TEST OF A 30 TON REFRIGERATION PLANT

THESIS FOR DEGREE OF M. E.

O. W. FAIRBANKS

1922

Refrigeration + refrigerating machinery

THESIS

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by

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Lansing, Michigan

M.E

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THESIS

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The plant under test is situated in Holland, Michigan on the edge of Black Lake.

The equipment consists of:-

1 - 100 H. P. horozontal fire-tube Boiler, made by the Muskegon Boiler Works. See sketch 2.

1 - 20 ton Ammonia Compressor, made by the Cleveland Ice Machine Co. See picture 3 and sketch 2.

1 - 50 H. P. Nagle Corliss Steam Engine, direct connected to above compressor. See picture 3 and sketch 2.

1 - 10 ton Ice Tank 14 ft. 6 in. X 36 ft. X 4 ft. deep containing 154 - 300 lb. ice cans and 96 - 2 in. ammonia expansion pipes 30 ft. long and connected three groups in parallel to a proper header. See sketches 2 and 3.

1 - 10 ton Ammonia Compressor, made by the york Mfg. Company. See sketches 2 and 3 and picture 4.

1- 40 H. P. Slide Valve Steam Engine, belt connected to above compressor. See picture 4 and sketches 2 and 3.

1 - 5 ton Ice Tank 11 ft. X 22 ft. X 3 ft. deep containing 82 - 200 lb. ice cans and a 20 in. dia. X 6 ft. long ammonia drum with 2 in. tubes. See sketch 2.

1 - $3\frac{1}{2}$ X 3 X 4 Single Cylinder Double Acting Feed Water Pump. See sketch 2.

1 - 5 X 3 X 3 Duplex Double Acting lake water Pump designated as pump No. 1. See sketch 2.

1 - 5 X 4 X 5 Single Cylinder Double Acting well water Pump, designated as pump No. 2. See sketch 2.

1 - 6 X 4 X 5 Duplex Double Acting lake water Pump, designated as pump No. 3. See sketch 2.

1 - 5 H. P. Slide Valve Steam Engine, belt connected to two brine agitators, one in each tank. See sketches 2 and 3.

1 Open Air Condenser, situated on the roof and consisting of two stands in parallel of 2 in. pipes, 20 pipes high and 20 ft. long. See picture 1 and sketch 3.

1 Double Tube Condenser, situated inside the engine room, connected in series with the Open Air Condenser and consisting of two stands in parallel of 2 in. pipe outside with 1-1/4 in. inside, 8 pipes high and 15 ft. long. See sketch 2.

1 Flat Cooler, situated inside the engine room and consisting of 4 - 2½ in. pipes and 4 - 2 in. pipes outside with 1-1/4 in. pipes inside, 8 pipes high and 18 ft. 10 in. long. See sketch 2.

2 Ammonia traps, 1 Steam Oil Trap, I Pure Water Reboiler, 1 Skimmer, 1 Pure Water Storage Tank (see sketch 2), 1 Ammonia Storage Tank, and many other small necessities not dealt with in this thesis.

SIGNIFICANT ITEMS AND PECULIAR CONDITIONS PERTAINING TO THIS PLANT.

All ice is made from condensed steam, reboiled, skimmed, filtered and cooled after leaving the exhaust from the engines and pumps.

The boiler feed water is obtained from two open wells about 22 ft. deep, at an average temperature of 53.2° F. It is forced through the double pipe condenser and flat cooler before being pumped into the boiler by the boiler feed water pump. Its temperature as it enters the boiler is about 110°F.

The open air condenser is partly protected from winds from the south by the upright portion of the building and the windbrake built above the building, and from the west by a windbrake built between it and the smoke stack. See photo 1 and sketch 3.

The cooling water for the single tube condenser is pumped directly from the lake by pumps 1 and 3. The temperature of the water varies with the temperature of the lake. During the test it varied from 72 to 80° F. See log sheets 1a and 1b.

OBJECT OF TEST.

The object of the test was to determine;-

A. The direct cost of manufacturing ice at this plant.

B. The rate of heat transfer from the pure water thru the various stages until it finally reaches the cooling water.

C. The influence of air temperatures and wind directions and velocities on the condensing properties of the single tube condenser.

D. The influence of cooling water temperatures on the condensing properties of the condensers.

From the required data taken many empirical plant constants were determined which are of value in comparing the plant performance of this plant with that of other plants. It was found necessary to take separate data on both ice tanks and on both ammonia compressors. From this data comparative values were deduced. These values on the ice tanks are of interest in that they show the comparative performance of the 5 ton ammonia drum tank with the 10 ton ammonia pipe tank.

A. DIRECT COST.

In determining the direct cost of manufacturing ice only these three items were considered:- Fuel, labor and oil. To determine the cost per ton of ice produced, it was necessary to determine the amount of ice produced per unit of time.

From 50 to 65 tests were taken to determine; first, the amount of fuel used and cost of same per hour; second, the amount of ice produced per day for each day of the test. The oil used was approximated over several days and an average taken. Cup grease and three kinds of oil were used, and the amounts used, price and price per hour are given below.

Kind	Amt. Used	Time	Cost	Cost per Hr. in dollars.
Compressor oil	1 pint	9 hrs.	42¢ per gal.	0.006
Cylinder oil	3 qts.	14 hrs.	85¢ per gal.	0.046
Machine oil	1 gal.	24 hrs.	42¢ per gal.	0.018
Cup grease	1/4 lb.	24 hrs.	15¢ per lb.	0.001
		Total cost per hour		$0.071

Labor costs cover the wages of three engineers and two ice pullers per day of 24 hours. Their wages are as follows:-

Chief Engineer's salary is $1300.00 per year.
First Assistant Engineer receives $5.00 per day of 9 hrs.
Second Assistant Engineer receives $4.00 per day of 9 hrs.
Ice Pullers each receive $3.75 per day for 12 hours pull.

Total labor cost per 24 hour day is $20.85 (the sum of three engineers and two ice pullers' daily wages).

Labor cost per hour is $20.85 / 24 = $0.869

The table showing fuel consumed is given on B. P. 1. The general averages show that 460 pounds of coal were consumed per hour at an average cost of $1.662 per hour.

The amount of ice produced is shown on B. P. 2. This shows that during the test 1,983,000 pounds or 991.5 tons of ice were produced. This was at an average rate of 1858 pounds per hour or 22.3 tons per day of 24 hours.

DIRECT COSTS PER TON OF ICE.

Oil cost per ton of ice is	0.071 X 2000 / 1858	= $0.076
Labor cost per ton of ice is	0.869 X 2000 / 1858	= 0.935
Fuel cost per ton of ice is	1.662 X 2000 / 1858	= 1.789
Total direct cost per ton of ice is		$2.800

B: HEAT TRANSFER.

The well water is pumped from the wells by pump No. 2. It passes through the double tube ammonia condenser, through the flat cooler, through the preheater, and through the boiler feed pump into the boiler. On this part of its journey it absorbs heat. It leaves the boiler as steam, passes through the engines and pumps, through the steam condenser where it is condensed into water, through the reboiler and skimmer, through the flat cooler and into the pure water storage tank. Here an ammonia coil removes heat from it and reduces its temperature from 87.7°F. to 46.7°F. (see page 10) From the storage tank the water is drawn into the ice cans and is frozen into ice. The brine in the ice tank absorbs the heat from the pure water through the cans, and it in turn gives up its heat to the ammonia in the ammonia pipes or drum through which it is caused to circulate by the brine agitators. Hence all the heat, including that taken directly from the water in the storage tank, that absorbed from the brine in both the ice tanks and that absorbed by the ammonia coils in cooling the cold storage room, must pass into the ammonia before it reaches the compressors.

In passing through the compressors the ammonia absorbs still more heat from the energy of compression. However the ammonia in the 10 ton compressor gives up a small amount of its heat to the water in the water jacket around its cylinders. The rest of the heat must be removed from the ammonia by the cooling waters in the single tube condenser and in the double tube condenser.

In order to determine the heat transfer per unit from the pure water to the brine, from the brine to the ammonia, from the ammonia to the cooling water, it was necessary to take the temperature and pressure measurements as tabulated below. Many of these values vary somewhat during the day so it was thought advisable to take the readings as near the same time each day as possible. The time chosen was between 2 and 3 P. M.

Temperature readings were taken of the following:-

1. Pure water as it enters the storage tank.
2. Pure water as it enters the ice cans to be frozen.
3. Outside air taken in the shade.
4. Cooling water from the lake as it leaves the pump to flow over the single tube condenser.
5. Cooling water as it leaves the single tube condenser.
6. Cooling water from the well as it enters the double tube condenser.
7. Cooling water as it leaves the double tube condenser.
8. Liquid ammonia as it enters the expansion coils and drum in the ice tanks.
9. Ammonia gas as it leaves the expansion coils and drum and enters the compressors.

