TEST OF A THREE TON REFRIGERATING PLANT

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TEST OF A THREE-TON REFRIGERATING PLANT.

INTRODUCTION.

The subject of this report is an ammonia-compression refrigerating plant of three tons refrigerating capacity. The problem consists of a series of tests under different back pressures. This requires the taking of data relating to the efficiencies of the boiler, engine, and compressor, besides a large number of observations of the temperatures and pressures at various points in the steam, water and ammonia lines.

Before proceeding with the test, a considerable amount of installation and preparatory work was necessary. This consisted chiefly in the installation of a steam condenser and vacuum pump; the construction of reducing motions for the steam and compressor cylinders; the construction of a mercury manometer for measuring the ammonia back pressure; changes and additions in the piping systems; the building of insulating boxes for the ammonia condenser and expansion coils.

A general view of the plant is shown in Plate I. Its essential elements are a 25 H.P. Erie Economic boiler; a 6" x 6" vertical compressor direct-connected to a 6" x 6" horizontal engine; a double-tube ammonia condenser; double-tube expansion coils; an ammonia liquid receiver and an accumulator. The refrigerating equipment was furnished by the York Manufacturing Company. A Wheeler surface condenser and a Marsh vacuum pump enable the engine to be run condensing, and a closed heater makes possible the preheating of the water to prevent too low a temperature being attained in the cooler or expansion coils.

The operation of the plant may be more clearly understood by following the ammonia, steam, and water piping through a complete cycle.

The compressed ammonia gas passes from

the compressor through an oil separator into the outer tubes of the condenser. The ammonia in the liquid state gravitates from the condenser into the receiver below. The liquid is then forced through the accumulator (or by-passes it) into the outer tubes of the cooling coils. Here it vaporizes, absorbing its latent heat from the water in the inner tubes, and the gas is drawn through the accumulator into the compressor cylinder, where it is again compressed, and the process is repeated.

Water from the city main is weighed and then fed into the boiler. Steam from the boiler flows into the main header, which supplies the engine, heater, and auxiliaries. The exhaust steam from the engine passes either into the condenser or the atmosphere as desired, the exhaust from the auxiliaries passing to the atmosphere.

Fresh water, instead of brine, is used in the expansion coils. Owing to the small pipe supplying water from the city main, it was found necessary to have a concrete sump to maintain a sufficient supply for operation. Water is taken from the sump and forced through the ammonia condenser. From the ammonia condenser it may go to the cooler and then to the steam condenser, or go first to the steam condenser and then to the cooler. In either case it may be sent through the heater before going to the cooler. After leaving the steam condenser or cooler, as the case may be, the water is weighed and returned to the sump.

PREPARATION FOR TEST.

INDICATOR REDUCING MOTIONS.

Plate II shows the indicator reducing motion for the steam cylinder of the refrigerating machine. The pantographic linkage was used since it gives a perfect straight line motion to the point to which the indicator cord is attached. The distance moved by this point is also directly proportional to the distance moved by the point of attachment to the crosshead. The pulley and fork at "C" permit the proper adjustment of of the indicator cord passing to the indicator. The proper height of the linkage can be adjusted by moving the clamped rod "R" along the standard "S". All the parts except the small brass pulley are made of soft steel.

Plate III shows the reducing motion for the ammonia cylinder. The size of the linkage is the same as that for the steam cylinder. The position of the string can be adjusted by moving the rod "B" within the bearing "A".

INSULATING BOXES FOR COILS.

Plate IV shows the insulating box for the ammonia condenser. It is made of 7/8" tongued and grooved pine boards held together by 2 x 3/4" sticks. The top and bottom sections have slots at "A" and "B" which fit over the side sections. This construction permits the removal of the top and sides in order to get at the coils. The space around the tubes is packed with mineral wool which reduces the passage of heat to the contents of the tubes.

Plate V shows the insulating box for the expansion coils. The construction is similar to that of the box for the condenser.

MERCURY MANOMETER.

Plate VI shows the mercury manometer which was constructed for measuring the ammonia back pressure on the compressor. By means of this manometer the pressure can be obtained with greater accuracy than with the ordinary pressure guage and it also eliminates

a calibration. The hose connections shown at the top could not be used. One tap is left open to the atmosphere and into the other tap is screwed the pipe connected with the gas line returning to the compressor. The glass rods used are 5/8" outside diameter. With the exception of the aluminum back, all the parts had to be made of steel so as not to be affected by the ammonia. The manometer was designed by Mr. H. [illegible]. Libby of the Mechanical Department.

STEAM CONDENSING APPARATUS.

Plate VII shows the layout of the steam condensing apparatus. The condenser is a double flow surface condenser manufactured by the Wheeler Condenser and Engineering Company. There are 41 tubes in the first or lower pass and 53 in the second pass. The tubes are 1/2" inside diameter and 5/8" outside diameter with a length of 47 1/8". The steam surface is 60.4 sq. ft. and the water surface 40.3 sq. ft. The condenser is supported by two 2 1/2" x 3/4" wrought iron supports imbedded 6" in the concrete foundation. The condenser is used only in connection with the refrigerating machine in order to determine its steam consumption. The cooling water inlet may come from either the ammonia condenser or the expansion coils as indicated on plate I. The Marsh vacuum pump has a 4" x 6" steam cylinder and 6" x 6" water cylinder.

CHANGES IN THE PIPING SYSTEM.

In order that tests may be made with and without the use of the accumulator a by-pass connection was made as indicated on Plate I. The liquid ammonia from the receiver may pass directly to the expansion valve or first pass through the accumulator coils where it would be cooled by the surrounding gas coming from the expansion coils. As formerly connected up, the liquid ammonia from the receiver would always have to pass through the accumulator on its way to the expansion coils.

When the steam condenser was installed it was necessary to change the present water piping somewhat. There being very little space for more than one set of weighing tanks it was decided that the same water be used in the ammonia condenser, cooler, and steam condenser. As stated previously the water from the sump may take two routes. It may pass the ammonia condenser, through the heater, through the cooler and then through the steam condenser or after passing through the ammonia condenser the water may go through the steam condenser, through the heater, and then through the cooler. 1 1/4" tees were inserted in the lines on each side of the condenser so that the steam condenser could be operated independent of the rest of the apparatus.

TRYING OUT THE APPARATUS.

The first attempt to try out the apparatus was made on Wednesday, May 1, 1912. On this occasion leaks were discovered at the manhole and one of the handholes of the boiler, and the fire was drawn from the grate. These leaks were attended to and on Thursday the compressor was run for the purpose of placing the system under air pressure. The discharge pressure did not rise, however, and steps were taken to locate the leak. It was found that when the valve in the water outlet from the ammonia condenser was closed, the pressure rose. This indicated a leak between the inner and annular space of the double tubes.

The ammonia condenser was then taken apart, and the two lower inner tubes were found to be cracked, evidently due to the freezing of the water which was left in the coils during the winter. This water from the coils had gravitated into the receiver, about 2 1/2" being visible in the gauge glass. The water was drained out of the receiver and two new 1 1/4" tubes were put in place, new gaskets being used.

On the same day the low pressure side was pumped up to an air pressure of 160 lbs. gauge (142 lbs. corrected) and left there until the next day. After this run, leaks at the safety valve and at one of the joints in the steam leads from the boiler were repaired.

On Friday, May 3, it was found that the low pressure system had held the pressure of the day before. The safety valve was set by the boiler inspector at 88 lbs. gauge (corrected). The gauge reading was 93 lbs., the intended blow-off pressure being 95 lbs. gauge.

After the ammonia condenser had been repaired, the high pressure system was tested out with air pressure and found satisfactory. On the

following Monday a small charge of ammonia was fed into the system, while under air pressure. The joints were then tried out for leaks by the sulphur test. Sticks of sulphur were lighted and moved around each joint. Where ammonia was escaping, dense fumes of sal-ammoniac would form. The only leaks discovered were at the flanged joints. The bolts on all the flanges were then drawn up and further application of the sulphur sticks gave no indication of objectionable leaks.

The system was now given a larger charge of ammonia and on Tuesday, since no leaks appeared, the remainder of the charge was put in, making a total of about 150 lbs. of ammonia. When charging the system the outlet valve on the receiver and all the valves between the receiver and the expansion valve were closed. Then the blind flange just below the expansion valve (see Plate I) was removed and a connection made to the ammonia drum. The gas was then drawn out of the drum, through the cooler and into the compressor. From the compressor the gas passed to the ammonia condenser where it was liquified. It then collected in the receiver below. The system now contained a mixture of ammonia and air. The air was removed by attaching small pet cocks to the purge pipes on the condenser and cooler. To these cocks rubber tubing was fastened. The other ends of the tubes were placed into a bucket of water. The ammonia gas being highly soluble in water dissolved, while the air escaped in bubbles to the surface of the water. When no more bubbles appeared the system was free of air.

