A Test of the City Pumping Station

Nashville, Tenn.

The plant consists of four 400 H.P. hand fired boilers, two built by Babcock & Wilcox Co., and two by Altman Taylor Machinery Co., a twenty million gal. vertical, triple expansion, Allis Chalmers pumping engine, a ten million gal. Holly pump, and two ten million gal. Worthington high duty pumps, and auxiliaries such as condensers, air pumps, feed water pumps, etc.

The tests as planned consisted of a twenty four hour boiler test, an efficiency test, slip test, and duty test of the twenty million gal. tripple expansion Allis Chalmers pumping engine, a slip test of the ten million gal. Holly pumps, and a slip and duty test of one of the ten million gal. Worthington pumps.

The Boiler Test.

The boiler equipment seemed to be in good order with the exception that the blow off valves could not be closed tightly, due to the non seating of the valve. The leakage was measured at intervals and found to be uniform and so the loss of heat thus occasioned was corrected for. The test was conducted according to the rules of the A. S. M. E. using the alternative method of starting and stopping. It is the practice at this plant for the fireman to carefully weigh in a wheelbarrow all of the coal fired. Weighing during the test was done in this manner. Due to some misunderstanding the ashes for the first twelve hours of run were not weighed, but accurate account was kept for the other twelve hours. This weight was doubled and called the total ash, since the load on the plant is a constant one and fuel consumption should be uniform.

The feed water was measured by a three inch venturi meter. A curve is drawn having boiler feed water in lbs. per minute as ordinates and time as abscissa. A mean ordinate thus being found for the whole time enables us to know the total boiler feed water.

The boilers have no steam domes or place for the collection of steam and so no place for a calorimeter close enough to indicate the performance of the boilers. A quantity of 98½% is assumed which is the quality for fair boiler operation where there is no superheating surface or steam dome.

The flue gas analysis was made with an Orsat apparatus and the percentage of CO_2 and O determined. The temperature of the flue gas was taken with a pyrometer.

The coal burned was run of mine and of all sizes. The fires werethin and often showed bad holes which gives a large excess of air, as is shown by the low percentage of CO_2 in the flue gas. The leaking blow off valve gives a constant and considerable loss of heat. This heat represents, where boiler and grate efficiency is 61.2 and coal gives 13030 B. t. u. per lb., 1280 tons of coal per year.

The manufacturers of the boilers were written to for dimensions of the grates and heating surfaces of the boilers, since the boilers were in use or were sealed and the dimensions could not well be taken. The Babcock & Wilcox Co. sent the dimensions for their boilers but the other company did not. The two boilers have the same rated capacity and so are assumed to have the same dimensions.

Report of Boiler Test.

Dimensions

Duration of trial	24 hours
Grate Surface	176 sq. ft.
Water heating surface	7920 sq. ft.
Height of chimney	125 ft.
Tubes Number	378
Diameter	4"

Pressure

Steam Gauge	157 lbs.
Absolute steam pressure	1714 lbs.
Draft gauge in inches water	$\frac{3}{4}$"

Temperature

Escaping gases	430°F.
Feed water	101° F.
Steam	369° F.

Fuel

Kind of coal	Run of mine
Locality	Fentress County
Moisture	1.35%
Ash	10.3%
B. T. U. per lb coal	13030
B. T. U. per lb combustible	14700
Total coal consumed	60200 lbs
Dry coal consumed	59450 lbs
Total refuse	9600
Total refuse percent of	16.15%
dry coal	49850 lbs
Total combustible	

Combustion per hour

Dry Coal	2470 lbs
Combustible	2078 lbs
Dry coal per sq. ft of grate	14.05 lbs
Combustion per sq. ft of grate	11.78 lbs
Dry coal per sq ft of heating surface	.312
Combustible per sq ft of heating surface	.262

Flue gas

CO_2 per cent of volume	4%
O	8%
Quality of steam (assumed)	98.5%

Total Water

Total [illegible] used	493960 lbs.
Total evaporated	485500 lbs.
Factor of evaporation	1.03 lbs.
Equiv. evaporated from and at 212°	501000 lbs.

Water per Hour

Amount used	20570 lbs.
Evap. dry steam	20210 lbs.
Equiv. evap. from and at 212°	20800 lbs.

Economic Evaporation.
Per lb. of Fuel

Actual per lb. dry coal	8.20 lbs.
Equiv. from and at 212° (dry coal)	8.42 lbs.

Per lb. of Combustible

Actual	9.75 lbs.
Equiv. from and at 212°	10.00

Rate of Evaporation
Per sq. ft. of grate per hour

Actual from feed water temp.	115.0 lbs.
Equiv. from and at 212°	118.2 lbs.

Per sq. ft. of water heating surface

Actual	2.56 lbs.
Equiv. from and at 212°	2.62 lbs.

