TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 328

THE EFFECT OF FUEL CONSUMPTION ON CYLINDER TEMPERATURES AND PERFORMANCE OF A COWLED WRIGHT J-5 ENGINE

By Oscar W. Schey
Langley Memorial Aeronautical Laboratory

Washington
November, 1929

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL NOTE NO. 328.

THE EFFECT OF FUEL CONSUMPTION ON CYLINDER TEMPERATURES AND PERFORMANCE OF A COWLED WRIGHT J-5 ENGINE.

By Oscar W. Schey.

Summary

This report presents the results of tests made by the National Advisory Committee for Aeronautics to determine the effect of fuel consumption on the cylinder temperatures and on the performance of a cowled Wright J-5 engine. The tests were conducted in the Committee's 20-foot propeller research tunnel in conjunction with other tests to determine the effect of cowling on drag, propulsive efficiency, cylinder temperatures, and performance of the same engine mounted in the nose of a cabin fuselage.

Sixty-nine iron-constantan thermocouples and three recording pyrometers were used for obtaining measurements of cylinder temperatures. The engine power was measured by means of a torque dynamometer mounted within the fuselage. The fuel consumption was computed from the time required to consume two pounds of fuel.

The test conditions in the tunnel simulated those of full throttle climbing on a hot day. All tests were conducted at air speeds of approximately 80 m.p.h. Six different sizes of

jets, varying from No. 51 to No. 46 drill size, inclusive, were used to vary the rate of fuel flow. The cowling used covered 73 per cent of the cylinder cooling surface. Slots were provided in the nose of this cowling to enable some of the cooling air to flow inside of the cowling.

The cylinder temperatures obtained with the leanest mixture were excessive, amounting, in some cases to almost 800°F. Enriching the mixture by varying the jet size from No. 51 to No. 46 resulted in a substantial reduction of cylinder temperatures amounting to an average of 196°F. at the rear spark-plug bosses and 165°F. at the front spark-plug bosses. The two cylinders which were shielded by the magnetos gave the greatest reduction in temperature, amounting to 303°F. and 254°F. for the rear spark-plug boss of cylinders Nos. 3 and 9, respectively. All of the forty-seven points selected on cylinder No. 1 showed some reduction in temperature when the leanest mixture was enriched.

Enriching the mixture to the extent obtained with the No. 49 jet resulted in an increase in power, but enriching the mixture to the extent obtained with Nos. 46 and 47 jets resulted in a large reduction in power over that obtained even with the leanest mixture.

Introduction

The effect of fuel-air ratio on engine performance has been the subject of numerous investigations, and one on which a large amount of valuable information has been published. Except for the pioneer efforts of Gibson and Heron and the work of a few recent investigators, most of these investigations have been conducted on water-cooled engines. Gibson conducted tests on air-cooled engines and found that the cylinder head and valve temperatures were considerably reduced by increasing the mixture-strength (Reference 1). Heron reported that the cylinder head temperatures of a 30 hp air-cooled engine were decreased from 580°F. to 480°F. by increasing the fuel consumption from 17 to 25 pounds per hour, but that a further increase in fuel consumption resulted in slightly higher temperatures (Reference 2). In recent tests completed at Wright Field on an air-cooled single-cylinder Liberty test engine it was found that by increasing the fuel consumption from 18.4 to 25.5 pounds per hour, the cylinder head temperatures were reduced from 580°F. to 460°F. (Reference 3).

Since few manufacturers, if any, determine the effect of fuel consumption on the full-throttle performance of an air-cooled engine in flight or under conditions simulating those in flight, the National Advisory Committee for Aeronautics undertook the research on this subject. At this time the equipment was set up and available for this work, as it had been used in tests to determine the effect of cowling on drag, propulsive efficiency, cylinder temperatures, and performance of a Wright J-5 engine mounted in the nose of a cabin fuselage.

For tests herein reported the engine used was standard in every respect except for the carburetor jet size, which was varied to obtain different rates of fuel consumption. Six different sizes of jets were used, varying from No. 51 to No. 46 drill size. Air speeds of approximately 80 m.p.h. were employed.

Apparatus and Method

These tests were conducted on a Wright J-5 engine mounted in the nost of a cabin fuselage which was placed in the air stream of the Committee's 20-foot propeller research tunnel (Reference 4). Air speeds of approximately 80 m.p.h. were used, which would correspond closely to full throttle climbing.

This engine has a $4\frac{1}{2}$-inch bore, a $5\frac{1}{2}$-inch stroke, a 5.4 compression ratio and is guaranteed by the manufacturer to develop 200 hp at 1800 r.p.m. The cylinders are of composite aluminum and steel construction. A cross section and several views of one of the cylinders are shown in Figures 1 and 2. A Stromberg NA-T4 carburetor, with jets of drill sizes varying from Nos. 51 to 46, inclusive, was used. Domestic aviation gasoline was used for all tests.

During the tests a cowling was used which covered approximately 73 per cent of the cylinder cooling surface (Figs. 3 and 4). This cowling was so designed that part of the cooling air could flow inside through slots in the nose, past the cylinders, and out through louvers at the rear of the engine. It had been selected from a series that had been used for drag tests and is not the most satisfactory in regard to cooling, as the engine was running very hot with the smallest jet size used, No. 51, which was the standard size for this engine (Reference 5).

The cylinder temperatures were measured with sixty-nine iron-constantan thermocouples of .020 inch diameter and three multiple duplex recording pyrometers. Forty-seven thermocouples were connected to cylinder No. 1 and twenty-two were distributed over the other eight cylinders. This enabled a complete study to be made of the temperature variation on the No. 1 cylinder and also gave sufficient information on each of the other cylinders so that the comparative cylinder temperatures could be obtained. The location of these thermocouples can be obtained from Table I, Figure 2, and the curves in Figure 6. The thermocouples on the head and fins were held in place by inserting them in small holes and peening the metal around the wires. Those for measuring the temperature around the spark-plug bosses were embedded 1/8 inch below the metal surface. The thermocouples for measuring the cylinder barrel temperatures were held firmly against the metal surface by means of clamp rings.

The specific fuel consumption was determined from the time required to consume 2 pounds of fuel and the measurement of power as determined from dynamometer and tachometer readings. The engine torque was measured by a dynamometer mounted within the fuselage (Reference 4). In addition, measurements were obtained of the oil in, oil out, and carburetor air temperatures, air speed and engine speed. All tests were conducted at full throttle.

