DETERMINATION OF THE FACTOR OF CONDENSATION IN AUTOMOBILE RADIATORS

BY

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CONTENTS

INTRODUCTION

Factor of Condensation of Various Types of Automobile Radiators.

Object: The purpose of this thesis is the empirical determination of the adaptability of the automobile radiator as a steam condenser. The information available on this subject is limited to comparatively few types of radiators. In truth, results obtained from previous experiments are based solely on conditions peculiar to the motor of that particular car without regard to the generality of certain conditions.

The factor of condensation is defined as being the British Thermal Units (B.T.U.) dissipated per hour per square foot of radiation surface per degree difference in temperature between the inside and outside. In making these determinations, it was necessary to make a number of corrections for calculations, such as correction for friction of air in the pipe, temperature of air while passing through the radiator, temperature of the steam passing through the radiator.

Measurement of Air in the Pipe.

This is one of the most important factors of this test. The air was forced through the condenser by a Sorocco fan, directly connected to a steam engine. The air was discharged from the fan into a galvanized iron pipe twenty-one inches in diameter and about thirty feet long. The radiator was placed at the discharge end of the pipe. The static pressure and impact velocity of the air was measured as it passed through the pipe. The measurements were made by the use of a pitot tube which was placed at a distance of about ten times the pipe diameter from the fan. The pitot tube used with suitable pressure measuring devices is particularly well adapted to the measuring of both pressure and volume, being easily and conveniently arranged for fan testing and also being simple, reliable and accurate. For common pressure measuring apparatus, for pressures above one inch, the water gage is satisfactory. For pressures from one inch to two or three feet, water manometers are reliable and convenient. Various forms of apparatus are used for measuring pressures of one inch or less. As simple and reliable a means as any is probably furnished by an inclined manometer containing gasoline. The tubes for this manometer should be of the same size, perfectly straight and parallel inside. Water should not be used when the angle of inclination from the horizontal is more than 3 to 1.

Set the back plate by boiling the bubbles in the manometer tubes and then swing the tubes up to the required angle to give a good reading, as 10 or 5 to 1. In fan testing for velocity reading at different restrictions two or three angles of inclination may be used to cover the wide range in pressure, and it is very convenient to cover this wide range with the gage by the single device of changing the angle. Great care and accuracy are necessary in changing a large angle as 40 to 1. For ordinary round galvanized pipe a simple and quick way to find the coefficient of friction of the air in the pipe is from the following formula:

$$F = \frac{Vel'' \times L'}{40 \times D'}$$

(Friction is expressed in inches of water.)

The velocity of the air in the pipe is calculated from the following formula:

$$V = 4100 \sqrt{Vel''}$$

(4100 being a velocity constant.)

(Velocity in inches is the impact reading of the manometer expressed in inches of water.)

The velocity of the air in a pipe is least at the surface of the pipe due to pipe friction. The locations of the pitot tube for the transverse readings in the pipe are found by the following method:

First, a determination is made as to the number of readings necessary for the determination of the velocity.

Divide the diameter of the pipe by the square root of twice the number of readings to be made from the circumference to the center of the diameter of the smallest velocity circle.

As for example:

Pipe diameter 21"

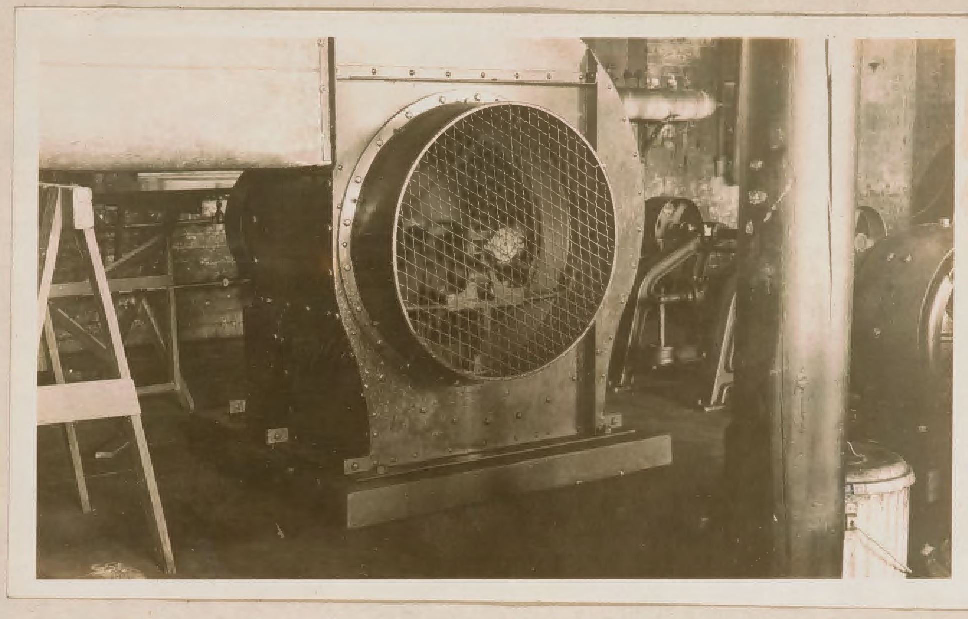
five readings to be made.

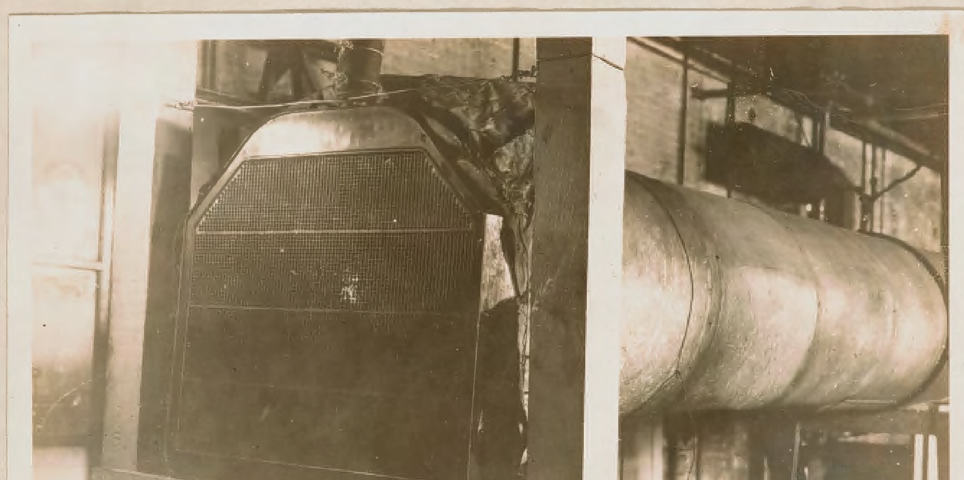
$\frac{21}{10} \times 3 =$

$\frac{21}{10} \times 5 =$ etc. gives diameter of velocity circles.

