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COMPARATIVE COOLING OF CYLINDERS OF NONUNIFORM FIN WIDTH WITH TIGHT-FITTING BAFFLES AND WITH BAFFLES THAT PROVIDE CONSTANT FLOW-PATH AREAS

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WASHINGTON

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SUMMARY

An examination of the cooling fins on several modern air-cooled engine cylinders showed large restrictions in the air-flow passages between individual fins, especially around the intake and exhaust ears of the cylinders, when baffles that were in close contact with the fins were used. Tight-fitting baffles, of NACA design, for a cylinder from a Wright R-1820-H engine and for a cylinder from a Pratt & Whitney R-2800-21 engine were altered to maintain a constant free-flow area from the front to the rear of each interfin air passage. Each cylinder was mounted on a single-cylinder crankcase and tested, first with the tight-fitting baffles and then with the altered baffles. Tests at sea-level conditions were made at constant indicated horsepowers of 66 for the Pratt & Whitney cylinder and 80 for the Wright cylinder (approximately cruising power in each case) with a fuel-air ratio of 0.08. The cooling-air pressure drop was varied from 2 to 30 inches of water. Temperatures were measured at 22 points on the cylinder head, at 10 points on the cylinder barrel, and at 2 points on the cylinder flange.

The results of this investigation showed that, by modifying tight-fitting baffles to maintain a constant free-flow area from the front to the rear of each interfin air passage, the weight of cooling air flowing over the cylinder heads for a given pressure drop was increased approximately 38 percent for the Wright R-1820-H cylinder and from 30 to 44 percent for the Pratt & Whitney R-2800-21 cylinder; the average head temperature of the Wright R-1820-H cylinder was reduced about 40° F; the temperature at one point on top of the head near the exhaust ear was reduced 104° F; the average head temperature of the Pratt & Whitney R-2800-21 cylinder was reduced approximately 23° F; and the hottest point measured on the cylinder head was reduced about 35° F.

INTRODUCTION

Most of the single-cylinder cooling tests conducted by the NACA to date have been made using baffles that fitted tightly against the fin tips because tests on electrically heated cylinder barrels (reference 1) indicated that the best cooling of the barrels was obtained with this baffle condition. The cylinders of reference 1 had fins of constant width. Fin width at any point along the fin is defined as the shortest distance between the fin base and the fin tip at the point in question. Flight tests of several baffles showed, moreover, that best heat transfer was obtained when the baffles were placed close to the fin tips (reference 2).

Recent tests by the NACA on a Wright R-1820-H engine cylinder in conjunction with baffles (of NACA design), which fitted tightly against the fin tips around the rear half of the cylinder, showed several hot spots on the cylinder head near the exhaust ear that resulted in high average cylinder temperatures. Examination of the cylinder showed a large variation in the width of the individual fins from the front to the rear of the cylinder head, especially in the area around the exhaust ear. For the baffles in close contact with the fin tips, the variation of width of individual fins caused a similar variation in cross-sectional area of the individual flow paths. At points the fins were very narrow and the restrictions were very bad, reducing the area in some cases to one fourth of the area upstream of the restriction. It was believed that these large reductions in free-flow area greatly restricted the flow and, therefore, that the cooling was impaired in front of and behind the restrictions, where the fin width was large and the local mass flow ρv was small. The local mass flow ρv, as referred to herein, is the product of the density ρ and the velocity v.

The tight-fitting baffles were therefore modified to eliminate those restrictions for the Wright cylinder. These modified baffles gave a constant free-flow area throughout each interfin air passage by providing varying clearance between the baffles and the fin tips. Cooling tests of the two types of baffle were made on the Wright cylinder mounted on a single-cylinder crankcase. As a result of these baffle tests for the Wright cylinder, the two types of baffle were also tested on a Pratt & Whitney R-2800-21 cylinder mounted on a single-cylinder crankcase.

The detrimental effect of restrictions in the interfin flow paths was also noted in reference 3. The baffles of a Pratt & Whitney R-1830-43 engine were modified to eliminate some of these restrictions with a consequent improvement in cylinder cooling.

The purpose of the present report is to present a comparison between the cooling obtained with tight-fitting baffles and the cooling obtained with baffles revised to give a constant free-flow area from the front to the rear of each interfin air passage. Both of these types of baffle were of NACA design. Cooling tests at sea-level conditions were made of each cylinder at constant fuel-air ratio and at constant power over a range of cooling-air pressure drop. The work was conducted at Langley Memorial Aeronautical Laboratory, Langley Field, Va., from July to September 1942.

APPARATUS AND PROCEDURE

Test units. - The setup of the test equipment is shown in figure 1. A cylinder from a Wright R-1820-H engine and one from a Pratt & Whitney R-2800-21 engine were used. Each cylinder was mounted on a single-cylinder crankcase. A centrifugal blower supplied cooling air to the engine through a duct. The cooling-air quantity was measured by thin-plate orifices mounted in the end of a tank connected to the inlet of the blower. A water brake and an electric dynamometer absorbed the power developed by the engine. Engine speed, torque, and fuel consumption were measured with standard test-engine equipment. A Nash blower provided combustion air at desired manifold pressures. A surge tank was installed in the combustion-air system ahead of the carburetor.

Baffles. - Sketches of the two types of baffle (both of NACA design) used for both cylinders are shown in figures 2 and 3. The baffles were connected to the blower duct by means of an adapter, as indicated in figure 2, and covered only the rear half of the cylinder head and barrel. The baffle-adapter combination, hereinafter denoted a jacket, enclosed the cylinder. The adapter formed a wide entrance section (see fig. 2) for the jacket giving low-velocity cooling air in front of the cylinder. In the original jackets, the rear half of the jackets fitted tightly against both the head and barrel fins, as shown in figures 2 and 3.

The revised jackets were essentially the same as the originals except that the portions of the jackets over the heads of both cylinders were modified to maintain a constant free-flow area from the front to the rear of each interfin air passage. In the revision of the jackets, the profiles of the head cooling fins of varying width (the unshaded areas in figs. 4 and 5) were used. The numbers below the fins correspond to those in figures 2 and 3. The fins over the top of the Pratt & Whitney cylinder head are prefixed by a T; those around the exhaust side, by an E; and those around the intake side, by an I. The restrictions to cooling-air flow in the original jackets are especially noticeable for fins 25, 26, 27, and 28 of figure 4 and fins T-1 and E-10 of figure 5. Templets (shown by the sectioned areas) were made of a thickness equal to the fin pitch and of a sufficient width to maintain a constant free-flow area from the front to the rear of each interfin passage. The revised jackets were made to fit over these templets.

Temperature- and pressure-measuring devices. - Iron-constantan thermocouples in conjunction with a potentiometer were used to measure the cylinder temperatures. Temperature measurements were made at 22 points on the head, at 10 points on the barrel, and at 2 points on the flange, as shown in figures 6 and 7. The temperature of the rear spark plug was measured by a thermocouple imbedded in a special spark-plug gasket. The cold junctions of all thermocouples were located in an insulated box. Temperatures in the cold-junction box, at the thin-plate orifices, and in the combustion-air surge tank were measured with liquid-in-glass thermometers.

The cooling air flowing over the cylinder head was separated from that flowing over the barrel by a partition (figs. 2 and 3). It was therefore possible to measure the temperature of the cooling air flowing over the cylinder head separately from that of the cooling air flowing over the barrel. The air-in temperature in each case was measured by a set of two thermocouples, electrically connected in series and located ahead of the cylinder; the air-out temperature was measured by a set of four thermocouples, electrically connected in series and located in the jacket exit. The cooling-air pressure drop, which included the jacket-exit loss, was measured by means of four equally spaced static openings in the large air duct ahead of the cylinder where the velocity pressure was negligible. These openings were interconnected by a ring surrounding the duct.

Tests. - The cylinders were first tested with the original jackets. Then the original jackets were altered as previously described and the cylinders were tested with the revised jackets. The tests were conducted at a constant fuel-air ratio of 0.08 and over a range of cooling-air pressure drop from approximately 2 to 30 inches of water. The tests were run at a constant indicated horsepower of 80 for the Wright cylinder and 66 for the Pratt & Whitney cylinder, which is in each case approximately cruising power.

RESULTS AND DISCUSSION

Effect of Restriction in Cooling-Air Flow

Paths on Cylinder Temperature

Comparison of cylinder temperatures obtained with original and revised jackets. - Table I gives differences between the temperatures at 32 points on the Wright cylinder and the inlet cooling-air temperature for two comparative series of data, one for the original jacket and one for the revised jacket. (See fig. 6 for location of thermocouples.) The average head temperature T_h is the average of thermocouples 13 and 15 through 34; the average barrell temperature T_b is the average of thermocouples 2 through 11. Because of small variations in cooling-air temperatures T_a from run to run, the temperature differences $T_x - T_a$, $T_h - T_a$, and $T_b - T_a$ were considered better indexes of cooling than the cylinder temperatures.

