THESIS

An Experimental Investigation of the Flow of Superheated Steam through Circular Orifices in Thin Plates

by

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OBJECT

The object of this thesis is to make an experimental investigation of the Flow of Superheated Steam through orifices in thin plates, (only orifices having a rounded approach to be used) and if possible to develop a formula which would be simple and yet give results which will be adequate for most engineering work.

THEORY AND FORMULAE.

If superheated steam is allowed to expand through an orifice without losses of any kind the expansion will be isentropic and the calculations to obtain the rate of flow would be very simple, but the friction of the steam passing through the orifice causes the expansion to fall somewhere between an isentropic and a constant heat expansion.

This requires that experiments be made with each orifice to determine the constants which determine the true expansion. These constants will probably change with varying degrees of superheat, initial pressure, when the expansion falls below the superheated state and reaches the region of wet steam, and with the ratio of $\frac{P_2}{P_1}$.

The determination of these constants is necessary in order to obtain the correct value of the velocity. After the velocity is determined the quantity flowing can be computed by the formula

$$Q = V A$$

or

$$W = \frac{A V}{S}$$

where

A = area of orifice in sq. ft.

V = velocity of the steam passing the neck of the orifice.

Q = Cubic feet of steam passing the neck per unit of time.

W = weight of steam in pounds passing the neck per unit of time.

S = cubic feet per pound of steam at the neck pressure.

The neck pressure is P_2 down to the critical pressure.

The velocity of the steam can be calculated by two different methods; by knowing the relations between p and S, or by the use of steam charts and tables.

In the case of the flow of vapors through orifices these is practically no energy lost so the process can be assumed to be adiabatic and to follow the law that

$$P S^n = C.$$

Knowing the relations between P and S the velocity without reheat can be found by the integral

$$\frac{V^2}{2g} = \int_{P_2}^{P_1} S\,dp$$

after substituting the value of S and performing the integration. The expression reduces to the form

$$V = \sqrt{2g \frac{n}{n-1} P_1 S_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right]}$$

where

P_1 = initial pressure in pounds per sq. inch absolute

S_1 = initial volume of the steam in cubic feet per pound.

P_2 = neck pressure.

The value of n in this equation for superheated steam is about 1.33 to 1.34. The degree of superheat does not seem to change this value very materially, but as soon as the expansion falls below

the saturation point, its value drops very rapidly. This makes the use of the formula just given for finding the velocity of the steam useless where the expansion falls below the saturation point.

By far the easiest and best method for finding the velocity is by the use of steam tables and charts. This method can be used regardless of whether the expansion falls below the saturation point or not, and is the method used in this thesis.

The only energy changes taking place in the expansion are changes from potential to kinetic energy. The total energy before and after the orifice, being the same, can be expressed in the form of an equation

$$\frac{V_1^2}{2g} + Q_1 = \frac{V_2^2}{2g} + Q_2$$

for one pound of steam. This equation can be put in the form

$$\frac{V_2^2}{2g} - \frac{V_1^2}{2g} = Q_1 - Q_2$$

which gives the method for finding the change in kinetic energy. Considering that $\frac{V_1^2}{2g} = 0$ the equation reduces to the form for the velocity

$$V = \sqrt{2g\,(Q_1 - Q_2)\,778}$$

where

$$Q_1 = (X_1 Y_1 + Q_1 + \bar{C}_{p_1} D_1)$$

$$Q_2 = (X_2 Y_2 + Q_2 + \bar{C}_{p_2} D_2)$$

V = velocity of the steam in feet per second at the neck of the orifice

Y = latent heat of vaporization

Q = heat of the liquid

C_p = specific heat at constant pressure

D = number of degrees of superheat if superheated

X = quality of the steam if wet.

This equation simplifies into

$$V = 223.8\sqrt{Q_1 - Q_2}$$

Q_1 and Q_2 can be taken directly from the steam tables or charts. The velocity reaches a maximum where $\frac{P_2}{P_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$ when n = 1.33 for superheated steam. (See appendix for proof.)

So far the reheat due to the friction of the steam passing through the orifice has only been mentioned and the statement made that a constant must be found which would give the true velocity for any expansion. This constant is mainly the result of the reheating of the steam through friction and thus decreasing the heat available to be transformed into kinetic energy. This can be shown to the best advantage by the use of diagrams. Using first the $T\phi$ chart (Fig. 1.) A is the point showing the initial condition of the steam at the pressure P_1 and temperature T_1. The expansion in the ideal case is adiabatic, hence along the isentropic line to the point B which is at the back pressure P_2 and temperature T_3. The true expansion takes place along the line AC,

C being the true final condition at the back pressure P_2 and temperature T_2.

The amount of this reheat is represented by the differences of the total heats at T_3 and T_2 or the area below the P_2 line between the entropy lines A B ϕ, and C ϕ_2. This area will be shown cross hatched in two directions.

The same result can be obtained from the Mollier diagram (Fig. 2) and be seen to a better advantage. The lettering in the temperature-entropy and heat-entropy diagrams are the same. The reheat is represented by the distance $Q_2 - Q_3$ and the reheat factor is the ratio of $(Q_2 - Q_3)$ to $(Q_1 - Q_3)$.

The values of K that will be found in the experiments is the ratio of the actual weight discharged to the theoretical weight of discharge. As all the quantities in the equation, with the exception of the true velocity, are known, this factor K is the factor that obtains the true velocity from the theoretical. The factor K in the following formula is the square root of (1 - reheat factor) or the ratio of the square root of $(Q_1 - Q_2)$ to $(Q_1 - Q_3)$. This is true because the square root of $(Q_1 - Q_2)$ must be taken in order to obtain the velocity and the value K is used to obtain the true velocity. The formula to obtain the true flow will be

$$W = \frac{A}{S_2} K 223.8 \sqrt{Q_1 - Q_3}$$

where $(Q_1 - Q_3)$ is the heat drop in the ideal case and is taken from the heat chart.

After the steam passes through the orifice and into the chamber at the pressure P_2, another change takes place. The kinetic energy in the steam is lost by eddy currents and by the impact of the swiftly moving steam against the steam in the discharge chamber which is at comparative rest. This action is similar to the action taking place in a throttling calorimeter. This will cause the temperature in the discharge chamber to rise and the temperature T_2 will give the temperature at P_2 minus radiation losses and the kinetic energy caused by the differences of volumes before and after passing the orifice.

APPARATUS AND METHOD OF MAKING TESTS

The apparatus is shown in (Fig. 3) a valve A, pressure gauge C, thermometer T_1, orifice O, thermometer T_2, gauge E, valve B, condenser D, and Fairbanks Morse scales (not shown) to weigh the condensate. The pipes leading to and from the orifice are two inch. The thermometer well for T_1 was placed in the pipe far enough so that the part of the thermometer used was entirely exposed to the temperature T_1. Stem corrections were necessary for T_2 because the valve B was too near to allow the use of a deep thermometer well. Stem corrections were taken from the set of curves placed in the appendix.

The valve B was used to regulate the back pressure P_2.

After this pressure was regulated the pressure conditions before and after the orifice could be kept the same throughout the test by regulating the valve A.

An externally fired superheater was used which gave the operator control over the degree of superheat at T_1 by regulating the fire under the superheater.

During any one test all the conditions were kept as constant as possible by close attention to the pressures and superheat. The tests for each back pressure were usually 20 to 30 minutes in length. During each test the pressures, temperatures, and weight of condensed steam were recorded several times. By taking these readings any irregularity not shown by the gauges and thermometers would appear and the trouble remedied before proceeding with the tests.

The orifices used are shown by the two drawings, Fig. 4 and Fig. 5.

RESULTS AND CONCLUSIONS

The results can be shown best by an inspection of the curves: the curve of theoretical flow, the curve obtained by experiment, and the curve of K which is the ratio of the actual curve to the theoretical.

It will be seen that the maximum flow does not take place at about .54 P_1 but that the flow gradually increases for values of $\frac{P_2}{P_1}$ less than .54 P_1. Rateau in his book on the flow of steam does not reach a maximum for P_2 equal to or a little less than

.58 P_1, but increases constantly as P_2 falls."

After a comparison of the curves it will be seen that one or two pounds change in the initial pressure, or from 5 to 10 degrees change in the initial temperature, does not produce an effect large enough to make any difference in the accuracy of the work; but regardless of this the conditions were kept as constant as possible throughout each test by constant observation.

By examining the data in the appendix it will be seen that the heat loss (between T_1 and T_2) due to radiation was about 2 B. t.u. per pound. This loss is so small that its value as compared to the total B.T.u. per pound of steam is negligible in producing any change in the result.

From the curves of K it will be seen that the value of K drops at first, reaching a minimum value in the neighborhood where $\frac{P_2}{P_1}$ is equal to .8; and from there the value of K rises and finally flattens out into a nearly straight line. This lowering of K is to be expected for the reason that when $\frac{P_2}{P_1}$ is nearly unity the velocity of flow is so small that practically no friction would result.

The possibility that the steam contained any moisture when it reached the orifice is very slight for the reason that it had to pass around 7 right angle bends after leaving the superheater and before going through the orifice. This changing of the direction of flow so many times caused friction and eddies which must have entirely done away with the possibility that the steam contained moisture when it reached the orifice.

No attempt was made to develop a formula for the flow, because the theoretical method, modified by the proper constant which must be obtained by experiment, is by far the easiest and most satisfactory method to use.

