

AIR TESTING LABORATORY FOR THE GREATER  
ARMOUR INSTITUTE OF TECHNOLOGY

BY

CHARLES T. WALTER

ARMOUR INSTITUTE OF TECHNOLOGY

1921

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A proposed design of the air  
testing laboratory for the



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A PROPOSED DESIGN OF THE AIR TESTING  
LABORATORY FOR THE GREATER ARMOUR  
INSTITUTE OF TECHNOLOGY

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A THESIS

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PRESENTED BY

CHARLES T. WALTER

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

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JUNE 2, 1921

APPROVED

  
Professor of Mechanical Engineering

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Dean of Engineering Studies

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Dean of Cultural Studies





## FOREWORD.

In working up this proposed design for the Air Testing Laboratory of the Greater Institute of Technology the author has assumed that sufficient funds will be available for the installing of the necessary equipment to make it one of the most complete and well appointed laboratories in the country. The author has also designed the project from the viewpoint of making it a complete commercial testing laboratory as well as a research and student experimental station. In connection with this point it might be mentioned that any commercial laboratory may be an excellent student experimental station, but all student experimental laboratories may not be satisfactory for commercial work.

It should be borne in mind when reading this treatise that Air engineering is a comparatively new art; so far at least as modern well equipped experimental stations are concerned. Very little data regarding the work to be carried out in, the design and the construction of Air Laboratories is



available at the present time, and for this reason the design of such a laboratory, along necessarily theoretical lines only, must be comparatively unsatisfactory.



Less than a year ago, the board of Trustees of the Armour Institute of Technology made known to the public their plan to move the Institute from its present location at Thirty-third and Federal Streets, Chicago, Illinois, to an eighty acre tract of land which they purchase for the purpose. This late acquisition to the Institute's property is bounded on the north by Seventy-fifth Street, on the east by Salfax Avenue, on the south by Seventy-ninth Street, and on the west by Yates Avenue. This site is within a block of both the Illinois Central Railroad, and the Baltimore and Ohio Railroad. It is also within a very short distance of Lake Michigan.

As near as the author can determine it is the plan of those who are endowing the Institute to make it one of the finest and most completely equipped technical institutions in this country.

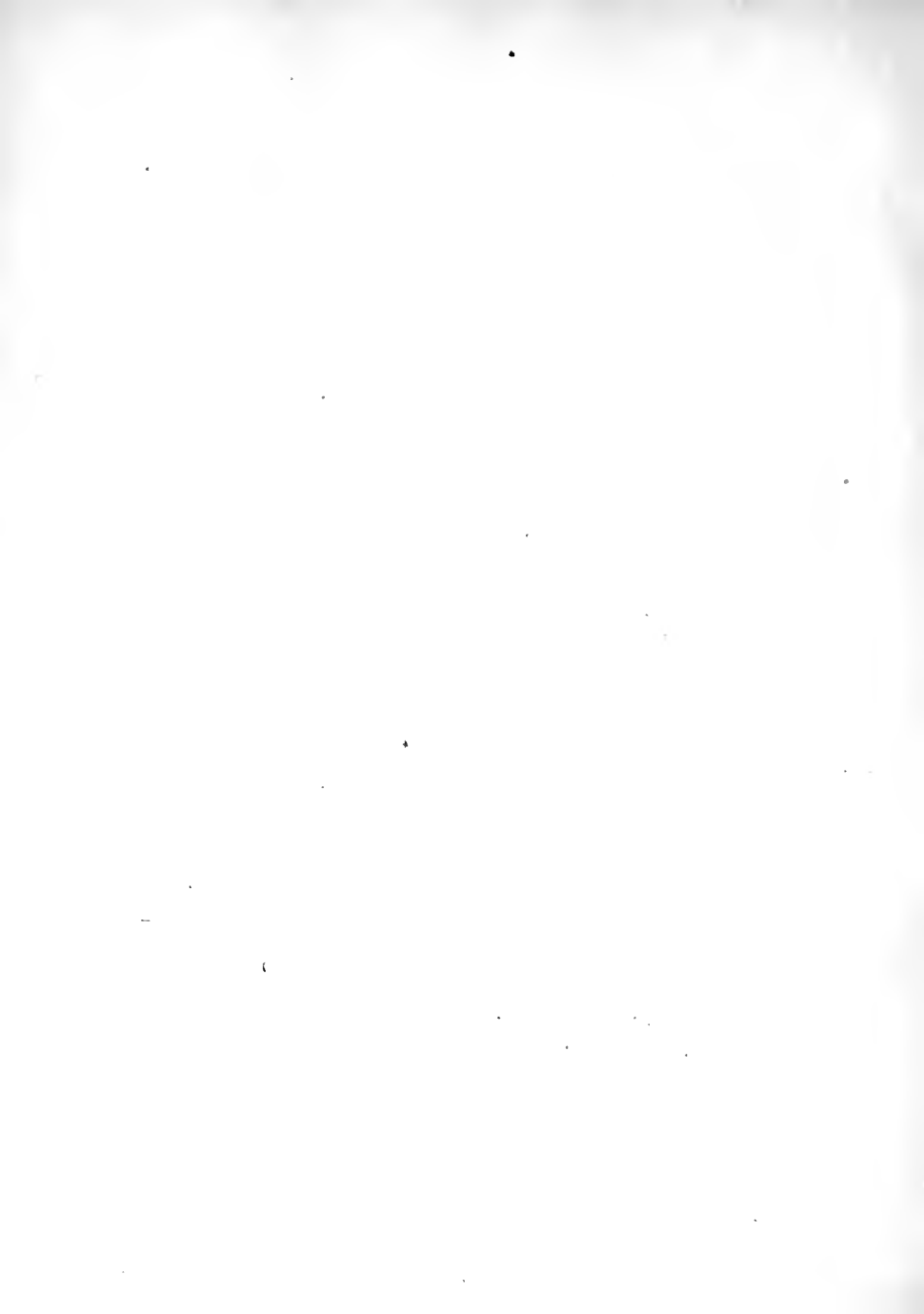
The various experimental laboratories of a technical institution represent probably its greatest side, and upon the completeness of their equipment depends the nature of the research, and



commercial work which may be carried out in them. The many State Universities throughout the country maintain laboratories, of one kind or another, which co-operate with the United States Bureau of Standards in carrying out valuable experiments and compiling valuable engineering data. There is apparently no reason why private institutions should not aid in this great work if they are given the proper equipment.

It is in the laboratory that mathematically accurate theories are tried out and modified, by unknown conditions, to practical statements; that the sometimes minute deviation between "what it should be and what it is" is sought. Surely in this day and age of the development of the arts, and the movement toward greater accuracy in the industries, too much stress cannot be put upon the refinement and completeness of equipment of the modern engineering laboratory.

Among the many laboratories of the New Armour Institute, there is to be included one in which all





experiments pertaining to the measuring of air and air flow may be carried out. It is the author's purpose, in this article, to discuss the equipment of this laboratory and submit a proposed design.

The accurate measurement of air and other gases has been receiving increased attention by engineers of both this country and Europe for the past few years. The vast quantities of natural and artificial gas consumed for power, lighting, and heating must be measured with precision, not only because of their intrinsic value, but because modern business methods demand accuracy. Blowers and ventilating fans are usually sold under a guarantee that they will deliver a certain volume of air or gas under given conditions, but often the different methods employed by the seller and the purchaser in measuring disagree and neither one has indisputable evidence that his method is correct. Other instances might be cited to show the need of more knowledge concerning the accuracy of various methods of measuring gases.



More and more of our industrial processes are being carried out under set conditions of air, temperature, and relative humidity. This is true particularly in the textile industry, the paper industry, and in industries having to do with the handling of paints and varnishes. It is probably not going too far to say that many millions of dollars could be saved each year in the United States alone, if more accurate knowledge concerning the effect of temperature and relative humidity on many of our industrial processes were available. Many of our American manufacturers who use conditioned air during any of their manufacturing steps are demanding that tests on their products be made under specific conditions of temperature and relative humidity.