The table shows that the hottest measured head temperature, indicated by thermocouple 31, was reduced 69° F by the revision and the next three hottest head temperatures, indicated by thermocouples 30, 32, and 28, were lowered 104° F, 52° F, and 30° F, respectively. Thermocouple 30 was located in fin space 21 and thermocouple 31 was located in fin space 26, as shown in figures 2 and 6. These fin spaces were of very irregular shape, as shown by figure 4. The reductions in temperatures obtained by revising the jacket to obtain interfin passages with constant free-flow area show the poor cooling that resulted, for the conditions of these tests, when the baffles were fitted tightly against an irregularly shaped fin.

The explanation for the reduction in cylinder temperature at thermocouples 28 and 32 for the revised jacket, even though these thermocouples were not located in an interfin passage of irregular shape, is that the entire exhaust side of the head was cooler because the fins across the top of the head near the exhaust ear were used more effectively with the revised jacket than with the original jacket. It is reasonable to expect that at the same pressure drop there was little difference in local mass flow between the fins at the point of minimum fin width when either the original or the revised jacket was used. Therefore, any improvement obtained with the revised jacket at this point may be largely attributed to the increase in cooling obtained at sections ahead of and behind the restriction. The increase in cooling at these sections is caused by the increase in mass flow resulting from the removal of the restriction. Cooling is probably less sensitive to changes of flow conditions when the main portion of the fin is upstream from the restriction than when it is downstream because the air might have a tendency to separate from the fin-base surface and follow the inner surface of the baffle instead of sweeping over the entire fin-surface area.

The data in table I show that the average head, average barrel, and rear spark-plug-gasket temperatures of the Wright cylinder were reduced 42° F, 35° F, and 30° F, respectively, by the revision of the jacket. The jacket revisions caused a reduction in temperature over the top of the head of approximately 60° F and an average reduction in temperature of about 30° F for the lower portion of the head having circular fins. Since the revision was made to only the portion of the jacket that covered the top of the head, it is reasonable for that portion of the head to be affected more by the revision than the lower portion. The decrease in barrel temperature is explained by the fact that the head was cooler for the revised jacket, which caused a decrease in heat flow from the head to the barrel. In addition, the reduction in piston temperatures resulting from the improved head cooling further reduces the heat flow to the barrel (reference 4).

Two factors that affect barrel temperatures are the heat given up to the lubricating oil and the blow-by past the piston rings. Because the effect of these factors was not determined for the tests of this cylinder, no conclusions can be drawn from the barrel temperatures. An examination of cooling data for the two jackets for this cylinder did indicate, however, that the decrease in average barrel temperature due to improved head cooling should be of the order of 60 percent of the decrease in average head temperature. This examination consisted in plotting average head temperature against average barrel temperature for both jackets. The data were obtained from unpublished tests in which the following items were varied: indicated horsepower, fuel-air ratio, spark setting, carburetor-air temperature, and cooling-air pressure drop. This plot showed an approximate relationship between average head and average barrel temperatures; and, for the range of temperature considered in this paper, this relationship indicated that, for a change in average head temperature, the average barrel temperature should change by the amount previously mentioned. A further examination of these cooling data indicated that the value shown in table I for thermocouple 9 for the original jacket is erratic.

Table II gives the differences between the temperatures at 32 points on the Pratt & Whitney cylinder and the cooling-air temperature ahead of the cylinder for two comparative series of data, one for the original jacket and one for the revised jacket. (See fig. 7 for thermocouple locations.) The average head temperature T_h is the average of temperatures of thermocouples 13 and 15 through 34; the average barrel temperature T_b is the average of thermocouples 2 through 11.

Table II shows that the hottest head temperature, indicated by thermocouple 29 (see fig. 7 for location), was lowered 35° F by the revision. The next three hottest head temperatures, indicated by thermocouple 31 (fin space T-16, fig. 3), thermocouple 30 (fin space T-9, fig. 3), and thermocouple 27 (fin space E-13, fig. 3) were reduced 9° F, 22° F, and 29° F, respectively, by the revision of the jacket. Although thermocouple 29 was not in an interfin passage, it was located directly behind an irregularly shaped interfin passage, which explains the reduction in temperature at this point obtained by revising the jacket. Several other thermocouples located in irregularly shaped interfin passages were thermocouples 24, 25, and 32 (fin spaces I-3, I-3, and E-4, respectively, fig. 3). The temperatures at thermocouples 24 and 25 were reduced 4° F and 16° F, respectively, but the temperature at thermocouple 32 was increased 10° F by the revision. The average head and rear spark-plug-gasket temperatures were reduced 23° F and 4° F, respectively, by the revision.

The data in table II indicate that the average barrel temperature was decreased 26° F. Inasmuch as the head portion of the jacket was the only part altered, the average barrel temperature could not have been lowered more than the average head temperature. An examination of cooling data (similar to the examination for the Wright cylinder) for this cylinder indicated that the decrease in average barrel temperature due to improved head cooling should be on the order of 70 percent of the decrease in the average head temperature or that the average barrel temperature should be decreased only about 16° F instead of 26° F for a decrease of 23° F in average head temperature. The apparent discrepancy is believed to be due to two factors. It was found that the oil pressure to the cylinder-liner spray, which sprayed oil on the piston at the bottom of the stroke, was greater for the tests of the revised jacket than for those of the original jacket. Tests were made to determine the effect of this factor and it was found that the higher oil pressure for the revised jacket tests lowered the average barrel temperature 6° F but had no effect on the average head temperature. The second factor is that the piston rings were replaced after the original jacket was tested and before the revised jacket was tested. Although no change in power was observed for wide-open throttle for the two cases, it is believed that the piston rings were not in as good condition for the case of the original jacket as for that of the revised jacket because of different lengths of service. The cylinder, therefore, had more leakage past the piston rings for tests of the original jacket; and the sweeping of the hot gases over the inside cylinder wall caused the average barrel temperature to be increased, which is a possible explanation for the decrease in barrel temperature not accounted for by the change in oil pressure. Because no change in power was observed for the two cases, it is believed that the change in piston-ring condition did not affect the average head temperature. Because this inconsistency exists, no conclusions can be drawn from the barrel data.

Although the cylinder-head temperatures were not lowered nearly so much for the Pratt & Whitney cylinder as for the Wright cylinder, they definitely show that the cooling of the Pratt & Whitney cylinder was improved by the revision. It may be noted from figures 4 and 5 that the restrictions in the interfin passages are much less for the Pratt & Whitney cylinder than for the Wright cylinder, especially for the case of the interfin passages around the exhaust ear of the cylinder head. (See fin spaces 19 to 24 in fig. 4 and fin spaces T-10 to T-17 in fig. 5.) The revisions to the jacket over the top of the head reduced the average cylinder temperature in this locality only about 15° F, but the revisions made on the sides of the head reduced the temperatures around the lower portion of the head approximately 35° F.

Effect of cooling-air pressure drop on average cylinder temperature. - The effect of the revision on average head and average barrel temperatures for the Wright cylinder and for the Pratt & Whitney cylinder over a range of cooling-air pressure drop is graphically shown in figure 8. It is noted from figure 8(a) that, for a range of pressure drop from 2 to 30 inches of water, the average head temperature was reduced 30° F to 40° F and the average barrel temperature was lowered 20° F to 25° F by revising the tight-fitting jacket for the Wright cylinder. The reason for the reduction in barrel temperature has been previously given. Figure 8(b) shows that the average head temperature for the Pratt & Whitney cylinder was lowered approximately 20° F by the revision. The curves indicate that the average barrel temperature of the Pratt & Whitney cylinder was lowered more than the average head temperature by the revision. This discrepancy has been previously explained.

The curves also show that the revised jacket for the Wright cylinder requires an average of approximately 60 percent of the pressure drop required by the original jacket to maintain a given average head temperature. The revised jacket for the Pratt & Whitney cylinder requires an average of about 70 percent of the pressure drop required by the original jacket to maintain a given average head temperature. Additional calculations showed that, even though the revised jackets required more cooling air for a given cooling pressure drop than the original jackets, the cooling power for maintaining a given average head temperature was considerably lower for the revised jacket because of the great reduction in cooling-air pressure drop. Cooling horsepower is represented by $\frac{Q\,\Delta p}{550}$, where Q is the quantity of air flow, cubic feet per second, and Δp is the pressure drop across the cylinder, pounds per square foot.