Results

The results of these tests are presented in the form of tables and curves. Table I gives the cylinder head temperatures obtained with each jet and the location of each of the sixty-nine thermocouples used. Table II gives the air speed, engine speed, brake horsepower, specific fuel consumption, barometric pressure, and the temperatures of the carburetor air, oil in, oil out, and air stream.

Figure 5 shows the effect of the rate of fuel consumption on the temperature of the front and rear spark-plug bosses. These curves indicate that the temperature of the spark-plug bosses is very sensitive to change in fuel consumption.

Figure 6 shows the effect of the rate of fuel consumption on the temperatures of the cylinder barrel. It is interesting to note that an increase in fuel consumption results in a reduction in the temperature at all points on the cylinder barrel.

The reduction in temperature obtained on several points of cylinder No. 1 by enriching the mixture is shown in Figure 7.

Figure 8 presents a comparison of the spark-plug-boss temperatures obtained on cylinder No. 3 as compared with the average for all the unshielded cylinders for different rates of fuel consumption. These curves show that a cylinder which is shielded from the air blast, or improperly cooled, will have a much greater rise in temperature with leaning of the mixture than one which is properly cooled.

Figure 9 shows the effect of varying the fuel consumption on the engine power and engine speed. Enriching the mixture results at first in an increase in power and speed, but a further increase in fuel consumption results in a rapid decrease in power and speed.

Discussion of Results

Some of the early investigators engaged in the development of air-cooled engines often resorted to a rich mixture as a means of obtaining better cooling. The excess fuel would be exhausted, together with the burned gases, as a highly superheated vapor and thus carry away a large amount of heat. Tests have shown that a rich mixture will reduce the temperature of the cylinder walls, valves, and intake passages, and consequently permit a charge of greater density to be induced. A rich mixture will thus indirectly reduce detonation and also give more power up to a certain value.

These tests were conducted with conditions simulating those of full throttle climbing and are considered severe, being conducive to high cylinder temperatures. The cooling air temperatures and the carburetor air temperatures and pressures were higher than those normally obtained in a climb, thus making conditions even more severe. This engine had a compression ratio of 5.4, which would undoubtedly cause detonation when hot and operating on domestic aviation gasoline such as was used in these tests. The cowling, one of a series which had been designed primarily for drag test, was not very satisfactory for cooling (Reference 6). As practically all conditions of these tests tended to raise the cylinder temperatures, it was considered advisable to conduct the tests with standard size jets or larger, to avoid destructive temperatures.

As a result fuel consumptions far beyond the range of practicability were obtained. The shape of the curves, however, would be very nearly the same with test conditions giving lower temperatures and fuel consumptions.

The temperatures here presented are accurate to $\pm 10^{\circ}$F. and are representative of conditions as stated. Each run was of sufficient duration to assure that the highest temperatures were obtained. The pyrometers used had high internal resistance, which reduced to a minimum the effect of resistance variation of the long leads used. Good thermal contact was obtained at each junction and the wires were faired along the cylinder for some distance from the hot junction so that no heat would be conducted away by the wires.

The results of these tests show that increasing the jet size from a No. 51 drill size to a No. 46 results in a large reduction in the cylinder temperatures. For the two extremes of mixture conditions the average rear spark-plug-boss temperature for the nine cylinders was reduced 196°F. On cylinder No. 3

the temperature of the rear spark-plug boss was reduced 300°F. The average reduction for the front spark-plug-boss temperature for the above conditions was 165°F. At the same time a reduction of 171°F. was obtained for the front spark-plug bosses on cylinder No. 3. Although the cylinder barrel temperatures showed a large reduction with increase in fuel consumption it was not as large as that obtained for the spark-plug bosses. For the eight thermocouples under each clamp ring the average reduction obtained by increasing the jet size from No. 51 to No. 46 was 161°F., 115°F., and 112°F., for top, middle, and bottom clamp rings, respectively.

The curves in Figure 7 show an interesting comparison of the reduction in cylinder temperatures obtained at several points on the same cylinder with change in fuel consumption. It may be noted that for the points which are low with the lean mixture there is very little reduction obtained with a richer mixture as compared with the reduction obtained for the points that are higher. These curves also show the difference in temperatures obtained on the head, spark-plug bosses, and several points on the barrel; and that the temperatures decrease rapidly at first as the mixture is enriched, but soon reach a point where increasing the fuel consumption has very little effect on the cylinder temperatures.

The temperatures for the rear part of the cylinder, or for that part which is shielded from the air blast, increase more rapidly as the mixture is leaned. Somewhat similar conditions are true for cylinders Nos. 3 and 9, which are shielded by the magnetos. With a rich mixture the front and rear spark-plug-boss temperatures for these cylinders are the same as the average for all the cylinders, but as the fuel-air ratio is increased the difference gradually increases and amounts to 100°F. with the leanest mixture.

The engine power was also considerably affected by varying the fuel consumption, as is shown by the curves in Figure 9. Increasing the specific fuel consumption from .7 to .9 lb. per b.hp increases the power 9.5 per cent, but a further increase in fuel consumption results in a reduction in power. This shows that the useful range of fuel-air ratios had been investigated. With Nos. 46 and 47 jets a large quantity of black smoke was exhausted, while with Nos. 50 and 51 jets the engine popped back at intervals. The smoothest operation was obtained with Nos. 48 and 49 jets. That there was a falling off in power with a fuel consumption of less than .9 lb. per b.hp per hr. was largely due to the lower volumetric efficiency obtained with high cylinder temperatures.

Increasing the amount of cooling surface which is cowled reduces the drag, but has the disadvantage of increasing the cylinder temperatures (Reference 5). There may, however, be conditions when an increase in the degree of cowling will give sufficient reduction in drag so that obtaining a reduction in cylinder temperature by slightly enriching the mixture may be justified.

Conclusions

The result of these tests on a Wright J-5 air-cooled engine indicates that enriching the mixture by increasing the carburetor jet size results in a reduction in cylinder head and barrel temperatures. By increasing the jet size from No. 51 to No. 46, an average reduction in temperature of the rear spark-plug bosses, front spark-plug bosses, and the cylinder heads of 196°, 165°, and 165°F., respectively, was obtained. The cylinder barrels also showed a substantial reduction in temperature when the mixture was enriched.

The cylinders shielded by the magnetos or the points on the cylinder that do not receive a free flow of cooling air increase most rapidly in temperature as the mixture is leaned. A free flow of air past the cylinders is essential for satisfactory operation on a lean mixture.

Enriching the mixture to the extent obtained with the No. 49 jet shows an increase in power, but beyond that point there is a rapid decrease in power with increase in mixture strength.

