells, operated from the same service which supplies electricity for the house. See Table 3 for approximate minimum allowances for lighting fixtures.

The average cost per outlet while the house is being wired should be borne in mind in settling many questions on what to many appear to be arbitrary points. For example, with a single additional switch outlet at the door between a kitchen and an often

Table 2. Per Cent of Structure Cost for Wiring Installation and Average Costs per Outlet*

	Approximate Value of House					
	$3,500		$6,000		$8,500	
	Per cent allowance	Cost per outlet	Per cent allowance	Cost per outlet	Per cent allowance	Cost per outlet
Knob-and-Tube Installation. No. 14 wire branch circuits	2.3	$3.75	2.3	$2.85	2.6	$2.72
Knob-and-Tube Installation. No. 12 wire branch circuit with 3 No. 6 service wires	2.5	4.17	2.5	3.10	2.8	2.94
Conduit Installation. No. 14 wire branch circuits	3.5	5.78	3.8	4.69	4.3	4.52
Conduit Installation. No. 12 wire branch circuits with 3 No. 5 service wires	3.8	6.26	3.9	5.13	4.5	4.75

* Figures given in this table are derived from figures shown in Table 1. The "cost per outlet" figures given apply only to work done in a house being constructed. Outlets for medium duty service vary and ordinarily take a higher average price than the figures given in this table.

used adjoining room, it is always possible to enter the kitchen without groping in the dark for the switch at the rear kitchen door. There can be little question about the worthwhileness of the convenience of this second switch controlling the kitchen light when measured against the few dollars that it costs to install for the lifetime of the house. A mental picture of this convenience which will be called into use thousands and thousands of times during the life of the house, leaves little room for questioning the expenditure. If, on the other hand, its usefulness is not imaginatively pictured, the amount, small as it is, will likely seem unnecessary and the occupants of the house will in time, if not at first, realize that there should have been a switch at the place at the time the house was built.

Practically all communities have local ordinances and local inspection departments which establish and enforce the necessary regulations on how the electrical work shall be done. A reliable contractor can be depended upon to carry out the work in accordance with these regulations and his work will receive the inspector's approval. Wiring installations can be carried out that will just pass inspection or they can be done so that there is a good margin between the grade of work and inspection limits. Avoid the contractor whose only recommendation is low price. In connection with local inspection it should be borne in mind that the approval obtained deals primarily with standards which must be met by the contractor for safety and fire prevention. It does not assure the home owner of the adequacy of the installation from the standpoint of its convenience or its similar practical requirements.

In those communities where local inspection is not practiced and particularly when farmhouses are wired, the home owner should engage an experienced inspector, from the nearest community to the house in question, or from the nearest inspection office of the fire underwriters, for its wiring inspection. Money thus spent is well spent from an insurance point of view. Furthermore, the contractor doing the work should be informed that his wiring is going to be subjected to such inspection. The good contractor will not be concerned, while the indifferent or poorly informed contractor will raise his standards to meet the inspection.

Most local ordinances are based upon the "National Electrical Code" of the National Board of Fire Underwriters and where there are no local ordinances in effect, the regulations as set forth in this code should be referred to and followed.

Wiring Specifications for Lighting and Appliances

General. The specification should cover a complete installation including the service entrance, which consists of the conduit on the outside of house or garage containing the necessary wires for connection to the power company lines, the main service switch, the board upon which the meter is mounted and whatever fittings are involved. Permits required by local ordinance or insurance departments should be taken out by the contractor before work is started and final inspections and certificates of inspection should be secured at completion of work. The National Electrical Code and / or the local code governing electrical installations should be strictly adhered to and should be a part of the specifications.

The service conduit carrying the supply lines into the house should be of sufficient size not only to provide for present usage but also for future requirements. Experience indicates that this will be more nearly provided for if the following method of computation is followed in determining the sizes of wires to be used in the service entrance. Allow two watts for every square foot of floor space up to and including the first 2,000 feet of floor area, plus one watt per square foot for the area over 2,000 square feet and to this figure add 1,000 watts. To the total wattage figure thus obtained, add the rated capacity of all fixed appliances such as the range, water heater, built-in space heater (bathroom), etc. From the load thus obtained determine the size of wire required for the service entrance. The floor area used for computation should include all spaces except open porches and unfinished spaces in the basement and attic. A minimum of three No. 6 wires with a 60-ampere switch is recommended.

Branch Circuits. It is recommended that all branch circuits be wired with No. 12, A W G copper wire (see discussion under section, "Wiring Methods, Wiring Costs and Inspection"). Since the use of heavier portable appliances is largely confined to the kitchen, dining-room, pantry and breakfast-room, it is recommended that all convenience outlets in these rooms be supplied by one separate appliance branch circuit. The laundry should also be supplied by one separate appliance branch circuit for the convenience outlets in this space. For the lighting in the entire house and for such appliances as are commonly used other than in the kitchen and laundry, one branch circuit for each 500 square feet of floor area is recommended. When no one branch circuit is confined to the serving of only one room but instead is distributed to several rooms, a better balance of operating conditions will obtain and overloading of circuits is minimized even though one room, the living-room, for example, is consuming more than the average allowance made for it.

The meter board upon which the meter is to be mounted should be located near the point where the service wires enter the house and should be erected on cleats, thereby affording air space behind it. An enclosed type of main service switch is recommended, this to be also mounted on the meter board. Standard meter boxes are also available which permit the installation of the meter in the wall or foundation of the house. This arrangement permits the reading of the meter from the outside of the house.

The panel board, which contains the branch circuit fuses, should be of the dead front type. Each fuse receptacle should be of 30-ampere rating. The fuses themselves should not be greater than 15-ampere rating. The rating of main service fuses should be determined by size of service conductors and total capacity of the branch circuits.

Circuit-breakers which take the place of fuses are now available for residential wiring installations. These devices require only the pressing of a switch handle to reestablish service, thereby eliminating the necessity of replacing a fuse.

Convenience outlets, except for those limited by local ordinances, should be duplex and also dead front. Outlets for portable equipment in the dining-room, breakfast-room, kitchen, pantry, and laundry and for permanent equipment in the bathroom should be supplied by circuits separate from lighting circuits. It is highly advisable to have the convenience outlets which are used primarily for lighting from portable lamps in a given room supplied separately from the circuits supplying the lighting fixtures in the same room. In the event of a blown fuse in the given room, all the lights will not be extinguished at the same time.

Medium duty and heavy duty circuits are required for fixed or portable electrical devices where the current demand is greater than that involved with the use of the smaller electrical appliances. Some of the outlets in the laundry, basement, kitchen, and bathroom require these types of branch circuits. The hot-water heater, range, some sizes of electric refrigerators, and built-in bathroom heater involve their usage.

Wiring for Ranges, Water Heaters, etc. Fuses or a circuit breaker should be installed adjacent to the range. Usually a maximum capacity of 7,500 watts is to be provided for in single-family dwellings. When the distance from the range to the supplying panel box or supply center is 50 feet or less, three No. 8 conductors should be used. When the total circuit length is over 50 feet, three No. 6 conductors are recommended.

The size of water heater employed depends upon a number of factors and due to these various factors it is advisable to consult with the local electric service company before making an installation. The rated capacity of these heaters ranges from about 1,500 watts to 5,000 watts. Branch circuit fuses or a circuit-breaker should be provided for this service. A two-wire 220-volt circuit is usually employed.

Radio wiring consists of aerial and ground wires. These are brought to an outlet having two connection posts; one for the ground and one for the aerial. This same outlet has separate connections for the supply of electricity to operate the radio receiver. It is recommended that the aerial be of No. 14 A W G phosphor bronze or copper wire while the ground wire is to be No. 14 A W G or larger. The ground wire should be securely attached to a water pipe with a good clamp connection. The wiring also includes the use of an approved lightning arrester in conjunction with all outdoor antennas.

The bell wiring system consists of a transformer for supplying electricity to the bells from the lighting circuit, the necessary wire, not less than No. 18 A W G and rubber covered, and the necessary push-buttons.

The master switch (also called burglar switch) is recommended for the assurance and safety which it provides. This switch, which is usually located in the main bedroom, enables one to turn on all of the lights to which it is connected regardless of whether the switches which control them are on or off. Exterior lights and certain lights in the principal rooms of the house are connected to the master switch.

Spare Circuits. In general the number of branch circuits provided in a wiring installation covers only the immediate requirements as set forth by the number of outlets and estimated loads carried on the plans of the house. Later additions must then be added to the existing circuits, a method which cannot be carried very far without overloading of circuits. Provision should be made for spare circuits at the time the original installation is made. One spare circuit for each five circuits in use is recommended.

Outlet Requirements and Positioning

Front Entrance. Two side outlets wherever architectural arrangement permits the use of two lighting-fixtures; otherwise one side or ceiling outlet. In the case of a single side outlet it is desirable to place it on the door-opening side. One single-pole switch for operating the lights. One or more convenience outlets, switch controlled. Also one outlet for an illuminated house number with its own switch control.

Side and Rear Entrances. One overhead or side outlet. One switch.

Vestibule. One ceiling outlet and one switch if floor area is in excess of 16 square feet.

Entrance Hall. One ceiling outlet and one switch. If this is the only outlet in the ceiling of hall, a second switch to operate this outlet is to be placed in the second floor hall, near the head of the stairs. At least one convenience outlet for each 12 feet of baseboard, not more than 12 feet apart, for portable lamps, vacuum cleaner, floor polisher, etc.

Living-room. One ceiling outlet, controlled from at least one wall switch. Rooms having two important doorways more than 10 feet apart require two switches controlling the ceiling lights, one at each doorway. Unusually large rooms whose length is more than one and one-half times the width are equipped with two ceiling outlets. Wall brackets are primarily decorative unless semi-indirect or indirect lighting fixtures are to be used. Brackets usually create the most pleasing appearance when used in balanced pairs. Unless there is some very specific reason for doing so, it is usually advisable to keep wall brackets off the center of wall spaces, for their monopoly of these positions usually interferes with the placing of furniture, pictures and hangings. It is advisable to have wall brackets collectively connected to a single wall switch. Convenience outlets should be located approximately every 12 feet, and to provide for radio sets, telephone tables, small tables, etc., at least one outlet should be provided in every separate wall space 3 feet or more in length. An outlet in the mantel is highly desirable for the electric clock, picture lighting, decorative mantel lamps or light ornaments.

Sun-room, Book-room or Library. Follow the same general specifications as given for the living-room.

Dining-room. One ceiling outlet, preferably with two circuits for multiple lighting-effect fixtures. Rooms having two doorways more than 10 feet apart require switches at both doorways for controlling the central fixture. A minimum of two convenience outlets is recommended (an outlet in the floor may be considered as one of the two outlets) plus outlets for each additional wall space adaptable to the use of buffet or serving table. As in the case of the living-room, wall-bracket fixtures are primarily for decorative or secondary lighting. Their use cannot be relied upon to replace the center fixtures unless the brackets selected are semi-indirect or indirect types. A buzzer connection is recommended, brought up through the floor under the table, for signalling the kitchen.

Breakfast-room. One ceiling outlet placed over the center of the table operated by a single wall switch. When the breakfast room is located between two rooms, and two doors occur, switches at each of these doors controlling the ceiling fixture are recommended when the doors are more than 10 feet apart. At least one convenience outlet is required. In rooms where the table is placed against the walls this outlet would be immediately above the table and in this wall.

Kitchen. One ceiling outlet for average kitchens; long narrow kitchens require two. Kitchens having two important doorways more than 10 feet apart require wall switches at each of these doorways controlling the ceiling outlet. Where there are more than two important doorways all separated by 10 feet or more, additional switches are installed at these doors for the control of the ceiling fixture. Ceiling outlets or brackets over sink, range and other important work spaces are important for the lighting of these areas. These outlets are controlled by wall switches or pull chain switches with insulating links in the chain. Convenience outlets near the sink and at the ironing board and other work areas. These are usually placed 3 to 4 feet above the floor. Convenience outlets for refrigerator, electric clock, dishwasher, and ventilating fan are also of first importance. Their positions are dependent upon the positions which the specific appliances take.

Hallways and passageways require at least one ceiling outlet. The placing of outlets for the lighting of stairways at both the bottom and top ends should be borne in mind. Additional outlets for every 15 feet of length of hall or passageway should be provided. Wall switches for these outlets, so that passage can be made with light ahead at all times and also so that lights behind can be turned off without retracing steps to do so are important. Doorways more than 10 feet apart should have switches located at them for the controlling of hall lights.

Bedrooms require one ceiling light controlled by one wall switch. Provide one convenience outlet for every 12 feet of baseboard and not more than 12 feet apart.

Bathrooms. One ceiling outlet plus two wall outlets, one on each side of the mirror. The wall outlets at the mirror are to be approximately 60 inches above the floor. Two wall switches at the entrance door are to be provided; one for controlling the ceiling outlet and the other the wall outlets at the mirror. Shower stalls and recessed bathtub alcoves require ceiling outlets. The wall switches for the control of these outlets should be outside of the shower or tub compartment. An outlet for a built-in bathroom air heater should be considered. A convenience outlet, 3 to 4 feet above the floor and to the right of the washstand should be included, where its installation is in accord with local ordinance.

Closets, in practically every case, require an outlet in the ceiling or over the doorway. Exceptions are primarily those where the closet is extremely shallow. The outlet may be controlled by a pull chain switch or automatic door switch.