Effect of jacket revision on relationship between rear spark-plug-gasket temperature and average head temperature. - Figure 9 gives the relationship between the rear spark-plug-gasket temperature and the average head temperature for both cylinders with the two types of jacket. From figure 9(a) this relationship is, by a coincidence, the same for the original and revised jackets for the Wright cylinder. Figure 9(b), however, shows that this relationship is different for the two jackets for the Pratt & Whitney cylinder. Over a range of average head temperature from 400° F to 480° F, the rear spark-plug-gasket temperature for the revised jacket is an average of about 32° F higher for a given average head temperature than that for the original jacket. For a given cooling-air pressure drop, however, the rear spark-plug-gasket temperatures for the two jackets are about the same, as is shown in table II. Because the cooling criterion at the present time is the rear spark-plug temperature and because the jacket did not improve the cooling of the rear spark plug, the revised jacket will require as large a cooling pressure drop as the original jacket to maintain a given rear spark-plug temperature, even though the other cylinder temperatures are lower.

On the other hand, the rear spark-plug temperature is the cooling criterion only because there are relationships between it and other cylinder temperatures (average head and hot spots). These relationships for a cylinder are true only for a given set of baffles. If baffles other than those for which the rear spark-plug-temperature limits were set are used, new spark-plug-temperature limits must be set that give weight to average cylinder temperatures and to hot-spot temperatures. It must be noted that none of the baffles reported herein were the manufacturers' baffles and therefore that the limits of the rear spark-plug temperatures set by the manufacturers do not necessarily apply to these baffles. Hence, the only fair bases on which to compare the two types of baffle described in this paper are the average cylinder temperatures and the hot-spot temperatures. From this viewpoint, it appears that the Pratt & Whitney cylinder could be operated at higher rear spark-plug temperatures (but at the same average head and hot-spot temperatures) with the revised jacket than with the original jacket and consequently at a lower cooling-air pressure drop.

Effect of Restrictions in Cooling-Air Flow Paths on Cooling-Air Mass Flow

It may be seen in figure 10 that the cooling-air mass flow across the heads of the cylinders for a given pressure drop was increased approximately 36 percent for the Wright cylinder and from 30 to 44 percent for the Pratt & Whitney cylinder by the revision. It is apparent that the revision should increase the mass flow over the cylinder heads because the free-flow area was increased. This increase in mass flow may be considered a good measure of the restrictions present when tight-fitting baffles were used on these cylinders. Since the revision was necessary for only a few of the passages, it can be seen that these passages were restricted greatly by the nonuniform width of the individual fins. Inasmuch as the barrel portion of the jacket was not altered, the curves of figure 10 showing the mass flow across the barrel should coincide for the two types of jacket for each cylinder. A fair check was obtained.

The increase in mass flow across the cylinder heads resulted in some cases in the feeding of relatively fresh cooling air to the rear of the passages. This effect is very desirable because, in general, the cylinder temperatures are higher at the rear than at the front of the cylinder and the fresh cooling air would tend to reduce the rear-cylinder temperatures.

GENERAL DISCUSSION

The results of this investigation have shown that, for the conditions of these tests, a large improvement in cooling can be obtained on cylinders having nonuniform width of the individual fins and tight-fitting baffles by varying the clearance between the fin tips and the baffles to maintain a constant interfin flow-path area. Examination of several service-type engine cylinders with their production-type baffles has revealed similar variations in the width of individual fins and the use of fairly small clearances (1/8 to 5/16 in.) between the baffles and the fin tips. The clearances between these production-type baffles and the fin tips, however, are not so small as those of the original baffles of this investigation. The authors believe, therefore, that the improvement in cooling to be had by revising these production-type baffles will not be quite so large as the improvement reported herein.

Research on these air-cooled aircraft engines should be conducted in order to determine the magnitude of the improvement obtainable by revising their production-type baffles in the manner previously described. If such research indicates that cooling is as sensitive to the clearance between the baffles and the fin tips as was indicated in the present tests, care must be exercised in the construction of baffles for multicylinder engines to make this clearance the same for all the cylinders. This special care in baffle construction would eliminate irregularities in temperature distribution between cylinders resulting from variation in flow caused by a difference in baffles for different cylinders. A revision of the nature described herein would neither increase the weight of the baffles nor make the manufacture and installation of the baffles more difficult.

Even though the baffle revision described in this report tends to offset cooling difficulties resulting from fins of irregular shape, care should be exercised in future cylinder design to eliminate irregularities in fin shape. Where it is impossible to eliminate these irregularities in fin shape, however, the baffles should be designed to correct them.

The modified baffle of the present investigation fitted tightly against the fin tips over the entire rear half of the cylinder where the individual fins were of uniform width. Other than removing the restrictions in the interfin passages, no attempt was made to obtain a uniform temperature distribution around the cylinder. Other investigators (references 3 and 5) have found that a more uniform temperature distribution and also a reduction in temperature at the rear of the cylinder may be obtained by leaving a clearance between the baffles and the fin tips at the leading edge of the baffle and by making the baffle fit tightly against the fin tips at only the rearmost portion of the cylinder. Even though the temperatures at the front of the cylinder were increased by this revision, the critical temperatures at the rear of the cylinder were reduced. This baffle modification merits consideration because the temperatures at the rear of the cylinder are almost invariably higher than those at the front and also because it is usually desirable to have a uniform temperature distribution around the cylinder.

SUMMARY OF RESULTS

For the Wright R-1820-H and the Pratt & Whitney R-2800-21 cylinders having fins of nonuniform width, the major results obtained with tight-fitting baffles revised to maintain a constant free-flow area from the front to the rear of each interfin air passage were:

1. The weight of cooling air flowing across the cylinder heads for a given pressure drop was increased approximately 36 percent for the Wright cylinder and from 30 to 44 percent for the Pratt & Whitney cylinder.

2. The average head tmperature of the Wright cylinder was reduced about 40° F and the temperature at one point on top of the head near the exhaust ear was reduced 104° F.

3. The average head temperature of the Pratt & Whitney cylinder was reduced approximately 23° F and the hottest point measured on the cylinder head (thermocouple 29) was reduced 35° F.

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TABLE I. - COMPARISON OF INDIVIDUAL AND AVERAGE CYLINDER TEMPERATURES OBTAINED WITH ORIGINAL AND REVISED JACKETS ON A WRIGHT R-1820-H CYLINDER

	Original jacket	Revised jacket	
Cooling-air pressure drop, in. water	5.10	5.02	
Indicated horsepower	80	80	
Fuel-air ratio	0.08	0.08	
Thermocouple number ↓ / Head temperature minus cooling-air temperature, °F →	$T_x - T_a$	$T_x - T_a$	Reduction
13	330	302	28
15	281	227	54
16	236	208	28
17	187	181	6
18	219	221	-2
19	315	288	27
20	324	-------	------
21	312	280	32
22	328	263	65
23	253	209	44
24	168	167	1
25	228	218	10
26	191	137	54
27	334	261	73
28	386	356	30
29	361	321	40
30	462	358	104
31	516	447	69
32	393	341	52
33	369	321	48
34	346	280	66
Thermocouple number ↓ / Barrel temperature minus cooling-air temperature, °F →	$T_x - T_a$	$T_x - T_a$	Reduction
2	223	203	20
3	223	-------	------
4	191	165	26
5	195	156	39
6	243	223	20
7	192	153	39
8	195	160	35
9	245	185	60
10	207	170	37
11	231	205	26
Average head temperature minus cooling-air temperature (T_h-T_a), °F	311	269	42
Average barrel temperature minus cooling-air temperature (T_b-T_a), °F	215	180	35
Rear spark-plug-gasket temperature minus cooling-air temperature, °F	351	321	30

TABLE II. - COMPARISON OF INDIVIDUAL AND AVERAGE CYLINDER TEMPERATURES OBTAINED WITH ORIGINAL AND REVISED JACKETS ON A PRATT & WHITNEY R-2800-21 CYLINDER

	Original jacket	Revised jacket	
Cooling-air pressure drop, in. water	11.2	11.3	
Indicated horsepower	66	66	
Fuel-air ratio	0.08	0.08	
Thermocouple number ↓ / Head temperature minus cooling-air temperature, °F →	$T_x - T_a$	$T_x - T_a$	Reduction
13	230	216	14
15	241	164	77
16	220	186	34
17	175	147	28
18	172	150	22
19	218	189	29
20	190	164	26
21	199	172	27
22	228	190	38
23	201	193	8
24	149	145	4
25	190	174	16
26	114	96	18
27	275	246	29
28	254	248	6
29	320	285	35
30	285	263	22
31	307	298	9
32	234	244	-10
33	207	-------	-------
34	245	217	28
Thermocouple number ↓ / Barrel temperature minus cooling-air temperature, °F →	$T_x - T_a$	$T_x - T_a$	Reduction
2	153	100	53
3	127	98	29
4	108	81	27
5	116	95	21
6	144	123	21
7	119	98	21
8	104	87	17
9	122	98	24
10	120	91	29
11	136	110	26
Average head temperature minus cooling-air temperature (T_h-T_a), °F	222	199	23
Average barrel temperature minus cooling-air temperature (T_b-T_a), °F	124	98	26
Rear spark-plug-gasket temperature minus cooling-air temperature, °F	232	228	4