The results of these tests show that the Wright J-5 engine can withstand severe temperatures for short periods of operation and also to what extent destructive temperature may be avoided by enriching the mixture.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., September 16, 1929.

References

1. Gibson, A. H. : Exhaust and Cylinder Head Temperatures in High-Speed Petrol Engines. Proc. Inst. Mech. Eng., 1923, ii, 4-6, 1045-1091.

2. Heron, S. D. : Air-Cooled Cylinder Design and Development. Trans. Soc. Auto. Eng., 1922, xvii, Part I, 347-430.

3. Griffith, M. O. : Single-Cylinder Test of the Air-Cooled Liberty Cylinder. Air Corps, Materiel Division, Technical Report Serial No. 2975, 1928.

4. Weick, Fred E. and Wood, Donald H. : The Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics. N.A.C.A. Technical Report No. 300, 1928.

5. Schey, Oscar W. and Biermann, Arnold E. : The Effect of Cowling on Cylinder Temperatures and Performance of a Wright J-5 Engine. N.A.C.A. Technical Report No. 332, 1929.

6. Weick, Fred E. : Drag and Cooling with Various Forms of Cowling for a "Whirlwind" Radial Air-Cooled Engine. N.A.C.A. Technical Report No. 313, Part I, 1928.

TABLE I

Maximum cylinder temperatures obtained during fuel consumption tests on a cowled Wright J-5 engine operating full throttle at an air speed of approximately 80 m.p.h.

No.	Location of Thermocouple Right and left looking forward from cockpit	Jet size					
		46	47	48	49	50	51
1	Cylinder No. 1, fin tip, left side of inlet passage	282	280	312	325	337	368
2	Cylinder No. 1, center of head, top of exhaust passage	431	430	479	476	500	511
3	Cylinder No. 1, fin tip, rear of exhaust passage	393	385	432	425	447	461
4	Cylinder No. 1, on front side of exhaust valve guide	378	372	412	404	420	414
5	Cylinder No. 1, near fin tip, front of exhaust passage	329	330	361	362	371	370
6	Cylinder No. 1, front side of inlet valve guide	188	192	212	218	220	229
7	Cylinder No. 1, in center of head over front spark plug	361	374	420	430	449	509
8	Cylinder No. 1, front of head side of exhaust passage	397	400	440	438	458	462
9	Cylinder No. 1, rear of head in side of exhaust passage	440	440	489	481	508	525
10	Cylinder No. 1, in center of head over rear spark plug	420	431	488	501	526	585
11	Cylinder No. 1, in left side of rear spark-plug boss	468	481	539	555	584	646
12	Cylinder No. 1, in left side of front spark-plug boss	382	396	444	460	482	550
13	Cylinder No. 1, fin tip, left of front spark-plug boss	335	347	382	395	416	470
14	Cylinder No. 1, under top clamp ring, right-rear	331	350	401	425	448	528
15	Cylinder No. 1, under top clamp ring, right	329	342	380	404	411	482

TABLE I (Cont.)

Maximum cylinder temperatures obtained during fuel consumption tests on a cowled Wright J-5 engine operating full throttle at an air speed of approximately 80 m.p.h.

No.	Location of Thermocouple	Jet size					
		46	47	48	49	50	51
16	Cylinder No. 1, under top clamp ring, right-front	281	300	341	358	370	422
17	Cylinder No. 1, under top clamp ring, front	323	342	388	399	418	470
18	Cylinder No. 1, under top clamp ring, left-front	341	352	385	399	408	445
19	Cylinder No. 1, under top clamp ring left	363	370	400	420	420	500
20	Cylinder No. 1, under top clamp ring, left-rear	400	422	462	490	513	578
21	Cylinder No. 1, under top clamp ring, rear	378	402	471	509	534	612
22	Cylinder No. 1, center of fin 18, in the rear	368	384	441	462	481	558
23	Cylinder No. 1, tip of fin 18, in the rear	345	363	420	439	469	548
24	Cylinder No. 1, tip of fin 18, on left side	310	320	345	358	358	433
25	Cylinder No. 1, center of fin 18, on left side	395	410	442	458	475	531
26	Cylinder No. 1, under middle clamp, rear	350	343	382	388	409	473
27	Cylinder No. 1, under middle clamp, right-rear	372	365	413	422	444	508
28	Cylinder No. 1, under middle clamp, right	273	322	331	374	351	245
29	Cylinder No. 1, under middle clamp, right-front	288	282	320	326	345	376

TABLE I (Cont.)

Maximum cylinder temperatures obtained during fuel consumption tests on a cowled Wright J-5 engine operating full throttle at an air speed of approximately 80 m.p.h.

No.	Location of Thermocouple	Jet size					
		46	47	48	49	50	51
30	Cylinder No. 1, center of fin 11, front	238	236	268	258	272	291
31	Cylinder No. 1, tip of fin 11, front	195	195	220	212	218	227
32	Cylinder No. 1, under middle clamp, front	285	281	320	315	335	366
33	Cylinder No. 1, under middle clamp, left-front	309	308	337	345	351	394
34	Cylinder No. 1, center of fin 11, on left side	304	306	337	345	353	404
35	Cylinder No. 1, under middle clamp, left	375	373	407	423	432	511
36	Cylinder No. 1, tip of fin 11, on left side	268	263	296	298	307	335
37	Cylinder No. 1, under middle clamp, left rear	390	385	422	438	461	543
38	Cylinder No. 1, under bottom clamp, rear, to right	352	341	390	398	422	477
39	Cylinder No. 1, under bottom clamp, right, to rear	353	364	400	415	431	480
40	Cylinder No. 1, under bottom clamp, right, to front	329	328	366	375	394	425
41	Cylinder No. 1, under bottom clamp, front, to right	245	238	270	284	285	320
42	Cylinder No. 1, tip of fin 1, front	275	284	293	344	295	248
43	Cylinder No. 1, under bottom clamp, front, to left	268	279	310	314	322	350
44	Cylinder No. 1, under bottom clamp, left, to front	298	306	345	345	363	400

TABLE I (Cont.)

Maximum cylinder temperatures obtained during fuel consumption tests on a cowled Wright J-5 engine operating full throttle at an air speed of approximately 80 m.p.h.