Third Floor. One ceiling outlet placed at the top of stairs, positioned to provide general lighting and also lighting the stairway. This outlet to be controlled by wall switches, one at the foot of the stairway and the other at some point convenient to the top of the stairway. Also one ceiling outlet for each enclosed space. At least one convenience outlet for an extension cord and lamp. The wiring and lighting specifications for third-floor bedrooms and bathrooms are the same as those given for these same rooms (bedroom and bathroom) in other parts of the house. It appears advisable to have at least a separate circuit run to the third floor in houses having this space unfinished to provide for the possibility of finishing all or a part of this space at some future time.

Basement requirements are met by placing ceiling outlets at the foot of the steps, controlled by a wall switch at the head of the steps; ceiling outlets in each enclosed space such as the coal room, fruit storage space, etc., controlled by wall switches at the entrance doors to these spaces or by pull chain switches with insulating links, when the outlets are within easy reach of the door; a single outlet in the ceiling about 3 feet from the wall over the work bench. If work benches are over 6 feet long, two such outlets are recommended. Outlets for heat-regulating devices, for a trouble lamp, bell ringing transformer, for oil-burning furnaces, at the work bench for the electric soldering iron or gluepot are all points of the installation to be considered. Porcelain sockets are recommended for the basement, laundry and garage.

Laundry or laundry section requires one ceiling outlet directly over the laundry trays, also one ceiling outlet or convenience outlet for the ironer. One ceiling outlet 3 feet in front of the center of laundry trays for clothes washer. This outlet should be equipped with a pendent type receptacle hung 5½ feet from the floor. One convenience outlet on a separate circuit of No. 12 A W G for heavier devices.

Garage requirements consist of one ceiling outlet over hood of car and one ceiling outlet at the rear of car controlled by wall switch at garage doors. In the case of double garages, one ceiling outlet over the hood of each car and one between and at the rear of the cars. One lighting outlet on the exterior of the garage with controlling wall switch at the garage entrance door and a second controlling switch at some point in the house, usually the kitchen. One convenience outlet on the center of the rear wall, 4 feet above the floor.

The Lighting Requirements and Lighting Fixtures

General. The existing evidence which points to the incompleteness and the poor arrangement of the wiring outlets of houses also points to what might be termed the deplorableness of a considerable amount of the lighting equipment in everyday use. Because much of this equipment was bought many years ago, it is conceivable how surveys of a few years ago revealed 30 per cent of the ceiling fixtures to be absolutely obsolete, while 50 per cent of the remaining number were far from being satisfactory. This might be of historical interest only if it were not for the fact that there appears to be no more intelligence displayed in the choice of fixtures today than was displayed years ago. While the lighting of the home does not appear to be subject to standardization, the principles involved apply whether the house be a simple cottage or a pretentious mansion. The modern, efficient light source, the tungsten-filament incandescent lamp, is much too bright to be used without some diffusing or redirecting equipment, yet the use of unshaded lamps abounds, with relatively few exceptions. The eye comfort, the charm and appearance of rooms and their furnishings, are all enhanced when properly chosen shades and other diffusing devices are used. Another question in point is that of the amounts of light in use. The oft repeated statement "too much light" is more often a case of glare from unshaded lamps. Economically, it is difficult to produce the condition of too much light. Out-of-doors on a dull, overcast day the intensities of light are easily one hundred times as great as those found in our best lighted offices. Usually our homes are considerably less well lighted than our best illuminated offices. The abuse to which we subject our eyes and the increasing hours of usage to which our eyes are subjected in close visual work call for more adequate amounts of light than we now commonly use. We have noted the percentage of people in various age groups who have defective vision. To illustrate this point in another way, it may be stated that one child of every five in grade schools (checked in twenty cities) and practically every second person in normal schools, colleges and universities has defective eyesight. These facts clearly indicate a need for more attention to the use of our eyes.

Light is inexpensive and fully controllable, so that there is little reason for placing the undue burden on our visual apparatus, the eyes, that we are so likely to do. If we were to shade all lamp bulbs and replace all lamp bulbs of unsuitable size with bulbs of correct size, the first step toward major improvement would be made. Next, the problem becomes that of placing lighting equipment of the correct design at those points where it best delivers light to work. Lastly, rooms to be most comfortably lighted must be free from excessive contrasts. A general distribution of light throughout a room, even though it is low in value, will materially assist in eliminating contrasts. If the goal of good lighting in the home—convenience, eye and nerve comfort, and charm—is to be attained, care must be exercised to utilize adequate amounts of distributed light, free from excessive contrasts, and to shade properly all lamp bulbs.

Lighting Recipes

Entrances. Two lanterns (See HH and KK, Fig. 1) utilizing 40 watts each, open at the bottom, and balanced on either side of the door, provide a welcoming invitation to the guest, and at the same time they reveal the features of individuals who have arrived at the door. When the hour is late and strangers ask for admittance or information, it is particularly satisfying to be able to see the faces of such individuals with unquestioned clarity. The lanterns also provide a means of illuminating the steps leading up to the door. With some arrangements of door and other architectual details, only a single lantern need be used. In these cases it will be either on the door-opening side of the door or above the door. A stencil of the house number may be incorporated in one of the lanterns or it may be a unit by itself. (See JJ and KK, Fig. 1.) In the latter case a low-wattage lamp (10 watts) is usually sufficient. The side, rear and garage entrances need utilitarian lighting, although the appearance of fixtures selected is not usually as important as those selected for the front of the house. (See FF, Fig. 1.)

Hallways. Main and entrance hallways usually create the first impressions as to the charm and livableness of a home. It is therefore most important to guard against the harshness and coldness which almost always accompany lighting from unshaded lamp bulbs. Clear glass and crystal fixtures, unlighted, may create a feeling of dignity, and even elegance, but they scarcely ever provide the softness which is such an important element of home charm and restfulness. A lantern type fixture (with diffusing glass panels) or a shallow fixture of diffusing glass, having its mass close to the ceiling, is usually both satisfactory and pleasing. (See Q and B, Fig. 1.) Total wattage of lamps in the fixture would range from 40 to 100 watts, the actual amount depending upon the type of glassware used in the fixture, size of hall and the darkness of finish in the hall. If the hallway is sufficiently large, floor torcheres, a table lamp, or wall brackets may be used for the decorative value they add. Upper hall fixtures should not only provide a well distributed light throughout the hall but also light on the stairway which is beneath it. The rear halls and passageways are satisfactorily lighted with small glass-enclosing units mounted close to the ceiling, equipped with 25- to 60-watt lamps.

Living-room. The present-day living-room must serve as a reception-room, living-room, reading-room, music-room, study and so on. The lighting equipment for such a variety of activities includes the central ceiling fixture, the wall bracket, the portable lamp, the lighted ornament, and even equipment built into the structure. The exact form and final effects obtained, however, are determined from the character of the house and most particularly from the character and habits of the people living in it. Obviously, if a home is devoted primarily to the simple living of a private family life, the effects to be obtained are considerably more simple and unpretentious than those for a home in which entertaining plays an important part. All forms of equipment are mentioned as being of importance, and yet this thought cannot always be adhered to, for the arrangement of doors, windows, etc., often prevents their installation or usage.

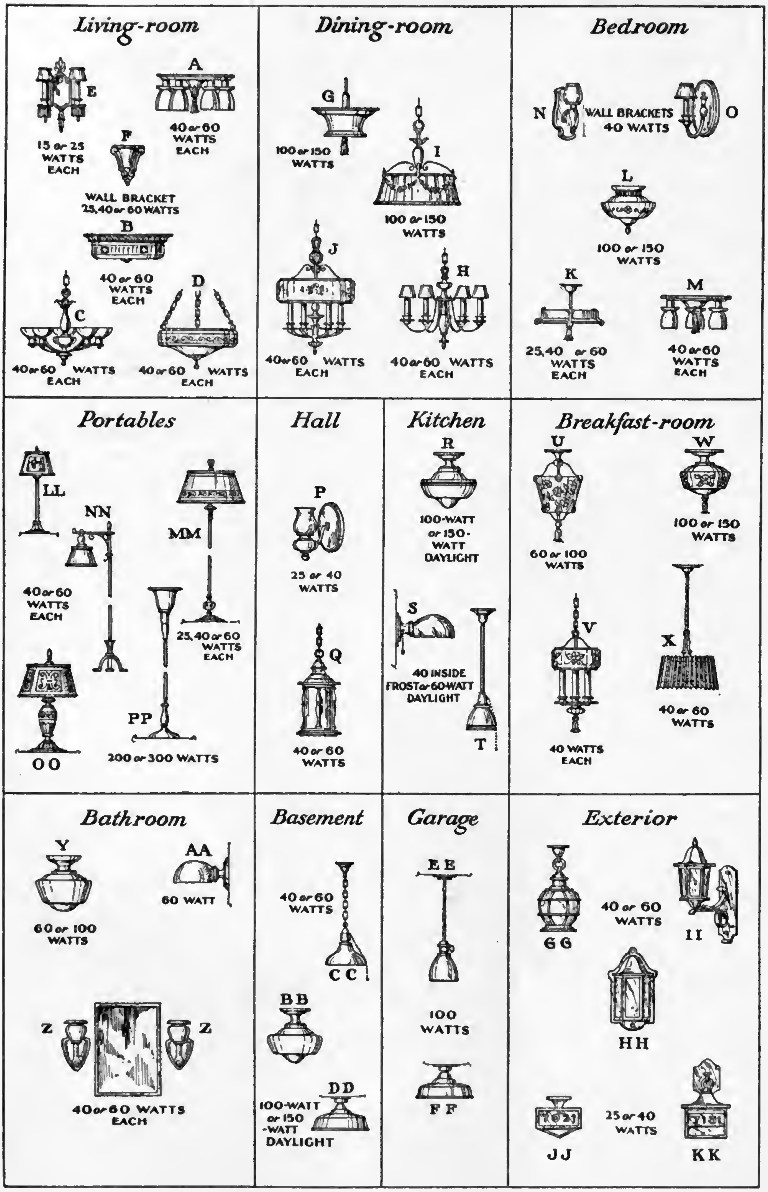
Living-room
E
15 or 25 WATTS EACH
A
40 or 60 WATTS EACH
F
WALL BRACKET 25,40 or 60 WATTS
B
40 or 60 WATTS EACH
C
40 or 60 WATTS EACH
D
40 or 60 WATTS EACH
Dining-room
G
100 or 150 WATTS
I
100 or 150 WATTS
J
40 or 60 WATTS EACH
H
40 or 60 WATTS EACH
Bedroom
N
WALL BRACKETS 40 WATTS
O
L
100 or 150 WATTS
K
25,40 or 60 WATTS EACH
M
40 or 60 WATTS EACH
Portables
LL
NN
MM
40 or 60 WATTS EACH
25,40 or 60 WATTS EACH
PP
200 or 300 WATTS
OO
Hall
P
25 or 40 WATTS
Q
40 or 60 WATTS
Kitchen
R
100-WATT or 150-WATT DAYLIGHT
S
40 INSIDE FROST or 60-WATT DAYLIGHT
T
Breakfast-room
U
60 or 100 WATTS
W
100 or 150 WATTS
V
40 WATTS EACH
X
40 or 60 WATTS
Bathroom
Y
60 or 100 WATTS
AA
60 WATT
Z
Z
40 or 60 WATTS EACH
Basement
40 or 60 WATTS
CC
BB
DD
100-WATT or 150-WATT DAYLIGHT
Garage
EE
100 WATTS
FF
Exterior
GG
40 or 60 WATTS
II
HH
JJ
25 or 40 WATTS
KK

Figure 1

With the wide variety of activities to be provided for, we find that the scope of conditions goes all the way from those quiet occasions when studying, reading and similar quiet occupations are pursued, to those occasions when a large and joyous company is gathered. The same lighting is surely not best suited for these two extremes. After a home is decorated and furnished, lighting is the only decorative element having sufficient mobility to provide extensive variety in the appearance and usefulness of a room. This, then, points to the necessity of considering the effects to be obtained from the equipment as well as the appearance of the unlighted or even lighted equipment. While a piece of lighting equipment may be quite harmonious with its surroundings in the daytime, it does not necessarily follow that it will continue to be so when called upon to produce the lighting which should be expected from it. In fact, unless one keeps in mind the first purpose of lighting equipment—to provide adequate, comfortable, and even decorative lighting effect—the appearance of the lighting equipment as an element of ornamentation or decoration is given undue weight.

For those times when general lighting is needed—tables set up for games, children at play on the floor, dancing, or a large group in conversation—the central ceiling fixture is difficult to equal for effectiveness. The height of the ceiling, however, must be considered in making the choice of this fixture. Low-ceilinged rooms maintain their apparent size and attractiveness when the fixture selected is of compact design and has its mass close to the ceiling. (See A and B, Fig. 1.) Higher-ceilinged rooms permit the use of fixtures which hang farther down from the ceiling, from a few inches to as much as several feet. (See C, D, G and H, Fig. 1.) These fixtures, due to variations in the number of sockets employed in their design, employ various sizes of lamps. However, under average conditions, these fixtures should be provided with lamps with an aggregate of about 200 watts. For example, a fixture having five sockets would use five 40-watt lamps.

When lower levels of general lighting are desired, as when a few people are engaged in conversation, the general upward light from open-top floor and table lamps will usually be adequate. Open-top shades on portable lamps are always desirable, for the general lighting they produce affords a more balanced lighting effect in the lower and upper parts of a room. Closed-top portables in not providing this softening effect create harsh contrasts which are trying on the eyes. Higher intensities of general lighting are also provided by either simple indirect-lighting floor lamps, (See PP, Fig. 1) without shades, or by means of this same type of portable lamp having a shade which conceals auxiliary lamp bulbs for direct lighting. The indirect lighting from these lamps is provided by one 200- or 300-watt lamp bulb or by a grouping of 100-watt lamp bulbs.