The knowledge of the actual temperature and relative humidity of air, and the means for regulating these variables, is of infinite value to those engaged in the packing industry because the preservation of thousands of tons of drying meats depends upon these factors. However far



this art has progressed with the packers, they are constantly conducting experiments to determine better conditions and better methods for carrying out their purpose.

Heating and ventilating in connection with air washing and conditioning is a subject which has been receiving considerable attention in the past few years. The problem of adequate ventilation and air condition is of such great importance that special legislation is being considered in connection with it.

The question of insulation material testing may be considered as coming under the general heading of the work of the air testing laboratory. Accurate knowledge as to the heat transmitting properties of a given insulating material, or a given wall structure, under certain given conditions is probably given too little weight by the average designing engineer. The many thousands of dollars which may be saved on a single contract by the choice of the proper insulating material



more than offsets any expense and difficulty incurred in obtaining accurate information regarding its performance. The choice of a most suitable insulating material, or a proper wall structure, depends upon the accurate knowledge of its heat transmitting characteristics and also upon the consideration of its first cost, cost of upkeep, cost of losses through it, value of space that it occupies, and interest on the investment. It is fundamentally a problem in finance, but to solve it accurate engineering data must be at hand. It is only in a well equipped laboratory that this information can be obtained.

There are conditions in engineering work which render the use of Pitot tubes orifices, and other similar devices for measuring air flow, impractical. Under such conditions, the anemometer may sometimes be used to advantage. The anemometer is a delicate mechanical device having many moving parts, and is therefore subject to gross error unless frequently calibrated by





absolutely reliable means. The United States Bureau of Standards recommends that this type of instrument be calibrated on the revolving arm. It is desirable at times when extreme accuracy with such an instrument is wanted that its calibration on the revolving arm be checked by passing it through the air in a straight line. A completely equipped air testing laboratory should contain both of the above mentioned types of devices for calibrating anemometers.

Statistics from manufacturers of high and medium pressure air machinery indicate that there is an ever increasing demand for such apparatus by the industries. Many of our industries are learning to apply compressed air economically to some of their processes. The question of whether air may be applied to a given operation more economically than other forms of motive power sometimes hinges upon the accuracy of the engineering knowledge regarding the apparatus. Too much

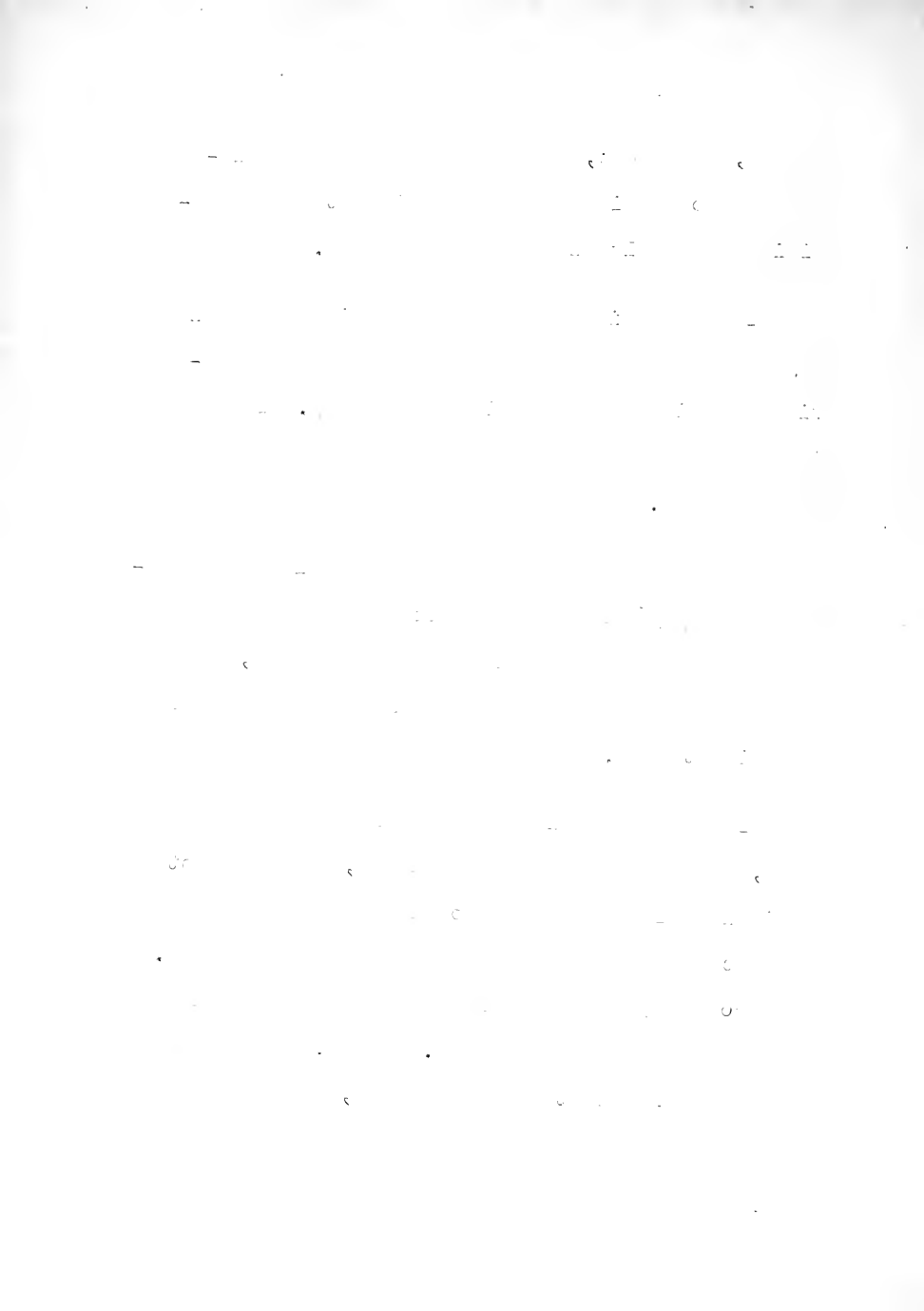


stress, therefore, cannot be laid upon the importance of having adequate equipment for determining such valuable engineering data.

The foregoing paragraphs give in a general way the nature of the work which should be provided for in an air testing laboratory. They are intended also to bring out the importance of such a laboratory.

It should be borne in mind that all the equipment in such a laboratory will be representative of the most modern development of the arts, and that all apparatus will be available for student experimentation.

The author would like to point out the fact that, to the best of his knowledge, there is not a single private institution in the country which has a completely equipped air testing laboratory. The proposed design herein submitted was developed through the assistance of Mr. Lynn E. Davies of The Armour Institute of Technology, to whom the



author feels greatly indebted. It would seem in keeping with the name of the present Armour Institute of Technology, and the names of the men more intimately connected with it, that the Greater Armour Institute of Technology be the first private institution in the country to contain a clearly defined, and completely equipped air testing laboratory.

Having given a general discussion of the kind of work to be provided for in the air testing laboratory, and before passing to the design proper, it will be well to bring out more specifically the problems to be considered. A well equipped air laboratory should be fitted with apparatus as follows:

- (a) A fundamentally correct means for measuring volumes of air or other gases.
- (b) Means for obtaining an accurately measurable air velocity in a duct for the purpose of calibrating Pitot tubes, orifices, and other forms of gas flow measuring devices.

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- (c) Means for obtaining measurable air velocities up to eighty eight feet per second in a duct of sufficient size for the purpose of testing ventilators, etc.
- (d) Means for carrying out complete tests on large, medium, and small sized fans and blowers.
- (e) Means for completely determining the performance of automotive cooling systems.
- (f) Means for tempering, washing, and humidifying air and maintaining given conditions in an isolated chamber.
- (g) Means for obtaining low temperatures (0° F) in an isolated room for the purpose of determining the heat transmitting characteristics of insulating materials and wall structures.
- (h) Means for supplying high, medium, and low pressure air for the purpose of carrying out tests on pneumatic machinery.

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(i) Approved apparatus for anemometer calibrating.

(j) Instruments for determining the pressure, temperature, and relative humidity of air with the necessary degree of accuracy.