No.	Location of Thermocouple	Jet size					
		46	47	48	49	50	51
45	Cylinder No. 1, tip of fin 1, left	285	287	320	320	341	380
46	Cylinder No. 1, under bottom clamp, left to rear	354	356	399	408	432	496
47	Cylinder No. 1, under bottom clamp, rear, to left	365	358	414	418	448	517
48	Cylinder No. 2, in left side of front spark-plug boss	385	395	431	459	498	521
49	Cylinder No. 2, in left side of rear spark-plug boss	478	488	547	580	630	657
50	Cylinder No. 2, in center of head, over rear spark plug	408	418	457	487	525	549
51	Cylinder No. 3, in left side of front spark-plug boss	406	430	476	587	637	687
52	Cylinder No. 3, in left side of rear spark-plug boss	485	521	570	681	727	788
53	Cylinder No. 3, in center of head, over rear spark plug	452	478	518	632	663	725
54	Cylinder No. 4, in left side of front spark-plug boss	396	400	480	502	535	558
55	Cylinder No. 4, in left side of rear spark-plug boss	463	472	560	593	622	647
56	Cylinder No. 4, in center of head, over rear spark plug	396	409	490	517	543	572
57	Cylinder No. 5, in left side of front spark-plug boss	394	426	438	491	500	507
58	Cylinder No. 5, in left side of rear spark-plug boss	465	522	537	595	605	612

TABLE I (Cont.)

Maximum cylinder temperatures obtained during fuel consumption tests on a cowled Wright J-5 engine operating full throttle at an air speed of approximately 80 m.p.h.

No.	Location of Thermocouple	Jet size					
		46	47	48	49	50	51
59	Cylinder No. 5, in center of head, over rear spark plug	423	472	485	541	550	552
60	Cylinder No. 6, in left side of front spark-plug boss	380	417	421	506	490	563
61	Cylinder No. 6, in left side of rear spark-plug boss	445	492	495	587	563	658
62	Cylinder No. 6, in center of head over rear spark plug	466	515	516	608	592	682
63	Cylinder No. 7, in left side of front spark-plug boss	363	372	409	421	467	502
64	Cylinder No. 7, in left side of rear spark-plug boss	458	458	498	515	578	655
65	Cylinder No. 8, in left side of front spark-plug boss		348	386	388	418	465
66	Cylinder No. 8, in left side of rear spark-plug boss		438	472	470	512	579
67	Cylinder No. 8, in center of head over rear spark plug		369	405	410	439	483
68	Cylinder No. 9, in left side of front spark-plug boss	415		444		563	640
69	Cylinder No. 9, in left side of rear spark-plug boss	505		548		689	759

TABLE II.

Performance measurements obtained on a cowled Wright J-5 engine during fuel-consumption tests

Jet drill size No.	Reading No.	Air speed m.p.h.	r.p.m.	Brake horsepower	Fuel rate lb./b.hp/hr.	Barometer in. of Hg	Temperature of carburetor air °F.	Temperature of oil in °F.	Temperature of oil out °F.	Temperature of air stream
46	1	81.6	1620	148.0	1.127	29.96	59	143	130	87.8
	2	81.8	1610	144.6	1.258	29.96	79	128	129	89.6
	3	81.6	1605	143.0		29.96	79	128	132	89.6
	4	81.6	1600	141.0	1.261	29.96	80	135	134	89.6
	5	81.9	1600	141.0	1.270	29.96	79	135	136	91.4
47	1	81.5	1620	141.6		30.06	80	150	150	89.6
	2	81.8	1580	133.0	1.237	30.06	76	148	146	89.6
	3	82.8	1570	130.7	1.227	30.06	78	145	145	89.6
	4	81.2	1570	131.0	1.223	30.06	78	145	145	89.6
	5	82.0	1580	133.0	1.204	30.06	78	145	146	91.4
48	1	82.1	1730	180.1	.899	29.96	86	138	139	91.4
	2	82.4	1710	175.0	.891	29.96	87	138	138	91.4
	3	82.6	1705	173.0	.878	29.96	87	143	144	91.4
	4	82.1	1705	173.0	.901	29.96	87	148	144	93.2
	5	82.0	1705	173.0	.895	29.96	87	152	153	93.2
49	1	81.0	1660	158.3	.861	30.06	78	148	146	89.6
	2	81.8	1620	147.2	.927	30.06	78	148	146	91.4
	3	81.6	1620	145.9	.914	30.06	80	148	150	91.4
	4	81.6	1620	145.9	.919	30.06	81	152	153	91.4
50	1	81.7	1740	189.8	.711	30.06	85	123	126	87.8
	2	81.9	1695	171.1	.771	30.06	84	134	136	87.8
	3	81.0	1680	167.1	.790	30.06	84	143	144	87.8
51	1	80.6	1700	175.7	.690	30.13	74	118	122	80.6
	2	80.7	1650	159.4	.710	30.13	74	135	136	82.4
	3	80.3	1625	154.8		30.13	74	144	145	82.4