10 & 11. Ammonia gas as it leaves each compressor.

12 & 13. The brine in each tank.

The high and low ammonia pressures were taken each day. The high shows the pressure of the ammonia entering the condenser pipes. The low shows the pressure of the ammonia leaving the expansion coils and drum.

The R. P. M. of both compressors and the double strokes of the three pumps pumping cooling water were taken for 47 days.

Temperatures 1, 6. and 7 of the water were taken by obtaining water through a valve at the desired location and by reading the temperature directly from a thermometer placed in it. Temperatures 2, 4 and 5 were taken by thrusting the the thermometer directly into the water where it was exposed.

AMMONIA TEMPERATURES. A flat place was filed on one side of the pipe through which the ammonia was passing. A piece of copper tubing about 4 inches long and big enough to easily hold a thermometer was filed flat on one side, plugged at the lower end and partly filled with mercury. This was tied to the pipe with the flat sides together. A piece of woolen cloth was bound round and round the tube and pipe together until it formed a covering about 1 or 1-1/2 inches thick. The cloth at the top was left slightly loose so that a thermometer could be thrust down into the mercury well and the temperature taken. See photo No. 2 and sketch No. 1.

The first readings of the temperatures showed that the cooler cooling water was flowing over the single tube condenser whereas the double tube condensers, where the final ammonia cooling took place, was receiving the warmer water. This condition was caused by pumping both the well water through pump No. 2 and the lake water through pump No. 1 onto the single tube condenser and using only lake water through pump No. 3 in the double tube condenser. The temperature of the well water was 52°F., of the lake water was 73°F. and of the well and lake water combined was 66°F. The pumps were changed about during the afternoon so that the cold water from the well was used in the double tube condenser and the lake water on the single tube condenser. There was an immediate drop of 10 pounds in the high ammonia pressure showing that there had been an improvement in the plant performance.

Readings of the various items given above were taken nearly every day from June 28th to August 31st. This data is given on log sheets 1a, 1b, 2a and 2b. The different readings of any one item fluctuated somewhat from day to day due to the varying conditions prevalent; when the brine temperature went up less ice was pulled, when the lake water was cold the liquid ammonia temperature was reduced causing a drop in nearly all temperatures as well as in the ammonia pressures. Hence these individual values do not furnish a satisfactory basis for thermodynamic computations, but the general averages of these values will show the average conditions and will form a very satisfactory basis for computations. The arithmetical averages of these items are given below. All readings of June 28th 2 P. M. were omitted due to the change in pumps.

AVERAGES.

Average temperature of pure water entering storage tank = 87.7°F
Average temperature of pure water entering ice cans = 46.7°F
Average temperature of cooling water entering single tube condenser = 76.2°F
Average temperature of cooling water leaving single tube condenser = 80.9°F
Average temperature of cooling water entering double tube condenser = 53.2°F
Average temperature of cooling water leaving double tube condenser = 81.1°F
Average temperature of ammonia liquid entering expansion coils and drum = 69.6°F
Average temperature of ammonia gas leaving expansion coils and drum = 12.9°F
Average temperature of ammonia gas leaving 20 ton compressor = 240.6°F
Average temperature of ammonia gas leaving 10 ton compressor = 188.0°F
Average temperature of brine in 10 ton tank = 15.0°F
Average temperature of brine in 5 ton tank = 13.9°F
Average low ammonia pressure = 22.5 lbs. per sq. in. gage
Average high ammonia pressure = 163.1 lbs. per sq. in. gage
Average R. P. M. of 20 ton compressor = 101.5
Average R. P. M. of 10 ton compressor = 175.6
Average double strokes of pump No. 1 = 113.0
Average double strokes of pump No. 2 = 47.0
Average double strokes of pump No. 3 = 50.5
Total number of hours plant was under operation during test = 1067

HEAT TRANSFER FROM PURE WATER TO BRINE.

The total amount of heat transferred from the pure water to the brine per hour is equivalent to the heat lost by the water in changing from water at 46.7°F to ice at 15.0°F. in the 10 ton tank or to ice at 13.9°F. in the 5 ton tank.

$$T.H. = W (t - 32 + L + s (32 - t_1))$$

Where T.H. is the total heat transferred from the pure water to the brine.
W is the weight of ice frozen.
t is the temperature of the water entering the ice cans.
L is the latent heat of fusion of ice = 144 B. T. U.
s is the specific heat of ice = 0.5
t_1 is the temperature of the ice taken from the brine and equals the temperature of the brine.

W for the 10 ton tank is equal to 300 X N. Where N is the number of 300 lb. cakes produced divided by the number of hours the plant was in operation. See log sheets 2a and 2b.

W for the 5 ton tank is equal to 200 X N_1. Where N_1 is the number of 200 lb. cakes produced divided by the number of hours the plant was in operation.

W for 10 ton tank = 1387 lbs.
W for 5 ton tank = 471 lbs.

Total heat transferred from pure water to brine in the 10 ton tank per hour = 1387 (46.7 - 32 + 144 + 0.5 (32 - 15)) = 231,906 B. T. U.

Total heat transferred from pure water to brine in the 5 ton tank per hour is 471 (46.7 - 32 + 144 + 0.5 (32 - 13.9)) = 79,010 B. T. U.

The rate of heat transfer through the ice cans = T.H./nA

Where T.H. is the total heat transferred, n is the number of ice cans in the tank and A is the area of each can where it is exposed to the brine.

n is 154 for the 10 ton tank and 82 for the 5 ton tank. See page 1 of this thesis.

Area of ice can exposed to brine = 1/2 L(B+D+b+d)+ bd.

Where L is the length of the can exposed to the brine, B and D are width and thickness of the can at the upper surface of the brine and b and d are the width and thickness at the small end of the can. See sketch No. 4 for these values.

A for 300 lb. can = 40.5/2 (22 + 11 + 20.5 + 9.5) + 20.5 X 9.5 = 1470.5 sq. in. or 10.21 sq. ft.

A for 200 lb. can = 26.5/2 (22 + 11.5 + 21 + 10.25) + 21 X 10.25 = 1073.2 sq. in. or 7.45 sq. ft.

Rate of heat transfer through ice cans in 10 ton tank = 231,906 /(154 X 10.21) = 141 B. T. U. per sq. ft. per hr.

Rate of heat transfer through ice cans in 5 ton tank = 79,010 /(82 X 7.45) = 129 B. T. U. per sq. ft. per hr.

HEAT TRANSFER TO AMMONIA.

The ammonia absorbs heat at four different places before it reaches the compressors:- in the pure water storage tank, in both ice tanks and in the cold storage room.

In the pure water storage tank the heat passes directly from the pure water through the ammonia pipes of the ammonia coil into the ammonia. The amount absorbed by the ammonia equals the amount lost by the pure water.

Heat lost by the water in the storage tank per hour

$= W (t' - t)$

Where W is the weight of water passing through the tank per hour and is equivalent to the weight of ice frozen = 1858 lbs. per hour. See B. P. 2.

t' is the temperature of the water entering the tank = 87.7°F. See page 10 item 1.

t is the temperature of the water leaving the tank and entering the ice cans = 46.7°F. See page 10 item 2.

Heat lost by water in storage tank = 1858 (87.7 - 46.7) = 76,178 B. T. U. per hour.

Heat absorbed by the ammonia in the 10 ton tank = heat transferred from the pure water to the brine. The brine gives up to the ammonia as much as it absorbs from the water in the ice cans, for it remains at a fairly constant temperature. Therefore the heat absorbed by the ammonia in the 10 ton tank = 231,906 B.T.U. per hour. See page 11 item 5.

Heat absorbed by the ammonia in the 5 ton tank = 79,010 B.T.U. per hour. See page 11 item 6.

Heat absorbed by ammonia in the cold storage room is estimated at 10% of the total heat taken up by the ammonia in the plant = 10/90 (231,906 + 79,010 + 76,178) = 43,010 B. T. U. per hour.

Total heat absorbed by the ammonia = 231,906 + 79,010 + 76,178 + 43,010 = 430,104 B. T. U. per hour.

Rate of heat transfer through the ammonia pipes in the 10 ton tank per sq. ft. of pipe surface = T.H. / A_p

Where T.H. is the total heat transferred per hour = 231,906 B. T. U. See page 11 item 5.

A_p = area of the ammonia pipes in sq. ft. in the tank = N_p X 2 X 3.1416 X RL / 12

Where N_p is the number of pipes in the tank = 96. See page 1 item 4 under equipment.

R is the radius of the pipes or half the diameter = 1 inch. See page 1 item 4 under equipment.

L is the length of each pipe in feet = 30 ft. See page 1 item 4 under equipment.