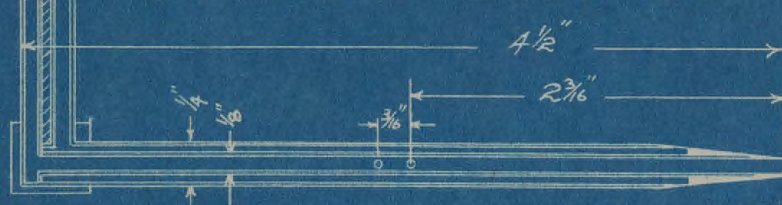
These velocity circles are divided into two equal area circles. It is on this line that the pitot tube is placed.

The calculated area of the pipe is 2.65 square feet.

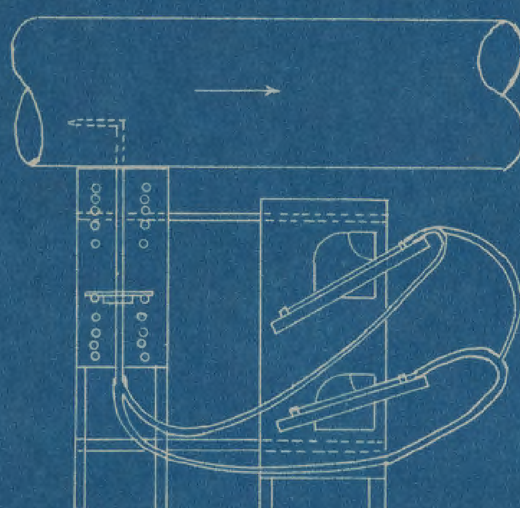




Pitot Tube Air Measurement



Apparatus For Measuring Impact and Static Pressures In An Air Pipe.



Chapter I.

THE DODGE RADIATOR.

The Dodge Radiator is made by the Dodge Motor Company, of Detroit, Michigan. This radiator is of the tubular type. It has six rows of twenty $\frac{1}{4}$ inch brass tubes each; these are $17\frac{3}{4}$ inches long. Around these tubes are 97 radiating brass fins 1/64 inch in thickness and 19-5/8 inches long. These fins are equally spaced, horizontally, over the full length of the tubes. In each fin between each row of tubes is a $\frac{1}{4}$ inch hole making six rows of nineteen holes each. This allows for a more thorough circulation of the air while passing through the radiator. The fins are 3-1/8 inches wide and 19-5/8 inches long.

The calculated total area of the radiation surface of this consenser is 86.5 square feet. The cooling system capacity is $2\frac{3}{4}$ gallons. The calculated air space of the condenser is 1.45 square feet.

DATA ON DODGE RADIATOR.

R.P.M. of Fan	Static Press. Inches of Gas.	Static Press. Inches of Water	Impact Press. Inches of Gas.	Impact Press. Inches of Water	Impact Press. Corrected for Friction
80	.080	.057	.010	.007	.0088
130	.125	.089	.015	.011	.0138
180	.240	.171	.020	.014	.0175
230	.473	.337	.028	.020	.0250
280	.640	.456	.077	.055	.0690
330	.700	.498	.110	.078	.0980
380	1.460	1.04	.150	.107	.1340
430	1.810	1.29	.200	.142	.1780
480	2.270	1.615	.250	.178	.2230

DATA ON DODGE RADIATOR (cont)

Vel.of Air in Condenser ft. per min.	Vel.of Air in Condenser. Cu.Ft.	Press. in Steam Line	Steam Press. at Condenser	Temperature of Steam	Latent Heat of Vaporization
715	1015	90	5	228.0	960
896	1272	85	6	230.6	958.3
1010	1485	85	6	230.6	958.3
1206	1712	86	7	233.1	956.7
2005	2845	88	8	235.6	958.1
2380	3380	78	10	240.0	958.0
2790	3960	78	10	280.0	952.0
3220	4570	90	13	246.4	947.8
3600	5110	91	13	246.4	947.8

DATA ON DODGE RADIATOR (cont)

Quality of Steam	Wt. of Tank and Water Beginning	Wt. of Tank and water at End	Temp.of Tank Water at Beginning	Temp. of Tank Water at End.
96.5	36.5	61.0	71	140
98.0	494.0	533.0	79	104
98.0	533	585.0	104	132
98.0	440	496.0	91	118
98.0	521	586.5	118	136
98.0	390	461.0	93	120
99.0	461	535.0	120	131
99.4	535	616.5	131	142
99.5	428.5	519.0	124	140

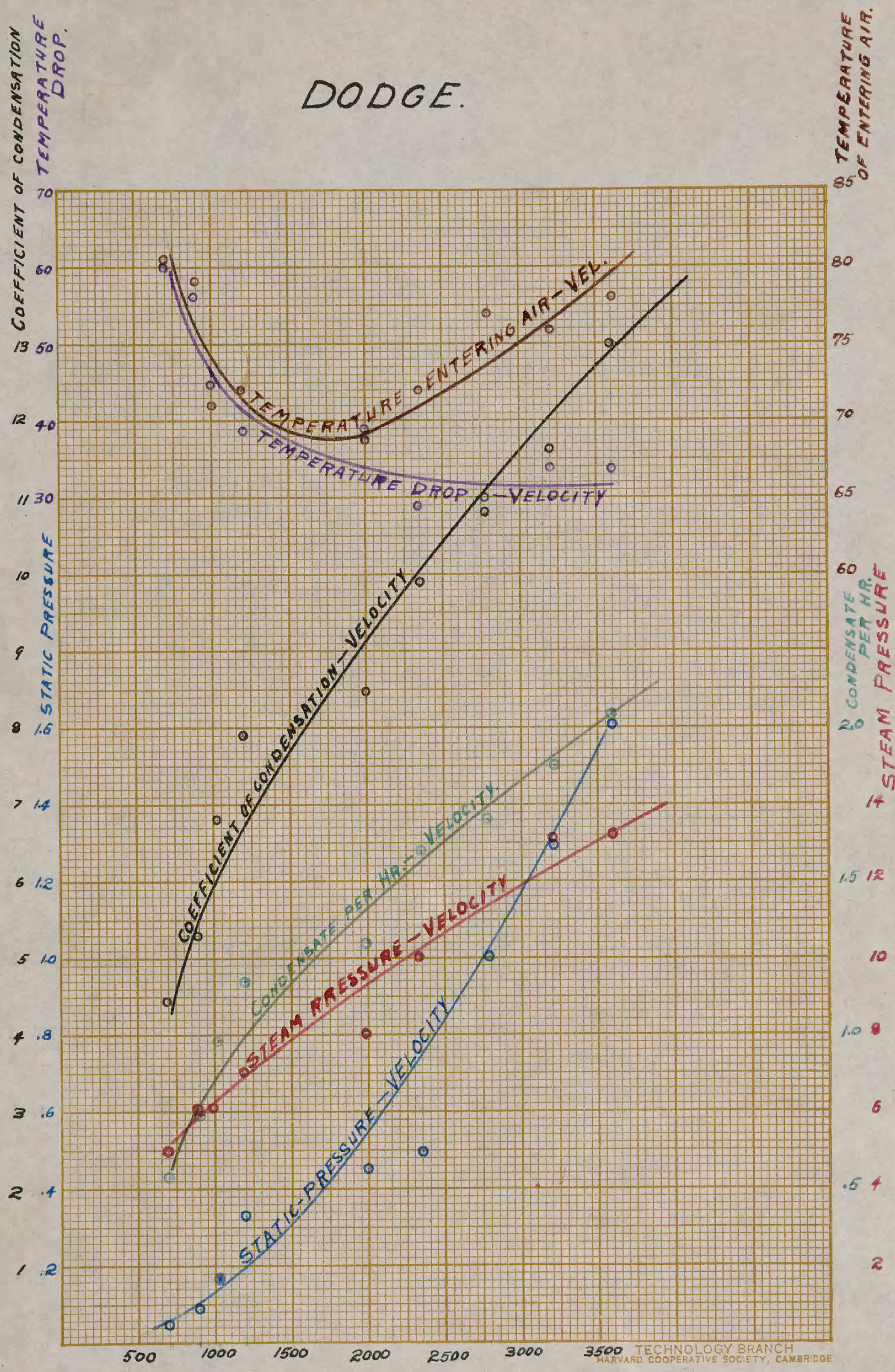
DATA ON DODGE RADIATOR (cont)