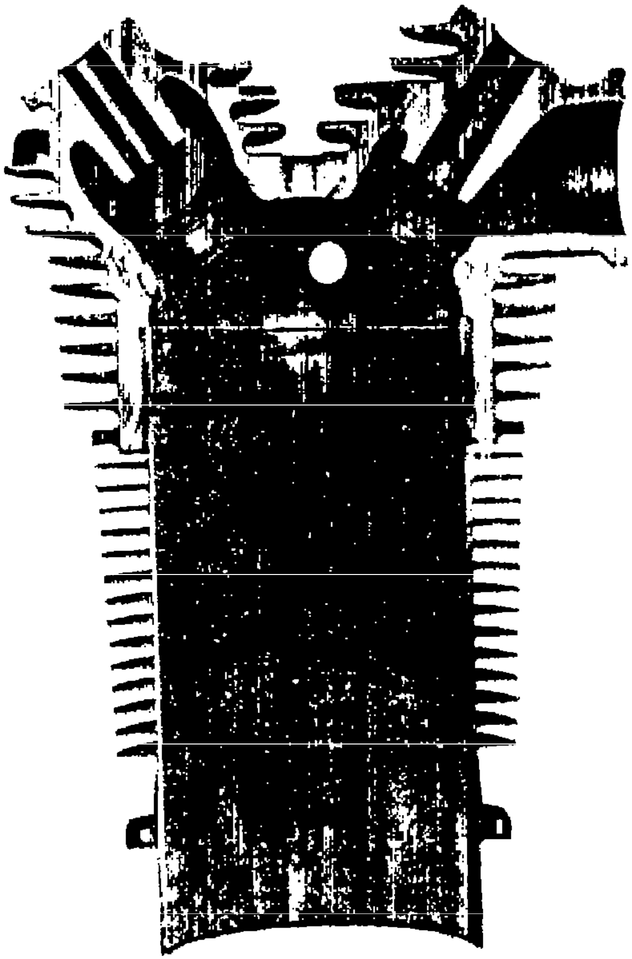


Fig.1 Cross-section of a Wright J-5 engine

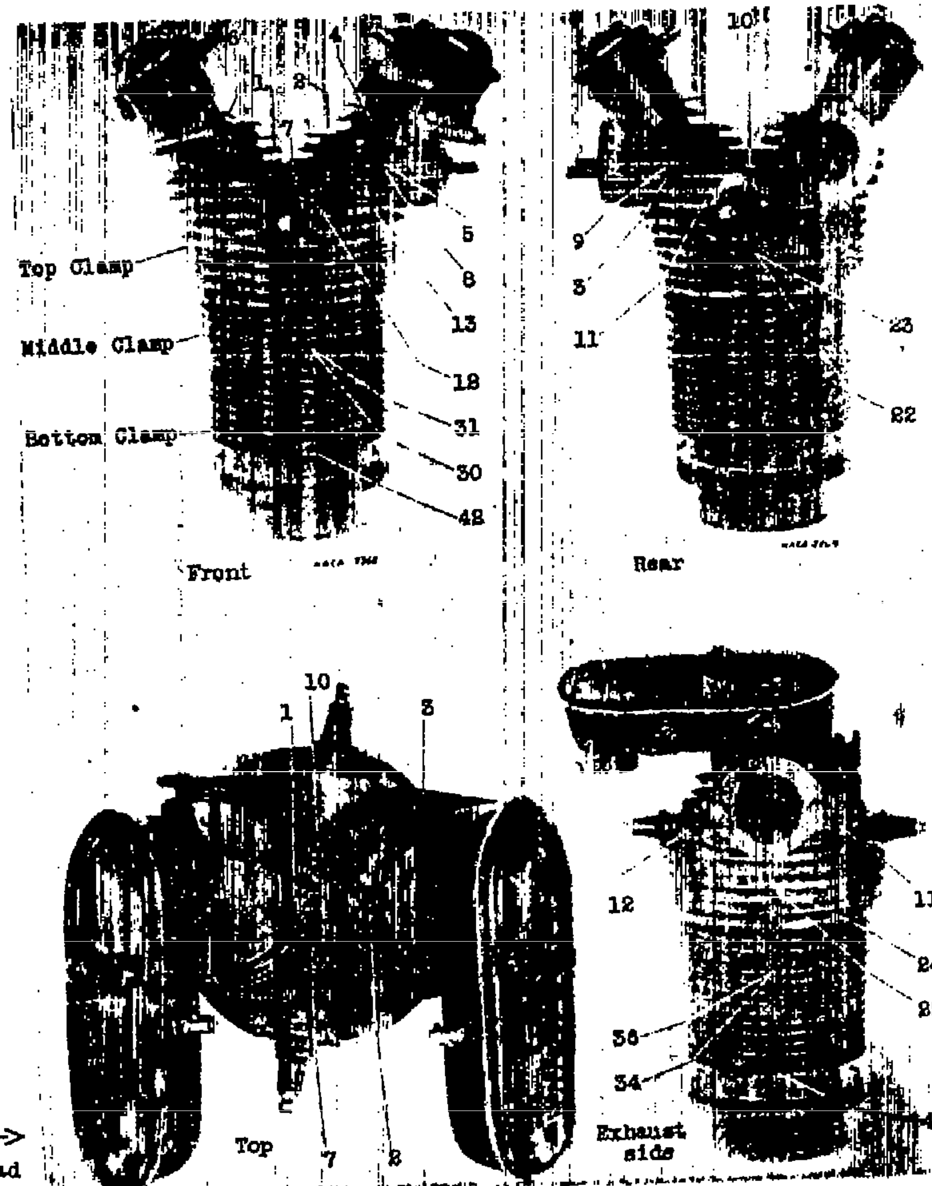


Fig.2 Location of thermocouples on head and fins of cylinder No.1