BIBLIOGRAPHY

Temperature Entropy Diagram

By Berry

Engineering Thermodynamics

by Lucke

Flow of Steam through Nozzles

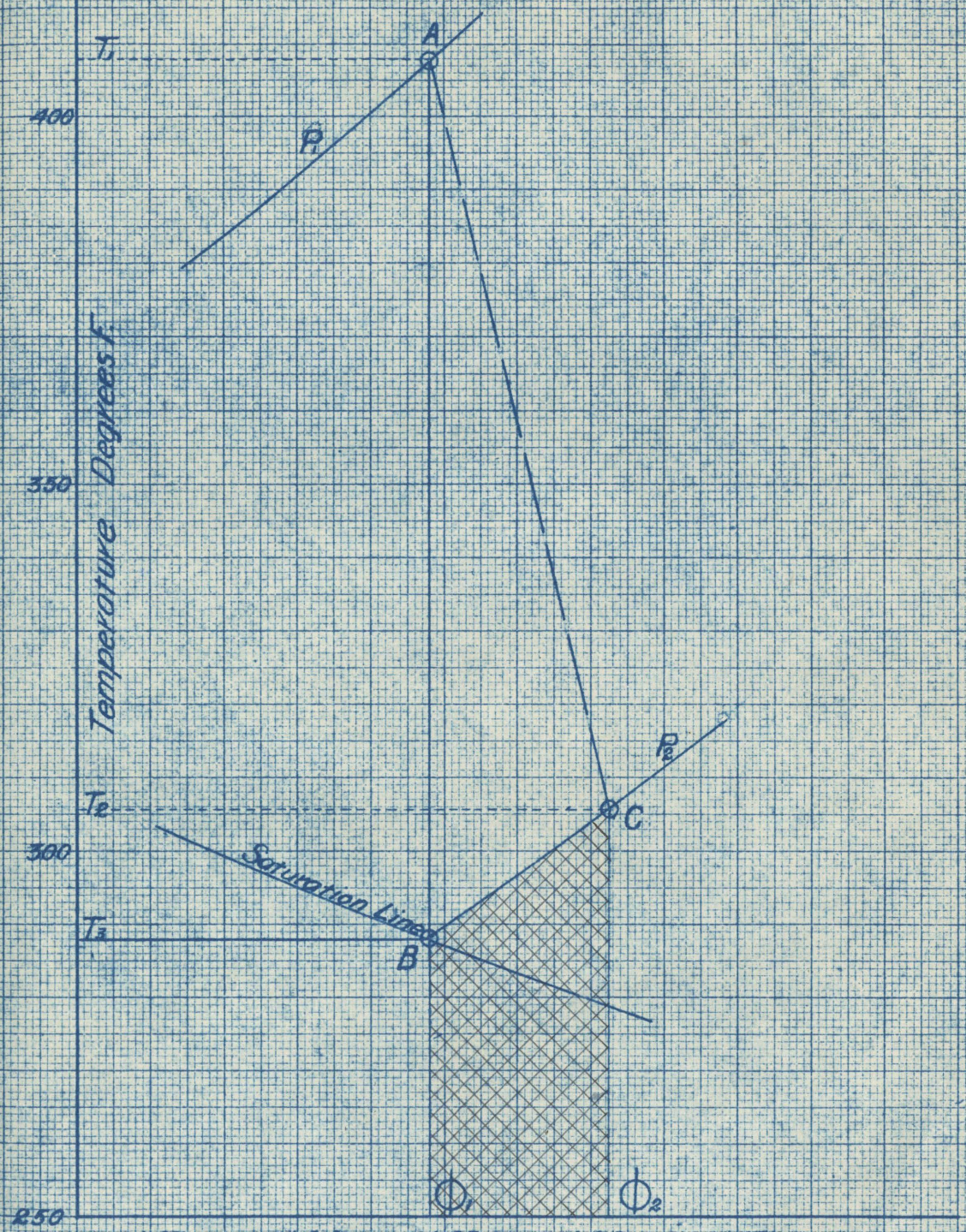
by Bateau

Steam Tables and Diagrams

by Mark and Davis.

Test No. 2
Temperature Entropy Diagram

Fig. 1

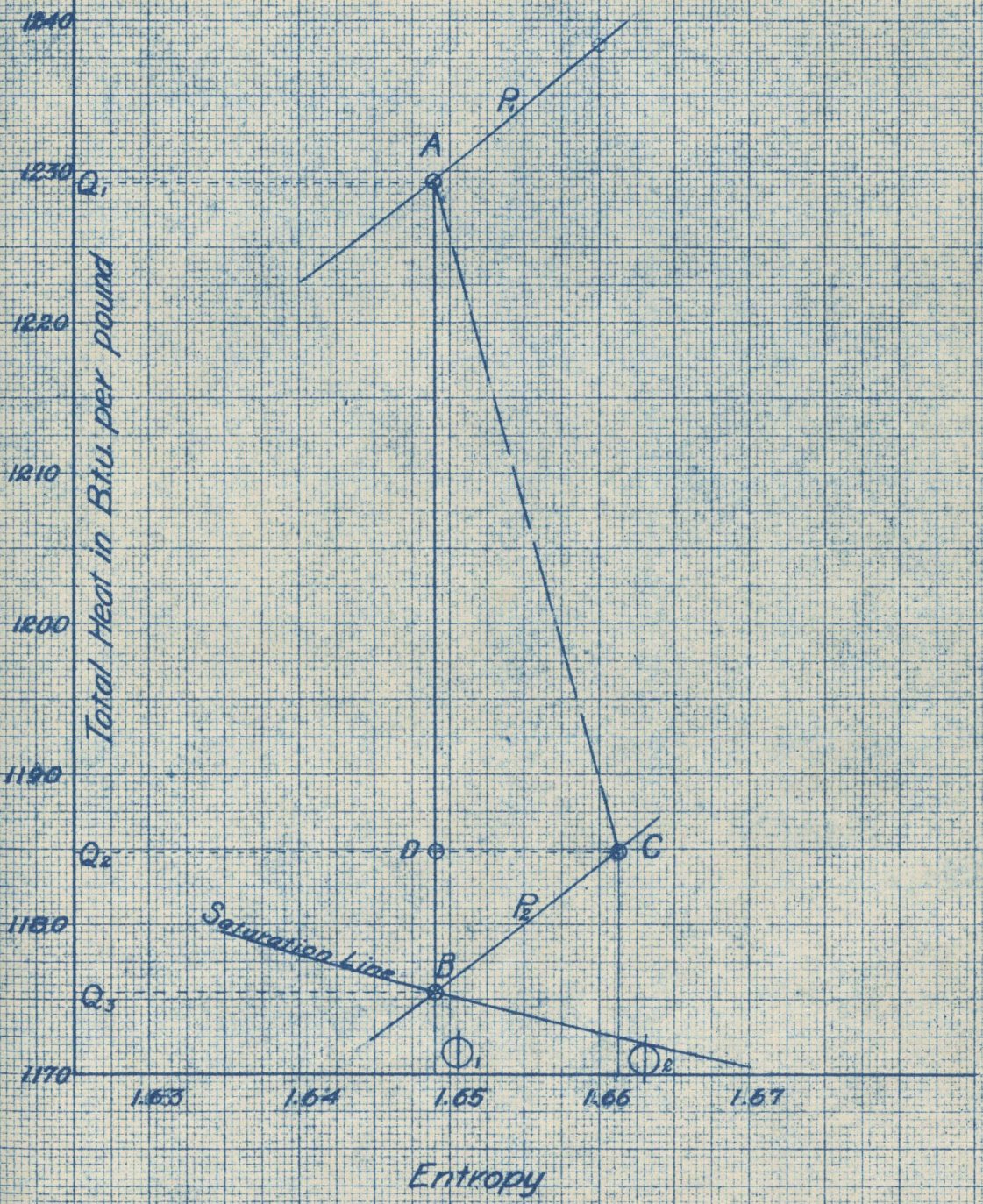


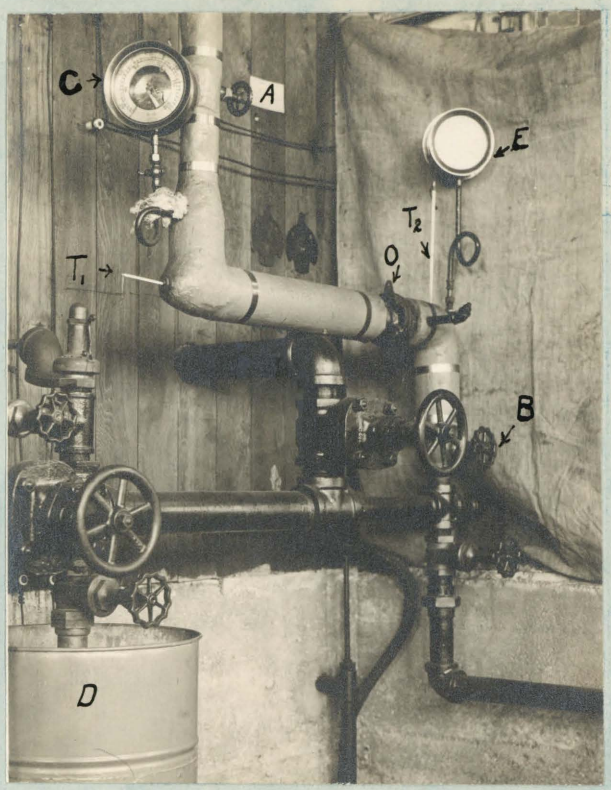
Thesis - Flow of Steam

R.O.C.

Test No. 2
Mollier Diagram

Fig. 2





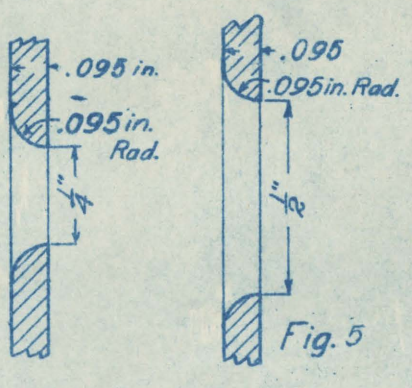
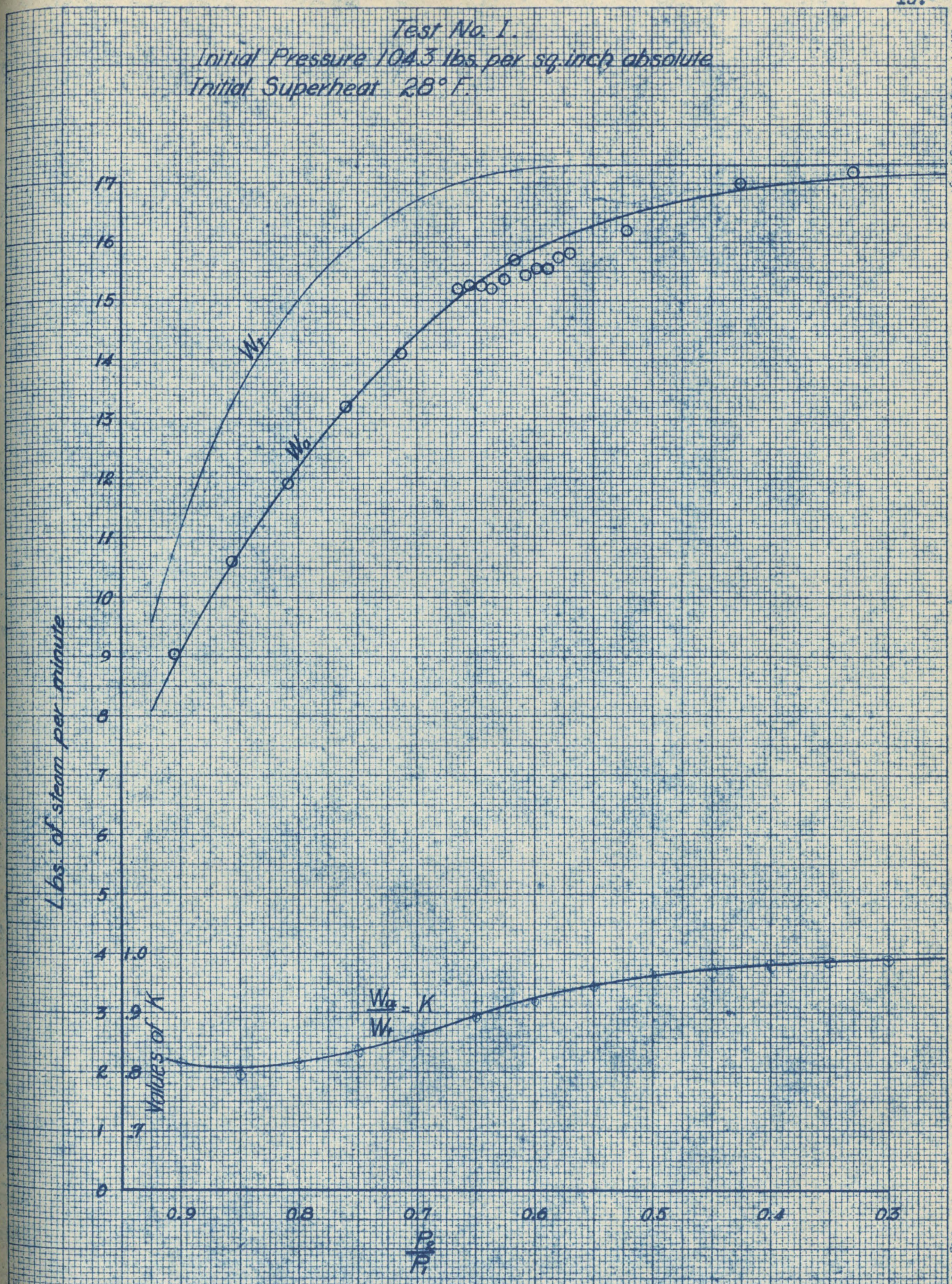


Fig. 4

Fig. 5

Test No. I.
Initial Pressure 104.3 lbs. per sq. inch absolute
Initial Superheat 28° F.