Horse Power

On basis 34½ lbs. equiv. evap. per hour	602.5
Builders rating	800.
Ratio of commercial to builders rating	.753
Heat generated per lb. dry coal	13300
Heat absorbed per lb. dry coal	8160
Heat absorbed per lb. combustible.	9704
Efficiency of boiler	66.0
Efficiency of boiler & grate	61.2

Test of the Twenty Million Gallon Vertical, Crank and Fly wheel, Triple Expansion, Triplex, Single Acting Allis Chalmers Pumping Engine.

Four thirty minute tests were made at varying speeds to show the efficiency, duty, and slip of the engine for each of the four speeds. The condensate from the condenser was pumped to the operating floor where it was caught in tanks and weighed. The air pump for the condenser is driven from the main engine by a collar around one of the plunger rods which operates the air pump plunger. A calorimeter was inserted in the main steam line close to the engine giving the quality of steam supplied. Tabor outside spring indicators were attached to each of the three cylinders and cards taken every ten minutes. In working up the indicated horse power of the engine there appears to be lost motion in the cards from the intermediate and low pressure cylinders which makes the mechanical efficiency part of this test of no value.

The slip of a pump is the ratio of the difference between the displacement of the plunger and the actual flow, to the displacement of the plunger or in other words the percentage of displacement which is not discharged. Both the displacement and actual discharge must be for the same time and measured in the same units. Since the work of the pump is the same regardless of slip, the slip represents a loss which must be watched. Slippage is due mainly to failure of valves to work perfectly so all pumps show some slip, but large slippage indicates bad valve operation and needless waste of energy. The valves of this pump had just been over hauled and their operation is especially good, as indicated by the slip test.

The flow of water in the 36" force main was measured by a pitometer. This instrument consists essentially of a "U" tube whose ends connect by means of rubber tubing to two orifices which are inserted into the force main thru a one inch corporation cock. These orifices are 180° with one another and parallel to the axis of the force main. In the "U" tube is some liquid of different specific gravity than water. The deflection in the "U" tube is a function of the velocity in the main for the position of the orifices. Preparatory to making the test a traverse of the force main was made and a relation, known as the pipe coefficient, between the average velocity in the main and the velocity at the center. The average velocity is determined by drawing a curve having abscissa as velocity in the ft. per sec. and position in force main as ordinates. A mean abscissa of this curve gives the average velocity. The pitometer was set with orifices at the center of the force main and the corresponding average velocity and discharge calculated from the data.

The delivered horse power of the pump was calculated from the area of the plunger, length of stroke, number of strokes per minute, and the sum of pressure and suction heads expressed in lbs. per sq. in. The water pressure gauge is located on the gauge board 8 ft. above the main floor. The suction head was read from a gauge operated by a float in the suction well. The zero of this gauge with reference to the center of the pressure gauge was determined and the suction head readings converted into actual suction head with reference to the pressure gauge. The pressure gauge on water main was compared with a standard gauge and found to read seven pounds high when it read 132 lbs.

The duty of a pump is expressed in two ways, i.e. ft. lbs. of work per million B. T. U.'s furnished and ft. lbs. of work per thousand lbs. of steam used. We were advised that the duty obtained in the acceptance test for this pump about seven years ago was one hundred eighty five million ft. lbs. per thousand lbs. of steam.

Report of Twenty Million Gallon Allis Chalmers Pumping Engine Test.

No. of steam cylinders	3
Diam. of steam cylinders in inches	36", 70", 106",
Diam. of piston rods (two to each cylinder)	$5\frac{1}{2}$"
Areas of steam pistons sq. in.	
Head end	1017.9, 3848.5, 8824.7,
Crank end	970.4, 3801.0, 8777.2.
No. of water plungers	3
Diam. of water plungers in in.	31"
Area of plunger rods sq. in.	754.77 sq. in.
Length of stroke in inches	72"

The duty and the Slip Test.

	Steam.			
	First	Second	Third	Fourth
Strokes per min	11.4	13.7	16.43	18.9
Duration of tests in minutes	30'	30'	30'	30'
Total steam supplied in lbs.	4122	5052	6267.5	7439.5
Quality percent	98.06	98.12	97.82	97.54
Net dry steam per hr.	8084	9914	12261	14513
B T U's per lb of steam	1180.3	1180.3	1179.4	1174.5

Performance.

