THE DIFFERENCE IN THE HEAT TRANSFER RATE OF GALVANIZED IRON AND ALUMINUM PIPE

By

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DRAWINGS. CHARTS.

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Preface:

This Thesis, as the title suggests, is a comparison of the heat transfer rates of galvanized iron and aluminum pipe. This subject was chosen at the suggestion of Prof. W.R. Woolrich, under whose direction the Thesis was prepared.

It is the writer's wish to acknowledge the very valuable aid and suggestions of Prof. Woolrich in preparing this material. Thanks are also extended to Mr. Paul W. Scates, a graduate student, of the University of Tennessee, for the assistance which he very kindly gave.

General Survey of the Field.

It has only been within the last few years that aluminum has come into practical use, especially aluminum pipe. Because of this fact there has been, so far, no necessity in knowing definitely just what the heat transfer rate of aluminum pipe is, or how it compares with the much more used iron pipe. Therefore, no other experiments similar to this have been performed. This does not mean, however, that the result of an experiment such as this will not be of value in the future, especially in the rapidly expanding field of air conditioning in the modern industrial plant and the up-to-date home. Even though it may not be practical to use aluminum pipe in the air conditioning, or cooling unit, it is important to know just why it should not be used.

In 1929, Prof. W.R. Woolrich, of the University of Tennessee, made extensive experiments on the effect of the humidity on the heat transfer rate, using black and galvanized iron pipe as the heat transferring material. This Thesis is, therefore, a continuation, to a limited extent, of these previous tests. The difference was that aluminum pipe was used instead of the iron pipe, and the tests were not so extensive; but sufficient to show a comparison.

Purpose:

The chief object in performing this experiment is to compare the heat transfer rate of aluminum pipe with that of galvanized iron pipe under the varying humidity conditions of the air surrounding the pipe, and the various temperatures of the heat carrying medium within the pipe, relative to the temperature of the outside air.

General Theory.

The apparatus used in performing this experiment was so arranged that the temperature and the velocity of the air flowing over the pipe were kept constant. Also the temperature of the heat carrying medium within the pipe, which was water, was kept constant at the inlet end of the test pipe. The rate of flow of water through the pipe was also kept constant. The only thing that was allowed to vary was the relative humidity of the air surrounding the pipe. Using this method it was possible to have two conditions of heat transfer namely; cold air flowing over a hot transfer surface, in which case the heat is transferred from the water to the air; and the condition of hot air, flowing over a cold transfer surface, in which case the heat is transferred from the air to the water.

It was found by Prof Woolrich that a variation in the humidity did not affect the heat transfer rate if the cold air was passed over the hot surface. (1) However it was found that if hot air was passed over a cold surface, the heat transfer rate increased as the percent of relative humidity increased; after the humidity had become high enough to cause condensation on the pipe due to the lowering of the temperature of the surrounding air.This condensation created a wetted surface on the pipe which gives

(1). "Refrigeration Engineering", June 1931.

much better contact between the air and the pipe, because here we have first a gas then a liquid, amd finally a solid through which the heat is transferred. It is obvious that this closer contact increases the rate of heat transfer. This theory was further carried out recently in an experiment on the effect of the humidity on the melting rate of ice performed by a graduate student of the University of Tennessee (2)

It is quite logical that the condition of having a wetted surface on the aluminum pipe, would have the same general effect on the heat transfer rate, and as far as the closeness of contact is concerned it should be the same. This assumption was made before the tests were made.

Another reason for there being a difference in the heat transfer rate of aluminum and galvanized iron pipe, is the question of the thermal conductivity of the material. The thermal conductivity of aluminum is a small fraction less than twice that of iron. Then one would expect a greater heat transfer rate in the case of the aluminum pipe.

The question of the condition of the surface of the two pipes is another element which would have some effect on the heat transfer rate; the brighter polish surface giving the lesser rate. The piece of aluminum pipe used had much more of a polished surface than did the galvanized iron. This was

(2) Scates, Paul W., "Factors Effecting Ice Melting Rate".

the natural finish of the pipe as it came from the mills.

The oxide coating which forms on aluminum surfaces could also have some effect on the heat transfer.

It is not the purpose of this Thesis however, that it be shown just to what extent each of the above mentioned elements affect the heat transmission. Our purpose is merely to see if there is a difference and in which direction.

Method and Apparatus..

The same apparatus was used in this experiment that has been used very successfully before in several similar tests. It is probably one of the best set-ups obtainable for this purpose. A diagram of the essential parts of the apparatus is shown in Figure 1. An air duct about 33 feet long and twenty inches in diameter, is connected to the discharge of a Sirroco fan. The fan is driven by a small steam engine, whose speed can be controlled by the throttle valve.

Extending backward from the discharge end of the duct and down the center of the duct,, was placed a twenty foot length of standard one and one fourth galvanized iron pipe. The inlet end of the pipe was connected to an elevated tank which was two and a half feet deep and two and a half feet in diameter, giving a capacity of about 90 gallons. The tank was some ten feet from the inlet end of the test pipe, and as near to the ceiling of the labaratory as was possible, and still be accessible for filling. The tank was enclosed in a wooden box, and insulated around the sides and bottom with saw-dust, and was connected to the inlet end of the test pipe, with a piece of insulated hose,, so that the water in flowing from the tank to the pipe would be as small as possible.

