RELATIVE EFFICIENCIES AND CAPACITIES
OBTAINED WITH
A
WARREN DUPLEX STEAM PUMP
EQUIPPED (a) WITH STRAIGHT PORTED VALVES
(b) WITH ROTARY INCLINED PORT VALVES

JUNE 1920

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(b) WITH ROTARY INCLINED PORT VALVES

A THESIS

SUBMITTED TO THE FACULTY OF THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

By

[illegible]

and

[illegible]

June 1,1920.

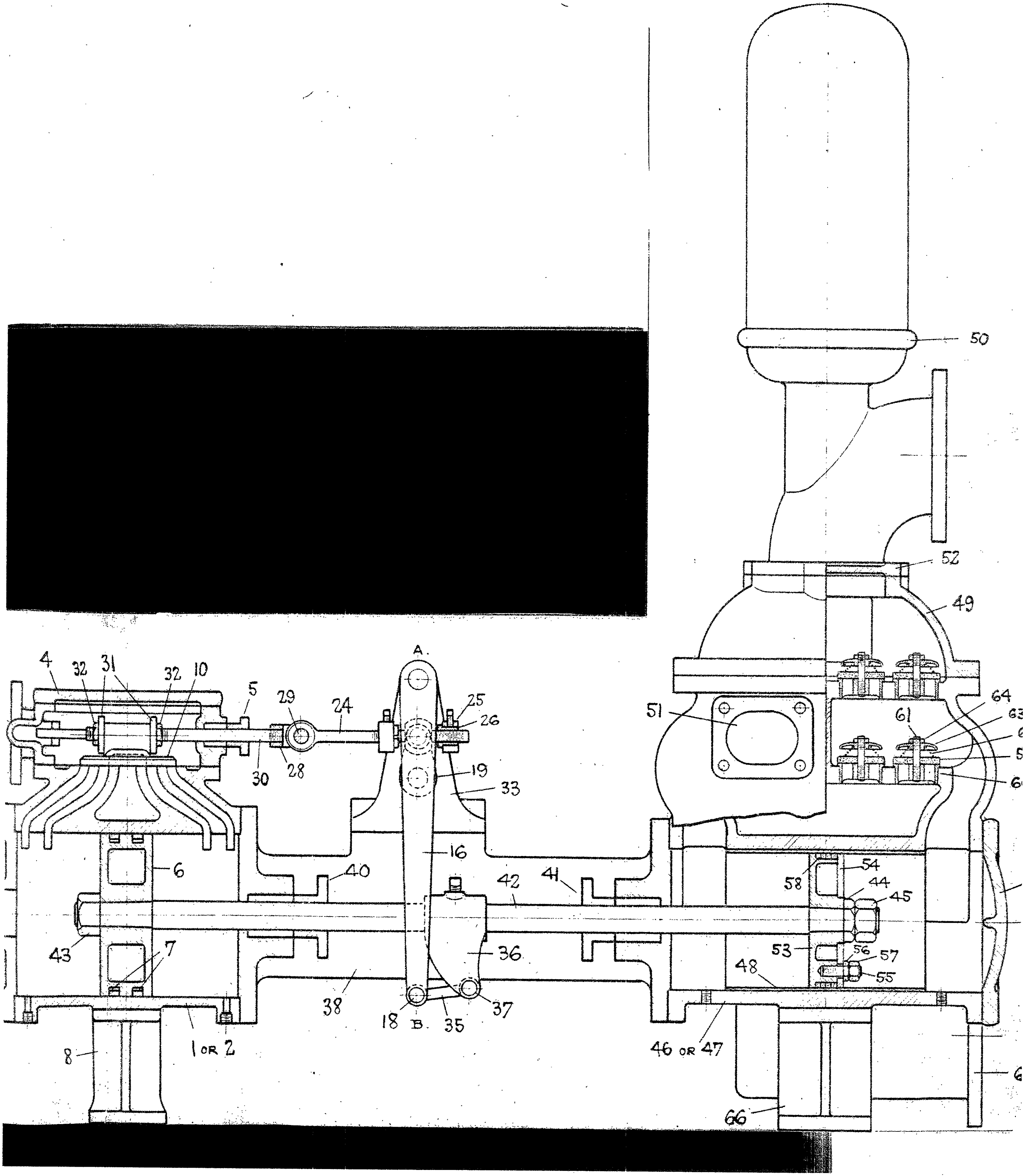
OBJECT

The purpose of the test is to study the relative merits of two types of pump valve, with special attention to the efficiency and capacity obtained. A further study was made in comparing velocities of the water through the valves and the losses in head due to the resistances in passing.

DESCRIPTION OF THE PUMP.

The pump used in these tests was a Warren Duplex Steam Pump No. 14344, size 16" x $10\frac{1}{2}$" x 12". A section through the centre line of the pump is shown on the inserted blueprint. The pump contains 24 suction valves and 24 discharge valves. The rated capacity of the pump is 1,000 gallons per minute at a piston speed of 50 feet per minute per side.

[redacted]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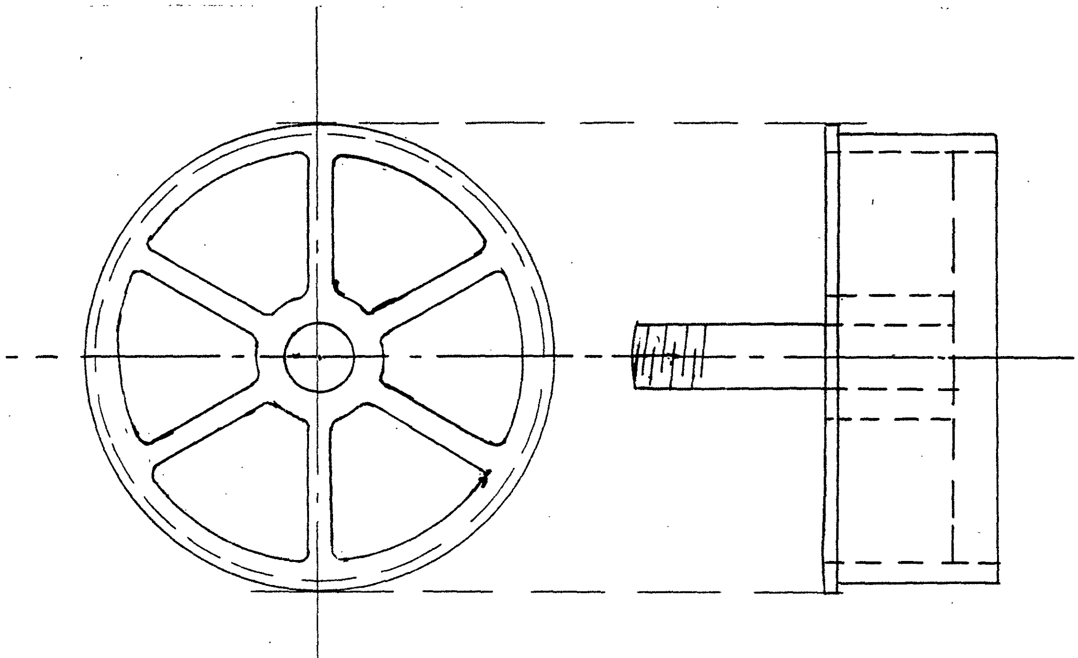
DESCRIPTION OF VALVES.

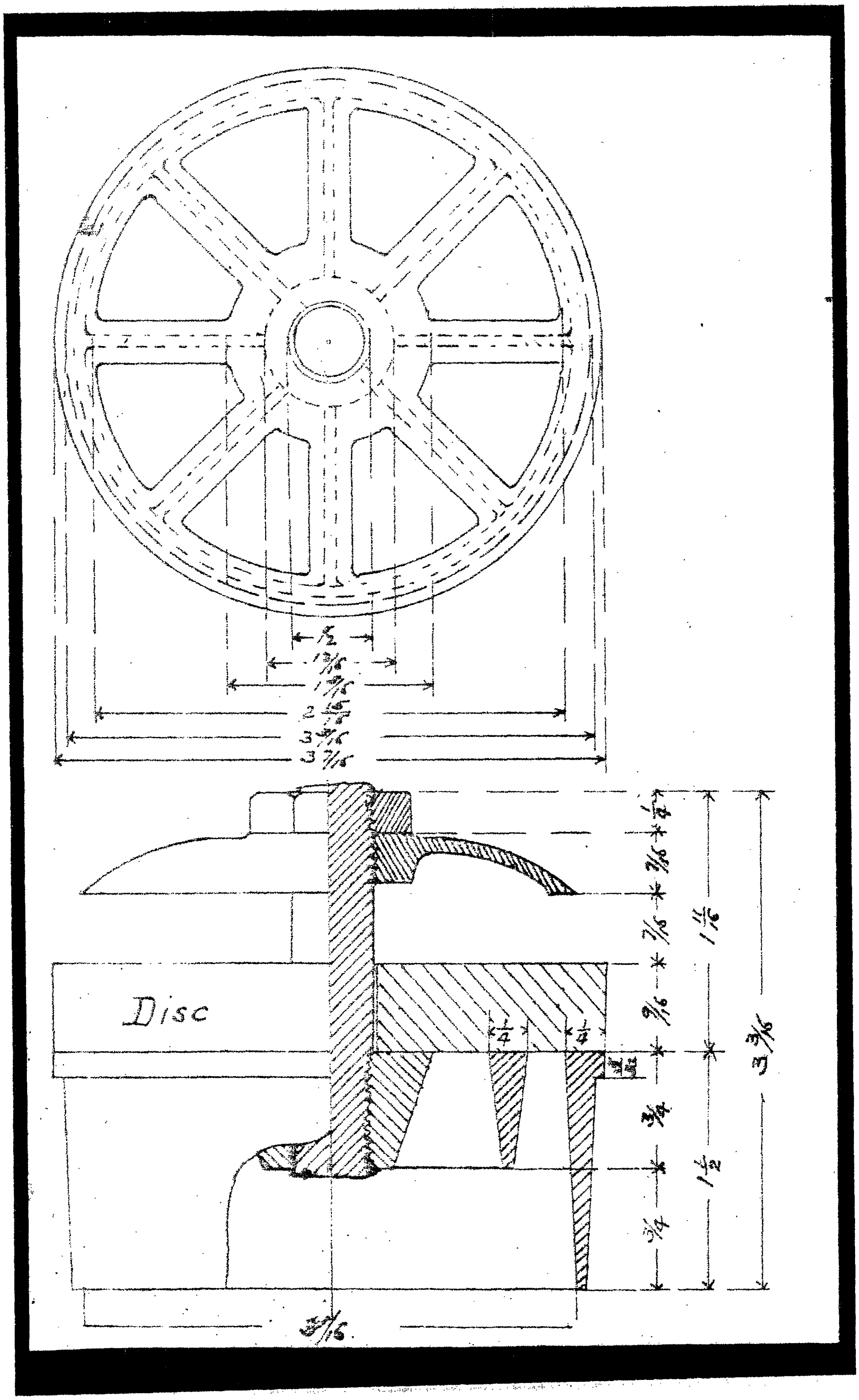
(a) Straight Ported Valves.

The straight ported valve tested is the valve regularly furnished with the pump by the makers. The valve is sketched below.



Seat and Stem
Straight Ported Valve.

It consists of a seat, disk, stem, spring and spring-plate. This valve is not fitted with **a guard plate.** The spring seats directly on the valve disk. The area of port opening per valve is 3.90 square inches.



Disc

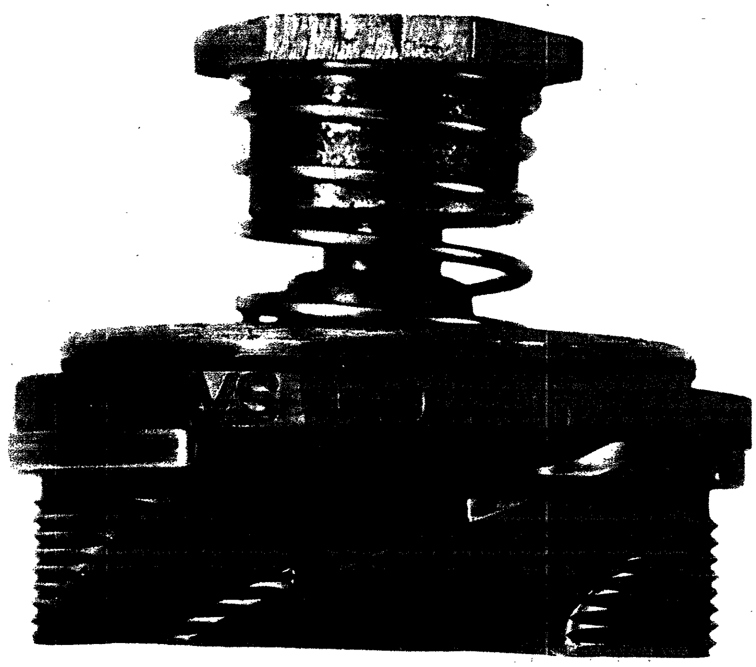
(b) Inclined Port Valve.