	First	Second	Third	Fourth
Steam per apparent I H P hr. wet in lbs.	12.70	12.32	12.10	11.95
Steam apparent I H P hr. dry in lbs.	12.45	12.10	11.88	11.40
Steam per D H P per hr. dry	11.50	11.53	11.62	11.40
B T U'S per apparent I H P hr.	15000	14580	14270	14100
Thermodynamic Efficiency %	32.2	32.2	32.2	32.2
Water rate of perfect engine	9.28	9.28	9.28	9.28
Ratio of actual to perfect water rate	1.37	1.33	1.30	1.28
B. T. U's per D H P	13600	13630	13710	13480
Thermal Efficiency percent	16.95	17.50	17.82	18.05
Duty in ft. lbs. per million B T U's supplied	(1st.)	145,700,000		
	(2d.)	145,500,000		
	(3d.)	144.300,000		
	(4th.)	147,800,000		
Duty in ft lbs per Thousand lbs. of dry steam supplied	(1st.)	172,000,000		
	(2d.)	171,600,000		
	(3d.)	170,500,000		
	(4th.)	173,800,000		
Slip in percent	(1st.)	2.46		
	(2d.)	1.49		
	(3d.)	.66		
	(4th.)	6.38		
Capacity in gal. per 24 hours	(1st.)	11300000		
	(2d.)	13750000		
	(3d.)	16700000		
	(4th.)	17920000		

Water.

	First	Second	Third	Fourth
Delivery pressure lbs. per sq. in gauge corrected	122.1	125.0	127.8	135.4
Suction pressure to center of delivery gage lbs per sq. in.	27.5	27.8	27.9	28.1
Total head in feet	345.5	351.1	359.6	377.5
Total volume actually delivered in cu. ft. per sec.	17.48	21.24	25.64	27.76
Total wt. delivered in lbs. per sec.	1091	1340	1590	1730
Wt in lbs per hour.	3930000,	4820000,	5725000,	6230000
Plunger displacement during test in cu. ft. per sec.	17.92	21.56	25.81	29.70
Delivered Horse Power	702.3	858.0	1051.5	1273.5

Steam Cards.

Scale of indicator springs in lbs per in.

High pressure	80 lbs.
Intermediate P.	20 lbs.
Low pressure	10 lbs.

Mean effective pressure lbs. per sq. in.

	First	Second	Third	Fourth
Head End	60.75	64.75	67.50	75.80
	15.50	15.80	14.17	14.75
	4.65	5.02	5.50	5.84
Crank End	60.75	64.50	68.50	75.75
	14.25	15.00	14.37	14.69
	4.4	4.57	5.15	5.37

Strokes per Min.	11.4	13.7	16.43	18.9
* I H P (apparent) Head End	333.7	424.8	512.2	636.6
I H P (apparent) Crank End	315.0	397.2	496.3	606.1
Total I H P (apparent)	648.7	822.0	1032.9	1242.7

* These values are unreasonable and so are in error

Slip Test of the Single Acting Ten Million Gallon Holly Pumping Engine.

The Holly pumping engine is equipped with two single acting Gaskell pumps operated through a walking beam mechanism. A slip test was made consisting of making a count of the number of strokes, and the discharge in the force main. This pump discharges so close to the pitometer that the velocity in the main does not reach a fair degree of uniformity before arriving at the pitometer and so the readings given do not give a reasonable discharge. To accurately measure the flow from this pump at this point would require three pitometers set at 120° with each other.

Slip and Duty tests on one of the Ten Million Gallon Worthington High Duty Pumps.

The slip test was impossible for the same reason that the test on the Holly pump failed. The duty test was made by weighing the discharge from the condenser and taking the work in ft. lbs. from the volume displaced.and the total head worked against. The condenser has a bad leak which makes it hard to differentiate the leakage from the condensate. An attempt to do so was made by measuring the discharge from the condenser while the pump was discharging water into the force main and then while the pump was dead and vacuum maintained.the same. The results do not show a reasonable agreement so it is presumed that the conditions were not duplicated closely.

Plant Operation.

