A COMPARATIVE TEST OF STEAM PIPE COVERINGS.

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To those unfamiliar with it, the subject of protecting steam pipes and heated surfaces from loss of heat must necessarily seem of small importance, for they are unaware of the great amount of heat that is lost from bare surfaces and the large proportion of it that can be saved by the use of a good covering. The average steam plant owner does not have this loss directly impressed upon himself. He may know there is one but he cannot easily determine its magnitude hence takes no precaution to arrest further loss.

In some few situations where fuel is very cheap, and for certain classes of work it may happen that coverings would not be desirable; yet wherever the economical production and use of steam is of importance a good covering will prove one of the best investments that can be made. Its use in certain cases becomes necessary apart from any saving that would ensue where the radiation from bare pipes would make an engine room unbearable.

Granting that coverings would prove a good investment, the would be purchaser is confronted by scores of manufacturers, making coverings of all conceivable materials and combinations of them supposed to have some insulating value. Each maker of coverings claims that his is the best and brings fourth a report of some test in which his product shows the greatest efficiency of those tested. In most cases these results are open to question, being sometimes made by interested or at least not entirely unbiased persons, and in others due to defects in the methods of apparatus employed. The manufacturer never tests his covering except in competition with poorer ones. In some cases, while the results are perfectly reliable, the tests were made several years ago, in two instances fifteen and seventeen years, and the coverings have not been subjected to comparison with ones of later and perhaps improved manufacture.

A test of a certain English Covering was made by an evidently non-technical man. An outdoor line 1500' long of 1 1/2'' pipe was covered with this composition to a thickness of 1". Steam was admitted at one end of the pipe, and a pressure gauge was attached at the other. The test was made by suddenly raising and lowering the pressure at the boiler end of the pipe and watching the guage at the other to see if it followed the change in the pressure. No measurement of the condensation was made. The experimenter concludes as follows. "The present trial proves to me again that with a good non-conducting composition it is quite possible to carry steam through narrow pipes in the the open air without any important loss of pressure and consequently almost no loss of fuel. It proves to me also again the correctness of my theoretical starting point, that for a given condensing surface the amount condensed is the same whether the steam submitted is at a high or low pressure." Comment is superfluous.

At another test experiments were made on the following materials applied to a 5" pipe. [1]Clay, dung, and vegetable fibre paste; [2]fossil meal and hair paste; [3]fossil meal and asbestos powder; [4]paper pulp, clay and vegetable fibre; [5]paper pulp alone; [6]asbestos fibre wrapped tightly; and [7]coal ashes and clay paste wrapped with straw. While these compositions may be fair non-conductors their practical value for pipe coverings is doubtful.

On account of the conflicting claims by different makers it was thought desirable to institute a series of tests of pipe coverings now on the market. The following is a brief description of the tests now completed.

Former Experiments.

A short review of the work done along this line by former experimenters may be of interest. In 1881 or 82 Mr. Chas. E. Emory made tests of different non-conductors but we do not know if he included pipe coverings also.

The first covering tests we have any record of were made by Professor J. M. Ordway at the Massachusetts Institute of Technology in 1882-3. He experimented with various methods. The first was to encase the pipe and covering in an insulated box in which a thermometer was inserted and to observe the rise of temperature in the box during a given time. The inverse ratio of the temperature attained by different trials in the same length of time was supposed to indicate the relative excellence of the coverings. He then tried the condensation method or determining the amount of heat lost by the steam condensed. This he says is indirect and therefore uncertain. It necessarily assumes that the pipe is filled at all times with dry steam. And besides the covering to be tried with the pipe it covers, there are the cap and other fittings which will lose heat in spite of any covering that can be applied, and the gross results must be corrected for this condensation.

He finally selected the calorimeter method as being direct and absolute. In this a tin case containing a known weight of water clamps around the covering. The amount of heat radiated into the water is determined from its rise of temperature. With this apparatus he made many experiments and obtained some valuable results. He also used an apparatus for testing loose substances consisting of a steam heated plate and a tank of water, a layer of the material to be tested being placed between the steam plate and the water tank. The whole was inclosed in an insulated box.