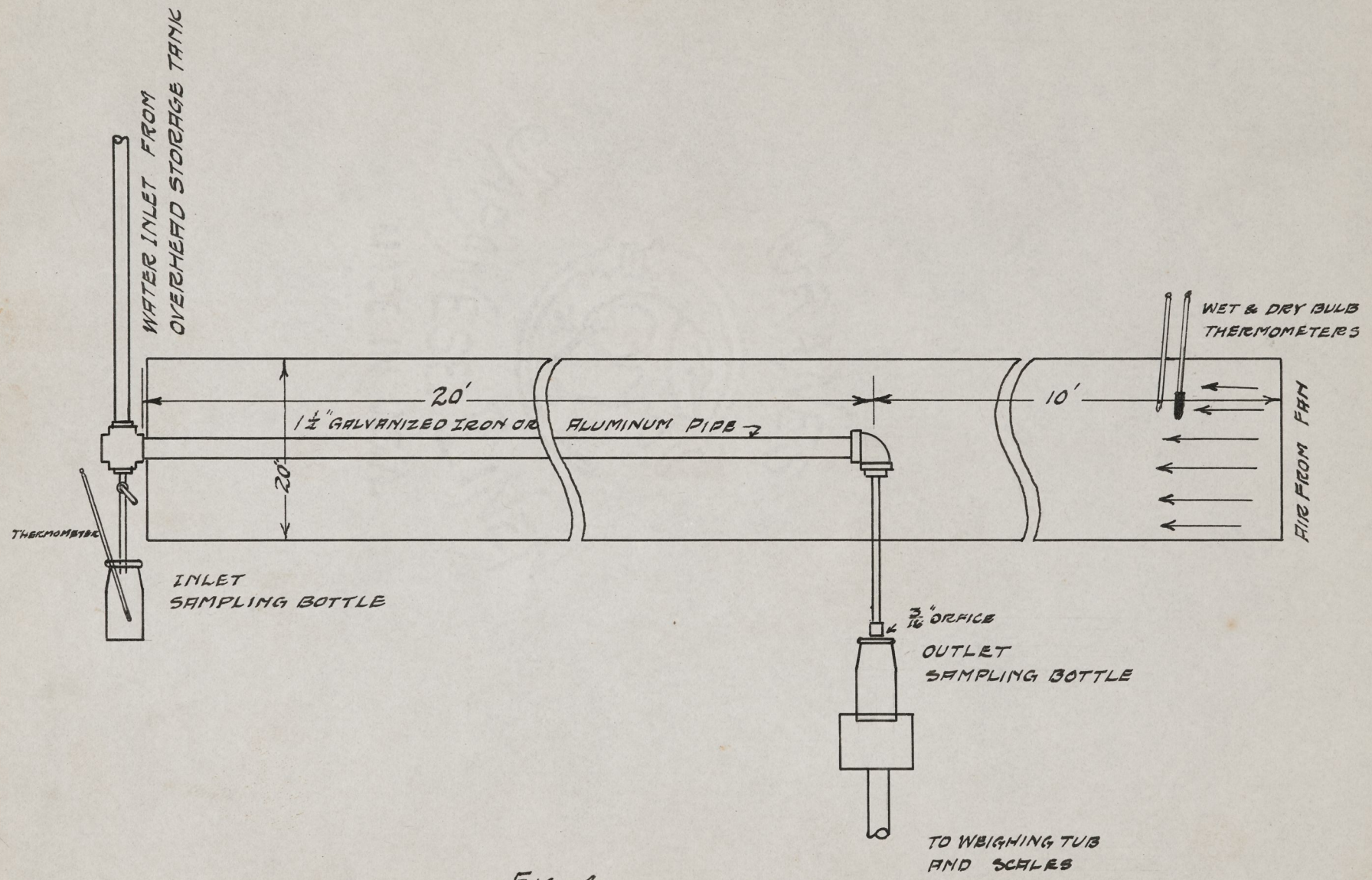

WATER INLET FROM OVERHEAD STORAGE TANK
20'
1½" GALVANIZED IRON OR ALUMINUM PIPE
20"
10'
WET & DRY BULB THERMOMETERS
AIR FROM FAN
THERMOMETER
INLET SAMPLING BOTTLE
3/16" ORFICE
OUTLET SAMPLING BOTTLE
TO WEIGHING TUB AND SCALES

FIG. 1

The outlet end of the test pipe was equipped with a short length of small pipe extending vertically downward to the outside of the duct. A three-sixteenth inch nozzle was placed on the end of this pipe which regulated the rate of flow. The water discharged into a sampling bottle, as shown, and from there it was carried to a weighing tub and scales for weighing.

The temperature of the water at the inlet and outlet end were taken in the sampling bottles, shown in the diagram.

The air temperature was measured with a thermometer placed in the air duct, between the fan and the test pipe.. Close besides this thermometer was placed a wet bulb thermometer for the purpose of determining the percent of relative humidity.

The air velocity was kept constant, by adjusting the throttle valve of the fan engine..

The greatest possible precaution were taken to avoid errors in the tests. Considerable time was required before some of them were ironed out, and acceptible data obtained.

In making the tests with the hot water and cold air, the overhead tank was filled about two thirds full of water, which was then heated with steam until the desired inlet temperature had been reached. It was found that the water lost about 8 degrees F. in flowing from the tank to the pipe.. To avoid error the water was heated, as near as pos-

sible to the same temperature each time, and if it was not exactly the same for one test as for another, the main object was to keep it constant during the test, so that each inlet temperature reading would have a corresponding outlet reading. To be able to maintain this situation, it required practice and was finally done by maintaining constant head in the tank, and by turning on just enough steam to keep the temperature constant. It required several minutes sometimes to make such an adjustment but after it was once done, tests could be made continuously.