Brackets in living-rooms create highly interesting and valuable spots of light and color, and in so doing they can play a very important part in decorating a room. (See E, Fig. 1.) They are often found installed as the primary light sources, but it is exceedingly difficult to achieve a satisfactory result with them as such. To be truly effective as a decorative element they must be shaded, although the great numbers in use, unshaded, would lead a casual observer to believe the contrary. Recently, urns and wall-pockets which provide satisfactory general, indirect lighting have been made available for the more usual wall-bracket positions. (See F, Fig. 1.) If they are used for main lighting, they should be balanced either on both sides or both ends of the room to produce at least a moderate balance of light throughout the room.

Local high intensity lighting at chairs, for the davenport, at the desk, piano, etc., is provided for with table and floor lamps. An adequate number of convenience outlets, as outlined in the preceding paragraphs on wiring specifications for the living-room, provide places for the connection of all necessary lamps no matter how furniture is arranged. Similarly an adequacy of these outlets provides for spots of light and color which are now obtainable from lighted ornaments.

Dining-room. The usual symmetrical arrangement of furniture in the dining-room permits of a symmetrical arrangement of lighting with the dining-table as the chief point of interest. With the table top more predominantly lighted than any other part of the room this interest is assured. The old style dome of previous years provided the effect of centering interest on the table top but, due to its large diameter, the lamps were visible to those seated at the table and were a source of considerable annoyance. More recently designed domes of lesser size (See I, Fig. 1) when hung 24 to 36 inches above the table, eliminate this annoyance and produce a most desirable and interesting effect. Fixtures fitting fairly close to the ceiling and which produce this same lighting effect are now in development. These should prove to be highly acceptable to those families who enjoy an occasional dinner lighted solely by means of paraffin candles, for the fixture, in being close to the ceiling, is completely out of the way with respect to the tall candles.

The five- or six-light candle fixture (See H and J, Fig. 1) has been one of the most popular fixtures and is commendable when the lamp bulbs are shaded.

The semi-indirect type of fixture is used in the dining-room, although it does not primarily light the table. It is particularly suited to the home having children or other members of the family who use this room for study purposes.

While there appear to be no stock fixtures available which incorporate both direct lighting for the dining-table and indirect lighting for either secondary effects or even a primary effect for the family using the dining-table as a study area, it is certain from observations of experimental fixtures of this type, that such fixtures would meet the uses of this room in a most commendable way. Due to the relatively short occupancy of the dining-room each day, more theatrical effects are possible; hence fixtures providing a number of lighting effects would be more acceptable than they would be in the other rooms of the home.

The discussion in the preceding paragraphs, pertaining to wall brackets in living-rooms, applies equally well to the subject of wall brackets in dining-rooms. In addition, shades denser than those used on living-room brackets are desirable in the dining-room for, unless they are exceedingly low in brightness, they become distraction sources, distracting one's attention from both the table and those seated at it.

The Breakfast-room or Breakfast-nook. These spaces are naturally considered as miniature dining-rooms. Small enclosing or dome-shaped shades, suspended over the table at such a height so as to preclude having light from the bare lamp bulb entering the eyes, are recommended. The shades when sunny in hue provide a cheerful effect which assists in counteracting the cheerlessness of dark winter mornings.

Kitchen. Light-colored walls and ceiling are particularly important for redirecting and diffusing light throughout this room. This treatment minimizes shadows, but, unless the room is exceptionally small, it does not eliminate the shadows cast by one's body when standing at the sink, range and other work areas adjacent to the wall. To provide for these work areas shaded bracket or pendent ceiling lights are to be provided at each point (See S and T, Fig. 1), one at the sink, at the range, at the kitchen cabinet, etc., in addition to an enclosing globe of white glass (See R, Fig. 1) located at the ceiling center. Long, narrow kitchens require two such units spaced equally distant from the ends of the room. "Daylight" lamps in the kitchen provide a color of light which blends with the light entering the windows at the ends of the day when daylight is inadequate. The light from these lamps also assists in detecting scorches when ironing is done in the kitchen. A better uniformity of appearance is obtained when "daylight" lamps are used in both the local lighting equipment over the work areas and the central ceiling fixture. Use 100-watt inside-frosted lamps in the central ceiling fixture and 40-watt inside-frosted lamps in the equipment over work areas or 150-watt and 60-watt "daylight" lamps respectively in these two types of equipment when the color quality of the "daylight" lamp is desired.

Bedrooms. While ceiling fixtures have been omitted from bedrooms in some cases, their absence deprives one of being able to provide general lighting in the room for dressing, finding articles of apparel in drawers, and general moving about. The fixture selected should be of low brightness so that it will not be a source of discomfort for one lying in bed. Either a glass unit of good diffusion hung close to the ceiling (See L, Fig. 1) or an indirect type of fixture (See G and K, Fig. 1) meets the requirements most satisfactorily. In larger rooms having higher ceilings, suspended types of fixtures such as the shaded candelabra fixture (See H, Fig. 1) may be used. This type of equipment is used when a more formal type of room is involved.

While brackets may be placed on both sides of dresser and dressing table mirrors for the lighting of one's face when standing at these mirrored pieces of furniture, a more flexible arrangement of lighting at these mirrors is obtained with properly chosen portable lamps. These are placed on the dresser or other similar pieces of furniture, one on each side of the mirror. Lamps for this purpose on a dressing table, before which one is seated, should be shorter than the ones used on a bureau before which one usually stands. Specially designed brackets are also available for attaching directly to the mirror at face height.

Other equipment consists of a bedside reading lamp and even a light under the bed. Since the portable equipment can play such an important part in the lighting of bedrooms the need for following the convenience outlet specifications given in preceding paragraphs becomes apparent.

Closets. Clothes closets are well provided for with a bracket light inside and above the door (preferably on the door-opening side) controlled by a pull chain switch or an automatic door switch. Since the hours of operation of closet lights are very low, considerably larger lamps (60 or 100 watts) than are generally used are recommended.

Bath. Upright brackets, (See ZZ, Fig. 1) one on each side of the mirror, with white glass shades open at the top, not only provide excellent lighting of the face but also provide the general lighting in the smaller light-colored rooms. Larger or darker finished rooms also require an enclosing unit of white glass at the ceiling. (See Y, Fig. 1.) The recent developments in ultra-violet producing incandescent lamps, "sunlight lamps," and suitable equipment for their use afford a means of health maintenance for every member of a family. Various approved portable, wall and ceiling types of equipment are now available for use in the various rooms of the home. The bathroom ceiling outlet appears to be an excellent location for one of these ceiling fixtures. While it is supplying the general lighting of the room it also provides the beneficial ultra-violet radiation to the exposed parts of the body of any occupant of the room. Since we are so often completely or partly disrobed in the bathroom, the desired exposures are probably more easily attained automatically than would be the case in other rooms.

Third Floor. Lighting equipment for the third floor follows the dictates set forth under bedroom, bathroom and hallways.

Basement. An enclosing white glass unit, similar to the one used on the kitchen ceiling, is used on all the principal outlets in the general area of the basement and also over the laundry trays, ironing machine and work bench. For the general areas the 60-watt lamp is usually satisfactory. The fixtures over the laundry trays, ironing machine and ironing board take 150-watt "daylight" lamps. These lamps are recommended, for their color quality of light enables one to detect soils and scorches more readily.

The recreation room is usually long and low ceilinged, and for this reason two shallow, enclosing ceiling fixtures (100 watts each) hung close to the ceiling usually best serve the requirements. Indirect lighting wall brackets also provide lighting in a most satisfactory way. The indirect lighting floor lamp is an indispensable item if card playing is indulged in when other forms of good general lighting have not been supplied or are not desired.

Garage. Either direct lighting with metal reflectors known as R. L. M. Domes (See FF, Fig. 1) or simple white glass enclosing globes or shades (See BB and EE, Fig. 1) with 150-watt lamps provide excellent lighting when outlets, as previously specified, are placed over the hood and at the rear of the car in single car garages. In double garages the outlets are over the hood of each car and between the two cars at the rear. Metal or glass reflectors are also installed over the doorway of the garage entrance, thereby providing light at this point and also for a part of the driveway and yard. To be most effective this lighting fixture is controlled at some point in the house, usually in the kitchen, and also at the garage.

Table 3. Approximate Minimum Allowances for Lighting Fixtures *

Approximate House Value	$3,500	$6,000	$8,500
Lighting Fixture Allowance	$57.00	$84.00	$140.00
Lighting Fixture Allowance, per cent of structure cost	1.6	1.4	1.6

* The figures given were obtained from equipping the three houses used for determining wiring costs set forth in Tables 1 and 2. These values are only to be considered as minimum figures, for the wiring installations in each case contained the minimum possible number of lighting fixture outlets and only the most modest and simple fixtures were selected. Greater amounts are easily justified where more beauty and lasting quality are desired. Shaded light was employed throughout.

Wiring and Lighting Rural Homes

With minor exceptions all of the wiring and lighting specifications given in the preceding paragraphs of the report apply to the rural home. The two general sources of electricity for the rural and farm home consist of the individual plant operated by the occupant of the house and electricity from the electric light and power company. The plant operated on the premises may be either the type which supplies electrical energy at 32 volts with a storage battery in conjunction with the generator or the type which operates at 110 volts with or without storage battery. In many cases these plants are being installed with no consideration given to the future possibilities of having these homes connected to the electric service company's lines. In the majority of cases it seems highly advisable to wire these homes for later connection to electric service company lines. When this is done there is no expense incurred inside of the house for changes, which is not always the case when only the requirements of the lower voltage supply are considered.

The size of individual plant ordinarily installed, due to its capacity, does not permit of the extensive use of either lighting or household appliances which service from the electric service company permits. If, then, only the possibilities of the individual plant are considered, considerably fewer outlets and fewer branch circuits will be installed. With this limited type of installation the house will never be comparable with, for example, the urban house of a given age until extensive additions and revisions are made. If there is any future likelihood of a rural home being served by an electric service company, and this should be taken up with the neighboring companies, the numbers and positions of outlets should be specified just as though the house were to be immediately connected to the electric service company lines. This system might prove to overburden the individual plant but this can be prevented by covering the necessary number of outlets to bring the used part of the installation down to such size as the individual plant can properly supply. Obviously, such an arrangement permits of an immediate change over to electric company service with but a few hours' work and is accomplished with a minimum of expense.

Wiring, as in the case of the urban house, should be done by an experienced contractor. Furthermore it is particularly important to go to a contractor who is familiar with the special requirements of farm wiring. Only those materials which are approved by the National Board of Fire Underwriters should be used. Too much emphasis cannot be placed upon doing the work in accordance with the "National Electrical Code" of the National Board of Fire Underwriters. The wiring of houses in the city is all subjected to inspection before the walls are closed. Similar inspection should be applied to the rural and farm home, and where there are no established facilities for effecting this inspection the home owner should engage a regular inspector from the nearest community.

The farm home, due to the many operations conducted in it and around it which are scarcely ever conducted in an urban home, derives even greater benefit from electricity than does the urban home. The greater amount of manual labor involved in the daily occupations of the farm home calls for assistance from additional hands or from electricity. Extensive studies of electricity on the farm have been made and very practical reports covering these studies are available.

CHAPTER VI

REFRIGERATION[1]

The inclusion of household refrigerators in the studies of the Committee on Fundamental Equipment is the first official recognition of this important subject of the conservation of food in the American home. While the amount spent on refrigeration in the home is not large in relation to the total expenditure for housing and equipment and its upkeep, this amount, properly expended, may represent an important investment toward promotion of the health and comfort of the family.

The subject of food conservation through refrigeration has received much attention and has been the object of definite research from the producer through the retailer. Only in recent years, however, has research been applied to the problems of home refrigeration. This committee has reviewed all available material with the aim of bringing together such information as would be a guide to the home owner in meeting his needs for refrigeration and on the basis of these findings has made certain definite recommendations.

Some means of refrigeration is looked upon as a necessity in the modern home; as a health measure if perishable food is to be kept fresh and untainted from the time it reaches home until it is served on the family table; as a convenience in providing a safe and conveniently located storage for these foods; as a convenience and probably an economy in purchasing, since larger quantities may be bought at less frequent intervals; for comfort by providing crisp salads, chilled fruits and cool drinks throughout the year.

Improved methods of handling foods commercially under refrigeration have made possible the transportation of food over wide areas and their storage and distribution over different seasons. These foods must receive adequate care after reaching the home if their quality is to be maintained. This need has been increased by the growth in the number of urban homes entirely dependent upon foods produced outside.

In the rural home there has developed a greater appreciation of

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[1] This chapter was drafted for the committee by the following members: Miss Louise Stanley and Miss Mary E. Pennington, Mrs. Paul E. Howe, and Messrs. George B. Bright and Jesse B. Churchill.

the service refrigeration offers in providing a place for keeping the food produced at home in good condition, as well as to provide storage for those foods which, for a certain portion of the year, must be obtained from outside sources with less convenient market facilities than are available to the urban home.

The housewife has learned more of the dangers that lurk in spoiled food. She knows the relation of bacteria to food spoilage and the importance of temperature in controlling the development of bacteria and resulting spoilage. The nutritionist has emphasized, with her, the importance of including an abundance of fresh fruits and vegetables in the diet and she knows the importance of proper temperature for storage of these in order to preserve their fresh flavor and crispness. Studies in home management show that the buying of food supplies for the home can be handled more economically when adequate space for good food storage at satisfactory temperature is provided.

Temperatures for Home Refrigeration

As a basis for setting up requirements for home storage and suggesting the most satisfactory ways of meeting these, a table has been prepared to bring together the available information on the temperature requirements and conditions of storage for foods ordinarily held in the home refrigerator. In this it is assumed that the home refrigerator is for temporary storage and not a cold storage plant. Only under very isolated conditions can the home compete economically with the commercial plant.