The next tests we have record of were made by Mr. Geo. M. Brill of Syracuse, N. Y., in 1895. In these tests about 60' of standard 8" wrought iron pipe was suspended where it would not be subjected to

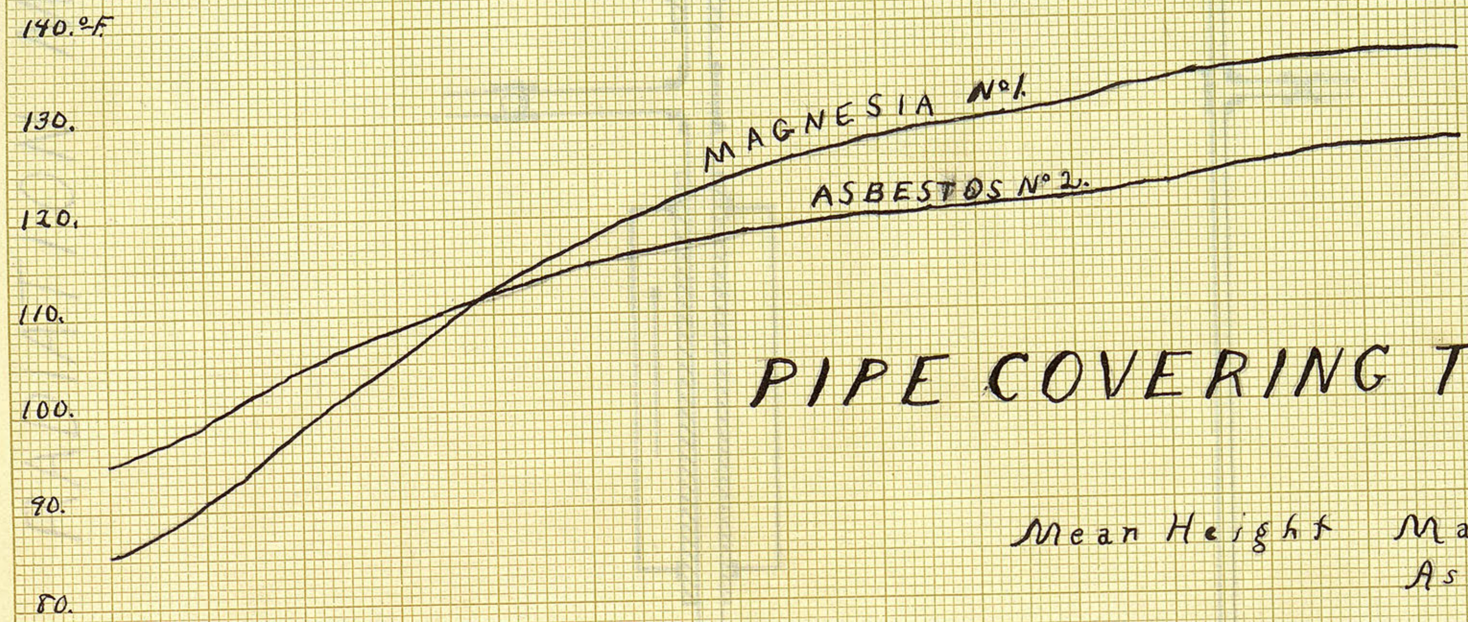
~~10~~ currents of air. The steam was admitted through a separator and its quality was tested by a throttling calorimeter. The pipe has a slope of 1' which caused the water of condensation to collect in a receiver 4' long by 12" diameter. These tests were made upon such a scale with sufficient care and in a manner to insure accuracy in the results obtained. In 1895 and later in 1898 Professor C. L. Norton continued the tests instituted by Professor Ordway. His method comprises a vertical section of steam pipe heated electrically from within by means of coils of wire in oil. The oil is stirred vigorously and serves as a very efficient carrier of heat from the wires to the pipe. Enough current is applied to keep the pipe at a constant temperature, and just equal the heat lost by radiation, conduction and convection. This can be determined by measuring the electrical energy supplied, the amount of heat furnished by the electrical method being capable of more accurate determination than that obtained by the condensation of steam.