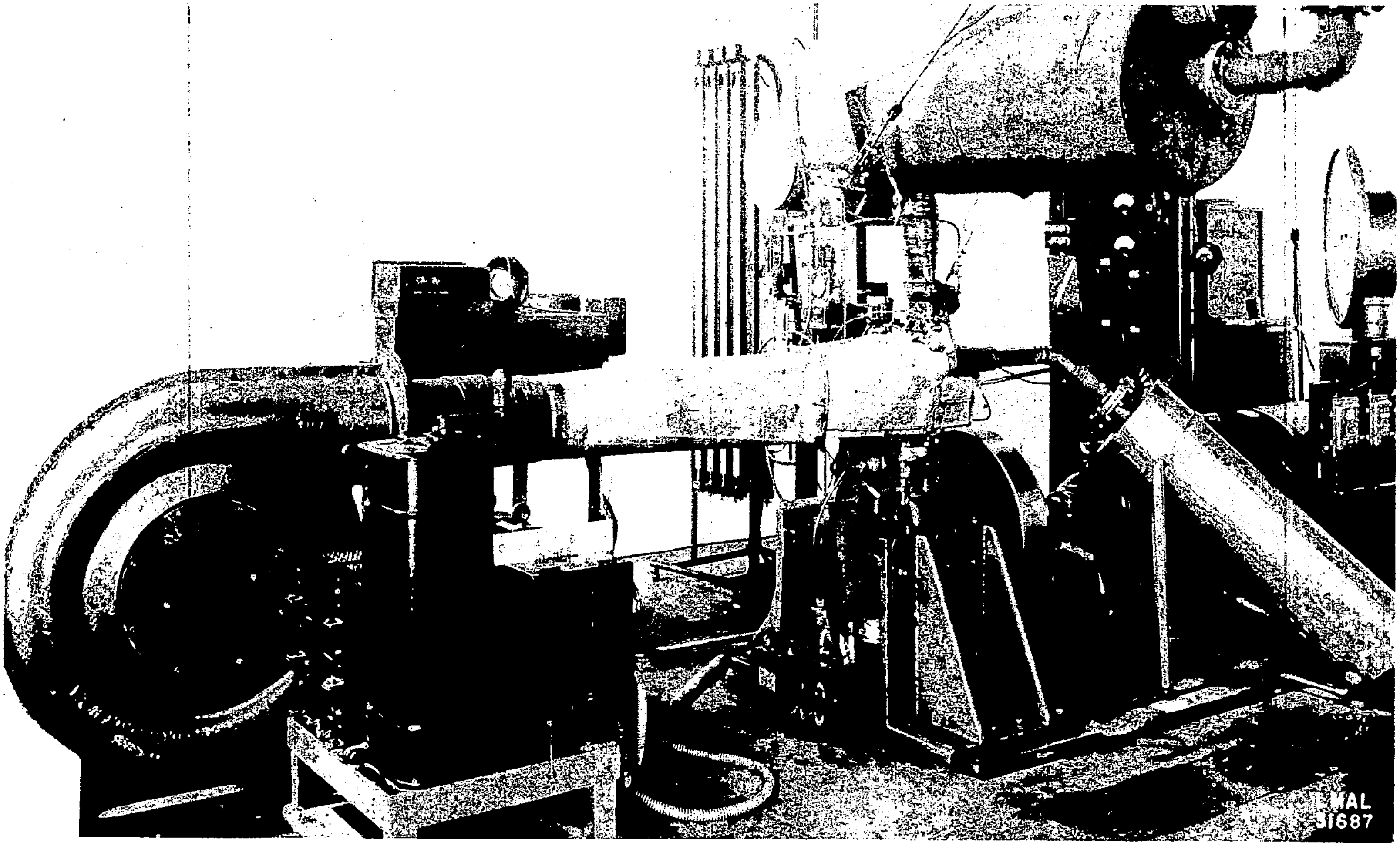


Figure 1. - Setup of single-cylinder test unit.

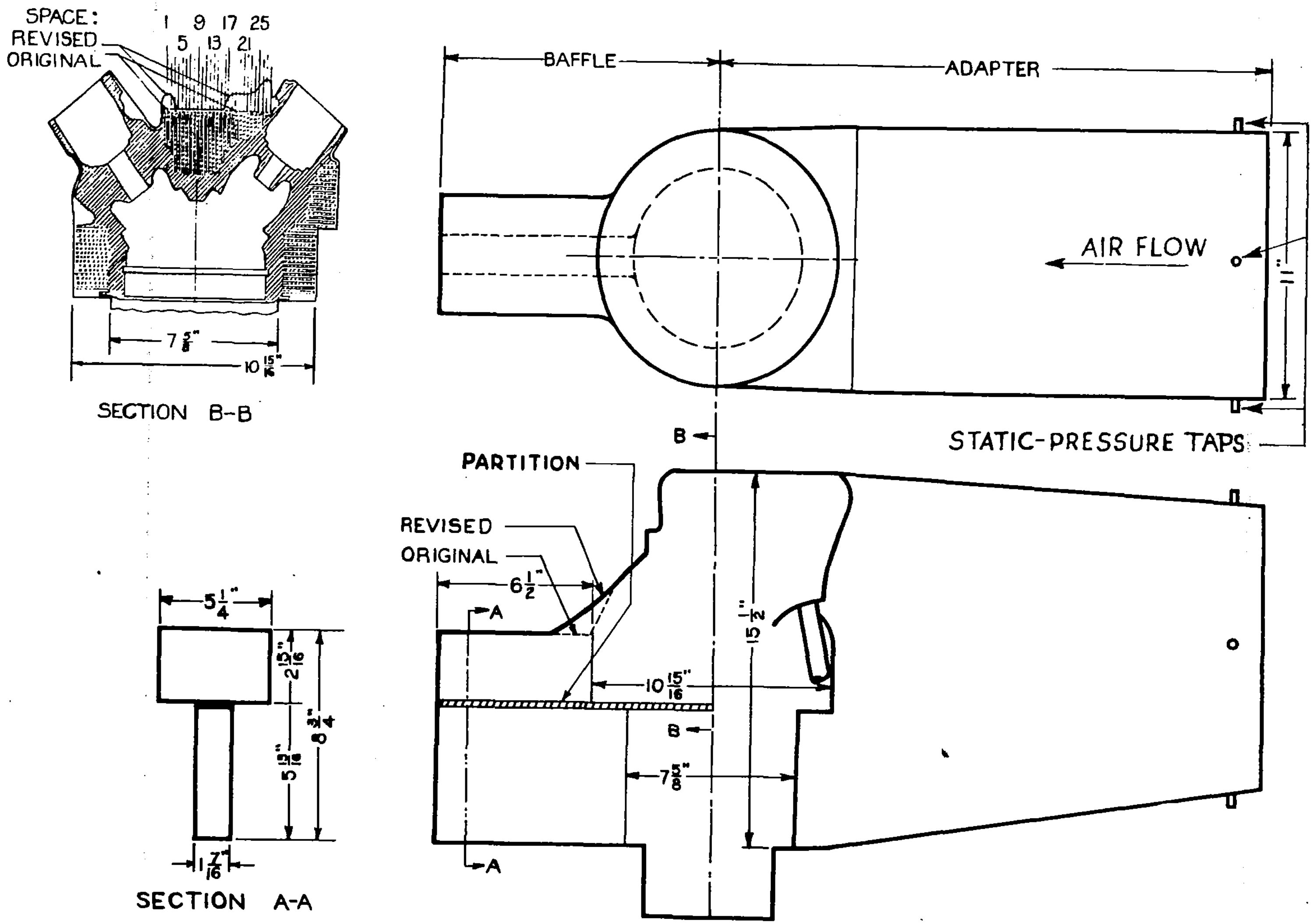


FIGURE 2.- GENERAL OUTLINE OF ORIGINAL AND REVISED JACKETS AROUND WRIGHT R-1820-H CYLINDER.

