TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 116

F-5-L BOAT SEAPLANE

COMPARATIVE PERFORMANCE WITH DIRECT DRIVE AND GEARED ENGINES.

Compiled by Lieut. W. S. Diehl,
Bureau of Aeronautics, U.S.N.

October, 1922.

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Comprehensive tests have been made at the Naval Air Station, Hampton Roads, Virginia, to compare the performance of the F-5-L Boat Seaplane fitted direct drive and geared Liberty engines. These tests were planned and conducted so as to eliminate as far as possible the personal equation of the pilot and the differences in performance of two airplanes of the same type. The gearing and propeller of a geared type Liberty engine weighs 130 lbs. more than a direct drive propeller on the F-5-L installation. This difference was charged up to the geared type in all tests by starting with a gross load of 13,360 lbs. as compared with a gross load of 13,100 lbs for the direct drive.

The personal equation of the pilots was partially eliminated by changing pilots and repeating each test. In a like manner, the inherent differences in performance of two airplanes was eliminated by exchanging the engines and repeating the tests. The time for take-off and the climb in twenty minutes are subject to great variation, but a comparatively high degree of accuracy was obtained by repeating these tests a large number of times.

An attempt was made to eliminate any difference which might be due to the propellers by testing each arrangement with two pro-

*Originally prepared as A.T.N.#222, Bureau of Aeronautics, Navy Department.

pellers. It will be noted that two airplanes were used; each was tested with direct drive and geared engines and with two propellers for each type of drive. This gives eight complete performance tests, in which each separate item was obtained by two or more runs with different pilots. For convenience these tests have been divided into four series in which the tests were made simultaneously. Table I shows the grouping of airplane, engines, and propellers in each series.

Tests Conducted.

Each series consisted of tests as follows:

(a) Time to take off - 24 runs for each arrangement, alternating pilots.
(b) Climb in 20 minutes - 4 runs for each arrangement, alternating pilots.
(c) Racing over a given course - (Course approximately 29 nautical miles) - 2 runs for each arrangement, alternating pilots.
(d) High speed runs - 2 runs for each arrangement, alternating pilots.
(e) Low speed runs - 2 runs for each arrangement, alternating pilots.
(f) Fuel consumption runs - 1 run for each arrangement, 4-hour flight, airplanes take off and land simultaneously.

Time to take off.

The data obtained on these tests are condensed in Table II. Each pilot made 12 take-offs and then changed airplanes. The time given in columns 5 and 6 is the average time for 12 trials. The r.p.m. given in columns 7 and 8 are the average for both engines during the corresponding trials.

A study of the averages given at the bottom of this table will be found interesting. First, the general average for 96 take-

offs of each type gives 37.5 sec. for the direct drive and 24.6 sec. for the geared drive. That is in general, the geared drive will take off in about 90% of the time required for the direct drive. The average power was practically equal.

A further study of averages shows a pronounced difference between the time required to take off in Series 1 and 2, or 3 and 4. This difference is greater for the direct drive than for the geared. In both cases the quicker getaway occurs with the higher pitch propeller.

Twenty-Minute Climbs.

For each arrangement, four tests were made, alternating pilots. For each set of tests the climbs were simultaneous. The data obtained is condensed in Table III.

The general average of all climbs shows that the geared type climbs 5,750 ft. in twenty minutes, as compared with 4,730 ft. for the standard direct drive. A study of the individual climbs shows that airplane A-3787 consistently climbs better than airplane A-3682. Part of the difference in climb is due to the greater average power developed by the geared type during these trials.

Racing Over a Given Course.

These tests are in pairs of timed simultaneous runs over a course approximately 29 nautical miles in length. The data is given in condensed form in Table IV.

The general average of the 8 runs shows that the geared type is 5.0% faster than the direct drive. Again, part of this differ-

ence is due to the higher power corresponding to the greater r.p.m. of the geared type - 1697 r.p.m. against 1632 r.p.m. The times of individual runs indicate the geared type to be consistently faster than the direct drive. The effect of the difference in airplanes and propellers is hardly as great on the high speed as it is on the climb in twenty minutes, since the high speed varies as the cube root of the power available and the climb varies directly as the excess power.