The first object of household refrigeration is to provide storage space at satisfactory temperatures for the preservation of foods such as milk[2] and meat,[3] which spoil most readily and endanger health if spoiled, and a secondary object is to keep other less perishable foods in attractive and palatable form for service.

The requirements of these objectives can be met at different temperatures. While a low temperature is of utmost importance for preservation of perishable food, but for the less perishable foods a higher temperature is satisfactory, so a range of temperature is permissible—in fact, is desirable.

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[2] Pabst, Anna M., "Milk in the Household Refrigerator." *Ice and Refrigeration,* January, 1929.

[3] Pabst, Anna M., "Preservation of Meat in the Household Refrigerator. How May Keeping Quality Be Estimated?" Unpublished. Abstract found in U. S. Department of Agriculture, Separate No. 1228 from Yearbook of 1931.

In Table 1 are summarized the generally accepted desirable temperatures for the holding of different groups of perishable foodstuffs under home conditions and for the time such foods are ordinarily kept in the home.

Table 1. Desirable Temperatures for Home Refrigerators of Foodstuffs *

Commodity	Storage Space	Temperature	Treatment
Milk and cream	Milk Comp. Just below cold air down drop	45° or below	Store in bottles retaining caps. Rinse bottle and place in refrigerator upon delivery.
Broth. Fruit juices (uncooked)	....	45° or below	In covered dish. Broth stored with cover of fat keeps longer.
Desserts containing raw milk or cream	....	45° or below	In oiled paper or paraffined containers.
Butter	....	45°	In original cartons or covered dish.
Fresh meat and poultry	Lowest portion Food Comp.	45° or below	Remove from wrapping. Place on uncovered dish in refrigerator.
Fish	Lowest portion Food Comp.	45° or below	In tight covered container.
Cooked foods containing milk	....	46° or below	In covered dishes.
Cooked meat. Cooked vegetables	....	46–50°	In loosely covered dish or covered with waxed paper.
Leafy salad vegetables. Tomatoes. Cucumbers	Middle portion Food Comp.	46–50°	Place in salad jar or covered pan as hydrator to prevent wilting or drying out.
Fats and oils	....	46–50°	In containers as delivered.
Opened jelly, jams or preserves	....	46–50°	In covered dishes or jars.
Cheese	....	46–50°	In tight container.
Cooked fruit	....	46–50°	Covered dishes or jars.
Eggs, delicate fruits, as berries, peaches and plums	Middle shelf Food Comp.	50° or below	Eggs in cartons as delivered. Fruits if possible, in ventilated containers.
Vegetables and resistant fruits	Top shelf or draft cooler	60° or below	In ventilated containers.

* Store any easily spoiled fresh food as soon as possible after delivery.

With use of central heating, often no room without heat is provided, even in the detached house, making it difficult to find suitable storage space for the more bulky perishable supplies. The modern apartment with limited space, all usually overheated, has left the refrigerator the only safe storage place for all perishable supplies and has tended to increase unnecessarily the amount of refrigerator space demanded, sometimes at the expense of temperature.

In the consideration of space per family, thought should be given to the desirability, especially in the families of low income, of a smaller refrigerated space adequately cooled to preserve those foods which may show toxic protein decomposition if held at too high a temperature, rather than a larger space at higher temperature. Thought should be given to the provision of draft coolers for the more bulky foods that require much space, but which do not require low temperatures for preservation and do not produce toxins if a certain amount of spoilage should occur. The requirements for home storage have been worked out with such an arrangement in mind.

Space Required

The amount of refrigerator space required by any family depends upon the size of the family, the marketing habits and the amount of entertaining done. In general, the trend is toward a greater amount of food space per family when it can be afforded. A family of five, with a convenient source for purchasing supplies, needs approximately six cubic feet of food space, though less can be used if there is supplementary cool storage. The rural household would require larger space for food storage than the urban family because of less available supplies and the necessity during certain seasons of storing surplus foods.

W. T. Ackerman, in a study of refrigeration on New Hampshire farms, found the amount of food storage space used varied from 5.5 to 30 cubic feet.

Present Practice as to Food Storage in Home

Modern refrigeration is a comparatively recent development and has probably not yet extended to a majority of homes. A study[4] made by the Bureau of Home Economics, U. S. Department of Agriculture, in 1927-28, gives a fairly good nation-wide picture of the present practice in regard to home storage of foods. Returns were received from 2,350 homemakers from 37 states. Of this number 1,337 had ice-cooled refrigerators, 156 electric refrigerators, and 857 reported no means of refrigeration. In most cases ice was used for only a portion of the year. The number of months ice was used varied with the climate and availability of

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[4] Unpublished data collected by Lucile Reynolds, Research Associate, Bureau of Home Economics, 1927-28.

ice service, as indicated in Table 2, for regions, rural, town or village homes, and income.

Table 2. Use of Ice

Region	Months in use	Type community	Months in use	Income	Months in use
West	5.5	Farms	5.0	Under $1,000	5.9
Central	5.2	Towns under 5,000	6.5	$1,000– 2,000	6.0
East	5.2	Towns over 5,000	7.1	2,000– 3,000	5.6
South	7.6			3,000– 4,000	7.0
				4,000– 5,000	8.5
				Over 5,000	7.8

The average yearly ice bill of all localities was $27.44. This varies by regions as follows:

	Total
West	$25.71
South	34.43
Central	22.17
East	14.76

The average amount paid for refrigerators according to reported income was as follows:

Under $1,000	$29.58
$1,000– 2,000	33.18
2,000– 3,000	35.75
3,000– 4,000	33.14
4,000– 5,000	46.62
Over 5,000	56.42

One hundred and fifty-six families reported use of electric refrigeration. The average of the incomes reported from families using electric refrigeration was $3,241. Most of these (96.6 per cent) obtained current from a central plant. The average cost of these refrigerators (1927 or before) was $294.86 and the average age at that time two years. These refrigerators were used the year round. The average cost of operation, 54 housewives reporting, was $23.31 per year.[5]

Figures on ice consumption collected in 1927 by the American Ice Company (Per Capita Consumption of Ice, *Ice and Refrigera-*

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[5] This does not include repair service, interest and depreciation.

tion, October, 1927, Vol. 73, p. 232) showed the per capita consumption varies from 2,314.4 pounds in Florida to 26.3 in South Dakota. In analyzing these figures they suggest as causes of this variation, climate, urbanization and living habits. These figures also did not take into consideration the use of natural ice in the three states with lowest consumption of manufactured ice.

A local survey (*Journal of Home Economics,* 1929, Vol. 21, p. 667), reports from a typical town of around 3,000 homes the following:

1,100	used no ice.
10	used mechanical refrigeration.
1,751	used ice.
1,480	of these used ice 6 months or less per year.
514	used cellars.

More recent figures have been collected by state and county extension agents, showing the extent to which refrigeration is being used in rural districts.

Table 3. Refrigeration in Rural Homes

State	Study made by	Number of farm homes	Where	Refrigerator	
				Ice	Electric
Kentucky.........	Exten. Service	280	McCracken & McLean Cos.	50	1
Maryland.........	Exten. Service	70	Carroll Co.	..	..
Nevada...........	Exten. Service	Not given	Washoe Co.	..	..
New Jersey.......	Exten. Service	223	Somerset & Gloucester Cos.	53	12
North Dakota.....	Exten. Service General Fed. of Women's Clubs	583	All over State	10	1
Oregon...........	Exten. Service	132	Jackson Co.	39	13
South Dakota.....	Exten. Service	1210	12 Counties	21	9
Vermont..........	Exten. Service	439	Franklin County	28	3
West Virginia.....	Exten. Service	171	Randolph Co..	11	0
Wyoming.........	Exten. Service	536	Goshen County	..	..
Wyoming.........	Exten. Service	213	Shoshoni Proj.	43	2
Colorado.........	Exten. Service	Not given	San Luis Valley	34	Ice and electric
Washington.......	Exten. Service	Not given	Snohomish County	30	12
Mississippi........	Exten. Service	828	Hinds County	38	2
North Carolina..................		(Owned homes) 75 (Tenant homes) 50	Franklin County	(Owned homes) 48 (Tenant homes) 20	1 0

Replies to a questionnaire sent June, 1931, to a small number of Chicago families from the lower-income groups, showed that out of 139 families reporting, 102, or 73 per cent had refrigeration and 37, or 27 per cent of these families had no refrigeration.

Cooling Devices Used as a Substitute for Refrigeration

Where refrigeration has not been available, housewives have substituted various procedures to obtain lower temperatures. None of them can be considered as satisfactory for preservation of milk, meat and other foods which spoil readily. Such devices are highly desirable where nothing else is obtainable, since they are an improvement over usual temperature conditions and serve to retard spoilage somewhat and enhance palatability. Also, they can often be used to advantage to supplement a smaller space held at temperatures satisfactory for preservation of the more perishable foods.

Cellars, Springs and Wells. Springs and wells occasionally afford satisfactory temperatures, but are inconvenient and not generally available. Such means of storage were formerly frequently used for milk, but are little used at the present time.

A well-insulated cellar maintains a more even temperature than any other portion of the house and is cooler at all times of the year than the kitchen. An early step saver was the dumb waiter, which made it possible for the housewife to lower the food from the hot kitchen into the cooler cellar. Cellars may provide satisfactory storage for fruits and vegetables, but during the warm months are unsatisfactory as storage places for the more perishable foods.

In a study made of 5,450 homes in Rochester, New York, in 1912, Williams[6] found that 2,450 families do without ice the year round and depend upon the cellar or pantry to afford the proper temperature for food preservation. The temperatures of the cellar bottoms of 266 of these homes were determined in August, 1912. The average temperature was found to be 63° F. Not one

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[6] Williams, John R., "A Study of Refrigeration in the House and the Efficiency of Household Refrigerators." *Proceedings,* Third International Congress of Refrigeration, 1913, Vol. III, p. 9.

cellar was found with a temperature below 55° F. The mean atmospheric temperature for that month was 68.9° F.

Evaporation Coolers. In the hot, dry sections of this country the cooling influence of evaporation is made use of in lowering temperatures of foods and storage places. The porous jug for the cooling of water and other liquids has been used by the Indians and Spanish in the Southwest. A porous pottery dome fitted over a pottery plate has been used for cooling food. If kept moist, the evaporation of water from this cover takes up the heat from the center portion and keeps the air enclosed by the dome at a lower temperature than the surrounding air. The actual temperature decrease is determined by the rate of evaporation. The same principle is used in making a larger food storage box called a "Desert" or "Iceless" refrigerator.

This so-called "iceless refrigerator" is essentially a cloth-covered box in which temperature is kept low enough for safe food storage through the evaporation of water from the cloth under the combined influence of the dry air and the wind of the desert regions. Such coolers would not be effective in other sections of the country.

This cooler is made on a boxlike frame of the desired size. A convenient size is about 5 feet high, 2 feet wide, and not more than 1 foot deep. The top and bottom should be slatted together to increase rigidity without preventing the circulation of air. The frame is then covered with rustproof screening and cloth, Canton flannel, burlap or coarse duck. Wicks of the same material are attached to the top edge so as to connect a pan of water placed on top of the cooler with the sides. Capillary action draws the water up into the wicks over the edge of the pan and down onto the cloth sides of the cooler. Most of the water evaporates, but a pan should be provided at the bottom to catch any surplus.

The rapid evaporation of the water takes up heat from the interior of the box. On dry, hot days the temperature may reach 50°. Since rapid evaporation is important, this cooler should be placed in a shady place where there is a free circulation of air. The door should fit snugly and have rust-proof hardware.

After a study of these coolers, Ruden[7] concludes:

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[7] Ruden, W. L., "Performance Tests on Evaporation Type Coolers." *Agricultural Engineering,* November 1929, Vol. 10, p. 349.

> "If properly constructed, the evaporation type cooler will give satisfactory results in all except the humid regions. However, it is not equal to a refrigerator except in very dry regions in reasonably high altitudes where the air temperature does not get very high. Rather, it should serve as a supplement to a refrigerator in taking care of vegetable and similar foods. . . . But where ice or mechanical refrigeration is out of the question, an evaporation type cooler will serve as a fair substitute."

These coolers must be placed on a porch or out of doors to take advantage of the best conditions for rapid evaporation so are not very convenient from the point of view of the location of the storage.

Window boxes have been used in many sections as a place for storage of food during the cool months when no ice was being taken. The boxes are built across the lower portion of the window and are usually closed by a sliding door. The supplies can be reached by raising the lower sash.

The temperatures obtained in such boxes are practically the same as the outside temperature and subject to wide variations, so are not satisfactory for preservation of most foodstuffs.

Draught coolers are specially ventilated closets for food storage. They are extensively used in the West, in sections with cool outdoor temperature for all or a portion of the day. They are simple in construction and cost little more than the same amount of cupboard space. They serve for supplementary food storage during periods with high outside temperatures when refrigeration is necessary for the more perishable products, or as the sole means of cooling during several months of the year. The cooler is usually situated on the north side of the house so as to be protected from the sun, and has an opening to the exterior at the bottom and the top so as to promote a current of air from the outside through the closet. Table 4 indicates temperatures obtained in such a cooler in relation to exterior and interior temperatures.

Oregon reports extensive use of such coolers. A Washington architect reports their use in practically all houses built there, either as supplemental to another form of refrigeration, at all seasons, or for use during the cooler months, using some other form of refrigeration during the hot season. Seattle is probably unusual in the fact that only about 50 per cent of the homes use ice.[8]

Table 4.* Cooler, Kitchen and Outdoor Temperatures (° F.) Seattle, Washington, September 11-12, 1931.