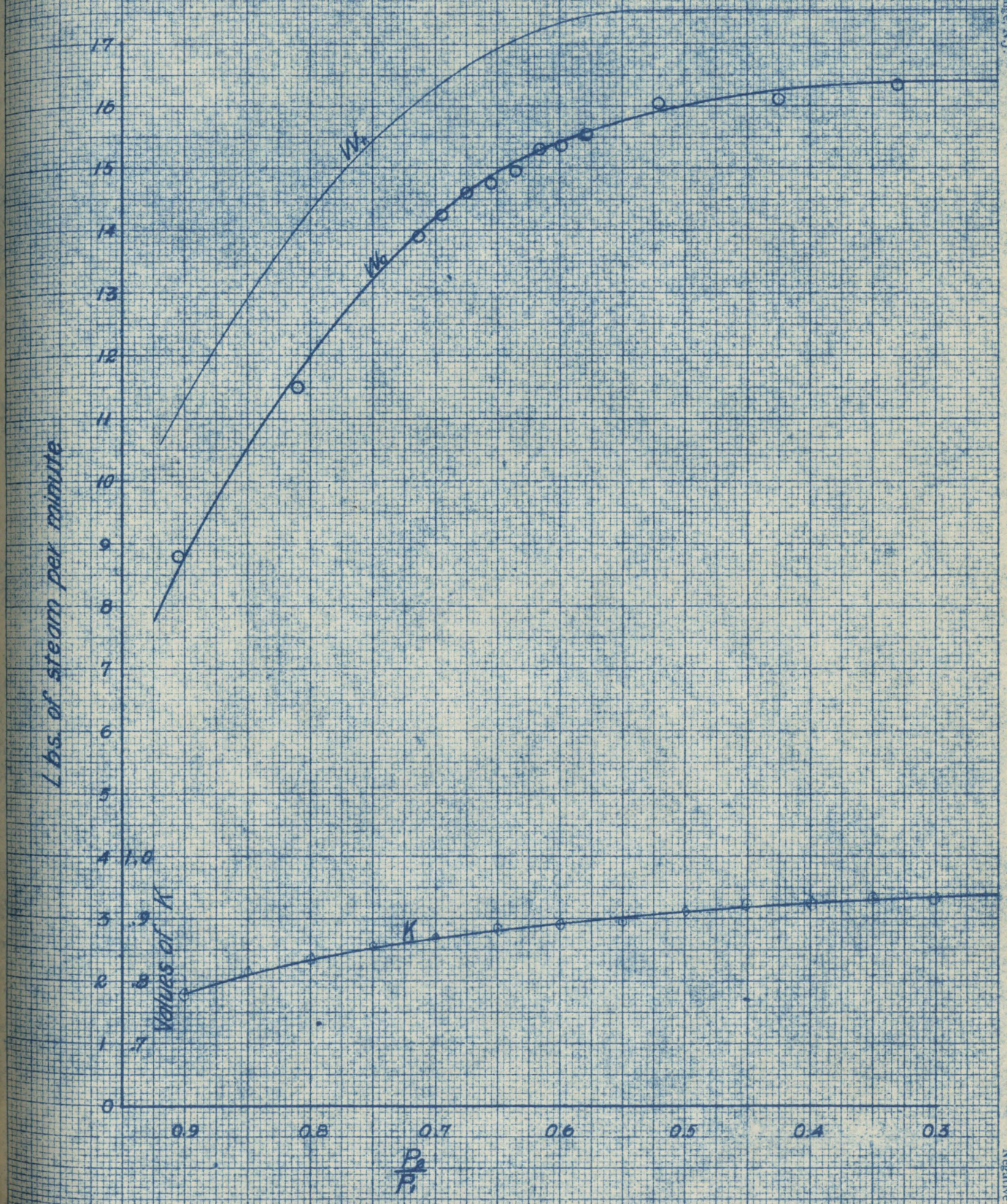
H. W. Webb, Glen Ridge, N.J.

Thesis Flow of Steam

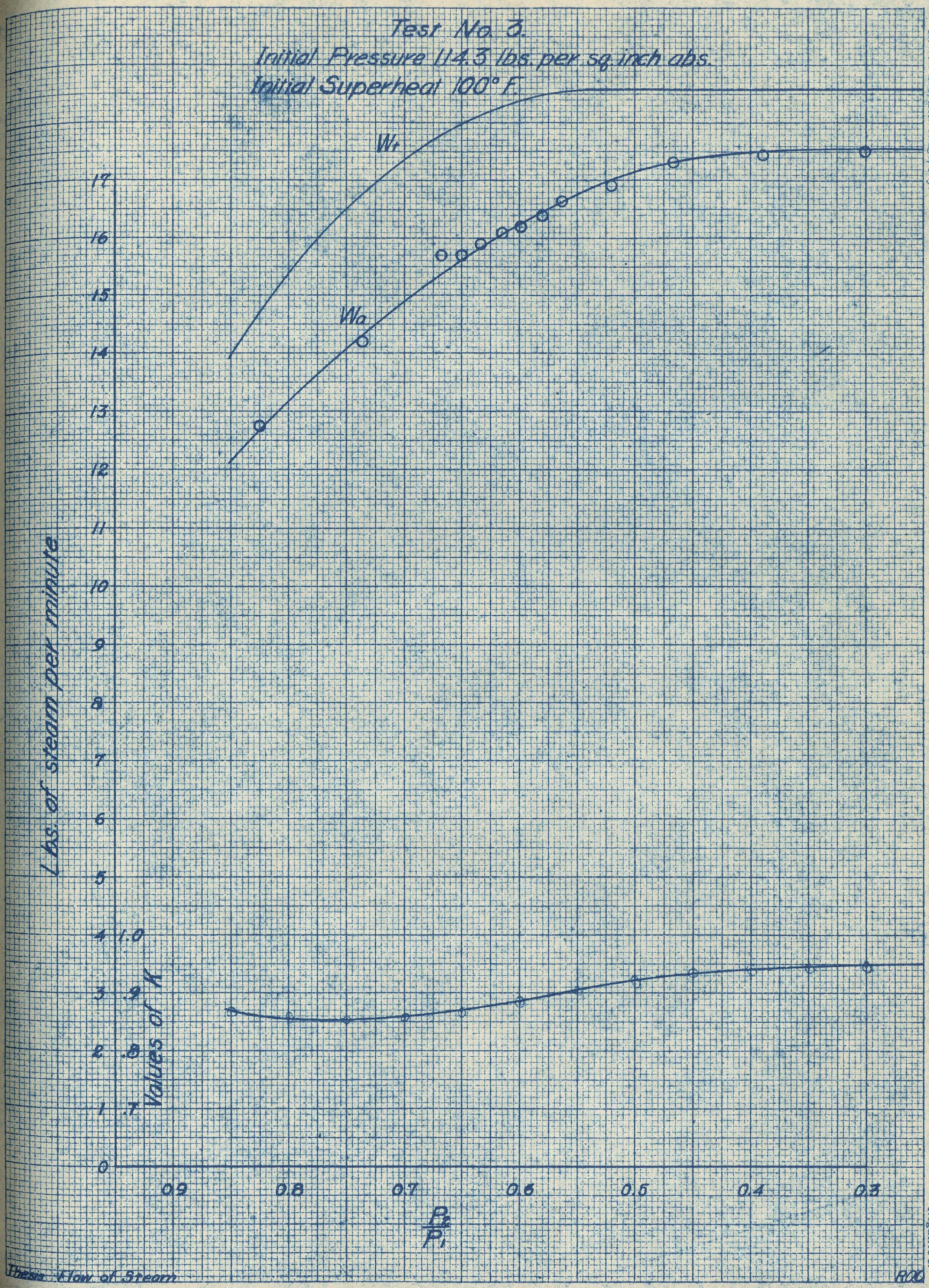
R.O.C.

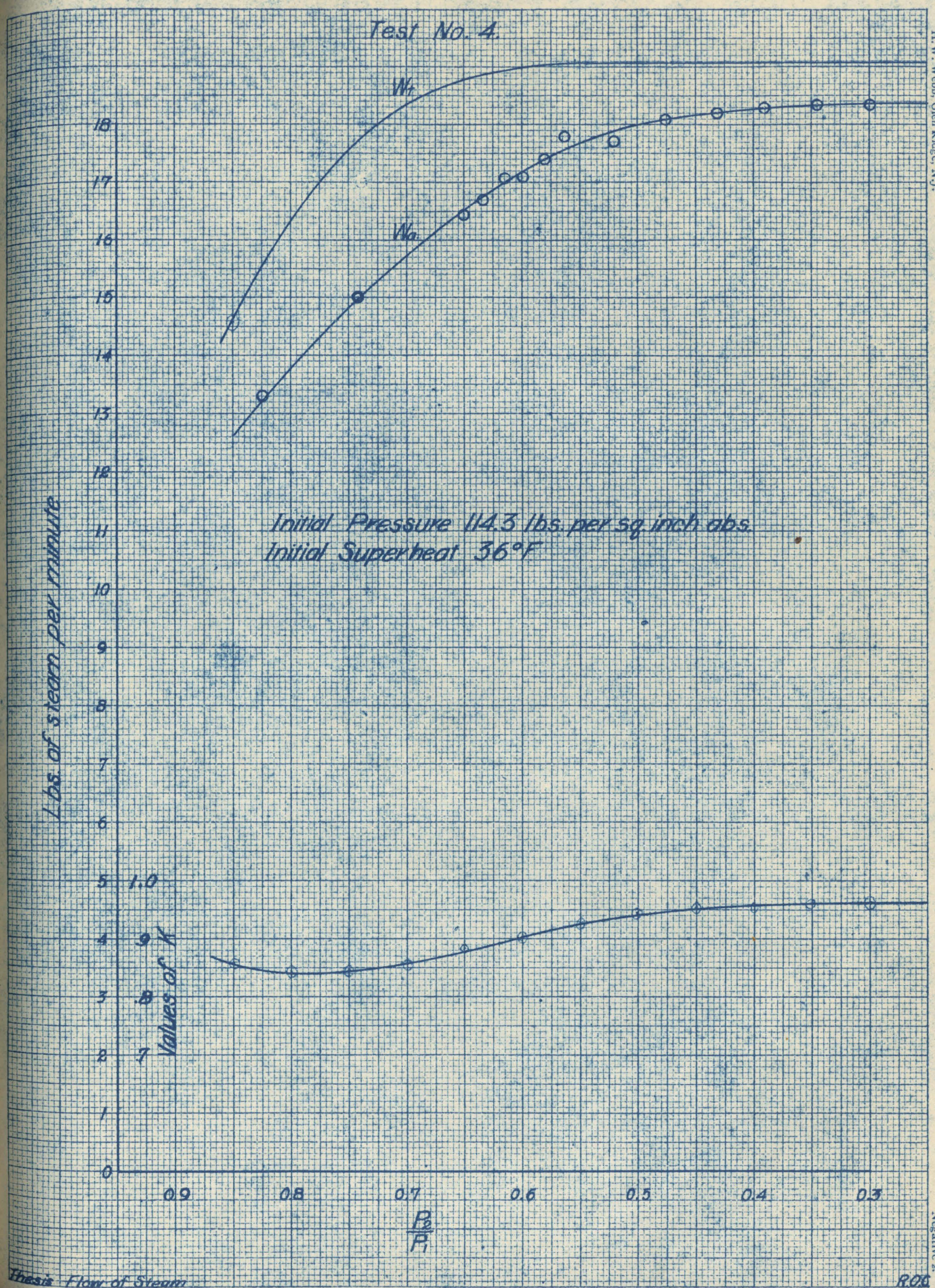
Negative 2.