The only fundamentally correct means for measuring directly the volume of a large quantity of flowing air or gas is the displacement or holder method. A holder of known dimensions drops a given distance in a given time, and then displaces a certain known volume of gas through a discharge pipe, at a determinable velocity, where it is again measured, by the meter to be tested. The temperature, pressure and humidity of the gas or air both in the holder and at the apparatus to be tested must be known in order that both volumes may be reduced to the same conditions, and a fair comparison thus made. With large outside containers it is a very difficult matter to obtain fair average readings of these quantities, especially of the temperature, because of the influence of the water in the holder, of the weather conditions outside,

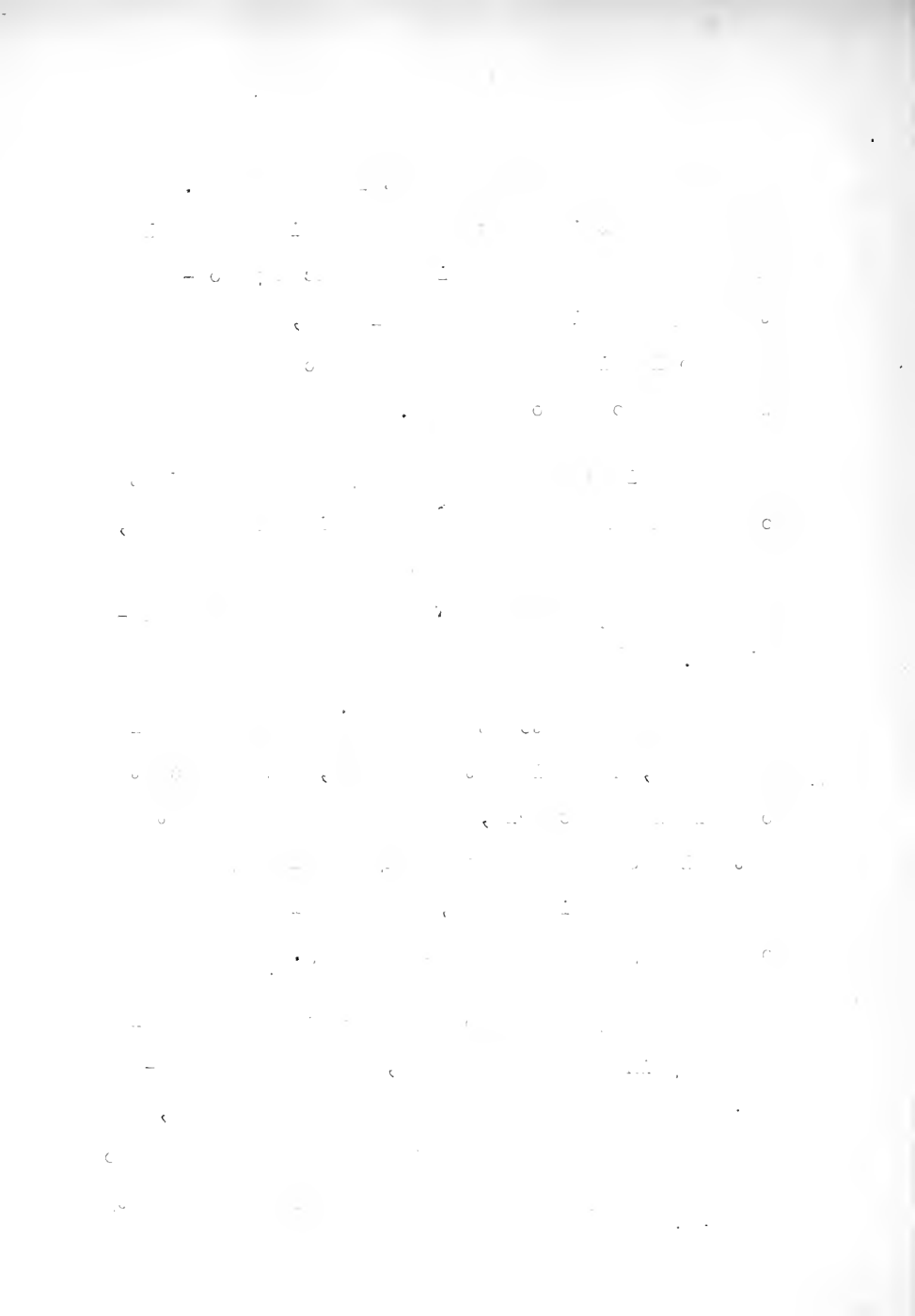


and of the large volume of gas in the holder. There are certain periods in the Spring and Fall when the temperature remains practically constant day and night for several days, and this is the only time when holder tests can be made with an approach to accuracy.

Small indoor gas holders may be made subject to careful temperature control during all seasons, and therefore the great error introduced by inside temperature variation is obviated in such installations .

It may be stated that gas holders in general are clumsy, intermittent in action, and difficult to manipulate properly, but because of the fact that holders represent our only absolutely accurate method of measuring gases, they are INDESPENSABLE to the fully equipped air laboratory.

Although the gas holder represents the final authority in gas measurements, and all other instruments must be referred to it as a standard, there are other more convenient and more satisfactory means for accurately measuring gas flow or quantity



for ordinary purposes. The Thomas meter represents such a means. When such a meter is calibrated against a gas holder its results may be taken as final authority.

As above mentioned, the Thomas meter has many advantages over the holder for ordinary purposes where it can be used, as for instance in the measurement of air flow for Pitot tubes and orifice calibration. Some of the specific advantages and characteristics of this meter are given in a treatise of the apparatus as applied to Pitot tubes calibration by W. C. Rowse. They are as follows:

- (a) "It measures weight of gas, and avoids the difficulties inherent in volumetric measurements."
- (b) "Its measurement of gas depends directly upon the specific heat of the gas. The specific heat varies but slightly with wide change of temperature, pressure, and humidity."
- (c) "Its accuracy is limited only by the



exactness of electrical measurements; such measurements can be made by engineers with a very great degree of refinement, with well known, highly developed instruments."

(d) "It has been thoroughly tested by experiments under the most varied conditions in this country and abroad, and in every instance it was proven that the meter was correct, not only in theory, but also in the actual measurement of gases."

(c) "Its operation is very simple, the readings are few and can be obtained with the greatest accuracy, while it requires almost no attention itself while in use."

The Thomas electric meter is based on the principle of heating the gas through a known range of temperature and measuring the energy required to cause this change; this measured heat is proportional to the weight of gas flowing. Electric energy is used as a source of heat as it can be





accurately measured and easily controlled. The temperature range is determined by the use of electrical resistance thermometers.

To show specifically the accuracy which may be expected from the Thomas meter, I will quote from an article on "Pitot Tubes for Gas Measurement", by W. J. Rowce, Appendix Number One. It reads as follows:

"The Thomas meter has been thoroughly tested under various conditions and as few of the tests are briefly referred to in the following notes, in order to show that it is a reliable and accurate means for measuring gases and that its use as a standard meter in these experiments with Pitot tubes was justified".

#### TESTS AGAINST CALIBRATED PITOT TUBES.

"A Thomas meter was tested by the Peoples' Natural Gas Company of Pittsburgh at their Brano Pumping Station, in a 10 inch suction line from



the gas wells to the pumps, and in series with a Pitot tube station. The latter was located a mile and a half from the pumping station where the electric meter was installed and every precaution was taken to prevent leakage in the intervening pipe line. The Pitot tube station was developed after years of experiment and at great expense. The Pitot tubes in the station were carefully calibrated under working conditions and were known to give accurate results when the calibration constants were used. A forty-five day test was run, from April 7th to June 3rd, 1911, during which period the rate of flow varied from 90,000 to 640,000 cubic feet per hour; the pressure of the gas varied from 46 to 135 pounds gauge; and the temperature varied from 45 ° to 65 °F. The results were as follows:

Total standard cubic feet of gas by	
Pitot tubes	337,546,182
Total standard cubic feet of gas by	
Thomas meter	336,732,018
Difference	814,164



Percent difference                      0.24.

A year later a test of the same meter was made without any change or adjustment whatever, and the Thomas meter was found to agree with the Pilot tubes within 0.42 percent."