A_p = 96 X 2 X 3.1416 X 1 X 30 / 12 = 1,508 sq. ft.

Rate of heat transfer through the ammonia pipes in the 10 ton tank = 231,906 / 1,508 = 154 B. T. U. per hour per sq. ft. of pipe surface.

Total heat extracted from the pure water by the ammonia = 231,906 + 79,010 + 76,178 = 387,094 B. T. U. per hour.

Percent extracted in storage tank = 76,178/387,094 = 19.7
Percent extracted in the 10 ton ice tank =
231,906 / 387,094 = - - - - - - - - - - - - - - - 59.9
Percent extracted in 5 ton ice tank =
79,010 / 387,094 = - - - - - - - - - - - - - - - 20.4

Note: The total amount of heat absorbed by the ammonia is somewhat in excess of the amounts shown above due to the slow leak of heat from the surrounding atmosphere through the insulation into the tanks and from the atmosphere into the uninsulated pipes leading to the compressors. Some heat is given up to the atmosphere from the discharge pipes from the compressors. These heat losses are comparatively small and will not be used in these calculations.

While being compressed in the ammonia compressors the ammonia absorbs heat from the energy of compression. The amount thus absorbed can be determined by a comparison of the total heat contained in the ammonia before and after compression. The total heat contained in a pound of ammonia depends upon its pressure and temperature. The total heat gained then equals the change in heat content per pound of ammonia multiplied by the total weight of ammonia pumped per hour. The superheated ammonia gas enters the compressors at 22.5 lbs. per sq. in. gage pressure and 12.9°F. and leaves the 20 ton compressor at 163.1 lbs. per sq. in. gage pressure and 240.6°F., and leaves the 10 ton compressor at 163.1 lbs. per sq. in. and 188.0°F. See averages on page 10.

1 lb. ammonia gas at 22.5 lbs. per sq. in. gage pressure and a temperature of 12.9°F. contains 535 B. T. U. using the atmospheric pressure as 14.7 lbs. per Sq. IN. See Marks' Mechanical Engineers Handbook Page 334.

1 lb. superheated ammonia gas at 163.1 gage pressure and 240.6°F. contains 655 B. T. U.

1 Lb. superheated ammonia gas at 163.1 gage pressure and 188.0°F. contains 625 B. T. U.

1 lb. ammonia liquid at 69.6°F. temperature contains 42.1 B. T. U. and, if it is at the saturation point it will have an absolute pressure of 129.2 lbs. per sq. in.

Amount of ammonia pumped per hour = total heat absorbed by the ammonia / heat absorbed per lb. of ammonia = 430,104 / (535 - 42.1) = 872.6 lbs.

The amount of ammonia pumped by each compressor equals its percentage of total volumetric displacement times 872.6 This supposes the efficiencies of the two machines to be the same.

Volumetric displacement of compressor piston per minute $= 3.1416 \times R^2 \times S \times D \times C \times R.P.M. / 1728$

Where R is the radius of the cylinder in inches.
S is the stroke in inches.
D is 1 for single acting and 2 for double acting.
C is the number of cylinders.
R.P.M. is the speed of the compressor in revolutions per minute. For values see page 10.
The 20 ton compressor is 9" X 16" single cylinder and double acting. The 10 ton compressor is 7-1/2 X 7-1/2" double cylinder and single acting.

Volumetric displacement of 20 ton compressor piston = $3.1416 \times 9^2/2^2 \times 16 \times 2 \times 1 \times 101.5 / 1728 = 120$ cu. ft.

Volumetric displacement of 10 ton compressor piston = $3.1416 \times (3\text{-}3/4)^2 \times 7\text{-}1/2 \times 1 \times 2 \times 175.6 / 1728 = 67$ cu.ft.

Weight of ammonia pumped by 20 ton compressor is 120 / (120 + 67) X 872.6 = 560 lbs. per hour.

Weight of ammonia pumped by 10 ton compressor is 67 / (120 + 67) X 872.6 = 312.6 lbs. per hour.

Part of gas pumped by 20 ton compressor = 560 / 872.6 = 64.1 %.

Part of gas pumped by 10 ton compressor = 312.6 / 872.6 = 35.9 %.

Heat absorbed by ammonia from the energy of compression = 872.6 (655 - 535) = 104,712 B. T. U. per hour.

HEAT TRANSFER TO COOLING WATER.

The amount of heat extracted in the 10 ton compressor by the cooling water in its water jacket = weight of ammonia pumped times loss in heat content below that of the 20 ton compressor = 312.6 (655 - 625) = 9,378 B. T. U. per hour. This is true because both compressors have the same suction pressure and temperature and the same compression pressure, hence the difference in the compression temperatures must be due to the cooling effect of the water in the water jacket.

Total heat extracted from the ammonia by the cooling water = 430,104 + 104,712 = 534,816 B. T. U. per hour.

The amount of heat extracted in each of the condensers depends directly upon the amount of cooling water supplied to each. It was impossible to measure the amounts of water supplied by each pump each day. If we assume the efficiencies of the pumps to be the same, then the volumetric displacements will be in direct proportion to the weight of water pumped. The volumetric efficiency of a pump depends upon its condition and length of stroke. The longer the stroke the higher the efficiency. Pump No. 1 has the shorter stroke (3") but it was in slightly better condition than Nos. 2 and 3, so it seems fair to assume the efficiencies the same.

Efficiencies of Cooling Water Pumps.

Volumetric displacement of the pistons of a pump =

$2 \times 3.1416 \times R^2 \times L \times C \times D.S.$

Where R is the radius of the cylinders in inches.
L is the length of the stroke in inches.

C is the number of cylinders.
D.S. is the number of double strokes per minute.
For values see pages 1, 2 and 10.

Volumetric displacement of pistons of pump No. 1 =

$2 X 3.1416 X 1.5^2 X 3 X 2 X 113$ = 9,582 cu. in. per min.

Volumetric displacement of piston of pump No. 2 =

$2 X 3.1416 X 2^2 X 5 X 1 X 47$ = 5,922 cu. in. per min.

Volumetric displacement of pistons of pump No. 3 =

$2 X 3.1416 X 2^2 X 5 X 2 X 50.5$ = 12,692 cu. in. per min.

Theoretical weight of water pumped per hour = V.D. X 60 X 62.4 / 1728

Where V. D. is the volumetric displacement in Cu. in.
62.4 is the weight of 1 cu. ft. of water.

Theoretical weight of water pumped by pump No. 2 per hour = 5,922 X 60 X 62.4 / 1728 = 12,840 pounds.

Theoretical weight of water pumped by pumps No. 1 and 3 per hour = (12,692 + 9,582) X 60 X 62.4 / 1728 = 48,240 pounds.

Theoretical amount of heat extracted in double tube condenser and in water jacket around 10 ton compressor = weight of water pumped times rise in temperature of the water = 12,840 (81.1 - 53.2) = 358,236 B. T. U. per hour at 100 % volumetric efficiency of pumps.

The same for the single tube condenser = 48,240 (80.9 - 76.2) = 226,728 B. T. U. per hour at 100% volumetric efficiency of the pumps. Temperature values taken from page 10.

Volumetric efficiency of pumps = actual amount of heat extracted divided by theoretical amount = 534,816 / (358,236 + 226,728) = 91.4%. See page 16 PP. 2.

HEAT TRANSFER TO COOLING WATER.

Heat extracted from ammonia thru single tube condenser = 91.4 % of 226,728 = 207,288 B.T.U. per hour. See page 17.

Heat extracted from ammonia through double tube condenser = 91.4 % of 358,236 - 9,378 = 318,150 B.T.U. per hour. 9,378 B.T.U. were extracted in water jacket. See pages 16-17.

Per cent of heat extracted through single tube condenser = 207,288 / 534,816 = 38.8

Per cent of heat extracted through double tube condenser = 318,150 / 534,816 = 59.5

Per cent of heat extracted by water in water jacket of 10 ton compressor = 9,378 / 534,816 = 1.7

Area of pipe surface in a condenser = n X 3.1416 X D X L / 12

Where n is the number of pipes.
D is the diameter of the pipe in inches.
L is the length of the pipe in feet.
For the values see page 2 items 4 and 5.

Effective area of single tube condenser pipes = 40 X 3.1416 X 2 X 20 / 12 = 419 sq. ft.

Effective area of double tube condenser pipes = 16 X 3.1416 X 1.25 X 15 / 12 = 78.5 sq. ft.

Heat transfer per sq. ft. from single tube condenser = 207,288 / 419 = 450 B.T.U. per hour = 7.5 B.T.U. per min.

Heat transfer per sq. ft. from double tube condenser = 318,150 / 78.5 = 4,053 B.T.U. per hour = 67.6 B. T.U. per min.