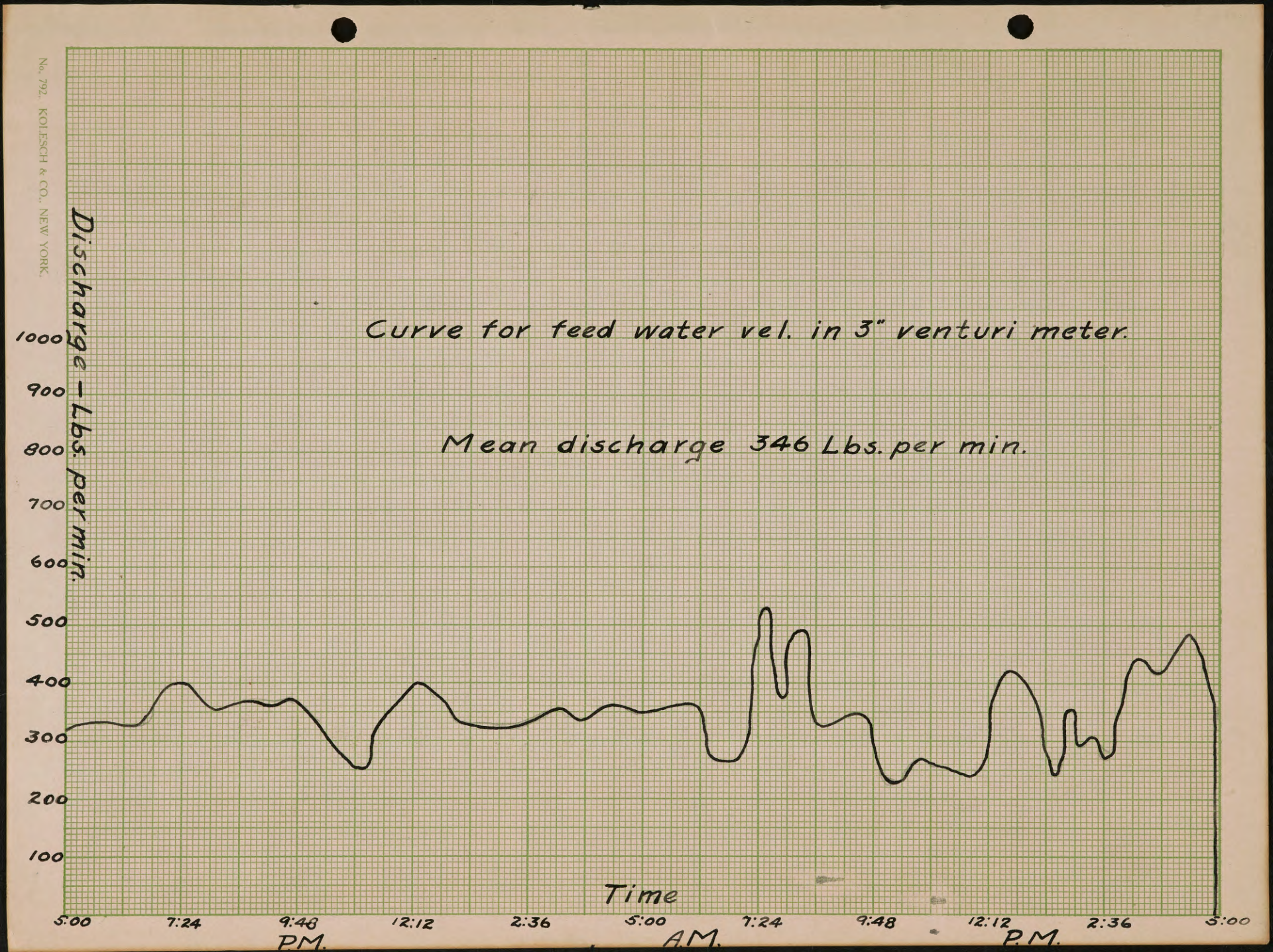
The twenty million gallon Allis Chalmers pump shows a very economical use of steam in 11.5 lbs. of steam per D H P . The boiler operation is bad in several particulars. The boilers are operated at 75% of rated capacity, indicating a larger boiler capacity than is needed for operating the plant. As a rule boilers may be safely operated at 125% capacity and at this rating give their maximum efficiency. Some large plants of the country operate at 150% to 200% capacity continuously, One boiler working at 150% capacity could carry the load with a material saving of coal.

The fires on the grates were thin at all times and sometimes showed bad holes, thus giving a large excess of air, which is shown by the low percentage of CO_2 in the flue gas analysis. The coal is not uniform in size and not adaptable to boiler operation. With a coal more nearly uniform and about three inches in size a closer fire bed is possible. This excess of air may be prevented by carrying the fuel bed thicker.