Steam Condensed in Rad. Per Hour	Steam Cond. per sq. ft. of Rad per hr.	Temp. of Entering Air	Temp. of Exit Air	Temp. Drop	Mean Temp. of Condensing Air.
47.2	.547	80	140	60	110.0
64.0	.742	79	125	56	97.0
84.9	.984	71	116	45	93.5
101.5	1.175	72	110	38	91.0
112.6	1.305	69	108	39	88.5
138.0	1.597	72	101	29	86.5
146.5	1.690	77	107	30	92.0
162.1	1.877	76	110	34	93.0
180.1	2.085	78	112	34	95.0

DATA ON DODGE RADIATOR (cont)

Temp. Difference Steam and Air	B.T.U. per hr. 1 sq. ft Radiator	Factor of Condensation
118.0	525	4.45
133.6	710	5.31
137.1	942	6.87
142.1	1125	7.92
147.0	1245	8.47
153.5	1520	9.90
148.0	1609	10.85
153.4	1780	11.60
154.0	1986	13.05

DODGE.



VELOCITY OF AIR IN RADIATOR, FT. PER MIN.

Chapter II

THE FEDERAL RADIATOR.

The Federal Radiator, made by the Federal Motor Company, of Detroit, Michigan, is of the tubular type. The radiator tested in this case was one of the U_2 model, used only on trucks. This condenser consists of six rows of twenty-eight 3/8 inch brass tubes each, twenty-three inches in length. These tubes are connected at the upper end to a water tank, and at the lower end to a tank which is much smaller. Around each tube running the full length of the tube is a helicoid brass fin 7/8 inch in diameter and 1/64 inch in thickness. This fin makes 121 turns on each tube. The radiator space on this radiator is 23 inches high and $26\frac{1}{4}$ inches wide.

The calculated total area of this radiator is 172 square feet and 4.1 square feet of air space through the radiator.

In the case of the Federal radiator, there were two complete tests made.

(1) No effort was made to hold the temperature of the condenser a constant throughout the entire test.

(2) The temperature of the condensate was held a constant for all the readings.

DATA ON FEDERAL RADIATOR

Temperature of Condensate held Constant.

R.P.M.	5-1 Gaso. Static	Gaso. Impact	Condenser Gage	Temp. of Entering Air	Temp. of Exhaust Air
80	.04	.02	2	76	116
130	.074	.062	3	79	116
180	.11	.084	4	79	116
230	.18	.11	7	81	118
280	.44	.22	$7\frac{1}{2}$	82	120
330	.55	.29	8	82	120
380	.75	.37	8	80	116
430	.94	.44	15	80	118
480	1.32	.55	17	83	120

DATA ON FEDERAL RADIATOR (cont)

Quality	Temp.of Water Beginning	Temp.of Water End	Wt. of Water Beginning	Wt. of Water End	Steam Line Press.
.97	190	0	225	307	78
.96	190	0	178	272	85
.97	190	0	222	330	90
.985	190	0	246	390	95
.95	190	0	115	279	80
.96	190	0	150	337	90
.98	190	0	197	403	80
.96	190	0	183	435	90
.98	190	0	117	281	85

DATA ON FEDERAL RADIATOR (cont)

Static Press. in inches of Water	Impact Press. In Water	Corrected Pressure	Velocity of air in condenser ft.per min.	Velocity of air in condenser cu.ft per min.
.028	.0142	.0177	349	1395
.053	.044	.0550	615	2520
.0783	.059	.0737	710	2900
.127	.0784	.098	824	3380
.314	.0157	.196	1168	4780
.396	.2065	.258	1339	5490
.534	.264	.338	1510	6190
.599	.314	.393	1648	6750
.940	.391	.489	1840	7550

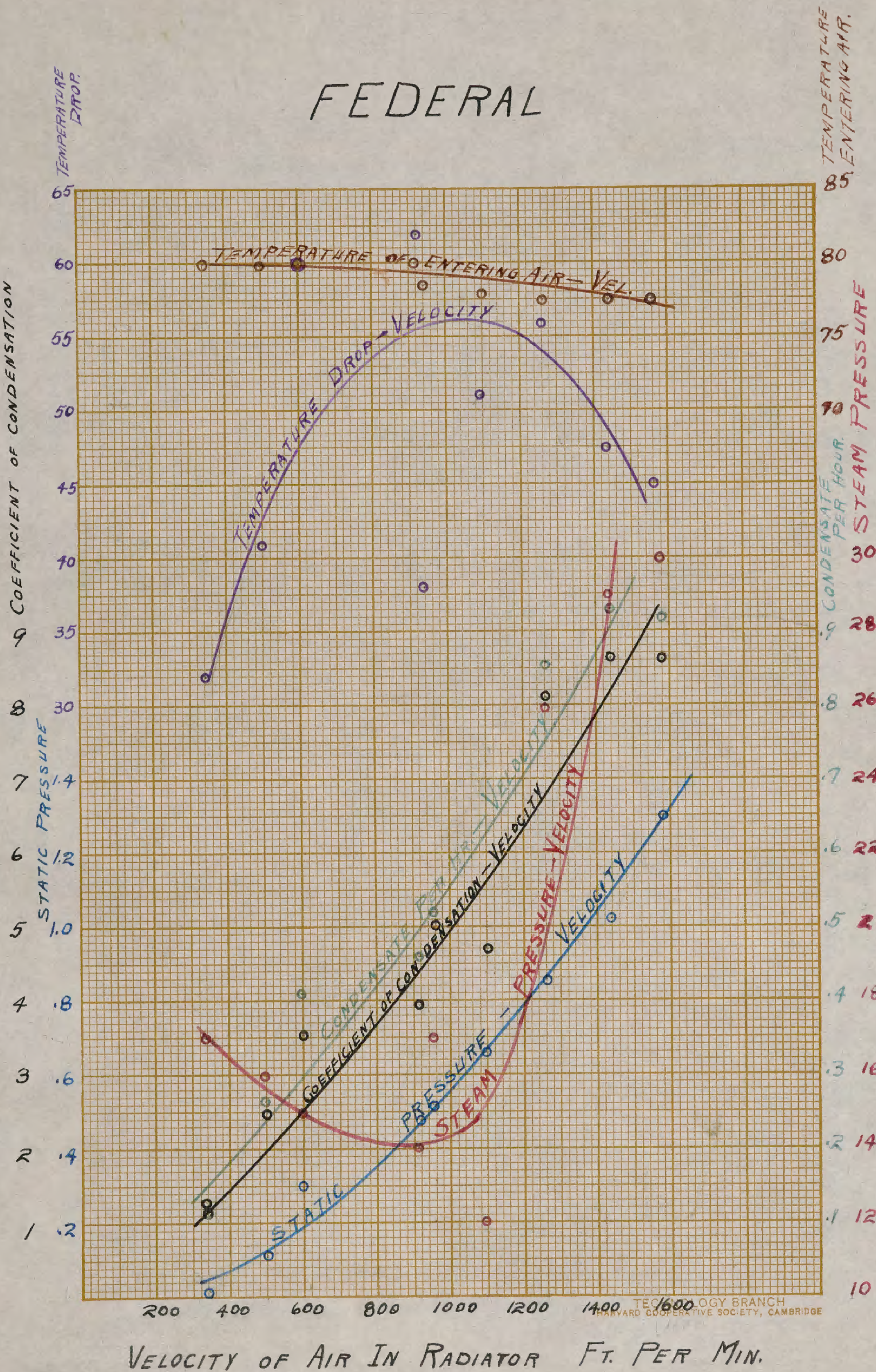
DATA ON FEDERAL RADIATOR (cont)