C. TESTS TO SHOW THE EFFECTS OF AIR TEMPERATURES AND WIND VELOCITIES ON THE CONDENSING PROPERTIES OF THE SINGLE TUBE CONDENSER.

The object is to determine if the temperature of the air surrounding the condenser, and if the velocity of the wind have any marked effect upon the effectiveness of the open air condenser. This effect will be shown by a lowering of the temperature of the cooling water leaving the condenser. However the temperature of the cooling water fluctuates with the temperature of the lake (See item 4 page 3) and the temperature of the cooling water leaving the condenser under fixed conditions would have a similar variation. That is, the change in the temperature of the water as it flows over the condenser would be a constant fixed value if all other conditions remained changeless. The variation in the change of temperature of the cooling water will, therefore, be the indicator for any effect of the air temperature or wind upon the condenser. This presupposes that the amount of ammonia pumped and the heat content of same is constant. This is not strictly true, but the percentage of fluctuation of these amounts would be low, as the compressors run at a constant speed and the temperature of the brine is kept as nearly constant as possible by varying the amounts of ice pulled.

The following items were taken for each day of the test and the values are given on log sheets 1a, 1b, 2a, and 2b.

Temperature of the air taken in the shade.
Direction and approximate strength of the wind.
Temperature of the cooling water entering the condenser.
Temperature of the cooling water leaving the condenser.

AIR TEMPERATURES AND CONDENSING PROPERTIES.

The right hand portion of curve sheet No. 1 shows the air temperatures and the cooling water temperatures plotted for each day of the test. The graphs show that the curve of the air temperatures has the same general trend as the curves showing the cooling water temperatures. When it is high, they are high; when it is low they are low. The curve of the air temperatures fluctuates much more than the curves of the cooling water.

Curve sheet No. 5 shows graphically the variations in the change of temperature of the cooling water above and below an average of 5 degrees and the air temperatures above and below the average of 75°F. These graphs show that when the air temperature is high a greater change in temperature of the cooling water is required (see Aug. 11-17), and when the air is cooler than normal the change in the cooling water temperature is less than normal (see July 3, July 18, August 1-3, 7-11, and 25-27). The change in the air temperature is several times the change in the increase of the cooling water temperature, and there are places where these curves do not follow each other. These places may be explained by the effects of the wind, the amounts of heat being pumped into the condenser, etc.

WIND DIRECTION AND VELOCITIES AND CONDENSING PROPERTIES.

The single tube condenser is protected from the wind on the west by the wind-brake between it and the smoke stack, and on the south by the upright part of the building and a wind brake up to the top of the condensers. It is open on the north and east. The condenser pipes run east and west so that a north wind would affect it most. Wind from the northeast and northwest would affect it considerably, and wind from the southwest would affect it somewhat, but wind from due west or south would have but little effect. The curve on the left half of curve sheet No. 5 is drawn according to the above considerations. The general arrangement of the condenser can be seen on sketch No. 3 and on photo 2.

The general trend of the wind curve on curve sheet No. 5 follows to some extent the curve showing the variations in the increase in temperature of the cooling water above or below its normal of 5°F. The following instances will serve to illustrate:-

On July 3rd the wind was strong from the north and the cooling water increase curve is 7° below normal, in fact the cooling water itself was cooled 1.5° more than it was heated by the condenser. See curve sheet No. 1.

On July 19th with the temperature of the air normal, the increase in the temperature of the cooling water is 3° below normal due to a slight northwest wind.

On July 25th with the air 4° above normal, the increase curve shows 2° below normal due to a light east wind changing

from the northeast on the 24th.

On August 18th the cooling water leaving the condenser was colder than when it entered, due partly to an air temperature 6^{o} below normal and partly to a medium northwest breeze.

On August 21st the air temperature dropped 6^{o}, to 4^{o} below normal, but the increase in temperature of the cooling water increased from normal 1^{o} due to a shift in the wind from a slight northeast to a slight south breeze.

On August 25th the increase in temperature of the cooling water was 1^{o}, or 4^{o} below normal due to an air temperature 6^{o} below normal and a strong northwest wind.

From these illustrations it is evident that the wind can be made to aid materially in the condensing process, and, although it adds an uncertain factor to the operation of an ice plant, still the plant which ignores this factor and excludes the wind by housing in the condensers will increase the cost of ice production materially. Whether the beneficial results are sufficient to warrant the installation of power driven fans to produce artifically blown air or not is hard to say. Experiments along this line would be interesting.

D. TESTS TO SHOW EFFECT OF COOLING WATER TEMPERATURES ON THE CONDENSING PROPERTIES OF CONDENSERS.

The above tests have shown that the cooling water on the single tube condenser does not increase the same amount every day. Referring to curve sheet No. 5, it will be seen that

there is a variation in this increase of as much as 4° above normal and 7° below normal. These variations are caused mainly by (1) deposits on the condenser from the condensing water, (2) variations in the heat content of the ammonia pumped into the condenser, (3) variations in the air temperature and (4) changes in the velocity and direction of the wind. Except for these slight variations, the temperature of the cooling water leaving the condenser follows very closely the temperature of the entering water. The curves on curve sheet No. 1 show that the temperature of the water leaving the double tube condenser follows very closely the temperature of the entering water. The increase in temperature there is nearly constant.

A comparison of the curves on curve sheets No. 1 and 2 shows that the high ammonia pressure is dependent in a large degree on the temperature of the condensing water leaving each of the condensers (This is varied somewhat by varying the amount of ice pulled). This is what we would expect, for the colder the cooling water, the colder it will leave the ammonia, and tables of saturate ammonia vapor show that the colder the point of vaporization the lower the condensing pressure will be. The cooler water then provides more rapid condensation and greatly aids the condensing properties of the condensers. In fact, if sufficient water could be obtained from the wells at 52.3°F. for both the condensers, the efficiency of the plant could be increased from 10 to 15 %. The Company has spent several hundreds of dollars trying to increase their well water supply.

PLANT PERFORMANCE UPON STARTING AFTER A SHUTDOWN.

The plant was shut down from 10 A. M. July 4th to 6 A. M. July 5th. Readings of several of the parts were taken as shown by log sheet No. 3 every hour. Curve sheet No. 3 shows the changes, in the temperature of the air, cooling water in the single tube condenser, and the brine in each of the tanks for the first 10 hours of running.

Notice the rise in the temperature of the air from 64° at 6 A. M. to its maximum 79° at 3 P. M.

The cooling water entering the single tube condenser is taken directly from the lake, and it has a rise in temperature corresponding to that of the air but of only 1.5°.

The temperature of the cooling water leaving the condenser has its maximum from 7 to 8 A. M. when the temperature difference amounts to 7°. This is due to the large amount of heat pumped from the brine and pure water tank through the ammonia into the condenser at starting. Also the wind was due south and did not help the condensing properties of the water. The rise in temperature of the cooling water decreased as the wind changed and as the brine became cooled, until at 12 M. it reached a minimum of 3°. The wind had changed to southwest where it could partly reach the condenser and, by evaporating part of the water, aid its condensing properties.

The brine in the 5 ton tank started at 27° at 6 A. M. and dropped rapidly till about 11 A. M. when the decrease became less until at 4 P. M. it reached its minimum value of 15°.

The brine in the 10 ton tank was at 25^{o} at 6 A. M. or just 2^{o} lower than the brine in the 5 ton tank. This is probably due to the cooling effect of the ammonia liquid left in the 96 pipes in the 10 ton tank when the plant was shut down. The 5 ton tank, having a drum instead of pipes, stopped the cooling process immediately and consequently warmed 2^{o} more. The 10 ton tank's brine made a quick drop between 6 and 7 A. M. of 3.5^{o}. This is due to the starting of the agitator. The decrease is small from 7 to 8 A. M. because it took time to fill the 96 pipes with ammonia. From 8 A. M. on the decrease is rapid, easing off gradually until at 3 P. M. it reached a minimum of 13.5^{o}.

COMPARISON OF TANKS.

	10 ton tank.	5 ton tank.	Total.
Size of cakes - - - -	300 lb.	200 lb.	
Total No. of cakes produced in 1067 hrs.	4934	2514	7448
Total weight produced in pounds. - - - - - -	1,480,200	502,800	1,983,000
in tons. - - - - - - -	740.1	251.4	991.5
Part of total production. - - - - -	74.6%	25.4%	100%
Tons per 24 hrs.	16.65	5.65	22.3
Pounds per hour.	1387	471	1858
Frequency of pulling	35 hours	35 hours	35 hours
Heat transferred per hour. - - - - -	231,906 B.T.U.	79,010 B.T.U.	310,916 B.T.U.
Part of heat transferred. - - -	74.6%	25.4%	100%
Cans per ton of ice each 24 hours. - - - -	9.2	14.5	

PLANT CONSTANTS DERIVED FROM DATA TAKEN.