Indicator cards taken from the compressor cylinder were narrow and extended and indicated improper working of the discharge and inlet valves. The compressor cylinder head was removed and the valves taken out and thoroughly cleaned. The cards obtained now were still unsatisfactory and the valves were again removed and also the piston. Burred edges were found on some of the piston rings and these were filed smooth. A better card was now obtained, although it was not the conven-

tional shape of an ammonia compressor card.

The indicator cards from the steam cylinder were satisfactory, showing a cut-off on both ends of about two-thirds of the stroke. The machine did not run very steadily at first, but as it continued running, conditions improved and the groan in the compressor cylinder was no longer audible.

The circulating pump and vacuum pump were found to operate satisfactorily. In charging the system the steam condenser was not used, the exhaust from the engine and circulating pump going to the atmosphere.

THE TESTS.

The original intention was to run the refrigerating machine condensing and to run tests with and without the use of the accumulator. When prepared to begin the tests, leaks were discovered at the inlet and outlet of the water heater and it was very difficult to get at the joints and solder them. It was therefore decided that the heater be cut out entirely and so the fittings at the heater were broken and the pipe rising from the ammonia condenser to the heater was connected directly with the water inlet to the cooler. Furthermore, it was found that the range of temperature produced in the cooler was not very great and consequently when using the steam condenser, the water leaving the cooler and running back into the sump was quite warm and this water entering the ammonia condenser required a higher pressure to condense the ammonia than was thought desirable. For this reason the steam condenser was not used and the engine exhausted to the atmosphere. After having started the first run on Thursday evening, May 9, a severe leak was discovered around the thermometer cup on the liquid ammonia outlet of the accumulator. Drawing up the thermometer cup did not stop the leak. Since our time for testing was limited we decided to run all our tests without the use of the accumulator. The mercury manometer for the use of measuring the ammonia back pressure could not be used since the required length of glass tubing could not be obtained in due time, so it was found necessary to use the gauge.

The first actual run was started on Friday morning, May 10, at 1:[illegible] o'clock. The average back pressure was 37.6 lbs. (corrected) Readings of the temperatures and pressures shown on the running log were taken every fifteen minutes for three hours. Indicator cards on the engine and compressor were also taken. The revolutions per minute were obtained from the continuous counter.

An attempt was made to make the next run with 60 lbs. back pressure but owing to the imperfect valve action it was impossible to maintain that pressure any great length of time. It was then decided to make a run with 30 lbs. back pressure. This run was started at 6:30 A.M. on the same day. Observations were taken every fifteen minutes. When the third reading was taken it was noticed that the continuous counter was not recording properly, and all previous readings of the counter for this test had to be rejected. This necessitated counting the strokes for a minute to obtain the revolutions per minute. For some unknown reason the engine stopped a little after 9:00 A.M. and the run stopped half an hour earlier.

The cards taken from the ammonia compressor were very poor and showed that the discharge valve was not working properly. The cylinder head was removed and a discharge valve put in. The valve on the steam cylinder was tightened because from the cards it seemed as though the valve was loose. The engine was then started up again and appeared to run better than before except that one of the bearings became too warm and had to be loosened. The valves appeared to be working better than before but the cards still showed that it was not absolutely right.

The third run was made Friday evening from 8:00 to 11:00 o'clock with results as shown on the running log.

The test was resumed on Saturday morning at 11:00 o'clock. Owing to the lack of time it was decided to make runs of two hours duration. Four runs were made with the back pressures at 11.4 lbs., 22.4 lbs., 2 lbs., and 5[illegible].9 lbs. (corrected values)

Between every run it was found necessary to let the air out of the system by running rubber tubing from the purge outlets into a bucket of water.

The circulating water, during a run, became very warm and this necessitated the pumping of the water from the sump and putting in fresh water.

After finishing the test, cards were taken from the compressor and engine cylinders with the engine running at low speeds.

OUTLINE OF THEORY.

The boiler efficiency would be the same for all the runs. Hence in order to obtain as long a period of fuel consumption as possible, the efficiency was figured by considering all seven runs as one and using the average values of all pressures and temperatures. Since the thermodynamic efficiency of an injector is practically 100% the heat absorbed by the boiler is the amount required to evaporate the cold supply water. If then λ = the total heat, t_F the supply water temperature, then the factor of evaporation $F = \frac{\lambda - (t_F - 32)}{970.4}$

Let W_1 = water evaporated per lb. of coal. Then the equivalent evaporation from and at 212°F = $W_1 \times F$.
Then the heat absorbed by boiler per lb. of coal = $W_1(\lambda - t_F + 32)$

Efficiency of boiler and grate $= \frac{W_1(\lambda - t_F + 32)}{\text{BTU}/\text{lb coal}}$

The ideal refrigerating machine is a reversible engine operating in a Carnot cycle in a reverse direction from that of a steam or any other heat engine. The efficiency of a Carnot engine when operating as a heat engine $= \frac{H - H_e}{H}$, where H = the source of heat and H_e = that going to the refrigerator. If the engine be run backward the "thermodynamic efficiency" would be $E_1 = \frac{H_e}{H - H_e} = \frac{T_c}{T - T_c}$ where T_c = the absolute temperature of the ammonia leaving the refrigerator and T = the absolute temperature of the ammonia entering the condenser.

The thermodynamic efficiency of an

engine working in a Carnot cycle is less than one, hence that in the refrigerating **cycle** must always be greater than unity.

The object of the refrigerating process is the removal of the heat H in the cooler, so that this may be considered the useful work. Hence the actual efficiency of a refrigerating machine $\frac{K_1}{A W_c} = E_2$; where $K_1 = Q(t_2 - t_4)$, Q being the water passing through the cooler per minute and t_3 and t_4 are respectively the inlet and outlet temperatures. W_c = H.P. of the compressor cylinder and $A W_c$ its heat equivalent. The above efficiency gives a result greater than unity because the ammonia receives heat from the water in the cooler and rejects heat into the condenser. That is, the work to be done by the compressor is not the mechanical equivalent of refrigeration, but only that necessary to supply the difference between the heat rejected by the ammonia into the condenser and that received in the cooler.

The heat removed by the condenser = $K = Q(t_2 - t_1)$ where Q = condensing water per minute and t_2 and t_1 = the outlet and inlet temperatures respectively.

The heat removed by the jacket water = $K_2 = Q_1(t_6 - t_5)$ where Q_1 = jacket water per minute and t_6 and t_5 the outlet and inlet temperatures respectively.

The refrigerating capacity in tons per twenty four hours = $\frac{Q(t_3 - t_4) \times 24 \times 60}{288,000}$, where 288,000 is the melting effect of one ton of ice in B.T.U.

The thermal efficiency of the plant referred to the coal pile equals the refrigeration produced per lb. of coal divided by the B.T.U. value of a lb. of coal as fired.

The heat balance of the refrigerating system is as follows: $H_1 + AW_c = H \pm H_3$ where H_1 the heat abstracted (refrigeration); W_c = I.H.P. of compressor cylinder; H = heat abstracted in the condenser; H_3 = total sum of losses by radiation and convection, etc.

DISCUSSION.

The only steam consumption determined in the test was that of the engine and circulating pump together. In order to determine the water rate of the engine running noncondensing the pump would have to be connected up with the condenser and its steam consumption determined. This consumption subtracted from the water fed to the boiler would give the water rate of the engine. This determination could not be made because of lack of time.

The boiler and grate efficiency is very low. We think this is partly due to the large excess of air passing through the grate since there are no ash doors and the opening is very large. For a greater part of the time, however, sheet metal was set up in front of this opening. The boiler was running at about 60% of its normal rating and the efficiency is probably lower at this load.

The speed of the engine in the first run looks doubtful. At the beginning of the second run it was discovered that the continuous counter was not recording properly. The speed recorded was too low. In all probability the R.P.M. of 9[illegible].7 in the first run is too low. This would account for the low I.H. of the steam cylinder and the high refrigeration produced per minute per I.H.P. of both cylinders.

In several runs the heat removed by the condenser is less than the cold produced, which is contrary to theory and to results obtained in good practise.