To produce the cold water the tank was kept about half full of finely chipped ice, and the water level kept just high enough to be seen at the low places in the ice.

The incoming water necessary to maintain constant head was distributed over the top of the ice by letting it drain from a slightly board, so that the warm water would not fall directly to the bottom of the tank, and go out through the outlet.

To avoid error in the inlet and outlet temperature of the water the same thermometer was used for taking both readings. The thermometer which was used for this purpose was graduated in tenth of a degree Centigrade, for the hot water, and five tenth of a degree Farenheit for the cold water tests.

The temperature of the air in the duct was kept constant, as far as possible, by raising and lowering the windows of the laboratory. This was one of the most difficult features of the experiment; especially if it was necessary to have several windown open while the wind was blowing outside.. As far as possible, the tests were made on cold days, so that it would not be necessary to have the windows open.

The humidity was controlled by opening numerous steam jet located at various points in the laboratory. Low humidities were obtained on days or nights when the outside air was very cold. The reason for doing this was based on the fact that the relative humidity of cold air is reduced when its temperature is raised. It was found that it was not safe to go above 90% relative humidity, because there was such a small differential in the wet and dry bulb temperature there, and exterpolation would be more accurate.

For each test no less than four temperature readings were taken, and the fan speed was carefully checked. Each test lasted twenty minutes or over. The temperature of the water at the outlet was taken immediately after the dry bulb temperature was tabulated, so that they would be corresponding values. The mean of the four or more readings were taken for making the calculation.

The only reason for making the test on the galvanized iron pipe, was to eliminate variation caused by two different persons running the experiment. But since this variation was very slight for the hot water tests, it was not necessary to repeat the test on the galvanized iron for the cold water.

Calculations:

The calculations of the heat transfer rate were very simple.

Let t_a = temp. of air deg. F.

t_i = inlet temp. of water deg. F.

t_o = Outlet Temp. of water deg. F.

W = Rate of flowing water, lbs. / hr.

A = Area of pipe is sq. ft.

Then the heat transfer rate,

$$H \quad \frac{W(t_i - t_o)}{A\left[\frac{(t_i + t_o)}{2} - t_a\right]} = \text{B.T.U. /hr.//sq. ft./deg.F.Dif.}$$

$W(t_i - t_o)$ is the total number of B.T.U. given up by the water per hr. and $\left[\frac{(t_i + t_o)}{2} - t_a\right]$ is the difference in the mean temperature of the water and the temperature of the air.

The following is a specific example of the calculations. (See Test No. 5)

$t_i = 196.3^\circ$ F.

$t_o = 173.5^\circ$ F.

$t_a = 80.9^\circ$ F.

$W = \frac{113 \times 60}{20} = 339\#/\text{hr.}$

Then,

$$H = \frac{339(196.3 - 173.5)}{9.0\left[\frac{(196.3 + 173.5)}{2} - 80.9\right]} = 8.25$$

B.T.U./ hr./ sq. ft. / deg.F. dif.

Results and Conclusions;

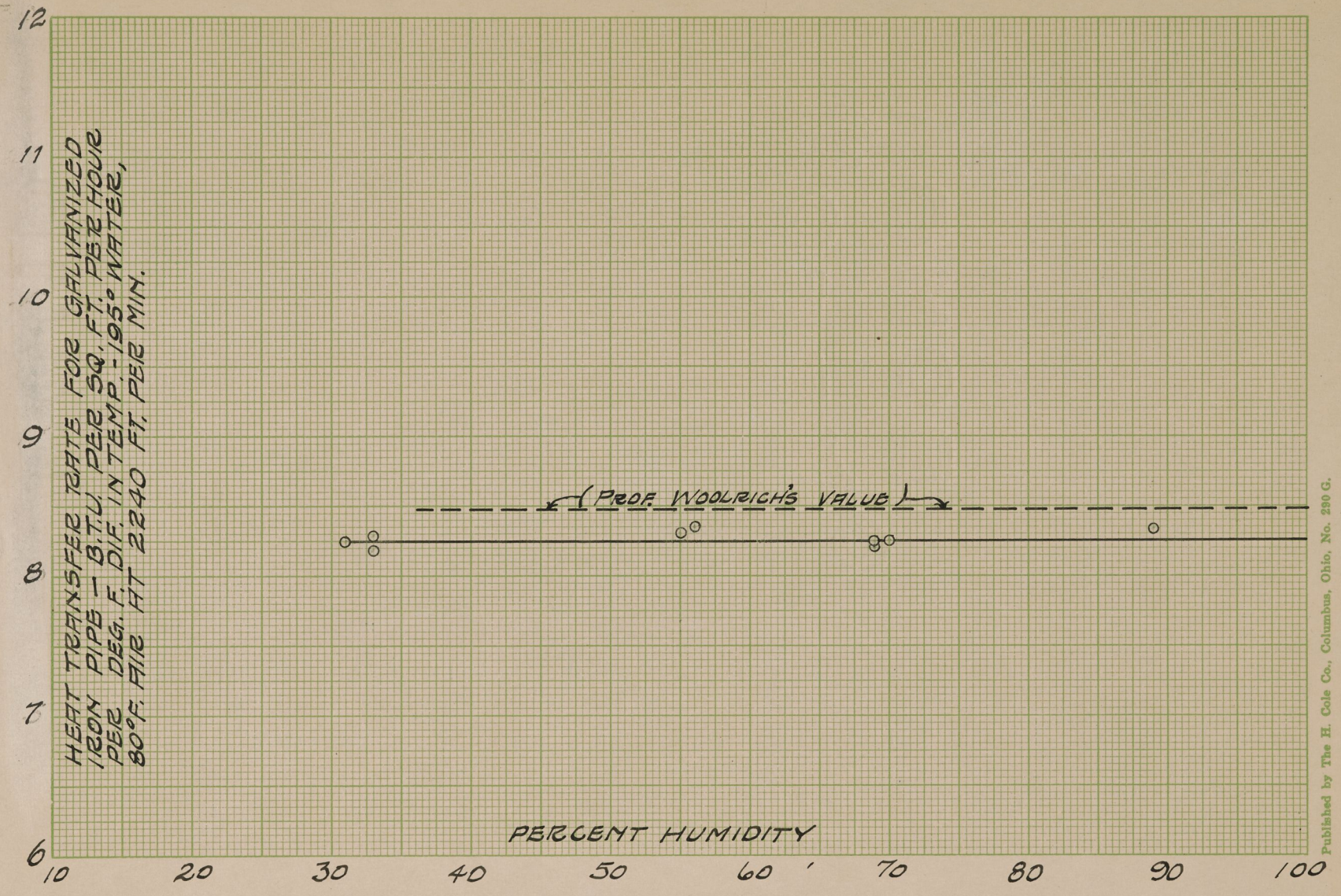
The results of the experiments performed in this Thesis are shown in the form of curves, which are plotted with the heat transfer rate as the ordinate, and the relative humidity as abscissa.