Plant overload is (22.3 - 15) / 15 = 48.7 %.

Weight of ammonia pumped per minute per ton of ice produced each 24 hours = 872.6 / (60 X 22.3) = 0.65 lbs.

Tons of ice produced per ton of coal consumed = 1858 / 460 = 4.04

Amount of cooling water pumped per ton of ice produced each 24 hours = (48,240 + 12,840) X 0.914 / 22.3 =

2,503 lbs. per hour.
41.7 lbs. per min.
5.6 gal. per min.

Condenser areas per ton of refrigeration.

Single tube = 419 / 22.3 X .50 = 9.4 sq. ft.
Double tube = 78.5 / 22.3 X.50 = 1.8 sq. ft.
Total - - - 11.2 sq. ft.

Volumetric displacement of compressors per ton of ice produced each 24 hours = (120 + 67) / 22.3 =

8.4 cu. ft. per min.
or 14,490 cu. in. per min.

SUMMARY.

A. The direct cost of manufacturing ice = $2.80 per ton.

B. The rates of heat transfer per hour in B. T. U. are as follows:-

From.	To.	Place	Remarks	B.T.U. per Hr.
Pure water	Brine	5 ton tank		79,010
Pure water	Brine	10 ton tank		231,906
Through ice cans		5 ton tank	Per sq. ft.	129
Through ice cans		10 ton tank	Per sq. ft.	141
Pure water	Ammonia	Storage tank		76,178
Brine	Ammonia	5 ton tank		79,010
Brine	Ammonia	10 ton tank		231,906
Through Ammonia Pipes		10 ton tank	Per sq. ft.	154
Air	Ammonia	Storage room		43,010
Energy of Comp.	Ammonia	Compressors		104,712
Ammonia	Cooling water	10 ton compr. jacket		9,378
Ammonia	Cooling water	Single tube condenser		207,288
Ammonia	Cooling water	Double tube condenser		318,150
Through pipes in single tube condenser			per sq. ft.	450
Through pipes in double tube condenser			per sq. ft.	4,053

C. The influence of the air temperature and wind velocity and direction on the condensing properties of the open air condenser is relatively small. However they do have a direct influence and this should be considered in operating an ice making or refrigeration plant.

D. The cooling water temperature has a fundamental effect upon the condensing properties of condensers and hence on all the principal operating units of a refrigeration plant. The location of plants is often determined, to a large extent, om the availability of large quantities of cold water. When cold water is not available at very reasonable rates, it is necessary to cool the water in cooling towers or ponds.

CONCLUSIONS BASED ON TESTS.

1. The low ammonia pressure is too low for securing very high efficiencies with the compressors. The pressure could as well be carried at 25 lbs per sq. in. gage and still keep the brine temperature below 15°F. Saturated ammonia gas at 25 lbs. gage or 39.7 lbs. absolute has a temperature of 11°F. See page 333 Marks' Mechanical Engineers handbook. The higher the low pressure the more ammonia the compressors would pump per stroke and the greater their efficiency. A higher low pressure could be supplied best by supplying more tank space.

2. The frequency of pulling the cans is too great. Kent page 1316 states that it should be 54 hours for both 11X22X44 and 11X22X32 inch cans. Marks' Mechanical Engineers Handbook page 1740 gives the time of freezing 200 lb. cans as 55 hours and 300 lb. as 60 hours. The 35 hours used at present could be lengthened out by using a higher brine temperature. This would use less ammonia per hour. The ammonia thus released could be used in another tank.

3. It was clearly shown in the test that the wind has a marked effect on the cooling properties of the single tube condenser. This condenser should be raised above all surrounding projections, and the pipes should be formed into a hollow square. Suitable V shaped trays should be supplied between the pipes to keep the water from blowing off the pipes and yet allow the wind to reach the water.

4. All live steam and cold ammonia pipes should be covered with an ample thickness of asbestos. The ratio of 4.04 tons of ice per ton of coal is too low. Frank L, Fairbanks on page 1741 of Marks" M. E. Handbook gives 2.25 to 8.22 tons of ice per ton of coal depending on the size of the plant. The lower values applying to small plants. Kent page 1314 gives 6 lbs. of ice per pound of good coal.

5. Colder water should be secured for cooling the open air condenser and the flat cooler if possible. The tests clearly show that the colder the cooling water, the lower the temperatures and the lower the ammonia pressures will be, and finally the easier and cheaper the plant can be run. The pure water from the flat cooler should be lowered from 87.7° to about 55°. This would cut down the amount of ammonia per hour used in the pure water tank and also reduce the temperature of the pure water to the ice cans to about 35°F.

6. Items 1 and 2 point to more tank space. I would suggest throwing the 5 ton tank out and installing a duplicate of the 10 ton tank touching it on the east. The space released by the 5 ton tank could be well used as ice storage. With 308 cans and pulling 7 cans per hour or the whole tank every 44 hours, the production would be increased to 25.2 tons per day.

INDEX TO CURVE SHEETS, BLUE PRINTS, SKETCHES AND PHOTOS.

CURVE SHEETS.

1. This shows the temperatures for each day of the test of:-
   1. Pure water to storage tank.
   2. Pure water to ice cans.
   3. Cooling water entering double tube condenser.
   4. Cooling water leaving double tube condenser.
   5. Ammonia entering expansion coils.
   6. Air in shade.
   7. Cooling water entering single tube condenser.
   8. Cooling water leaving single tube condenser.

   Wind pressure and direction.

2. This shows the temperature or pressure for each day of the test of:-
   1. High ammonia pressure.
   2. Low ammonia pressure.
   3. Temperature of the brine in the 10 ton tank.
   4. Temperature of the brine in the 5 ton tank.

3. This shows the hourly variations in temperatures from 6 A. M. to 4 P. M. on July 5th after a shut down of 20 hours of the following:-
   1. Cooling water entering single tube condenser.
   2. Cooling water leaving single tube condenser.
   3. Air in shade.
   4. Brine in 5 ton tank.
   5. Brine in 10 ton tank.

4. This shows the following items on the production of ice for each day of the test:-
   1. Production each day.
   2. Average hourly production each day.
   3. Total production.

5. This shows the following items for each day of the test:-

   1. Velocity and direction of the wind laid out as a curve according to its possibilities in affecting the condensing properties of the condenser.

   2. The rise in temperature of the cooling water while passing over the single tube condenser, above or below the average rise of $5^{o}F$.

   3. The variations above or below the average temperature of the air.

6. This shows the heat content of the water as it passes from the well, through the many stages, to the ice cans into ice, taking the heat content of ice at $0^{o}F$. as 0.

DA AUG 19
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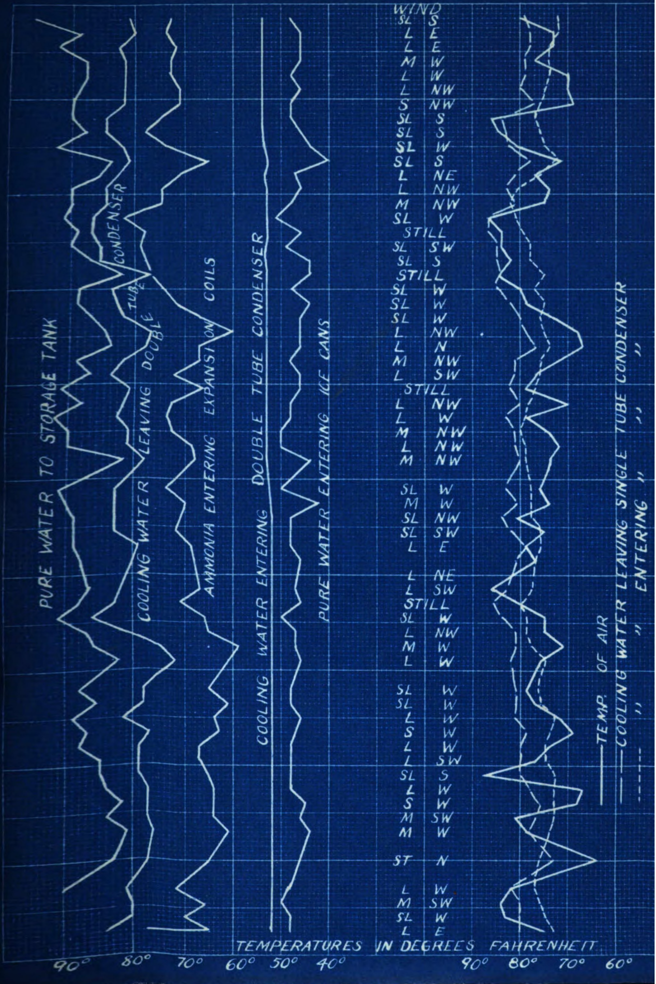
TIME
JULY 5 1922
6 A.M
7
8
9
10
11
12 M
1 PM
2
3
4