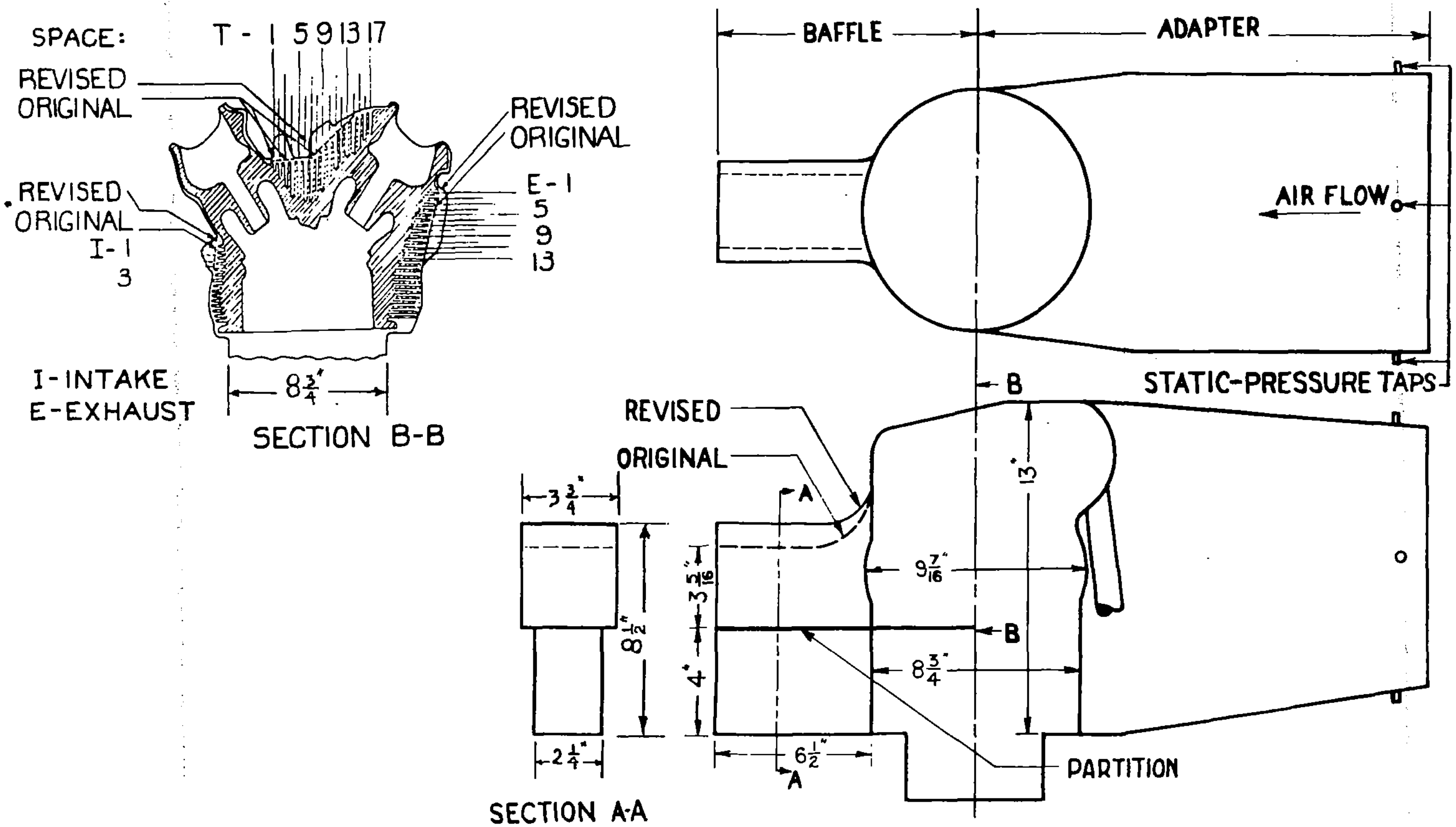


FIGURE 3.- GENERAL OUTLINE OF ORIGINAL AND REVISED JACKETS AROUND PRATT & WHITNEY R-2800-21 CYLINDER.