#### TESTS AGAINST HOLDERS.

"A Thomas meter is used to measure in the common discharge line from the booster station of the Milwaukee Gas Light Company. The holder tests were made with the greatest care on October 13th and 14th, 1911, at a time when the temperature had remained constant during the day and night for several days. Two different holders were used. One test was made at the maximum capacity of the meter, when the gas was being pumped from the large holder through the meter at a pressure of about forty inches of water. A second test was made at the minimum capacity of the meter, when the gas was flowing from the smaller holder through the meter at holder pressure".

"The results were as follows:



Holder used	Larger	Smaller
Duration of test	2 hrs. 15 min.	5 hrs.
Total cu. ft. of air by Thomas meter at 50 in. Hg and 60°F	1,956,000	497,500
Difference	2,671	1,128
Per cent difference	0.137	0.324"

#### TESTS AGAINST WET METERS.

"A Thomas meter was imported into Germany to be used in some scientific investigation of blowers and compressors. It was tested against a carefully calibrated wet meter at the Berlin IV Precinct Gas Works under the direct supervision of their engineers, who are of recognized technical ability and who exercised the most painstaking care throughout the test. A few representative results of the Berlin test are given below:



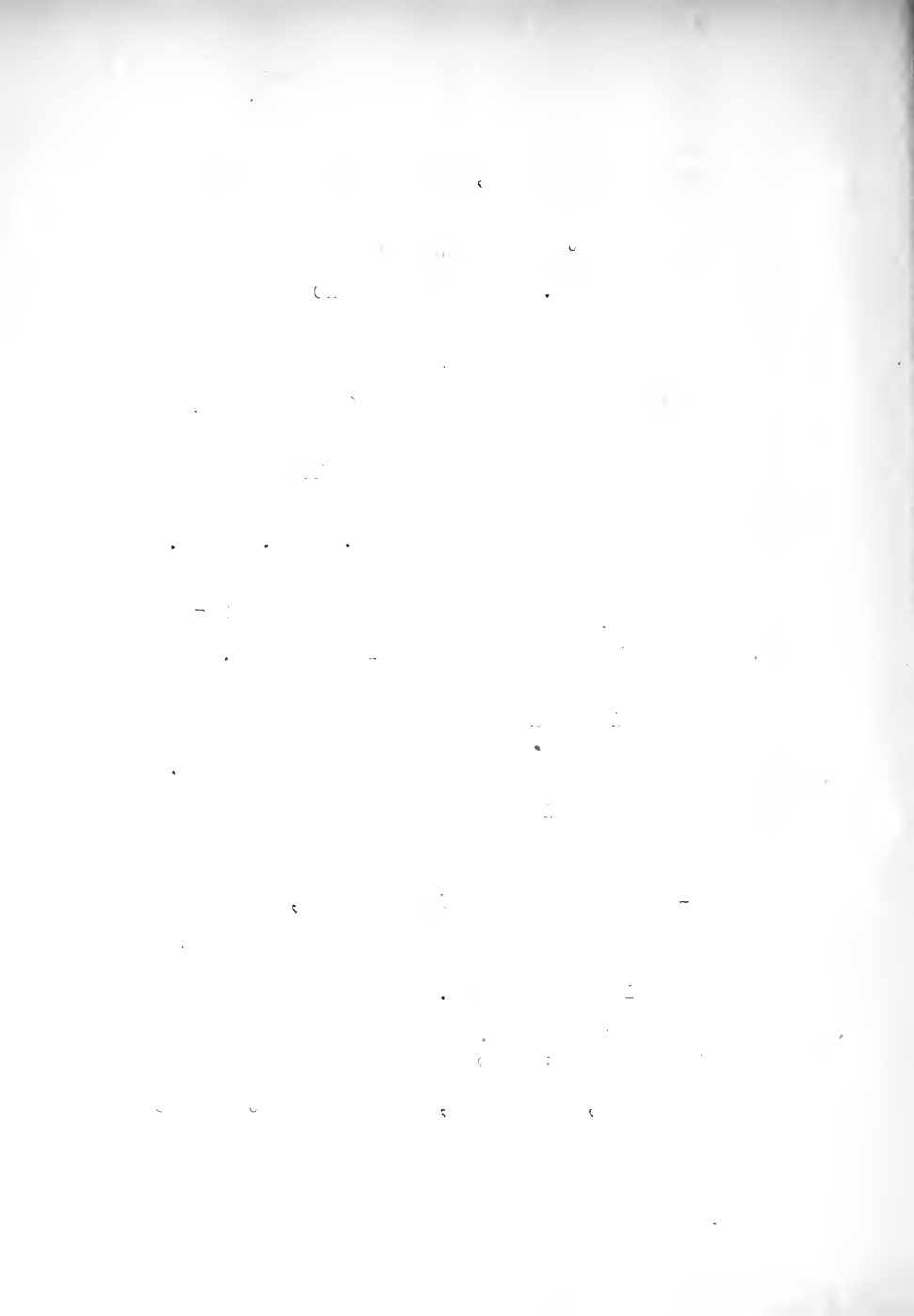


Duration of test, hours	1½	3½	3½
Cubic feet of gas by wet meter at 15.5°C and 760	5410	7111	14600
Cubic feet of gas by Thomas meter	5400	7076	14537
Difference	10	35	63
Per cent difference	0.20	0.49	0.46 "

TESTS AT THE WORKS OF THE CUTLER-  
HAMMER MANUFACTURING COMPANY.

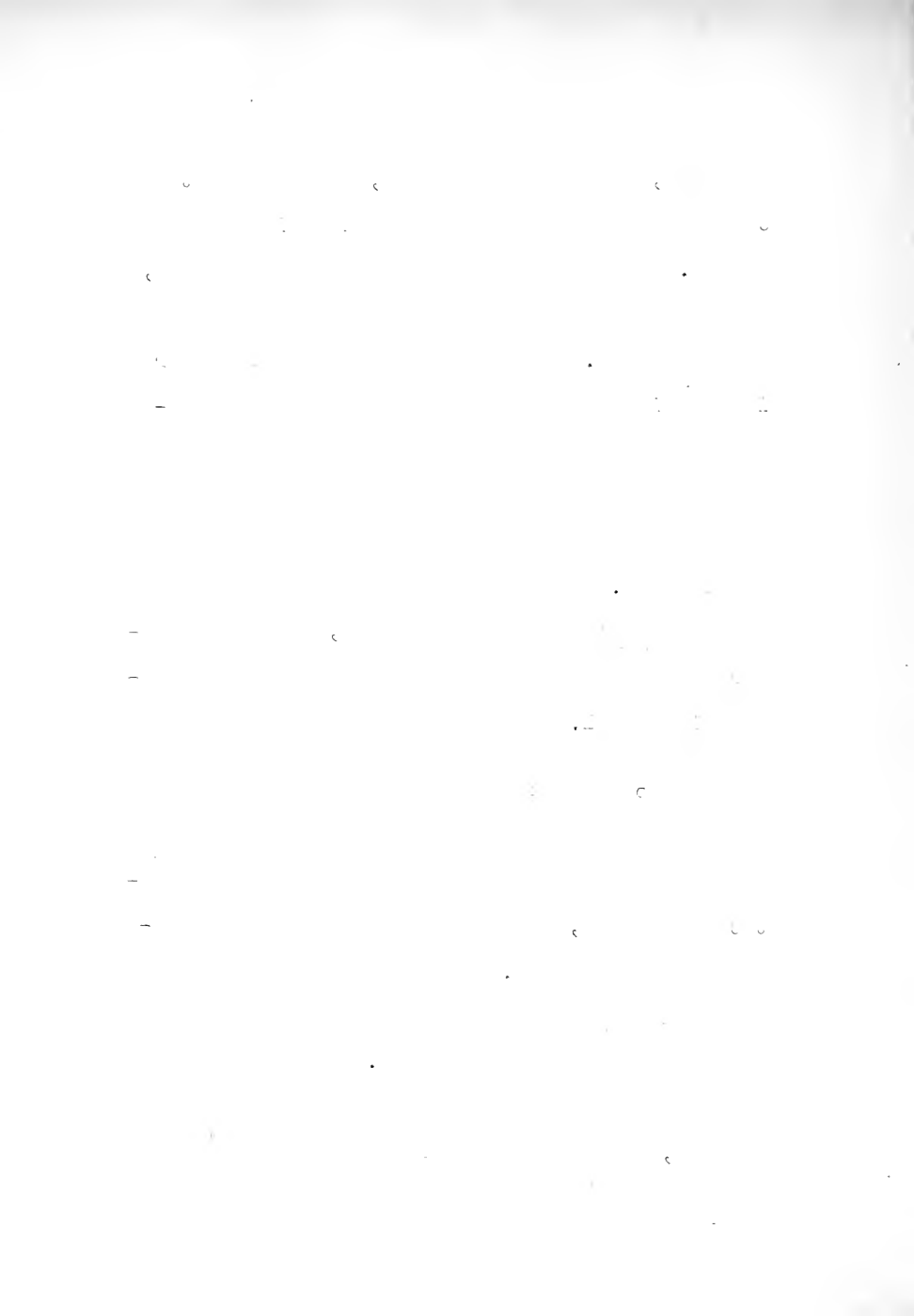
"Experimental work is constantly being carried out by the manufacturers of the Thomas meter. Two of the most interesting tests conducted there are described here through the courtesy of the Cutler-Hammer Manufacturing Company, as they demonstrate the accuracy of the Thomas meter under varying conditions."