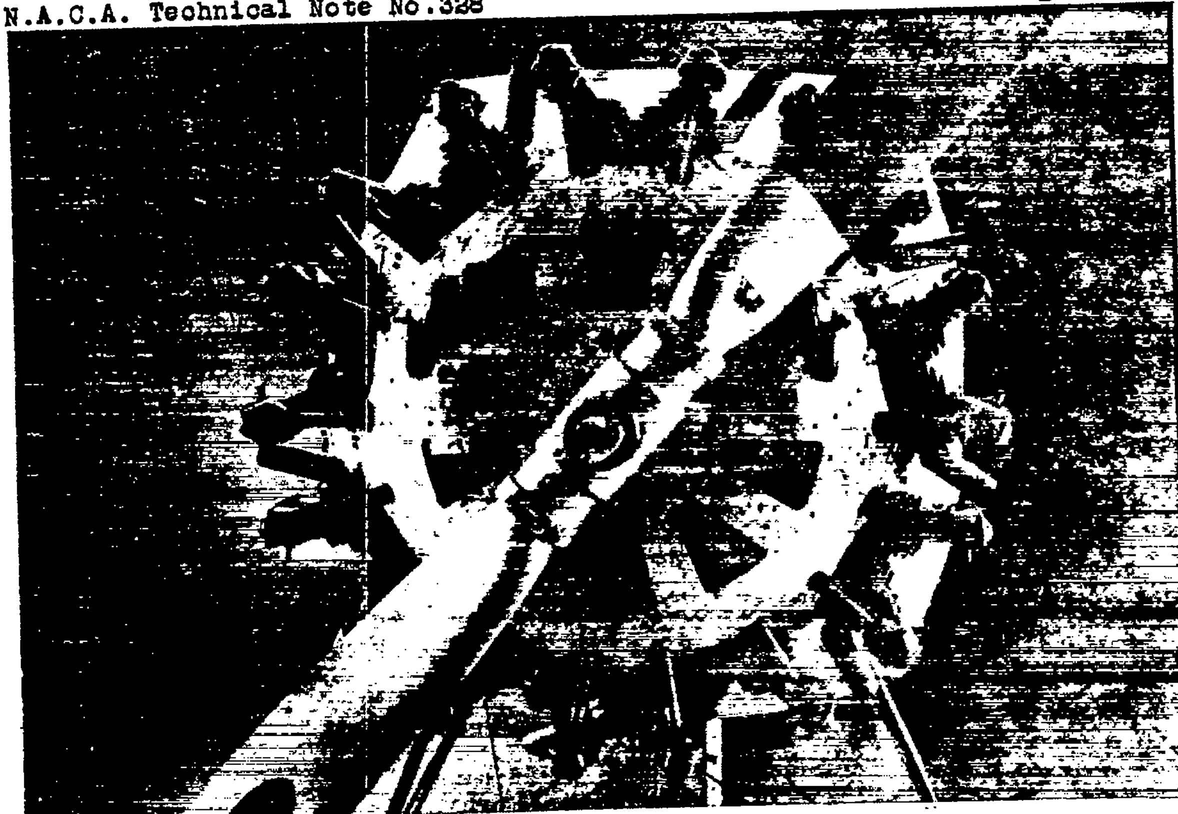


Fig.3 Front view of cowling No.7

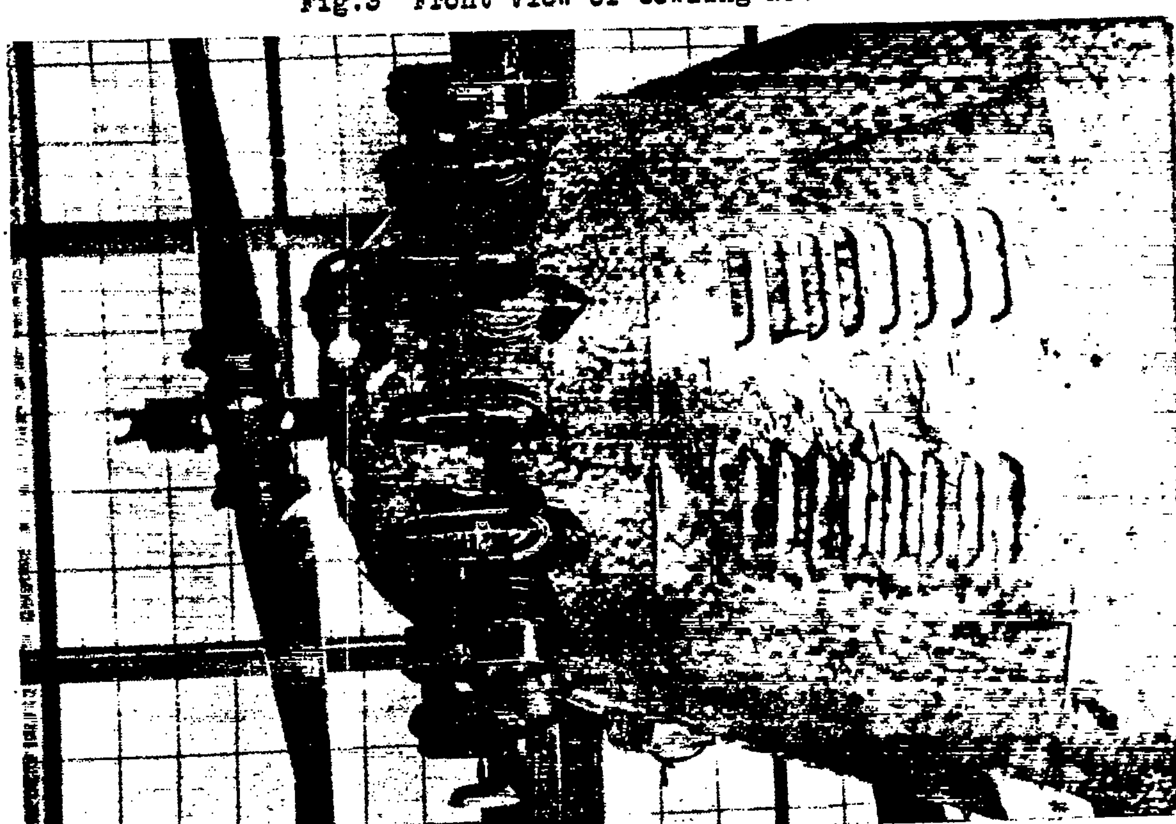
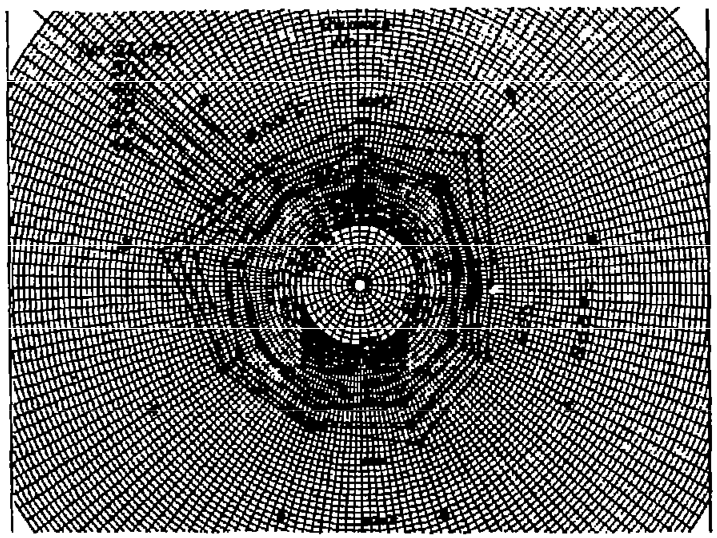
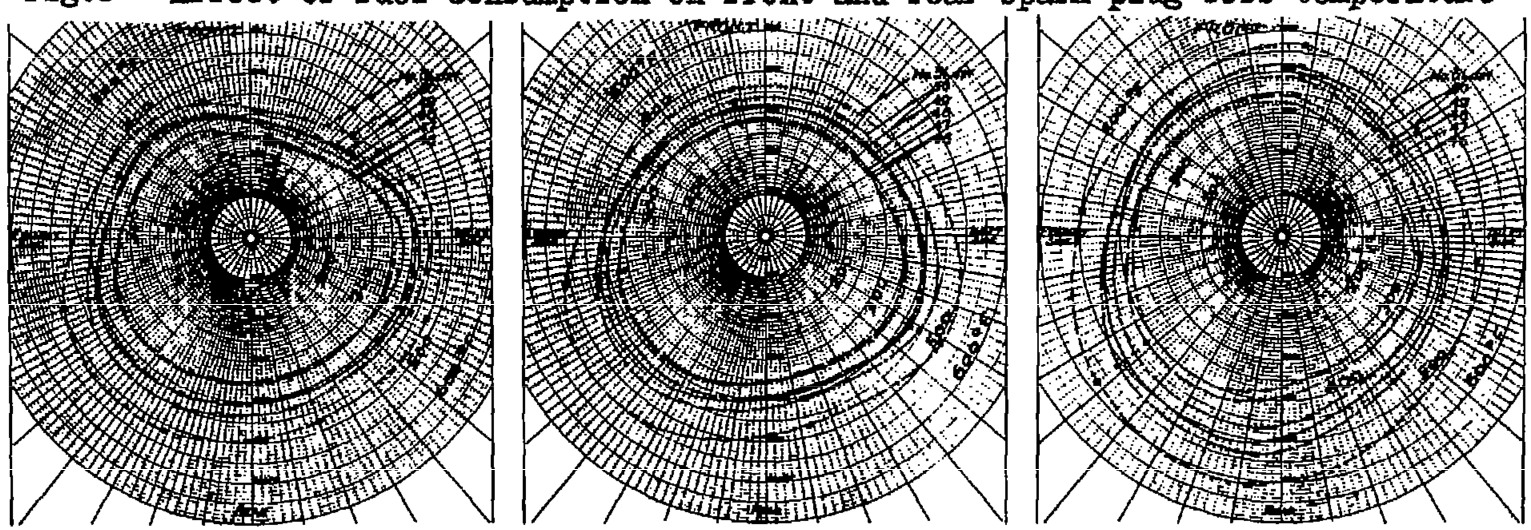