In 1899 the Atlantic Refining Company of Philadelphia made a test including six different coverings. They used a 60' length of 4" wrought iron pipe, and determined the heat lost by the condensation.

Another series of tests, though not directly of pipe coverings, has been carried on by the Nonpariel Cork Manufacturing Company of Bridgeport, Connecticut. They use a chamber of known radiating power with one side constructed of the material to be tested. The chamber is heated internally by electricity and is inclosed in a room held at a constant temperature by means of a refrigerating machine. While established primarily for the purpose of testing cold storage insulations they also test pipe covering materials.

METHOD.

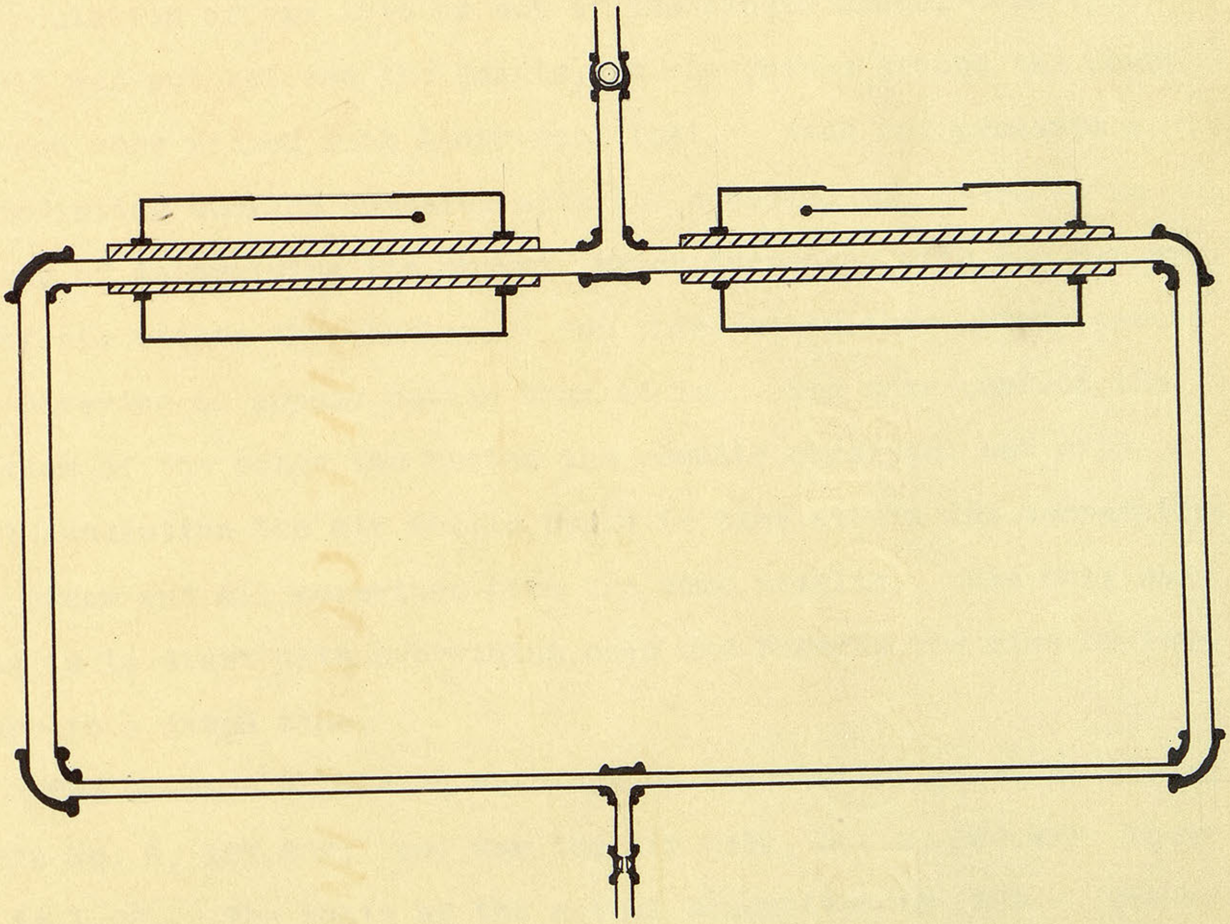
The first used was the direct radiation method. Two pipes with the coverings to be tested were inclosed in two similar boxes.