In all the runs except the seventh the heat removed in the jacket water is greater than the indicated work of the compressor. This is certainly due to the very poor operation of the valves.

Curves #1 and #3 show that the [illegible] increases with increase of back pressure up to a

maximum and then decreases.

Curve #4 shows the tonnage to increase with increase of back pressure as it should. There must however, be a turning point in the curve because when the back pressure became equal to the condensing pressure there would be no expansion and therfore no refrigeration.

Curve #5 shows the I.H.P. per [illegible] tor to decrease with increase of back pressure as it should.

Curve #7 shows that the temperature of the gas entering the cooler (after passing the expansion valve) increases with the increase of back pressure. This would be expected since the expansion is decreased and hence a less drop in temperature.

The shape of card which should be obtained from the compressor when operating properly is shown in the annexed diagram. The work required to open the compressor valves is indicated by small projections at the pressure and suction lines. The effect of clearance is shown by a sloping of the curve "[illegible]". According to Siebel the expansion and compression curves of the indicator cards obtained in the test show that the valves leak very badly. During the entire time of the test only two satisfactory cards were obtained.

On the whole we consider the results of the test very unsatisfactory. The low mechanical efficiency is due to the leaking of the valves and these should be reground or to their seats and the entire machine should be given a thorough overhauling. We also think that some of the poor results were due to the incorrect readings of most of the thermometers. The thermometers were calibrated against a standard thermometer which had been calibrated at the U.S. Bureau of Standards, a few years before.

Run #5

Sample [illegible]

Coal [illegible]

Wt of pan = [illegible] gm. [illegible]

Wt of pan + coal = [illegible]

Wt of coal = [illegible]

Time of combustion = [illegible]

Radiation [illegible]

[illegible]

[illegible]

Max. [illegible] = [illegible]

Max. rise, correction [illegible]

Calorific value = [illegible] BTU [illegible]

Boiler Efficiency

Average gauge pressure = [illegible] [illegible]

Temp feed water = [illegible]

Factor of evaporation = [illegible]

Total coal used = [illegible] [illegible]

Feed water = [illegible]

Water evap. per lb coal as fired = [illegible]

Equiv. Evap from & at 212°F = [illegible]

Heat absorbed by boiler [illegible] BTU

% Eff. of boiler & [illegible] = [illegible]

I.H.P. (Steam End)

H.E. = [illegible] = [illegible] = [illegible]

C.E. = [illegible] = [illegible] [illegible]

I.H.P. (Comp. End)

I.H.P. = [illegible] = [illegible]

Mech. Eff. = [illegible] = [illegible]

Heat Removed by Condenser = [illegible]

$k = a(t_2 - t_1)$ = [illegible] = [illegible] BTU

Coal produced [illegible] = [illegible]

Heat removed by jacket [illegible] = [illegible]

Heat equiv. of work done [illegible] = [illegible]

Thermodynamic Eff. = [illegible] = [illegible] = [illegible]

Actual Eff. = [illegible] = [illegible] = [illegible]

Eff. Ref. = [illegible]

Refrigeration [illegible]

[illegible]

Refrigeration [illegible]

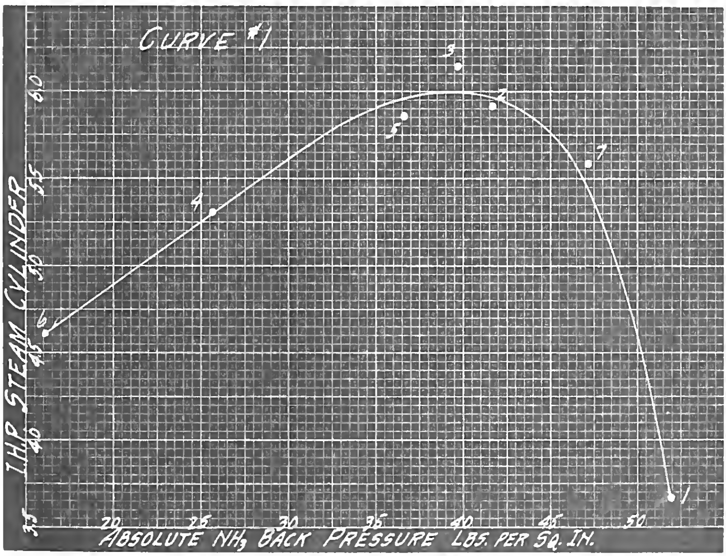
[illegible]

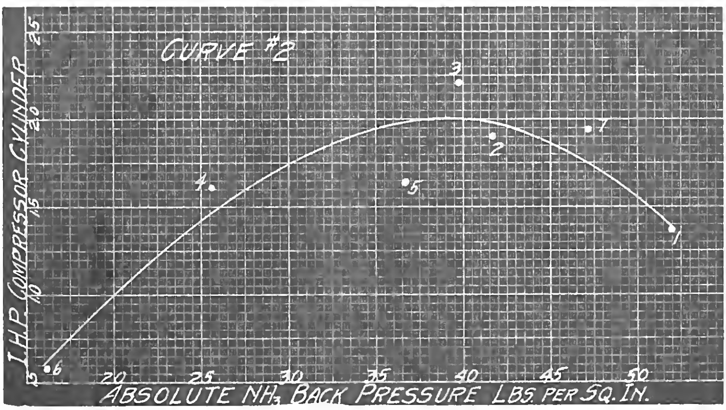
Refrigeration [illegible]

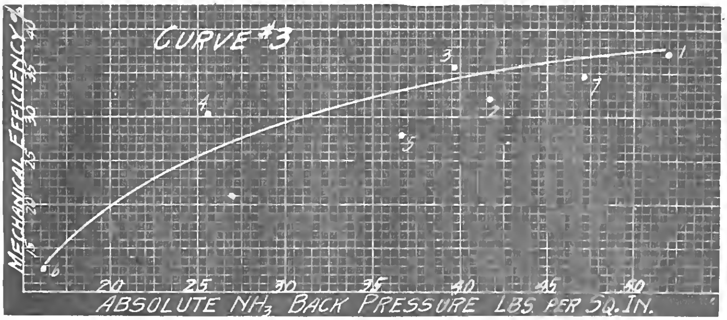
[illegible]

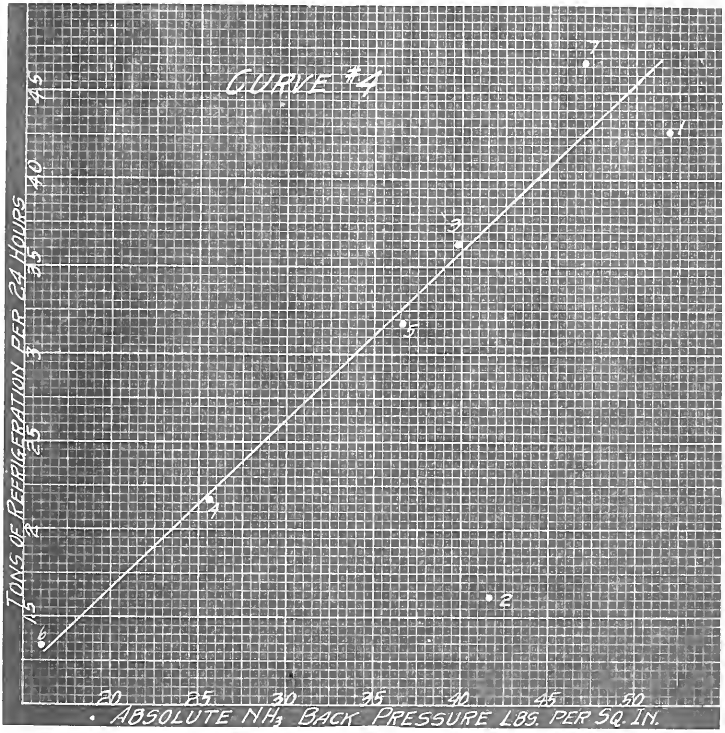
Refrigerating capacity = [illegible]