"First test: Two automatically operated Thomas meters, one of 25,000 cubic feet per hour



capacity, and the other of 50,000 cubic feet capacity were put in the same pipe line in series. When air was flowing through the pipe, it was noted that each meter recorded the same amount of air. By means of an electric heater in the pipe between the two meters the temperature of the air entering the second meter was gradually increased until it was 60°F higher than the temperature of the air entering the first meter. The amounts recorded on each meter were meanwhile carefully watched, and it was observed that the readings still remained practically identical."

"Second test: A manually operated test meter was connected in a horizontal position in series with an automatically controlled meter in a vertical position, with a right angled bend intervening between them. This arrangement was made purposely to prevent the air passing through the two meters in the same manner. The test meter was manually operated on 110 and 220 volts direct current, and the automatic meter on 220 volt



alternating current. The automatic meter had a capacity of 500,000 cubic feet of free gas per hour. The results at different rates of flow were as follows:

9 per cent of maximum flow, error in automatic meter +0.2%.

42 per cent of maximum flow, error in automatic meter +0.2%.

81 per cent of maximum flow, error in automatic meter +0.0%.

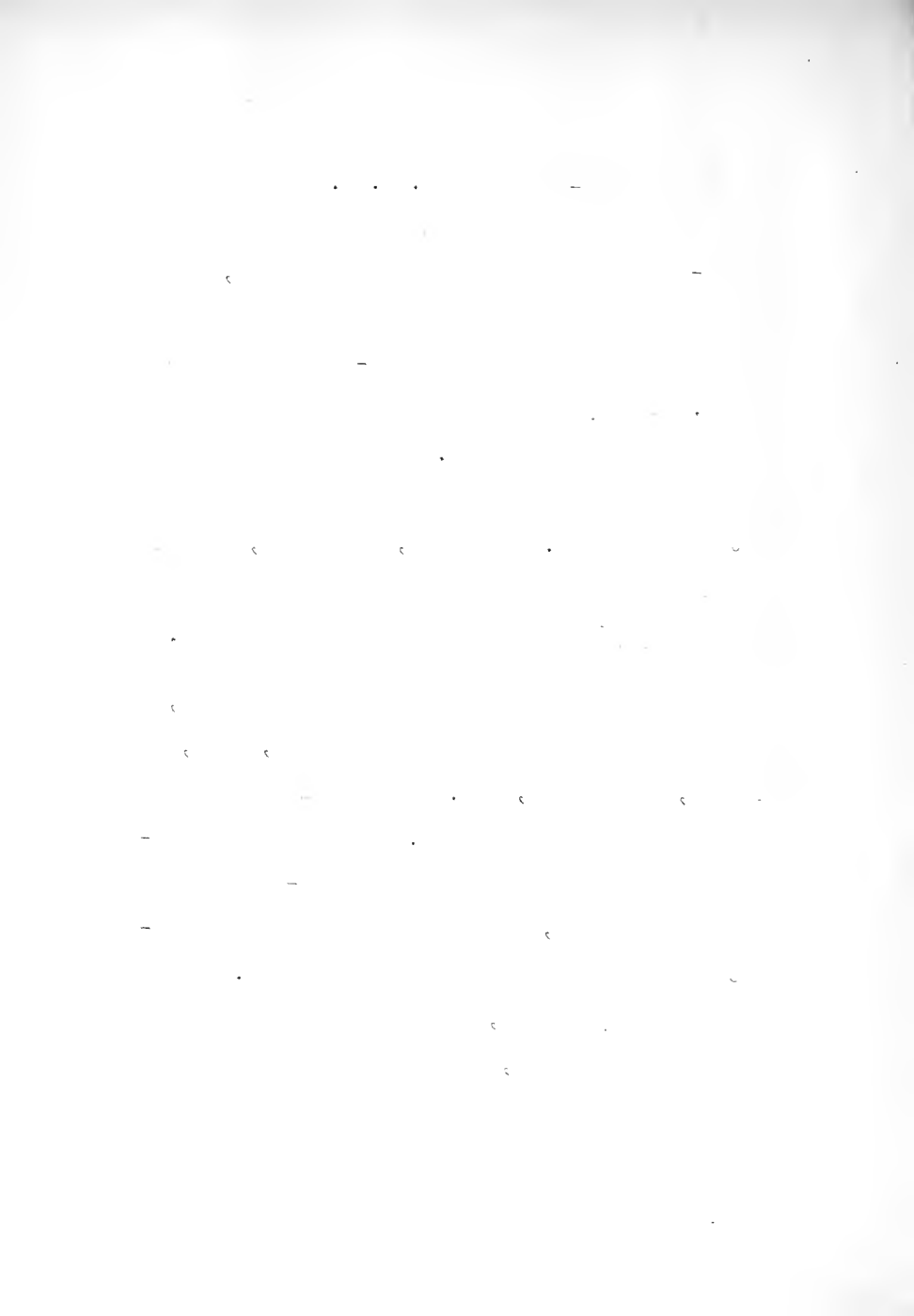
The unquestionable accuracy of the Thomas meter and the great convenience that it offers for general use make it an indispensable piece of apparatus for the carefully equipped air testing laboratory.

For the purpose of carrying out tests on large sized ventilators etc., high air velocities through comparatively large air ducts are required.



For this general purpose Mr. L. E. Davies of the Armour Institute of Technology recommends that a thirty-six inch circular duct be provided, and connected with a fan of sufficient capacity to produce velocities up to eighty-eight feet per second. The measurement of the air flow through the agency of Pitot tubes. Because of its great size and weight an installation of this kind must be permanent. The duct, therefore, cannot readily be used in connection with fans and blowers other than the one it is designed for.

For the purpose of carrying out tests on, and determining the characteristics of, fans, blowers, exhausters, etc., a special air duct and dynamometer is required. For purposes within the realm of probability a twenty-four inch circular air duct, and a fifty horse power electric dynamometer will prove satisfactory. For experimental purposes, in which great volumes of air are not required, a fan temporarily connected





with this apparatus may be used. The duct must be provided with the necessary Pitot tubes, thermometers, and psychrometer. All experimental work requiring a cross sectional area of duct of less than  $\pi$  square feet may be carried out with this equipment.

In connection with the above mentioned apparatus may be included a means for carrying out tests on automotive cooling systems. Under the present competition existing in automotive industry, great improvements are being made in all details. This improvement has not been unmarked in the case of the automobile radiator. Much experimenting has been going on in connection with the structure of such radiators, and exact engineering data regarding the performance of different structures is in demand. It is, therefore, desirable that a convenient means be available for securing such data. The most general object sought in the testing of auto-



mobile cooling systems is determining of the head dissipating characteristics of the device under varying conditions of air speed, air temperature, water temperature, and velocity.