It is interesting to note that the observed difference in high speed checks very closely with that calculated from the ratio of propeller efficiencies. The maximum efficiency of the high pitch direct drive propeller is about 70%, for the corresponding geared drive propeller it is about 78%. The ratio of these efficiencies is 1.11. The ratio of the powers corresponding to 1697 r.p.m. and 1632 r.p.m. is 1.04. The geared drive therefore supplied (1.04 x 1.11 = 1.155), 15.5% more thrust horsepower than the direct drive at high speed. The cube root of 1.155 is 1.049. Therefore, the high speed of the geared drive is calculated to have been 4.9% greater than for the direct drive.

High Speed Runs.

These tests are a check on the "Racing" tests, and are subject to the same comment. They indicate that the geared drive at 1690 r.p.m. is on the average 2.3% faster than the direct drive at 1630 r.p.m. No pronounced effect due to airplane or propeller is evident. The condensed data are given in Table V.

Low Speed Runs.

The data obtained on low speed runs is included in Table VI, but it is not to be given great weight. The low speeds should be substantially the same. The average value is between 44k and 45k.

Fuel Consumption Runs.

These tests were made by measuring the fuel consumed in a flight of approximately four hours' duration, the two airplanes taking off, flying, and landing together. The results which are given in Table VII are somewhat inconclusive, owing to the small differences in every run, except the first. The great difference in this run is questionable. Omitting this run, it appears that the fuel consumption is greater for the geared drive, but it also appears that the entire difference may be due to the difference in the airplanes (compare series 2 and 4). The only conclusion justified is that a difference, if present, is small.

Conclusions.

1. An F-5-L with geared engines takes off in approximately 90% of the time required for the same airplane with standard direct drive engines.

2. An F-5-L with geared engines climbs in twenty minutes to an altitude approximately 20% greater than that obtained with the standard direct drive on the same airplane.

3. There is a large difference between the climbs of two airplanes of the same type. This difference will always be more pronounced when the climb is normally slow. In the case of the F-5-L

airplanes under consideration it is of the order of 10% difference in altitude on a 20-minute climb.

4. The maximum speed of an F-5-L with geared engines is about 3.5% greater than maximum speed of the same airplane with standard direct drive engines (at the same engine r.p.m.).

5. The fuel consumption is probably less affected by the type of drive than by inherent differences in the performance of different airplanes.

6. The following resume shows the average change in performance due to substitution of the geared drive for direct drive in an F-5-L:

(a) Time to take off - - - - - - - 10% decrease.
(b) Climb in 20 minutes - - - - - - 20% increase.
(c) High speed - - - - - - - - - - - - 3.5% "
(d) Low speed (estimated) - - - - - - 1.0 "

Table I.

F-5-L Tests.

Comparison of Standard and Geared Types.

Series		1	2	3	4
Airplane No.	Standard	A-3682	A-3682	A-3787	A-3787
	Geared	A-3787	A-3787	A-3682	A-3682
Propeller	Standard	SE-5111	X-4987-T	SE-5111	X-4987-T
	Geared	SE-5161	SE-5163	SE-5161	SE-5163
Port Engine	Standard	5511	5511	3571	3571
	Geared	5510	5510	5510	4229
Stbd Engine	Standard	5676	5676	5676	5676
	Geared	A-3271	A-3271	A-3271	A-3271
Gross Load	Standard	13100	13100	13100	13100
	Geared	13360	13360	13360	13360

NOTE: The following carburetor setting was used in all tests: Choke 30; main 130; compensating 155.

Propellers: Direct drive - SE-5111 10.0'D, 5.54' P
" " - X-4987-T 10.0'D, 5.13' P
Geared - SE-5161 11.25'D, 10.0' P
" - SE-5163 11.0'D, 8.34' P

Table II.

F-5-L Time to Take Off.

Comparison of Direct and Geared Drives on Liberty Engine.