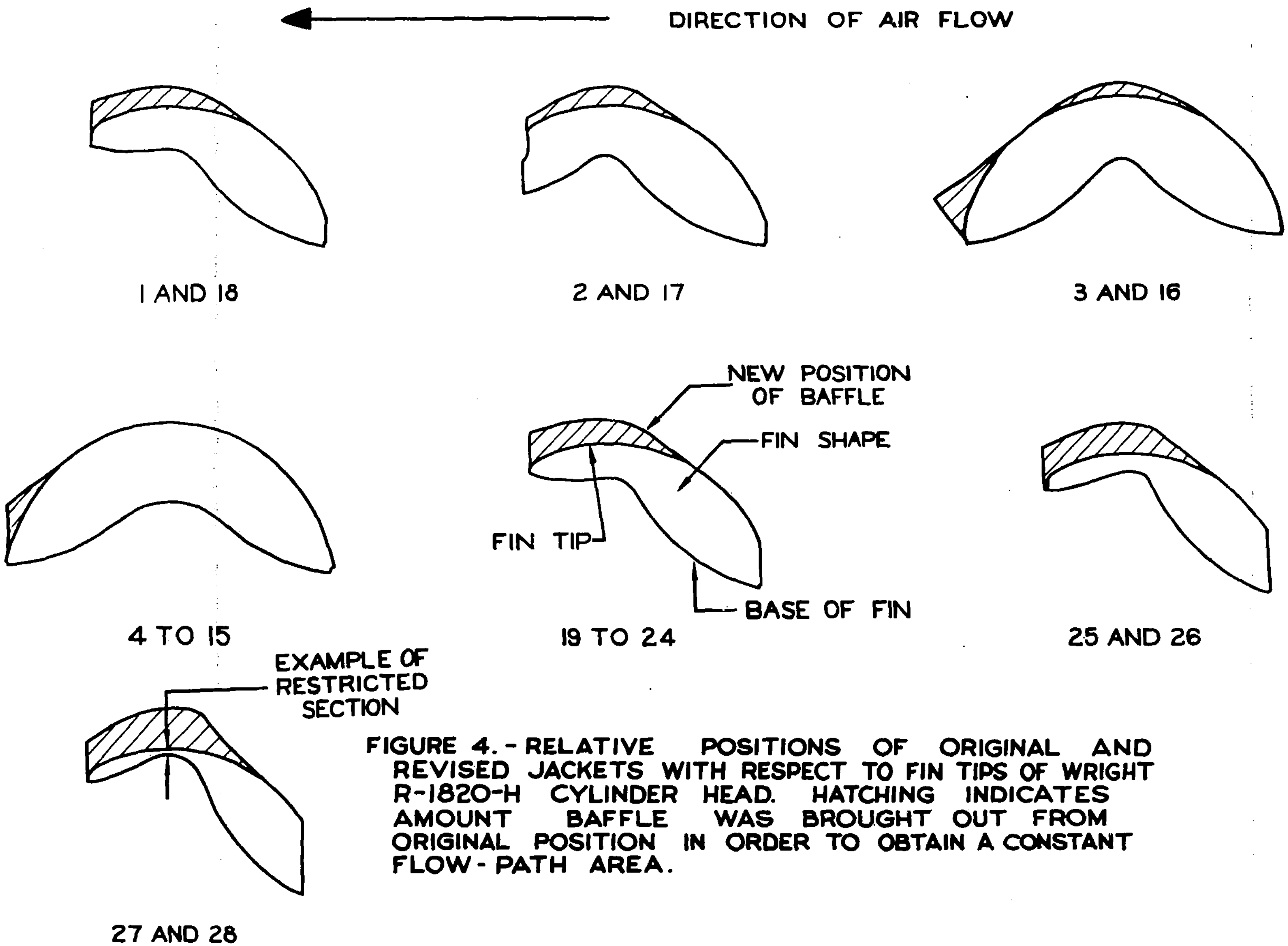
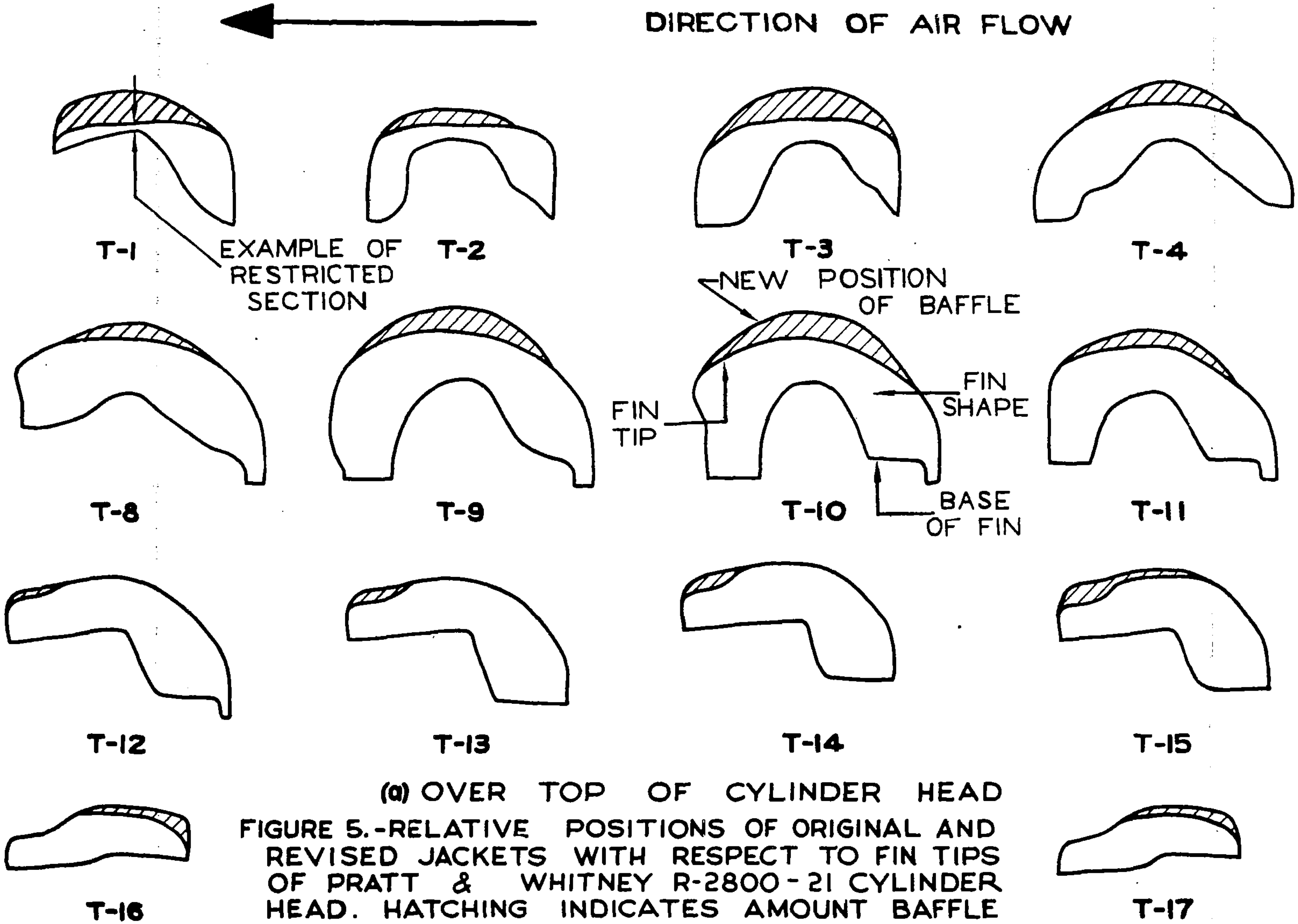
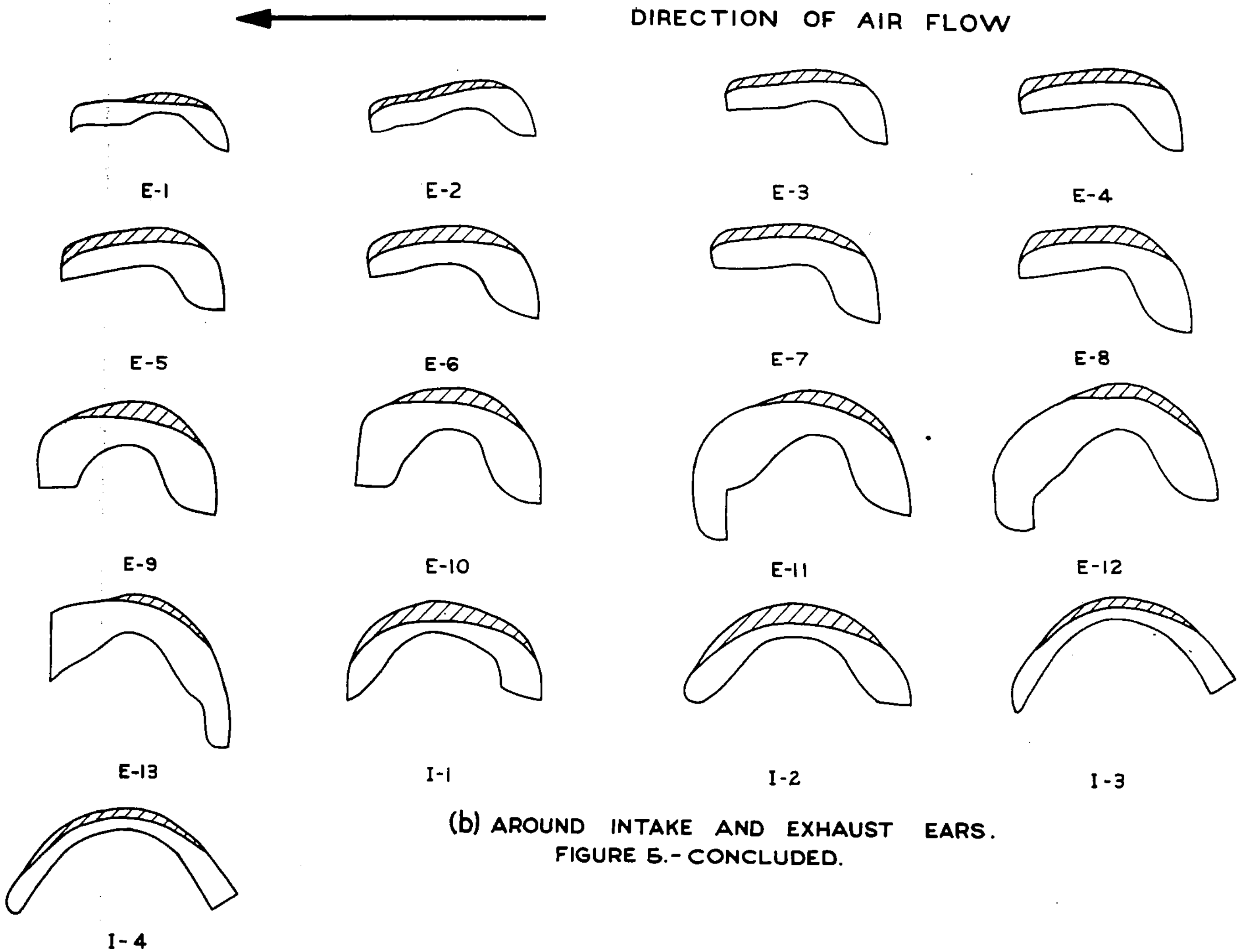


FIGURE 4. - RELATIVE POSITIONS OF ORIGINAL AND REVISED JACKETS WITH RESPECT TO FIN TIPS OF WRIGHT R-1820-H CYLINDER HEAD. HATCHING INDICATES AMOUNT BAFFLE WAS BROUGHT OUT FROM ORIGINAL POSITION IN ORDER TO OBTAIN A CONSTANT FLOW-PATH AREA.

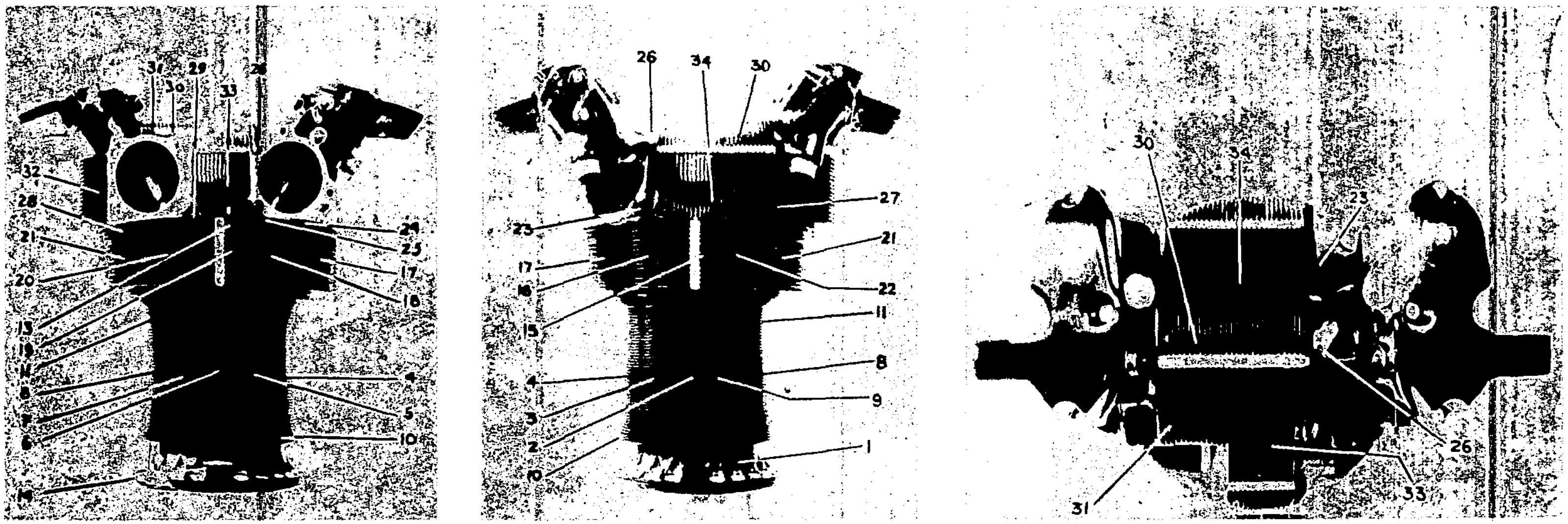


(a) OVER TOP OF CYLINDER HEAD

FIGURE 5.-RELATIVE POSITIONS OF ORIGINAL AND REVISED JACKETS WITH RESPECT TO FIN TIPS OF PRATT & WHITNEY R-2800-21 CYLINDER HEAD. HATCHING INDICATES AMOUNT BAFFLE WAS BROUGHT OUT FROM ORIGINAL POSITION IN ORDER TO OBTAIN A CONSTANT FLOW-PATH AREA.