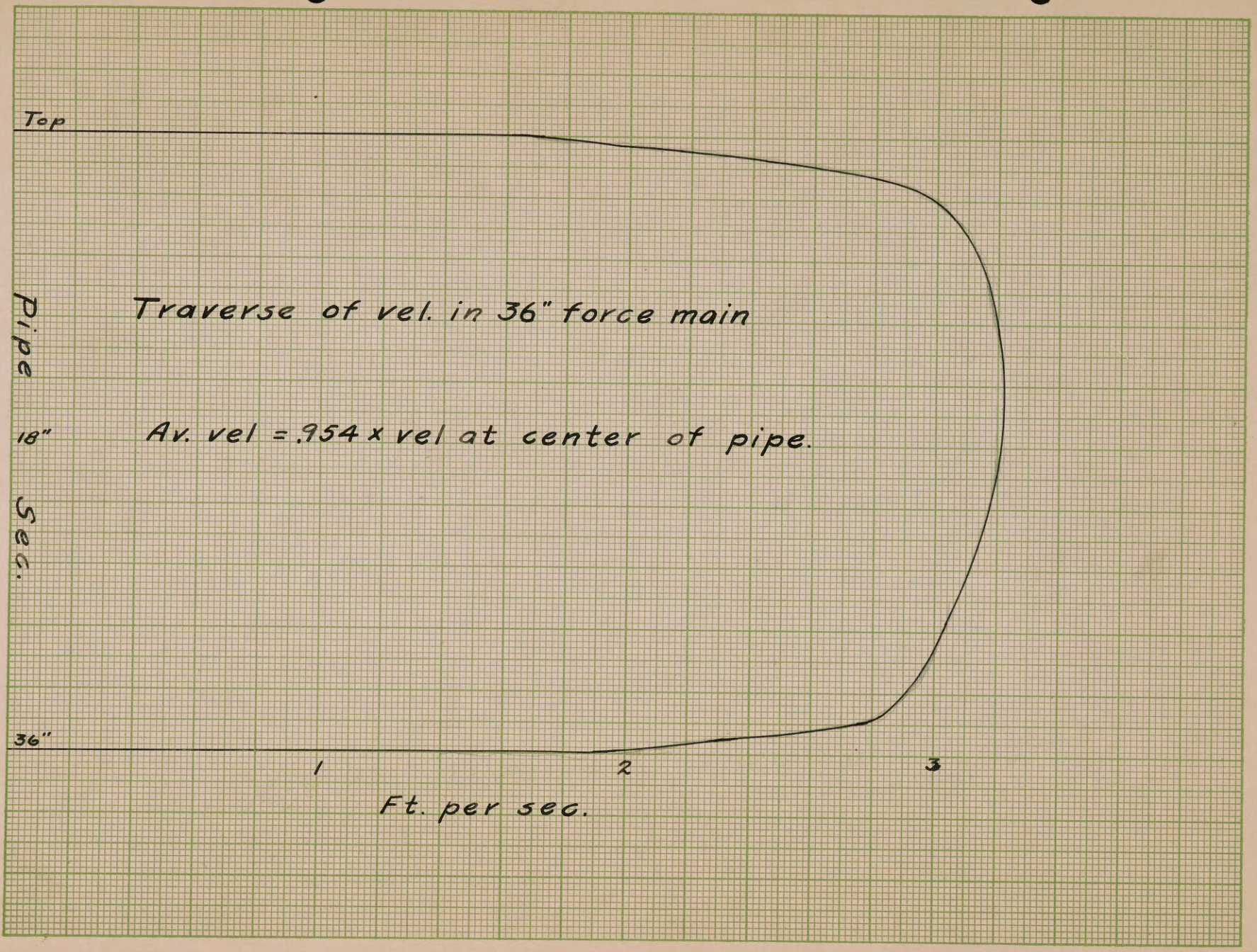
By a systematic study of flue gas analysis the percentage of CO_2 may be brought to about 13% by adjusting the thickness of fire and admission. With an excess of air a large part of the heat is absorbed in heating the increased volume of air.

The condenser for one of the Worthington pumps has a bad leak which cuts down the vacuum to about twenty two inches and lowers the efficiency of the pump. This leak is always subject to the pressure of the main and the continuous loss of water is considerable.

No. 792. KOLESCH & CO., NEW YORK.



No. 792. KOLESCH & CO., NEW YORK.



DRILLING OF 9 THROTTLE VALVE
12-1 DRILLED HOLES ON
14 B.C. DIA FLANGE 16"

FLOOR LINE

FLOOR LINE ELEV 174062'