Fig.4 Side view of cowling No.7



Front Rear

Fig.5 Effect of fuel consumption on front and rear spark-plug boss temperature



Bottom clamp Middle clamp Top clamp

Fig.6 Effect of fuel consumption on cylinder-barrel temperatures of cylinder No.1

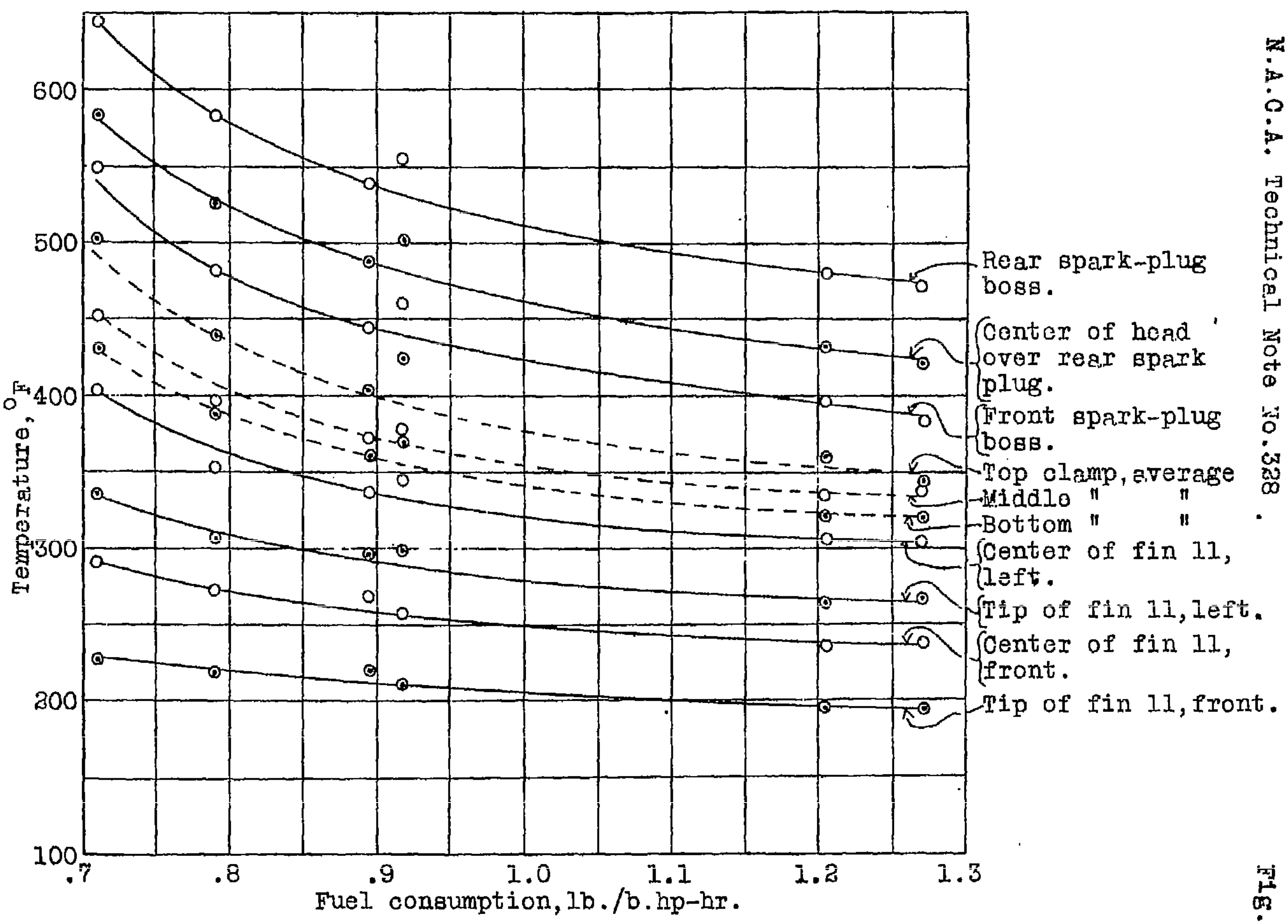


Fig.7 Effect of fuel consumption on cylinder temperatures.