Figure 2 shows the values obtained for the galvanized iron pipe, using hot water inside of the pipe. Also on the same sheet is shown the values obtained by Prof. Woolrich in a similar experiment.(i) This curve is the broken line. Since the scale of ordinates is very large there is very little difference in the two values (about 2 %).

Figure 3 which is plotted to the same scale of ordinates, shows the value of the aluminum pipe tests. This curve is shown in black. On the same sheet with this curve, is the curve for the galvanized iron pipe (shown in blue). The surprising fact that the heat transfer rate of aluminum pipe is less than that of the galvanized pipe, as shown, and that the assumption made in the beginning was wrong. The difference is about one percent.

About the only explanation that can be given as to why the rate is less for the aluminum pipe is that the effect of the polish and the almost invisible oxide film, more than counteracts the increase caused by the greater thermal conductivity of aluminum.

(i) See Page 3.



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FIG. 2.

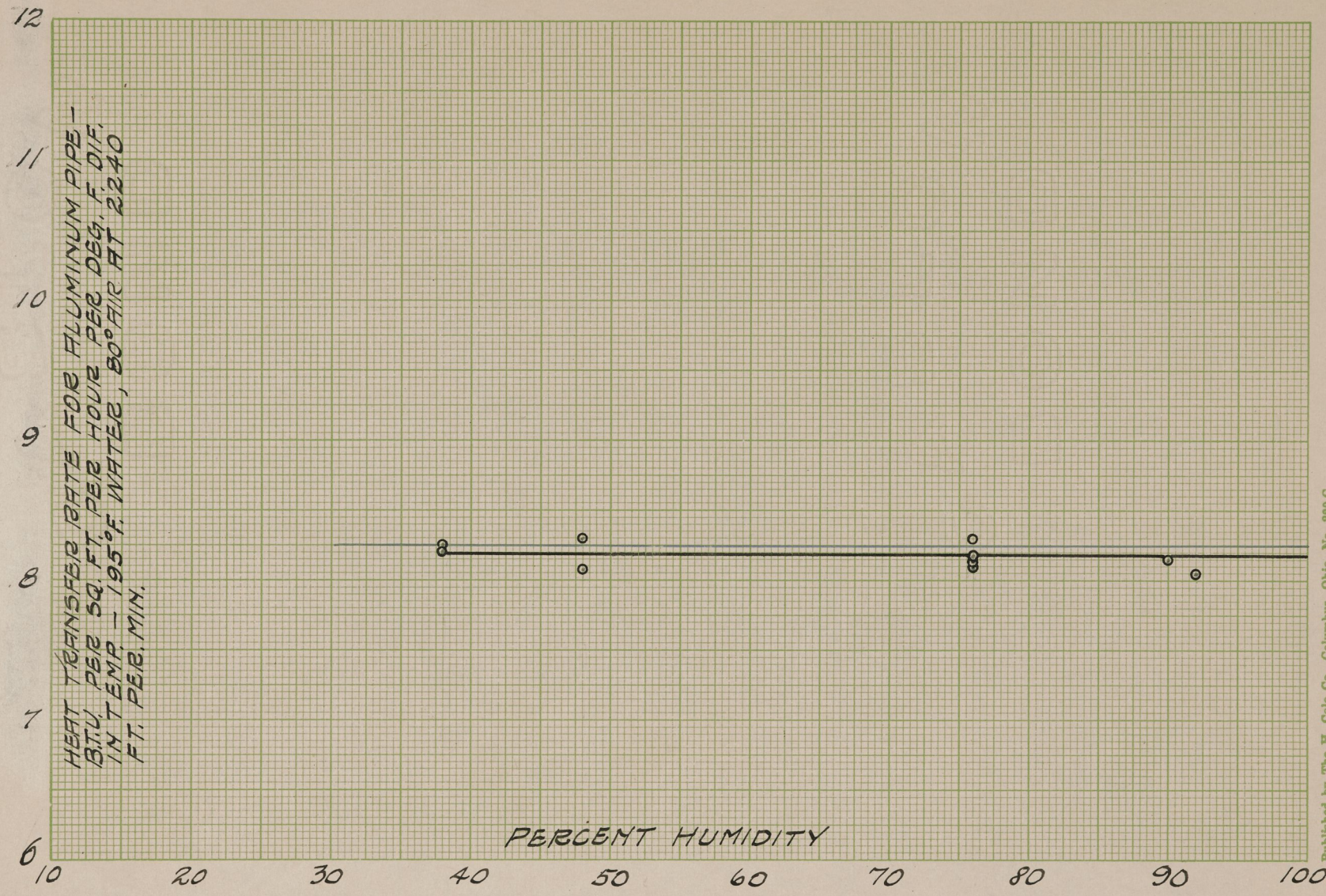


FIG. 3.