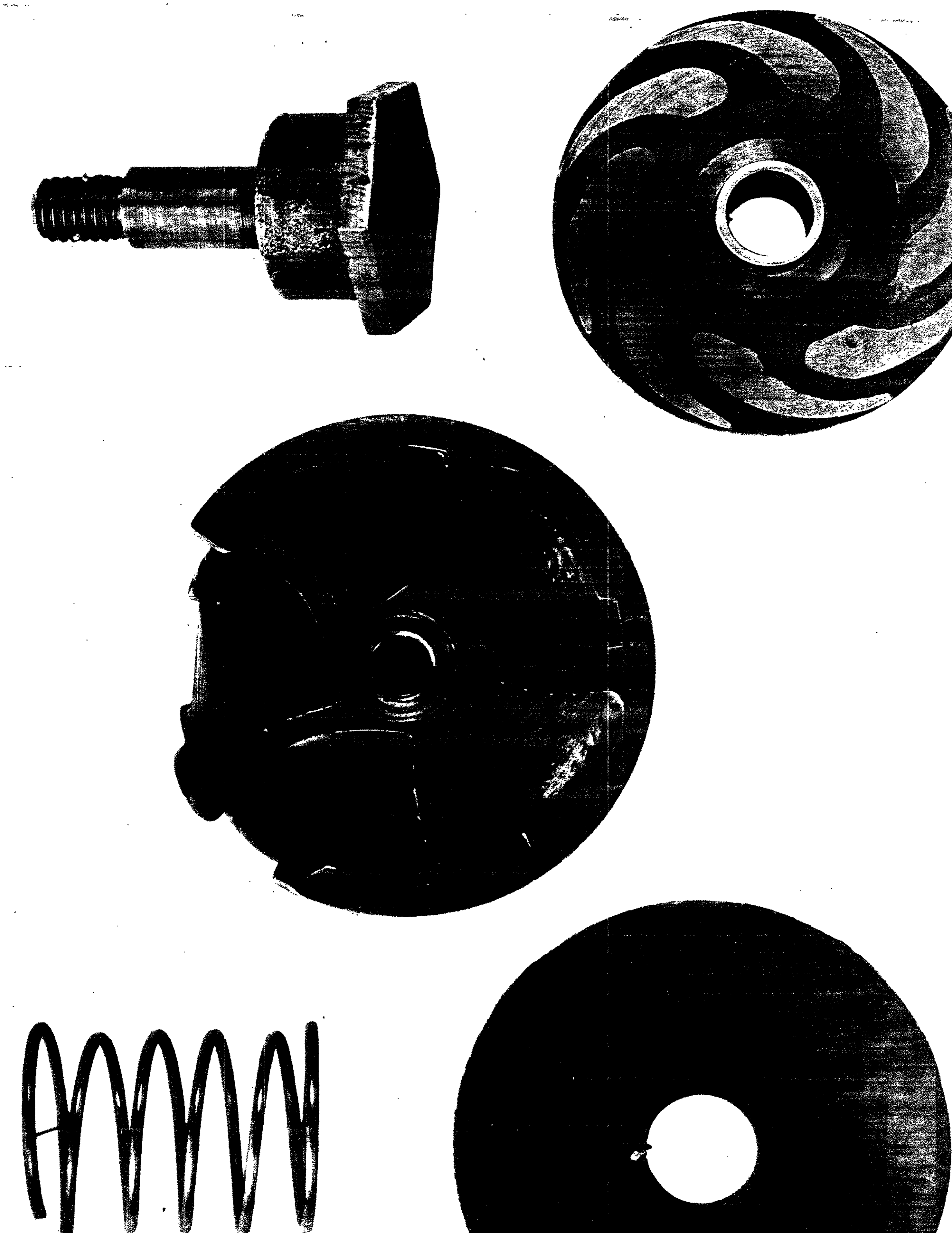
The inclined port valve tested is the Sims Rotary Pump Valve. The essential differences between this type and the type first tested lie in the seat and guard plate. The seat of this valve has inclined ports. The surfaces of the ribs in the seat are rectilinear warped surfaces designed to allow the water to pass through the ports with a minimum of deflection and waste of energy due to eddying. Instead of the water being delivered perpendicularly against the seat, it is delivered at a much reduced angle and less energy is lost in changing the direction of flow.

The seat contains a recess at the centre into which the hub of the guard plate fits forming a sort of dash pot. The guard plate does not rest upon the disk when it is seated. The purpose of the fins on the guard plate is to rotate it through the action of the water being squeezed out as the disk rises toward the guard plate upon opening.

The rotation of the guard plate is very small, being not more than one hundredth of an inch per stroke.

The pictures following will show more clearly the construction of this valve. The valve illustrated is not the valve installed but is of the same type and has the same essential features.





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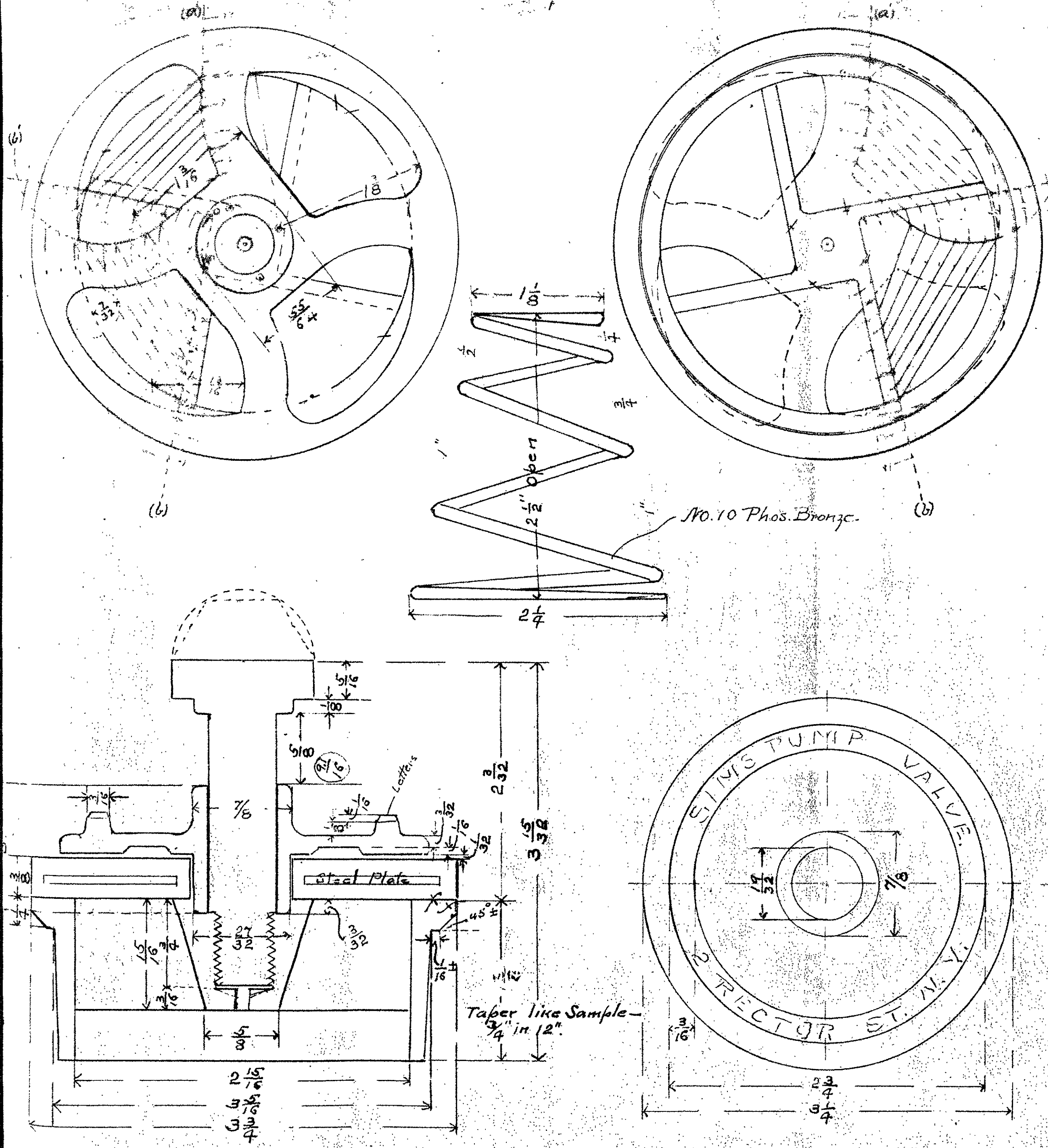
No. A 107.1

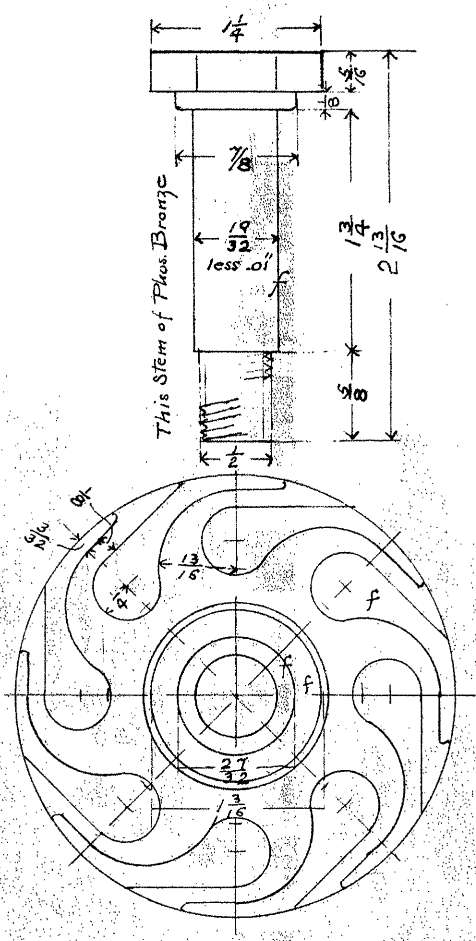
SIMS PUMP VALVE

$3\frac{3}{4}-2\frac{15}{16} \times 1\frac{3}{8}-\frac{15}{16}$

FOR WARREN DUPLEX No. 14344
SIZE $16 \times 10\frac{1}{2} \times 12$

April 1920.





COMPARISON OF THE VALVES

Comparison of Warren and Sims Pump Valves used in tests made on Warren 16 x 10½ x 12 Duplex No. 19344 at Mass. Inst. of Technology by Messers. Carroll and Alexander - 1920.

(Piston speed of Pump 60 ft. a minute - rated capacity)

	Warren	Sims
Port Area top of Ribs - minimum	3.906 □"	5.234 □"
" " bottom of Ribs	6.021	5.826
" " drum at bottom of Ribs	6.780	6.780
" " at bottom of drum	7.150	6.780
Piston Area	82.62	82.62
Total minimum port area - for 24 Valves	93.75	125.61
Excess minimum port area over piston area	13½%	52%
Relative vertical velocity of fluid against disc	134. to	100.
Angle of impinging current against disc	90°	30° to 40° +

METHOD OF TESTING.

(a) Capacity and Efficiency.

Test runs were made in accordance with the A.S.M.E. test code for pumping engines.

In order to get a number of points from which to plot the efficiencies and capacities, tests were made under varying discharge heads and at various speeds with each set of valves. The completed curves give us an excellent means of comparing the performance of the pump with the two types of valves installed. Nine runs were made with each type of valve. The duration of each run was thirty minutes. The pump was run at the desired pressure or speed until successive readings of the condensate checked denoting that the pump was running smoothly. Then the thirty minute run was made.

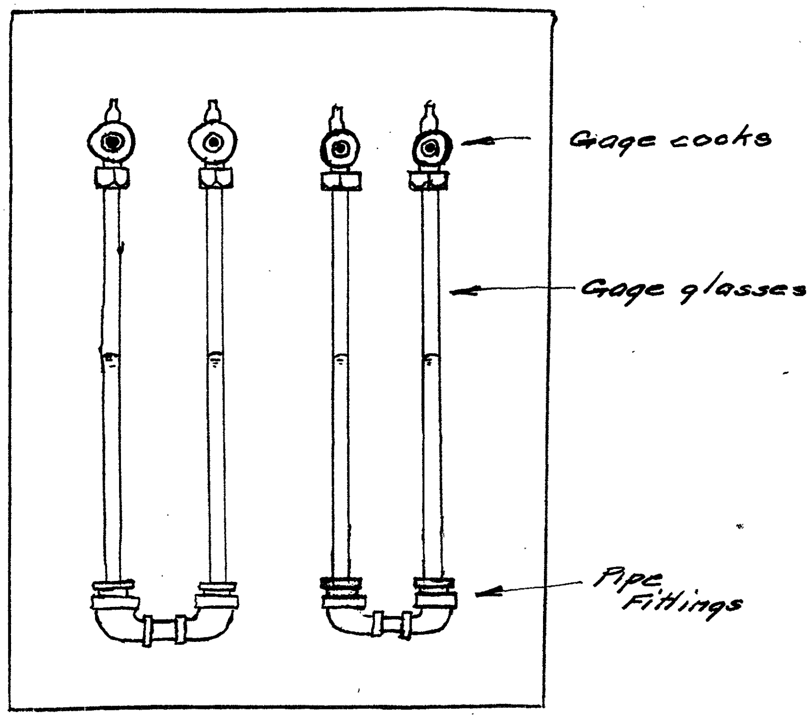
The data was recorded at five-minute intervals. Condensate was weighed in weighing tanks and the water discharge was measured by means of calibrated tanks.

The water end of the pump was fitted with indicator cocks and indicator cards for the water end were taken during the test. The cards were used to show the water work and the behavior of the water in the cylinder.

The water horse power as obtained from the cards was used as a check on the water horse power as computed from the data.

(b) <u>Measurement of Losses through the Valves.</u>

It was planned to find the losses through the valves by measuring the pressures on both sides of the suction and discharge valves. The apparatus for doing this was arranged as shown in the sketch below.



Differential Gauges for Measuring Pressure differences thru valves

It was made up of two differential gauges, one for the section valves and the other for the discharge valves. The gauges were made from gauge glasses, pipe fittings and gauge glass cocks as noted on the sketch. They were mounted on a drawing board on the side of the pump.

It was planned to use this on one end of one side of the pump only. The arrangement of the gauges was as follows:

one leg of the suction gauge was connected to the pump on the piston side of the suction valves by means of brass tubing. The other leg of the gauge was connected in the same manner to the pump on the suction side of the suction valves. A ball check valve was placed in each line to prevent the fluctuation of the water columns in the gauge glasses when the pump reversed. The liquid used in the glasses was carbontetrachloride (specific gravity 1.6), colored with cylinder oil.

In the same manner one leg of the discharge gauge was connected into the pump on the piston side of the valves and the other into the discharge chamber.

The first attempts to measure the difference in pressures in these gauges failed as the liquid columns were blown out of sight. This was at first thought to be due to the fact that the lines to the gauges were not full of water, and they were therefore primed. It was found, however, that even after priming the gauges would not record anything which might be considered a difference in pressure and the heights of the columns fluctuated so much it was impossible to measure them. It was decided that the trouble was due to the inability of the apparatus to transmit the pressure without transmitting the numerous impulses and shocks due to the reversing of the pump and the closing of the valves. The problem of designing an apparatus that would absorb the impulses and still transmit and measure the pressures was finally given up as the time remaining was too short to permit of further experimentation.

It was then hoped that the difference in pressure through the valves might be determined from the indicator cards taken from the water cylinders. This was to be done as follows: The discharge pressure as recorded by the discharge gauge at the time the card was taken was plotted to scale above the atmospheric line on the card and the suction pressure (computed) was plotted to scale below the atmospheric line. The distance between the lines plotted for the discharge pressure and the discharge pressure line as drawn by the indicator pencil represents the loss through the valves. In the same way, the distance between the suction line plotted and the line drawn by the indicator is the loss through the suction valve.