T NO. 1

DATE 1922

JUNE 28 30 JULY 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 AUGUST 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

CURVE SHE


PURE WATER TO STORAGE TANK
CONDENSER
COOLING WATER LEAVING DOUBLE TUBE CONDENSER
AMMONIA ENTERING EXPANSION COILS
COOLING WATER ENTERING DOUBLE TUBE CONDENSER
PURE WATER ENTERING ICE CANS
WIND
SL S
L E
L E
M W
L W
L NW
S NW
SL S
SL S
SL W
SL S
L NE
L NW
M NW
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STILL
SL SW
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S W
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SL S
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M SW
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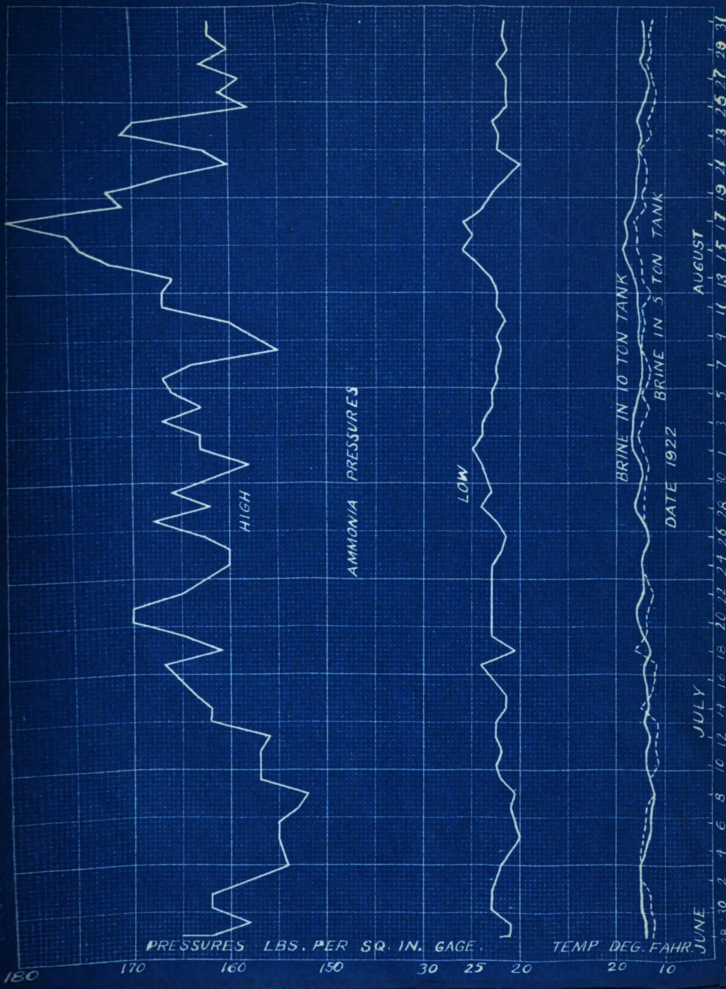
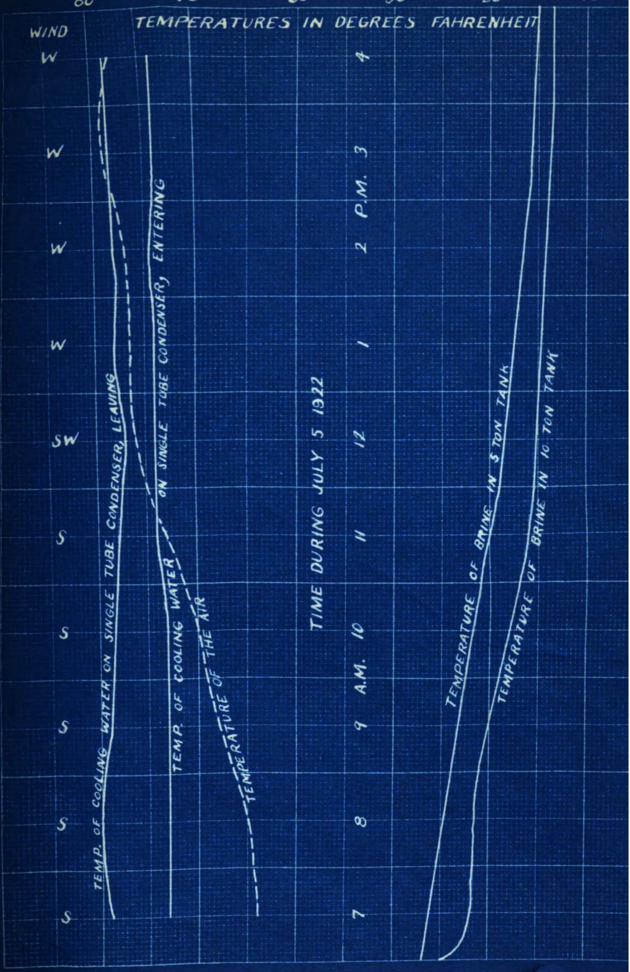
M SW
SL W
L E
TEMP. OF AIR
COOLING WATER LEAVING SINGLE TUBE CONDENSER
" " ENTERING " " "
TEMPERATURES IN DEGREES FAHRENHEIT
90° 80° 70° 60° 50° 40°
90° 80° 70° 60°