28 EXH. PIPE

CONDENSER

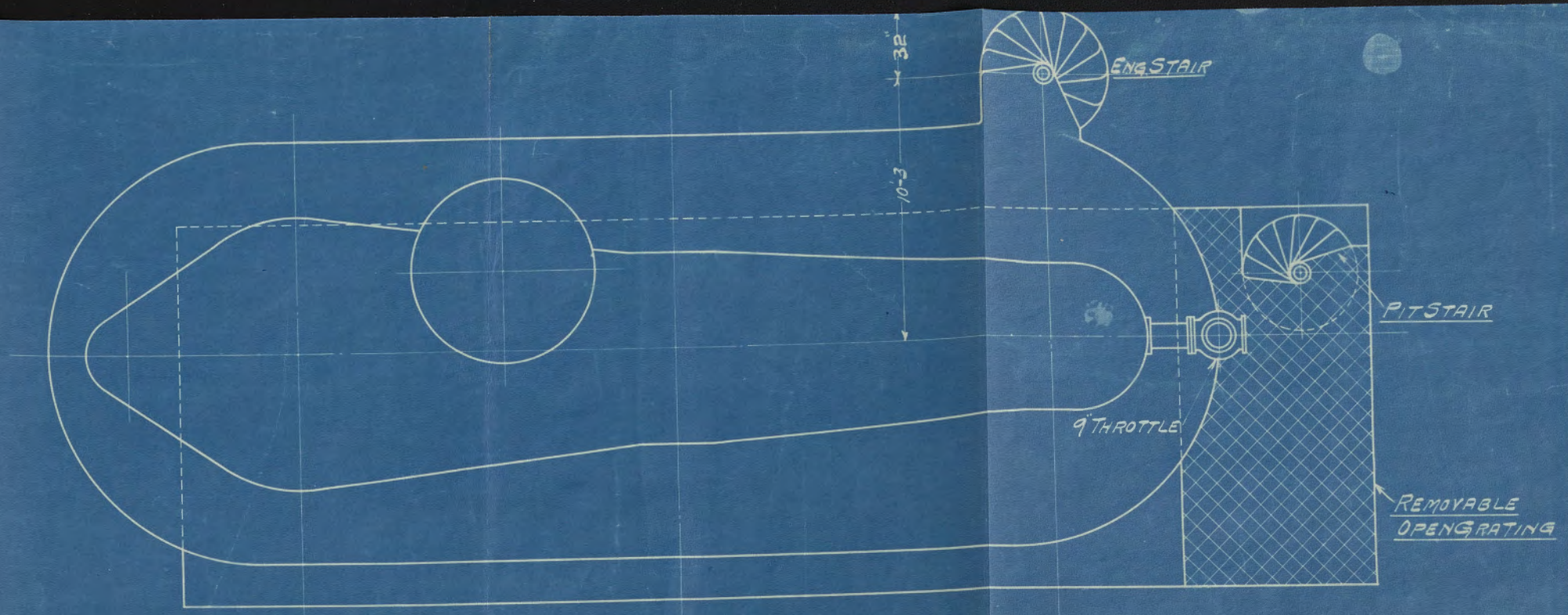
OIL FILTERING HOT WELL

AIR PUMP

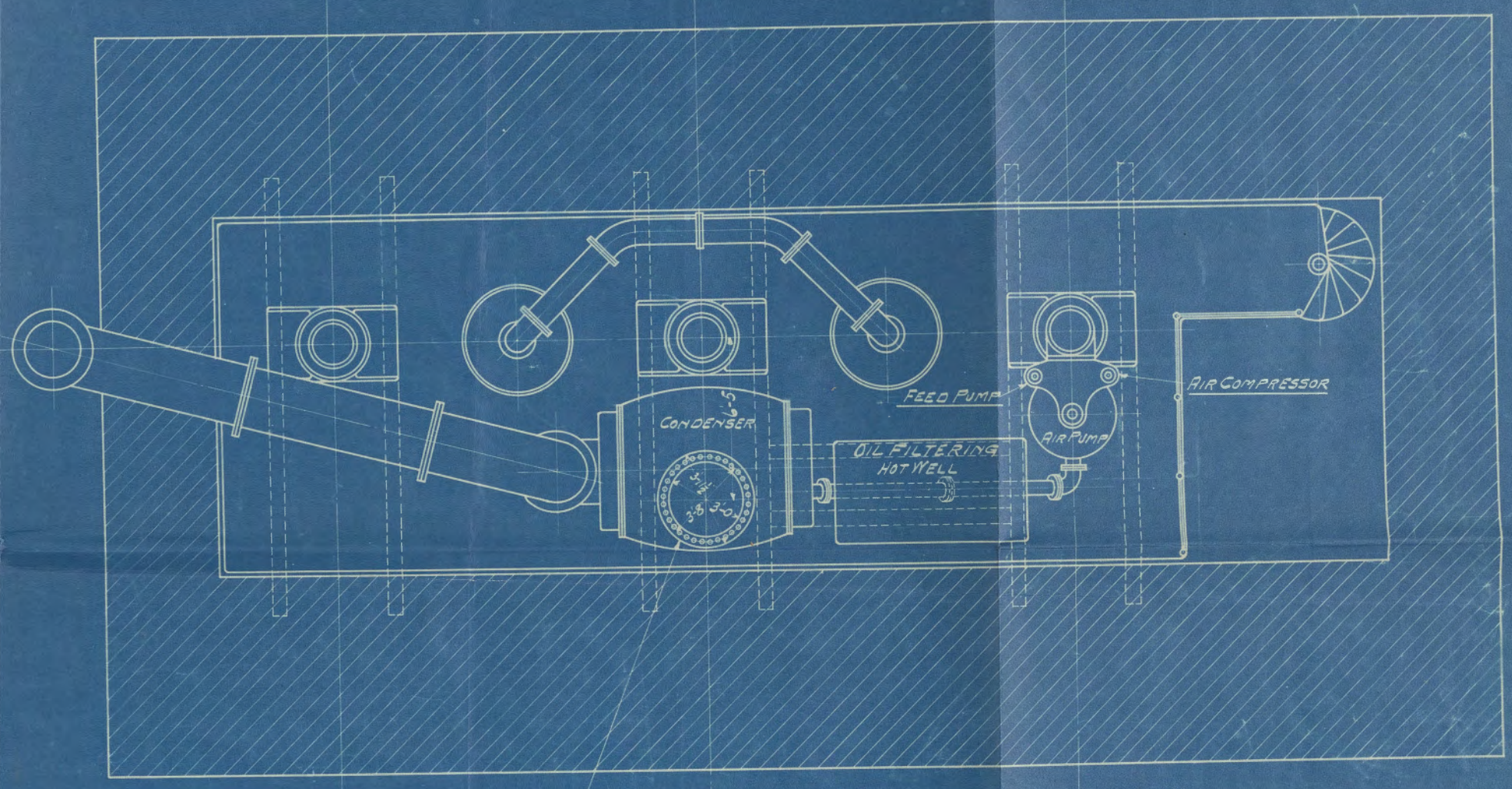
ELEVATION 112.392'