	Upper cooler	Lower cooler	Kitchen	Outdoors
September 11, 1931.				
Time 6:30 P. M. Temperature...	61	64	86	60
Time 8:30 P. M. Temperature...	57	63	86	57
September 12, 1931.				
Time 6:30 A. M. Temperature...	54.5	54	77	47
Time 8:30 A. M. Temperature...	57	63	87	59
Time 10:30 A. M. Temperature...	60	63	80	60
Time 12:30 P. M. Temperature...	63.5	64	82	63.5
Time 2:30 P. M. Temperature...	64	64	77	64
Time 4:30 P. M. Temperature...	64	64	75	64
Time 6:30 P. M. Temperature...	63	63	69	63
Time 8:30 P. M. Temperature...	60	64	75	60

* Data (unpublished) provided by Martha Dresslar, University of Washington, Seattle, Washington.

The advent of mechanical refrigeration has made little or no change in the inclusion of coolers in Seattle homes of any class; they are built-in regardless of anticipated refrigeration of either the ice or mechanical type. Where there is to be refrigeration the year round, the cooler is used for vegetable and fruit storage, for odorous and semi-perishable foods, and often as a temporary storage place for hot or warm foods, especially the left-overs, until they have cooled sufficiently to warrant putting them into a refrigerator. This supplementary use is especially valuable in the case of the mechanical refrigerators.

Standards for Home Refrigerators

The housewife is primarily interested in suitable storage space at a satisfactory temperature range. Satisfactory temperatures

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[8] Of the 50 per cent using ice, 95 per cent are summer or intermittent users and only about 5 per cent use it the year round. Only about one per cent of former users of ice are reported as having installed mechanical refrigerators, taking the residence section as a whole. In the wealthy districts 20 per cent of former customers now use mechanical refrigeration.

may be obtained in home refrigerators by use of either ice or mechanical refrigeration. Satisfactory performance in either case is determined by the cabinet in which the refrigerant is used and the handling of the refrigerant in that cabinet.

The *size* of the cabinet should be stated plainly in terms of usable food-storage space in cubic feet. This is measured in ice refrigerators by subtracting from the total interior volume all space occupied by ice compartment, the baffles, any space for air ducts or any obstructions preventing use for food storage.

Usable food space in mechanical cabinets is calculated by deducting from the total interior volume the volume obtained by multiplying the over-all vertical dimension from top of refrigerator to bottom of cooling unit by the maximum over-all width of the evaporating unit, including baffles, by the depth of the cabinet. If the unit contains a chilling tray the volume of this may be added. Ice trays are not included as usable food space.

Satisfactory temperatures must be maintained in the cabinet under standard conditions of operation. The milk compartment should maintain a temperature of 45° or below and the average temperature of the food compartment should not exceed 50° at any time.

If a cabinet is to maintain satisfactory temperatures without undue cost for refrigeration, it must be of rigid construction, well insulated, with insulation held firmly in place, of such form that it will not settle, and so installed as to make it as nearly as possible waterproof.

Insulation. Cabinet efficiency depends more upon the insulation and its method of installation than any one factor. The value of the insulation depends as much upon the method of installation as the kind of insulation.[9] The tendency in modern refrigerator con-

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[9] Letter Circular No. 376 of the Bureau of Standards, October 17, 1929: . . . "an ordinary household refrigerator should have the equivalent of not less than two inches of insulation. . . .

"The question of the so-called 'moisture resisting qualities' of insulating materials merits some mention at this point, since it is an important one in refrigerator or other cold storage insulation. . . . No tests have been made at the Bureau to compare materials on the basis of their moisture resisting qualities since tests of this kind should be made on completed constructions rather than simply on the materials themselves.

"To the best of our knowledge, no commercial insulating material is in any sense waterproof or moistureproof. If immersed in water or kept in air at 100 per cent humidity, one material may absorb water less rapidly than another, but this fact is of minor importance. All the materials in question are permeastruction has been toward installation of the insulation so as to make it as nearly as possible water- and airproof, by tightness of inside and outside lining and fastening of the insulation to both walls by waterproof cement.

Refrigerators on the market giving satisfactory performance show over-all B.t.u. values which vary from 2.8 to 5.2 per square foot per degree difference in temperature per twenty-four hours. This over-all B.t.u. of the refrigerator is dependent, not only upon the value of the insulation used, but is also affected by completeness of insulation cover, channels for heat loss through wall, tightness of doors, and the type of outside and inside wall, which points must be carefully checked in refrigerator construction.

The studies show that adequate insulation, while it increases the cost of the cabinet, materially decreases the cost of the refrigerant required to maintain standard temperatures.

Construction of Cabinet. *Framing* must be rigid, strong enough to support all the materials entering into the construction of the box and the refrigerant.

The *inner lining* should be smooth, easily cleaned, with rounded corners and as nearly as possible water- and air-tight. Porcelain lining is desirable. A porcelain bottom in an enamel lining increases its length of life and efficiency. Galvanized iron linings are practically obsolete, and should be. Since lining should not absorb either odors or moisture, wood is obviously ruled out.

The *exterior covering* should be smooth and easily cleaned, should maintain original finish, and be water resistant. Experience of the past indicates that in climates where high temperature and humidity prevail, lacquered or enameled metal sheathing may deteriorate quickly and require refinishing or they may stay in good condition for several years. The preference at present is for porcelain exteriors. A number of promising new materials are being developed. The trend has been toward metal sheathing which is still in experimental stage. The above requirement should apply whether sheathing is of wood or steel.

Doors should fit tightly against gaskets held with pressure latches that hold

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ble to water vapor, and if the insulation is colder than the outside air and is not protected on the outside, most of the water vapor which diffuses into the insulation from the outside will condense and accumulate, eventually producing a more or less saturated state and lowering the insulating value many times. In a completely saturated state there is undoubtedly very little difference between the respective thermal conductivities of various commercial materials. The only remedy for this state of affairs is adequate protection on the outside by means of air-tight coatings, and when possible, vents from the insulation to the inside should be provided. The latter allow the insulation to dry out, since the inside air is colder. As a general rule applying to insulated structures, air proof the warm side and ventilate the cold side to the colder air. In no case can the insulating materials themselves be relied upon to prevent water accumulation."

securely. The better grade cabinets carry two gaskets per door. There should be a bearing surface of at least one-half inch around each door. A wider bearing surface is preferable. Doors should carry the same amount of insulation as the rest of the wall.

The *hinges* should be sufficiently strong to withstand the pressure. All hardware should be of good quality and non-rusting.

Shelves should be nontarnishable, strong, easily cleaned, and permit easy air movement. Sliding shelves are desirable for deep boxes. For stationary shelves, hooks are better than grooves. Shelf spacing should provide for the foods logically stored in each. The shelf in the coldest portion of the small food compartment should be at least 10 inches high to accommodate milk bottles. Too great a distance between shelves lowers economy of use.

Durability is important in determining cost and efficiency of operation, not only in decreasing the depreciation charge, but also the upkeep. If breathing spaces are left in the walls and the insulation slips or absorbs moisture, efficiency is lowered.

A drain is required in all cabinets for use with ice. Some cabinets for mechanical installations are so equipped with a drain to carry away the water resulting from defrosting; others depend upon a tray placed under the unit to collect this water which must be emptied. Since this tray serves to deflect air currents as well as to catch the drip during defrosting, the housewife should receive instructions as to whether it should remain in place "between times."

The *drainpipe* should be short, straight, removable, with a trap or an outside drain or plumbing connection. The box should be at least 10 inches off the floor to allow for ventilation, ease in cleaning, and access to drain when necessary. Drain should be provided in a convenient location for refrigerator using ice as refrigerant.

Cold-air Ducts and Baffles. In cabinets used with ice, adequate circulation over the ice and through every part of the box must be insured. This will not be accomplished without larger openings than have been customary from ice compartment to food compartment and larger returns for warm air to ice compartment and insulated baffles between ice and food storage compartments.

Pennington ("The Cold-air Duct in the Household Refrigerator," *Refrigeration,* July, 1929, Vol. 46, (1), p. 63) suggests that the cold-air duct should be about 25 per cent of the total area of the bottom of the ice compartment. So far we have had no grounds on which to modify the long baffle, which in the larger sizes (100-pound boxes) is usually 5 inches above the floor and 6 inches below the top.

Modern Refrigeration

Household refrigeration may have been slow in developing to its present stage of efficiency, but the progress since 1927 has been marked. Unquestionably the development of mechanical refrigeration during this period has done much to stimulate interest in home refrigeration as a whole. The situation is described by Charles H. Roe: [10]

> "When electrical refrigerators first began to be available, we saw some scrambling around within the ice industry, and presently we found ourselves rapidly becoming 'refrigeration-conscious.' The Bureau of Home Economics of the United States Department of Agriculture began telling housewives the benefits of refrigeration and how best to utilize whatever facilities they had. The manufacturers of iced refrigerators, organized into a trade association, began to ask each other what they could do about it. Someone came along with a slogan featuring 50 degrees as a danger point and immediately all kinds of tests and experiments were under way to see just what happened when a bottle of milk or a pound of beef is kept at 51° F. Architects demanded standardization of refrigerator sizes so they could build standard little cubbyholes to put them in. The ice people wanted standardization of sizes of icebox doors so standard cakes of ice would go into them. The American Home Economics Association asked for the development of methods to distinguish good refrigerators from poor ones; the National Association of Ice Industries began testing refrigerators and encouraging the building of better and better ice boxes. And in the meantime, someone had built a refrigerator operated by a gas flame. You see, the advent of the electric refrigerator stimulated the sponsors of other kinds of refrigeration to the production of better methods and better equipment. . . .
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> "In 1927, organization of domestic consumers proposed to the American Standards Association that efforts be made to bring about a better degree of standardization in domestic refrigerators. As a result there was organized a Sectional Committee (known in the ASA files as Committee B-38,) designed to develop standards for dimensions and ratings as well as to work out those methods of testing the performance qualities which would faciliate standard rating. The scope of this committee included not only iced refrigerators, but those mechanical refrigerators as well which are operated with electricity, gas or otherwise. Being a stranger in a strange land, this committee encountered various difficulties. It has struggled along so far with comparatively little of a tangible nature to its credit. It has, however, gained a lot of experience that ought to be useful to it in its further efforts. Its greatest single accomplishment is a method of testing iced refrigerators."

Dr. Williams, [11] in 1912, in connection with Rochester survey of home refrigeration facilities, had pointed out the inefficiencies of many of the so-called ice refrigerators. Starr [12] had called at-

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[10] Roe, Charles H., "Electric Refrigerators and Electric Refrigeration," *Ice and Refrigeration,* June, 1931, Vol. 80 (6), p. 473.

[11] Williams, John R., *op. cit.*

[12] Starr, John E., "First Principles in Household Refrigerator Construction," *Ice and Refrigeration,* February, 1927, Vol. 72, No. 2, p. 178-9.

tention to the danger that the popular demand for appearance, sanitation and convenience might overshadow the elements that are essential in good refrigeration, and that the prime purpose of refrigeration is "the proper and efficient preservation of short storage perishables at the least total cost, including the cost of appliance and the cost of operation." Cleanliness, sanitation and appearance, he indicates, are important, but really side issues to the main problem, which is the provision of proper temperatures. A given weight of ice has always the same cooling power. The extent to which this is made useful in home refrigeration depends upon the cabinet. As a result of the committee set-up described by Dr. Roe, not only has a method of testing been worked out, but standards have been set up for ice refrigerators, together with methods of testing and rating them. In consequence, the past five years have seen great strides in the efficiency of the cabinets placed on the market.

Ice Refrigerators

There are two types of refrigerators for use with ice. These are defined as follows:[13]

"*Side icers.* Three- or four-door cabinets in which the ice compartment door is vertical, and opens at the front of the cabinet, the long dimension of the door being vertical.

"*Front icers* (also known as "apartment type"). Two-door cabinets, in which the ice compartment door is vertical, and opens at the front of the cabinet, the long dimension of the door being horizontal."

The dimensions of these vary. The size of ice refrigerators is ordinarily stated in terms of ice capacity or amount of ice recommended. Even on this basis, there has been a wide variation in size of ice compartments for rated ice capacity, as well as wide variation in the relation of the size of the ice compartment to the total interior volume of the cabinet. This is brought out in an anonymous article in *Ice and Refrigeration*[14] and the table accompanying this.

A step toward standardization of ice box sizes was taken at a conference called by the Bureau of Standards, which resulted in

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[13] "Refrigerator Ice Compartments." Simplified Practice Recommendation, R109-29, U. S. Department of Commerce, Feb. 27, 1930, p. 1.

[14] *Ice and Refrigeration,* October, 1927, Vol. 73, No. 4, p. 231.

the Simplified Practice Recommendation for Refrigerator Ice Compartments. This suggests the capacities of ice compartments for refrigerators of different sizes as follows:[15]

Table 5. Side Icers

Ice capacity	Clear opening of door		Horizontal clear depth from inside of door to inside of rear wall
	Width	Height	
Pounds	*Inches*	*Inches*	*Inches*
25	8	12	12
50	12	16	12
75	12	20	14
100	12	23	16
150	12	23	21

Front Icers

Ice capacity	Width	Height	Horizontal clear depth from inside of door to inside of rear wall
25	12	8	12
50	16	12	12
75	20	12	14
100	23	12	16
150	23	12	21

These sizes are based upon the earlier Simplified Practice Recommendation stating the ice cake sizes.[16]

Table 6. Ice Cake Sizes

Weight in pounds	Limiting dimensions
	Inches
25	12 by 12 by 8
50	12 by 12 by 16
75	12 by 12 by 24
100	12 by 16 by 24
150	12 by 24 by 24

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[15] "Refrigerator Ice Compartments." Simplified Practice Recommendation, R109-29, U. S. Department of Commerce, Feb. 27, 1930, p. 1.