CURVE SHEET NO 2




TEMPERATURES IN DEGREES FAHRENHEIT
WIND
W
W
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SW
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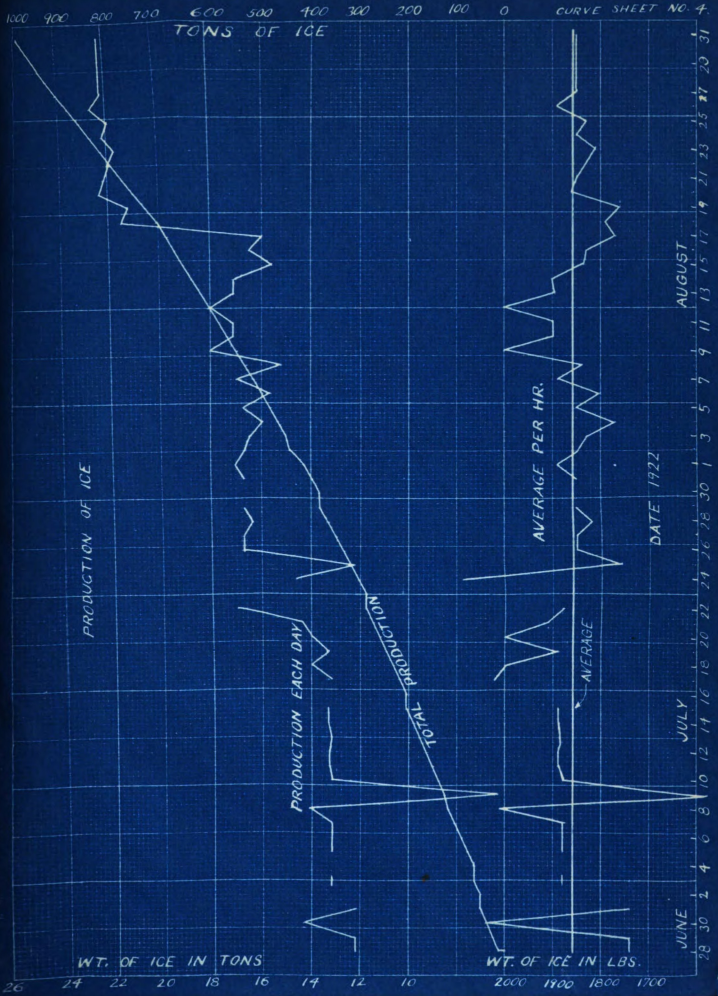
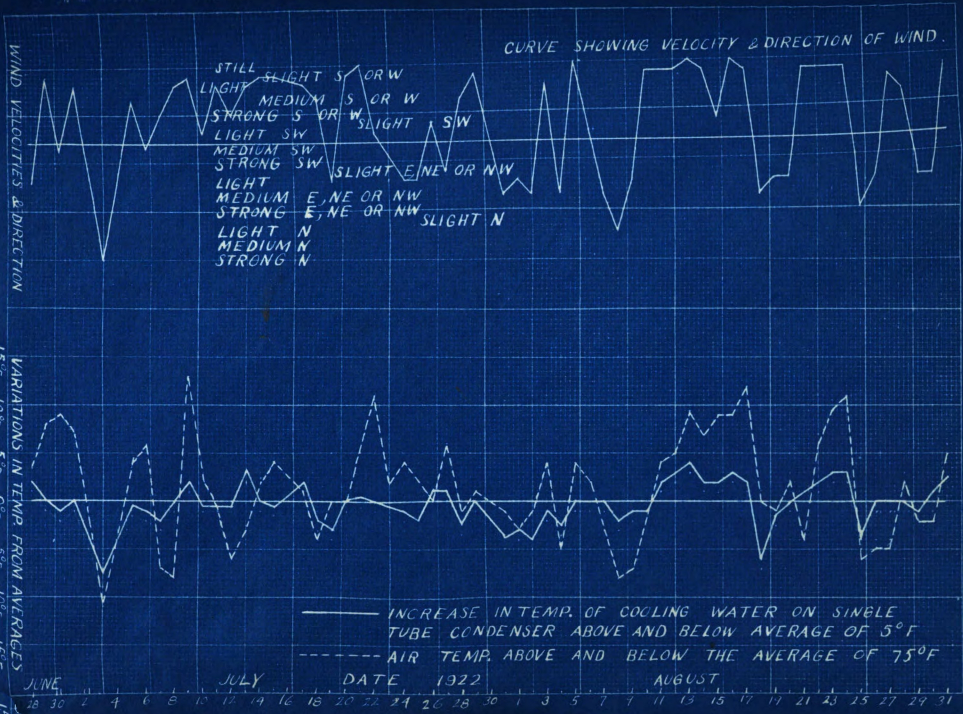
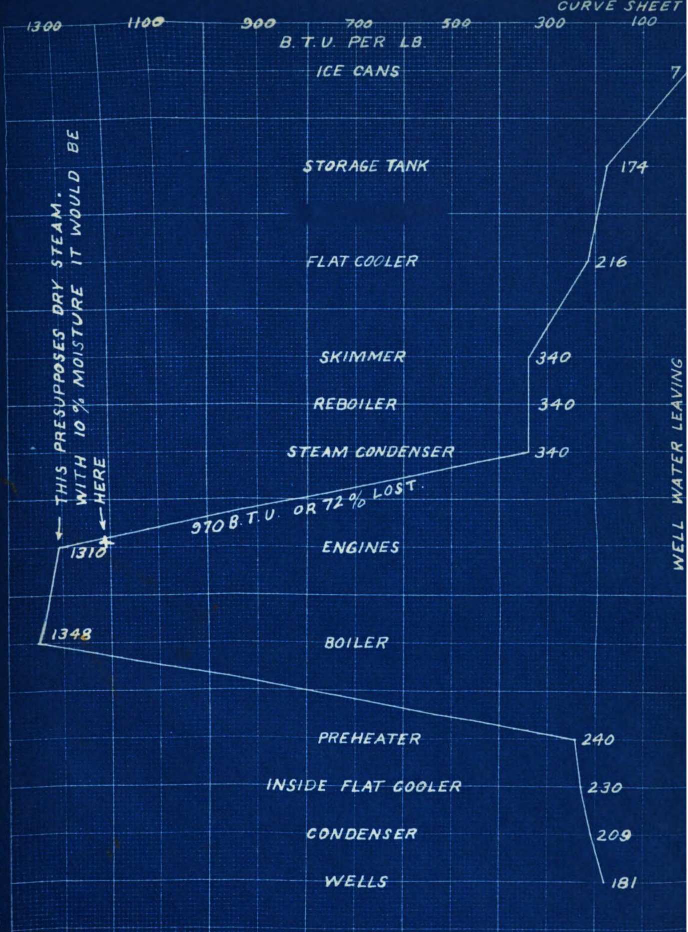
S
S
TEMP. OF COOLING WATER ON SINGLE TUBE CONDENSER, LEAVING
TEMP. OF COOLING WATER ON SINGLE TUBE CONDENSER, ENTERING
TEMPERATURE OF THE AIR
TIME DURING JULY 5 1922
7 8 9 A.M. 10 11 12 1 2 P.M. 3 4
TEMPERATURE OF BRINE IN 5 TON TANK
TEMPERATURE OF BRINE IN 10 TON TANK


CURVE SHEET NO. 4
TONS OF ICE
1000 900 800 700 600 500 400 300 200 100 0
PRODUCTION OF ICE
PRODUCTION EACH DAY
TOTAL PRODUCTION
AVERAGE PER HR.
AVERAGE
DATE 1922
JUNE
JULY
AUGUST
28 30 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
WT. OF ICE IN TONS
26 24 22 20 18 16 14 12 10
WT. OF ICE IN LBS.
2000 1900 1800 1700


CURVE SHOWING VELOCITY & DIRECTION OF WIND.
WIND VELOCITIES & DIRECTION
STILL
SLIGHT S OR W
LIGHT
MEDIUM S OR W
STRONG S OR W
LIGHT SW
MEDIUM SW
STRONG SW
SLIGHT SW
SLIGHT E, NE OR NW
LIGHT
MEDIUM E, NE OR NW
STRONG E, NE OR NW
SLIGHT N
LIGHT N
MEDIUM N
STRONG N
VARIATIONS IN TEMP. FROM AVERAGES
15°F 10°F 5°F 0°F 5°F 10°F 15°F
INCREASE IN TEMP. OF COOLING WATER ON SINGLE TUBE CONDENSER ABOVE AND BELOW AVERAGE OF 5°F
AIR TEMP. ABOVE AND BELOW THE AVERAGE OF 75°F
JUNE
JULY
DATE 1922
AUGUST
28 30 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31



CURVE SHOWING TOTAL HEAT IN THE WATER ABOVE ICE AT 0°. FROM THE WELLS INTO ICE.

FUEL			
WT. OF COAL LBS. PER HR.	FUEL COST PER HR.	WT. OF COAL LBS. PER HR.	FUEL COST PER HR.
450	$1.463	487	$1.583
460	1.495	447	1.453
420	1.365	507	1.648
490	1.593	527	1.713
432	1.404	538	1.749
444	1.443	420	1.365
408	1.326	454	1.476
408	1.326	576	1.872
495	1.609	472	1.534
347	1.128	472	1.534
421	1.368	469	1.524
393	1.277	541	1.758
425	1.381	514	1.671
440	1.430	497	1.615
427	1.388	514	1.671
460	1.495	450	2.464
462	1.502	484	2.650
457	1.485	464	2.541
467	1.518	480	2.628
427	1.388	403	2.196
468	1.521	442	2.420
437	1.420	402	2.201
473	1.537	458	2.576
436	1.417		
514	1.671	AVERAGE 460	AVERAGE $1.662

Consumption of fuel per 24 hrs = 460 X 24 ÷ 2000 = 5.52 tons.
Cost of fuel per 24 hrs. = 1.662 X 24 = $39.89

Weight of coal used per hour in pounds = total weight used in pounds ÷ length of time it lasted in hours.

Fuel cost per hr. = Cost per ton X weight of coal used per hr. ÷ 2000.

Original data used is given on Log sheets 2a and 2b.

PRODUCTION OF ICE

TOTAL PRODUCTION		LBS. PER	TOTAL PRODUCTION		LBS. PER
LBS.	TONS	HOUR	LBS.	TONS	HOUR
24400	12.2	1743	33300	16.7	1850
24400	12.2	1743	32900	16.5	1828
28600	14.3	2043	31900	16.0	1772
24400	12.2	1743	33300	16.7	1850
26300	13.2	1878	31400	15.7	1797
26300	13.2	1878	34000	17.0	1889
26300	13.2	1878	30400	15.2	1843
26300	13.2	1878	36000	18.0	2000
28200	14.1	2014	34200	17.1	1900
12600	6.3	1575	34200	17.1	1900
26300	13.2	1878	36000	18.0	2000
26500	13.3	1893	34100	17.1	1894
26500	13.3	1893	34200	17.1	1900
26400	13.2	1886	31200	15.6	1835
26500	13.3	1893	32900	16.5	1828
26500	13.3	1893	31900	16.0	1772 Aug 17
28300	13.2	2021	42900	21.5	1787
28000	14.0	2000	42300	21.2	1763
26500	13.3	1893	44700	22.4	1863
28000	14.0	2000	44400	22.2	1850
28700	14.4	1913	44000	22.0	1833
33900	17.0	1883	43400	21.7	1808
29200	14.6	2086	44400	22.2	1850
24600	12.3	1757	44000	22.0	1833
33300	16.7	1850	45300	22.7	1888
33300	16.7	1850	44400	22.2	1850
32800	16.4	1822	44400	22.2	1850
33300	16.7	1850	44400	22.2	1850
33300	16.7	1850	44400	22.2	1850
34000	17.0	1889	44400	22.2	1850
TOTAL & AVERAGES			1,983,000	991.5	1858

Average production for 24 hrs. = 1858 X 24 ÷ 2000 = 22.3 Tons.