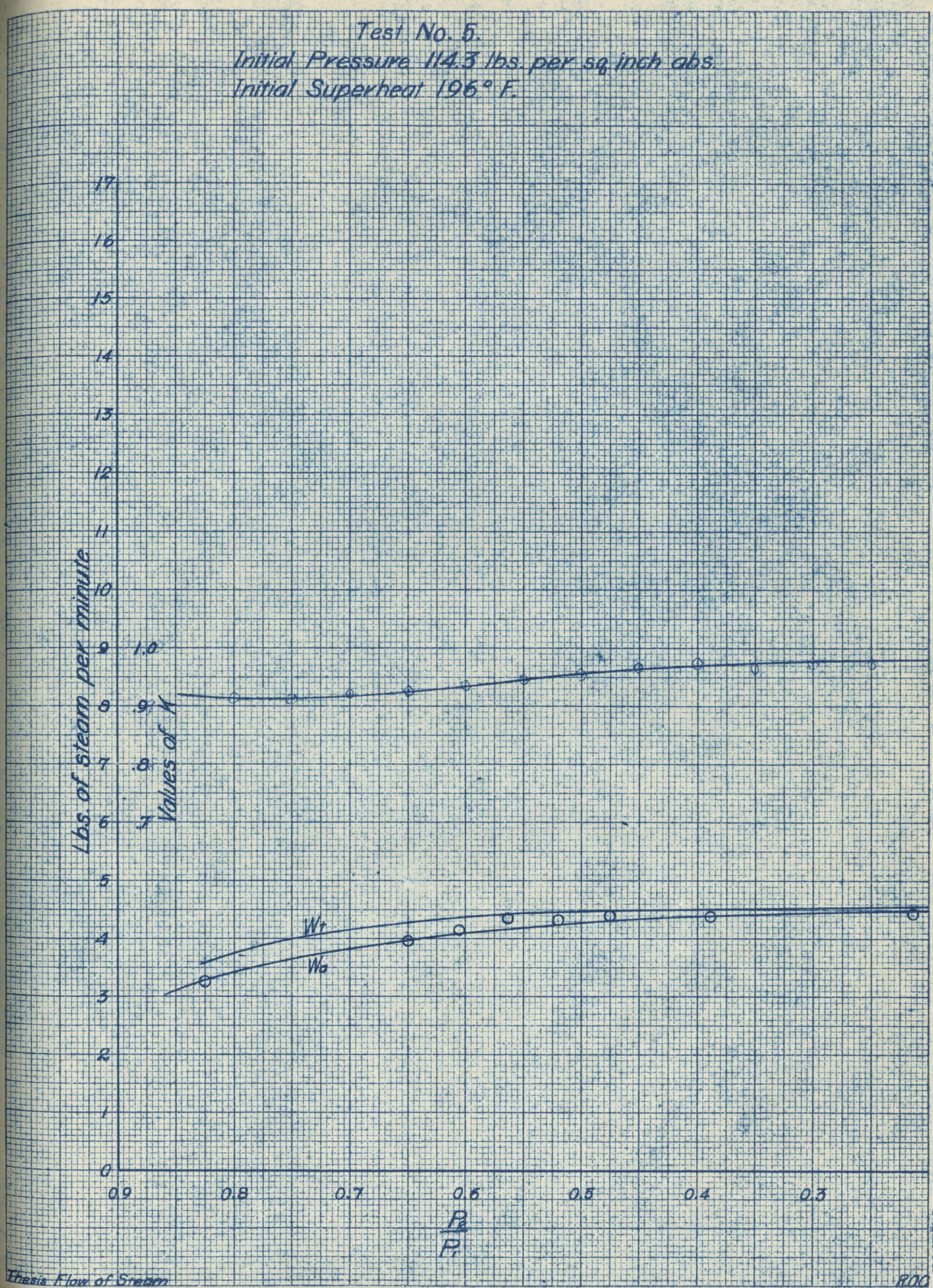
Test No. 2.
Initial Pressure 104.3 lbs. per sq. inch abs.
Initial Superheat 77° F.



Mass Flow of Steam







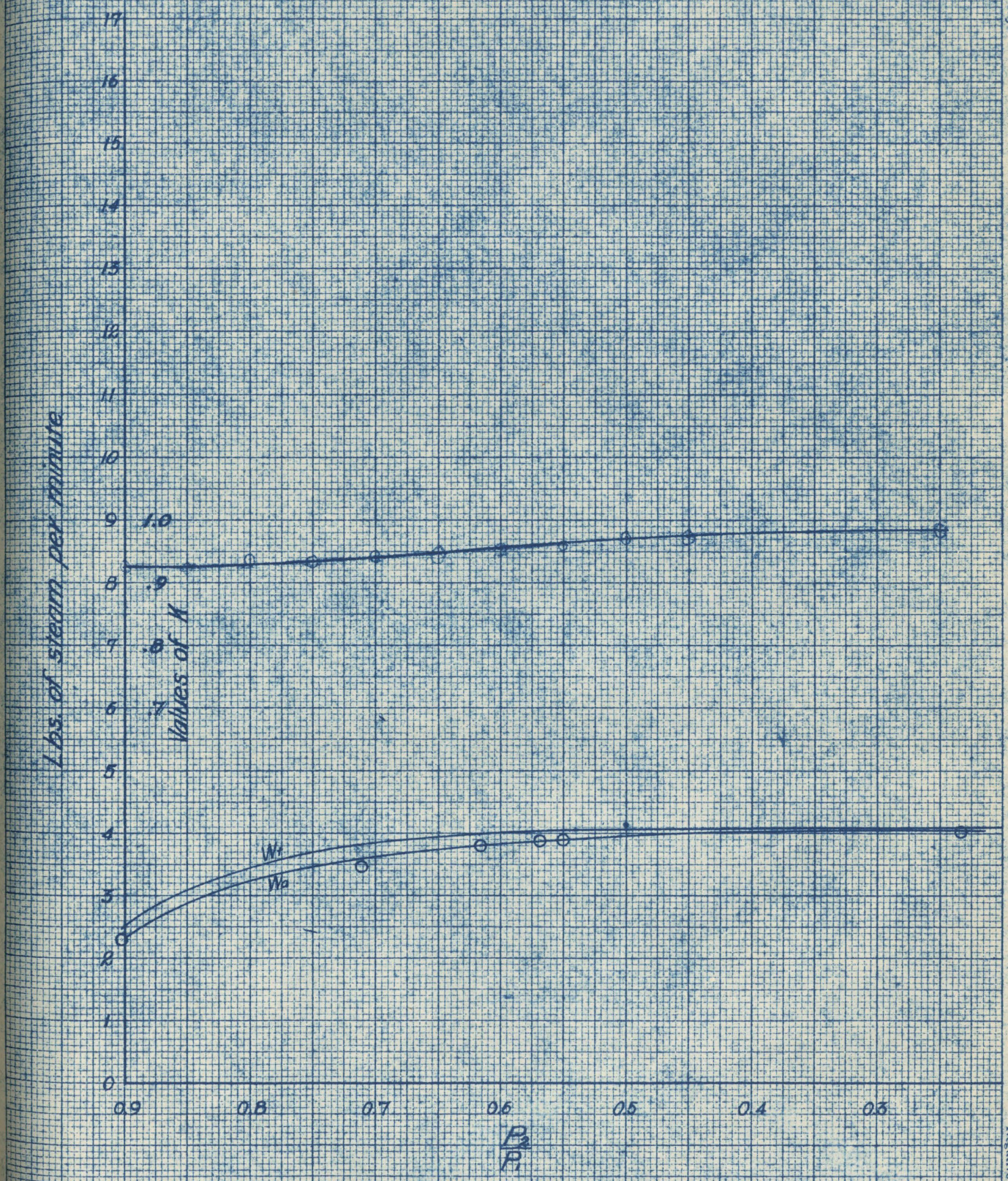
H. W. Webb, Glen Ridge, N.J.

Negative 2.

Thesis Flow of Steam

R.00

Test No. 6.
Initial Pressure 104.3 lbs. per sq. inch abs.
Initial Superheat 196° F.



Thesis Flow of Steam

ROC

Curves Showing the Relations of K in the Six Tests. Taken from the Curve Sheets

Numbers on curves refer to the Test No.

Test No. 1.
P_1 = 104.3 lbs. per sq. in. abs.
Superheat = 28° F.

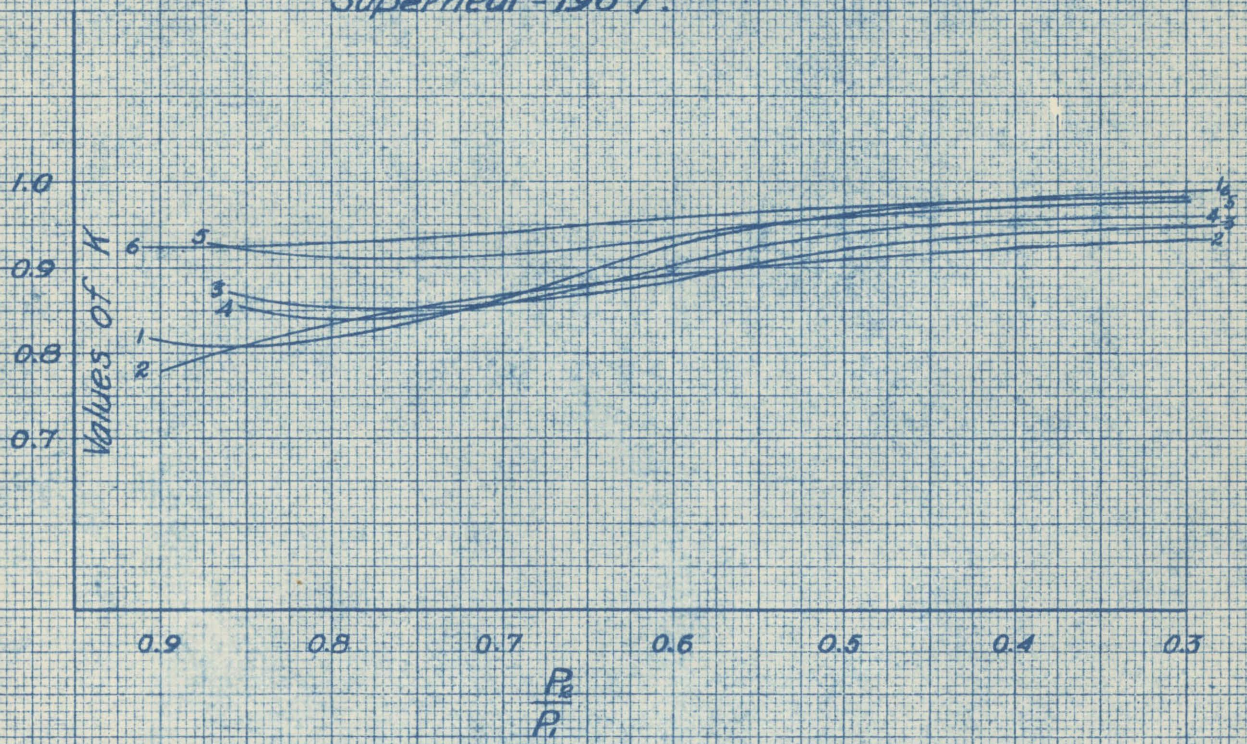
Test No. 2.
P_1 = 104.3 lbs. per sq. in. abs.
Superheat = 77° F.