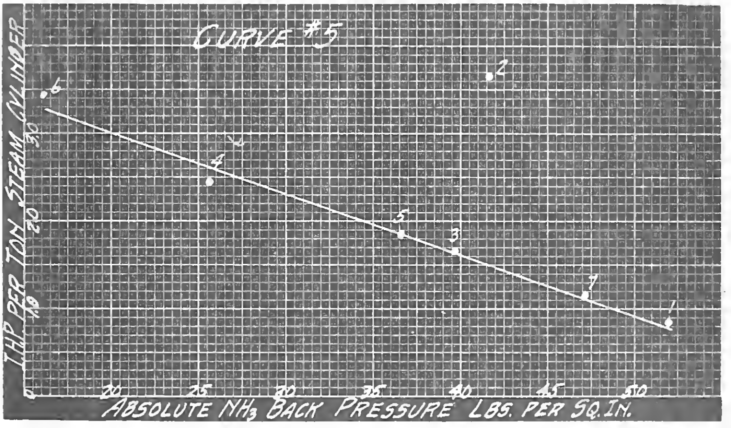
[illegible] Refrigeration [illegible]

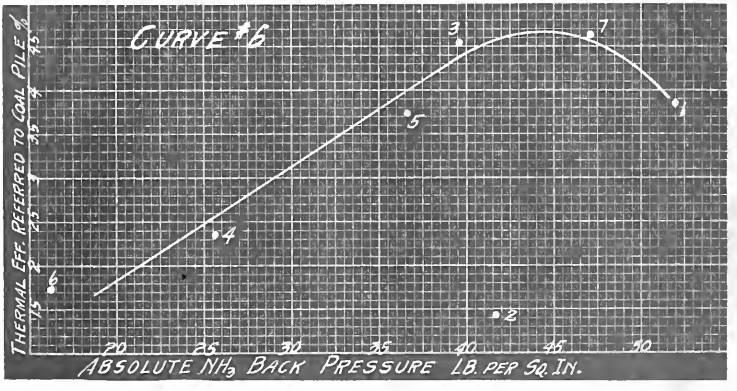

CURVE #1
I.H.P. STEAM CYLINDER
ABSOLUTE NH3 BACK PRESSURE LBS. PER SQ. IN.
35
40
45
50
55
60
20
25
30
35
40
45
50
1
2
3
4
5
6
7

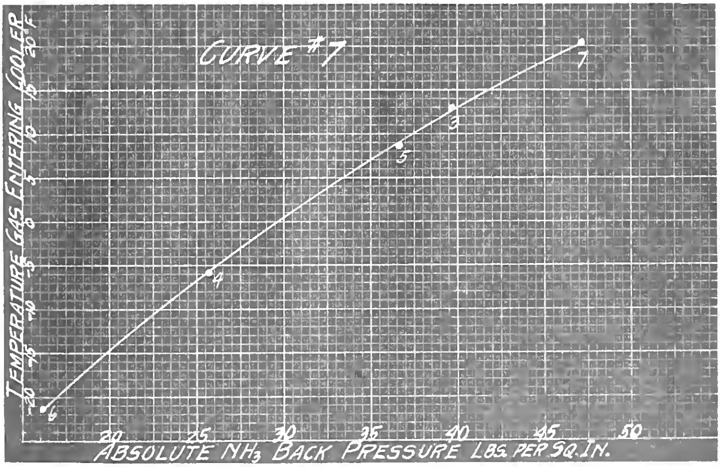

CURVE #2
I.H.P. COMPRESSOR CYLINDER
ABSOLUTE NH3 BACK PRESSURE LBS. PER SQ. IN.
15
20
25
30
35
40
45
50
10
1
2
3
4
5
6
7


CURVE #3
MECHANICAL EFFICIENCY %
15
20
25
30
35
40
20
25
30
35
40
45
50
ABSOLUTE NH_3 BACK PRESSURE LBS. PER SQ. IN.

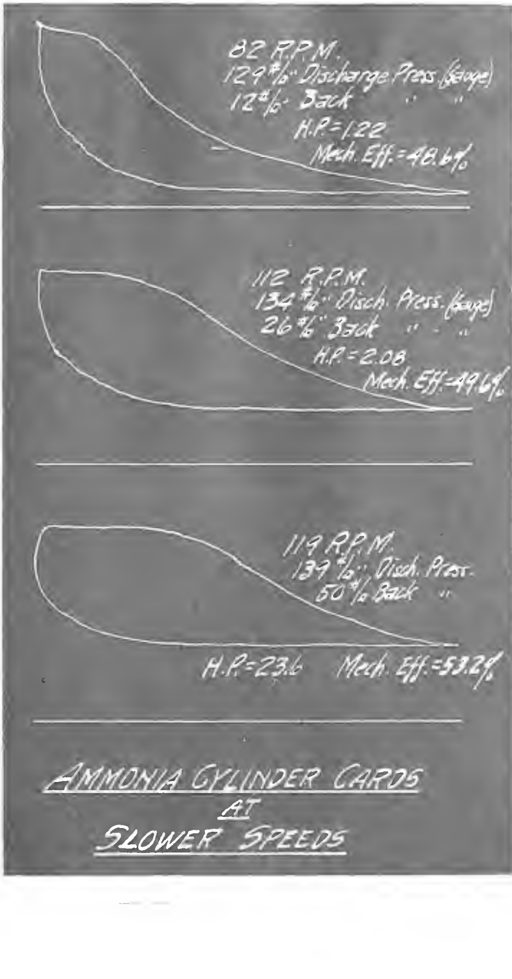

CURVE #4
TONS OF REFRIGERATION PER 24 HOURS
ABSOLUTE NH3 BACK PRESSURE LBS. PER SQ. IN.
15
20
25
30
35
40
45
20
25
30
35
40
45
50
1
2
3
4
5
6
7


CURVE #5
THP PER TON STEAM CYLINDER
30
20
10
20
25
30
35
40
45
50
ABSOLUTE NH_3 BACK PRESSURE LBS. PER SQ. IN.

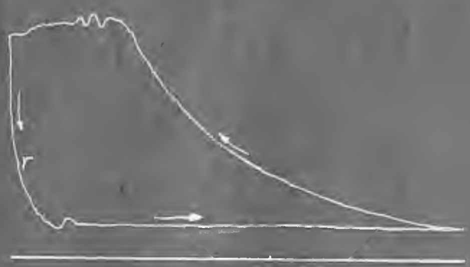

CURVE #6
THERMAL EFF. REFERRED TO COAL PILE %
ABSOLUTE NH_3 BACK PRESSURE LB. PER SQ. IN.
20
25
30
35
40
45
50
1.5
2
2.5
3
3.5
4
4.5
1
2
3
4
5
6
7



CURVE #7
TEMPERATURE GAS ENTERING COOLER
-20
-15
-10
-5
0
5
10
15
20°F
20
25
30
35
40
45
50
ABSOLUTE NH3 BACK PRESSURE LBS. PER SQ. IN.
6
4
5
3
7



AMMONIA CYLINDER CARDS
AT
SLOWER SPEEDS



CARD OF A PROPERLY WORKING COMPRESSOR

This is one of the only two ideal cards obtained during the entire seven runs.

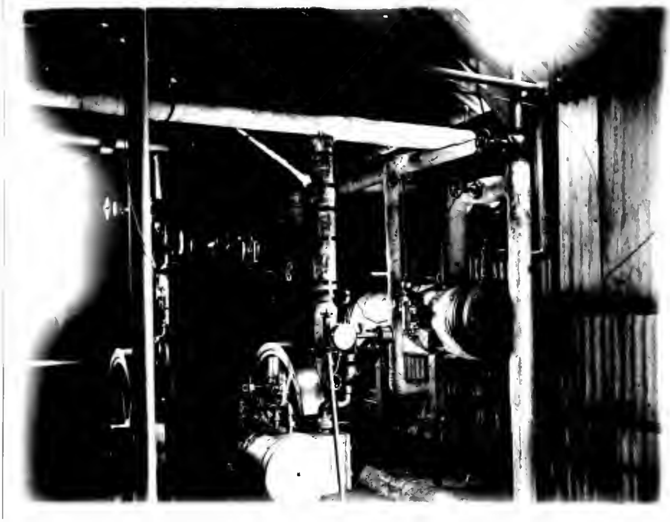
Compressor

Expansion Coils with Accumulator
Behind

Expansion Coils showing Mineral Wool Used as Insulating Material.