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There is still another element which may tend to reduce the transfer rate. "If a piece of aluminum is dipped in a vessel of water it will be noticed that the water sheds off quickly; as tho the metal were oily. This shows that there is not so much adhesion between aluminum and water as there is between iron and water; consequently there is less contact between the water on the inside of the pipe and the aluminum, than there is for the iron.(1) This evidently to an unknown extent would retard the rate of heat transfer.

Figure 4 shows a comparison between the curves for the galvanized iron pipe (broken line) and the aluminum pipe (solid line) using cold water. In this case the heat transfer rate of the aluminum pipe is about on an average, 10% less than that of the galvanized iron pipe.

Here we have again the possibility that the heat transfer rate is reduced by the "oiliness" of the aluminum pipe surface. This time the effect is produced on both sides of the pipe, because there is a film of condensed moisture on the outside which did not exist before.

The purpose of Figure 5 is merely to show all of the curves on the same sheet, for comparison.

From the results of this test on aluminum pipe it was concluded that the possibilities of using aluminum pipe, as a heat transferring metal, are very slight, as far as heat transfer rate is concerned.

(1) Substance of a conversation with Prof. Woolrich.

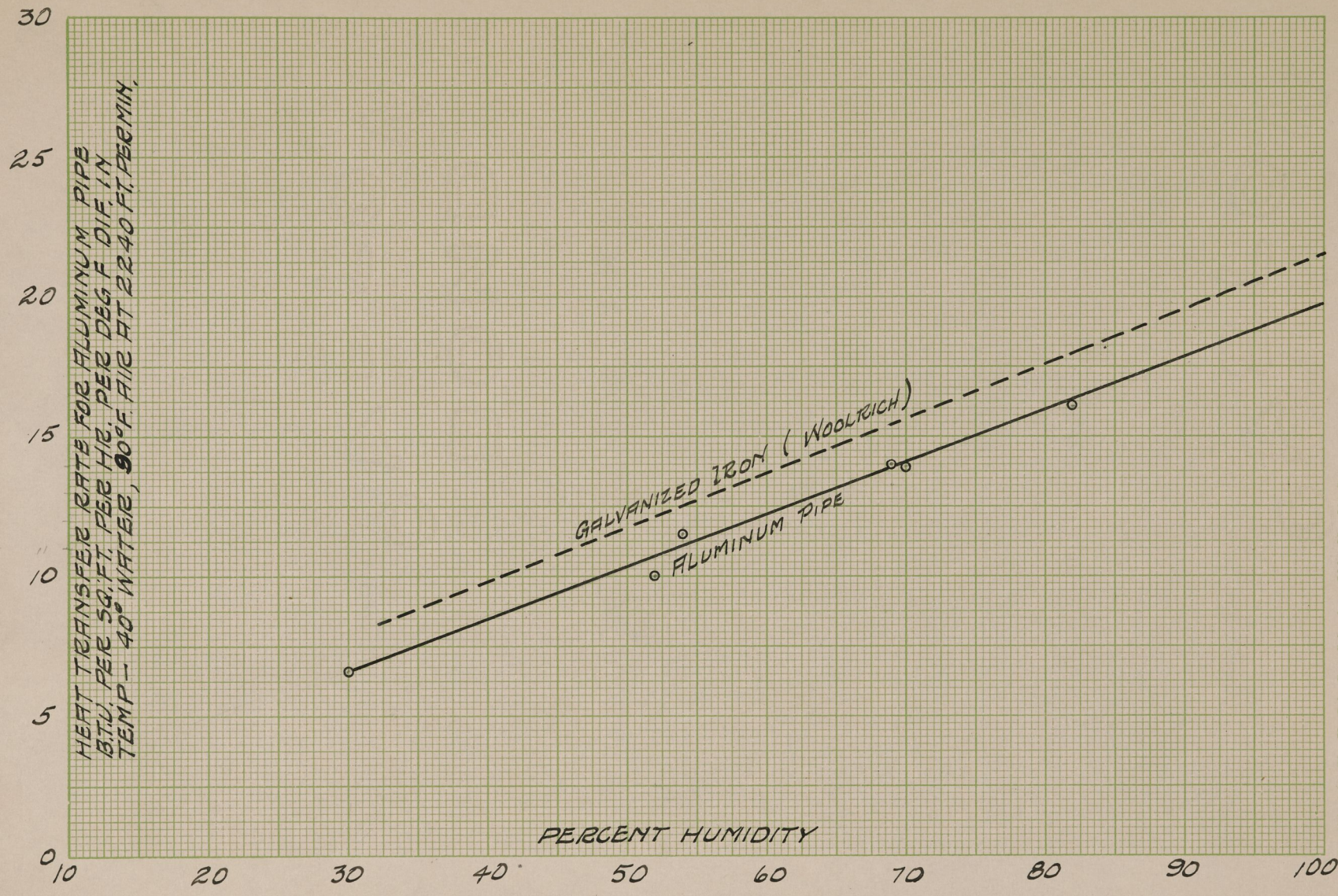


FIG. 4

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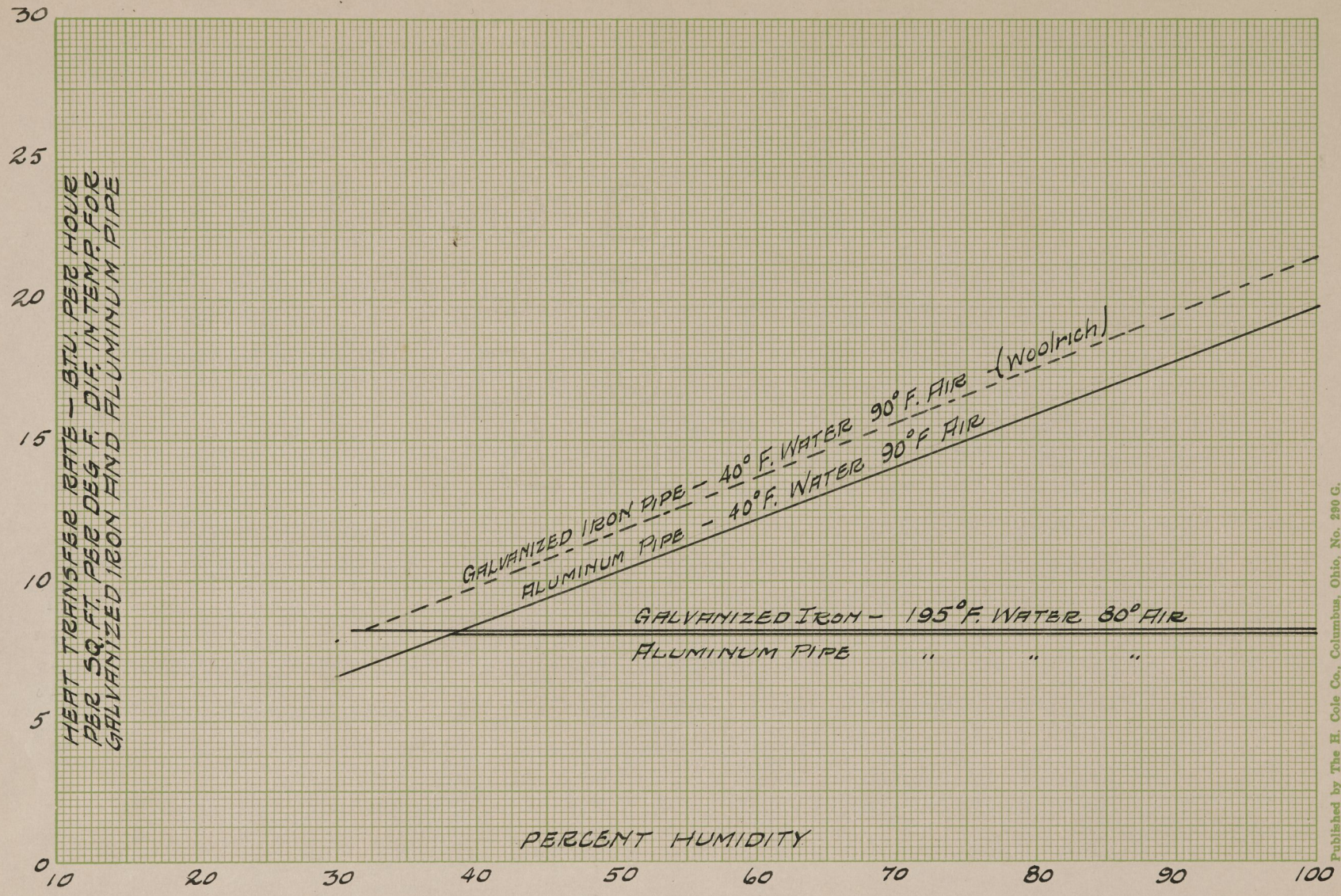


FIG. 5

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However, as it was stated before, it is important to know this fact; therefore a work like this is of value..

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1. Scates; Paul W., "Factors Effecting the Melting Rate of Ice".

2. Woolrich, W.R., "The Effect of Humidity on the Heat Transmission of Pipes".

Refrigeration Engineering. June 1931.

APPENDIX.

A P P E N D I X A

GALVANIZED IRON PIPE

AREA OF PIPE	9 Sq. FT.
WATER	195 Deg. F.
AIR	80 Deg. F.
AIR VELOCITY	2240 Ft. Per Min.

TEST NO. 1.

Duration of Test	20 minutes
Rate of flow	310.0 Lb. / hr.
Average Int. Temp	196.16 Deg. F.
Average Out. Temp.	171.86 Deg. F.
Dry Bulb Temp.	82.5 Deg. F.
Wet Bulb Temp.	63.0 Deg. F.
Avg. R.P.M.	378

Heat Trans. Rate 8.28 B.T.U. / hr./sq.ft./Deg. F. Dif.

TEST NO. 2.

Duration of Test	21 minutes.
Rate of Flow	314.0 Lb./ hr.
Average Int. Temp.	195.98 Deg. F.
Average Out. Temp.	171.68 Deg. F.
Dry Bulb Temp.	83.5 Deg. F
Wet Bulb Temp.	64.0 Deg. F.
Avg. R.P.M.	376

Heat Trans. Rate 8.18 B.T.U. / hr./ sq.ft./Deg. F.Dif.