Steam Temp	Latent Heat of Vapori-zation	Steam Condensed per hour	Steam Con-densed per sq. ft of radiation per hour	Temp. Drop
218.5	967	82	.474	40
221.5	965.8	94	.544	37
224	964.4	108	.623	37
232.5	959.	144	.832	37
233	958.5	164	.950	38
234	957.8	187	1.080	38
234	957.8	206	1.290	36
248	948.6	252	1.455	38
253.5	945	264	1.525	37

DATA ON FEDERAL RADIATOR
(cont)

Mean Temp. of Condensing Air	Temp. difference in steam and air	B.T.U.per hr per sq.ft radiation	Factor
92	126.5	256	2.79
97.5	124.0	292	3.00
97.5	126.5	336	3.45
99.5	133.0	457	4.60
101.	132	500	4.95
101.	133	573	5.68
98.	136	700	7.15
99.	149	765	7.73
101.5	152	815	8.05

FEDERAL



TEMPERATURE DROP.
TEMPERATURE ENTERING AIR.
COEFFICIENT OF CONDENSATION
STATIC PRESSURE
CONDENSATE PER HOUR.
STEAM PRESSURE
TEMPERATURE OF ENTERING AIR — VEL.
TEMPERATURE DROP — VELOCITY
CONDENSATE PER AIR — VELOCITY
COEFFICIENT OF CONDENSATION — VELOCITY
STEAM PRESSURE — VELOCITY
STATIC PRESSURE — VELOCITY
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1600
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VELOCITY OF AIR IN RADIATOR FT. PER MIN.

DATA ON FEDERAL RADIATOR

R.P.M.	5-1 In Static	Gasoline Impact	Gage Press. at Condenser	Temp. of Entering Air	Temp. of Exhaust Air
80	.01	.02	17	80	112
130	.160	.04	16	80	121
180	.29	.06	15	80	140
230	.68	.14	14	80	142
280	.73	.15	17	78	116
330	.92	.20	12	78	129
380	1.23	.27	26	78	134
430	1.56	.34	29	78	126
480	1.83	.41	30	78	123

DATA ON FEDERAL RADIATOR (cont)

Quality	Temp. of Water Beginning	Temp. of Water End	Wt. of Water Beginning	Wt. of Water End
.95	110	112	137	159
.95	110	120	162	208
.945	120	144	208	280
.96	143	152	280	360
.96	144	144	93	183
.985	120	127	183	270
.98	127	151	270	420
.97	151	156	420	582
.963	156	157	582	742

DATA ON FEDERAL RADIATOR (cont)

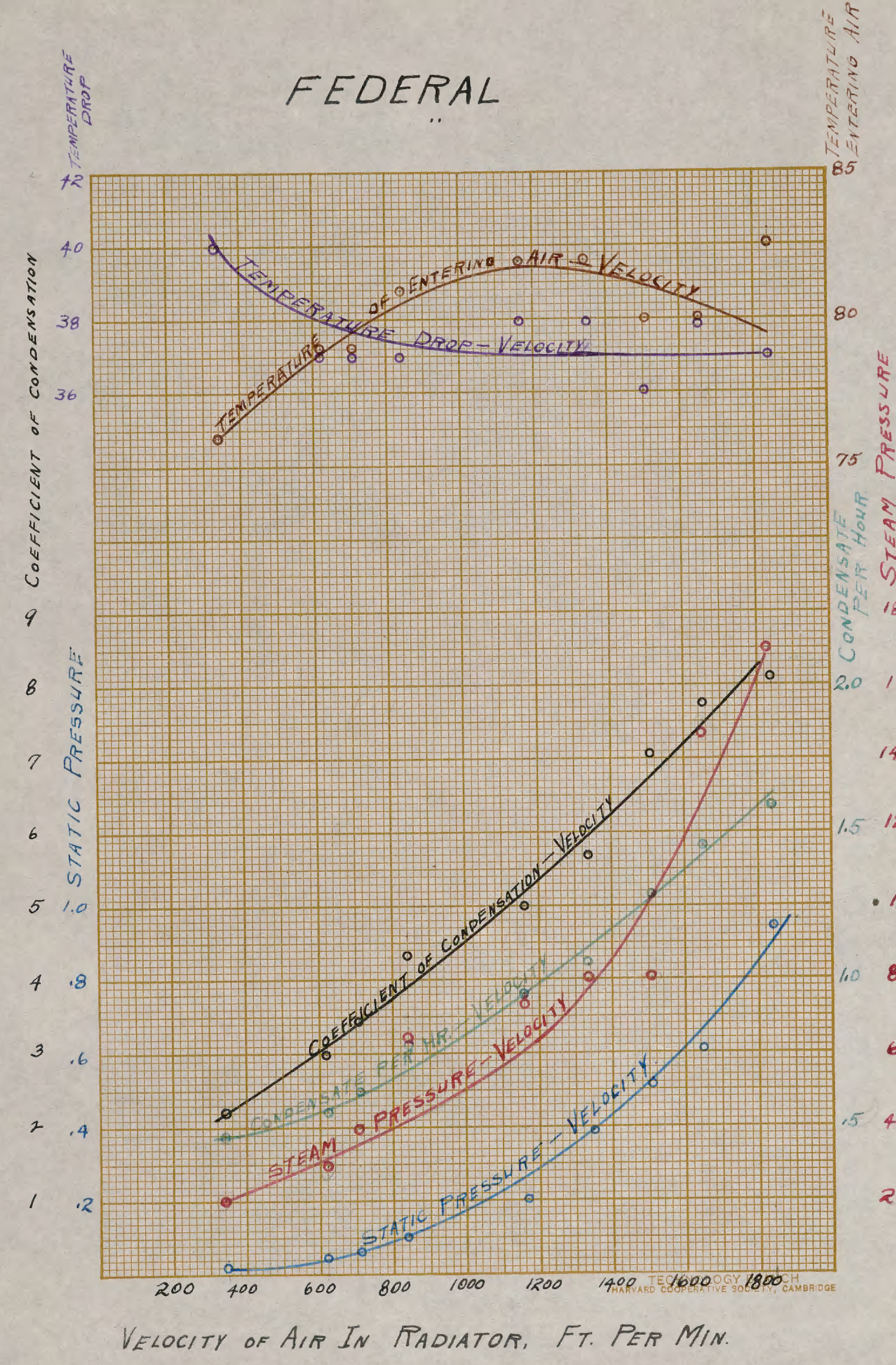
Steam Press.	Static Press. in Water	Impact Press. in Water	Corrected Impact	Velocity of Air in Condenser ft. per min
85	.0071	.0142	.0177	349
90	.114	.0285	.0356	496
85	.306	.0427	.0534	604
90	.484	.0997	.1248	929
95	.519	.1068	.1333	958
95	.655	.142	.177	1105
85	.876	.192	.240	1260
80	1.111	.242	.302	1444
87	1.303	.292	.365	1588