Test No. 3.
P_1 = 114.3 lbs. per sq. in. abs.
Superheat = 100° F.

Test No. 4.
P_1 = 114.3 lbs. per sq. in. abs.
Superheat = 36° F.

Test No. 5.
P_1 = 114.3 lbs. per sq. in. abs.
Superheat = 196° F.

Test No. 6.
P_1 = 104.3 lbs. per sq. in. abs.
Superheat = 196° F.



TEST NO. I CORRECTED AVERAGES

1/2 inch orifice rounded approach.

P_1	P_2	T_1	T_2	Degrees of superheat		Lbs.per
lbs.per sq.in.abs.		Degrees F		t_1	t_2	Min.
104.3	94.3	355	346	24	24	9.05
104.3	89.3	358	348	27	29	10.6
104.3	84.3	367	353	36	38	11.9
104.3	79.3	351	342	20	21	13.2
104.3	74.3	348	335	17.	29	14.10
104.3	69.3	351	337	20	35	15.20
104.3	68.3	357	344	26	43	15.25
104.3	67.3	359	345	28	45	15.25
104.3	66.3	361	347	30	48	15.20
104.3	65.3	362	348	31	50	15.35
104.3	64.3	363	342	32	45	15.70
104.3	63.3	362	347	31	51	15.45
104.3	62.3	363	348	32	53	15.55
104.3	61.3	362	347	31	53	15.55
104.3	60.3	362	347	31	54	15.75
104.3	59.3	362	346	31	54	15.80
104.3	54.3	361	342	30	56	16.20
104.3	44.3	358	318	27	45	17.00
104.3	34.3	355	313	24	56	17.20

Average superheat 28° F.

TEST NO. 2 CORRECTED AVERAGES

1/2 inch orifice rounded approach

P_1	P_2	T_1	T_2	t_1	t_2	Lbs per
Lbs.per sq.in.abs.		Degrees F		Deg. of superheat		Min.
104.3	94.3	405	400	74	77	8.8
104.3	84.3	400	392	69	77	11.5
104.3	74.3	407	396	76	90	13.9
104.3	72.3	406	394	75	90	14.25
104.3	70.3	407	394	76	92	14.60
104.3	68.3	407	394	76	93	14.75
104.3	66.3	408	394	77	95	14.95
104.3	64.3	401	388	70	91	15.3
104.3	62.3	405	390	74	96	15.35
104.3	60.3	399	382	68	90	15.55
104.3	54.3	413	397	82	112	16.05
104.3	44.3	421	399	90	126	16.10
104.3	34.3	426	405	95	148	16.35

Average Superheat 77° F.

TEST NO. 3 CORRECTED AVERAGES

1/2 inch orifice rounded approach

P_1	P_2	T_1	T_2	t_1	t_2	Lbs.per
Lbs.per sq.in.abs.		Degrees F.		Degs. of superheat		sq. in.
114.3	94.3	430	416	93	93	12.75
114.3	84.3	438	424	101	109	14.20
114.3	74.3	433	418	96	112	15.70
114.3	76.3	428	415	91	107	15.70
114.3	72.3	437	424	100	120	15.90
114.3	70.3	439	425	102	122	16.10
114.3	68.3	439	425	102	124	16.20
114.3	66.3	440	426	103	127	16.40
114.3	64.3	440	425	103	128	16.65
114.3	59.3	439	423	102	132	16.90
114.3	53.3	438	419	101	134	17.30
114.3	44.3	438	417	101	144	17.45
114.3	34.3	439	415	102	158	17.50

Average superheat 100° F.

TEST NO. 4. CORRECTED AVERAGES

1/2 inch orifice rounded approach.

P_1	P_2	T_1	T_2	t_1	t_2	Lbs. per
Lbs.per sq.in. abs.		Degrees F.		Degs. of superheat		sq. in.
114.3	94.3	367	356	30	35	13.3
114.3	84.3	374	362	37	47	15.0
114.3	74.3	375	360	38	53	15.95?
114.3	74.3	374	359	37	52	16.45
114.3	72.3	375	359	38	54	16.70
114.3	70.3	374	357	37	54	17.05
114.3	68.3	376	357	39	56	17.10
114.3	66.3	372	353	35	54	17.40
114.3	64.3	371	351	34	54	17.60
114.3	62.3	373	352	36	57	17.80
114.3	59.3	373	351	36	60	17.70
114.3	54.3	372	347	35	61	18.10
114.3	49.3	372	346	35	66	18.20
114.3	44.3	373	345	36	72	18.30
114.3	39.3	374	344	37	78	18.34
114.3	34.3	374	341	37	83	18.34
114.3	24.3	373	338	36	100	18.45
114.3	18.3	372	335	35	113	18.30

Average superheat 36° F.

TEST NO. 5 CORRECTED AVERAGES
1/4 inch orifice rounded approach.

P_1 Lbs.per sq.in.	P_2 abs.	T_1 Degrees F.	T_2	t_1 Degrees of superheat	t_2	Lbs. per sq.in.
114.3	94.3	531	510	194	187	3.26
114.3	74.3	545	524	208	218	3.96
114.3	69.3	531	510	194	208	4.15
114.3	64.3	524	502	187	205	4.37
114.3	59.3	534	510	197	218	4.33
114.3	54.3	527	504	190	218	4.40
114.3	44.3	534	508	197	235	4.38
114.3	24.3	534	507	197	269	4.43

Average superheat 196° F.

TEST NO. 6 CORRECTED AVERAGES

1/4 inch orifice rounded approach

P_1	P_2	T_1	T_2	t_1	t_2	Lbs.per	V_1	V_2
Lbs.per sq. in. abs.		Degrees F.		Degrees superheat		minute	cu.ft.	cu.ft.
104.3	94.3	525	596	194	183	2.30	5.47	6.00
104.3	74.3	532	513	201	206	3.48	5.5	7.75
104.3	64.3	524	505	193	208	3.80	5.46	8.70
104.3	59.3	523	518	192	226	3.88	5.45	9.70
104.3	57.3	521	497	190	208	3.90	5.43	9.75
104.3	24.3	533	505	202	267	4.03	5.51	23.50
	Average superheat			196° F.			5.48	

TEST NO. I

T_2 submerged 40° F.

Room Temperature 80°.

1/2 inch orifice rounded approach.

Time Hr.Min.	P_1 Lbs. per sq. in.	P_2	T_1 F°	T_2 F°	Gross wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per Min.
2:05	90	80	352	332	46	46	0	0
2:15	90	80	366	346	134	46	88	8.8
2:25	90	80	362	342	226	134	92	9.2
2:35	90	80	359	340	318	226	92	9.2
2:45	90	80	358	340	408	318	90	9.0
			Totals					
0:40			1797	1700	1132	770	362	
			Averages					
	90	80	355	340				9.05
			Corrected Averages					
	104.3	94.3	355	346				9.05

Time Hr.Min.	P_1 Lbs.	P_2 per sq.in	T_1 F°	T_2 F°	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
3:00	90	75	360	342	46	46	0	
3:10	90	75	358	342	152	46	106	10.6
3:20	90	75	357	341	258	152	106	10.6
3:30	90	75	357	342	364	258	106	10.6
			Totals					
0:30			1432	1367	820	502	318	
			Averages					
	90	75	358	342				10.6
			Corrected Averages					
	P_1 abs. 104.3	P_2 abs. 89.3	358	348				10.6
			- - - - - - -					
3:30	90	70	363	344	70	70	0	0
3:41	90	70	367	347	200	70	130	11.8
3:50	90	70	366	346	308	200	108	12.0
4:00	90	70	368	347	427	308	119	11.9
4:07	90	70	369	348	57	57	0	0
4:17	90	70	369	348	175	57	118	11.8
			Totals					
0:40			2202	2080	1237	762	475	
			Averages					
	90	70	367	347				11.9
			Corrected Averages.					
	104.3	84.3	367	353				11.9

Time Hr.Min.	P_1 Lbs. per sq. in.	P_2	T_1 F^o	T_2 F^o	Gross wt.lbs.	Tare wt.lbs.	Net wt lbs.	Lbs. per min.
3:38	90	65	353	337	45.5	45.5	0	0
3:50	90	65	349	335	204.5	45.5	159	13.25
4:00	90	65	350	335	337	204.5	133.5	13.35
4:10	90	65	350	334	467	337	130	13.00
			Totals					
0:32			1402	1341	1054	632.5	422.5	
			Averages					
			351	336				13.2
			Corrected Averages					
	104.3	79.3	351	342				13.2
			- - - - - -					
4:15	90	60	349	331	48	48	0	0
4:30	90	60	347	330	260	48	212	14.14
4:44:30	90	60	344	326	464	260	204	14.07
			Totals					
0:29:30			1040	987	772	356	416	
			Averages					
	90	60	348	329				14.1
			Corrected averages.					
	104.3	74.3	348	335				14.1

Time Hr.Min.	P_1 lbs. per	P_2 sq. in.	T_1 F^o	T_2 F^o	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
1:12	90	55	349	328	46	46	0	0
1:22	90	55	351	331	198	46	152	15.2
1:32	90	55	354	334	350	198	152	15.2
				Totals				
0:20			1054	993	594	290	304	30.4
				Averages				
	90	55	351	331				15.2
				Corrected Averages.				
	104.3	69.3	351	337				15.2
				- - - - - -				
1:45	90	54	357	337	46	46	0	
1:55	90	54	357	337	198.5	46	152.5	15.25
				Totals				
10			714	674	244.5	92	152.5	
				Averages				
	90	54	357	337				15.25
				Corrected Averages				
	104.3	68.3	357	344				15.25

Time Hr.	Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
1;	58	90	53	358	337	243.5	243.5	0	0
2:	08	90	53	360	339	396.	243.5	152.5	15.25
					Totals				
0:	10			718	676	639.5	487.	152.5	15.25
					Averages				
		90	53	359	338				15.25
					Corrected Averages				
		104.3	67.3	359	345				15.25
					- - - - - -				
2:	11	90	52	360	340	46	46	0	
2:	21	90	52	362	341	198	46	152	15.2
					Totals				
0:	10			722	681	244	92	152	15.2
					Averages				
		90	52	361	340				15.2
					Corrected Averages				
		104.3	66.3	361	347				15.2

Time Hr.Min.	P_1 Lbs. per sq.in.	P_2	T_1 F°	T_2 F°	Gross Wt. lbs.	Tare wt.lbs.	Net Wt.lbs.	Lbs. per min.
2:24	90	51	362	341	243.5	243.5	0	0
2:34	90	51	362	341	397	243.5	153.5	15.35
				Totals				
0:10			724	682	640.5	487.	153.5	15.35
				Averages				
	90	51	362	341				15.35
				Corrected Averages				
	104.3	65.3	362	348				15.35
				- - - - - - -				
4:20	90	50	367	340	215	215	0	
4:30	90	50	362	334	370	215	155	15.5
4:40	90	50	361	334	200	43	157	15.7
4:50	90	50	360	332	358	200	158	15.8
				Totals				
0:30			1450	1340	1143	673	470	15.7
				Averages				
	90	50	363	335				15.7
				Corrected Averages				
	104.3	64.3	363	342				15.7