Steam Cylinder

Circulating Pump



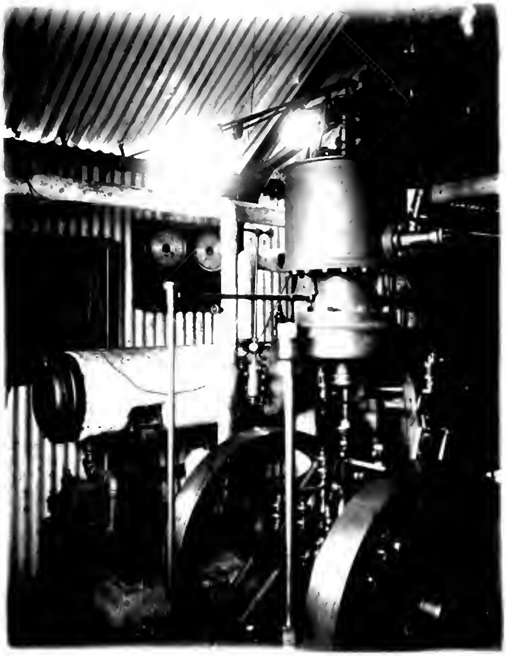
Steam Cylinder   Steam Condenser & Vacuum Pump

Close View of
Engine

NH_3 Condenser

Accumulator

Receiver



Steam Condenser & Vacuum Pump

Compressor

TIME

RUN #2 RUNNING LOG MAY 10, 1912

TIME	BOILER ROOM WEIGHTS: COAL	ASH	FEED WATER	BOILER ROOM TEMPS: SUPPLY WATER	WATER TO BOILER	STEAM CALORIMETER	STEAM PRESS	ENGINE ROOM WTS: WATER USED IN SYSTEM	JACKET WATER	ENGINE ROOM PRESS'R: STEAM TO ENGINE	DISCHARGE FROM COMP	RETURN TO COMP	TEMPERATURES: STEAM CALORIMETER	WATER: JACKET INLET	JACKET OUTLET	CONDENSER INLET	CONDENSER OUTLET	COOLER INLET	COOLER OUTLET	AMMONIA: COMPRESSOR OUTLET	COMPRESSOR INLET	CONDENSER INLET	CONDENSER OUTLET	COOLER INLET	COOLER OUTLET	BEFORE EXPAN. VALVE	BAROMETER	CONTINUOUS COUNTER
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		76	75	[illegible]	—
[illegible]						[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	"		74	[illegible]	"	—
[illegible]																											"	[illegible]
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	"	[illegible]
[illegible]						[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]			"		[illegible]	[illegible]	"	[illegible]
[illegible]				[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	"	[illegible]	"		"	"	"	161
[illegible]						[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		"	[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]		[illegible]	"	"	[illegible]
[illegible]						[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]		[illegible]	"	"	[illegible]
[illegible]							[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"		[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"		"	[illegible]	"	160
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

TIME	COAL	ASH																										
8:00 A.M.				[illegible]		[illegible]	[illegible]			[illegible]														113	[illegible]	11	29.16	[illegible]
8:15				"	[illegible]		[illegible]			[illegible]	[illegible]		"								[illegible]	[illegible]	[illegible]	144	110	112	"	0117
8:30				[illegible]	1.72	[illegible]	[illegible]			[illegible]		"	"	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	146	81	79	"	[illegible]
8:45						[illegible]	[illegible]			"	[illegible]	"	[illegible]	71	[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	"	[illegible]
9:00						244	77			"	[illegible]	[illegible]	[illegible]	[illegible]		67	78	[illegible]	"	[illegible]	[illegible]	"		[illegible]	[illegible]	[illegible]	"	[illegible]
9:15						250	[illegible]			[illegible]	"	[illegible]	[illegible]	"	110.4	68	78	78	69	[illegible]	"	"	"	[illegible]	[illegible]	78	"	7696
9:30				[illegible]	1.67		[illegible]			58	[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	80	81	[illegible]			142	81	[illegible]	77	77.5	29.14	1998
9:45						233	[illegible]			56	"	"	[illegible]	[illegible]	[illegible]	"	"	80	71	174	[illegible]	140	79	111	80	80	[illegible]	[illegible]
10:00				66	1.52	232	[illegible]			[illegible]	"	28	[illegible]	[illegible]	[illegible]	78	"	"	[illegible]	"	81	149	[illegible]	91	79	"	"	[illegible]
10:15						224.5	"			"	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	"	"	184	82	"	"	"	[illegible]	"	[illegible]	[illegible]
10:30						238	85			58	"	26	226	"	164	72	86	81	"	192	81	137	[illegible]	[illegible]	[illegible]	81	[illegible]	[illegible]
10:45				[illegible]	1.48	233	84			60	117.0	29	250	50	120	73	84	83	74	188	"	148	84	116	80	83	"	9860
11:00	[illegible]	25.6	133.1			242	82	1178.3	316.7	62	117.5	30	247	"	111.5	74	85	85	75	182	80	147.8	85	14	81	83	"	7761
[illegible]				66	1.56	239.7	81.9			56.7	154.8	29.4	248.2	51.8	110.5	48.5	[illegible]	73.1	108.5	177.4	80.4	128.7	78.3	13	75	77.7	29.13	R.P.M.
[illegible]	[illegible]	25.6	133.1	66	1.56	[illegible]	[illegible]	1178.3	316.7	56.7	109.8	25.4	257.8	51.8	110.5	49.5	76.2	77.1	70.5	178.4	77.4	139.7	78.3	13	74	77.7	[illegible]	[illegible]

RUN #4 — RUNNING LOG — MAY 11 1912

BOILER ROOM / ENGINE ROOM (Weights, Temps, Pressures)

Time	Boiler Room: Weights: Coal	Ash	Feed Water	Temps: Supply Water	Water to Boiler	Steam Calorimeter	Steam Press	Engine Room: Wts: Water Used in System	Jacket Water	Pressures: Steam to Engine	NH3 Discharge from Comp.	NH3 Return to Comp.	Temperatures: Steam Calorimeter
10.45 A.M.				78	161?	226				47?	[illegible]	[illegible]	[illegible]
11.00				67	135	233				"	136?	[illegible]	234?
11.15				66	132	224	80?			50	142?	[illegible]	[illegible]
11.30				65	[illegible]	224	"			49	140	12.5	"
11.45				"	"	"	"			50	142?	14	240?
12.00				56	127	232?	"			"	144	16	244?
12.15				54?	125	24?	77			"	149	18	236?
12.30				66?	135?	236?	80?			"	142?	14.5	242
12.45				60	126	240	"			"	138?	14	238?
1.00	200	198?	745?	62	"	232	86?	9867?	3417?	47?	141	12.5	246?
AVER.				62.4	130	231.9	80.2			49.0	140.3	14.4	241.7
AVER. CORR.	200	193	74.6?	63.4	131	231.9	74.7?	9827?	3417	49	134.3?	11.4?	241.1

ENGINE ROOM — TEMPERATURES (Water, Ammonia), Barometer, Counter

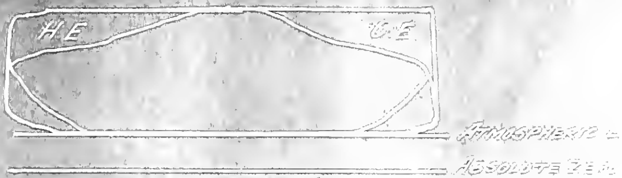
Time	Water: Jacket Inlet	Jacket Outlet	Condenser Inlet	Condenser Outlet	Cooler Inlet	Cooler Outlet	Ammonia: Compressor Outlet	Compressor Inlet	Condenser Inlet	Condenser Outlet	Cooler Inlet	Cooler Outlet	Before Expan. Valve	Barometer	Continuous Counter
10.45 A.M.	[illegible]	[illegible]	[illegible]	70?	64?		148?	[illegible]	84?	69?	16?	61	67		0961
11.00	50?	74?	64?	"	"		152?	14?	91	"	6.5?	68	68		9477
11.15	[illegible]	[illegible]	"	66?	73?	66?	150?	14?	102?	[illegible]	-16?	70?	70?		[illegible]
11.30	"	49?	[illegible]	62?	[illegible]	64?	154?	"	[illegible]	[illegible]	[illegible]	[illegible]	71?	[illegible]	[illegible]
11.45	"	106?	64?	"	74	"	152?	"	106?	58?	-7?	72?	72		[illegible]
12.00	"	108?	61	75?	"	"	158?	"	112	74?	7.5?	"	"		3339?
12.15	51	110	63	71	71?	"	172?	"	106	74?	6?	73	73		5732?
12.30	50	107?	57?	76	"	68	"	"	117?	7.5?	-6.5	74	73	2291?	9114?
12.45	52	102	68	71	77	"	170?	77	"	70?	-6?	74?	74?		[illegible]
1.00	52	112	68?	"	"	69	"	76	116	71	-14.5?	73	73?		3156?
AVER.	51.6	99.1?	60.8?	74.2	73.8	66.1	164.7	75.5	108.6	73.9	-5.9	74.5	71.5?	29.98?	
AVER. CORR.	51.6	99.9?	70?	74.2?	73.8	66.7?	164.7	74.0	108.6	73.9?	-5.9	74.5	71.3?	14.71?	[illegible]