DRILLING FOR 42 SUCTION PIPE 36-1¼ DRILLED HOLES ON 41½ B.C. DIA FLANGE 4'-4¾

FLOOR LINE

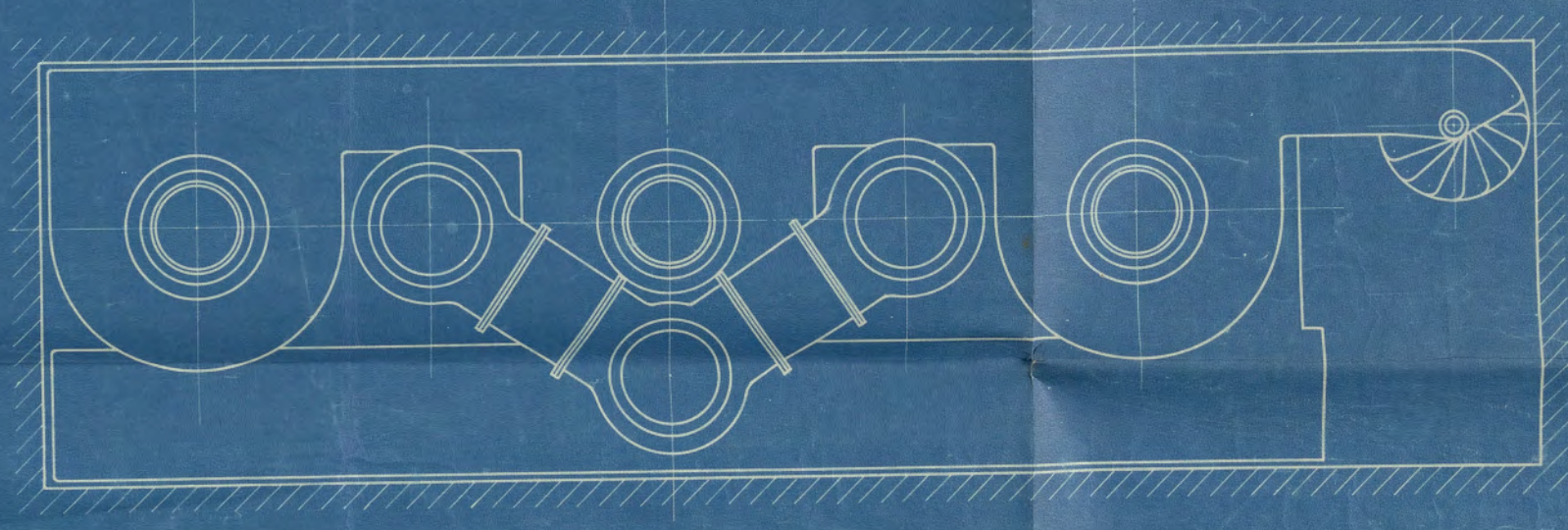


PLAN OF STEAM END



DRILLING FOR 36" DISCHARGE PIPE
32-1 1/16 DRILLED HOLES ON 3'-8" B.C.
DIA. FLANGE 3'-11 1/2"

SECTION A-A



SECTION B-B

GENERAL ARRANGEMENT
20 MILL. GAL. VERT. TRIPLE EXP. PUMPING ENG.
36-70-106 & 31 x 72
CITY OF NASHVILLE, TENN.

ALLIS-CHALMERS COMPANY
PUMP & ENGINE DEPARTMENT
MILWAUKEE, WIS.

12-3-06
Fan
Blast
Allis
Blower

INDEXED

7

NEW BREECHING

15' 5" | 5' 0" | 17" | 20' 2¾" | 17" | 5' 0" | 30' 0"

DAMPER

EXPANSION JOINT

SEE DRAWING B380

5' 6"

5' 6"

F

5' 0" RAD.

10" GATE VALVE

11' 8½"

20' 1¾"

BLANK FLANGE

D

H

FLANGED SIDE OUTLET ELBOW
CRANE CO'S CATALOGUE "40 1908
FIG. 131 E PAGE 457

2' 0"

6' 6" DIA.

19' 7½"

BRICK STACK
125' 0" HIGH.

CRANE PIPE BRACKET STYLE 'K'
PAGE 502-CATALOGUE NO. 40.