PIPE COVERING TEST.

Mean Height	Magnesia	127.8
	Asbestos	120.4
	Ratio	1.06

RADIATION METHOD.



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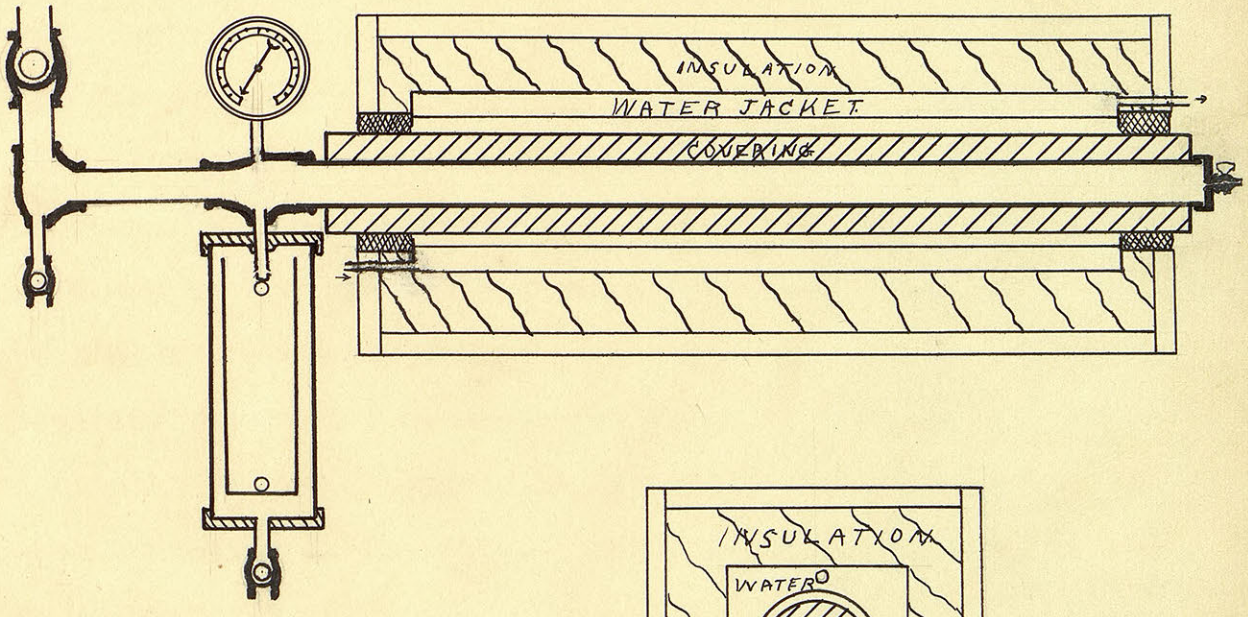
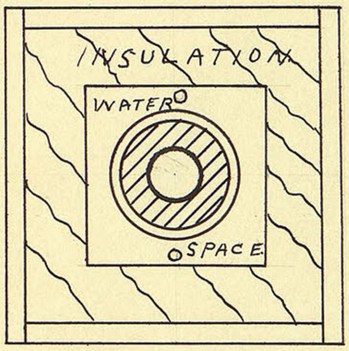
Steam was let into the pipes and readings taken every five minutes. The comparative efficiencies of the coverings varies inversely as the rise of temperature in a given time. This method has little to commend it. It is difficult to fit the boxes so closely as to prevent circulation of air into or out of the closed space. In this case felt was put between the joints, and the joints around the cover at the end were packed with heavy wool felt. Each box presents a large radiating surface compared with the covering and there is no ready way of determining its amount, which increases with the temperature of air within the chamber. For this reason this method causes a poor covering to appear better than it is. The more perfect the insulation of the boxes the better the results obtained, but with perfect insulation the air inside would in time attain the temperature of the steam and all coverings give the same results. The only useful way is to start with everything cold and observe the rise of temperature in a given time.