Total production = 300 X no. of 300 lb cakes + 200 X no. of 200 lb. Cakes.

Total production in tons = total production in lbs. ÷ 2000.

Pounds per hour = total production in lbs ÷ no of hrs. or required to produce them.

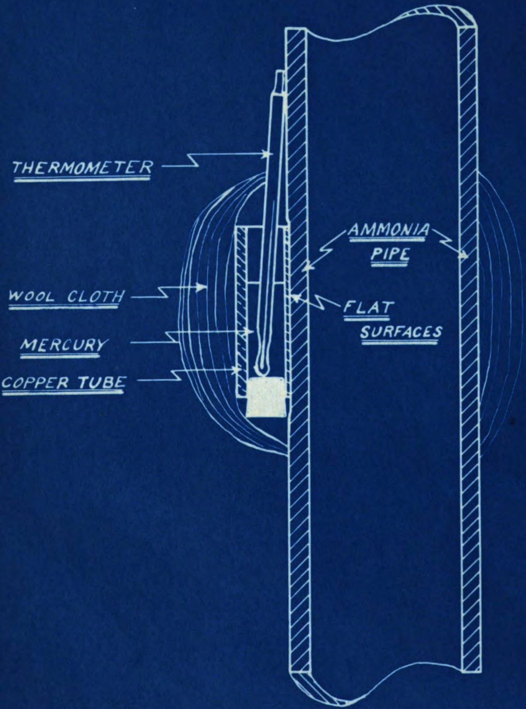
Original data used is given on log sheets 2a and 2b.

COMPARISON OF COSTS OF DIFFERENT FUELS

FUEL	AMOUNT	COST	TIME HRS.	TIME MIN.	COST PER HOUR
KINDLING WOOD	4 CORDS	2^{75} PER CD.	2	20	$4.71
16" BEECH & MAPLE	2 CORDS	3^{00} PER CD.	2	5	2.88
{ CORD WOOD	1 CORD	2^{50} PER CD.	2	32	2.06
AND COAL }	840 lbs.	6^{50} PER TON			
POCAHONTAS SLACK	520 lbs	8^{00} PER TON	1	5	1.92
SOFT COAL	460 lbs	6^{50} PER T.	1		1.49
" "	460 lbs.	10^{95} PER T.	1		2.44
" "	460 lbs.	11^{25} PER T.	1		2.58

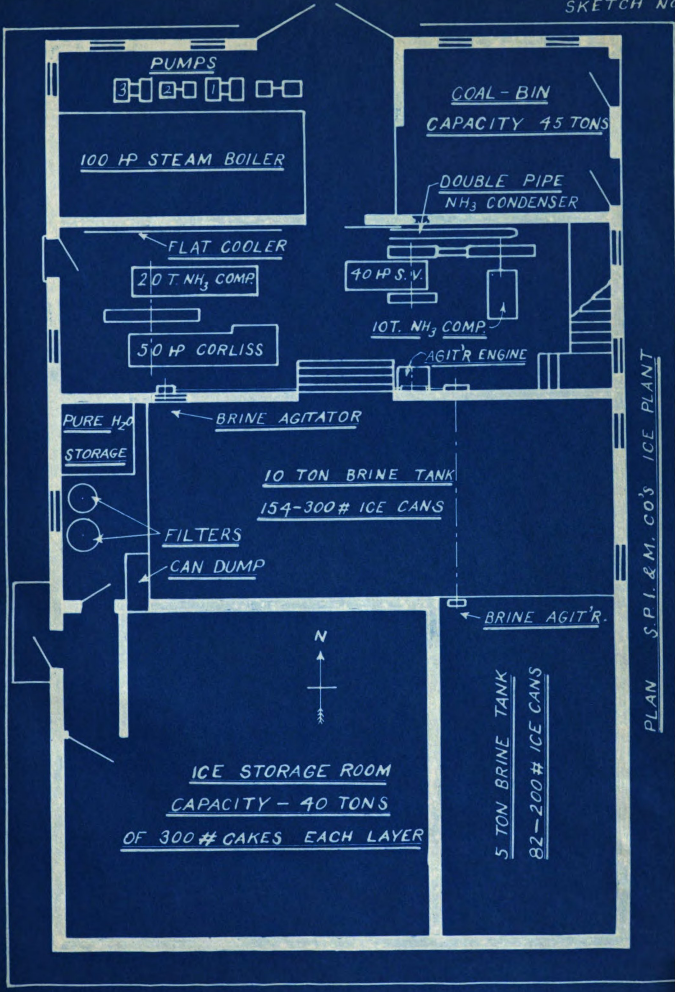
RELATIVE COST OF FUELS

NO. 1.

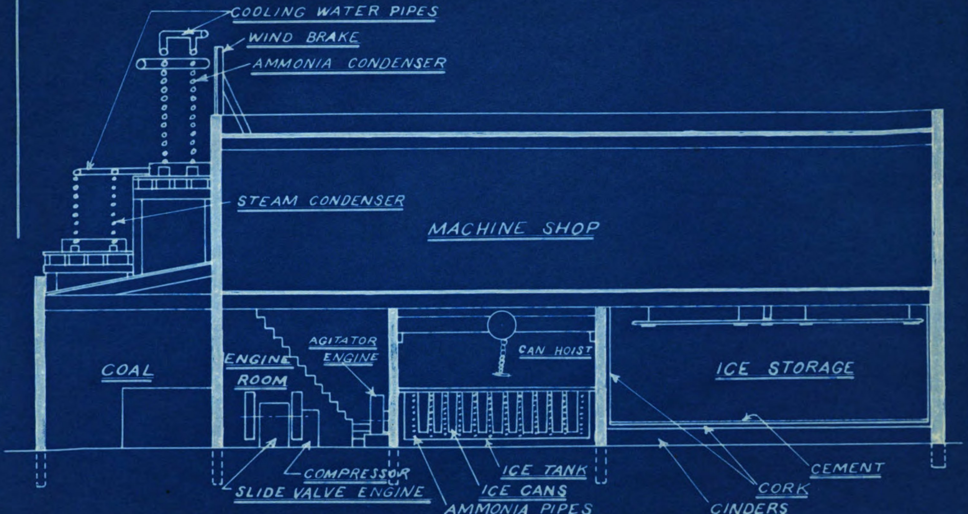


METHOD OF TAKING AMMONIA TEMPERATURES

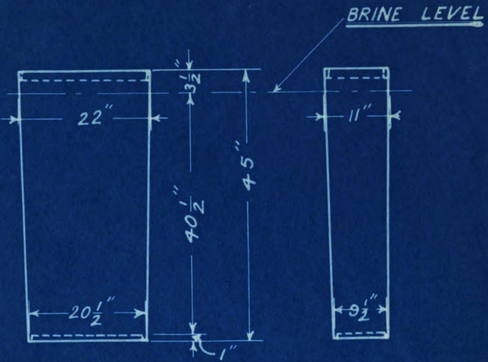
SKETCH NO



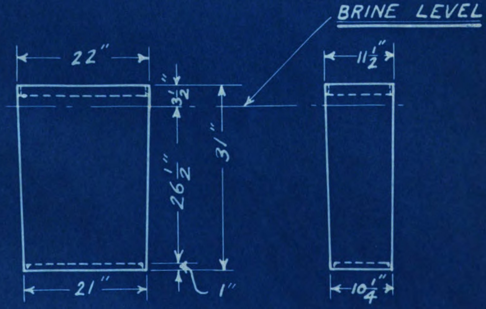
PUMPS
3
2
1
COAL - BIN
CAPACITY 45 TONS
100 HP STEAM BOILER
DOUBLE PIPE
NH_3 CONDENSER
FLAT COOLER
20 T. NH_3 COMP.
40 HP S. V.
10T. NH_3 COMP.
50 HP CORLISS
AGIT'R ENGINE
PURE H_2O
STORAGE
BRINE AGITATOR
10 TON BRINE TANK
154-300# ICE CANS
FILTERS
CAN DUMP
BRINE AGIT'R.
N
ICE STORAGE ROOM
CAPACITY - 40 TONS
OF 300# CAKES EACH LAYER
5 TON BRINE TANK
82-200# ICE CANS
PLAN S.P.I. & M. CO'S ICE PLANT



CROSS SECTIONAL ELEVATION OF S.P.I.&M.CO. PLANT



300 LB. ICE CAN

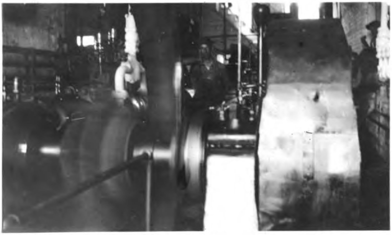


200 LB. ICE CAN

1

2

3



4

5

ROOM USE ONLY