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
2:37	90	49	362	340	45.5	45.5	0	0
2:47	90	49	362	341	200	45.5	154.5	15.45
				Totals				
0:10			724	681	245.5	91	154.5	15.45
				Averages				
	90	49	362	340				15.45
				Corrected Averages.				
	104.3	63.3	362	347				15.45
				- - - - - - - - -				
2:50	90	48	362	340	246.5	246.5		
3:00	90	48	364	342	402	246.5	155.5	15.55
				Totals				
0:10			726	682	648.5	493.	155.5	15.55
				Averages				
	90	48	363	341				15.55
				Corrected Averages				
	104.3	62.3	363	348				15.55

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per Min.
3:03	90	47	363	341	45.5	45.5	0	0
3:13	90	47	362	340	201	45.5	155.5	15.55
				Totals				
0:10			725	681	246.5	91	155.5	15.55
				Averages				
	90	47	362	340				15.55
				Corrected Averages.				
	104.3	61.3	362	347				15.55
				- - - - - - - -				
3:15	90	46	362	340	232.5	232.5	0	0
3:25	90	46	362	340	390	232.5	157.5	15.75
				Totals				
0:10			724	680	622.5	465	157.5	15.75
				Averages				
	90	46	362	340				15.75
				Corrected Averages.				
	104.3	60.3	362	347				15.75

Time Hr.Min.	P_1 Lbs.per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
3:30	90	45	362	339	45.5	45.5	0	0
3:40	90	45	362	339	204	45.5	158.5	15.85
3:50	90	45	361	336	362	204	158	15.8
3:54	90	45			425	362	63	15.75
4:00	90	45	361	338	140.5	46	94.5	15.75
			Totals					
0:30			1446	1354	1177	703.	474	
			Averages					
	90	45	362	339				15.8
			Corrected Averages					
	104.3	59.3	362	346				15.8
			- - - - - - -					
4:03	90	40	361	336	72.5	72.5	0	0
4:13	90	40	361	335	235	72.5	162.5	16.25
4:23	90	40	361	335	396	235	161	16.1
4:33	90	40	359	334	208.5	45.5	163	16.3
			Totals					
0:30			1442	1340	912	425.5	486.5	16.2
			Averages					
	90	40	361	335				16.2
			Corrected Averages.					
	104.3	54.3	361	342				16.2

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
12:32	90	30	355	307	64	64	0	0
12:42	90	30	357	310	236	64	172	17.2
12:52:30	90	30	359	313	418	236	182	17.3
1:02	90	30	359	315	205	46	159	16.6
1:12	90	30	359	315	373	205	168	16.8
				Totals				
0:40			1789	1560	1296	615	681	
				Averages				
	90	30	358	312				17.00
				Corrected Averages				
	104.3	44.3	358	318				17.00
				- - - - - -				
1:18	90	20	356	307	75	75	0	0
1:28	90	20	355	307	247	75	172	17.2
1:38	90	20	354	307	419	247	172	17.2
1:48	90	20	355	308	217	46	171	17.1
1:58	90	20	354	306	389	217	172	17.2
				Totals				
0:40			1774	1537	1347	660	687	
				Averages				
	90	20	355	307				17.2
				Corrected Averages				
	104.3	34.3	355	313				17.2

TEST NO. 2

T_2 submerged 80° F.

Room temperature 80° F.

1/2 inch orifice rounded approach.

Time Hr.Min.	P_1 Lbs.	P_2 per sq.in.	T_1 F°	T_2 F°	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per Min.
9:23	90	80	396	384	46	46	0	0
9:33	90	80	403	390	134	46	88	8.8
9:43	90	80	410	396	222	134	88	8.8
9:53	90	80	416	402	309	222	87	8.7
10:03	90	80	402	388	397	309	88	8.8
			Totals					
0:40			2027	1960	1108	757	351	
			Averages					
	90	80	405	392				8.8
			Corrected Averages					
	104.3	94.3	405	400				8.8

Time Hr.Min.	P_1 Lbs. per sq.in.	P_2	T_1 F°	T_2 F°	Gross Wt. Lbs.	Tare Wt.lbs.	Net wt.lbs.	Lbs. per Min.
10:06	90	70	402	380	46	46	0	0
10:16	90	70	372	358	159	46	113	11.3
10:26	90	70	390	377	276	159	117	11.7
10:36	90	70	405	390	392	276	116	11.6
10:40					439	392	47	11.72
10:46	90	70	412	396	115	46	69	11.5
10:56	90	70	416	400	229	115	114	11.4
			Totals					
0:50			2397	2301	1656	1080	576	
			Averages					
	90	70	400	384				11.5
			Corrected Averages					
	104.3	84.3	400	392				11.5
			- - - - - - -					
10:20	90	60	404	385	46	46	0	0
10:31	90	60	406	387	199	46	153	13.9
10:40	90	60	408	390	324	199	125	13.9
10:49	90	60	409	390	447	324	125	13.8
			Averages					
	90	60	407	388				13.9
			Corrected Averages.					
	104.3	74.3	407	396				13.9

Time Hr.Min.	P_1 Lbs. per sq.in.	P_2	T_1 F°	T_2 F°	Gross Wt. lbs.	Tare Wt.lbs.	Net Wt.lbs.	Lbs. per Min.
9:31	90	58	408	388	46	46	0	0
9:41	90	58	406	386	188	46	142	14.2
9:55	90	58	406	386	388	188	200	14.3
			Averages					
	90	58	406	386				14.25
			Corrected Averages					
	104.3	72.3	406	394				14.25
			- - - - - - -					
9:59	90	56	407	386	46	46	0	0
10:09	90	56	407	386	193	46	147	14.7
10:19	90	56	408	387	339	193	146	14.6
			Averages					
	90	56	407	386				14.6
			Corrected Averages.					
	104.3	70.3	407	394				14.6
			- - - - - - -					
10:22	90	54	408	386	46	46	0	0
10:32	90	54	407	386	192	46	146	14.6
10:42	90	54	407	386	341	192	149	14.9
			Averages					
	90	54	407	386				14.75
			Corrected Averages.					
	104.3	68.3	407	394				14.75

Time Hr.Min.	P_1 Lbs. per sq.in	P_2	T_1 F°	T_2 F°2	Gross wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per Min.
10:45	90	52	407	386	46	46	0	0
10:55	90	52	408	386	195	46	149	14.9
11:05	90	52	408	386	345	195	150	15.0
				Averages				
	90	52	408	386				14.95
				Corrected Averages.				
	104.3	66.3	408	394				14.95
				- - - - - - - - -				
10:55	90	50	409	387	46	46	0	0
11:15	90	50	398	376	352	46	306	15.3
11:21	90	50	396	374	443	352	91	15.2
				Averages				
	90	50	401	380				15.3
				Corrected Averages.				
	104.3	64.3	401	388				15.3
				- - - - - - - - -				
11:06	90	48	407	384	46	46	0	0
11:18	90	48	405	381	200	46	154	15.4
11:28	90	48	404	380	353	200	153	15.3
				Averages				
	90	48	405	382				15.35
				Corrected Averages				
	104.3	62.3	405	390				15.35

Time Hr. Min.	P_1 Lbs. per sq.in.	P_2	T_1 F°	T_2 F°	Gross wt. lbs.	Tare wt. lbs.	Net wt. lbs.	Lbs. per min.
11:32	90	46	402	378	46	46	0	0
11:42	90	46	398	374	200	46	154	15.4
11:52	90	46	395	371	357	200	157	15.7
				Averages				
	90	46	399	374				15.55
				Corrected Averages.				
	104.3	60.3	399	382				15.55
				- - - - - - - - -				
1:21	90	40	408	382	46	46	0	0
1:30	90	40	412	386	189	46	143	15.9
1:40	90	40	416	390	350	189	161	16.1
1:45	90	40	417	390	431	350	81	16.2
				Averages				
	90	40	413	387				16.05
				Corrected Averages				
	104.3	54.3	413	397				16.05
				- - - - - - - - -				
1:50	90	30	418	388	46	46	0	0
2:00	90	30	420	392	206	46	160	16.0
2:10	90	30	424	394	369	206	163	16.3
				Averages				
	90	30	421	391				16.1
				Corrected Averages				
	104.3	44.3	421	399				16.1

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross Wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
2:40	90	20	426	394	46	46	0	0
2:50	90	20	426	395	209	46	163	16.3
3:00	90	20	426	395	375	209	164	16.4
3:10	90	20	427	397	208	46	162	16.2
			Averages					
	90	20	426	396				16.35
			Corrected Averages.					
	104.3	34.3	426	405				16.35

TEST NO. 3

Thermometer T_2 submerged 80° F.

Room Temperature 80°

1/2 inch orifice rounded approach.

Time Hr.	Min.	P_1 Lbs.	P_2 per sq.in.	T_1 F°	T_2 F°	Gross Wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
9:	27	100	80	420	396	46	46	0	0
9:	37	100	80	429	406	178	46	132	13.2
9:	47	100	80	434	411	304	178	126	12.6
9:	57	100	80	438	416	430	304	126	12.6
				Averages.					
		100	80	430	407				12.75
				Corrected Averages.					
		114.3	94.3	430	416				12.75
				- - - - - - - - -					
10:	00	100	70	440	416	46	46	0	0
10:	15	100	70	437	414	258	46	212	14.15
10:	29	100	70	438	414	457	258	199	14.2
				Averages					
		100	70	438	414				14.2
				Corrected Averages.					
		114.3	84.3	438	424				14.2

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
10:33	100	60	437	412	46	46	0	0
10:43	100	60	433	406	203	46	157	15.7
10:53	100	60	431	407	362	203	159	15.9
10:58	100	60	432	408	439	362	77	15.4
11:06	100	60	430	405	171	46	125	15.65
			Averages					
	100	60	433	418				15.7
			Corrected Averages.					
	114.3	74.3	433	418				15.7
			- - - - - - - - -					
11:10	100	62	427	404	46	46	0	0
11:20	100	62	432	408	201	46	155	15.5
11:30	100	62	426	403	360	201	159	15.9
			Averages					
	100	62	428	405				15.7
			Corrected Averages.					
	114.3	76.3	428	415				15.7

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross Wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
1:25	100	58	432	409	46	46	0	0
1:35	100	58	439	416	205	46	159	15.9
1:51	100	58	440	416	460	205	225	15.9
				Averages				
	100	58	437	414				15.9
				Corrected Averages.				
	114.3	72.3	437	424				15.9
				- - - - - - - - -				
1:53	100	56	440	416	46	46	0	0
2:03	100	56	439	415	207	46	161	16.1
2:13	100	56	439	415	368	207	161	16.1
				Averages.				
	100	56	439	415				16.1
				Corrected Averages.				
	114.3	70.3	439	425				16.1
				- - - - - - - - -				
2:15	100	54	439	415	46	46	0	0
2:26	100	54	439	415	224	46	178	16.2
2:36	100	54	439	416	386	224	162	16.2
				Averages.				
	100	54	439	415				16.2
				Corrected Averages				
	114.3	68.3	439	425				16.2