RUN #5 — RUNNING LOG — MAY 11, 1912

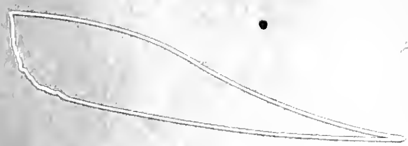
TIME	BOILER ROOM — WEIGHTS — COAL	ASH	FEED WATER	TEMPS — SUPPLY WATER	WATER TO BOILER	STEAM CALORIMETER	STEAM PRESS	ENGINE ROOM — WTS. — WATER USED IN SYSTEM	JACKET WATER	PRESSURES — STEAM TO ENGINE	NH3 DISCHARGE FROM COMP	NH3 RETURN TO COMP	TEMPERATURES — STEAM CALORIMETER	WATER — JACKET INLET	JACKET OUTLET	CONDENSER INLET	CONDENSER OUTLET	COOLER INLET	COOLER OUTLET	AMMONIA — COMPRESSOR OUTLET	COMPRESSOR INLET	CONDENSER INLET	CONDENSER OUTLET	COOLER INLET	COOLER OUTLET	BEFORE EXPAN. VALVE	BAROMETER	CONTINUOUS COUNTER
2:00 P.M.				60	108	238	85			55	162	22	245	51	120	72	82	81	72	134	74	126	81.5	4.5	76	76	28.91	2865
2:15				60		231	84			"	164	25	243	50	100	71.5	84	80.5	"	131	73	130	83	8.5	77.5	78	"	5327
2:30				57		232	80			"	164	22	241	"	73	"	82	80.5	74	176	"	"	86	7.5	79	"	28.93	7784
2:45				56	143	230	75			53	160	27	237	51	104	71.5	81	80	72	173	72	134	81	11	77	"	"	9155
3:00				60		234	87			55	157	25	234	50	107	"	80	74	71.5	174	"	133	80	9	76	77	"	2520
3:15				56	148	250	86			"	162	27	240	"	76	77	81	80	72.5	172	"	"	81	11	"	78	28.92	
3:30				57		228	"			"	161	23	242	"	77	75	"	"	74	166	71	126.5	"	5.5	"	77.5	"	7399
3:45						234	"			53	164	26	239	"	90	73.5	82	81	72.5	166	"	125	81.5	8	77	77	"	9757
4:00	161	6.4	898			233	75	12597	3725	51	163	29	237	52	110	"	"	81.5	74.5	168	"	124.5	82	14.5	"	"	28.90	2139
AVER.				58.3	149.3	[illegible]	80.8			54.1	163.7	25.4	240.3	50.4	101.9	73.1	81.8	80.7	72.6	173.2	72.1	127.4	81.4	8.83	76.7	77.4	28.92	
AVER. CORR.	161	6.4	898	58.3	150.3	234.5	74.1	12597	3725	54.1	146.2	22.4	240.3	50.4	101.9	73.1	79.8	78.7	72.6	173.2	72.1	127.4	81.4	8.83	76.7	77.4	14.2 lbs.	R.P.M. = 160.6

RUN #6 — RUNNING LOG — MAY 11, 1912

	BOILER ROOM							ENGINE ROOM																				
	WEIGHTS			TEMP'S				WTS		PRESSURES			TEMPERATURES															
														WATER						AMMONIA								
TIME	COAL	ASH	FEED WATER	SUPPLY WATER	WATER TO BOILER	STEAM CALORIMETER	STEAM PRESS	WATER USED IN SYSTEM	JACKET WATER	STEAM TO ENGINE	NH3 DISCHARGE FROM COMP	NH3 RETURN TO COMP	STEAM CALORIMETER	JACKET INLET	JACKET OUTLET	CONDENSER INLET	CONDENSER OUTLET	COOLER INLET	COOLER OUTLET	COMPRESSOR OUTLET	COMPRESSOR INLET	CONDENSER INLET	CONDENSER OUTLET	COOLER INLET	COOLER OUTLET	BEFORE EXPAN VALVE	BAROMETER	CONTINUOUS COUNTER
4.45 P.M.				72	160	238	80			46	145	3	230	50	106	69	74	74	72	148	71	106	75	-25	72	72	28.90	0036
5.00				"		248	86			43	144	3	237	51	86	70	75	"	71	144	"	"	70	-16	"	"	28.94	2537
5.15				"		236	85			45	"	5	240	"	108	"	"	75	"	148	70	100	74	-19	70	"	28.96	5040
5.30				"		232	87			44	145	4	239	50	111	72	76	76	72	"	"	102	"	-21	"	70	28.95	7521
5.45				"		241	85			"	"	4.5	230	"	113	"	"	"	"	"	"	97	75	-22.5	72	"	28.96	0022
6.00				"		222	83			"	141	10	236	49	81	"	77	"	74.5	150	"	"	76	-24	70	"	"	2482
6.15				98	142	226	80			45	148	4.5	235	"	83	73	"	"	73	137	"	95	"	-24.5	71	71	"	4943
6.30				"		238	80			47	150	6	232	"	96	"	78	77	73.5	142	69	92	76.5	-18.5	72	70	"	7441
6.45	1482	55	805	"		241	77	13995	3514	45	"	5	236	"	98	74	"	73	73	141	68	91	78	-21	71	"	28.97	9877
Av's				87.6	141.6	235.4	82.6			44.7	144.6	5	235.5	49.8	97.3	71.7	75.2	75.0	72.1	145.3	67.9	98.4	74.7	-21.26	71.1	70.8	28.95	
AV'GS	1482	55	805	87.3	141	235.4	77.5	13996	3514	44.7	144.6	2	236.5	49.6	98.0	71.7	74.2	74.4	72.1	145.3	67.9	98.4	74.7	-21.3	71.1	70.8	1441	R.P.M. 66.7

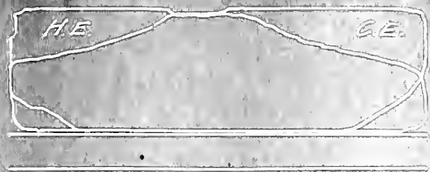


SAMPLE STEAM CARDS
60 LB. SPRING



SAMPLE AMMONIA CARD
100 LB SPRING

TIME	Head End Area	Length	[illegible]	Crank End [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1:00	2.04	3.03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1:15	2.24	3.06	.730	2.27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1:30	2.28	3.06	.745	2.24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1:45	2.27	3.06	.742	2.27	[illegible]	.742	[illegible]	[illegible]	[illegible]
2:00	2.15	3.07	[illegible]	2.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:15	2.23	3.07	.728	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2:30	2.37	3.11	.763	[illegible]	3.11	[illegible]	[illegible]	[illegible]	[illegible]
2:45	2.33	3.06	.762	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:00	2.52	3.06	.824	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:15	2.38	3.06	[illegible]	2.43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3:30	2.37	3.05	.777	2.34	3.05	[illegible]	[illegible]	[illegible]	[illegible]
3:45	2.27	3.05	.746	2.25	3.05	[illegible]	[illegible]	[illegible]	[illegible]
4:00	2.32	3.05	.760	2.33	3.05	[illegible]	[illegible]	[illegible]	[illegible]
Av.			.747			[illegible]			[illegible]
% Corr.			[illegible]			[illegible]			[illegible]



Atmospheric Line
Absolute Zero "

SAMPLE STEAM CARDS
60 LB. SPRING

AVERAGE R.P.M. = 130.16
AVERAGE NH_3 DISCHARGE PRES. [illegible] = 171
" " " BACK " " = 27.3

Atmospheric Line
Absolute Zero "

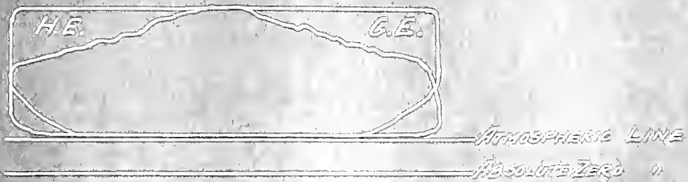
SAMPLE AMMONIA CARDS
100 LB. SPRING

RUN NO. 2.