Sample cards are shown in the Appendix.

The only indicators available for use on the water end, however, were steam indicators and it was found that the action of these was most inaccurate and irregular. This was due to the fact that the water would not recede from beneath the indicator piston on the suction stroke quickly enough to allow the piston to really draw the suction pressure. Also, due to the number of impulses caused by the opening and closing of the valve the cards drawn by the indicator were very poor and cannot be considered in the calculation of the test.

Two hydraulic indicators were then obtained. These were equipped, however, with springs intended to measure pressures from 500 to 2000 pounds per square inch. Steam indicator springs were then tried. The scale of the spring was determined from the ratio between the area of the steam piston and water piston. The smaller scale spring to be obtained in the laboratory (10 lbs.) gave a card only a quarter of an inch in height representing a pressure of 80 pounds per square inch. It was evident at once that it would be useless to attempt to measure a difference in pressure of but a few pounds in this way.

The measurement of the difference in pressures through the valve was then given up for the time being.

(c) Velocities through the Valves.

The velocities through the valves were determined from the area of valve openings and the quantity discharged. The area of valve opening per valve was obtained by plotting the area and measuring it with a planimeter.

DATA.

Constants for Pump.

Diameter of steam cylinder 16".

Diameter of water cylinder $10\frac{1}{2}$".

Distance from the floor to the centre line of the pump cylinder $19\frac{1}{2}$".

Distance from the centre line of the pump cylinder to the centre of the discharge gauge 4' 8".

DATA - TEST #1

TIME: 30 min.

STEAM.

Entrance Pressure	Ent. Temp.	Exhaust Pres.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S. H.E.	M.E.P. L.H.S. P.E.
30.5	157	0	21.1	24.5	21.2	12.0
24.5	158		21.7	25.4	22.4	12.2
34.5	159		21.6	24.8	21.6	12.1
34.5	159		21.8	24.3	23.6	11.5
35.0	158.5		21.1	23.4	22.8	12.5
35.0	159		21.0	22.8	22.8	12.1
35.0	159			26.4	23.2	11.7
Av. 34.8	158.5	0	21.4	24.7	22.5	12.0

Discharge Pres. Water	Stroke R.H.S.	L.H.S.	Strokes Per ½ min.	Dist. from Surface Water to Floor
45.0	12.5"	12.0"	22	4'
44.5	12.5"	12.0"	22	3' 11½"
44.5			23	4'
45.5				
45.0				
45.0				
Av. 44.9	12.5	12.0	22.6	47.8"

Barometer 30.07" Hg.
Temperature of Steam Thermometer 96° Far.
No. Degrees Exposed 130 Cent. degrees.
Steam Springs 20 lbs. Water Springs 40 lbs.
Average condensate 5 min. 138.5 lbs.
Rise in the tanks 34.7"

DATA - TEST #2.

TIME: 30 Min.

STEAM:

Entrance Pressure	Ent. Temp.	Exhaust Pres.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S. H.E.	M.E.P. L.H.S. P.E.
39.0	164.5	0	22.7	32.2	27.6	14.3
38.5	164.5	0	22.4	31.8	28.0	14.7
38.0	165.0	0	22.6	31.2	26.9	14.2
38.0	165.0	0	22.4	31.3	25.6	14.8
38.0	165.0	0	22.4	31.8	26.0	14.4
38.0	165.0	0	22.4	31.8	27.7	14.2
38.0	165.0	0	22.6	31.8	26.4	14.7
Av.38.0	165.0	0	22.5	31.7	26.8	14.5

Discharge Pres. Water	Stroke R.H.S.	L.H.S.	Strokes Per ½ min.	Dist, from Surface Water to Floor
56.0	12.5	12.25	20	46½"
55.5	12.5	12.25	20	43½"
55.0	12.5	12.25	21	25 "
55.0	12.5	12.25	20	
55.0	12.5	12.25	20	
55.0	12.5	12.25	20	
Av. 55.2	12.5	12.25	20	45 "

Barometer 30.07" Hg.
Temperature Steam Thermometer 95° Far.
No. degrees exposed 135 Centigrade degrees.
Steam Springs 20 lbs.
Water Springs 60 lbs.
Av. condensate 5 min. 137# Rise in the tanks 22.29"

DATA - TEST #3.

TIME: 30 Min.

STEAM:

Entrance Pressure	Ent. Temp.	Exhaust Prés.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S. H.E.	M.E.P. L.H.S. P.E.
45.0	165.0	0	25.2	31.3	29.2	16.0
45.0	165.0	0	25.0	33.6	29.6	16.3
45.0	166.0	0	25.2	32.6	30.0	16.0
44.5	167.0	0	24.3	33.6	29.3	16.6
44.5	167.0	0	24.9	33.1	29.3	16.1
45.0	167.0	0	25.4	32.8	31.7	15.8
45.0	167.0	0	25.0	33.8	28.0	16.5
Av.44.9	166.3	0	25.0	33.0	29.6	16.2

Discharge Pres. Water	Stroke R.H.S.	L.H.S.	Strokes per ½ min.	Dist. from surface water to floor
72.5	12.5	12.25	18	48"
72.5	12.5	12.25	19	47¾"
72.0	12.5	12.25	18	48 "
71.5	12.5	12.25	18	48 "
71.5	12.5	12.25	18	47 "
71.5	12.5	12.25	18	
72.0	12.5	12.25	18	
Av.71.7	12.5	12.25	18.1	47.9"

Barometer 30.10"Hg.
Temperature Steam Thermometer 89° Far.
No. degrees exposed 137 Centigrade degrees.
Steam Springs 20 lbs. Water Springs 80 lbs.
Average condensate 5 min. 124 lbs. Rise in Tanks 22.89 feet.

DATA - TEST #4.

TIME: 30 Min.

STEAM:

Entrance Pressure	Ent. Temp.	Exhaust Pres.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S. H.E.	M.E.P. L.H.S. P.E.
50.0	165	0	28.7	44.0	40.2	37.8
50.0	165	0	28.7	42.0	40.2	38.0
50.0	165	0	30.1	44.0	39.6	38.6
50.5	165	0	29.1	44.0	41.7	38.5
50.5	165	0	29.4	44.0	39.2	38.4
50.0	165	0	28.9	42.2	39.2	38.4
50.0	165	0	28.7	44.3	40.4	38.4
Av. 50.1	165	0	29.1	43.5	40.1	38.3

Discharge Pres. Water	Stroke R.H.S.	L.H.S.	Strokes per ½ min.	Dist. from surface water to floor
89	12.25	12.0	11	47"
89	12.25	12.0	11	47"
88.5	12.25	12.0	11	47"
89.0	12.25	12.0	11	47"
89.0	12.25	12.0	11	46"
89.0	12.25	12.0	11	47"
89.0	12.25	12.0	11	47"
Av. 89.0	12.25	12.0	11	46.5"

Barometer 30.10" Hg.
Temperature Steam Thermometer 97° Far.
No. degrees exposed 136 Centigrade degrees.
Steam Springs 40 lbs. Water Springs 80 lbs.
Average condensate 5 min. 103 lbs. Rise in Tanks 13.4 feet.

DATA - TEST #5.

TIME: 30 Min.

STEAM:

Entrance Pressure	Ent. Temp.	Exhaust Pres.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S. H.E.	M.E.P. L.H.S. P.E.
59.5	167	0	35.0	51.4	41.8	45.5
59.5	167	0	35.3	51.4	42.8	45.7
59.5	167	0	34.4	51.4	43.5	46.1
59.5	167	0	34.4	51.4	43.1	46.5
59.5	167	0	36.0	52.0	42.9	46.6
59.5	167	0	35.6	51.0	41.7	45.7
59.5	167	0	34.8	51.4	42.8	46.1
Av. 59.5	167	0	35.1	51.4	42.7	46.0

Discharge Pres. Water	Stroke R.H.S.	L.H.S.	Strokes per ¼ min.	Dist. from surface water to floor
103.0	12.25	12.0	12	44½"
102.0	12.25	12.0	12.5	45¼"
102.5	12.25	12.0	13.0	46"
102.5	12.25	12.0	13.0	47"
102.0	12.25	12.0	12.0	
102.0	12.25	12.0		
102.0	12.25	12.0		
Av. 102.5	12.25	12.0	12.5	46.3

Barometer 30.1 **Hg.**
Temperature Steam Thermometer 112° Far.
No. degrees exposed 137 **Centigrade degrees.**
Steam Springs 40 **lbs. Water Springs** 100 **lbs.**
Average condensate 5 min. 106 **lbs. Rise in Tanks** 14.9 **feet.**

DATA - TEST #6

TIME: 30 min.

STEAM.

Entrance Pressure	Ent. Temp.	Exhaust Pres.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S H.E.	M.E.P. L.H.S P.E.
74	169	0	36.4	65.4	51.5	60
74	169	0	35.6	64.8	52.1	57.75
74	169	0	36.6	64.4	52.	59.5
74	169	0	36.6	63.9	52.9	57.8
74	169	0	36.6	63.9	51.4	58.7
74	169	0	36.6	66.5	52.	59.7
74	169	0	36.6	64.	51.9	59.5
Av. 74	169	0	36.4	64.7	52.	59

Discharge Pres. Water	Stroke R. H. S.	L.H.S.	Strokes per ½ min.	Dist. from Surface Water to floor
122.5	12.25	11.5	13.5	50½"
120.	12.25	11.5	13.5	51¼"
119.5	12.25	11.5	13.5	51¾"
119.	12.25	11.5	13.5	51¼"
119	12.25	11.5	13.5	
120	12.25	11.5	13.5	
119	12.25	11.5	13.5	
Av. 119.8	12.25	11.5	13.5	51¼"

Barometer 30.1 Hg.
Temperature of Steam Thermometer 110° Far.
No. degrees exposed 139 Centigrade degrees.
Steam Springs 60 lbs. Water Springs 100 lbs.
Average condensate 5 min. 154 lbs.
Rise in tanks 15.73 feet.

DATA - TEST #7.

TIME: 30 min.

STEAM.

Entrance Pressure	Ent. Temp.	Exhaust Pres.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S H.E.	M.E.P. L.H.S P.E.
68	169	0	29.4	59.1	51.4	42.1
68	169	0	29.8	59.0	51.3	40.6
68	169	0	29.8	59.0	51.3	41.5
68	169	0	29.3	61.2	51.8	41.5
68	169	0	29.3	59.8	51.5	42.3
68	169	0	29.2	59.8	51.3	41.5
68	169	0	28.9	60.0	51.2	41.8
Av. 68	169	0	29.3	59.7	51.4	41.8

Discharge Pres. Water	Stroke R. H. S.	L.H.S.	Strokes per ½ min.	Dist. from Surface Water to floor
100	12	11.5	15.5	50½"
100	12	11.5	15	51.
99.5	11.75	11.5	15	51½
100	11.75	11.5	15.5	51¾
100	11.75	11.5	15.5	51½
100	11.75	11.5	15.	
100	11.75	11.5	15	
Av. 100	11.75	11.5	15.2	51.5"

Barometer 30.1
Temperature of Steam Thermometer 108°Far.
No. degrees exposed 127 Centigrade degrees.
Steam Springs 60 lbs. Water Springs 60 lbs.
Average condensate 5 min. 82.8lbs.
Rise in tanks 13.35feet.

DATA - TEST #8

TIME: 30 min.

STEAM.

Entrance Pressure	Ent. Temp.	Exhaust Pres.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S H.E.	M.E.P. L.H.S P.E.
65	174	0	16.2	48.7	21.6	40.5
65	174	0	16.5	48.3	20.9	41.
65	174	0	17.2	48.3	21.8	40.6
65	174	0	16.4	49.4	21.2	41.1
65	174	0	16.6	49.2	20.5	38.8
65	174	0	17.2	48.6	21.2	40.7
65	174	0	17.5	48.6	21.4	40.5
Av. 65	174	0	16.8	48.7	21.2	40.5

Discharge Pres.	Stroke R.H.S.	L. H. S.	Strokes per ½ min.	Dist. from Surface Water from Floor
67	11½	11¼	23.5	45.5
59	11.5	11.25	23.5	47
62	11.5	11.25	24.0	47.5
62.5	11.5	11.25	24.0	48
62.5	11.5	11.25	24.5	49
62.5	11.5	11.25	24.5	
63.	11.5	11.25	24.5	
Av. 62.1	11.5	11.25	24.5	47.2

Barometer 30.1 Hg.
Temperature of Steam Thermometer 108°Far.
No. degrees exposed 144 Centigrade degrees
Steam springs 60 lbs. Water springs 60 lbs.
Average condensate 5 min. 206.3 lbs.
Rise in tanks 27.95 feet.

DATA - TEST #9.

TIME: 30 min.

STEAM.

Entrance Pressure	Ent. Temp.	Exhaust Pres.	M.E.P. R.H.S. H.E.	M.E.P. R.H.S. P.E.	M.E.P. L.H.S H.E.	M.E.P. L.H.S P.E.
37.5	157	0	17.35	31.45	24.0	23.3
37.5	157	0	18.0	31.2	24.2	23.7
37.5	157	0	18.0	31.4	24.4	23.6
38.0	157	0	17.5	31.0	24.7	22.8
37.5	157	0	17.4	31.4	25.5	23.0
37.5	157	0	18.1	31.8	25.0	23.3
38.0	157	0	18.3	31.6	25.0	23.2
Av. 37.7	157	0	17.8	31.4	24.7	23.3

Discharge Pres.	Stroke R.H.S.	L. H. S.	Strokes per ¼ min.	Dist. from Surface Water from Floor
60	12	11.5	12.5	45"
60.0	12	11.5	12.0	45"
60.0	12	11.5	12.0	44½"
59.5	12	11.5	12.5	44½"
59.0	12	11.5	12.5	44½"
59.5	12	11.5	12.5	
59.0	12	11.5	12.0	
Av. 59.5	12	11.5	12.3	44¾"

Barometer 30.1"Hg.
Temperature of Steam Thermometer 108° Far.
No. degrees exposed 127 Centigrade degrees
Steam springs 60 lbs. Water springs 60 lbs.
Average condensate 5 min. 82.8 lbs.
Rise in tanks 13.4 feet.