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt. lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
2:42	100	52	440	416	46	46	0	0
2:53	100	52	440	416	225	46	179	16.3
3:03	100	52	440	416	390	225	165	16.5
			Averages					
	100	52	440	416				16.4
			Corrected Averages.					
	114.3	66.3	440	426				16.4
			- - - - - - -					
3:06	100	50	440	416	46	46	0	0
3:16	100	50	440	415	212	46	166	16.6
3:26	100	50	440	414	379	212	167	16.7
			Averages					
	100	50	440	415				16.65
			Corrected Averages					
	114.3	64.3	440	425				16.65
			- - - - - - - -					
3:28	100	45	440	414	46	46	0	0
3:38	100	45	439	413	214	46	168	16.8
3:48	100	45	439	413	384	214	170	17.0
			Averages					
	100	45	439	413				16.9
			Corrected Averages					
	114.3	59.3	439	423				16.9

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F^0	T_2 F^0	Gross lbs. wt.	Tare lbs.wt.	Net lbs.wt.	Lbs. per min.
3:51	100	40	439	412	46	46	0	0
4:02	100	40	437	410	235	46	189	17.2
4:12	100	40	437	409	409	235	174	17.4
				Averages				
	100	40	438	410				17.3
				Corrected Averages.				
	114.3	53.3	438	419				17.3
				- - - - - - - -				
4:14	100	30	436	406	46	46	0	0
4:24	100	30	440	410	219	46	173	17.3
4:34	100	30	437	407	395	219	176	17.6
				Averages.				
	100	30	438	408				17.45
				Corrected Averages				
	114.3	44.3	438	417				17.45
				- - - - - - - - -				
4:36	100	20	436	403	46	46	0	0
4:46	100	20	440	407	222	46	176	17.6
4:51	100	20	442	410	309	222	87	17.4
				Averages				
	100	20	439	407				17.5
				Corrected Averages.				
	114.3	34.3	439	415				17.5

TEST NO. 4

T_2 submerged 60° F.

Room Temperature 60° F.

1/2 inch orifice rounded approach.

Time Hr.Min.	P_1 Lbs. per sq. in.	P_2	T_1 F°	T_2 F°	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
8:37	100	80	361	344	46	46	0	0
8:47	100	80	367	350	180	46	134	13.4
8:57	100	80	373	356	312	180	132	13.2
			Averages.					
	100	80	367	350				13.3
			Corrected Averages.					
	114.3	94.3	367	358				13.3
			- - - - - - - - -					
9:00	100	70	375	355	46	46	0	0
9:12	100	70	374	354	226	46	180	15.0
9:20	100	70	374	354	346	226	120	15.0
			Averages					
	100	70	374	354				15.0
			Corrected Averages.					
	114.3	84.3	374	362				15.0
			- - - - - - - - -					
9:23	100	62	375	352	46	46	0	0
9:33	100	62	376	353	205	46	159	15.9
9:44	100	62	374	351	381	205	176	16.0
			Averages					
	100	62	375	352				15.95
			Corrected Averages					
	114.3	74.3	375	360				15.95

Time Hr.Min.	P_1 Lns. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
9:46	100	60	374	350	46	46	0	0
9:56	100	60	374	350	210	46	157	16.4
10:06	100	60	375	352	375	210	165	16.5
			Averages					
	100	60	374	351				16.45
			Corrected Averages					
	114.3	74.3	374	359				16.45
			- - - - - - - - -					
10:08	100	58	375	351	46	46	0	0
10:18	100	58	377	354	212	46	166	16.6
10:28	100	58	374	349	380	212	168	16.8
			Averages.					
	100	58	375	351				16.70
			Corrected Averages					
	114.3	72.3	375	359				16.70
			- - - - - - - - -					
10:30	100	56	373	348	46	46	0	0
10:40	100	56	375	350	216	46	170	17.0
10:50	100	56	375	350	387	216	171	17.1
			Averages					
	100	56	374	349				17.05
			Corrected Averages.					
	114.3	70.3	374	357				17.05

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
10:52	100	54	376	350	46	46	0	0
11:02	100	54	377	351	216	46	170	17.0
11:12	100	54	375	350	388	216	172	17.2
				Averages.				
	100	54	376	350				17.1
				Corrected Averages.				
	114.3	68.3	376	357				17.1
				- - - - - - - - -				
11:14	100	52	374	348	46	46	0	0
11:24	100	52	380	344	221	46	175	17.5
11:34	100	52	372	346	394	221	173	17.3
				Averages.				
	100	52	372	346				17.4
				Corrected Averages.				
	114.3	66.3	372	353				17.4
				- - - - - - - - -				
11:36	100	50	372	345	46	46	0	0
11:47	100	50	372	345	238	46	192	17.5
11:57	100	50	369	342	415	238	177	17.7
				Averages.				
	100	50	371	344				17.6
				Corrected Averages				
	114.3	64.3	371	351				17.6

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross Wt.lbs.	Tare Wt.lbs.	Net Wt.lbs.	Lbs. per min.
1:13	100	48	376	349	46	46	0	0
1:23	100	48	372	344	224	46	178	17.8
1:33	100	48	372	344	402	224	178	17.8
				Averages.				
	100	48	373	346				17.8
				Corrected Averages				
	114.3	62.3	373	352				17.8
				- - - - - - - -				
1:35	100	45	372	344	46	46	0	0
1:45	100	45	374	345	223	46	177	17.7
				Averages				
	100	45	373	345				17.7
				Corrected Averages				
	114.3	59.3	373	351				17.7
				- - - - - - - -				
1:47	100	40	373	342	46	46	0	0
1:57	100	40	372	340	227	46	181	18.1
2:07	100	40	372	342	408	227	181	18.1
				Averages.				
	100	40	372	341				18.1
				Corrected Averages				
	114.3	54.3	372	347				18.1

Time Hr.Min	P_1 Lbs.per	P_2 sq.in.	T_1 F^{o1}	T_2 F^{o2}	Gross wt.lbs.	Tare wt.lbs.	Net wt.lbs.	Lbs. per min.
2:09	100	35	372	340	46	46	0	0
2:19	100	35	372	340	228	46	182	18.2
			Averages.					
	100	35	372	340				18.2
			Corrected Averages.					
	114.3	49.3	372	346				18.2
			- - - - - - - -					
2:21	100	30	372	338	46	46	0	0
2:31	100	30	372	338	229	46	183	18.3
2:41	100	30	374	340	412	229	183	18.3
			Averages					
	100	30	373	339				18.3
			Corrected Averages.					
	114.3	44.3	373	345				18.3
			- - - - - - - - -					
2:43	100	25	374	338	46	46	0	0
2:55	100	25	374	339	266	46	220	18.34
			Averages					
	100	25	374	338				18.34
			Corrected Averages					
	114.3	39.3	374	344				18.34

Time Hr.Min.	P_1 Lbs.per	P_2 sq.in.	T_1 F°	T_2 F°	Gross Wt.lbs.	Ware wt.lbs.	Net wt.lbs.	Lbs. per Min.
2:57	100	20	375	336	46	46	0	0
3:07	100	20	373	334	229	46	183	18.3
3:17	100	20	374	336	413	229	184	18.4
			Averages					
	100	20	374	335				18.34
			Corrected Averages					
	114.3	34.3	374	341				18.34
			- - - - - - - - -					
3:20	100	10	374	333	46	46	0	
3:35	100	10	371	330	323	46	277	18.45
			Averages					
	100	10	373	332				18.45
			Corrected Averages					
	114.3	24.3	373	338				18.45
			- - - - - - - - -					
3:40	100	4	371	328	46	46	0	
3:50	100	4	372	330	229	46	183	18.3
			Averages					
	100	4	372	329				18.3
			Corrected Averages.					
	114.3	18.3	372	335				18.3

TEST NO. 5

T_2 submerged 80° F.

Room Temperature 80°

1/2 inch orifice rounded approach.

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross Wt. lbs.	Tare Wt.lbs.	Net Wt.lbs.	Lbs. per min.
10:16	100	80	508	475	45.5	45.5	0	0
10:26	100	80	532	495	82.5	45.5	37	3.7
10:36	100	80	553	513	112	82.5	29.5	2.95
10:47	100	80	541	503	147	112	35	3.18
10:56	100	80	519	486	176	147	29	3.22
			Averages					
	100	80	531	495				3.26
			Corrected Averages.					
	114.3	94.3	531	510				3.26
			- - - - - - - -					
10:59	100	60	520	486	187	187	0	0
11:12	100	60	550	512	237.5	187	50.5	3.9
11:22	100	60	563	523	278.5	237.5	41.	4.1
11:32	100	60	547	510	317.5	278.5	39	3.9
			Averages.					
	100	60	545	508				3.96
			Corrected Averages.					
	114.3	74.3	545	524				3.96

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross Wt.lbs.	Tare Wt.lbs.	Net Wt.lbs.	Lbs. per min.
11:35	100	55	541	504	45.5	45.5	0	0
11:45	100	55	530	494	87	45.5	41.5	4.15
11:55	100	55	528	492	128.5	87	41.5	4.15
12:05	100	55	525	489	170	128.5	41.5	4.15
				Averages				
	100	55	531	495				4.15
				Corrected Averages				
	114.3	69.3	531	510				4.15
				- - - - - - - - -				
12:08	100	50	525	488	182.5	182.5	0	0
12:20	100	50	525	488	233	182.5	50.5	4.21
12:32	100	50	530	492	283.5	233	50.5	4.21
12:46	100	50	514	479	348.5	283.5	65.0	4.65
				Averages.				
	100	50	524	487				4.37
				Corrected averages.				
	114.3	64.3	524	502				4.37

Time Hr.Min.	P_1 Lbs. per	P_2 sq.in.	T_1 F°	T_2 F°	Gross Wt.lbs.	Tare Wt.lbs.	Net Wt.lbs.	Lbs. per min.
12:50	100	45	513	477	45.5	45.5	0	0
1:00	100	45	527	489	89.5	45.5	44	4.40
1:10	100	45	543	503	133	89.5	43.5	4.35
1:21	100	45	553	512	179.5	133	46.5	4.23
			Averages.					
	100	45	534	495				4.33
			Corrected Averages					
	114.3	59.3	534	510				4.33
			- - - - - - - - -					
1:23	100	40	550	509	188.5	18855	0	0
1:34	100	40	517	479	235.	188.5	46.5	4.23
1:53	100	40	515	478	320.5	235.	85.5	4.5
			Averages.					
	100	40	527	489				4.4
			Corrected Averages.					
	114.3	54.3	527	504				4.4
			- - - - - - - - -					
1:58	100	30	532	490	45.5	45.5	0	0
2:10	100	30	536	496	98	45.5	52.5	4.38
			Corrected Averages.					
	114.3	44.3	534	508				4.38
			- - - - - - - - -					
2:15	100	10	533	492	120.5	120.5	0	
2:29	100	10	534	492	182.5	120.5	62.	4.43
			Corrected Averages.					
	114.3	24.3	534	507				4.43

TEST NO. 6

Degrees on Th_2 exposed to T_2 = 80° F.

Room Temperature 80° F.

1/4 inch orifice rounded approach.