DATA ON FEDERAL RADIATOR (cont)

Vel. of Air in Condenser cu.ft per min.	Steam Temp.	Latent Heat of Vapori-zation	Steam Con-densed per Hour	Steam Con-densed per Sq. Ft. of Radiation.
1430	253.5	945	22	.127
2080	251.8	946.3	46	.266
2470	249.7	947.4	72	.416
3800	248	948.6	80	.463
3930	253.5	945	90	.520
4530	243.5	951.7	87	.504
5170	268	935	150	.868
5920	272.5	931	162	.938
6500	274	931.0	162	.925

DATA ON FEDERAL RADIATOR, (cont)

Temp. Drop	Mean Temp. of Condensing Air	Temp. Difference Steam and Air	B.T.U. per Hour per Sq. ft. radiation	Factor of Condensation.
32	96	157.5	119.2	1.24
41	100.5	151.3	248	2.48
60	110	139.7	388	3.53
62	111	137.0	438	3.95
38	97	156.5	491	5.06
51	104	139.5	493	4.72
56	106	162.0	856	8.10
48	102	170.5	883	8.65
45	100.5	173.5	865	8.62



FEDERAL
TEMPERATURE DROP
TEMPERATURE ENTERING AIR
COEFFICIENT OF CONDENSATION
STATIC PRESSURE
CONDENSATE PER HOUR
STEAM PRESSURE
TEMPERATURE OF ENTERING AIR - VELOCITY
TEMPERATURE DROP - VELOCITY
COEFFICIENT OF CONDENSATION - VELOCITY
CONDENSATE PER HR. - VELOCITY
STEAM PRESSURE - VELOCITY
STATIC PRESSURE - VELOCITY
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VELOCITY OF AIR IN RADIATOR, FT. PER MIN.

Chapter III

THE ELGIN RADIATOR

The Elgin radiator, manufactured by the Elgin Motor Company, of Elgin, Illinois, is of the honeycomb type. This radiator consists of a number of zig-zag tubes running from the upper tank to the small one at the bottom of the radiator.

The calculated total radiation surface was 49.3 square feet. The radiator was only two inches thick. The air space was 1.72 square feet.

DATA ON ELGIN RADIATOR

Temperature of condensate held constant.

R.P.M.	5 - 1 Gasoline Static	5 - 1 Gasoline Impact	Condenser Gauge	Temp. of Entering Air	Temp. of Exhaust Air
80	.019	.015	0	80	110
130	.064	.02	1	79	97
180	.19	.054	1.5	76	96
230	.296	.082	2	79	99
280	.474	.126	2	79	97
330	.61	.154	$2\frac{1}{2}$	80	102
380	.92	.21	3	81	101
430	1.23	.33	5	86	100
480	1.48	.44	6	80	104

DATA ON ELGIN RADIATOR (cont)

Quality	Temp. of Water Beginning	Temp. of Water Ending	Wt. of Water Beginning	Weight of Water Ending	Steam Line Press.
80.9	175	0	370	406	88
81.0	165	0	327	370	85
88.4	175	0	271	327	90
99.0	180	0	202	267	85
91.8	185	0	125	202	85
94.7	182	0	42	123	80
95.4	198	0	148	248	85
94.5	198	0	206	308	95
98.5	201	0	195	305	85

DATA ON ELGIN RADIATOR (cont)

Static Press. in. of Water	Impact Press. in. of Water	Corrected Press.	Vel. of Air in Condenser ft.per min.	Vel. of Air in Condenser cu.ft. per min.	Steam Temp.
.0135	.01078	.0134	849	1458	212
.0455	.01424	.0178	974	1672	215.5
.1353	.0384	.0480	1595	2741	216.5
.2107	.0583	.0729	1951	3360	218.5
.3374	.0897	.1121	2450	4225	218.5
.4343	.1096	.1370	2715	4660	220
.6550	.1495	.1869	3160	5450	221.5
.8757	.2349	.2936	3960	6820	227.5
1.0537	.3132	.3915	4575	8260	235