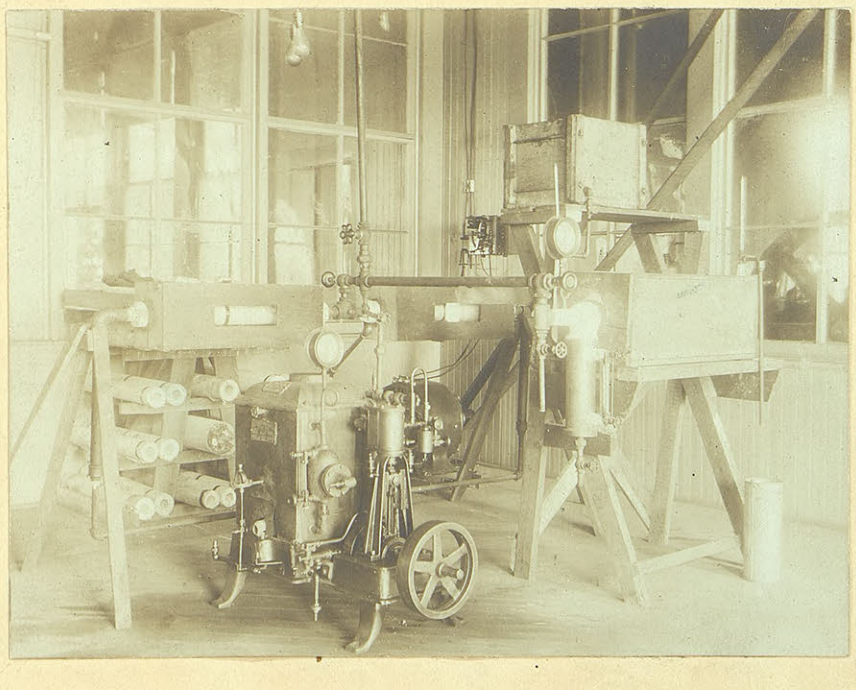
The average of eleven readings by this method gave for the Magnesia No. 1, 127.8°F; and for the Air Cell, No. 2, 120.4°F. Their ratio is 1.06. The ratio of the actual conduction is .332 - .274 or 1.22. The difference between the ratios 1.06 and 1.22 shows that this method does not even give good comparative results.

The method finally adopted was as follows. A measured amount of water flows through a jacket around the pipe and the covering. Its rise in temperature is noted. From this we find the number of B. T. U. absorbed through the covering and by dividing by the proper constants it is obtained in terms of B. T. U., per square foot per minute, and B. T. U. per square foot per hour per 1°F difference of temperature. The result is checked by attaching a steam guage to show the pressure and measuring the amount of condensation.

CALORIMETRIC METHOD.







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DESCRIPTION OF APPARATUS.

This consisted of a 1 1/2" pipe having a clear length of about 37" to carry the covering. One end os closed by a cap, tapped for an air cock. The other fits into a reducing tee from which a short 1 1/4" pipe connects to a 1 1/4" tee placed vertically. An admission valve is attached to the top of this and a 1/2" drip valve to the bottom. At the bottom of the reducing tee is attached a separating calorimeter having a capacity for 12 oz. of condensed water. This has a live steam jacket which prevents further condensation there. A steam guage is also connected to the pipe. The pipe has a slight slope towards the calorimeter.