RESULTS

STRAIGHT PORTED VALVES

RESULTS

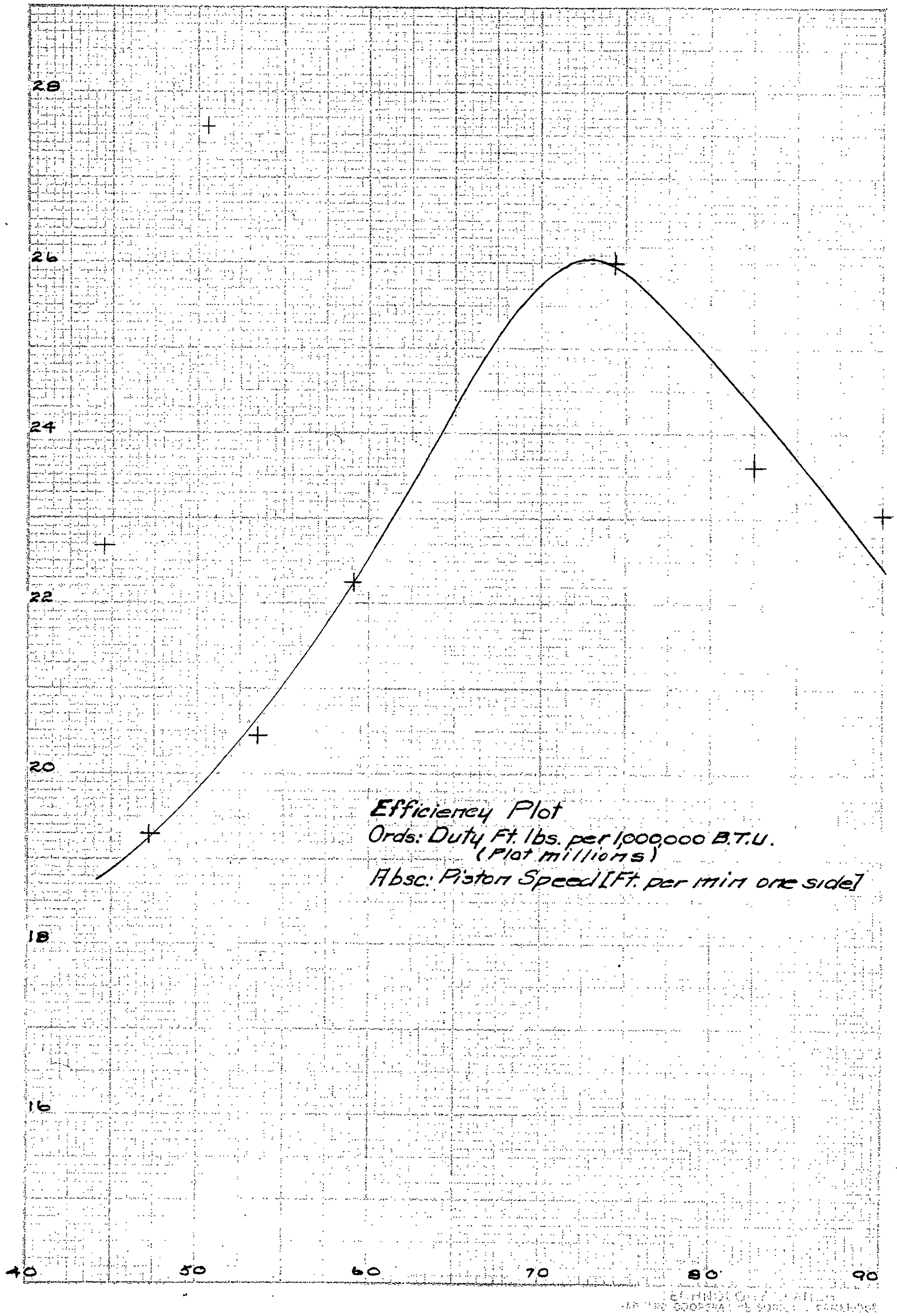
Test No.	1	2	3
Strokes per min.	44	40	36
Piston speed Feet per min.	180	165	148.6
Discharge head (ft.)	114.1	137.0	175.3
Discharge (cu. ft. per min.)	91.	76.6	60.
Gals. per min.	680	573	450
Gals, per hr.	40800	34308	27000
Gals. per 24 hrs.	980000	825000	649000
Water H.P.	19.7	20.0	19.9
Steam I.H.P.	22.1	23.9	22.2
Lbs. Steam per hr.	1660	1645	1490
Lbs. Steam per I.H.P. per hour	75.0	69.0	67.2
B.T.U's per I.H.P./ hr.	76600	70200	68500
B.T.U's per lb. Steam	1012.5	1018.7	1018.2
Piston displacement (cu. ft. per min.)	108.5	97.4	87.5
Percent Slip	16.2	21.3	31.4
Mechanical efficiency	89.0	83.5	89.9
Duty (ft. lbs. per 1,000,000 B.T.U.)	23050000	23600000	26000000
Velocity through valves	7.04	5.91	4.65

RESULTS

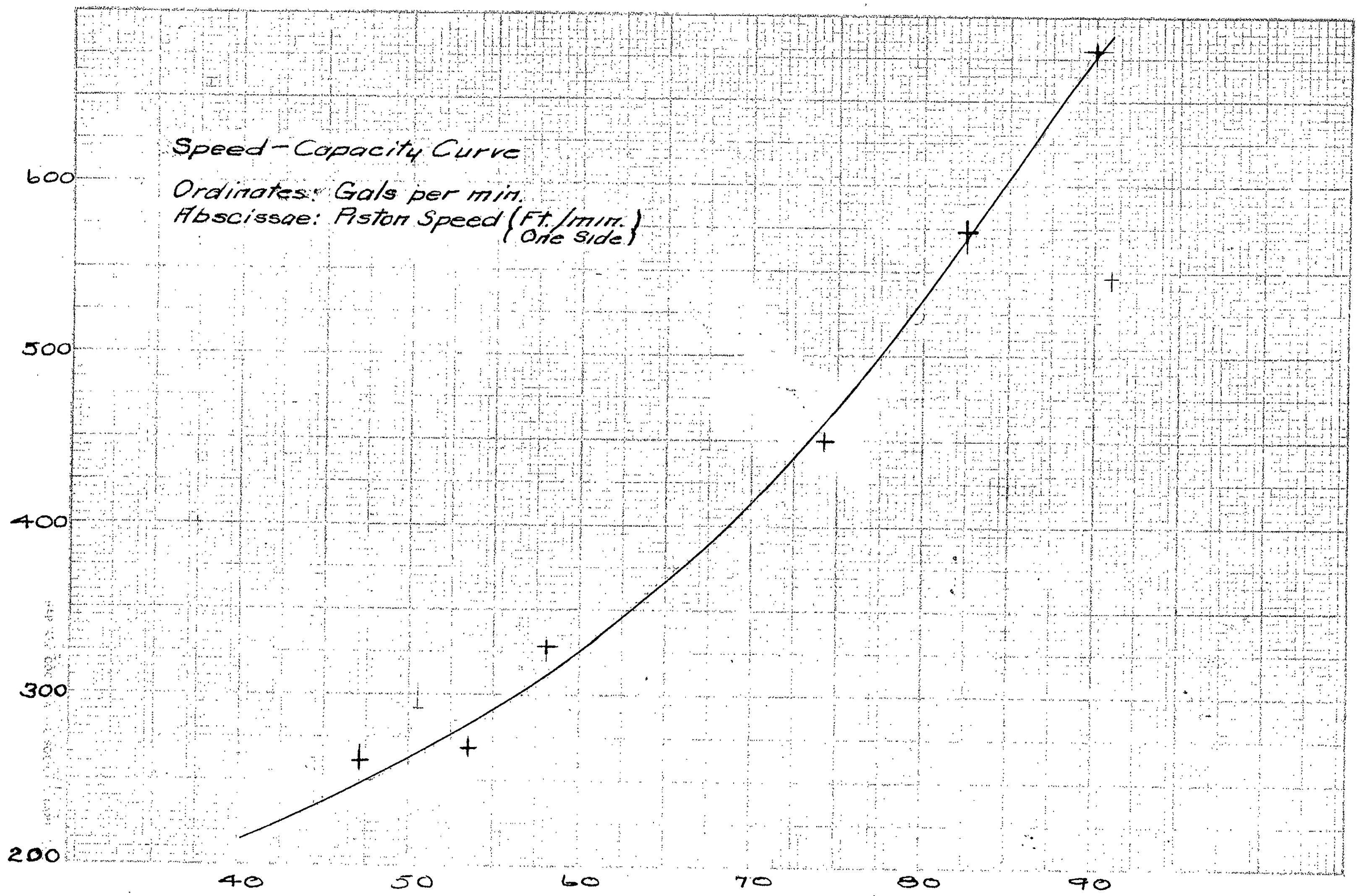
Test No.	4	5	6
Strokes per min.	22	25	27
Piston speed } Feet per min. }	89.0	101	107
Discharge head (ft.)	214.7	244.2	284.6
Discharge (cu. ft. per min.)	35.2	39.0	35.9
Gals. per min.	263	292	269
Gals. per hr.	15800	17500	16160
Gals. per 24 hrs.	378000	420000	388000
Water H.P.	14.4	18.1	19.4
Steam I.H.P.	20.2	26.7	25.2
Lbs. Steam per hr.	1236	1280	1850
Lbs. Steam per I.H.P. per hour	61.0	47.9	73.5
B.T.U's per I.H.P./ hr.	62000	48600	74500
B.T.U's per lb. Steam	1018.2	1014.7	1016.3
Piston displacement (cu. ft. per min.)	52.3	59.6	63.0
Percent Slip	32.7	34.5	43
Mechanical efficiency	71.0	67.8	77
Duty (ft. lbs. per 1,000,000 B.T.U.)	22590000	27590000	20440000
Velocity through valves	2.74	3.02	2.78

RESULTS

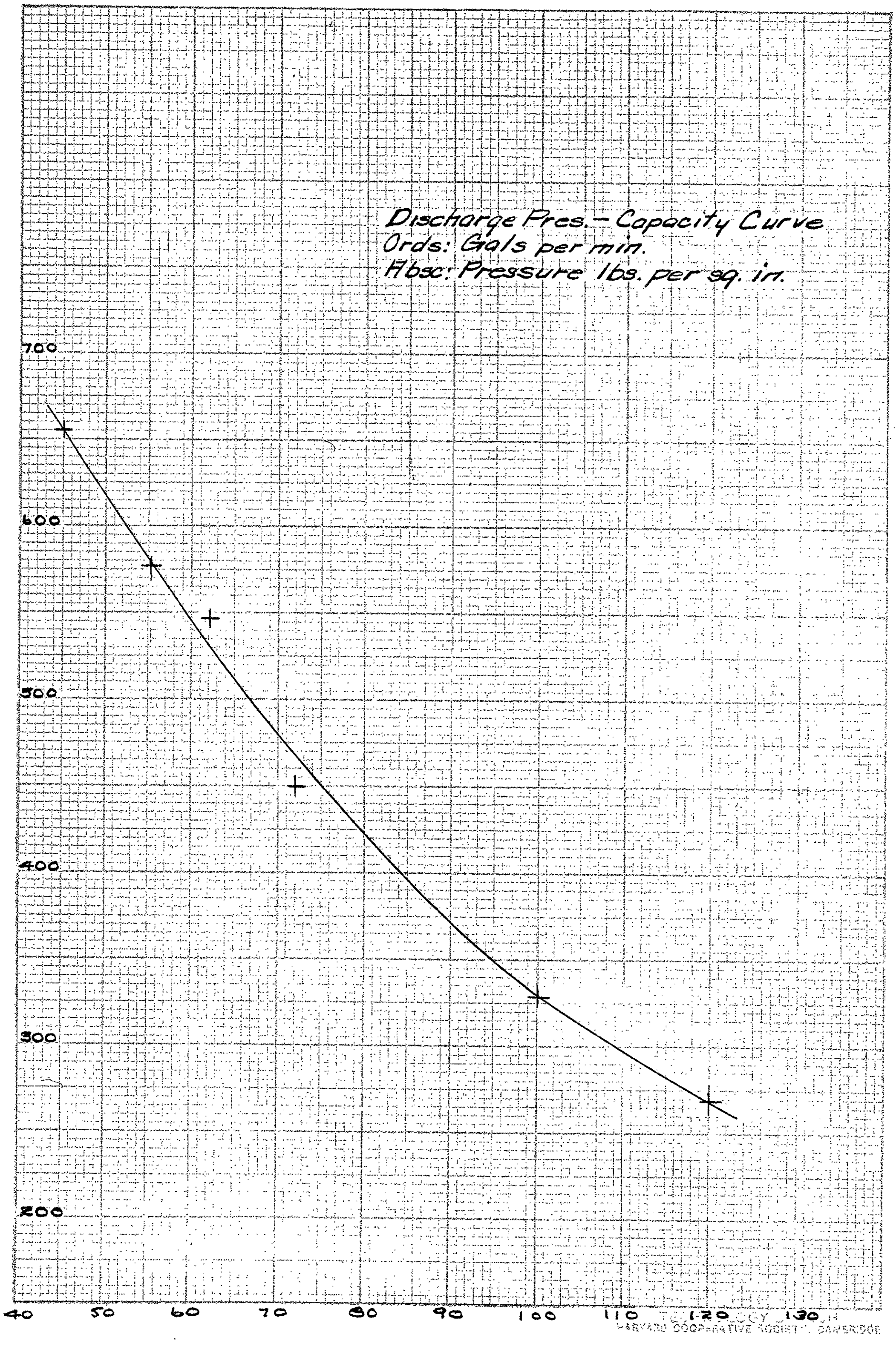
Test No.	7	8	9
Strokes per min.	30	48	24.5
Piston speed } Feet per min. }	116.2	182	94.4
Discharge head (ft.)	240.6	153.3	147
Discharge (cu. ft. per min.)	43.8	73.2	35
Gals. per min.	328	547	262
Gals, per hr.	19700	32800	15700
Gals. per 24 hrs.	472200	786000	377000
Water H.P.	20.4	21.3	9.76
Steam I.H.P.	32.0	34.8	14.1
Lbs. Steam per hr.	1785	2480	995
Lbs. Steam per I.H.P. per hour	55.7	71	70.7
B.T.U's per I.H.P./ hr.	50600	72400	71700
B.T.U's per lb. Steam	1015.6	1018.5	1010.8
Piston displacement (cu. ft. per min.)	68.4	107	56.5
Percent Slip	35.9	31.6	38
Mechanical efficiency	63.5	61.1	69.3
Duty (ft. lbs. per 1,000,000 B.T.U.)	22250000	16800000	19300000
Velocity through valves	3.14	5.68	2.72



Efficiency Plot
Ords: Duty Ft. lbs. per 1,000,000 B.T.U. (Plot millions)
Absc: Piston Speed [Ft. per min one side]
28
26
24
22
20
18
16
40
50
60
70
80
90



Speed-Capacity Curve
Ordinates: Gals per min.
Abscissae: Piston Speed (Ft./min.) (One Side)
600
500
400
300
200
40
50
60
70
80
90



Discharge Pres.—Capacity Curve
Ords: Gals per min.
Absc: Pressure lbs. per sq. in.
700
600
500
400
300
200
40
50
60
70
80
90
100
110
120
130

CONCLUSION.