(b) AROUND INTAKE AND EXHAUST EARS.
FIGURE 5.- CONCLUDED.



NACA
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Figure 6.- Three views of Wright R-1820-H cylinder showing location of thermocouples.

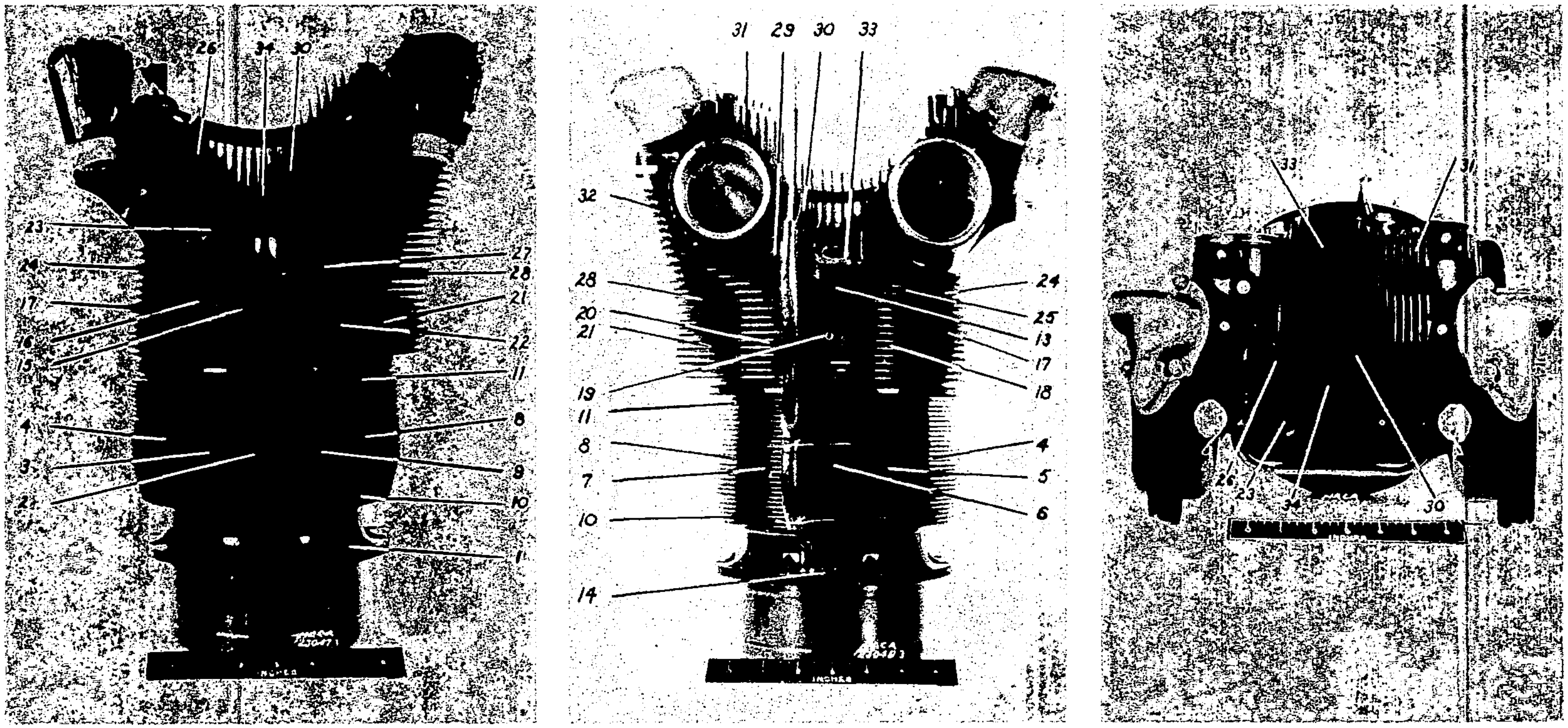
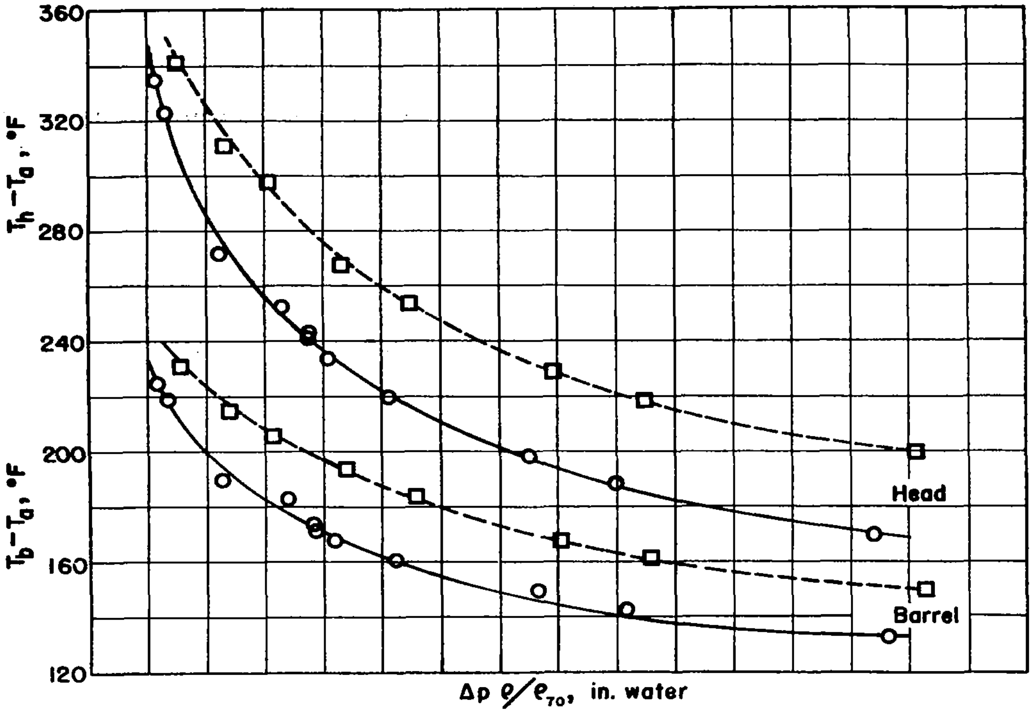
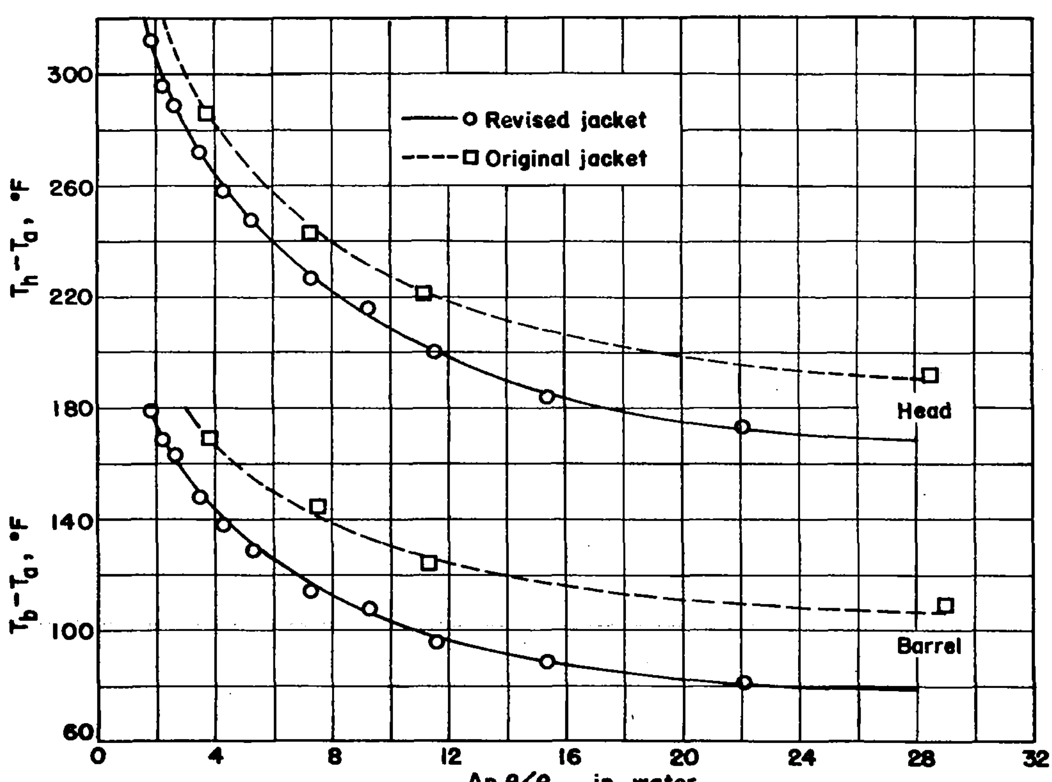


Figure 7. - Three views of Pratt and Whitney R-2800-21 cylinder showing location of thermocouples.