The water jacket is 29 3/8" long, 7 1/2" aquare and has a central hole through it of 5 7/16" diameter. This is enclosed in a well insulated box 14 X 14 X 34". At each end of the water jacket is a diaphragm having a hole in it 4 1/4" diameter. Outside od this is a sleeve 2 1/4" long with a diameter of 5 1/2". Wool felt is packed tightly in this around the covering to prevent the passage of air into or out of the box. The covering is fastened on the pipe in the usual manner and the ends are well sealed with plastic composition. The water enters the jacket at the bottom at one end, and comes out at the top at the toher. Thermometers are placed at these points.

PROCEDURE.

The covering to be tested is first mounted on a steam pipe and heated in the air about ten hours. It was then transferred to the testing pipe and placed in the testing box. Steam was admitted and the circulating water was started. Thermometer readings were made every ten minutes while the weight of circulating water was taken every half hour. The thermometers used were very accurate but to avoid error their positions were changed at the middle of each test. The pressure was regulated by manipulation of the admission and drip valves. The drip valve was always slightly open in order to extract anu condensation occuring before the entrance of the steam into the pipe. Each test was continued from three to five hours.

DESCRIPTION OF COVERINGS.

All coverings were covered with canvas and with few exceptions were held on the pipe by brass bands.

No. 1. Calcite composition - Philip Carey Mfg. Co., Lockland, Ohio.

No. 2. Asbestos Air Cell - Chicago Fire Proof Cov. Co., Chicago. Four ply, comigated asbestos paper, one layer felt board outside.

No. 3. "Imperial". H. F. Watson Co., Chicago. Indented layers of asbestos paper.

No. 4. N. Y. Asbestos Magnesia Moulded, H. F. Watson Co.

No. 5. "W. B." H. F. Watson Co. Two inner layers asbestos, wool felt outside.

No. 6 Magnesia, Maurille Co. Co., Milwaukee.Magnesis composition covered by one layer felt board.

No. 7. Asbestos Sponge Felted Mauirlle Co. Co.

No. 8. Magnesia - Keasbey and Mattison, Ambles, Pennsylvania.

No. 9. Asbestor Air Cell. Ambler Asbestos Air Cell Cov. Co., New York.

No. 10. Granite rock wool. American Insulating Material Manufacturing Co., St. Louis, Mo.

No. 11. Nonpariel Cork Mfg. Co., Bridgeport, Conn. Solid cork, lined with asbestos paper.

No. 12. Nonpariel Cork "Octagonal". Cork in strips, lined with asbestos paper.

No. 13. Asbestos Air Cell. Standard Pipe Covering Co., Cleveland, Ohio.

No. 14. Mineral Wool, Standard Pipe Covering Co.,.

No. 15. "Hercules" Asbestos Mfg. Co., Philadelphia, Pa.

Asbestos and wool felt covering with large air spaces.

DIMENSIONS OF COVERINGS.

No. Cov.	Internal Diam.	Thickness	Wt. oz. per foot.
1	2"	1 1/16"	31.8 oz.
2	2 1/10	1	14.4
3	2 1/16	7/8	25.4
4	2 1/8	1	30.2
5	2	7/8	26.
6	2 1/8	1	29.2
7	2	1	33.5
8	1 15/16	7/8	16.3
9	1 15/16	7/8	23.7
10	2-	13/16	16.5
11	2	1 3/16	37.6
12	2	1	16.
13	2	5/8	10.7
14	2	1	14.9
15	2	15/16	17.8
16	2-	1 1/16	32.4