It is impossible at this time to arrive at any conclusion in regard to the relative capacity and efficiency of the two types of valves owing to the fact that because of labor difficulties the inclined port valves which were made to order did not arrive in time for testing.

At the suggestion of Prof. Miller, this thesis is being submitted with the results of the tests on the straight ported valves only.

As soon as the inclined ported valves arrive, which should be within a day or so, they will be tested and the results, data and conclusions with regard to the relative merits of the two types of valves will be submitted as an Appendix to this thesis.

The present discussion, therefore, will be limited to the results of the tests on the straight ported valves.

DISCUSSION OF RESULTS

The action of the pump and auxiliaries during the tests was not satisfactory. The results show considerable variation and irregularity in performance, and failed in any of the tests to deliver the rated capacity. The best run made at rated speed showed a capacity of about two thirds the rating. This may be accounted for perhaps by the presence of several strips of wood in the suction chamber. These were discovered when the suction valves were removed for the purpose of installing the new ones. The actual effect this wood had on the capacity and efficiency of the pump cannot be determined, but in the opinion of the writers there was a sufficient number of the pieces if placed in contact with the valve ports to cut out at least one third of the effective area. It is also probable that there was more foreign matter in the chamber than was removed which receded down the suction pipe when the pump stopped, and it is believed that this trapped in the suction pipe injured the action of the pump to varying extents according to the amount which lodged against the valve ports.

Another reason for the poor performance shown may be the inefficiency of the condensor. This condensor was the large Worthington condenser in the basement of the Steam Laboratory. The action of the condenser pump was very poor; the strokes in the two sides were unequal and all attempts to remedy this difficulty failed. Great difficulty was experienced in getting a uniform flow of condensate, and much time was lost in waiting for conditions to become stable before making a run.

The pump tests on the whole are not satisfactory and it would not be fair to compare the straight ported valves with the inclined ported valves on the basis of these tests.

The cards of which there is shown a sample set in the Appendix are all of pretty good shape. The steam cards are very uniform with the exception of the left side cards. The pump end of the left hand side steam end did not at any time do its share of the pump work. It is probable that one of the pieces of wood found in the suction chamber was holding open one or more valves. The valve chambers were opened on two occasions during the test to see if anything was under the valve seat. Nothing was found as the foreign substance would drop away as soon as the pump stopped.

The water cards shown are better than most of those obtained during the tests. It was almost impossible to get two successive cards that looked alike, and if the pencil was allowed to run over the card twice two results were obtained. The discharge pressure plotted to scale is shown on two cards, but the writers hesitate to call the area above this line the energy lost through the valves.

APPENDIX.

CALCULATIONS

(1)

Strokes per minute.

22 x 2 = 44

(2) Discharge head in feet

Suction head $\frac{47.8 + 19.5}{12} = 5.63'$

Distance centre line of the cylinder
to centre line discharge gauge = 4.67'

Discharge pressure to ft.

44.9 x 2.31 = 103.8

114.1'

(3) Cubic feet of water per min. from tanks

34.7 x 78.5 = 2730 cu. ft. / 30 min.

$\frac{2730}{30}$ = 91. cu. ft./min.

gal./min. 91 x 7.48, = 680

gal/hour 680 x 60 = 40300 gal/hour

gal/24 hrs. 40800 x 24 = 980000 gal./24 hours

(4) Water Horse Power

$$H.P. = \frac{\text{cu.ft./min.} \times 62\tfrac{1}{2} \times \text{head}}{33{,}000} = \frac{91 \times 62\tfrac{1}{2} \times 114.1}{33{,}000}$$

H,P. = 19.7

(5) I.H.P.

$$\text{R.H.S.H.E.} \quad \frac{12.5 \times 45.2 \times 21.38 \times 201}{12 \times 33{,}000} = 6.1 \text{ H.P.}$$

$$\text{R.H.S.P.E.} \quad \frac{12.5 \times 45.2 \times 24.7 \times 197.9}{12 \times 33{,}000} = 6.8 \text{ H.P.}$$

$$\text{L.H.S.H.E} \quad \frac{12 \times 45.2 \times 22.5 \times 201}{12 \times 33{,}000} = 3.17 \text{ H.P.}$$

L.H.S.P.E. $\frac{45.2 \times 12 \times 197.9}{33,000}$ = 6.03

TOTAL I.H.P. 22.10

(6) Lbs.of steam per hour

138.5 x 12 = 1660 lbs.

(7) Lbs. of steam per I.H.P./hr.

$\frac{1660}{22.10}$ = 75.0 lbs.

(8) B.T.U's per lb. of steam

P' = 34.8 + 15.1 = 49.9

T' = 320° F. T = 281° F. °s superheat = 39°

P'' = 15.1 lbs. q'' = 181.3 H' = 1193.8

B.T.Us/ lb. of steam = H' - q''

= 1193.8 - 181.3 = 1012.5 BTU

(9) B.T.U's per indicated H.P. per hr.

1012.5 x 75 = 76600 B.T.Us per indicated H.P. per hr.

(10) Cu. ft. piston displacement per min.

Volume of cylinder x length of stroke = piston displac.

R.H.S.H.E. $\frac{83.4 \times 12.5}{1728}$ = .604

R.H.S.P.E. $\frac{86.5 \times 12.5}{1728}$ = .625

L.H.S.H.E. $\frac{83.4 \times 12}{1728}$ = .578

L.H.S.C.E. $\frac{86.5 \times 12}{1728}$ = .60

2.40

45.2 x 2.40 = 108.5 cu.ft.

(11) % Slip

$$\frac{108.3 - 91}{108.5} = \frac{17.5}{108.5} = 16.2\%$$

(12) Mechanical efficiency

$$\frac{19.7}{22.1} = 89.4\%$$

(13) Duty

$$\frac{62.5 \times 91 \times 114.1 \times 60 \times 1{,}000{,}000}{1660 \times 1012.5} = 23{,}050{,}000$$

(14) Velocity through the valves

12 valves always open.

12 x area per valve = total area

velocity = the quantity divided by the area

$$V = \frac{91 \times 144}{12 \times 3.90 \times 60} = 4.67 \text{ ft. per sec.}$$

TEST #2

(1) $20 \times 2 = 40$

(2) $\frac{45 + 19.5}{12} + 4.67 + 127.0 = 137.04$

(3) $29.3 \times 78.5 = 2300$

$\frac{2300}{30} = 76.6$

Gals.per min. $76.6 \times 7.48 = 5,730$

Gals.per hr. $5730 \times 60 = 34.380$

"/ 24 hrs. $34380 \times 24 = 825,000$

(4) H.P. = $\frac{76.6 \times 62.5 \times 137.04}{33,000} = 20$

(5) R.H.S.H.E. $\frac{12.5 \times 40 \times 22.5 \times 201}{12 \times 33,000} = 5.7$

R.H.S?C.E. $\frac{12.5 \times 40 \times 31.7 \times 197.9}{12 \times 33,000} = 7.92$

L.H.S.H.E. $\frac{12.25 \times 40 \times 26.8 \times 201}{12 \times 33,000} = 6.7$

L.H.S.P.E. $\frac{12.25 \times 40 \times 14.45 \times 197.9}{12 \times 33,000} = 3.54$

Total = 23.86

(6) $137 \times 12 = 1645$

(7) $\frac{1645}{23.9} = 69.0$

(8) P' = 52.8 lbs.

T'= 166.4° C. 331.5° F.

T = 284.4° F. °s = 47.1

H' = 1199 q'' = 180.3

H' - q'' = 1018.7 B.T.U.

(9) 1018.7 x 69 = 70,200

(10) R.H.S.H.E. $\frac{83.4 \times 12.5}{1728} = .604$

R.H.S.C.E. $\frac{86.5 \times 12.5}{1728} = .625$

L.H.S.H.E. $\frac{83.4 \times 12.25}{1728} = .591$

L.H.S.C.E. $\frac{86.5 \times 12.25}{1728} = .614$

2.43

40 x 2.43 = 97.4 cu. ft.

(11) $\frac{97.4 - 76.6}{97.4} = 21.3$

(12) $\frac{20}{23.9} = 83.5\%$

(13) $\frac{62.5 \times 36.6 \times 137.0 \times 60 \times 1,000,000}{1645 \times 1018.7} = 23,600,000$

(14) .0514 x 76.6 = 3.93 ft.

TEST #3

(1) $18 \times 2 = 36$

(2) $\frac{47.9 + 19.5}{12} + 4.67 + 165 = 175.3$ ft.

(3) $22.9 \times 78.5 = 1800$ cu.ft.

($\frac{1800}{30} = 60$

Gals. per min. $= 60 \times 7.48 = 450$

" per hr. $= 450 \times 60 = 27000$

" " 24 hrs. $= 27000 \times 24 = 649000$

(4) $\frac{60 \times 62.5 \times 175.3}{33,000} = 20$ H.P.

(5) I.H.P.

R.H.S.H.E. $\frac{12.5 \times 36 \times 201 \times 25}{12 \times 33,000} = 5.7$

R.H.S.C.E. $\frac{12.5 \times 36 \times 33 \times 198}{12 \times 33,000} = 7.43$

L.H.S.H.E. $\frac{12.25 \times 36 \times 29.6 \times 201}{12 \times 33,000}$ 5.5

L.H.S.C.E. $\frac{12.25 \times 36 \times 16.2 \times 198}{12 \times 33,000} = 3.56$

22.19

(6) $124 \times 12 = 1490$ lbs.per hr.

(7) $\frac{1490}{22.2} = 67.2$ lbs. per I.H.P./hr.

(8) B.T.U.s / lb. of steam.

$H' = 1198.5$

$q'' = 180.3$

$H' - q'' = 1018.2$

(9) $1018.2 \times 67.2 = 68500$ B.T.Us per I.H.P./hr.

(10) R.H.S.H.E. $\frac{83.4 \times 12.5}{1728} = .604$

R.H.S.C.E. $\frac{86.5 \times 12.5}{1728} = .625$

L.H.S. H.E. $\frac{83.4 \times 12.25}{1728} = .591$

L.H.S.C.E. $\frac{86.5 \times 12.25}{1728} = .614$

2.43

$36 \times 2.43 = 87.5$

(11) $\frac{87.5 - 60}{87.5} = 31.4\%$

(12) $\frac{19.9}{22.2} = 89.8\%$

(13) $\frac{62.5 \times 60 \times 175.3 \times 60 \times 1,000,000}{1490 \times 1018.2} = 26,000,000$

(14) $.0512 \times 60 = 3.08$ ft. per sec.

TEST #4.

(1) $11 \times 2 = 22$

(2) suction head = 5.5

discharge centre line cylinder 4.7

" pressure head 204.5

Total 214.7

(3) $$\frac{13.42 \times 78.5}{1} = 1055 \text{ cu.ft./ 30 min.}$$

$$\frac{1055}{30} = 35.2 \text{ cu.ft./min.}$$

35.2 x 7.48 = 263 gls.per min.

263 x 60 = 15800 gals per hr.

15800 x 24 = 378000 " " 24 hrs.

(4) $$\frac{35.2 \times 62.5 \times 214.7}{33,000} = 14.35 \text{ H.P.}$$

(5) R.H.S.H.E. $$\frac{12.25 \times 22 \times 201 \times 29.1}{12 \times 33,000} = 3.98$$

R.H.S.C.E. $$\frac{12.25 \times 22 \times 198 \times 43.5}{12 \times 33,000} = 5.85$$

L.H.S.H.E. $$\frac{22 \times 201 \times 40.1}{12 \times 33,000} = 5.37$$

L.H.S.C.E. $$\frac{22 \times 198 \times 38.3}{12 \times 33,000} = 5.04$$

Total: 20.24

(6) 103 x 12 = 1236 lbs. per hr.

(7) $$\frac{1236}{20.24} = 61 \text{ lbs. per I.H.P. per hr.}$$

(8) $H' = 1195.06$

$q'' = 180.33$

$H' - q'' = 1014.73$ B.T.Us

(9) $1014.73 \times 61 = 62000$ B.T.U's/H.P./hr.

(10) R.H.S.H.E. $\frac{83.4 \times 12.25}{1728} = .591$

R.H.S,C.E. $\frac{86.5 \times 12.25}{1728} = .614$

L.H.S.H.E. $\frac{83.4 \times 12}{1728} = .580$

L.H.S.C.E. $\frac{86.5 \times 12}{1728} = .600$

$\overline{2.39}$

$22 \times 2.39 = 52.3$ cu.ft. displacement

(11) $\frac{52.3 - 35.2}{52.3} = 32.7\%$

(12) $\frac{14.35}{20.24} = 71\%$

(13) $\frac{62.5 \times 35.2 \quad 60 \times 214.7 \times 1,000,000}{1014.73 \times 1236} = 22,590,000$

(14) $.0512 \times 35.2 = 1.80$ ft. per sec.

TEST #5

(1) $12.5 \times 2 = 25$

(2) $5.49 + 4.67 + 234 = 244.22$

(3) $14.90 \times 78.5 = 1170$ cu.ft.

$\frac{1170}{30} = 39.0$ cu.ft.per min.

$39.7 \times 7.48 = 292$ gals.per min.

$292 \times 60 = 17,500$ " " heur

$17500 \times 24 = 420,000$ gals. per 24 hrs.

(4) $\frac{39 \times 62.5 \times 244.2}{33,000} = 18.1$ H.P.