Time Hr.Min.	P_1 Lbs.per	P_2 sq.in.	T_1 F°	T_2 F°	Gross Wt.lbs.	Tare Wt.lbs.	Net Wt.lbs.	Lbs. per min.
2:34	90	80	527	492	202	202	0	0
2:45	90	80	515	483	222.5	202	20.5	1.865?
2:56	90	80	523	490	252.5	222.5	30.0	2.73 ?
3:06	90	80	535	499	275.5	252.5	23.0	2.3
			Corrected Averages					
	104.3	94.3	525	506				2.3
			- - - - - - - - -					
3:10	90	60	545	507	286	286	0	0
3:20	90	60	565	528	320.5	286	34.5	3.45
3:32	90	60	517	486	362.5	320.5	42.	3.5
3:38	90	60	502	472	383.5	362.5	21.	3.5
			Corrected averages.					
	104.3	74.3	532	513				3.48
			- - - - - - - - -					
4:00	90	50	510	477	45.5	45.5	0	0
4:10	90	50	527	493	84.	45.5	38.5	3.85
4:15	90	50	536	500	102.5	84	18.5	3.70
			Corrected Averages					
	104.3	64.3	524	505				3.80

Time Hr.Min.	P_1 Lbs.per	P_2 sq.in.	T_1 F^1	T_2 F^2	Gross Wt.lbs.	Tare Wt.lbs.	Net Wt.lbs	Lbs. per min.
4:18	90	45	541	504	114	114	0	0
4:30	90	45	546	510	160	114	46	3.84
4:35	90	45	529	494	160	160	20	4.00
			Corrected averages					
	104.3	59.3	523	518				3.88
			- - - - - - - - -					
5:00	90	43	505	462	264	264	0	0
5:10	90	43	525	490	303	264	39	3.9
5:15	90	43	532	496	322.5	303	19.5	3.9
			Corrected averages					
	10413	57.3	521	497				3.9
			- - - - - - - - -					
5:18	90	10	535	493	334.5	334.5	0	0
5:28	90	10	535	493	375	334.5	40.5	4.05
5:35	90	10	530	488	403	375	28	4.00
			Corrected averages					
	104.3	24.3	533	505				4.03

DATA COLLECTED FROM COMPUTATIONS TO OBTAIN
THE THEORETICAL WEIGHT OF DISCHARGE.

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TEST NO. 1

Average Degrees of Superheat = 28° F.

P_1 = 104.3 lbs. abs. Q_1 = 1202

$\frac{P_2}{P_1}$	P_2	$Q_1 - Q_2$	Quality	Velocity	Volume	Weight
.905	94.3	8	15°	630	4.81	10.70
.857	89.3	13	9°	810	5.00	13.22
.808	84.3	18	2°	950	5.24	14.80
.760	79.3	23	.997	1070	5.52	15.83
.713	74.3	28	.993	1180	5.85	16.47
.616	64.3	39	.983	1415	6.64	17.20
.575	60.	44	.980	1480	7.01	17.30
.537	56.	50	.975	1580	7.46	17.28

TEST NO. 2

Average Degrees of Superheat = 77° F.

Q_1 = 1229 P_1 = 104.3 lbs. abs.

$\frac{P_2}{P_1}$	P_2	$Q_1 - Q_2$	Quality	Velocity	Volume	Weight
.905	94.3 89.3	10	65°	720	5.20	11.30
.808	84.3	19	53°	980	5.67	14.10
.713	74.3	30	36°	1225	6.23	16.05
.616	64.3	43	18°	1470	6.96	17.25
.580	60.3	48	10°	1550	7.29	17.35
.540	56.3	54	100°	1645	7.65	17.55

TEST NO. 3

Average Degrees of Superheat = 100°

P_1 = 114.3 Q_1 = 1243

P_2	$\frac{P_2}{P_1}$	$Q_1 - Q_2$	Quality	Velocity	Volume	Weight
94.3	.825	18	75°	950	5.27	14.70
89.3	.782	23	68°	1075	5.49	15.96
84.3	.738	28	60°	1175	5.73	16.70
74.3	.650	39	45°	1390	6.32	17.95
64.3	.563	51	26°	1600	7.03	18.58

TEST No. 4

Average Degrees of Superheat = 36°

P_1 = 114.3 Q_1 = 1209

P_2	$\frac{P_2}{P_1}$	$Q_1 - Q_2$	Quality	Velocity	Volume	Weight
97	.85	14	16° sup.	837	4.68	14.6
85	.744	25	1° sup.	1118	5.17	17.68
80	.700	30	.997	1224	5.44	18.35
70	.613	40	.988	1414	6.13	18.84
65	.569	46.5	.983	1524	6.53	19.04
62	.543	50.5	98	1588	6.81	19.06

TEST NO. 5

Average Degrees of Superheat = 196° F.

P_1 = 114.3 Q_1 = 1291

P_2	$\frac{P_2}{P_1}$	$Q_1 - Q_2$	Quality	Velocity	Volume	Weight
94.3	.825	21	164	1030	5.90	3.56
89.3	.782	26	158	1145	6.06	3.86
84.3	.738	32	148	1265	6.43	4.02
74.3	.650	44	129	1480	7.07	4.27
64.3	.563	57	108	1685	7.79	4.41
61.7	.54	63	100	1775	8.09	4.48

TEST NO. 6

Average Degrees Superheat = 196° F.

P_1 = 104.3 Q_1 = 1288

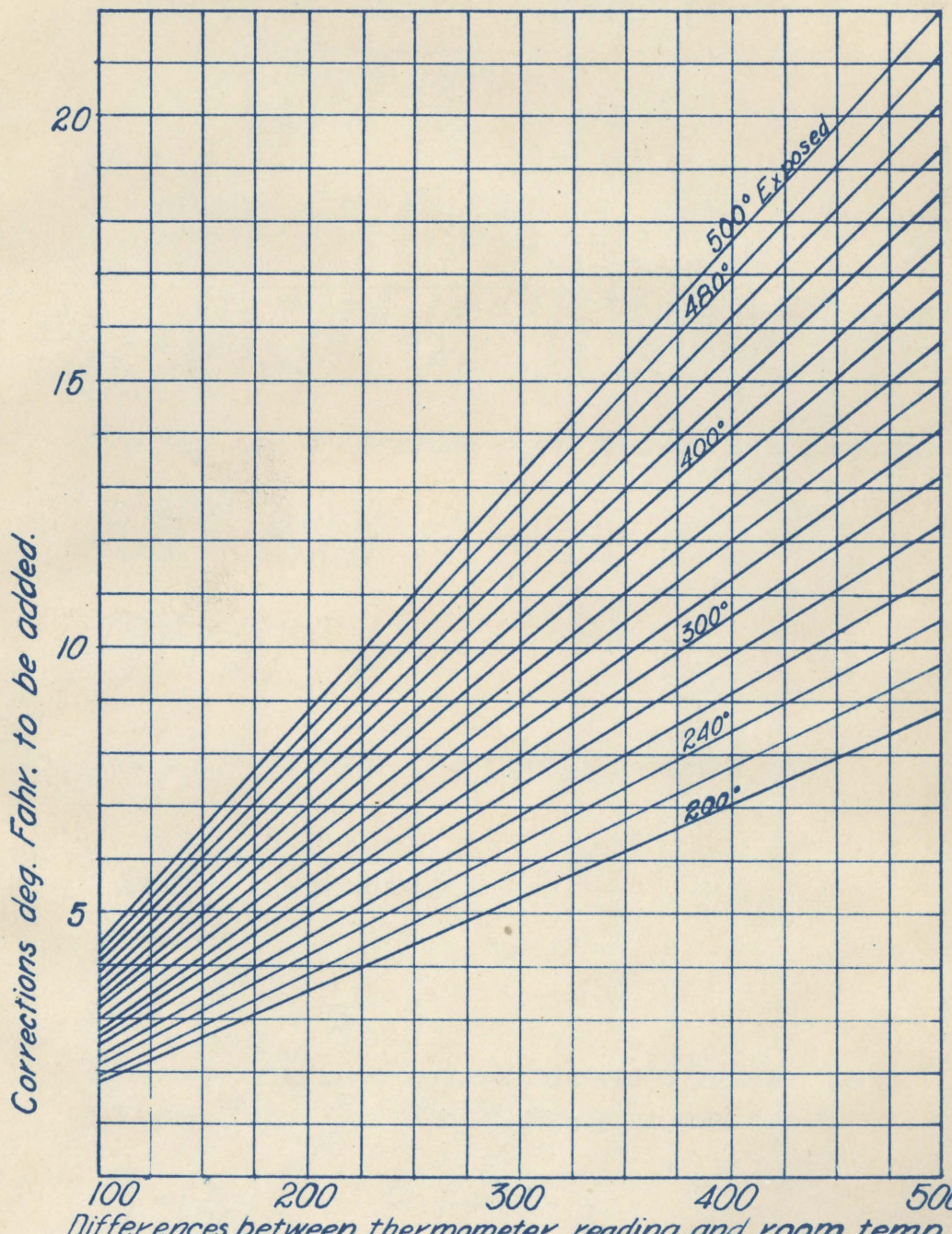
P_2	$\frac{P_2}{P_1}$	$Q_1 - Q_2$	Quality	Velocity	Volume	Weight
94.3	.905	10	180	725	6.01	2.46
89.3	.857	17	170	920	6.25	3.00
84.3	.809	22	162	1050	6.55	3.27
74.3	.713	35	142	1330	7.19	3.77
64.3	.617	49	120	1565	8.02	3.97
60.3	.578	54	113	1645	8. 44	3.98
56.3	.540	62	100	1760	8.85	4.06

THERMOMETER STEM EXPOSURE CORRECTIONS

$K = 0.000,088\,D(t - t')$

K = stem correction. t = thermometer reading

t' = room temperature. D = degrees exposed to t'



Thesis Flow of Steam R.O.C.

Proof that Maximum Weight of Flow Occurs when $\frac{P_2}{P_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$

$$W = \frac{V A}{S_2} = \frac{V A}{S_1}\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} = \frac{A}{S_1}\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}\sqrt{\frac{2gn}{n-1}P_1 S_1\left[1-\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right]}$$

$$= C\sqrt{\frac{P_1}{S_1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}} - \left(\frac{P_2}{P_1}\right)^{\frac{n+1}{n}}\right]}$$

where $C = A\sqrt{\left(\frac{2gn}{n-1}\right)}$

$$\frac{dW}{d\left(\frac{P_2}{P_1}\right)} = C\left\{\frac{1}{2}\sqrt{\frac{P_1}{S_1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}} - \left(\frac{P_2}{P_1}\right)^{\frac{n+1}{n}}\right]}\right\}^{-\frac{1}{2}}\left\{\frac{P_1}{S_1}\left[\frac{2}{n}\left(\frac{P_2}{P_1}\right)^{\frac{2-n}{n}} - \left(\frac{n+1}{n}\right)\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}\right]\right\}$$

Placing the expression equal to zero and simplifying

$$\frac{2}{n}\left(\frac{P_2}{P_1}\right)^{\frac{2-n}{n}} - \left(\frac{n+1}{n}\right)\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} = 0$$

$$\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}\left[2\left(\frac{P_2}{P_1}\right)^{\frac{1-n}{n}} - (n+1)\right] = 0$$

as $\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$ cannot be equal to zero

$$2\left(\frac{P_2}{P_1}\right)^{\frac{1-n}{n}} - (n+1) = 0$$

$$\left(\frac{P_2}{P_1}\right)^{\frac{1-n}{n}} = \frac{n+1}{2}$$

Raising this expression to the (-1) power and solving for $\frac{P_2}{P_1}$ the expression reduces to

$$\frac{P_2}{P_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}} \quad \text{Q.E.D.}$$