Probably the most convenient apparatus for making such determinations consists of a truck, which may be set up in front of a suitable side duct, having mounted upon it a means for securely mounting a radiator, and a nozzle for conducting the air stream to the fan for said radiator. Also an over head water heater for supplying a stream of hot water, through the proper hose connections, to the radiator. The air nozzle will contain sufficient Pitot tubes and thermometers for carefully determining the air velocity and temperature.

The Webster Atmospheric Corporation of Philadelphia, Pa. are specialists in the manufacture of air washing and humidifying apparatus. From their catalogues it appears that they make several types and sizes of apparatus for commer-



cial use. In spite of the great amount of general information available in their catalogue, the author has been unable to choose a machine to suit the purpose of our requirements. The company is however in a position to furnish any special purpose machinery that we may need. The details of the equipment recommended by the company's engineers not being at hand, the author is merely allowing ample space in the final layout of the laboratory for its installation.

The author recommends the use of the Webster System of Automatic Humidity control because of the fact that it is simple, accurate, and scientifically correct in principle, being based on independent control of the dry and wet bulb temperature of the conditioned air, through the use of ordinary thermostats, with which all operating engineers are familiar.

For refrigeration work, such as used in



insulation testing, means must be provided for accurately regulating the temperature in the cold room, and for quickly dropping this temperature when necessary. For service of this kind the direct expansion refrigeration system comes nearest to the ideal. To give the necessary temperature control in a room of the size to be used in this case; ninety feet, by forty-five feet, by twelve feet a five ton refrigeration machine will probably be required. Given a machine of this size great flexibility should be obtainable.

Because this installation will be extensively used for commercial work, and because when in use it will be operating for days at a time, the compressor should be electrically driven, and all control should be automatic as possible. Quietness of operation is a condition to be sought in this particular case, and the simplest way to get this is through the electric motor.

While there are many ways of arranging the





expansion coils in a system of this kind, probably the most simple and satisfactory scheme is to distribute the pipe along the side walls of the room and near the ceiling. For this installation four thousand linear feet of two inch pipe will be required. This amount of pipe distributed as have suggested and spaced five inches on centers will require a depth of ten feet. Four expansion valves, two for each side of the room should give the necessary flexibility of control.

The problem of anticipating the probable requirements of the New Institution for compressed air is one which neither the author nor Mr. Davies has been able to satisfactorily solve. The question must seemingly remain open until such a time as the further plans for the Greater Institution are developed so that a logical solution is possible. Keeping this point in mind, the author is allowing sufficient space for the accommodation of two medium size air compressors. Provisions are also being made for the installation of air storage tanks. These tanks are to be suspended from the



ceiling structure in order to leave more free and clear floor space.

The author wishes to submit the following proposal for the design of the Air Testing Laboratory for the Greater Armour Institute of Technology. The laboratory shall contain the following equipment:

(1) One gas holder of fourteen thousand cubic feet capacity, having a diameter of thirty feet, and a drop of twenty feet.

(2) One Thomas meter, having a capacity of not less than fifty thousand cubic feet per hour.

(3) One Number Eleven Turbo-conoidal Fan (type T) made by the Buffalo Forge Company, to be direct current variable speed motor, and also connected to a thirty-six inch diameter by thirty-six feet air duct. Motor control board to be placed as indicated on drawings.



(4) One Number G<sub>1</sub> Niagara-Conoidal Fan (Type N), also of the Buffalo Forge Company, to be direct but removably connected to a twenty-five horse power direct current electro-dynamometer, and also removably connected to a twenty-four inch by twenty-four foot circular air duct.

(5) One overhead steam water heater, for the purpose of supplying hot water for air cooled water cooler tests.

(6) One truck carrying an adjustable radiator mounting and air nozzle for testing radiators and the like.

(7) One blower, having a set of interchangeable blades of different characteristics, permanently connected to an electric dynamometer, and fourteen inch air duct.



- (8) One special Webster Air Washer and Humidifier, connected directly with a ninety by forty-five foot room.
- (9) One ninety by forty-five foot insulating testing room, to be refrigerated by a five ton twin cylinder, C. P. vertical ammonia compressor, Type M, electrically driven.
- (10) One high and one medium pressure air compressors of capacities and pressures to be determined later.
- (11) Air storage tanks for above compressors.
- (12) One Westinghouse Locomotive Air compressor.
- (13) One rotating arm anemometer calibrator.
- (14) One "straight line" anemometer testing mechanism.

The above mentioned equipment is to be placed as shown in the accompanying drawings.





The gas holder must necessarily have its base extending down into the basement; below the level of the laboratory floor, and it will extend upward through the first floor above it. This construction is clearly shown in the section drawing.

The two large size blowers must, because of their bulk, be placed in a pit below the mean floor level in order that the air ducts may be located a convenient distance from the floor. This arrangement is also shown in the sectional drawing.

The placing of the remainder of the equipment is clearly shown in the plan view of the laboratory. In arranging this apparatus, the greatest care was taken to place it so as to afford the greatest economy of space, and at the same time keep all equipment for one experiment entirely independent of that equipment adjacent it. Careful consideration was

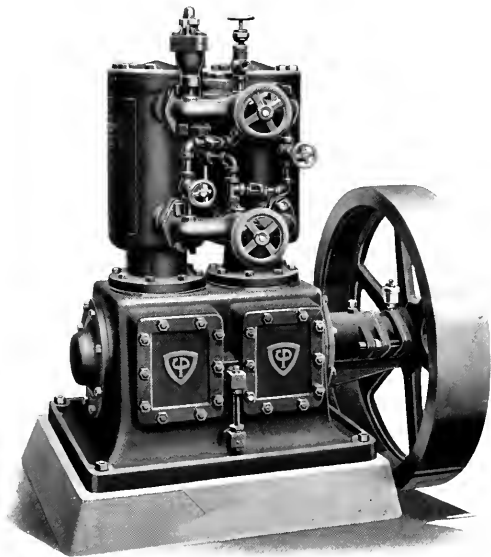


Given also to the allowing of proper spacing between mechanisms so as to facilitate working on any apparatus.

In the layout of this laboratory no floor supporting columns are shown. As no information regarding the probable design of the buildings proper was available, the author simply assumed eighteen foot bays and made the design flexible enough to permit of any likely changes which may be made necessary in adapting it to the architect's final design.



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*Twin Cylinder CP Vertical Compressor  
Type M*