Cov. No.	Duration of test hr.	Steam pressure.	Mean tem. water	°F. dif. tem.	B.T.U. per 1/2 hr	B.T.U. per sq ft. per min.	B.T.U. per sq ft. 1°F per hr.	Ratio to bare pipe.
bare pipe	4 1/4	97 1/2	85	251	422.36	11.58	2.773	100%
1	3	97 1/2	85	251	141.2	3.96	.920	33.2%
2	4	46	78	215 1/2	99.4	2.79	.759	27.4
3	1 3/4	97 1/2	77	259	137.7	3.86	.874	31.5
4	2 1/2	97 1/2	80	256	170.2	4.77	1.093	39.4
5	3 1/2	97 1/2	73	263	125.6	3.52	.785	28.3
6	3 1/2	97 1/2	77	259	130	3.36	.825	29.7
7	3 1/2	97 1/2	75	261	117.2	3.28	.738	26.6
8	4	97 1/2	78	258	167.2	4.69	1.064	38.4
9	3 1/2	97 1/2	75	261	151.3	4.24	.954	34.4
10	3	97 1/2	77	259	187.4	5.25	1.190	42.9
11	3 1/2	97 1/2	77	259	132.9	3.72	.843	30.4
12	3 1/2	97 1/2	75	261	110.7	3.10	.697	25.1
13	3	20	75	185	77.85	2.18	.692	24.9
14	3	97 1/2	77	259	195.3	5.47	1.240	44.7
15	2 1/2	97 1/2	72	264	141.2	3.96	.880	31.7
16	3 1/2	97 1/2	75	261	153.7	4.31	.968	34.9

DISCUSSION OF RESULTS.

Water was circulated at the rate of about 30# per hour. The range of temperature was such that the temperature of the water leaving the jacket was about as much above the outside temperature as it was below it when entering, so the heat transmission in one direction equals that in the other and can be neglected.

Because the College plant could not supply steam at the high pressure required a small oil-fired Shipman boiler was used. It was impossible to hold the pressure in the pipe absolutely constant and a sensitive reducing valve would be preferable to the two hand valves; but the variation of the temperature of the steam is such a small proportion of the total difference between the steam and the water that it does not appreciably change the results. For the same reason while the temperature of the water cannot be read closer than 1/2°F., the probable is so small compared to the total range of temperature that the results are not materially affected. While the accuracy of the results can not be guaranteed within a small per cent, the error, if any, is so small and equally affects each covering tested that the results may be accepted as being practically correct.

One serious source of error lies in the fact that but one trial was made of each sample. Several should be made and the average results taken. The results obtained by this method are high when compared with those given by other experimenters; but it is believed that these more nearly approximate the losses found in practice. The former experimenters took pains to prevent circulation of air around their pipes, while in practice there is always a large passage of air over the pipes which cannot fail to cause a greatly increased loss of heat.

The relative transmission of the coverings to the bare pipe are very high. This is because the heat transmission of the bare pipe is undoubtedly too low; probably 20% at least. It is supposed to be due to improper drainage of the condensed steam.

In only a few cases is there any great absolute difference between the different coverings. The most efficient by the test is the Nonpariel Cork "Octagonal". It was tested under a low pressure and the range of temperature was less than in the other cases. It seems to be the case that the heat transmitted per 1° difference of temperature is not constant, but increases as the difference of temperature increases.

It is expected that with less thickness of covering the differences would have been greater. It is evident that the difference will diminish as the thickness of the coverings increases; as an indifferent non-conducting substance will serve to prevent the passage of heat if applied in sufficient thickness. While the coverings tested were of normal thickness, it seems that this thickness was sufficient to reduce by a considerable degree the effect of the superior non-conducting properties which the material of one covering may have possessed ove another.

While the non-conducting power of a covering is of fundamental importance there are other properties that must be considered. We must take into account the cost, weight, bulk, necessary thickness, durability, ease of application and removal, repair and renewal, simplicity, appearence, freedom from smell, temptation to insects or mice, combustibility, resistance to moisture, liability to crack, and possible chemical effect upon the pipe.

It is impossible to claim that any one covering, no matter how perfect, is the best to use in all places. The suitability of a covering for a specific case depends upon the conditions that prevail there, and in the final reduction the covering that gives the greatest ultimate saving for the amount tested is the one best adapted to that service.