(5) R.H.S.H.E. $\frac{35.1 \times 12.25 \times 201 \times 25}{12 \times 33,000} = 5.45$

R.H.S.C.E. $\frac{51.42 \times 12.25 \times 197.9 \times 25}{12 \times 33,000} = 7.85$

L.H.S.H.E. $\frac{42.65 \times 12 \times 201 \times 25}{12 \times 33,000} = 6.50$

L.H.S.C.E. $\frac{46.02 \times 12 \times 197.9 \times 25}{12 \times 33,000} = 6.90$

26.7

(6) $106.3 \times 12 = 1280$

(7) $\frac{1280}{26.7} = 47.9$

(8) $H' = 1196.6$ $q'' = 180.3$

$H' - q'' = 1016.3$ B.T.U'S

(9) 1016 x 77.9 = 48,600

(10) R.H.S.H.E. $\frac{83.4 \times 12.25}{1728} = .591$

R.H.S.C.E. $\frac{86.5 \times 12.25}{1728} = .614$

L.H.S.H.E. $\frac{83.4 \times 12}{1728} = .580$

L.H.S.C.E. $\frac{86.5 \times 12}{1728} = .600$

2.39

25 x 2.39 = 59.6 cu.ft.

(11) $\frac{59.6 - 39}{59.6} = 34.5\%$

(12) $\frac{18.1}{26.7} = 67.8\%$

(13) $\frac{62.5 \times 39 \times 244.2 \times 1,000,000 \times 60}{1016.3 \times 1280} = 27,590,000$

(14) .0512 x 39.0 = 2.0 ft./ sec.

TEST #6

(1) $13.5 \times 2 = 27$

(2) $5.90 + 4.67 + 274 = 284.57$

(3) $13.73 \times 78.5 = 1080$ cu.ft.

$\frac{1080}{30} = 35.9$ cu.ft. per min.

$35.9 \times 7.48 = 269$ gals. per min.

$269 \times 60 = 16160$ " " Hour

$16160 \times 24 = 388,000$ gals per 24 hrs.

(4) $\frac{35.9 \times 62\frac{1}{2} \times 284.6}{33,000} = 19.4$ H.P.

(5) $\frac{36.41 \times 12.25 \times 27 \times 201}{12 \times 33,000} = 6.14$

$\frac{64.8 \times 12.25 \times 27 \times 197.9}{12 \times 33,000} = 11.7$

$\frac{51.97 \times 11.5 \times 27 \times 201}{12 \times 33,000} = 8.2$

$\frac{59.0 \times 11.5 \times 27 \times 197.9}{12 \times 33,000} = 9.15$

Total I.H.P. $= 25.19$

(6) $154 \times 12 = 1850$

(7) $\frac{1850}{25.19} = 73.5$ lbs. per I.H.P./hr.

(8) $H' = 1194.7$

$q'' = 180.3$

$H' - q'' = 1014.3$ B.T.U's

(9) $1014.3 \times 73.5 = 74,500$ B.T.U's

(10) $\frac{83.4 \times 12.25}{1728} = .591$

$\frac{86.5 \times 12.25}{1728} \times ' = .614$

$\frac{83.4 \times 11.5}{1728} = .550$

$\frac{86.5 \times 11.5}{1728} = .577$

2.33

$27 \times 2.33 = 63.0$ cu. ft.

(11) $\frac{63.0 - 35.9}{63} = 43\%$

(12) $\frac{19.37}{25.19} = 77\%$

(13) $\frac{62\frac{1}{2} \times 60 \times 35.9 \times 284.6 \times 1,000,000}{1850 \times 1014.3} = 20,440,000$

(14) $.0512 \times 35.9 = 1.84$ ft. per sec.

TEST #7

(1) 15 x 2 = 30

(2) 5.9 + 4.7 + 230 = 240.6

(3) 16.8 x 78.5 = 1315 cu. ft.

$\frac{1315}{30}$ = 43.8

43.8 x 7.48 = 328 gals per min.

328 x 60 = 19700 " " hour

19700 x 24 472200 " " 24 hrs.

(4) H.P. = $\frac{43.8 \times 62.5 \times 240.6}{33,000}$ = 20.4

(5) $\frac{29.35 \times 11.75 \times 30 \times 201}{12 \times 33,000}$ = 5.25

$\frac{59.7 \times 11.75 \times 30 \times 197.9}{12 \times 33,000}$ = 10.55

$\frac{51.4 \times 11.45 \times 30 \times 201}{12 \times 33,000}$ = 9.05

$\frac{41.6 \times 11.5 \times 30 \times 197.9}{12 \times 33,000}$ = 7.17

Total I.H.P 32.02

(6) 148.8 x 12 = 1785 lbs. per hr.

(7) $\frac{1785}{32.02}$ = 55.7 lbs. per I.H.P. per hr.

(8) H' - q'' = 1015.6 B.T.U's per lb.

(9) $1015.6 \times 55.7 = 56600$ B.T.U's per I.H.P. per hr.

(10) $\frac{83.4 \times 11.75}{1728} = .567$

$\frac{86.5 \times 11.75}{1728} = .590$

$\frac{83.4 \times 11.5}{1728} = .550$

$\frac{86.5 \times 11.5}{1728} = .577$

2.28

$30 \times 2.28 = 68.4$ cu. ft per min.

(11) $\frac{68.4 - 43.8}{68.4} = 35.9\%$

(12) $\frac{20.4}{32.02} = 63.5\%$

(13) $\frac{62.5 \times 43.8 \times 60 \times 240.6 \times 1,000,000}{1785 \times 1016} = 22,250,000$

(14) $.0512 \times 43.8 = 2.25$ ft. per sec.

TEST #8

(1) 48 strokes per min.

(2) suction head 5.6

Distance = 4.67

Pressure head 143

153.27

(3) 27.95 x 78.5 = 2,200

$\frac{2200}{30} = 73.2$

73.2 x 7.48 = 547

547 x 60 = 32800

32800 x 24 = 786,000

(4) $\frac{73.2 \times 62.5 \times 153.27}{33,000} = 21.3$ H.P.

(5) R.H.S.H.E. $\frac{16.8 \times 11.5 \times 43 \times 201}{12 \times 33,000} = 4.7$

R.H.S.C.E $\frac{48.72 \times 11.5 \times 48 \times 198}{12 \times 33,000} = 13.42$

L.H.S.H.E $\frac{21.22 \times 11.25 \times 48 \times 201}{12 \times 33,000} = 5.82$

L.H.S.C.E. $\frac{40.45 \times 11.25 \times 48 \times 198}{12 \times 33,000} = 10.9$

34.84

(6) 206.3 x 12 xx 2480

(7) $\frac{2480}{3424} = 71$

(8) ~~65~~ H' = 1198.8 q'' = 180.33

$H' - q'' = 108.5$

(9) $108.5 \times 71 = 72,400$

(10) R.H.S.H.E. $\frac{83.4 \times 11.5}{1728} = .550$

R.H.S.C.E. $\frac{86.5 \times 11.5}{1728} = .577$

L.H.S.H.E. $\frac{83.4 \times 11.25}{1728} = .544$

L.H.S.C.E. $\frac{86.5 \times 11.25}{1728} = .562$

2.23

$2.23 \times 48 = 107$

(11) $\frac{107 - 73.2}{107} = 31.58\%$

(12) $\frac{21.31}{34.81} = 61\%$

(13) $\frac{62.5 \times 73.2 \times 60 \times 153.8 \times 1,000,000}{2480 \times 1018.5} = 16,800,000$

(14) $.0512 \times 73.2 = 3.75$ ft. per sec.

TEST #9

(1) Strokes per min. 24.5

(2) Discharge head in ft.

$$\begin{array}{r} 5.35 \\ 4.7 \\ \underline{137.0} \\ 147.05 \end{array}$$

(3) $15.35 \times 78.5 = 1050$

$\frac{1050}{30} = 35$

$35 \times 7.48 = 262$

$262 \times 60 = 15,700$

$15,700 \times 24 = 377,000$

(4) $\frac{35 \times 62.5 \times 147}{33,000} = 9.76$ H.P.

(5) R.H.S.H.E. $\frac{17.8 \times 12 \times 24.5 \times 201}{12 \times 33,000} = 2.65$

R.H.S.C.E $\frac{31.41 \times 12 \times 24.5 \times 198}{12 \times 33,000} = 4.61$

L.H.S.H.E $\frac{24.68 \times 11.5 \times 24.5 \times 201}{12 \times 33,000} = 3.52$

L.H.S.C.E. $\frac{23.3 \times 11.5 \times 24.5 \times 198}{12 \times 33,000} = 3.3$

$\overline{14.08}$

(6) $82.8 \times 12 = 995$

(7) $\frac{995}{14.08} = 70.7$

(8) $H' = 1191.1$

$q'' = 180.33$

$H' - q'' = 1010.77$

(9) $1010.77 \times 70.7 = 71,700$

(10). R.H.S.H.E. $\frac{83.4 \times 12}{1728} = .755$

R.H.S.C.E. $\frac{86.5 \times 12}{1728} = .600$

L.H.S.H.E. $\frac{83.4 \times 11.5}{1728} = .550$

L.H.S.C.E. $\frac{86.5 \times 11.5}{1728} = .577$

2.30

(11) $\frac{56.5 - 35}{56.5} = 38\%$

(12) $\frac{9.76}{14.08} = 69.3\%$

(13) $\frac{35 \times 62.5 \times 60 \times 147.1 \times 1,000,000}{995 \times 1010.77} = 19,300,000$

(14) $.0512 \times 35 = 1.79$ ft. per sec.

SAMPLE CARDS

STRAIGHT PORTED VALVES

water #1 left side H, E

Test #1

A = 3.35
l = 2.80

P = 3.35 x 40 / 2.80

= 47.7 lbs/in²

water #1. left side C, E,

A = 4.00
l = 2.80

P = 4.00 x 40 / 2.80

= 57.2 lbs/in²

Test #1 Steam R.H.S. H.E. #4

A = 3.20

l = 2.96

M.E.P. = $\frac{49.2}{2}$ lbs/in²

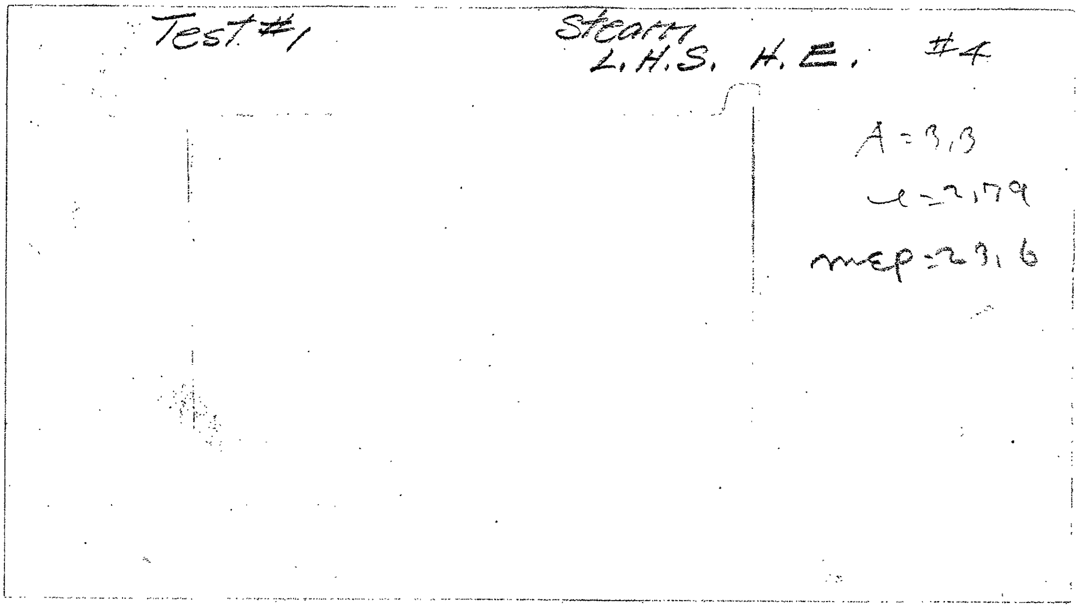
= 21.6 lbs/in²

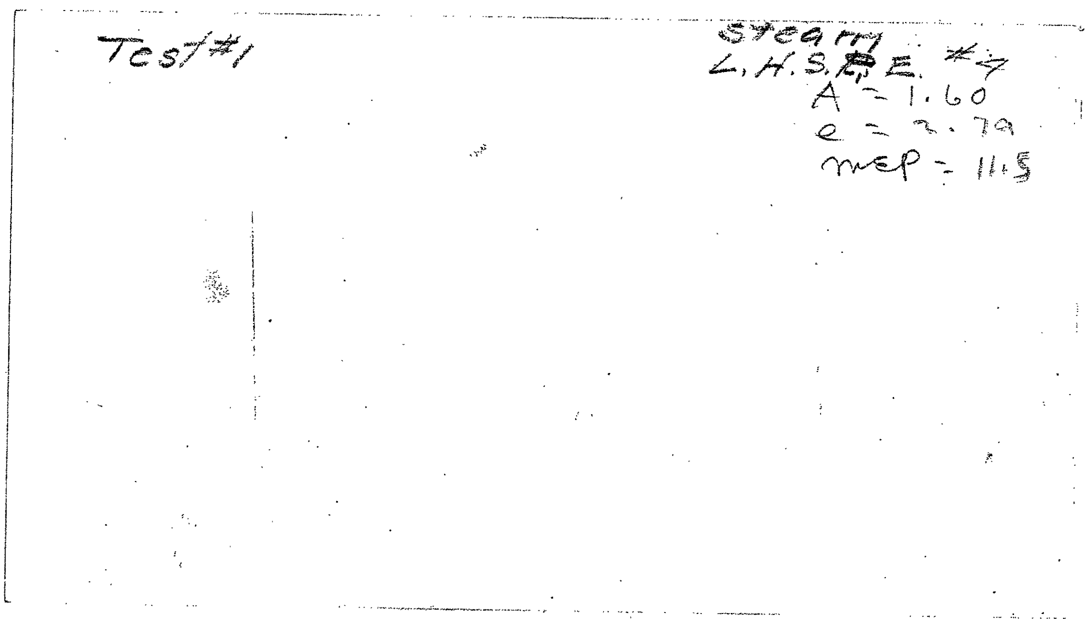
Test #1 Steam R.H.S. P.E. #4

A = 3.60

l = 2.96

MEP = 24.3

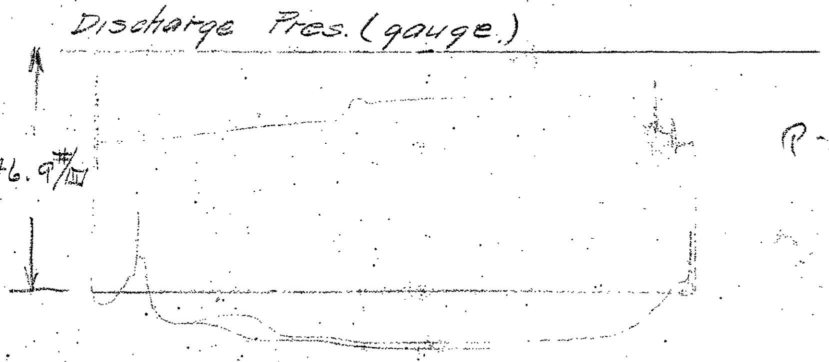

Test #1
Steam
L.H.S. H.E. #4
A = 3.3
e = 2.79
mep = 23.6


Test #1
Steam
L.H.S. H.E. #4
A = 1.60
e = 2.79
mep = 11.5

water

#1 right side

H.E.