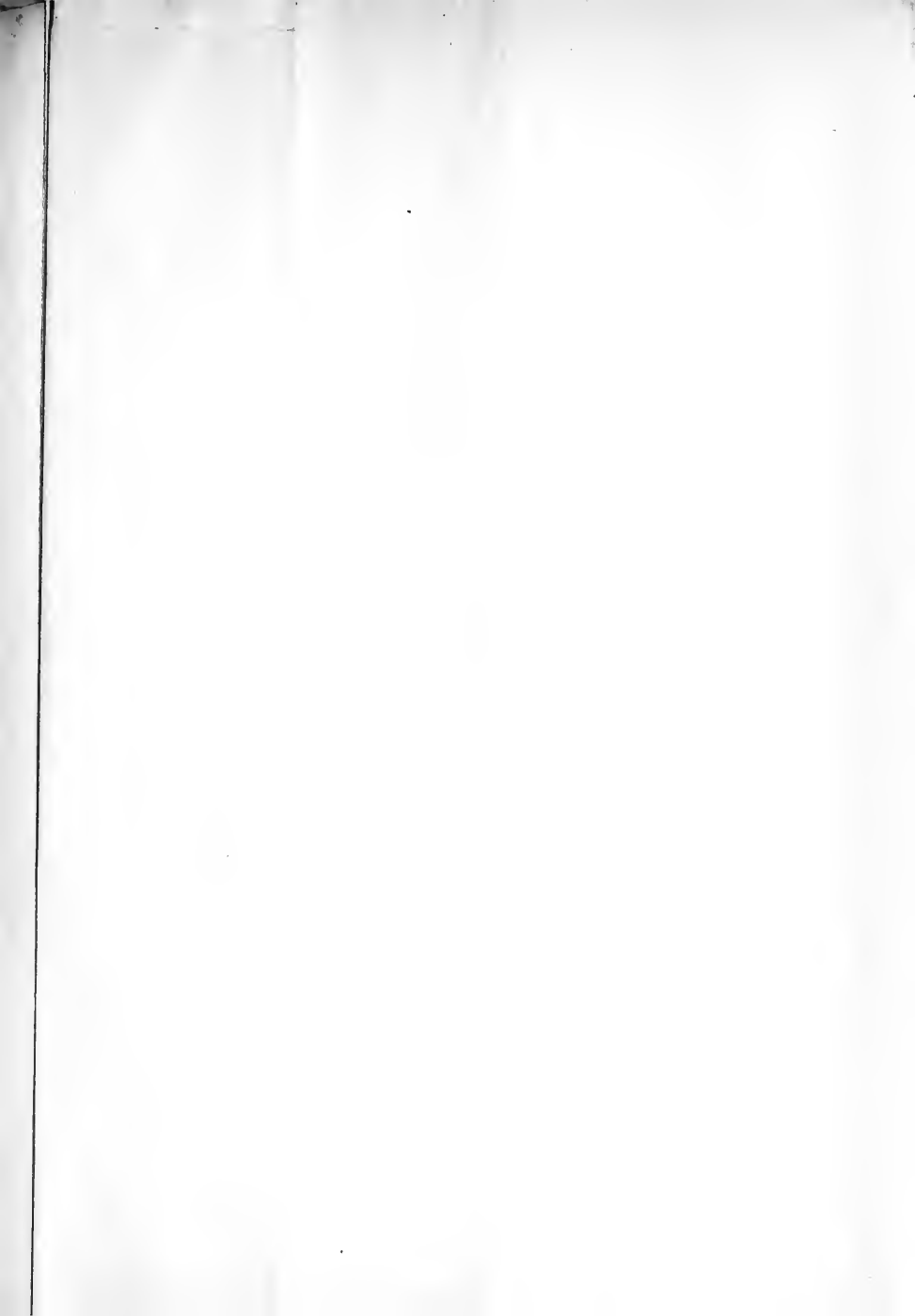
**T**HE Type M Vertical Compressor is made in 5 and 6-ton sizes. It is built with two cylinders, each cast separately. This machine is conservatively rated and will do long and faithful work even under unfavorable and severe conditions.

Unless otherwise specified, frame is regularly finished in English Vermilion.

All *CP* Compressors with separate cylinders can be furnished with two suction connections for producing refrigeration with increased efficiency when different temperatures are required for different cooling rooms. Other manufacturers need two compressors for supplying sufficient refrigeration in such cases.

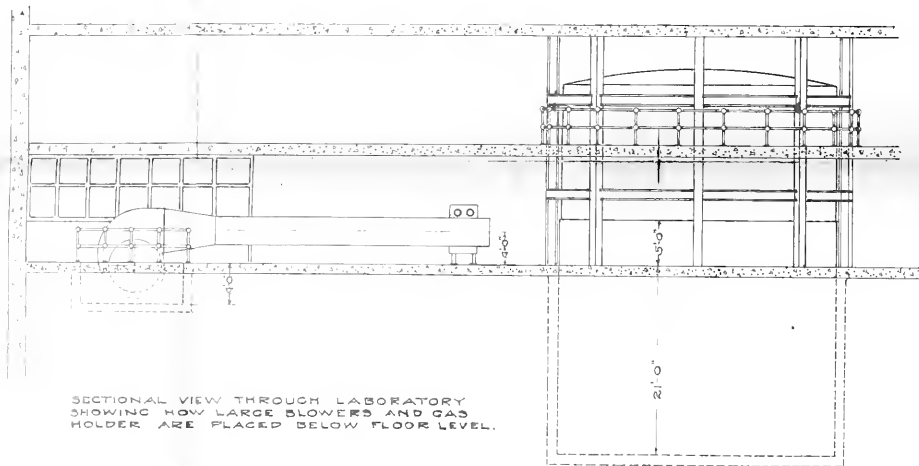
This machine may be equipped with electric motor and automatic control at extra cost.