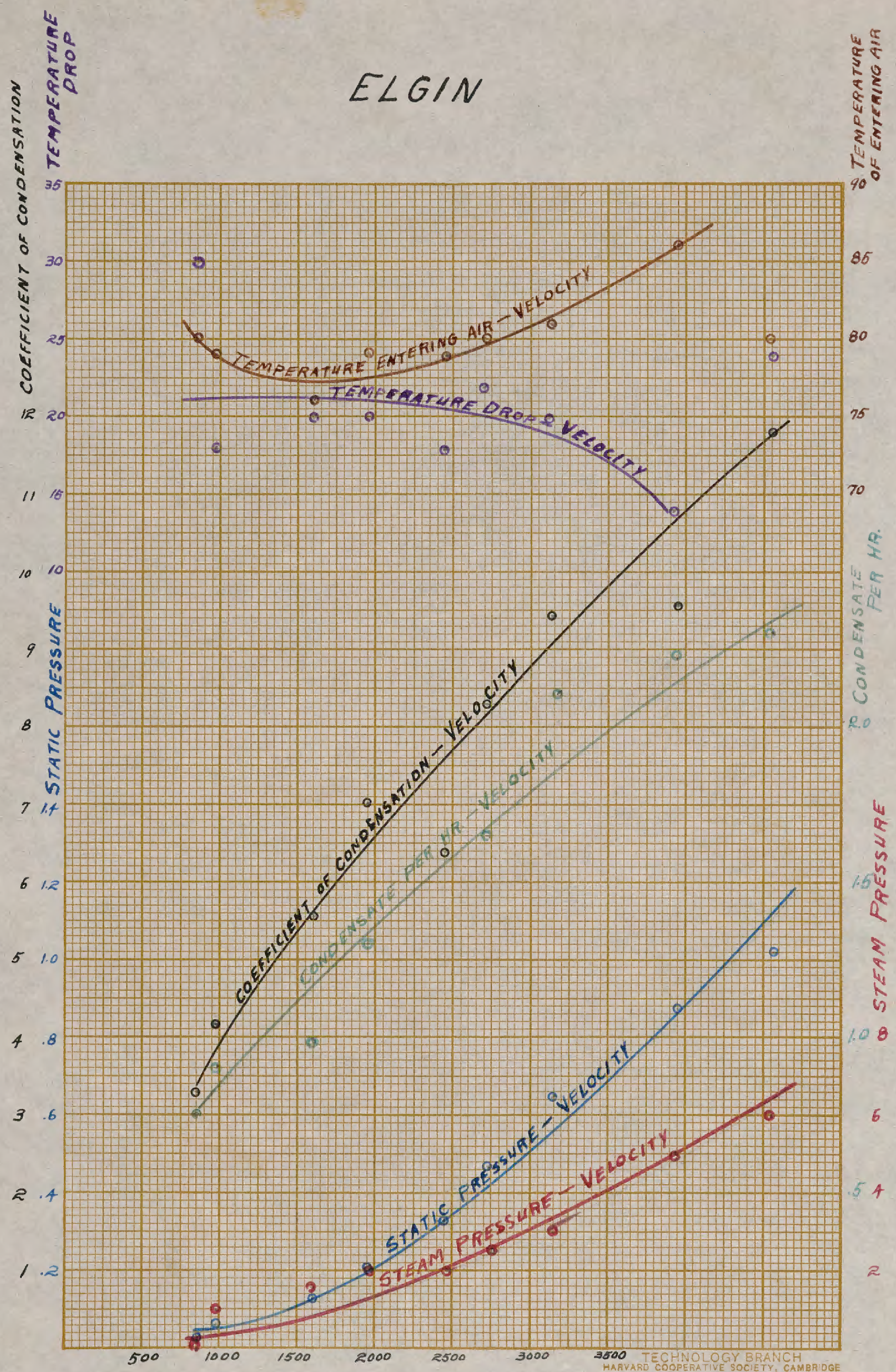
DATA ON ELGIN RADIATOR (cont)

Latent Heat of Vaporization	Steam condensed per Hour	Steam Condensed per sq.ft of Radiation per hour.	Temp. Drop	Mean Temp. of Condensate Water
971.7	36	.73	30	175
969.5	43	.87	18	165
969	56	.99	20	175
968	65	1.32	20	180
968	77	1.56	18	185
966.5	81	1.64	22	182
966.	100	2.14	20	198
962	102	2.38	14	198
957	120	2.43	24	201

DATA ON ELGIN RADIATOR (cont)

Temp. Difference in Steam and Air	B. T. U. per hour per sq.ft. of radiation	Factor of Condensation
37.0	575	3.28
50.5	686	4.16
41.5	970	5.54
38.5	1260	7.00
33.5	1172	6.34
38.0	1505	8.28
23.5	1860	9.45
29.5	1882	9.52
34.0	2295	11.80

ELGIN



VELOCITY OF AIR IN RADIATOR, FT. PER MIN.

Chapter IV

THE WINTON RADIATOR.

The radiator used on the late model Winton car is manufactured by the G. S. O. Manufacturing Company, of New Haven. Until the last three years this radiator was made by the Harrison Radiator Company, of Lockport, New York. The older model was the one tested in this case. This radiator was of the honeycomb type.

The dimensions of the radiating space are $23\frac{1}{4}$ inches wide and 20 inches high. The radiator was made in four horizontal sections of five inches each. The horizontal fins were 1/16 inch in thickness while the vertical fins were 1/32 inch thick. The three sectional partitions were 3/32 inch thick. The radiator was 4 inches thick. The calculated radiation surface was 178 square feet. The air space through the radiator was 2.75 square feet. There were two separate tests made of this radiator:

1. In which no attempt was made to hold the temperature of the condensate constant.

2. The temperature of the condensate was held a constant throughout the entire test.

DATA ON WINTON RADIATOR
Temperature of Condensate Varying.

R.P.M.	5 - 1 Gasoline Static	5 - 1 Gasoline Impact	Condenser Gauge	Steam Condensed	Temp. of Entering Air
80	.08	.04	1	86	79
120	.06	.04	2	113	72
180	.16	.088	4	125	76
230	.40	.238	8	175	75
280	.44	.25	8	175	80
330	.65	.35	14	188	82
380	.82	.444	14	200	70
430	1.03	.50	14	218	71

DATA ON WINTON RADIATOR (cont)

R.P.M.	5 - 1 Gasoline Static	Impact	Condenser Gauge	Steam Condensed	Temp. of Entering Air
480	1.25	.59	15	249	89

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DATA ON WINCON RADIATOR (cont)

Temp. of Exhaust Air	Quality	Temp. of Water Beginning	Temp of Water Ending	Wt. of Water Beginning	Weight of Water Endimg
134	90	71	89	220	306
124	92	138	136	270	383
127	92	120	139	145	270
122	92	98	132	131	305
128	96	152	144	156	331
126	96	110	166	162	350
116	98	112	118	175	375
114	97.4	110	112	162	380
124	99	188	0	119	368

DATA ON WINTON RADIATOR (cont)

Steam Press	Static Press. Inch of Water	Impact Press. Inch of Water	Corrected Impact	Vel. of Air in Condenser ft. per min.
90	.057	.028	.035	741
90	.043	.028	.035	741
92	.114	.073	.0912	1267
65	.284	.169	.210	1805
95	.313	.178	.221	1935
95	.463	.249	.312	2100
95	.583	.316	.395	2595
90	.733	.356	.445	2750
95	.890	.420	.525	2982