16' 1"

3' 0" RAD.

3' 0" RAD.

12' 3"

18' 11½"

CRANE ROLLER SLEEVE
STYLE 'D' PAGE 502
CATALOGUE NO 40

11½" | 6' 1" | 23" | 6' 4"

PLAN OF SOUTH BOILER HOUSE.

10 PIPE LINE

16' 11⅛"

PIPING CONTRACTOR TO FURNISH AND PLACE IN POSITION WALL PLATES AND ALSO BRACKET FASTENED TO STACK FOR SUPPORTING 10" LINE.

39' 9½"

C

10" GATE VALVE

2' 0⅝" | 2' 3⅝"

PIPING CONTRACTOR TO REMOVE TEE NOW IN PLACE AT THIS POINT AND PLACE NEW FOUR WAY TEE FIG 135 E CRANE CO'S CATALOGUE "40 1908 PAGE 457

N

NO 7

IN

CRANE ROLLER SLEEVE STYLE 'D'
PAGE 502-CATALOGUE NO. 40.

NEW BREECHING

4' 10⅝" | 15' 5" | 4' 10½" | 16"

DAMPER

SEE DRAWING B380

B

A

FRONT LINE OF BOILERS

BLANK FLANGE

20' 1¾"

43' 0"

NOTE:
NEW PIPING FROM A TO B.
" " C TO D
" " E TO F.

16' 7⅞" | 11½" | 6' 4" | 11½"

PLAN OF NORTH BOILER HOUSE.

60' 1½"

24' 10⅞"

16' 2"

5' 6"

5' 6"

16' 3⅝"

3' 5"

9' 3"

7' 11½"

3' 9⅜"

36"

2' 6"

9' 4"

20' 1¾"

24"

5' 0"

6' 0"

18' 2"

BOTTOM OF ROOF TRUSSES

18' 9½"

11' 9½"

18' 4¾"

20' 0"

FLOOR LINES

NOTE:-
NEW BOILERS, PIPING AND BREECHING SHOWN IN FULL LINES.

NOTE:-
STEAM PIPE & FITTINGS EXTRA HEAVY FOR 200 Lbs. STEAM PRESSURE.
ALL PIPE FLANGES TO BE EXTRA HEAVY CAST STEEL CRANELAP SHORT HUB.
ALL ELBOWS AND TEES TO BE EXTRA HEAVY CAST STEEL.
VALVES TO BE CRANE & CO'S OR WESTERN VALVE CO'S FLANGED EXTRA HEAVY STRAIGHT WAY VALVES, WITH OUTSIDE SCREW & YOKE AND BY PASS, AND TO BE MADE OF SEMISTEEL.
GASKETS TO BE CORRUGATED NORWEGIAN STEEL MADE UP WITH SMOOTH-ON, OR CRANE & CO'S KLINGERIT GASKETS.
ALL PIPE TO BE COVERED WITH 85% MAGNESIA COVERING 2" THICK. VALVES ELLS & TEES TO BE COVERED WITH 85% MAGNESIA COVERING 1½" THICK. COVERING TO HAVE CANVAS SEWED ON & FASTENED WITH SOLID BRASS RINGS.

NOTE -
PIPING CONTRACTOR TO TAKE HIS OWN MEASUREMENTS AND BE RESPONSIBLE. THEREFORE MEASUREMENTS ON THIS DRAWING ARE ONLY APPROXIMATE.

W
S.
N.
E

D

H

10" FOUR WAY TEE.

C

A

10" DROP PIPE

6' 0"

3' 0"

¾" PIPE TO TRAP

16' 10½"

FRONT ELEVATION OF NEW BOILER.

10" DROP PIPE

¾" PIPE TO TRAP

FRONT ELEVATION OF BOILERS NOW IN USE.

BOTTOM OF ROOF TRUSSES

B

3' 6" RAD.

49¼" | 49¼"

13' 6½" TO BOTTOM OF BREECHING

4' 8"

15"

16' 2"

20' 0"

12' 7"

1½"

4½"

12"

9"

FLOOR LINE

15' 5"

SECTION THRU FURNACE OF NEW BOILER.

REVISED.
2-13-09 W.F.D. CHANGED PIPING
2-26-09 E.M. ADDED DROP PIPE & NOTES
3-20-09 H.K. CHANGED NOTES ON PIPING.
5-14-09 W.F.D.
6-1-09 A.L.

THE BABCOCK & WILCOX CO

GENERAL OFFICES. NEW YORK, N.Y. WORKS. BARBERTON, OHIO

PROPOSED LAYOUT OF BOILER ROOMS FOR CITY OF NASHVILLE

DRAWN BY A.E.L. INSPECTED BY
TRACED BY W.F.D. SCALE 1/4" = 1FT.
DATE JAN. 28, 1909

8378-134.

#3