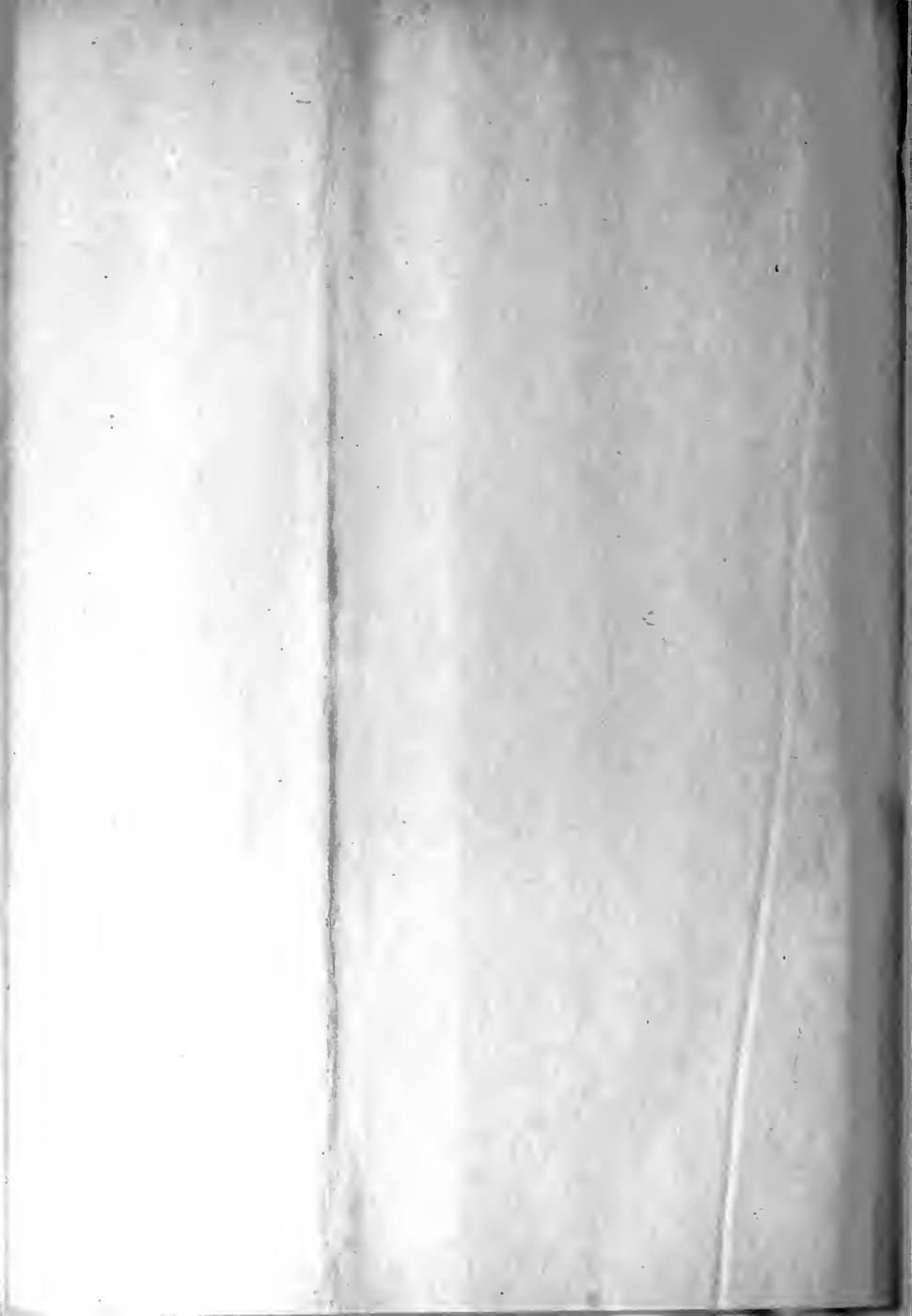


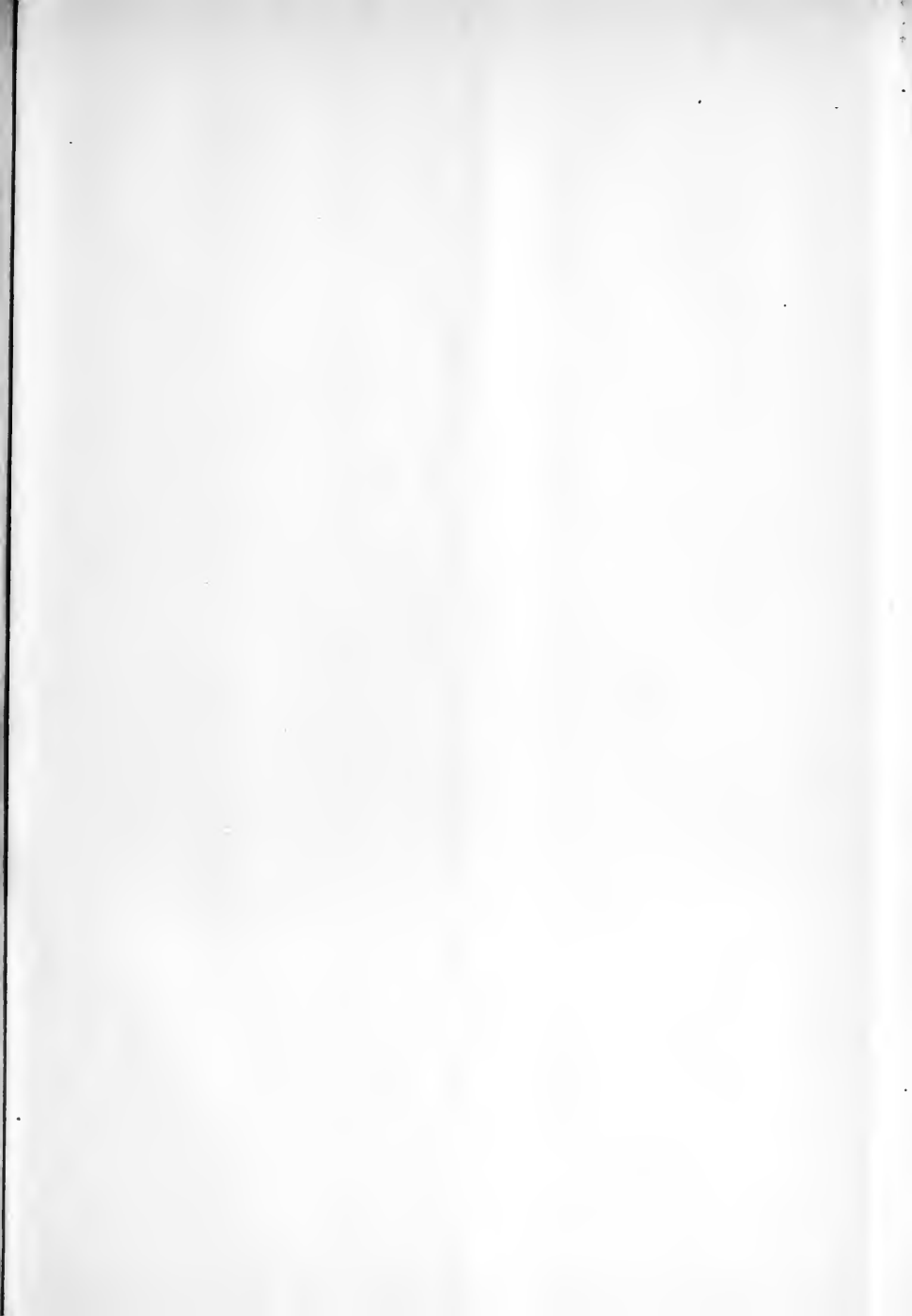




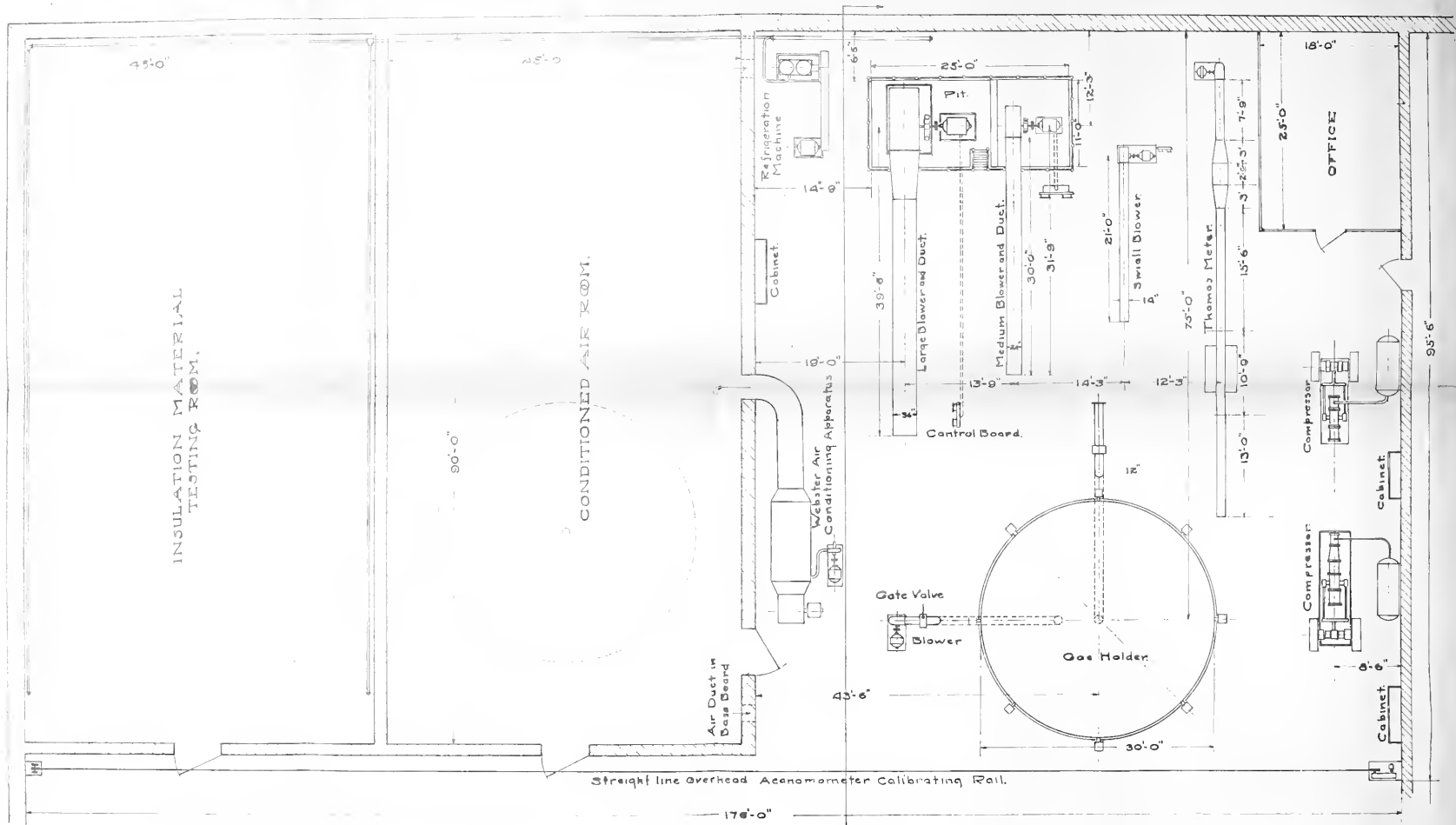
SECTIONAL VIEW THROUGH LABORATORY  
 SHOWING HOW LARGE BLOWERS AND GAS  
 HOLDER ARE PLACED BELOW FLOOR LEVEL.

SECTIONAL VIEW  
 THROUGH  
 THE AIR TESTING LABORATORY  
 FOR  
 THE GREATER ARMOUR INSTITUTE OF TECHNOLOGY.  
 Scale:-  $\frac{1}{8}"=1'$ .









PLAN VIEW  
 OF  
 THE AIR TESTING LABORATORY  
 FOR  
 THE GREATER ARMOUR INSTITUTE OF TECHNOLOGY.  
 Scale:  $\frac{1}{8}'' = 1'$ .