A = 3.00

l = 2.90

$P = \frac{3.00 \times 40}{2.90}$

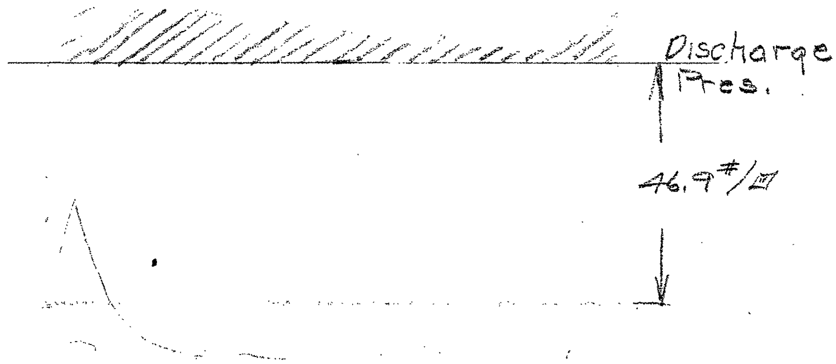
= 41.4 lb/in

Indicators Irregular and unreliable.

water

#1 right side

C.E.



A = 4.1

l = 2.81

$P = \frac{4.1 \times 40}{2.81} = 58.15$ lb/in

Shaded area loss thru valves ?

DATA

INCLINED PORT VALVE TESTS.

DATA - TEST NO. 1.

Averages of Readings

Duration of test (minutes)			30
Steam entrance pressure, pounds per square inch			40
Steam entrance temperature, degrees Centigrade			156
M.E.P.	R.H.S.	H. E.	21.7
		C. E.	33.0
	L.H.S.	H. E.	29.8
		C. E.	29.2
Discharge pressure water, pounds per square inch			60.5
Length of stroke (inches)		R.H.S.	12.75 in.
		L.H.S.	12.50 in.
Strokes per minute			21
Distance surface of water to floor, inches			46
Barometer (inches of Hg.)			30.10 in.
Temperature surroundings, degrees Fahrenheit			100
Number degrees exposed, degrees Centigrade			126
Size steam springs, pounds			60
Size water springs, pounds			60
Average condensate 5 minutes, pounds			176
Rise in tanks (total) feet			30.0

DATA - TEST NO. 2.

Averages of Readings

Duration of test (minutes)	30
Steam entrance pressure, pounds per square inch	65
Steam entrance temperature, degrees Fahrenheit	172
M.E.P. R.H.S. H.E.	15.2
M.E.P. R.H.S. C.E.	48.1
M.E.P. L.H.S. H.E.	25.7
M.E.P. L.H.S. C.E.	40.2
Discharge pressure water, lbs. per sq. in.	
Length of stroke (inches) R.H.S.	12.25
Length of stroke (inches) L.H.S.	11.50
Strokes per minute	22.0
Distance surface of water to floor (inches)	47.5
Barometer (inches of Hg.)	30.10
Temperature surroundings, degrees Fahrenheit	100
Number degrees exposed, degrees Centigrade	143
Size steam springs, pounds	60
Size water springs, pounds	60
Average condensate for 5 minutes, pounds	200
Rise in tanks, feet	31.4

DATA -- TEST NO. 3.

Duration (minutes)			30
Steam entrance pressure, pounds per square inch			64
Steam entrance temperature, degrees Centigrade			168
M.E.P.	R.H.S.	H.E.	39.7
		C.E.	54.5
	L.H.S.	H.E.	42.4
		C.E.	50.1
Discharge pressure water, pounds per square inch			104.0
Length of stroke, inches		H.E.	12.75
		C.E.	12.50
Strokes per minute			26
Distance surface of water to floor, inches			47
Barometer (inches of Hg.)			30.1
Temperature surroundings (degrees Fahrenheit)			110
Number degrees exposed (degrees Centigrade)			138
Size of steam springs, pounds			60
Size of water springs, pounds			100
Average condensate for 5 minutes, pounds			153
Rise in tanks, feet			17.4

DATA - TEST No. 4.

Duration (minutes)			30
Steam entrance pressure, pounds per square inch			75
Steam entrance temperature, degrees Centigrade			168
M. E. P.	R.H.S.	H.E.	38.2
		C.E.	66.0
	L.H.S.	H.E.	44.6
		C.E.	57.3
Discharge pressure water, pounds per square inch			121.0
Length of stroke, inches,		H.E.	12.75
		C.E.	12.50
Strokes per minute			23
Distance surface of water to floor, inches			47
Barometer, inches of Hg.			30.07
Temperature of surroundings, degrees Fahrenheit			101
No. of degrees exposed, degrees Centigrade			138
Size of steam springs, pounds			60
Size of water springs, pounds			100
Average condensate for 5 minutes, pounds			153
Rise in tanks, feet			13.3

DATA - TEST NO. 5.

Duration (minutes)			30
Steam entrance pressure, pounds per square inch			66
Steam entrance temperature, degrees Centigrade			167
M. E. P.	R.H.S.	H.E.	32.8
		C.E.	54.6
	L.H.S.	H.E.	43.1
		C.E.	49.5
Discharge pressure water, pounds per square inch			103
Length of strokes, inches		H.E.	12.75
		C.E.	12.50
Strokes per minute			24.5
Distance surface of water to floor			46.2
Barometer, inches of Hg.			30.07
Temperature of surroundings, degrees Fahrenheit			90
No. degrees exposed, degrees Centigrade			137
Size steam springs, pounds			40
Size water springs, pounds			100
Average condensate for 5 minutes, pounds			144
Rise in tanks, feet			15.7

DATA - TEST NO. 6.

Duration (minutes)			30
Steam entrance pressure, pounds per square inch			61
Steam entrance temperature, degrees Centigrade			164
M. E. P.	R.H.S.	H.E.	29.4
		C.E.	49.5
	L.H.S.	H.E.	39.4
		C.E.	47.5
Discharge pressure water, pounds per square inch			92.0
Length of stroke, inches		H.E.	12.25
		C.E.	11.50
Strokes per minute			21
Distance surface of water to floor, inches			45.5
Barometer, inches of Hg.			30.07
Temperature surroundings, degrees Fahrenheit			120
No. degrees exposed, degrees Centigrade			134
Size steam springs, pounds			40
Size water springs, pounds			80
Average condensate for 5 minutes, pounds			112
Rise in tanks, feet			11.34

DATA -- TEST NO. 7.

Durations (minutes)			30
Steam entrance pressure, pounds per square inch			64
Steam entrance temperature, degrees Centigrade			168
M. E. P.	R.H.S.	H.E.	20.9
		C.E.	44.8
	L.H.S.	H.E.	22.2
		C.E.	43.4
Discharge pressure water, pounds per square inch			72
Length of stroke, inches,		H.E.	11.50
		C.E.	11.25
Strokes per minute			33
Distance surface of water to floor, inches . .			45.5
Barometer, inches of Hg.			30.10
Temperature surroundings, degrees Fahrenheit.			95
Number degrees exposed, degrees Centigrade...			138
Size steam springs, pounds			40
Size water springs, pounds			80
Average condensate for 5 minutes, pounds			162
Rise in tanks, feet			19.0

DATA - TEST NO. 8.

Duration (minutes)			30
Steam entrance pressure, pounds per square inch			57
Steam entrance temperature, degrees Centigrade			165
M. E. P.	R.H.S.	H.E.	24.0
		C.E.	48.5
	L.H.S.	H.E.	21.2
		C.E.	42.1
Discharge pressure water, pounds per square inch			59
Length of strokes, inches		H.E.	12.0
		C.E.	11.5
Strokes per minute			42
Distance surface water to floor, inches			54
Barometer, inches of Hg.			30.10
Temperature surroundings, degrees Fahrenheit			95
Number degrees exposed, degrees Centigrade			135
Size steam springs, pounds			60
Size water springs, pounds			80
Average condensate for 5 minutes, pounds			176
Rise in tanks, feet			30

DATA - TEST NO. 9.

Duration (minutes)			30
Steam entrance pressure, pounds per square inch			36
Steam entrance temperature, degrees Centigrade			156
M. E. P.	R.H.S.	H.E.	17.5
		C.E.	26.7
	L.H.S.	H.E.	19.7
		C.E.	24.9
Discharge pressure water, pounds per square inch			43
Length of stroke, inches		H.E.	12.75
		C.E.	12.25
Strokes per minute			28
Distance surface water to floor, inches			49
Barometer, inches of Hg.			30.10
Temperature surroundings, degrees Fahrenheit			88
Number degrees exposed, degrees Centigrade			126
Size steam springs, pounds			20
Size water springs, pounds			40
Average condensate for 5 minutes, pounds			94
Rise in tanks, feet			18.1

RESULTS.

RESULTS.

Test number	1	2	3
Strokes per minute	21	44	26
Piston speed, ft. per min.	88.5	181.4	109.4
Discharge head, feet	149.1	155.3	248.2
Discharge, cu. ft. per min.	37.2	82.0	45.4
Gallons per minute	278	613	340
Gallons per hour	16,704	36,780	20,400
Gallons per 24 hours	402,000	884,000	490,000
Water Horse Power	10.5	24.1	21.4
Steam I. H. P.	15.2	34.0	30.8
Pounds steam per hour	910	2,400	1,840
Pounds steam per I.H.P. per hour	58	70.5	59.6
B.T.U. per I.H.P. per hour	58,500	71,800	60,500
B.T.U. per pound steam	1,008	1,019	1,015
Piston displacement, cu. ft. per minute	52.0	102.5	64.5
Per cent. slip	28.4	20	29.6
Mechanical Efficiency	69.2	71	69.4
Duty, ft. pounds per 1,000,000 B.T.U.	20,800,000	15,590,000	23,500,000
Velocity through valves, ft. per second	1.42	3.14	1.74

RESULTS.

Test number	4	5	6
Strokes per minute	23	24.5	21
Piston speed, ft. per min.	95.8	102	83.1
Discharge head, feet	287	246	222
Discharge, cu. ft. per min.	34.8	41.0	29.7
Gallons per minute	260	306	222
Gallons per hour	15,600	18,360	13,320
Gallons per 24 hours	374,000	441,000	320,000
Water Horse Power	19.0	19.1	12.5
Steam I. H. P.	29.7	27.7	20.7
Pounds steam per hour	1,840	1,730	1,342
Pounds steam per I.H.P. per hr.	62.0	62.4	64.7
B.T.U. per I.H.P. per hour	62,850	63,250	65,600
B.T.U. per pound steam	1,013	1,014	1,012
Piston displacement, cu. ft. per min.	56.5	60.2	49
Per cent. slip	38.4	31.8	39.3
Mechanical Efficiency	63.8	69.0	60.2
Duty, ft. pounds per 1,000,000 B.T.U.	20,100,000	21,600,000	18,250,000
Velocity through valves, feet per second	1.33	1.57	1.14

RESULTS.

Test Number	7	8	9
Strokes per minute	33	42	28
Piston speed, ft. per min.	125.4	82.4	
Discharge head, feet	176	146	110.4
Discharge, cu.ft. per min.	49.7	78.5	47.5
Gallons per minute	372	588	354
Gallons per hour	22,300	35,300	21,270
Gallons per 24 hours	535,900	849,000	511,000
Water Horse Power	16.6	21.6	9.95
Steam I.H.P.	24.7	33.7	15.6
Pounds steam per hour	1,940	2,115	1,129
Pounds steam per I.H.P. per hr.	78.5	62.6	72.2
B.T.U. per I.H.P. per hour	79,700	63,500	73,200
B.T.U. per pound steam	1,015	1,013	1,011
Piston displacement, cu. ft. per minute	73.6	96.5	68.9
Per cent. slip	32.4	18.8	31.1
Mechanical efficiency	67.0	64.0	63.6
Duty, ft. pounds per 1,000,000 B.T.U.	16,650,000	20,300,000	17,260,000
Velocity through valves, feet per second	1.90	3.0	1.82

CONCLUSIONS.

CONCLUSIONS.

The results of the tests on the inclined port valves show a wide variation from the results obtained with the straight ported type. The authors, however, do not believe that the tests are an indication of the relative merits of the two types of valves, inasmuch as the condition of the pump was such as would entirely vitiate any conclusion which might be made.

The pump needed a thorough overhauling, and although this was evident before the first set of tests was completed, it was impossible, on account of lack of time, to overhaul the pump and repeat the tests. It was hoped that it would be possible, by running the pump under similar conditions for both sets of tests, to reach some decision as regards the merits of the valves.

The straight ported valves gave better results than the inclined post valves, but it is impossible to state that these results were obtained under the same conditions.

The inclined port valves improved the running of the pump very much in spite of the fact that they were new. They were much less noisy and decreased the water hammer very much.

We have concluded that it would be unfair to decide the relative merits of the two types of pump valves on the basis of the tests, since the results are so uncertain.

The following reasons explain why the data is considered unreliable. First, when the new valves were being installed, the large quantity of wood and foreign matter found in the suction chamber would indicate that it would also be possible for air to be drawn into the suction pipe, which would spoil the proper action of the pump. Second, the piping to the pump produced a very bad water hammer, and it was impossible to run the pump at high speeds without causing very excessive vibration of the pump and piping. Third, in order to run the pump without excessive knocking and pounding, it was necessary to open the pet cock on the air chamber in the suction line so as to allow a pronounced leakage of air into the line. This would also interfere with the action of the pump. Finally, the steam valves were badly out of adjustment and due to the inexperience of the experimenters, this was not discovered until the tests were almost complete.