TEST NO. 3.

Duration of Test	20 minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	195.9 Deg. F.
Average Out. Temp.	173.0 Deg. F.
Dry Bulb Temp.	80.6 Deg. F.
Wet Bulb Temp.	69.0 Deg. F.
Avg. R.P.M.	370

Heat Trans. Rate 8.3 B.T.U. / hr./sq. ft./deg. F.dif.

TEST NO. 4.

Duration of Test	20 minutes
Rate of flow	342.0 Lb. / hr.
Average Int. Temp.	196.0 Deg. F.
Average Out. Temp.	173.0 Deg. F.
Dry Bulb Temp.	81.0 Deg. F.
Wet Bulb Temp.	69.6 Deg. F.
Avg. R.P.M.	374

Heat Trans. Rate 8.35 B.T.U./hr./sq.ft./deg.F.Dif.

TEST NO. 5.

Duration of test	20 minutes
Rate of flow	342.0 Lb. / hr.
Average Int. Temp.	196.3 Deg.F.
Average Out. Temp.	173.5 Deg.F.
Dry Bulb Temp.	81.9 Deg.F.
Wet Bulb Temp.	73.6 Deg.F.
Avg. R.P.M.	380

Heat Trans. Rate 8.25 B.T.U./hr./sq.ft./Deg. F. dif.

TEST NO. 6.

Duration of Test	23 minutes.
Rate of flow	318.0Lb./ hr.
Average Int. Temp.	196.4 Deg.F.
Average Out. Temp.	77.8 Deg.F.
Dry Bulb Temp.	79.7 Deg. F..
Wet Bulb Temp.	72.0 Deg. F.
Avg. R.P.M.	380

Heat Trans. Rate 8.25 B.T.U. / hr./sq. ft./deg.F.dif.

TEST NO. 7.

Duration of test	20 minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	196.5 Deg. F.
Average Out. Temp.	173.8 Deg. F.
Dry Bulb Temp.	80.9 Deg.F.
Wet Bulb Temp.	73.0 Deg. F.
Avg. R.P.M.	380

Heat Trans. Rate 8.21 B.T.U. /hr./sq.ft./deg.F. dif.

TEST NO. 8.

Duration of Test.	22 minutes
Rate of flow	316.5 Lb. / hr.
Average Int. Temp.	197.3 Deg.F.
Average Out. Temp.	172.4 Deg. F.
Dry Bulb Temp.	80.0 Deg. F.
Wet Bulb Temp.	77.0 Deg.F.
Avg. R.P.M.	370

Heat Trans. Rate 8.34 B.T.U. /hr/sq.ft./deg.F.dif.

TEST NO. 9.

Duration of test	22 minutes
Rate of flow	319.0 Lb./ hr.
Average Int. Temp.	197.3 Deg. F.
Average Out. Temp.	173.1 Deg. F.
Dry Bulb Temp.	81.0 Deg. F.
Wet Bulb Temp.	73.0 Deg. F.
Avg. R.P.M..	376

Heat Trans. Rate 8.22 B.T.U./hr./sq.ft./deg.F.dif..

TEST NO. 10.

Duration of test	23 minutes
Rate of flow	331.5 Lb. / hr.
Average Int. Temp.	194.7 Deg.F.
Average Out. Temp.	172.0 Deg. F.
Dry Bulb Temp.	82.0 Deg. F.
Wet Bulb Temp.	63.0 Deg.F.
Avg. R.P.M..	372

Heat Trans. Rate 8.25 B.T.U./hr./sq.ft./deg.F.dif.

A P P E N D I X B.

ALUMINUM PIPE

AREA OF PIPE	9.13 SQ. FT.
WATER TEMP.	195 DEG.F.
AIR TEMP.	80 DEG. F.
AIR VELOCITY	2240 FT. / MIN.

TEST NO. 1.

Duration of Test	20 minutes
Rate of flow	312.0 Lb. / hr.
Average Int. Temp.	197.3 Deg.F.
Average Out. Temp.	173.0 Deg. F.
Dry Bulb Temp	80.0 Deg. F.
Wet Bulb Temp.	66.0 Deg. F.
Avg. R.P.M.	374

Heat Trans. Rate 8.06 B.T.U./hr./sq. ft./deg. F. dif.

TEST NO. 2.

Duration of test	20 minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	196.6 Deg. F.
Average Out. Temp.	173.0 Deg. F.
Dry Bulb Temp.	80.0 Deg. F.
Wet Bulb Temp.	66.0 Deg. F.
Avg R.P.M.	380

Heat Trans. Rate 8.3 B.T.U. / hr./sq.ft./deg.F.dif.

TEST NO. 3.

Duration of test	20 minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	196.0 Deg.F.
Average Out. Temp.	172.6 Deg.F.
Dry Bulb Temp.	80.0 Deg.F.
Wet Bulb Temp.	74.0 Deg. F.
Avg. R.P.M..	380

Heat Trans. Rate 8.3 B.T.U./hr./sq. ft./deg.F. dif.

TEST NO. 4.

Duration of test	20 minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	195.4 Deg. F.
Average Out. Temp.	172.8 Deg. F.
Dry Bulb Temp	80.0 Deg. F.
Wet Bulb Temp.	74.0 Deg. F.
Avg R.P.M.	380

Heat Trans. Rate 8.08 B.T.U./hr./sq. ft./deg. F.dif.