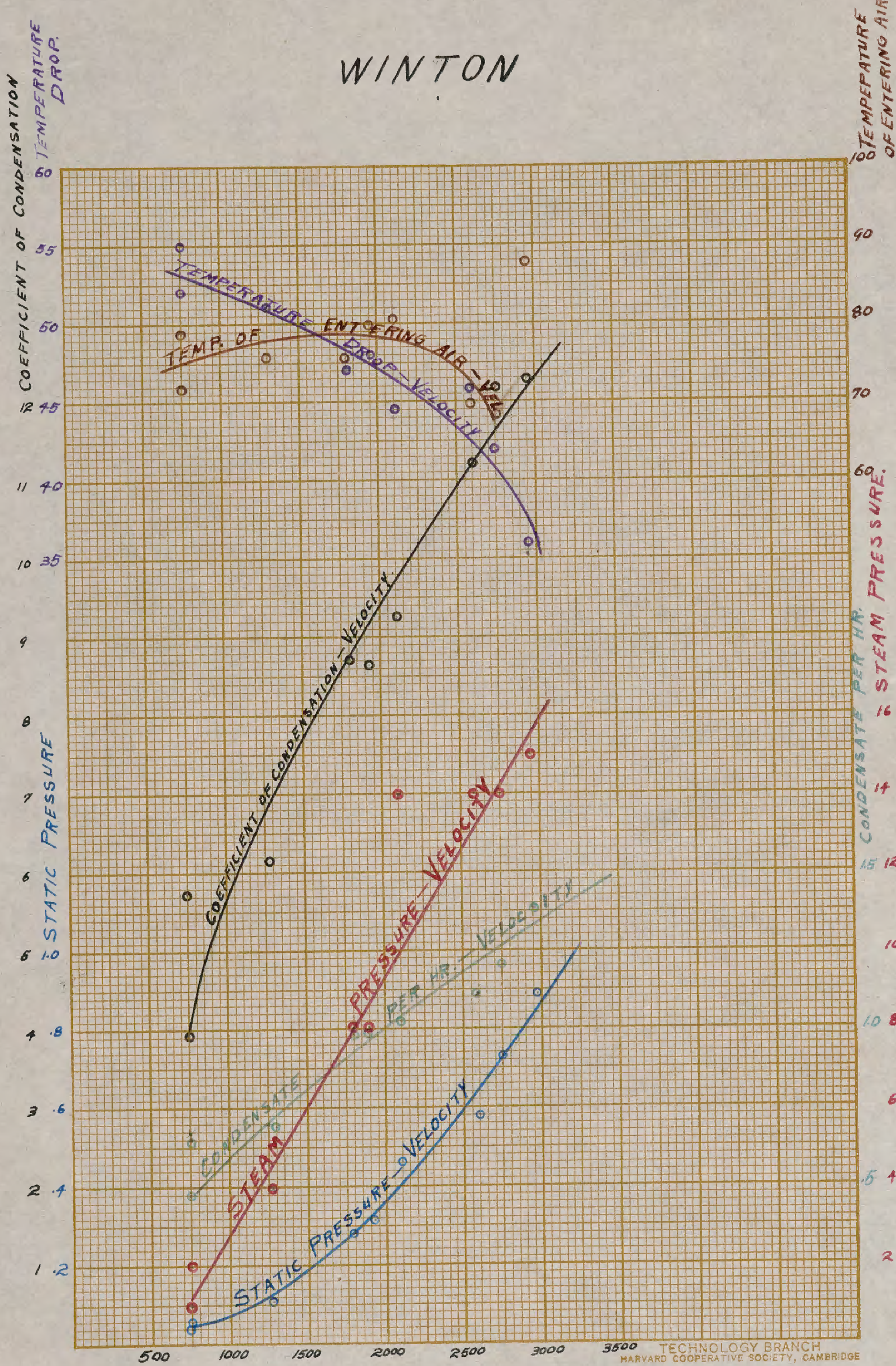
DATA ON WINTON RADIATOR (cont)

Vel. of Air in Condenser Cu. ft per minute	Steam Temp.	Latent Heat of Vaporization	Steam Condensed per Hour	Steam Condensed per sq. ft. of Radiation per Hour.
2000	215.5	969.5	86	.48
2000	218.5	967.8	113	.63
3440	224.5	964	125	.70
5090	235	957	174	.97
5220	235	957	175	.97
5670	248	949	188	1.05
7000	248	949	200	1.12
7430	248	949	218	1.22
8051	249.5	947.5	249	1.39

DATA ON WINTON RADIATOR, (cont)

Temp. Drop	Mean Temp. of Condensed Air	Temp. Difference of Steam and Air	B. T. U. per Hour per sq. ft. radiation	Factor of Condensation
55	106.5	99.0	421	3.98
52	98	120.5	565	5.76
51	101.5	123.0	622	6.12
47	98.5	146.5	860	8.74
48	104	131.0	904	8.67
44	104	144.0	960	9.24
46	93	155.0	1043	11.21
43	92.5	145.5	1129	12.2
35	106.5	143.0	1310	12.3

WINTON



VELOCITY OF AIR IN RADIATOR, FT. PER MIN.

DATA ON WINTON RADIATOR

Temperature of Condensate Held Constant.

R. P. M.	5-1 Gasoline Static	Impact	Condenser Gage	Steam Condensed	Temp of Entering Air
80	.06	.04	1	70	75
130	.08	.04	2	89	75
180	.23	.104	6	141	76
230	.33	.18	8	166	78
280	.45	.21	9	166	82
330	.644	.314	11	205	75
380	.912	.416	13	226	75
430	1.01	.45	14	228	82
480	1.29	.59	15	249	89

DATA ON WINTON RADIATOR (cont)

Temp. of Exhaust Air	Quality	Temp. of Water Beginning	Temp. of Water Ending	Weight of Water Beginning	Weight of Water Ending
112	90	185	0	314	384
125	92	187	0	287	376
123	96	188	0	146	287
124	97.5	191	0	220	386
127	97.5	190	0	339	505
120	98	189	0	140	345
122	98.5	189	0	150	376
122	99	192	0	138	366
124	99	188	0	119	368

DATA ON WINTON RADIATOR (cont)

Steam Press	Static Press. in. of water.	Impact Press. in. of Water	Corrected Impact	Vel. of Air in Con. ft. per min.
90	.0427	.0284	.0355	729
85	.0569	.0284	.0355	729
82	.1637	.0740	.0925	1325
85	.2349	.1281	.1600	1650
95	.3204	.1495	.1870	1780
92	.4585	.2235	.2790	2175
75	.6493	.2962	.3708	2518
95	.7191	.3204	.4010	2620
95	.9184	.4200	.525	2950