[16] "Ice Cake Sizes." Simplified Practice Recommendation, R96-28, U. S. Department of Commerce, 1929, p. 7.

The amount of food space a given amount of ice will cool is a measure of the efficiency of the box and is determined by its insulation or overall B.t.u. Pennington[17] suggests grading boxes A, B, C on the basis of the amount of food space a given amount of ice will maintain at the required temperature. On this basis the National Association of Ice Industries is now grading boxes and making them available to their distributors.

Faced with the responsibility of recommending refrigeration facilities for families of low income, in fact being asked to recommend a refrigerator for use in a house costing not more than $2,000, the committee felt that it was impossible to recommend any of the refrigerators on the market. At the most, not more than $15 could be allowed for the purchase of a refrigerator. A study of any so-called cabinets on the market within this price range indicates that not only would the cost of upkeep be higher than could be recommended for families of the low-income group (around $1,800 a year), but the temperatures too high for effective food preservation. That many families feel that they cannot afford to buy a refrigerator nor pay the price of ice, is indicated by the figures quoted above. They do not realize that the saving resulting from food storage at satisfactory temperatures would go far toward defraying the cost of ice. Since the cabinets in the price range available to them are poorly insulated, costly to maintain and do not hold the temperatures effective in food preservation, it seemed desirable to look up the possible use of the ice chest.

Ice chests are inexpensive, and have long been recognized as having a higher degree of efficiency than the cheaper refrigerator, hence further investigation of this possible solution of low temperature food storage appeared desirable.

Lanman,[18] testing two small ice "chests," one of them insulated with ¾ inch of corkboard, the other having an air space and paper in the walls, finds temperatures as follows:

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[17] Pennington, M. E., "What We Ought to Know About Refrigerators." *Ice and Refrigeration,* 1930, Vol. 29, Illus., p. 54.

[18] Lanman, Faith, "A Study of Ice Chests." *Bimonthly Bulletin 153,* Ohio Agricultural Experiment Station, Wooster, Ohio, November-December, 1931.

Table 7. Average Temperatures in Insulated and Non-Insulated Ice Chests

			Insulated chest			Non-insulated chest		
Total interior space cu. ft.	Weight of ice lbs.	Average room temperature °F.	Average minimum temp. chest °F.	Average maximum temp. chest °F.	Ice meltage per 24 hrs. lbs.	Average minimum temp. chest °F.	Average maximum temp. chest °F.	Ice meltage per 24 hrs. lbs.
3.1	25	82.6	45.8	58.9	14.4	49.5	61.2	16.1

The temperatures in the lower part of these well-insulated chests, even when the atmospheric temperature was over 80° F., fell within the range set for the holding of milk provided the period is not more than twenty-four hours, and close to that recommended for longer storage. The same may be said for meat. If supplemented by a cellar or cool closet for the keeping of hardy vegetables and fruits with heavy skins, such as oranges, grapefruit and bananas, there is provided an economical and efficient refrigeration system for the very modest home, be it rural or urban, at approximately one-half, or less, than would be the cost of an adequate refrigerator.

It was felt by the committee that even more satisfactory temperatures could be reached in these ice chests with a little more attention to their construction. Therefore, in order to be able to recommend suitable facilities for families of incomes around $1,800, specially designed and constructed ice-cooled chests have been built by one of the manufacturers and are now being tested. It has been shown that these chests can maintain temperatures adequate for the preservation of milk and meat with a minimum use of ice. It is probable that a line of these chests will go on the market, tested and approved for certain temperatures and ice consumption, just as the ice cabinets are.

When purchasing efficient ice-cooled chests, the customer should be sure that the walls contain at least one and one half inches of a recognized insulator, the inside lining of heavy galvanized iron, that a metal rack is on the floor with at least 1½ inches of unobstructed space below for air movement, and that the wall of the ice compartment located at one end is made of heavy corrugated metal extending from about two inches below the top to about two inches above the rack on the bottom. There should be a water seal on the drain.

The customer should look, also, for the nameplate of the manufacturer and a statement of the performance of the chest under test conditions.

Table 8. Food Capacity and Ice Capacity in Classified Refrigerators

Amount of ice pounds	A	B	C
	Cu. ft. food space minimum	Cu. ft. food space minimum	Cu. ft. food space minimum
100	8	6	5
75	6	5	4
50	5	4	3.5

As the amount available for purchase of a refrigerator increases, cabinets suited to the size of the family and its budget can be intelligently selected on the basis of cost, available food space, ice meltage, durability, and appearance.

The scheme of classification on which the sizes in Table 8 are predicated assume that in every cabinet, regardless of class or size, the average temperature in the space devoted to milk will not exceed 45° F.

The higher price of the box is justified both on the basis of lower ice meltage and durability. A standard box of A grade, under test in the laboratory of the Bureau of Home Economics for a period of five years, gives the same performance now that it did at the beginning of the test period.

Mechanical Refrigeration

Ice placed in a refrigerator absorbs heat by melting—changing from a solid to a liquid at a low temperature. Mechanical units operate on the principle that certain substances known as refrigerants, such as sulphur dioxide and ammonia, absorb heat by vaporizing—changing from a liquid to a gas—at a low temperature. By forcing the refrigerant to vaporize inside the chamber to be cooled, and then changing it back to a liquid outside of the chamber, forcing it to flow back to vaporize again, continuous refrigeration is possible.

During the past five years there has been considerable activity in the development of mechanical units to provide refrigeration. The earlier units were, many of them, installed in existing cabinets. The industry soon recognized that the service of its unit was largely controlled by the cabinet and in practically all jobs now intended for home installation the units are self-contained in cabinets tested by the manufacturers and the units are installed and tested before leaving the factory.

These units are of two general types, the compression type and the absorption type. In the compression type machine the refrigerant is put under pressure in a mechanical compressor run by a motor. This liquid under pressure is then carried by a pipe to a freezing unit inside the refrigerator where the pressure is reduced by a valve. As the liquid refrigerant passes through the valve, it vaporizes and takes up heat in so doing, and as a result of this cools the box. The refrigerant, which is now in the form of a gas, is returned to the compressor through another pipe and the operation repeated. Household units of this type are described by Bowen [19] as follows:

Compression Type Machines.

"The small domestic refrigerating plant includes all the elements of the larger plant but is designed for automatic operation throughout, except an occasional oiling, and the number of wearing surfaces requiring lubrication are reduced to a minimum. The expansion valve is designed to function automatically, and the starting and stopping of the machine is accomplished automatically by means of a suitable thermostat which cuts on and off the electric current to the motor as the temperature in the refrigerator rises and falls. This latter feature has given rise to the name 'Electric Refrigeration,' and by many it is believed that electricity, in some mysterious way, is directly responsible for the refrigerating, or cooling effect, produced. As a matter of fact, electricity is only the motive power generally employed for compressing the

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[19] Bowen, John T., *Household Refrigerating Plants,* Bureau of Agricultural Engineering, U. S. Department of Agriculture, (unpublished).

refrigerating gas or vapor. Other sources of power might be employed, such as the gas engine, steam engine, etc. The employment of electricity does, however, offer great advantages over any other source of power owing to cleanliness, economy in space, economy in power, better arrangement of machinery, automatic control easily and reliably obtained, less noise and easier installation and maintenance. . . .

"The function of the expansion valve of the plant is to so regulate the flow of the liquid refrigerant from the high to the low pressure side, that the desired suction pressure and consequent temperature will be maintained in the cooling coils. In large plants this is accomplished by the manipulation of a simple hand regulated expansion valve, but in the case of the household machine it must be performed automatically. . . .

"There are two popular sizes of machines on the market requiring 1/10 to 1/3 horsepower motor, respectively. The monthly current consumption for operating, based on a size which requires a ¼ horsepower motor, consuming about 300 watts per hour, assuming that the machine is operated eight hours per day for thirty days, is:

$$\frac{300 \times 8 \times 30}{1000} = 72 \text{ kilowatt hours}$$

Multiplying this by the cost per kilowatt hour, the monthly cost of current is:

Rate per K.W. hr.	Monthly cost of operation
$0.03	$2.16
0.0325	2.34
0.04	2.88
0.05	3.60
0.06	4.32
0.07	5.04
0.08	5.76
0.09	6.48
0.10	7.20

"A prospective purchaser can ascertain from the power company the cost per kilowatt hour of electric energy and from the above table estimate the cost of power for operating a household machine.

"To this must be added the interest on the money invested, depreciation, repairs, and maintenance, in order to arrive at the actual cost. While the aim has been to make the operation of these small machines automatic, and a large degree of success has been attained, they are not absolutely foolproof.

"The heat that is absorbed at the low temperature plane, that is, from the refrigerator, together with the heat equivalent of the mechanical work required to boost up this heat to a temperature plane sufficiently high to allow it to 'flow down hill' into the cooling medium, is removed in the condenser. The cooling medium employed in large machines is water, but in the case of the small household machines air is generally used. So a definite volume of air for cooling the condenser, must be available. The quantity of air required depends upon the initial and final temperatures.

"It follows, therefore, that an air-cooled machine can not operate satisfactorily in an unventilated closet or room. And furthermore, the colder the air, or the greater the volume blown over the condenser, the more satisfactorily the machine will work and the less power will be consumed for a given amount of refrigeration.

"Therefore, the machine should be located in a clean, dry, and cool place where an ample flow of cool air can be maintained over the machine and condenser. A warm kitchen is a poor place for locating the machine and should be avoided if possible.

"The number of hours that a machine will be in operation during each twenty-four is governed by the size and condition of the refrigerator, the room temperature, and the number of times the refrigerator is opened. Average conditions may be assumed to require about eight hours' operation in twenty-four.

"Assuming:

6	per cent interest on the money invested
10	per cent depreciation
4	per cent repairs, maintenance, etc.
20	per cent total

"Then if the outfit cost $250, there will be an annual charge of $50 or $4.17 per month in addition to the current consumption."

The absorption type unit makes use of a small boiler to vaporize and thereby raise the pressure of the refrigerant so that it can be changed back to a liquid at ordinary temperature. The major steps in the cycle of such a refrigerant are as follows: [20]

A solution of the refrigerant (usually ammonia in water) is placed in the boiler and heat applied. The refrigerant is driven out of the solvent as a gas under pressure and is then condensed to a liquid. This liquid flows to the freezing unit and is vaporized, taking up heat and cooling the box. The refrigerant, now in the form of the gas, is absorbed again in the solvent and flows back to the boiler.

The condenser in this type of refrigerator is water cooled. These boxes must be so located as to have a continuous flow of water. The amount of water required will vary with the temperature. In hot weather as much as 200 gallons of water may be required per day for an ordinary household size. There must be a source of heat, the more usual being gas, though refrigerators of this type are on the market which are heated by electricity, bottled gas or

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[20] Adapted from "How the Gas Refrigerator Works." *Domestic Engineering,* December 8, 1928, Vol. 125, No. 10.

kerosene. The burner in either case is located under the generator-absorber. The heat from this causes the ammonia in the liquid to vaporize, this vapor passes to the condenser, where it is cooled by the circulating water. Under this treatment the vapor is changed to liquid form and flows down into the receiver. This process continues until a sufficient quantity of the ammonia collects in the receiver. The circulating water is then automatically discontinued in the condenser and diverted to the cooling coil of the generator-absorber and the gas is automatically turned out. When the generator-absorber has cooled down to a predetermined point of temperature the liquid ammonia refrigerant commences to pass from the receiver through the expansion valve into the expansion coil. This coil is located in the unit inside the refrigerator. The evaporation of the ammonia gas from this liquid in the unit draws heat from the refrigerator and its contents. The spent ammonia gas then passes back to the generator-absorber and the process repeats itself. This type of refrigerator has fewer moving parts than any other. It does require a continuous flow of water at satisfactory temperatures and must be connected up with either gas or electricity. Ordinarily there is no flue connection from refrigerators so connected. This seems to be a debatable point and some authorities recommend that where gas-fired refrigerators are installed there should be a flue connection.

The best known of the absorption type machines was developed in Sweden.[21] The apparatus is described by Hull[22] as follows:

"Current supplied to the heating element heats the rich solution in the generator. The ammonia gas expelled from the rich solution fills the upper free space of the generator and flows through the pipe into the water-cooled condenser. Because of the cooling the hot ammonia gases are condensed to pure ammonia liquid. This liquid flows to the evaporator. There in the presence of hydrogen the liquid ammonia evaporates. Through the evaporation heat is withdrawn from the brine tank surrounding the evaporator and consequently cold is produced. The ammonia gases in the evaporator diffuse into the hydrogen, and the mixture sinks downward, because as compared to the gas mixture in the absorber it is heavy. In its downward movement it passes on to the absorber. In this vessel the gas mixture meets with the water (poor solution) coming from the generator. The liquid level in the generator is higher than the 'poor solution' pipe to the absorber; there is therefore, a continual flow of poor liquid into the absorber. In the absorber the poor solution absorbs from the gas mixture the ammonia gas and collects at the bottom of the absorber as 'strong or rich liquid,' while the lighter hydrogen free from ammonia ascends and through the pipe connecting the absorber with the evaporator, again enters the top of the evaporator.

"The rich solution is conveyed through the coils of the pipe around the lower end of the heating element and is thereby preheated so that the ammonia

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[21] A modification of the earlier machine by Gappert, using H gas in pipe connecting evaporator with condenser.

