SECRET 84th Part of Report No. A.&.A.E.E./766

AIRCRAFT AND ARMAMENT EXPERIMENTAL ESTABLISHMENT
BOSCOMBE DOWN.

Lancaster I HK.541
(4 Merlin 24)

Overload trials, in India, to determine the operational capabilities of the Lancaster under high temperature conditions.

A.S. Crouch, D.I.C., A.C.G.I., and H.G. Newbigin.

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This report deals with the aircraft or equipment as tested, Action to remedy defects or decisions to accept items not in strict compliance with the specification are matters for decision & action by the Ministry of Aircraft Production.

Progress of issue of report.

Report No.	Title
79th Part of A&AEE/766	W.4963 - Dowty oil compression shock-absorber in tail wheel strut.
80th do.	PB.995 - Brief handling trials with a 22,000 lb. DP bomb installed in an aircraft having a dorsal turret.
81st do.	PD.435 - Performance at weights up to 72,000 lb.
82nd do.	PB.592 - Further handling trials with 22,000 lb. and 12,000 lb. DP bombs in modified bomb bay fairing.
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Summary.

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The tests show that it is practical to operate the Lancaster at a weight of 72,000 lb. in conditions of high air temperature. A technique to obtain maximum range is suggested and range flights made adopting the method showed that with 3,154 gallons and 6,000 lb. of bombs the maximum still air range is 3,470 statute miles or 3,010 nautical miles.

The cooling afforded by the MC. type power plants is adequate now that a concession to raise the maximum oil inlet to engine temperature to 95°C for one hours duration on climb has been given.

The aircraft can be pulled off in 1,050 yds. at 72,000 lb., but the distance using a more normal Squadron technique for take-off is 1,450 yds.

1. Introduction.

1.1 General. Performance and cooling trials have been made, in India, to determine the practicability of operating the Lancaster at an overload weight of 72,000 lb. in conditions of high air temperature, and to establish a flying technique to enable air crews operating in the Far East War to obtain maximum range.

Lancaster I HK.541, which was fitted with M.C. type power plants, and had been undergoing Service trials in Bomber Command, was selected for this work. The aircraft was fitted with a "mock-up" of the proposed saddle tank and the power plants were fully tropicalised prior to the commencement of the trials.

The aircraft was tested by an A.&.A.E.E. team with the co-operation of No. 1577 (SD) Flight at Mauripur (Sind).

1.2 Short history of trials. This Report is concerned mainly with the performance characteristics of the aircraft, but this short history is included for general information, and in particular to clarify the position as regards the oil and coolant temperatures recorded for the starboard outer engine.

No serious maintenance difficulties were experienced, and reports have been rendered to D.D.S.M. by the D.S.M. staff present during the trials.

To comply with instructions before departure, the twin contact tail wheel was changed after every ten landings, although no signs of approaching failure were apparent. Two wheels were brought back to U.K. for inspection. At no time was shimmy experienced during taxying and take-off even at the full load of 72,000 lb., but on occasions shimmy developed during the landing run, more particularly on rough runways.

As anticipated, rivets were found to be shearing on the under surface mainplane skin to spar. The holes were tapped and 2 B.A. screws fitted.

The flame ducts were found to be unsatisfactory, and during the progress of the trials repeated repairs had to be made by welding.

Starboard outer engine. During transit from U.K. to India, this engine showed steadily decreasing oil pressure, and the oil and coolant temperatures were higher than on the other three engines. No readily apparent reason for this could be ascertained. Since there was no indication of loss of power, and time was short before the anticipated breaking up of good flying weather conditions, tests were commenced.

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However, on 21st May, the oil pressure had dropped to 42 lb/sq.in. and since by that time a spare power plant had arrived from U.K., it was decided to change the power plants.

During the next flight the new engine showed the same characteristics but not so marked. The thrustat valve was suspected and changed but without success.

On May 28th, it was discovered that the radiator flap control rods were shorter, and the radiator duct exit area 11% less on this engine than on the others. Apparently, the control rods for a temperate power plant were fitted to this tropical power plant in error. This was rectified and at the same time the thrustat valves of the starboard engines interchanged. The starboard outer engine was now satisfactory, but part of the trouble had now been transferred to the starboard inner engine showing the thrustat valve to be defective. This thrustat valve was despatched to Messrs. Rolls Royce for inspection.

The records for the starboard outer engine are not therefore representative. until the last local test flight and for the two range flights on June 3rd and 5th.

2. Condition of aircraft relevant to tests.

2.1 External features. The aircraft was a standard production Lancaster I except for the following details:-

No dorsal turret fitted, position blanked off, level with fuselage.
Cabin canopy removed.
"Mock-up" of proposed saddle tank fitted, extending from the cabin to forward of the dorsal turret position.
Astro-dome fitted in roof immediately aft of the pilot's seat.
Tropicalised M.C. type power plants fitted with secondary surface Serck coolers.
4 fishtail ejector exhausts, air cleaners and ice-guards.
Metal elevators (Mod. 1101).
Lincoln type undercarriage.