After the tests had been finished, we also found that it was possible to entirely close the discharge valve and still run the pump at a piston speed of about thirty feet per minute. The reason for this is the large slip past the piston and it was found possible to insert a thin steel rule between the piston and the cylinder and move it through an arc of one hundred and twenty degrees.

The trouble with the valve motion was also discovered at the end of the test. The collars on the valve stems on both sides of the pump were found loose. It was possible to turn them easily by hand. This would explain the unequal division of the work as indicated on the steam cards between the two sides of the pump.

It is evident from the reasons enumerated above that the data obtained in these tests was entirely undependable, and no decision can be offered as to the relative value of the two types of valve.

TABLE OF CONTENTS

SAMPLE CARDS

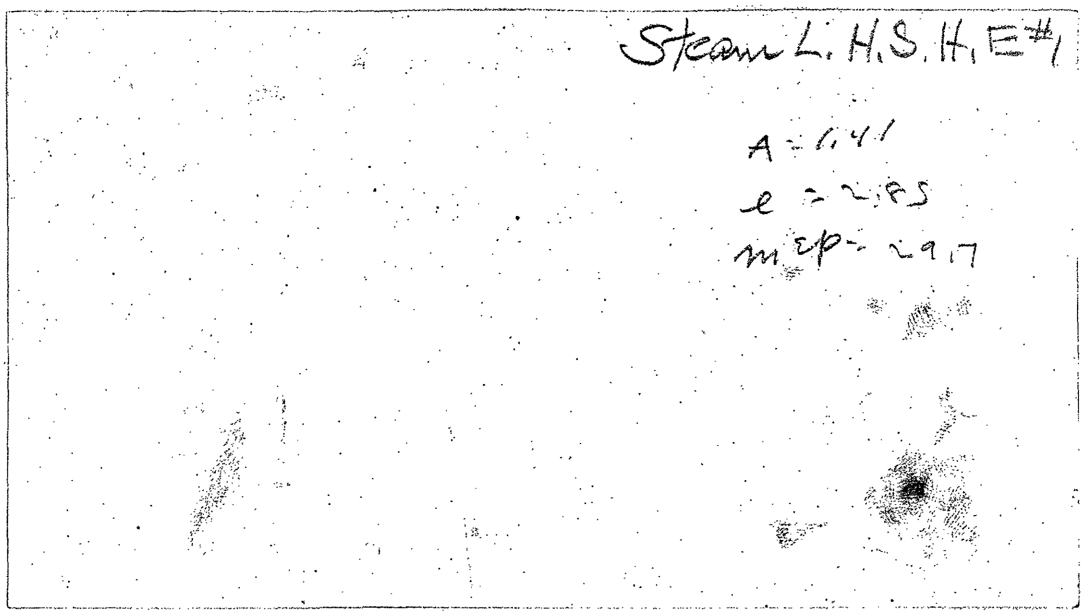
INCLINED PORT VALVES

Steam P. H.S.H.E #1

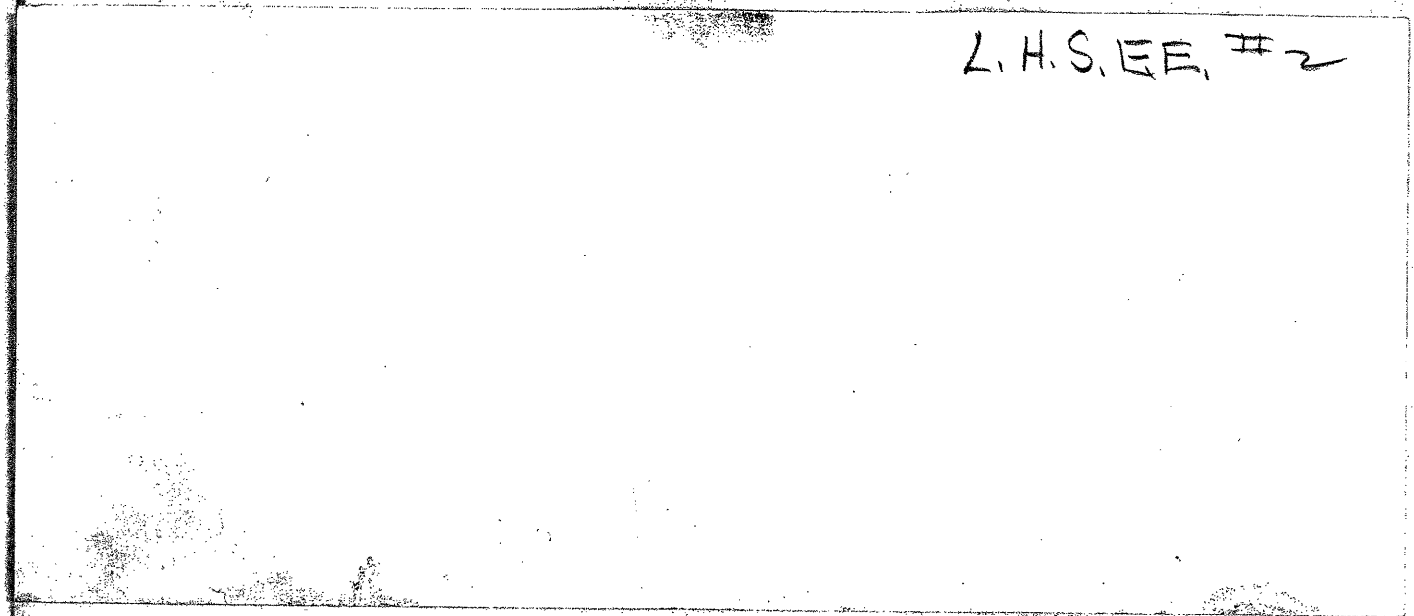
A = 1.05
e = 2.87
mep = 21.82

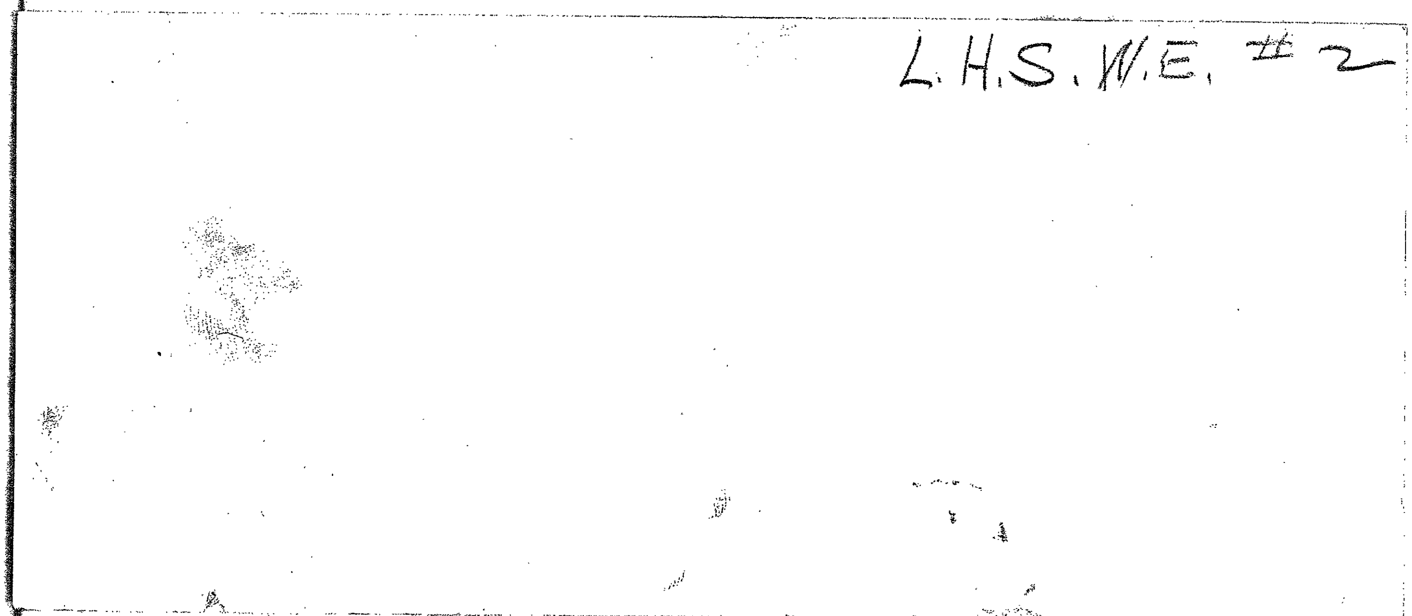
Steam P. H.S.C.E. #7

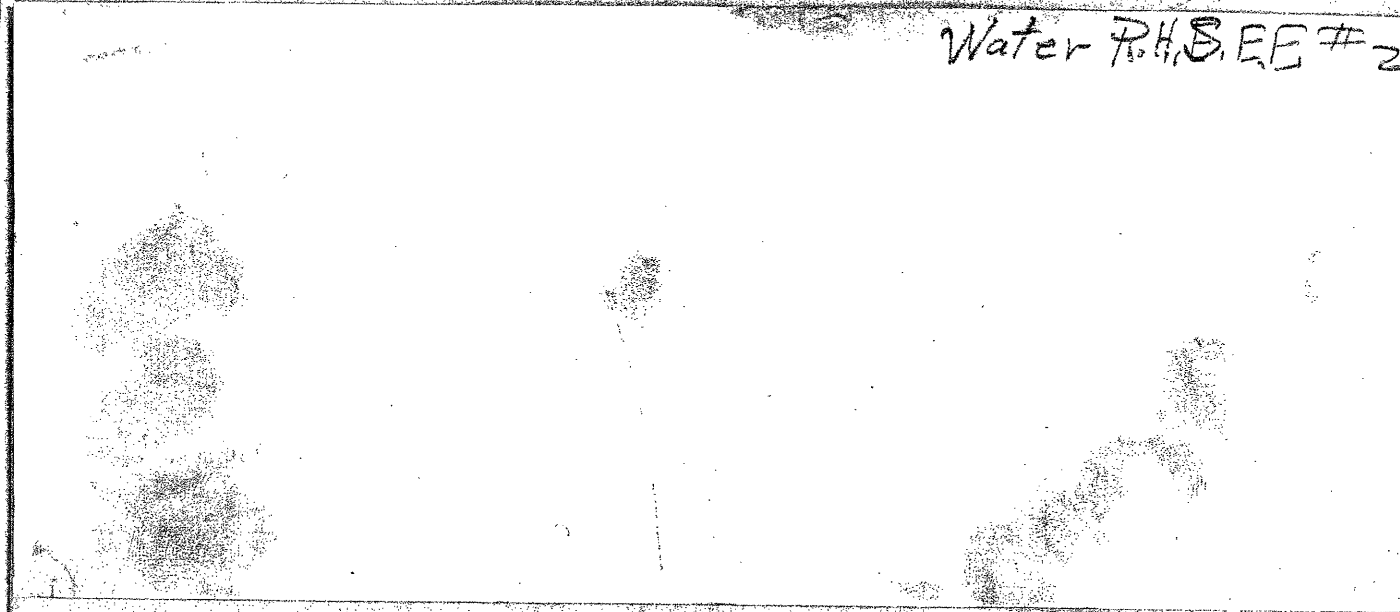
A = 1.65
e = 3.00
mep = 33

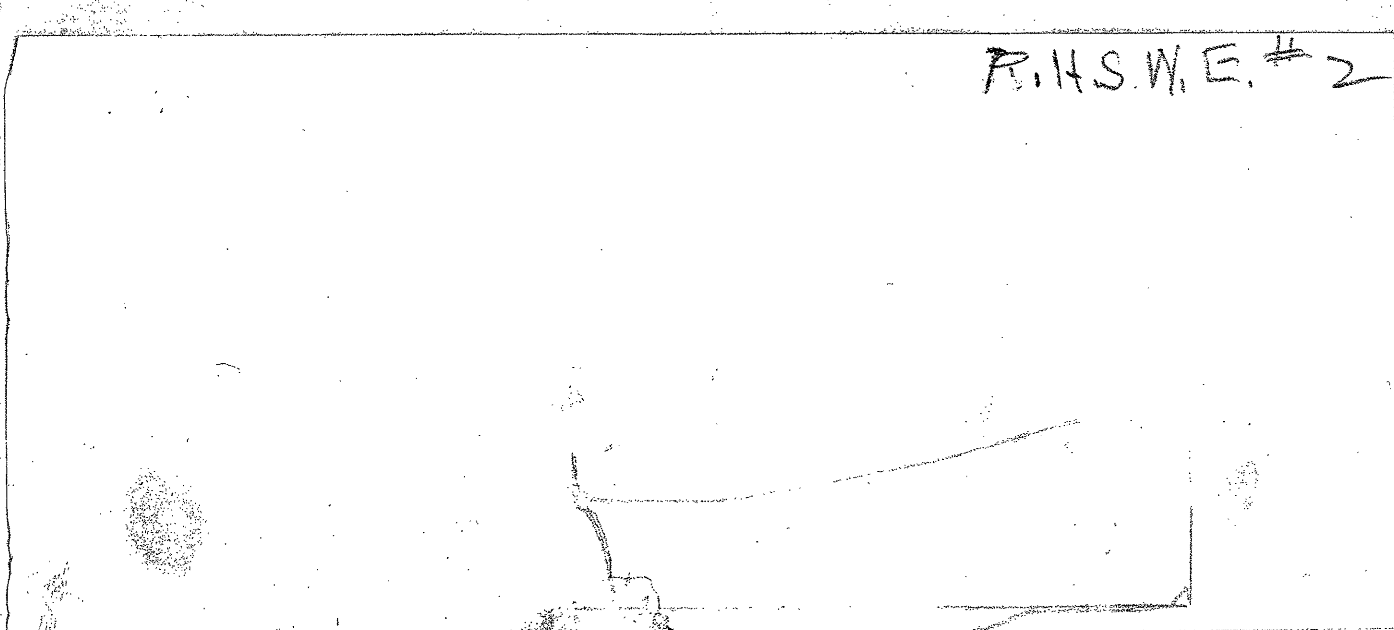

Steam L.H.S. H.E #1
A = 1.41
e = 2.85
mep = 29.7


Steam L.H.S. C.E. #1
A = 1.41
e = 2.90
mep = 29.2


L.H.S. EE. #2


L.H.S. W.E. #2


Water R.H.S.E.E #2


R.H.S.W.E. #2