Time	Steam Cylinder						NH_3 Cylinder		
	Head End			Crank End			Area	Length	
	Area	Length	[illegible]	Area	Length	[illegible]			
[illegible]	2.32	3.06	.773	2.3[illegible]	3.0[illegible]	.766	.74	[illegible]	.231
6.45	2.37	3.20	.741	2.33	3.21	.716	.73	[illegible]	[illegible]
7.30							1.00	[illegible]	[illegible]
7.45	2.49	3.10	.803	2.42	[illegible]	.752	.982	[illegible]	.324
8.00	2.10	3.20	.656	2.14	3.20	[illegible]	[illegible]	[illegible]	.317
8.15	2.28	2.98	.76[illegible]	2.19	2.98	.74[illegible]			
8.30	2.35	3.30	.713	2.32	3.30	.70[illegible]			
8.45							[illegible]	[illegible]	[illegible]
9.00							.79	[illegible]	[illegible]
Av.			.742			.72[illegible]			
M.E.P. Corr.			[illegible]			[illegible]			

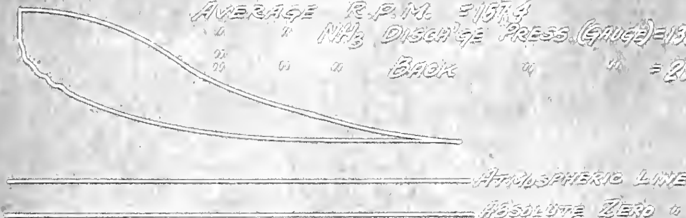
[illegible]

[illegible]



SAMPLE STEAM CARDS
60 LB. SPRING

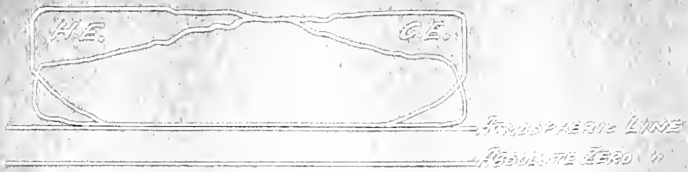
Average R.P.M. = 157.4
" " NH_3 Disch'ge Press. (Gauge) = 138.8
" " " Back " " = 25.4



SAMPLE AMMONIA CARD
100 LB. SPRING

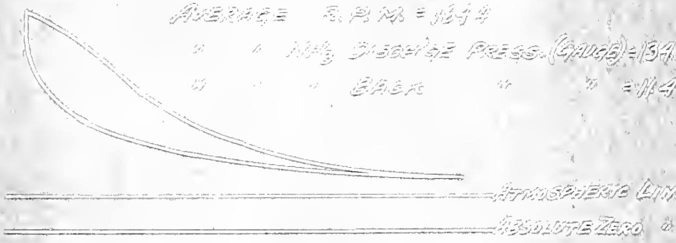
RUN NO. 3.

Time	Steam Cylinder						NH_3 Cylinder		
	Head End			Crank End			Area	Length	M.O.
	Area	Length	M.O.	Area	Length	M.O.			
8:00	2.20	2.96	.741	2.11	2.96	.709	1.10	3.16	.348
8:15	2.13	3.01	.707	2.13	3.01	.707	1.09	3.20	.340
8:30	2.25	3.02	.745	2.33	3.02	.770	1.00	3.19	.313
8:45	2.38	3.07	.776	2.32	3.07	.756	.96	3.17	.303
9:00	2.28	3.10	.739	2.29	3.10	.740	1.11	3.16	.350
9:15	2.45	3.10	.739	2.44	3.10	.733	1.15	3.17	.363
9:30	2.37	3.09	.768	2.33	3.09	.754	1.00	3.16	.316
9:45	2.44	3.08	.792	2.38	3.08	.774	.94	3.16	.297
10:00	2.36	3.01	.784	2.45	3.01	.813	1.04	3.14	.332
10:15	2.40	3.01	.798	2.35	3.01	.780	.93	3.16	.294
10:30	2.50	3.00	.834	2.50	3.00	.834	1.24	3.18	.390
10:45	2.49	2.97	.839	2.37	2.97	.796	1.00	3.09	.324
11:00	2.57	2.96	.870	2.58	2.96	.873	1.10	3.12	.351
Av.			.779			.772			.332
Av. Corr.			47.3 #/□"			46 #/□"			32.6 #/□"



SAMPLE STEAM CARDS
60 LB. SPRING

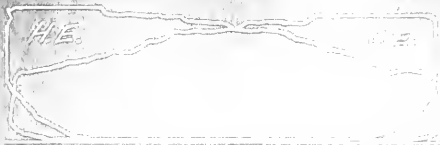
AVERAGE R.P.M. = 134.4
" " NH_3 DISCH'GE PRESS. (GAUGE) = 134.3
" " " BACK " " = 11.4



SAMPLE AMMONIA CARD
100 LB. SPRING

RUN NO. 4.

Time	Steam Cylinder						NH_3 Cylinder		
	Head End			Crank End			Area	Length	M.O.
	Area	Length	M.O.	Area	Length	M.O.			
10:45	1.95	3.[illegible]	.625	[illegible]	3.11	[illegible]	[illegible]	3.12	.218
11:00	2.02	3.12	.648	[illegible]	3.12	[illegible]	.60	3.12	.192
11:15	2.10	3.12	.674	[illegible]	3.13	[illegible]	.63	3.13	.201
11:30	1.94	3.12	.623	1.95	3.12	.625	.83	3.12	.266
11:45	2.10	3.12	.674	2.00	3.12	.642	.78	3.14	.248
12:00	2.01	3.12	.641	2.00	3.12	.641	.68	3.16	.215
12:15	2.14	3.12	.687	2.17	3.12	.695	1.03	3.12	.33
12:30	2.04	3.07	.665	1.99	3.07	.649	.72	3.12	.231
12:45	2.05	3.04	.675	1.96	3.04	.645	.72	3.14	.229
1:00	1.96	3.05	.646	1.97	3.05	.646	.60	3.10	.194
Av.			.656			.638			.232
Av. Corr.			[illegible]			[illegible]			23.0[illegible]



H.E.

Atmospheric Line

Absolute Zero

Sample Steam Card

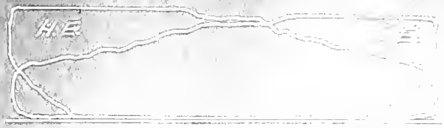
= 22.4

Atmospheric Line

Absolute Zero

Sample [illegible]

