THESIS

TEST OF ICE FACTORY MACHINERY

OF THE

ATLANTIC ICE COMPANY

AT

KNOXVILLE TENNESSEE

FOR THE DEGREE OF

BATCHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

BY

J.C.COLE

UNDER

PROF. W.R.WOOLRICH

The object of this thesis was to make a complete test of the refrigerating plant of the Atlantic Ice Company. In making preparation for the test it was found that it was not possible, due to the arrangement of piping to cut out the various units from the exhaust pipe and thus find their steam consumption. The amount of ammonia circulated also could not be waived, which would have to be known in order to determine the ice making capacity of the plant.

The boiler tested is one of a battery of two return tubular boilers rated at 150 H.P. The boiler was made by B.B.Dallas of Knoxville and is equipped with a Hawley Down Draft Furnace.

The refrigerating machine was built by the York Manufacturing Company. The engine is of the Corliss type. The ammonia cylinders, of which there are two, are vertical and single acting.

The air compressor which is a piston compressor was built by the Ingersoll-Sargent Drill Company. This furnishes air for pumping condensing water from a nearby well and for lifting ice cans.

There is also a large condensing water pump, a small pump for lifting distilled water to an elevated tank, a brine pump , boiler feed pump, and a small engine used for stiring the brine , all of which used steam from the boiler tested.

In the operation of the plant the boiler feed water is taken from the city supply, passed thru a closed heater, is evaporated and used in the various engines, after which it is passed thru the heater out into the closed condenser and after which it is used in making ice.

The boiler test was conducted according to the American Society of Mechanical Engineers Code and all precautions were taken to make the test a reliable one. The apparatus used in the test such as scales, gages and so forth were carefully calibrated before the test. The coal was weighed in 200 pound lots in platform scales. Feed water was weighed at the point where it enters the feed water heater by platform scales and allowed to flow into the heater by gravity. The temperature of the feed water was taken at the point where it was pumped from the heater. The level of the water in the gage glass was noted at the beginning of the test and great care was exercised to have it at this same level at the end. Steam pressure and draft gage were read at intervals of fifteen minutes and temperature of flue gasses was taken at more or less irregular periods. The coal was sampled at the time of weighing. From this a representative sample was taken and the proximate analysis and heat value determined in the University laboratory . During the last two thirds of the period of the test flue gas analyses were made every half hour

Indicator cards were taken on the Corliss engine and both steam and air cylinders of the compressor every fifteen minutes. A sampling nozzle was inserted in the vertical steam pipe leading to the main engine and determinations for moisture made every fifteen minutes. The accuracy of this determination is doubtful but there was nothing to indicate that wet steam was being made.

The results of the test are given below.

BOILER TEST

Date of test	May 5 and 6 1917

DIMENTIONS, PROPERTIONS ETC.

Kind of boiler	Fire Tube
Kind of Furnace	Hawley Down-draft
Grate surface width 6'9" length 6'	area 40 Sq.Ft.
Approximate width of air space in grates	1/2 In.
Water heating surface	2000 Sq. Ft.
Ratio of water heating surface to grate surface	50:1
Ratio of minimum draft area to grate surface	1:7.3
Height of chimney	125 Ft.
Area of chimney	12.56 SQ.FT.
Duration of trial	24 Hours
Kind of coal	Bituminous
Size of coal	Run of Mine
Locality	Cross Mountain

AVERAGE PRESSURES, TEMPERATURES

Steam pressure by gage	97.0#
Barometric pressure	14.2 "
Absolute steam pressure	111.2"
Force of draft, near damper	0.47 In.
Temperature of external air	65 F.
Temperature of boiler room	65 F.
Temperature of feed water	181.4 F.
Temperature of gasses leaving boiler	616 F.

QUALITY OF STEAM

Percentage of moisture in steam	1.1 %
Quality of steam	98.9

BOILER TEST (CONTINUED)

TOTAL QUNATITIES

Weight of coal as fired	16,000#
Percentage of moisture in coal	1.2 %
Total weight of dry coal consumed	15,808 #
Total ash and refuse	2247#
Total combustible consumed	13,561 #
Total weight of water fed to boiler	132959 #
Total water evaporated, corrected for moisture in steam	131497 #
Factor of evaporation	1.0837
Total equivalent evaporation from and at 212 F.	142503 #

HOURLY QUANTITIES AND RATES

Dry coal consumed per hour	659 #
Combustible consumed per hour	565 #
Dry coal per Sq. Ft of grate sufface per hour	16.4#
Water evaporated per hour- corrected for quality of steam	5479#
Equivalent " " " from and at 212 F.	5937 #
Equivalent evaporation per hour from and at 212 F per Sq. Ft. of water heating surface	2.96 #