Series	Pilot Standard	Pilot Geared	No. Runs	Time to take-off Standard	Time to take-off Geared	R.P.M. Stand.	R.P.M. Geared
1	P	E	12	25.7	25.6	1470	1400
	E	P	12	26.2	23.8	1470	1400
2	P	E	12	29.3	24.4	1560	1570
	E	P	12	28.1	25.3	1560	1570
3	P	E	12	25.5	24.8	1440	1420
	E	P	12	24.9	23.2	1440	1420
4	V	P	12	31.5	25.9	1560	1615
	P	V	12	28.8	24.2	1560	1615
Averages.							
Average			96	27.5	24.6	1508	1501
Average (1)			24	25.9	24.7	1470	1400
" (2)			24	28.7	24.8	1560	1570
" (3)			24	25.2	24.0	1440	1420
" (4)			24	30.2	25.1	1560	1615
(1) & (3)			48	25.6	24.4	1455	1410
(2) & (4)			48	29.4	24.9	1560	1592

Table III.

F-5-L 20-Minute Climbs.

Series	Pilot		Altitude-ft.		R.P.M.		Difference in climb
	Stand.	Geared	Stand.	Geared	Stand.	Geared	
1	P	E	4100	5100	1535	1525	1000
	P	E	4050	5100	1535	1525	1050
	E	P	3800	5950	1540	1500	2150
	E	P	4200	5700	1540	1500	1500
2	V	E	4400	6300	1640	1710	1900
	V	E	4600	6400	1640	1710	1800
	E	V	4500	6100	1640	1710	1600
	E	V	4800	6500	1650	1710	1700
3	E	V	5300	6200	1480	1470	900
	V	E	5300	6000	1465	1465	700
	E	V	4700	5050	1480	1465	350
	V	E	4800	5400	1490	1465	600
4	P	E	5300	5600	1620	1710	300
	P	E	5300	5800	1610	1710	600
	E	P	5300	5200	1630	1700	-100
	E	P	5400	5700	1610	1710	300
Average			4730	5750	1570	1593	1020

Table IV.

F-5-L Comparison of Standard and Geared Types.

Timed Runs (simultaneous) over a 29-knot Course.

Series	Pilot		Time			R.P.M.	
	Stand.	Geared	Standard	Geared	Difference	Stand.	Geared
1	P	E	25'-18"	24'-30"	0'-48"	1580	1600
	E	P	23'-30"	22'-50"	0'-40"	1575	1600
2	V	E	24'-08"	21'-23"	2'-45"	1710	1792
	E	V	23'-38"	22'-18"	1'-20"	1700	1812
3	E	V	26'-30"	25'-52"	0'-28"	1550	1580
	V	E	27'-01"	25'-56"	1'-05"	1550	1580
4	E	P	23'-30"	22'-00"	1'-30"	1685	1795
	P	E	24'-00"	23'-00"	1'-00"	1675	1810
Average			24'-41"	23'-20"	1'-12"	1632	1697

Table V .

F-5-L High Speed Runs.

Comparison of Standard and Geared Types.

Series	Pilot		Maximum Speed		R.P.M	
	Standard	Geared	Standard	Geared	Standard	Geared
1	P	V	70	73	1590	1600
	V	P	70	72	1587	1600
2	P	E	73	74	1700	1840
	E	P	73	74	1710	1800
3	E	P	73	74	1550	1590
	P	E	72	74	1550	1590
4	V	P	72	74	1680	1780
	P	V	72	73	1670	1780
Average			71.9	73.5	1630	1690

Table VI.

F-5-L Minimum Airspeed and R.P.M.

Comparison of Standard and Geared Types.

Series	Pilot		Minimum Speed		R.P.M.	
	Stand.	Geared	Stand.	Geared	Stand.	Geared
1	P	V	50	45	1300	1240
	V	P	45	43	1240	1220
2	P	E	45	44	1380	1400
	E	P	45	45	1390	1400
3	E	P	43	42	1225	1200
	P	E	44	43	1230	1220
4	V	P	48	44	1400	1350
	P	V	45	45	1350	1400

Table VII.

F-5-L Fuel Consumption.

Comparison of Standard and Geared Types.

Series	Pilot		Gas		Oil		R.P.M.	
	Stand.	Geared	Stand.	Geared	Stand	Geared	Stand.	Geare
1	P	E	43.92	38.4	2.4	2.4	1400	1300
2	P	E	45.87	44.75	4.25	3.5	1450	1500
3a	E	D	45.4	46.25	2.43	2.0	1450	1450
3b	E	P	41.65	43.06	2.41	2.0	1350	1350
4	V	P	42.0	43.0	2.75	2.0	1480	1500
Average			43.77	43.09				
Average (neglecting Series 1)			43.73	44.26				