The following points were also noted :-

FN.5 nose turret with no guns fitted.
FN.120 tail turret, incorporating "Gransden Lodge" clear vision opening, with no guns fitted.
Large type hemispherical transparent bomb-aimer's cupola (Mod. 780)
Marstrand twin contact tailwheel.
W/T aerials from masts, beside the astro-dome, to fins.
BA bar aerial under rear fuselage.
Trailing aerial fairing at port wing root.
Monica and IFF strut aerials fitted.
Twin dipole aerials on fins.
Three pulsometer pump fairings under each wing.
Flush rivetting throughout. The finish was average for the type.

Standard four view photographs of a similar aircraft are given in Fig. 22 and photographs of the M.C. type power plants are given in Figs. 23 and 24.

2.2 Propellers. Hamilton 3-blade constant speed, fully feathering propellers, type A5/159 with a diameter of 13 ft., were fitted to all engines. The numbers of the propellers fitted were :-

PO	NK. 105320
PI	NK. 115131
SI	NK. 104685
SO	NK. 121450

The fine pitch setting was 26°. Range of blade angle available was 26° - 91°.

/2.3

2.3 Engine installation. Merlin 24 engines were fitted in fully tropicalised MC. type power plants. The M.C. type power plant differs from the M.A. type (normally fitted to Lancasters in this country) in various details including the following:-

The overall size of the M.C. type power plant is increased due to the larger frontal area of the radiator and the consequent bulging of the front and side panels (as can be discerned in Fig. 23).

Four fishtail type capacity manifold exhaust system, in lieu of multi-ejector manifolds, with exhaust flame damping ducts.

The coolers have been arranged in series, the radiator consisting of three rows and the oil cooler of one row (see Fig. 24). The cooler installation has an increased frontal area of approximately 36%. Details are as follows :-

Coolant radiators: Serck three row Drawing No. WS. 9034
Oil coolers : Serck one row Drawing No. WS. 9035

Frontal area of radiator block: 3.4 sq. ft.

Radiator exit duct area (sq. ft.)

	PO	PI	SI	SO (Original)	SO (replacement)*
Flap open	2.59	2.61	2.50	2.55	2.57
Flap closed	1.85	1.89	1.80	1.79	1.80

* Prior to fitting the tropical type flap control rods on the 29th May, the areas were (a) flap open 2.36 sq. ft., (b) flap closed, 1.59 sq. ft.

No thermostats were fitted in the coolant system. The thermostatic switches were preset at 115°C.

The thrustat valves in the oil system (type FBZ/A/266) with a working range of 55-75°C were fitted throughout. It will be noted that with the normal temperature rise of 20°C across the engine all the oil will be passing through the cooler, provided the observed oil 'in' temperature is above 55°C.

The engine numbers were:-

Position	Firm's No.	A.M. No.
PO	204845	510310
PI	204527	510151
SI	204235	510005
SO	204589	510182
	208387	578876

The starboard outer power plant was changed after the second test flight at Mauripur, (i.e., between 21st -23rd May), due to the oil pressure having decreased progressively with time to approximately 42 lb/sq.in.

Tropical air-intakes were fitted with cleaner elements. The air cleaners cannot be by-passed in flight (photographs of this type of cleaner are given in the 31st part of this Report).

The carburettor fitted to the Merlin 24 is an SU type AVT.40/218 (fully automatic mixture control). The enrichment needle, type (CE.44) has a projection of 0.250 in. at +9 lb/sq.in. boost. The altitude needle (PA.6) has a projection of 0.100 in. at standard atmospheric pressure.

/2.4

2.4 Engine limitations. Subsequent to the trials, the engine limitations agreed for Lancaster with Merlin 24 engines for Tiger Force operations are :-

Condition	RPM	Boost lb/in^2	Oil temp. °C engine 'in'	Coolant temp. °C Engine 'Out'
Maximum for take-off	3000	+18	15 (min)	60 (min.)
Maximum for climb (one hour)	2850	+ 9	95	125
Maximum for cruise	2650	+ 7	90	115

Oil pressure: normal 45 to 80 lb/sq.in., emergency minimum: 30 lb/sq.in.

These differ from the standard Merlin 24 limitations by the following concessions :-

(i) An increase of 5° in the maximum engine 'in' oil temperature for 1 hours duration on climb.
(ii) An increase of 10° in the maximum engine 'out' coolant temperature for cruising flight.

2.5 Fuel tankage. The aircraft had three fuel tanks in each wing having the following capacities:-

No.1	(Inner)	580 gallons each
No.2	(Centre)	383 " "
No.3	(Outer)	114 " "

Total: 2 x 1077 = 2154 gallons.

The proposed saddle tank is to have a capacity of 1000 gallons, thus the total capacity of an aircraft with the saddle tank fitted will be 3154 gallons.

2.6 Airspeed system. All speeds given in this Report refer to the pilot's airspeed indicator, the pitot side of which was connected to the pitot side of the Mk.VIIIB head (positioned to Mod. 883). The static source was the port static vent in the standard position when no H_2S blister is fitted. The position and setting of the Mk.VIIIB head is given in Fig.1 and the position of the static vents in Fig.2.