PROXIMATE ANALYSIS OF COAL

Fixed carbon (by difference)	47.0%
Volatile matter	38.4%
Moisture	1.2%
Ash	13.4%
B.t.u. per pound of dry coal	12700B.t.u.
B.t.u. per pound of combustible	14660 "

CAPACITY

Evaporation per hour from and at 212 F.	5937 #
Boiler horse power developed	143.1

BOILER TEST(CONTINUED)

Builders rating	150 B.h.p.
Percentage of rated capacity developed	95.4%

ECONOMY RESULTS

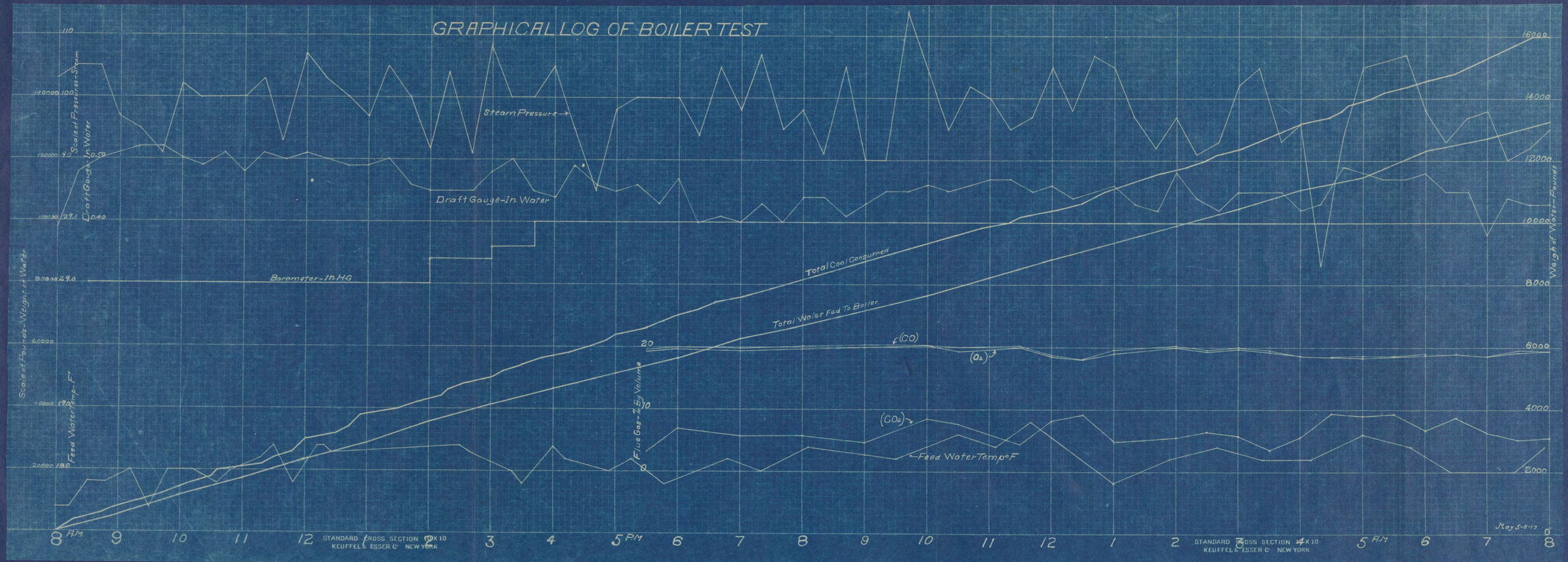
Water fed per pound of coal	8.24 #
Water evaporated per pound of dry coal	8.32#
Equivalent evaporation from and at 212 F. per pound of coal as fired	8.91#
Equivalent evaporation from and at 212F. per pound of dry coal-	9.01#
Equivalent evaporation form and at 212F. per pound of combustible,	10.5

EFFICIENCY

Efficiency of boiler, furnace and grate	68.8%
Efficiency of boiler and furnace	69.5%

ANALYSIS OF DRY GASES BY VOLUME

Carbon diozide ($C O_2$)	6.8%
Oxygen (O_2)	12.1%
Carbon Monoxide (C O)	0.1%
Nitrogen by difference	81.0%
Air, excess coefficient	2.5 Approx.