[22] Hull, H. B., *Household Refrigeration,* Chicago, Nickerson and Collins, 1927, p. 313.

gas bubbles around the pipe. These bubbles carry along globules of liquid, which thereby reach the upper portion of the generator, from which we began the cycle of operation.

"Outside the cycle of the ammonia which takes place in all four vessels (generator, condenser, evaporator and absorber) there occur in the apparatus still two other cycles. On the one hand the circulation of the water, or poor solution from the bottom of the generator, to the top of the absorber down to the bottom of that vessel as strong solution, then to the top of generator, through the thermosyphon pipe. On the other hand, the circulation of the hydrogen gas from the bottom of the evaporator to bottom of absorber and from top of absorber to top of evaporator."

As modified in this country, the mechanism is adapted for use with gas and has the following changes:

"The unit before being charged with ammonia, distilled water and hydrogen is given a careful air and hydraulic test under the most rigid factory supervision and after being charged is hermetically sealed by welding. The original charge does not have to be renewed, as there is no leakage.

"The unit is equipped with a thermostatic safety burner which automatically shuts off the gas supplied if for any reason the supply is interrupted. One of the features of the unit is that the operation involves absolutely no danger even if the condenser water supply should be interrupted for any length of time.

"Inasmuch as there are no moving parts, and being rigidly constructed, no servicing is necessary. . . . The fact that the machine is noiseless, free from moving parts, compact, economical in operation and has apparently unlimited life, cannot but make us reflect on its effect on domestic refrigeration."

The continuous type of gas refrigerator burns from 1,500 to 2,200 cubic feet of manufactured gas per month, or about half this quantity of natural gas. At the national average domestic rate for manufactured gas, therefore, the cost per month with this fuel would be between $1.70 and $2.50. With natural gas the cost would be between $.60 and $1.50. In addition to the fuel, there is water required, the cost of which would vary, depending upon whether meter or flat rates are in force. The water consumption would be between 325 and 600 cubic feet per month. To this should be added any cost of upkeep and the interest on the investment.

Selecting a Mechanical Refrigerator

In selecting a mechanical refrigerator the committee recommends that the reliability of the manufacturer is the most important point; second is the selection of the unit for which local servicing of a reliable character is available.

"The Machine.[23] Since it is extremely difficult for the layman to judge the technical points of a refrigerating machine, his best criterion is the reliability of the manufacturer and agent. Several manufacturers have been making and selling electric refrigerators for a number of years and their machines have proved commercially satisfactory. In buying a machine the purchaser should inquire how long the manufacturer has been in business, how many machines of the model under consideration have been sold, how long they have been in use, and how many are in use in the immediate vicinity or city; and he should examine into the facilities available for emergency service and maintenance work in case the machine needs attention. Ofttimes the reliability and business integrity of the local selling agent, his ability to render prompt service when needed—for example, on Sundays and holidays, as well as week days—will be of first importance in making a selection. . . . The older, better-known machines are about on a par and of equal merit.

"In the case of newer machines which have not been on the market long enough to meet the test of time, the manufacturer should be of such financial strength and business integrity as to leave no doubt of his ability to make good in marketing a new device."

Cost of Operation. The customer should observe a refrigerator cabinet of the same type during operation, and get from the dealer a statement as to temperature maintained and cost in power for operation under test conditions.

"There are in the United States today about forty manufacturers of electric refrigerators. Most of them make a variety of sizes and styles in various finishes and for prices extending over a considerable range. We find them lined with enameled steel or glass; outer surfaces of painted wood or enameled steel; mechanical units located in the bottom or at the top, open or sealed in; or, even placed down in the cellar. They have little radio dials for adjusting something or other, lights inside, and defrosting switches. They have a variety of shelf arrangements, some with milk compartments on the bottom and some at the top. How is anyone to know which one to buy or which to promote? They have different kinds of motors, with various degrees of noiselessness. Some start more frequently and some run for longer periods than others. Some have little automatic safeguards for the electrical features and some do not. How can one make an intelligent choice? It is reasonable to expect that with so many designers and manufacturers of electric refrigerators there would be differences in the amount of electricity consumed. Anyone can compare the original purchase prices, but who can say which refrigerator operates with the least cost for electricity? To many customers the operating cost is of great importance. True, much depends upon the local rate, but even knowing the rates, the information as to operating cost is of such importance and is relatively so easily obtainable, that it would seem to me to be practicable to inform the domestic purchaser quite accurately thereon. There

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[23] Miller, G. E., "Electrical Refrigeration for the Home," *Journal of Home Economics,* June, 1926, Vol. 18, p. 303.

must be differences in durability of the mechanism, too, but if information on that point is extant it is not generally available.

"Now it might be argued that *all* electric refrigerators are worthy and the household purchaser can choose the one that fits her pocketbook and matches her kitchen color scheme, and be sure of getting her money's worth. My reply is that such *might* be the case, but there is nothing to prove that it *is* so. Moreover, it is not likely that forty manufacturers will all build equally well. The fact remains that each purchaser wants the greatest value for his money and the best guide he has is that the So-and-Sos have an Antarctic and think it is all right, so perhaps he should buy an Antarctic also. (Italics Ours.)

"But there is a growing reserve of information on certain aspects of this subject. For several years past, many of the larger central station companies, members of the National Electric Light Association, have been testing electric refrigerators in accordance with the procedure established by the Committee on Electric Refrigeration in 1924–25. Upon the basis of these tests, these power companies have information as to the relative energy consumption of various makes of refrigerators, the temperatures attained inside, and something as to the capacity of the machines when operating at high summer temperatures. . . . The . . . purchaser has a right to this information. He doesn't often know how to ask for it except in the one case—every purchaser wants to know in advance how much it costs to operate an electric refrigerator." [24]

Capacity of Machine as Indicated by Time of Operation. It is of importance to ascertain that the units purchased have sufficient capacity to keep the refrigerator cabinet at the desired temperature without operating, under normal and average conditions, over fifty per cent of the time. It also should be ascertained that the unit is provided with facilities for freezing an abundant supply of ice cubes; and that information in regard to the time of freezing and the number of cubes should be ascertained before purchase.

It is to be especially emphasized that in mechanical, as in ice refrigeration, the cost of operation depends upon the construction of the cabinet and its insulation. It also should be borne in mind that the performance will vary with the food load, the frequency of opening the doors, the use of the freezing unit, the location of the refrigeration cabinet with reference to surrounding temperature, and the ventilation of the condenser if an air condenser is a part of the unit.

A quiet unit is to be desired, and a sample of the unit should be heard in operation to be sure of its performance. Wherever pos-

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[24] Roe, Charles H., *op. cit.*

sible, if a like unit has been in service, it should be examined to note influence of period of service upon noise during operation.

Refrigerant.

> "The refrigerants most commonly used in household machines are sulphur dioxide, methyl chloride, and butane. The quantity used is small and, when the equipment is properly installed, will last indefinitely." [25]

Certain of these refrigerants have such striking odors that any leakage is readily detected. Any refrigerator without an easily detected odor should have added a warning agent with a sharp and penetrating odor. The statement on the box should carry not only the name, chemical formula and amount of the refrigerant, but in case a warning agent has been added, the name and chemical formula of such agent.

The consumer should ascertain that the refrigerant employed has been approved and classified by the American Standard Safety Code for Mechanical Refrigeration, approved by the American Standards Association, and that its use in the equipment under consideration is strictly in accordance with the regulations of that code.

Multiple Hook-ups. The committee believes that refrigerating systems containing large quantities of poisonous and dangerous chemicals should not be installed in apartment houses. It is not considered good practice to use direct expansion systems in cold storage plants where large quantities of refrigerant can escape and cause damage to goods in storage. The majority of cold storage plants operated throughout the country today are using the indirect or brine system, because everyone who has had experience with refrigerating systems using piping and connections know that they are all subject to leaks from time to time. Any leak at any point would permit the discharge of the entire contents of the refrigerant in any one place. If industry has profited by discontinuing the use of direct expansion systems, real estate owners will undoubtedly find, if they are compelled to pay damages due to accidents or deaths, that it would be more profitable to install either the unit system or indirect system in their apartment houses.

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[25] Miller, G. E., *op. cit.*

Durability. As important as first cost and cost of operation is the relative durability of the automatic refrigerator. However, this is a matter most difficult of determination. It is possible to make judgments based upon life tests of the mechanical units and upon the cabinets under various adverse conditions, but there are no comprehensive data of this kind generally available. Here, as in many other cases, time is the great testing engineer, but it is always possible that ways can be found in answer to a demand, to provide reliable information on durability.

Choice of Refrigerant

In deciding upon the type of refrigerator, one must be guided by the comparative initial cost, cost of upkeep, convenience, and probable life. The availability and cost of ice must be balanced against the cost of gas, electricity, or oil, as the case may be.

Location of Refrigerator

The function of the household refrigerator is to serve as a safe and convenient storage for foods to be used in the preparation of meals. The obvious place for the refrigerator is near the center that is used in the preparation of food. If there is a ventilated pantry or store room, and it is conveniently located with reference to the food preparation center in the kitchen, this is the ideal place.

But the floor plan of many houses does not provide a conveniently located pantry or entry for the refrigerator and the housewife may prefer it in the kitchen. Obviously, more ice will be consumed, more gas and electricity will be used in a room where the temperature in the region of the refrigerator varies between 70 and 90 degrees than in one with a temperature less than 70 degrees.

An ice-cooled refrigerator is preferably located near an outside wall so that an opening may be cut through and the ice put in from the outside, and it should be equipped with a separate drain, with indirect sewer connections for discharge of ice meltage.

If the motor of the mechanical cabinet is a part of the construction and is air cooled, the cabinet should be located so as to provide adequate air circulation or the cost of operation will be increased. If the motor is separate, it is frequently desirable to install it in the basement. These cabinets may or may not be provided with a drain. The absorption type must be installed with access to both water and gas or other source of heat.

The installation of a mechanical refrigerator is a job that requires engineering skill. If the installation is faulty, the best cabinet on the market will not give satisfaction. Manufacturers and dealers are beginning to recognize this fact and are employing competent engineers to train men especially for this work. The cabinet and motor must be put in place, the electric, gas, and water connections made, and the thermostat in the unit must be adjusted. After the refrigerator is in operation it is the practice of most firms to provide "free" servicing to their patrons for three years.

Management

The care with which the refrigerator is operated has much to do with its performance.

Method of Icing. If icing temperature is to be maintained in the usual ice-cooled box the ice should be kept at not less than one-half capacity. In a study made at the Bureau of Home Economics to determine the influence of icing methods on the amount of ice [26] used and the temperatures of the cabinet, it was found that as the size of the ice decreased there was less ice meltage and higher temperatures. In boxes equipped with the Rice ice-fins,[27] the temperatures are maintained better up to the last bit of ice.

Table 9. Comparative Effects of Several Icing Methods

	One 100 lb. piece	Two long 50 lb. pieces	Two square 50 lb. pieces	Four 25 lb. pieces
Room temperature, F.°	79.1	80.1	79.0	79.2
Upper refrigerating temperature	55.7	54.8	56.2	53.5
Lower refrigerating temperature	43.2	42.7	43.8	41.7
Average refrigerating temperature	49.5	48.8	50.0	47.6
Ice melting rate per 24 hr., lb.	21.6	23.3	21.8	23.5

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[26] Unpublished data, Bureau of Home Economics.

[27] Belshaw, C. F., "Refrigerator Icing Methods," *Refrigerating Engineering,* American Society of Refrigerating Engineers, December, 1929.

The ice melting and consequent cooling effect is also influenced by the surface of the ice exposed. Table 9 from an article by Belshaw,[28] illustrates this point.

Pennington [29] recommends the following icing methods:

> "Now that the Simplified Practice Division of the Department of Commerce, acting with the refrigerating industries and the customer, has fixed the sizes for the ice door of the refrigerators and the depth (front to back) of the ice compartment, we can promulgate definite methods for the placing of the ice in a refrigerator.
>
> "If a refrigerator is properly iced, in almost every case when service is continuous, there are at least three distinct sizes of pieces of ice in the ice compartment. This is based on the rule that the quantity of ice must never be less than one-half the rated capacity of the ice chamber. First, we have the standard cut corresponding to one-half the rated capacity. This piece is symmetrical and straight sided, as all scored ice is, and occupies the center of the stage in the ice compartment. On top of this freshly cut piece is the largest piece remaining from the previous icing which has a flat base but which has melted into a more or less cone shape.
>
> "The third size is the small irregular pieces which are the leftovers from other icings. These pieces are ideal for chipping for table service, but are too often neglected because they are not easily accessible to the housewife. Therefore, they should be collected and placed in the very front of the ice compartment where they are easily reached and always in full view.
>
> "It is the increased depth of the ice compartment of the new and better refrigerators which enables us to practice such a method of icing.
>
> "These deeper refrigerators are not only a gain to the consumer because of the accessibility of the ice for chipping, but the cooling efficiency of a refrigerator which is relatively deep for its width is greater than the wide, shallow cabinets. The wider the refrigerator, the greater the size of the doors; and doors are never as efficient as the walls. The deeper refrigerator also tends to promote better air circulation."

Operation of Mechanically Cooled Refrigerators. When the electrically cooled refrigerator is installed in the home, the service men adjust the thermostat so that the temperature in the cooling unit is fairly constant. This adjustment regulates the operation of the motor. When the temperature of the cooling unit rises to a certain point, the motor starts automatically. When it falls to a certain point, the motor stops. In the gas-fired refrigerator the gas flame is controlled by a thermostat. Whenever the temperature in the food compartment rises above a certain point, the flow of gas is increased. This, in turn increases the flow of the

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[28] *Ibid.*

[29] Pennington, M. E., "Icing the New Refrigerators." *Refrigeration,* October, 1929, p. 58.

refrigerant through the coils and reduces the temperature of the food compartment.