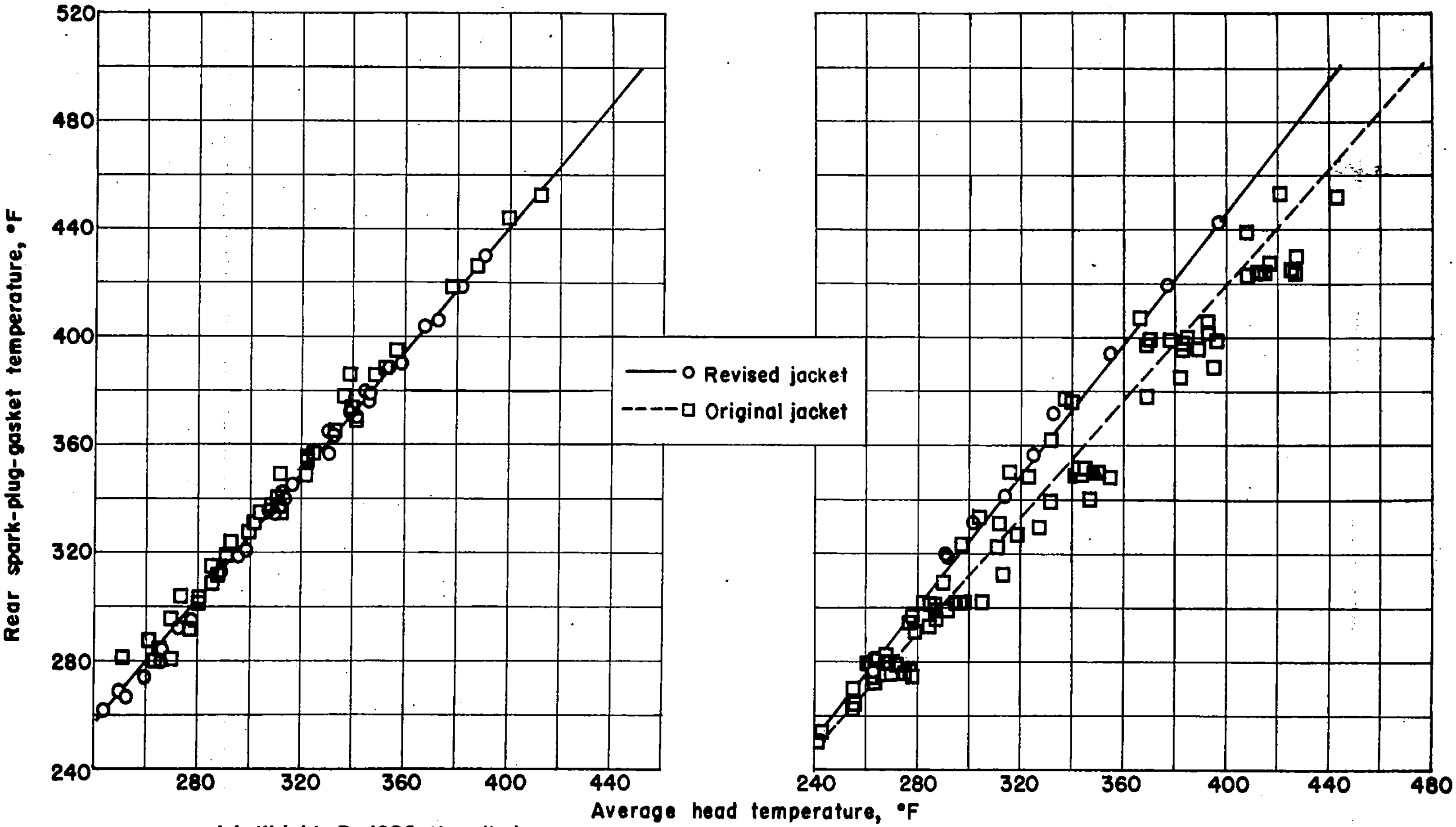


(a) Wright R-1820-H cylinder. Indicated horsepower, 80.



(b) Pratt & Whitney R-2800-21 cylinder. Indicated horsepower, 66.

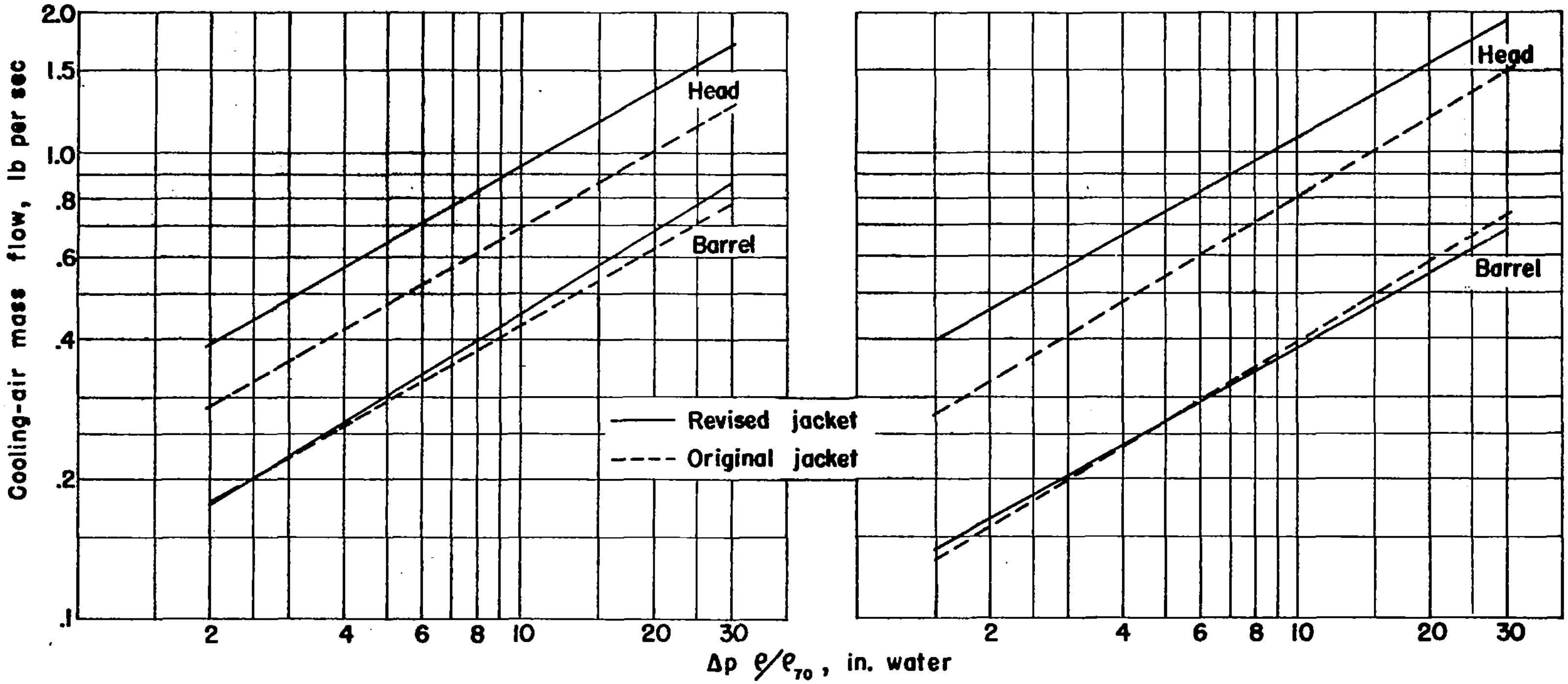
Figure 8.– Effect of jacket design on average head and average barrel temperature (corrected for variations in cooling-air temperature). Fuel–air ratio, 0.08.



(a) Wright R-1820-H cylinder.

(b) Pratt & Whitney R-2800-21 cylinder.

Figure 9.– Variation of rear spark-plug-gasket temperature with average head temperature.



(a) Wright R-1820-H cylinder.

(b) Pratt & Whitney R-2800-21 cylinder.

Figure 10.– Effect of jacket revision on cooling-air mass flow.