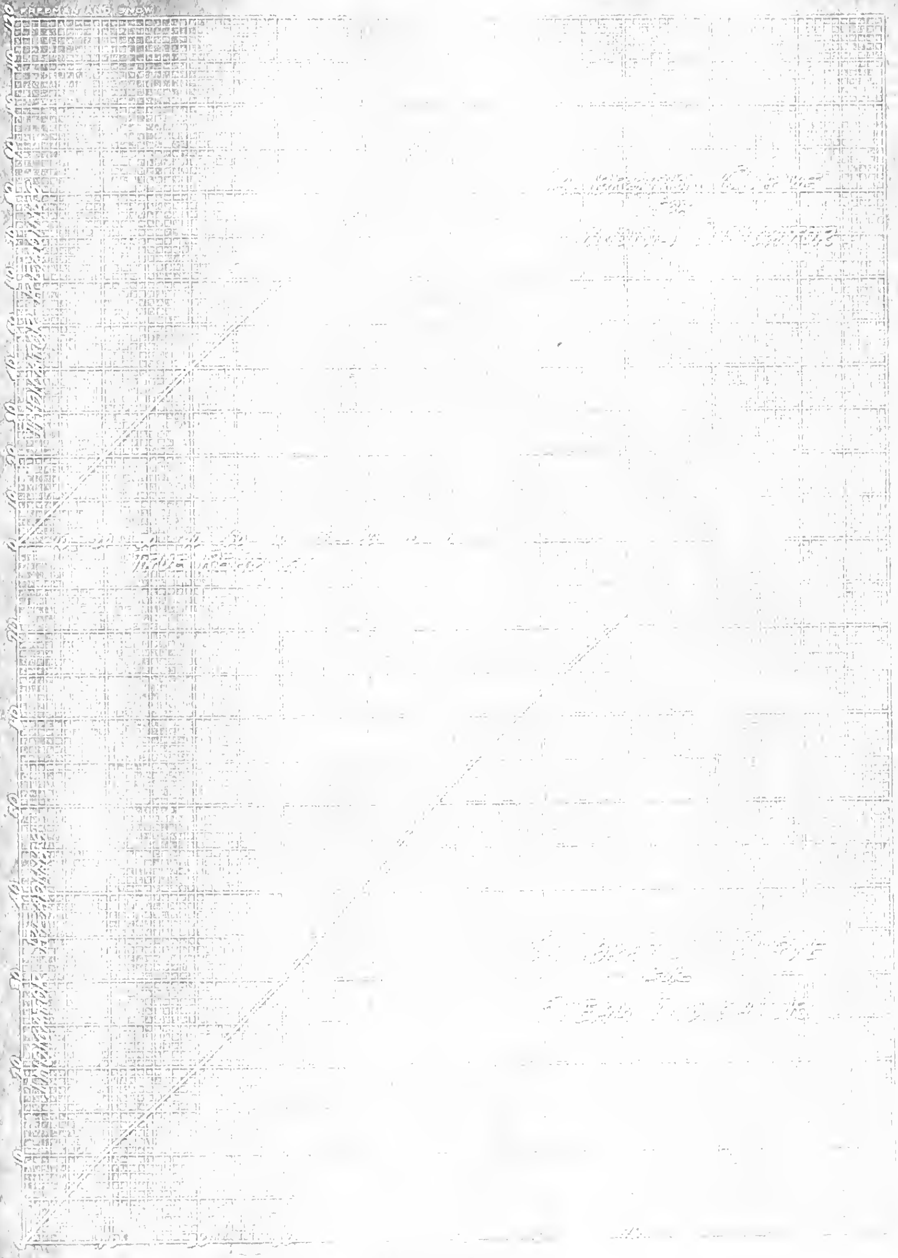
Time	Steam [illegible]							[illegible] Cylinder	
	Head End			[illegible]					
	Area	Length	[illegible]	Area	Length	[illegible]	[illegible]	[illegible]	[illegible]
2.00	2.29	3.05	.75	[illegible]	[illegible]	[illegible]		[illegible]	.219
2.15	2.39	3.25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.226
2.30	2.30	3.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.226
2.45	2.26	3.10	.723	2.23	[illegible]	[illegible]	[illegible]	[illegible]	.235
3.00	2.34	3.075	[illegible]	[illegible]	[illegible]	[illegible]			
3.15	2.39	3.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.232
3.30	2.26	3.05	.72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.231
3.45	2.33	3.10	.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.250
4.00	2.30	3.10	.742	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Av.			[illegible]			[illegible]			[illegible]
H.P.			[illegible]			[illegible]			[illegible]



Time	[illegible]		[illegible]
	Head End		[illegible]
	Area	Length	[illegible]
4:45	1.67	3.[illegible]	[illegible]
5:00	1.69	3.[illegible]	[illegible]
5:15	1.70	2.95	[illegible]
5:30	1.75	2.95	[illegible]
5:45	1.74	3.[illegible]	[illegible]
6:00	1.73	3.[illegible]	[illegible]
6:15	1.78	3.05	[illegible]
6:30	1.59	3.[illegible]	[illegible]
6:45	1.53	3.075	[illegible]
Av.			[illegible]
Av. Corr.			[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	2.2[illegible]
[illegible]	
6	2.20
7	2.25
8	2.25
[illegible]	2.45
10	2.22

[illegible]

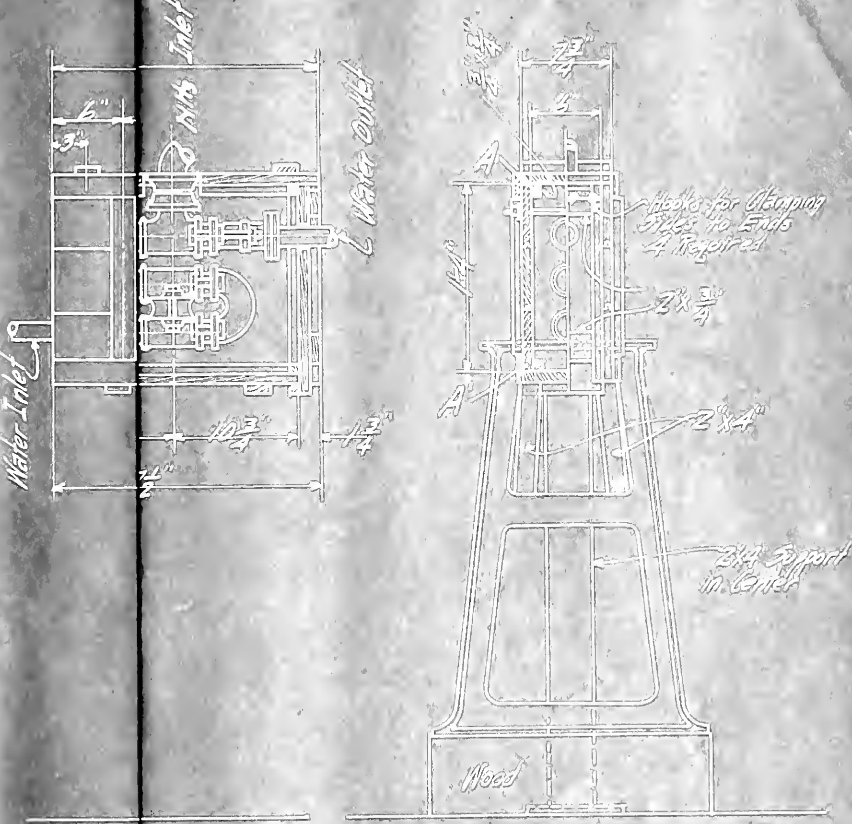

FREEMAN AND SNOW


Heater


CROSS HEAD
SECTION A-


S OF INDICATOR REDUCING MOTION
FOR AMMONIA CYLINDER OF
REE TON YORK ICE MACHINE
THESIS BY
EERBAUM P.L. KEACHIE N.W. STRALE
CALE:- 6"=1 FT. JAN. 24, 1912
PIN D
FRAME
5/16 Set Screw
B
Pin C
Ammonia Cylinder

PLATE IV



HALF SECTION

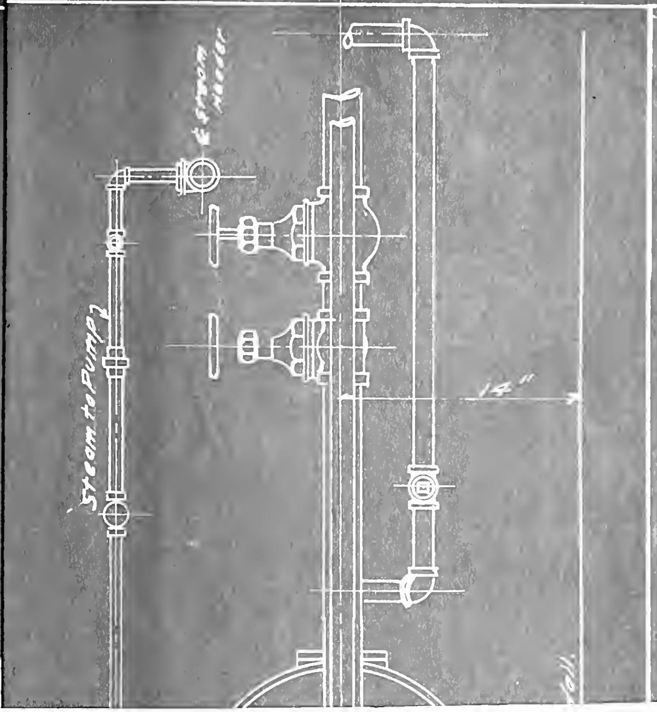
ONDENSER

1912

PLATE IV

Deerbaum - Keschie - Strale

PLATE IV


Steam Header
Steam to Pump
14"

SUMMARY OF AVERAGE RESULTS

	NUMBER OF RUN	1	2	3	4	5	6	7
1	Coal per hour lbs. [illegible]	[illegible]	1096.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	Feed water per hour lbs.	[illegible]	[illegible]	[illegible]	3310	4490	[illegible]	4600.0
3	[illegible] Boiler [illegible]	75	74	76.7	74.7	74.7	77.6	75.6
4	[illegible]	[illegible]	[illegible]	97.83	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	1163.5	1165.2	1161.0	[illegible]	1155.9	[illegible]
6	[illegible]				4381			
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44.1	53.6
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]