If the mechanical refrigerator is to operate successfully, the thermostat must be in satisfactory condition. The manufacturer is responsible for equipping the refrigerator with a thermostat, and the service man is responsible for adjusting it satisfactorily. The housewife should not attempt to adjust it herself, except in those equipped with a so-called cold control.

When the refrigerator is installed, the service man gives directions for the care of the mechanism. In some makes of mechanical refrigerators the motor needs occasional oiling. In others, the mechanism is all enclosed and requires no oiling.

Defrosting. It is necessary frequently to remove the frost that collects on the freezing unit of the mechanical refrigerator, from the moisture in the air of the refrigerator; some from the air entering the refrigerator, some from the food stored there. As the air in the cabinet circulates, it comes in contact with the coils containing the refrigerant. The air is thus chilled, the moisture it contains is condensed and is deposited on the coils. Ice is a poor conductor, hence it is necessary to remove it, if the mechanism is to function properly. It is impossible to say definitely how often any one refrigerator should be defrosted. It will depend upon such factors as the relative humidity of the air, the amount and kind of food stored in the refrigerator, and the percentage of time which the motor operates.

Cleaning. The ice compartment of an ice-cooled refrigerator should be flushed out weekly and the drain flushed with a hot solution of sal soda (one tablespoon to the gallon). Whether a weekly or bi-weekly flushing is necessary depends in part upon whether natural or manufactured ice is used. If the former, and the water from which the ice is made contains dirt and other impurities, part of it probably will be deposited on the sides and bottom of the ice compartment, and in the drainpipe. Hence more thorough and frequent cleaning will be necessary. If, as is true of the supply in many cities today, the ice which householders use is manufactured from the water in the city mains, there is less probability that slime and other impurities will collect and hence the need for weekly cleaning is not so urgent.

Cleaning the refrigerator is not the ceremony it once was, especially if the cabinet is a modern high-grade one with an enamel lining. If any food is spilled, it should, of course, be wiped up at once. Once a week the trays in shelves and bottom should be washed with a damp cloth wrung out of warm water, rinsed, and wiped thoroughly with a dry cloth. It is not necessary ordinarily to remove all the food in order to do this. If the lining of the cabinet is chipped, or the finish is worn off, or there is a threshold, thus providing dark corners, more care will have to be taken.

Placement of Food. Food placed in the compartment reserved for the refrigerating unit or for ice interferes with the circulation of air. However, one model of a gas-fired refrigerator on the market is so designed that there is adequate space in front of the cooling unit to accommodate the milk and cream bottles.

Each refrigerator should be studied, the position of the down drop for cold air and the exit for warm air from the food storage compartment should be located. Presumably the coolest spot available for food storage is the shelf directly under the ice compartment or cooling unit. If there is any question, the shelf where the lowest temperature prevails can be located with a thermometer. Provided it is high enough to accommodate the bottles, this shelf should be reserved for milk and cream. If there is room, this is the best shelf, too, on which to store butter, fresh meat, meat broths, cream soups, and left-over cooked cereal. The next coolest shelf should be reserved for uncooked meats, left-overs, fats used in cooking, and table oils. In the "side icer" style of cabinet this presumably will be the bottom of the refrigerator. Eggs and mild-flavored fresh fruits and vegetables may be placed on the next shelf. The upper shelf in the side icer cabinet will be reserved for strongly flavored foods such as bananas, cheese, and cantaloupe. Then, if any odors are given off, they will be deposited on the film of water surrounding the ice and will be carried down the drain or deposited with the frost on the freezing unit.

There is less variation in the temperature on the various shelves of the "top icer" than in the "side icer" style of cabinet. But presumably the coldest space in the food storage compartment will be the top shelf, directly under the ice or cooling unit. If the down drop for cold air is in the center, the middle section of the top shelf will be the place for milk and cream. Unfortunately the space between the top shelf and the ceiling of the food compartment is frequently so low that only a half-pint bottle can stand there, and the milk must be placed on the floor of the cabinet, the shelf that is farthest from the refrigerant. However, there is less variation in the temperature on the various shelves of the "top icer" type of cabinet than in the "side icer." If there is room, the top shelf is the place for butter, meat broths, and uncooked meats. Left-over cooked foods and custards may be stored on the second shelf and fresh fruits and vegetables on the third shelf. The warmest shelf will be the floor of the refrigerator. If the ducts through which the warm air is returned to the ice compartment or cooling unit are located at either side, the outer edge of the floor will be the place for the strongly flavored foods.

The Use of Special Containers. Special containers for refrigerator use are obtainable in either glass or enamel ware. These containers are either rectangular or round in shape and have straight sides so take up a minimum of room. Frequently they come in sets of two or three with a cover for the top receptacle only. If glass is used, it is possible without removing the dish to see the kind and amount of food it contains. Some of these containers are so designed that they may be put directly on the dining table. This is particularly desirable for such foods as custards and chilled fruits.

Many people use glass fruit jars for storing food in the refrigerator. They require a minimum amount of shelf space, and if there is sufficient room between the shelves, they make very satisfactory containers for such foods as soup stocks, gravies, salad dressings, some cooked vegetables and fruits. Drinking water for table use may be kept in a covered jar in the refrigerator.

Avoid Overcrowding. For the successful operation of a refrigerator, air circulation apparently is essential. There must, therefore, be a passage way for the air. If the shelves are so crowded that the passage ways are all closed, circulation will be interfered with, the heated air cannot escape, and the temperature of the food storage compartment will go up. It is especially important that the outlet for cold air from the ice compartment and the inlet for the return of warm air to the ice compartment shall not be obstructed.

Nameplate

The committee recommends that steps be taken under the committee set up by the American Standards Association as an agency which brings together the various interested groups, to develop nameplates for both ice and mechanical refrigerators, using for rating, the approved methods of testing developed under the guidance of that committee. These plates should carry the following information:

The name on the ice refrigerator should give:

1. The correct net food volume, in cubic feet.
2. The temperature of milk compartment and average for food compartment, with statement of test temperature.
3. The ice consumed per day of twenty-four hours at 80° and 90° test room temperatures.

The nameplate on the mechanical refrigerator should give:

1. The name, correct chemical formula, and quantity of refrigerant.
2. If refrigerant contains a warning agent, the name and correct chemical formula of such agent.
3. The net usable food volume, in cubic feet.
4. The temperature of milk compartment and average for food compartment, with statement of test temperature.
5. The power consumed at above temperatures.

APPENDIX

HEATING REQUIREMENTS, EQUIPMENT AND COSTS

The data in this appendix were collected and compiled by the Group on Heating, Ventilating and Air Conditioning, to illustrate in a detailed way some of the points brought out in the report of the group, constituting Chapter III, Part III, page 114.

Table 1. Fundamental Heating Data for Various Districts of the United States

District number	Design temperature for heating system	Maximum heating requirement in per cent, 0° F. outside, 70° inside	Average heating requirement in per cent of maximum	Index number for relative amount of heat to be supplied per season
Number 1:				
Maine New Hampshire Vermont Northern New York	−12.5	118	45	126
Number 2:				
Southern New York Massachusetts Rhode Island Connecticut New Jersey Pennsylvania	0	100	44	100
Number 3:				
Delaware Maryland District of Columbia	+10	90	42	87
Number 4:				
Virginia North Carolina Tennessee Alabama Georgia South Carolina	+14	80	32	64
Number 5:				
Kentucky Missouri Arkansas West Virginia	− 2.5	103	35	85

Table 1—*Continued*

District number	Design temperature for heating system	Maximum heating requirement in per cent, 0° F. outside, 70° inside	Average heating requirement in per cent of maximum	Index number for relative amount of heat to be supplied per season
Number 6:				
Louisiana	+22.5	70	26	33
Mississippi				
Number 7:				
Ohio	− 2	103	42	103
Indiana				
Illinois				
Number 8:				
Michigan	−19	127	46	141
Minnesota				
Iowa				
North Dakota				
South Dakota				
Wisconsin				
Number 9:				
Texas	+15	80	33	54
Arizona				
Number 10:				
Nebraska	− 6	109	41	105
Kansas				
Colorado				
Nevada				
Number 11:				
Utah	+ 2	97	42	92
New Mexico				
Oklahoma				
Number 12:				
California	+40	43	42	39
Number 13:				
Florida	+25	64	18	21
Number 14:				
Montana	−23.3	130	40	118
Wyoming				
Idaho				
Number 15:				
Washington	+ 2.5	97	40	97
Oregon				

Table 2. Comparative Costs of Various Types of Heating Equipment in Per Cent of One-pipe Steam in District Number 2 Based on 0° to 70°

District number	Convection heaters and stoves	Pipeless furnace	Piped furnace	Air conditioning furnace without cooling	Air conditioning furnace with summer cooling	One-pipe steam	Two-pipe vapor	Hot water
1	20	35	65	150	250	100	125	125
2	20	35	65	150	250	100	125	125
3	17	30	55	125	225	85	105	105
4	13	25	45	100	200	65	80	80
5	17	30	55	125	225	85	105	105
6	11	25	35	100	200	55	70	70
7	20	35	65	150	250	100	125	125
8	20	35	65	150	250	100	125	125
9	13	25	45	100	200	65	80	80
10	17	30	55	125	225	85	105	105
11	15	25	50	100	200	75	95	95
12	7	25	25	100	200	35	45	45
13	11	25	35	100	200	55	70	70
14	20	35	65	150	250	100	125	125
15	17	30	55	125	225	85	105	105

Table 3. Comparative Overall Operating Efficiencies of and Fuel Required by One-pipe Steam-heating Systems with Different Kinds of Fuels in Different Districts *

District number	Hard† coal, per cent	Soft† coal, per cent	Fuel‡ oil, per cent	Manufactured ‡gas, per cent	Fuel per square foot of radiation				Per season per cent average efficiency all fuels
					Pounds hard coal, 11,500 B.t.u. per pound	Pounds soft coal, 14,000 B.t.u. per pound	Gallons fuel oil, 140,000 B.t.u. per gallon	Cubic feet gas, 550 B.t.u. per cubic foot	
1	50	45	60	80	100	90	7.0	1,250	60
2	50	45	60	80	80	72	5.5	1,040	60
3	50	45	60	80	70	63	5.0	900	60
4	40	35	50	70	65	60	5.9	1,100	50
5	40	35	50	70	85	77	5.6	1,000	50
6	30	27	40	60	55	50	3.5	600	40
7	50	45	60	80	82	74	5.8	1,060	60
8	50	45	60	80	113	100	7.9	1,500	60
9	40	35	50	70	55	50	3.7	660	50
10	50	45	60	80	84	76	5.8	1,000	60
11	50	45	60	80	72	65	5.0	950	60
12	50	45	60	80	32	30	2.3	400	60
13	30	27	40	60	30	27	2.0	300	40
14	50	45	60	80	95	85	6.7	1,100	60
15	50	45	60	80	80	72	5.5	1,040	60

* These figures are based on average conditions with uninsulated houses of good construction, but may be quite different for differences in construction, unusual weather conditions, inferior fuel or poor operation.

No account is taken of the usual improvement in construction and other usual precautions taken in the colder climates which tend to offset some of the differences indicated above for the fuel requirements in the different districts.

Efficiency for natural gas may be taken from 5 to 10 per cent less than for manufactured gas.

† Coal, hand-fired apparatus without automatic control. The efficiencies for coal, based on results with hand-fired apparatus without automatic control may be increased from 10 to 15 per cent with stokers and automatic control.

‡ Gas- and oil-fired apparatus with automatic control. Gas-fired apparatus with special boilers and most favorable conditions. Figures given for efficiencies with gas may be reduced by 10 per cent under many actual installation conditions. Conversion gas-fired jobs may run from 10 to 20 per cent higher in fuel consumption.

Oil burners with specially designed boilers may show efficiencies from 5 to 10 per cent greater than shown.

Table 4. Comparative Fuel Consumption of Different Kinds of Heating Systems in Terms of Fuel Required for One-pipe Steam System *

	One-pipe steam	Two-pipe vapor	Hot-water	Piped furnace	Pipeless furnace
Hard coal, fired without automatic control........	1.00	0.90	0.85	0.80	0.75
Soft coal, fired without automatic control............	1.00	0.90	0.85	0.80	0.75
Fuel oil, fired with automatic control............	1.00	0.90	0.85	0.80	0.75
Gas, fired with automatic control..................	1.00	0.90	0.85	0.80	0.75

* These are average figures based on good installations and reasonably accurate regulations of the fire in accordance with weather requirements. Gas-fired apparatus with special boilers or furnaces. The differentials indicated may not be realized in practice and as a matter of fact may be reversed under certain conditions. The two-pipe vapor system for instance may show no saving in fuel over the one-pipe system unless the two-pipe system is run for a considerable part of the time below atmospheric pressure.

A well vented and easily circulated system of either type may readily show better results than a poorly vented slow circulating system of the other type.

A one-pipe system with vacuum air valves may closely approach the economy of the two-pipe vapor system if properly operated.

The hot-water system will show the economy indicated when operated with water temperature in proportion to the weather requirements and when not allowed to do appreciably more heating during the night than would be effected by other systems. Hot water is very susceptible to regularity of heating and may in this way require more fuel than another system which may be allowed to heat spasmodically.

The furnace or any other system if allowed to "run away" or do an appreciable amount of overheating will not show the economy indicated. The pipeless furnace while rated as the most economical may not produce equal or uniform heating effects.

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