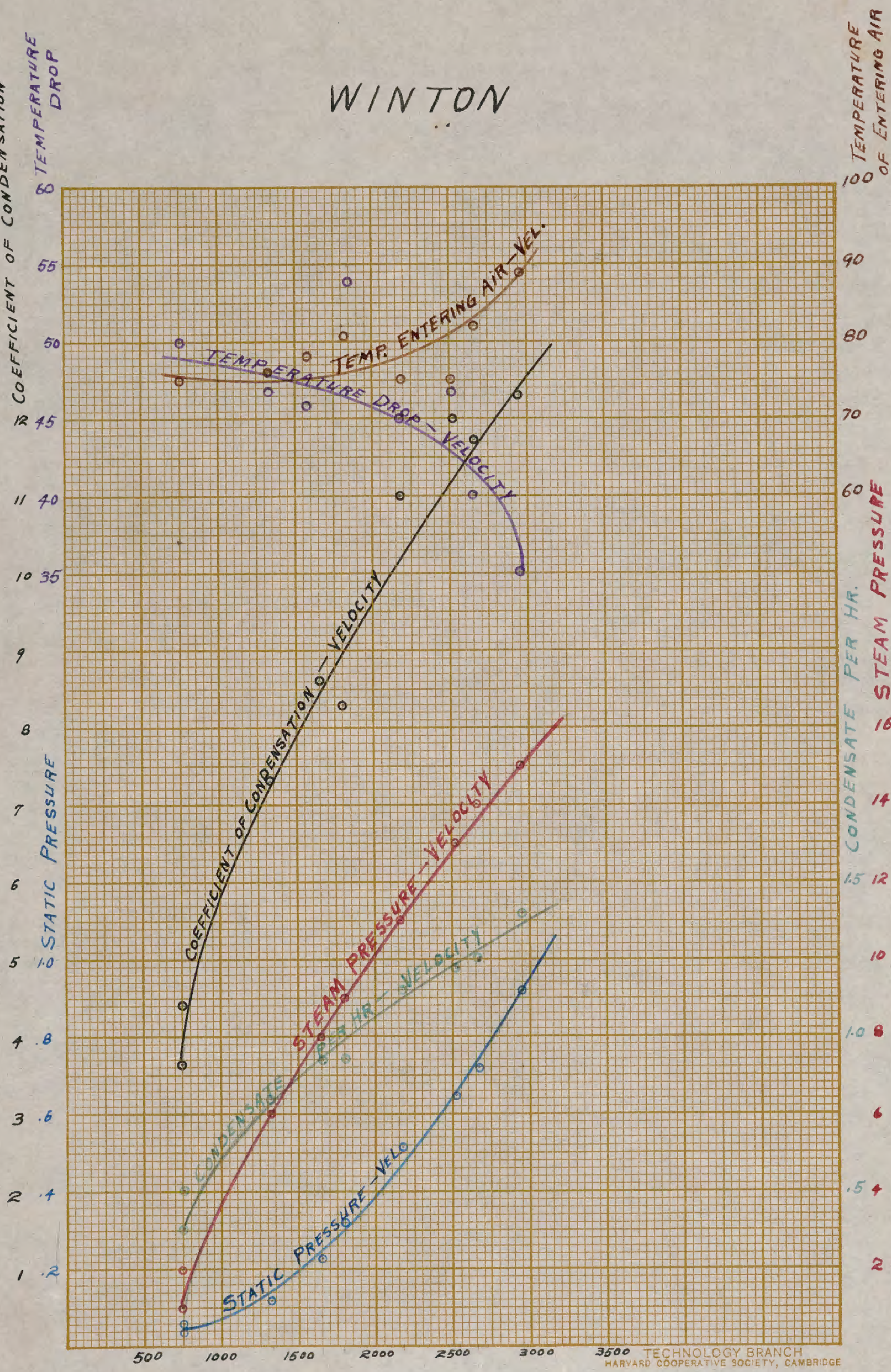
DATA ON WINTON RADIATOR (cont)

Vel. of Air in Condenser cu.ft per minute	Steam Temp	Latent Heat of Vaporiza-tion	Steam Condensed per hr.	Steam Con-densed per sq.ft of radiation per hour
1969	215.5	969.5	70	.39
1969	218.5	968	89	.50
3565	230	960.4	141	.79
4390	235	957	166	.93
4805	237	956	166	.93
5870	241.5	953	205	1.15
6790	246	949.5	226	1.27
7070	248	948.6	228	1.28
7960	250	947	249	1.4

DATA ON WINTON RADIATOR (cont)

Temp. Drop	Mean Temp. of Air Condensed	Temperature Difference Steam and Air	B.T.U. per hr per sq.ft. of radiation	Factor of Condensation
37	93.5	122.0	343	3.67
50	100	118.5	445	4.45
47	99.5	130.5	730	7.34
46	101	134	870	8.6
55	104.5	132.5	868	8.31
45	97.5	144.0	1073	11.0
47	98.5	147.5	1188	12.01
40	102	146	12.0	11.75
35	106.5	143.5	13.2	12.3

WINTON



VELOCITY OF AIR IN RADIATOR, FT. PER MIN.

CALCULATIONS.

Each test was run for a period of one hour. There were nine tests made on each radiator.

The fan was run at a minimum speed of 80 revolutions per minute (r.p.m.) to a maximum speed of 480 r.p.m., increasing the speed with each test by increments of 50 r.p.m.

The static pressure and impact velocity were secured by the use of gasoline in the manometer, gasoline being much more sensitive than water. These readings were converted into the corresponding values in inches of water by multiplying by the constant 0.712.

The temperature of the air entering the fan was recorded, also the temperature of the air after passing through the radiator, thus giving the amount of heat carried away by the air. But there must be a correction made here for the change in temperature of the air while passing through the radiator. This correction is made by taking the mean temperature of the air on entering and leaving the condenser.

The quality of the steam was taken by a separating calorimeter, placed in the steam line near the entrance of the radiator, but so placed that the air from the radiator does not come in contact with any of the steam line.

The condensate was caught in a tank partly filled with water which was weighed, and the temperature of which was recorded at the beginning of the hour and again at the end. The increase in weight gives the total amount of steam condensed; the increase in temperature gives the amount of heat carried away in the condensate.

There were two steam pressure gages to be recorded, one placed in the main steam line which registered the boiler steam pressure; another one near the condenser which gave the pressure after the steam had passed through a pressure reducing valve, thus giving the amount of steam being condensed by the condenser.

The impact velocity expressed in inches of water must be corrected for the angle of inclination of the manometer. This correction is made by multiplying the impact velocity in inches of water by 1.25.

The velocity of the air in feet per minute when passing through the condenser is calculated by the following formula:

$$V = \text{corrected impact velocity} \times \frac{\text{Area of pipe}}{\text{Air Space in Radiator}}$$

The velocity of air in condenser expressed in cubic feet per minute is gotten by multiplying the velocity in condenser in feet per minute by the total air space in radiator.

The steam temperature and latent heat of liquid were taken from the steam tables.

The steam condensed per square foot of radiator per hour was arrived at by dividing the total amount of steam condensed per hour, by the radiation area expressed in square feet.

The temperature drop was found by taking the difference in temperature of the air on entering the condenser and that on leaving the condenser.

The difference in temperature of the steam and that of air passing through the condenser was found by subtracting the temperature of the condensing air from the temperature of the steam as found from steam tables.

The B.T.U. loss per hour per square foot of radiation surface was found by multiplying the latent heat of the liquid by the quality of the steam, by the amount of steam condensed per hour, this then divided by the area of the radiation surface expressed in square feet.

Then for the final result. The co-efficient of condensation was arrived at by dividing the B.T.U. loss per hour per square foot of radiation by the mean temperature of the condensing air.

CONCLUSION.

For a general conlsusion from the result of all radiators tested, it has been found that the factor of condensation varies directly as the velocity of the air supplied to the radiator, i.e. as the velocity of air increases the capacity for removing heat in B.T.U. increases.

The honeycomb type of radiation is at present the most used, largely on account of its adaptability and of the fact that it is well suited to large production at moderate cost.

It was found by experiment that radiation from fins and similar surfaces not in actual contact with the circulating water was found to be of value only for a short distance out from the water space, and they are not as advantageous as surfaces in actual contact with the water. Consequently the use of stiffening wires, strips, etc. add to resistance without increasing the radiation surface and should be avoided. Furthermore, it seems that the radiating surfaces should be practically continuous from front to rear.

The percentage of air which flows through a honeycomb radiator was found to be very nearly equal to the percentage of space open to air flow in the radiation. The rest of the air obviously flows around the radiator. The numerical value of the air flowing through the cells was found to be 70 to 85 per cent of the air which would be expected to strike the face area of the radiator. (Air Craft Radiators, page 537, S. A. E. 1919, Part I, by A. Black.)

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APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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