TEST NO. 5.

Duration of Test	21 minutes
Rate of flow	339.0 Lb./ hr.
Average Int. Temp.	196.2 Deg.F.
Average Out. Temp.	173.2 Deg.F.
Dry Bulb Temp.	80.0 Deg. F.
Wet Bulb Temp.	74.0 Deg. F.
Avg.R.P.M.	380

Heat Trans. Rate 8.16 B.T.U./hr./sq. ft./ deg.F.dif.

TEST NO. 6.

Duration of test	20 minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	196.4 Deg.F.
Average Out. Temp.	173.4 Deg. F.
Dry Bulb Temp.	80.0 Deg. F.
Wet Bulb Temp.	74.0 Deg. F.
Avg R.P.M.	380

Heat Trans Rate 8.14 B.T.U./hr./sq. ft./deg.F. dif.

TEST NO.. 7.

Duration of test	21 minutes
Rate of flow	307.0 Lb. / hr.
Average Int. Temp.	195.0 Deg. F.
Average Out. Temp.	170.0 Deg.F.
Dry Bulb Temp.	80.0 Deg. F.
Wet Bulb Temp.	63.0 Deg. F.
Avg R.P.M.	378

Heat Trans. Rate 8.2 B.T.U./hr./sq. ft./deg.F. dif.

TEST NO. 8.

Duration of test	21 minutes
Rate of flow	310.0 Lb./ hr.
Average Int. Temp.	195.7 Deg. F.
Average Out. Temp.	170.8 Deg. F.
Dry Bulb Temp.	80.9 Deg. F.
Wet Bulb Temp.	63.5 Deg. F.
Avg R.P.M.	380

Heat Trans. Rate 8.25 B.T.U./hr./sq. ft./deg. F. Dif.

TEST NO. 9.

Duration of test	20 minutes
Rate of flow	307.5 Lb./ hr.
Average Int. Temp.	195.5 Deg. F.
Average Out. Temp	171.1 Deg. F.
Dry Bulb Temp.	80.9 Deg. F.
Wet Bulb Temp.	78.0 Deg. F.
Avg R.P.M.	380

Heat Trans. Rate 8.03 B.T.U./hr./sq. ft./deg.F. dif.

TEST NO. 10.

Duration of test	21 minutes
Rate of flow	308.5 Lb./ hr.
Average Int. Temp.	195.7 Deg. F.
Average Out. Temp.	171.0 Deg. F.
Dry Bulb Temp	80.9 Deg. F.
Wet Bulb Temp.	78.5 Deg. F.
Avg R.P.M.	378

Heat Trans. Rate 8.14 B.T.U./hr./sq. ft./deg.F. dif.

A P P E N D I X C.

ALUMINUM PIPE

AREA OF PIPE	9.13 SQ. FT.
WATER TEMP.	40 DEG. F.
AIR TEMP.	90 DEG. F.
AIR VELOCITY	2240 FT. PER MIN.

TEST NO.1.

Duration of test	22.5 minutes
Rate of flow	328.0 Lb. / hr.
Average Int. Temp.	40.31 Deg. F.
Average Out. Temp..	53.39 Deg. F.
Dry Bulb Temp	87.75 Deg. F.
Wet Bulb Temp.	75.0 Deg. F
Avg R.P.M.	378

Heat Trans. Rate 11.5 B.T.U./hr./sq. ft./deg.F.dif.

TEST NO. 2.

Duration of test	20 minutes
Rate of flow	336.0 Lb./ hr.
Average Int. Temp.	43.33 Deg. F.
Average Out. Temp.	54.6 Deg. F.
Dry Bulb Temp.	88.0 Deg. F.
Wet Bulb Temp.	88.0 Deg. F.
Avg. R.P.M.	376

Heat Trans. Rate 10.0 B.T.U./hr./sq. ft./deg. F. dif.

TEST NO. 3.

Duration of test	20 minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	41.43 Deg. F.
Average Out. Temp.	56.6 Deg. F.
Dry Bulb Temp.	89.5 Deg. F.
Wet Bulb Temp.	81.3 Deg.FF.
Avg R.P.M.	378

Heat Trans. Rate 13.9 B.T.U./hr./sq. ft./deg.F. dif.

TEST NO. 4.

Duration of test	20 minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	43.0 Deg. F.
Average Out. Temp.	57.9 Deg. F.
Dry Bulb Temp.	89.9 Deg. F.
Wet Bulb Temp.	81.0 Deg. F.
Avg. R.P.M.	380

Heat Trans. Rate 14.0 B.T.U./hr./sq. ft./deg. F. dif.

TEST NO. 5.

Duration of test	22 minutes
Rate of flow	335.0 Lb./ hr.
Average Int. Temp.	42.9 Deg. F.
Average Out. Temp.	61.25 Deg. F.
Dry Bulb Temp.	92.9 Deg. F.
Wet Bulb Temp.	87.5 Deg. F.
Avg. R.P.M.	378

Heat Trans. Rate 16.1 B.T.U./hr./sq. ft./deg.F. dif.

TEST NO. 6.

Duration of test	2o minutes
Rate of flow	342.0 Lb./ hr.
Average Int. Temp.	42.6 Deg. F.
Average Out. Temp.	50.5 Deg. F.
Dry Bulb Temp.	91.0 Deg. F.
Wet Bulb Temp.	68.0 Deg. F.
Avg R.P.M.	380

Heat Trans. Rate 6.6 B.T.U./hr./sq. ft./deg.F. dif.

APPROVAL.

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory in a manner to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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