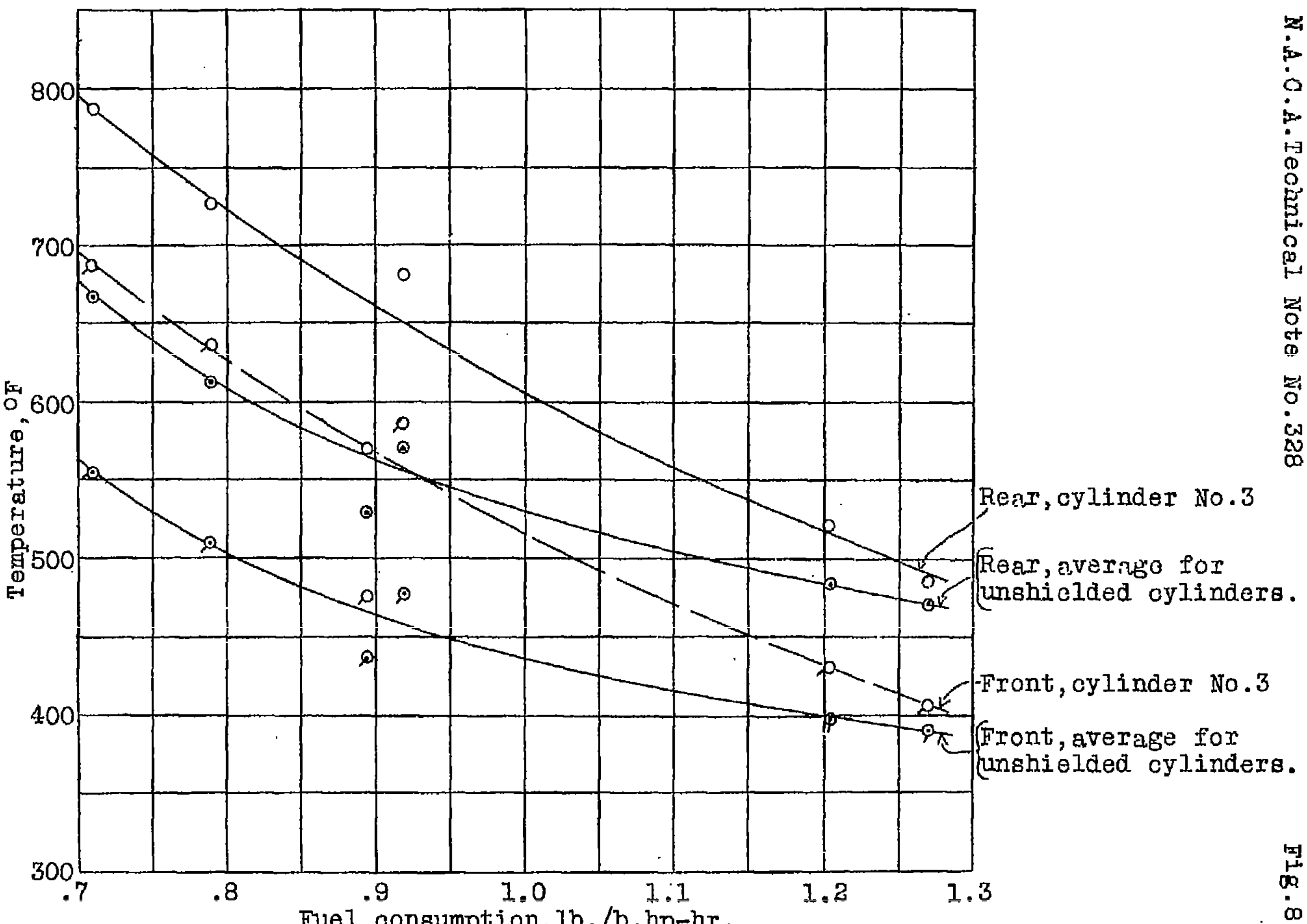


Fig.8 Effect of fuel consumption on temperatures of spark-plug bosses of a cylinder that is shielded by a magneto as compared with the average temperatures of the spark-plug bosses on unshielded cylinders.

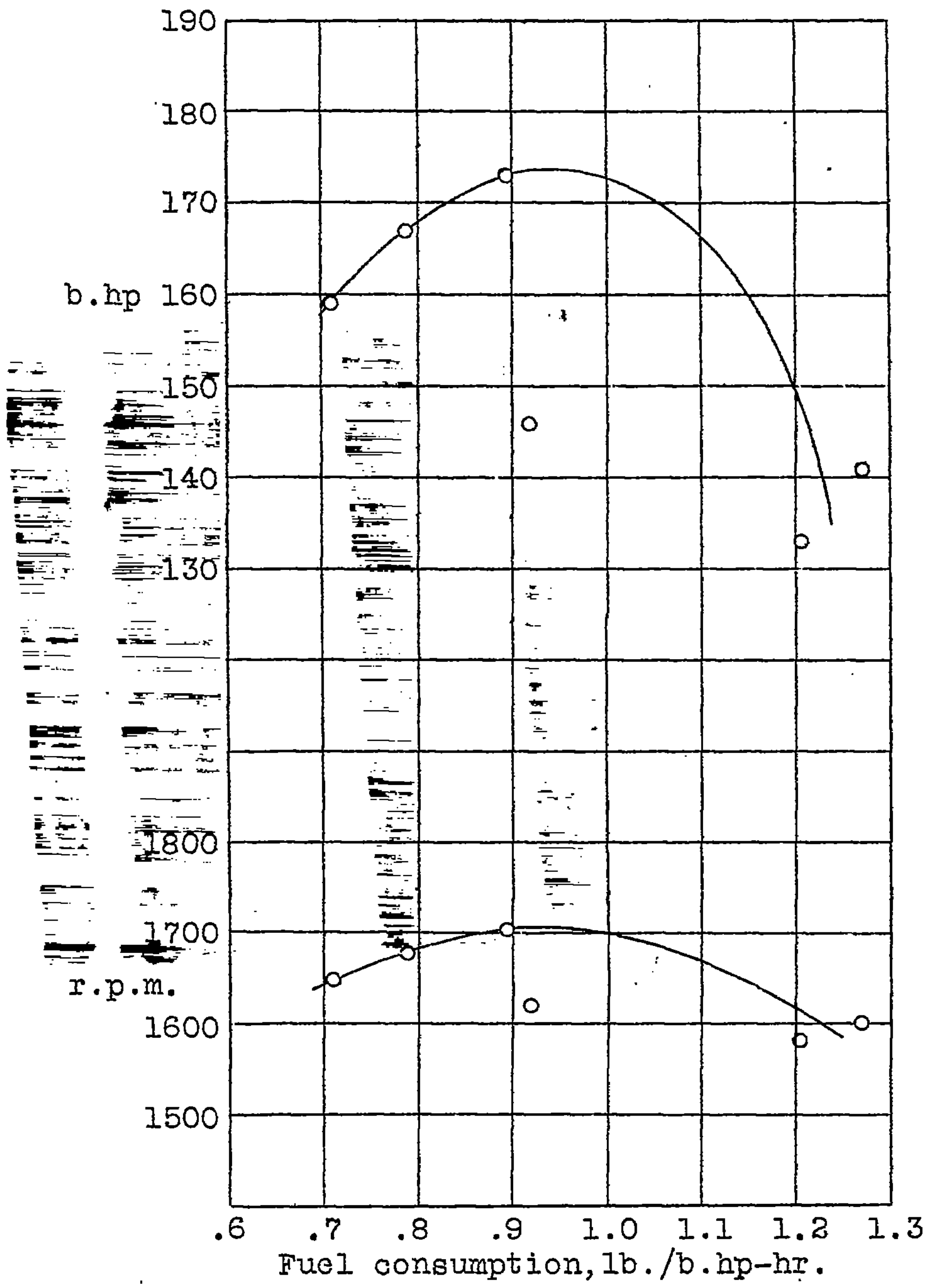


Fig.9 Effect of fuel consumption on engine power.