GRAPHICAL LOG OF BOILER TEST
Scale of Pressures - Steam
Draft Gauge - In. Water
Steam Pressure
Draft Gauge - In. Water
Barometer - In. HG
Scale of Pounds - Weight of Water
Feed Water Temp - F°
Total Coal Consumed
Total Water Fed To Boiler
Flue Gas - % By Volume
(CO)
(O2)
(CO2)
Feed Water Temp° F
Weight of Water - Pounds
8 A.M. 9 10 11 12 1 2 3 4 5 P.M. 6 7 8 9 10 11 12 1 2 3 4 5 A.M. 6 7 8
May 5-6-17
STANDARD CROSS SECTION 10 X 10
KEUFFEL & ESSER C° NEW YORK
STANDARD CROSS SECTION 4 X 10
KEUFFEL & ESSER C° NEW YORK

AMMONIA COMPRESSOR

Date of Test	May 5 and 6, 1917
Duration of test	24 hours
Type of engine	Simple Corliss

DIMENTIONS ETC.

Diameter of Cylinder	24 Inches
Stroke of Piston	2 Feet
Diameter of Piston Rod	3 1/4 Inches
Piston displacement h.e.	6.28 Cu. Ft.
Piston displacement c.e.	5.70 " "

AVERAGE PRESSURES AND TEMPERATURES

Pressure in steam pipe near throttle	96.8 Lb.
Barometric pressure in inches of mercury	29.06 In.
Absolute steam pressure	111.0 Lb.
Temperature of feed water	181.4 F.

TOTAL QUANTITIES

Total water fed to boiler	132959 Lb.
Moisture in steam near throttle	1.1%
Factor of correction for quality of steam	0.989

INDICATOR DIAGRAMS

Commercial cut off in percent of stroke	12.5 %
Initial pressure in pounds per Sq. Inch above atmosphere	99#
Back pressure at lowest point above atmosphere	2.5 #
Mean effective pressure in pounds per Sq. In. h.e.	26.1
c.e.	25.5

SPEED

Revolutions per minute	60.3
Piston speed in feet per minute	241

AMMONIA COMPRESSOR(CONT.)

POWER

Indicated horse powerh.e.	43.0 i.h.p.
Indicated horse power c.e.	41.4 "
Total indicated Horse power	84.4 "

CAPACITY

Total water frozen into ice in 24 hours	100000#
Total water frozen into ice per hour	4165#
Pounds of ice frozen per pound of coal as fired	6.25#
Pounds of ice frozen per pound of combustible	7.37#

AIR COMPRESSOR

Date of test	May 5and 6,1917
Duration of test	24 hours
Type of compressor	Piston
Compressor built by Ingersoll-Sargent Drill Company.	

HORSE POWER -STEAM CYLINDER

Diameter of piston	12 In.
Diameter of Piston rod	1.5 In.
Area of piston	h.e. 113.1Sq.In.- c.e.111.3 Sq.In.
Length of stroke	1 Ft.
Spring of indicator	60 Lb.
Revolutions per minute	55.8 Rev.
Average M.E.P. head end	26.8 #
Average M.E.P. Crank end	26.3 #
Average I.H.P. head end	5.13 I.H.P.
Average I.H.P. crank end	4.96 "
Total I.H.P. Steam cylinder	10.1 "

HORSE POWER -AIR CYLINDER

Diameter of piston	10 In.
Diameter of Piston rod	1.5 "
Area of piston	h.e. 78.54 Sq.In. --c.e. 76.77 Sq.In.
Lenght of stroke	1 Ft.
Spring of indicator	60 #
Average M.E.P. h.e.	28.1 #
Average M.E.P. c.e.	27.5 #
Average I.H.P. h.e.	3.57 I.H.P.
Average I.H.P. c.e.	3.57 I.H.P.
Mechanical efficiency of Machine	71%

CONCLUSIONS FROM BOILER TRIAL

Although the test shows a combined efficiency of boiler and furnace of 69%, such a performance could not be expected for continuous operation under the average conditions of practice. In this case, however, the boiler was operated at almost a constant load and at 95% of it's rated capacity. This and the fact that the test was conducted under ideal conditions, the boiler surfaces being freshly cleaned, the rate of combustion carefully adjusted for maximum economy and especial attention given to firing, probably accounts for the economy shown by the water apparently evaporated. A study of the flue gas analysis shows about 30 pounds of air per pound of fuel. With the stack temperature recorded this shows that at least 25% of the heat of the fuel was going up the chimney. The piping arrangement was not complicated and there is little doubt but that all the water weighed was pumped to the boiler and made into steam. The blow off pipe which lead from the boiler was exposed and was found to be cold.

The flue gas analysis shows a very low percentage of CO -2 . This can only be due to leakage of air thru the boiler setting or to excess air taken in thru the grate bars. The boiler setting however was in fairly good condition and consequently would not admit any great volume of air . This excess air was probably taken in

through the grate bar, which would be entirely possible with the thin fire maintained throughout the test.