2.7 Loading. The following loadings were used during the series of tests:-

(a) 56,600 lb., c.g. 49.1 in. aft of the datum point (undercarriage down)
(b) 50,650 lb., c.g. 49.6 in. " " " " " (" ")
(c) 57,850 lb., c.g. 51.1 in. " " " " " (" ")
(d) 62,950 lb., c.g. 50.5 in. " " " " " (" ")
(e) 66,500 lb., c.g. 49.5 in. " " " " " (" ")
(f) 69,600 lb., c.g. 49.5 in. " " " " " (" ")
(g) 72,000 lb., c.g. 49.6 in. " " " " " (" ")
(h) 55,250 lb., c.g. 49.9 in. " " " " " (" ")

Loading (a) was used for position error trials and air thermometer calibrations which were made before the aircraft left for India.

Loading (f) was used for take-off only. Immediately after take-off 3,000 lb. of bombs were dropped, the loading then being the same as (e).

2.8 Instrumentation. The instruments used to record the oil and coolant temperatures were of the ratiometer type. The fuel flows were measured by Kent rate-of-flow type of flowmeters.

The air temperatures were measured by three thermometers (two mercury-in-steel, and one balance bridge type) mounted on the nose of the aircraft.

/3.

3. Tests made.

3.1 Position error trials. The position errors of the port and starboard static vents were measured in level flight by the aneroid method over the speed range 142-255 mph ASI prior to the aircraft leaving for India. These trials were repeated when the aircraft returned to the A.&.A.E.E.

3.2 Take-off trials. The take-off distance to unstick, at each of the loadings (c) to (g), was measured visually by observers stationed at known distances along the runway.

Two methods were adopted for the take-off (i) to pull the aircraft off at the lowest 'unstick' speed compatible with safety, (a "tail down" take-off,)(ii), using a more normal squadron method of flying the aircraft off, (a "tail up" take-off).

All take-offs were made using 3000 rpm, +18 lb/sq.in. boost with flaps 20°.

3.3 Climb performance. The climb performance was measured at loadings (b) to (g) using 2650 rpm, and +7 lb/sq.in. boost in MS gear, at an airspeed of 160 mph ASI, except for loadings (b) and (c) when the ASI was 165 mph and 155 mph respectively. The climbs at loadings (c) and (d) were continued in FS gear, using maximum climbing power, and an ASI of 160 mph. Radiator flaps were closed for all tests.

3.4 Cooling trials. Oil and coolant temperatures were recorded under the following conditions :-

(i) during taxying, run-up, take-off and initial climb.
(ii) During the climbs mentioned in para.3.3 above.
(iii) in level flight with radiator flaps closed.

In general, the tests were made (a) at maximum cruising power and (b) at a reduced power to give a speed approximating to the minimum speed for comfortable continuous cruising.

Height ft.	RPM	Boost lb/in^2	S/c gear	Take-off loading	Remarks.
23,500	2650	FT	FS	(c)	
20,000	2650	FT	FS	(d)	
18,000	2650	FT	FS	(d)	Repeat at lower engine rpm at FT.
15,000	2650	+7	FS	(d)	" " " " "
12,000	2650	FT	MS	(e)	
10,000	2650	FT	MS	(c) (e) (g)	Repeat at lower engine rpm at FT
9,000	2850	FT	MS	(e)	
5,000	2650	+7	MS	(e) (g)	Repeat at lower engine rpm at FT.

Note: FT means using maximum boost available.

(iv) A complete record of oil and coolant temperatures when flying at conditions for maximum range were obtained during two long range flights.

3.5 Fuel consumption trials. The tests included measurements of airspeed and fuel flow on all engines under the following conditions :-

/Table.

Height ft.	S/c gear	Take-off loading	Grid or envelope	Remarks.
20,000	FS	(c)	Envelope	
18,000	FS	(d)	Envelope	
15,000	FS	(b) (c) (d)	Envelope and grid	Grid done at loading (b)
15,000	MS	(c)	Envelope	
10,000	MS	(b) (c) (e) (g)	Envelope and grid	Grids at loadings (b) (e)
8,000	MS	(g)	Envelope	
5,000	MS	(c) (g)	Envelope and grid	Grid at loading (c)

Cold air intakes were used and radiator flaps were closed throughout.

3.6 Range flights. Two long range flights were made to simulate a typical bombing sortie for Tiger Force operations. The flights were made adopting a procedure determined by the results of the earlier tests.

4. Results of tests.

The air temperatures encountered were below the Tropical Summer Standard of Appendix 6 of AP.970. As an outcome of a discussion at B.A.F.S.E.A. Headquarters, it was decided to correct the general performance results to a standard of ICAN +19°C, the mean of the present tropical and temperate summer standard, since it was considered that performance results corrected to this standard will be of more value than if corrected to the full tropical standard ICAN +26°C.

Subsequent estimated data (given in Appendix I), obtained from the Air Ministry Meteorological Office, show that the average of the maximum temperatures above 10,000 ft. in the area of operations is ICAN +19.9°C.

The climb and performance results have been corrected by the methods of Report No. A.&.A.E.E./Res/170, using a supercharger constant of C = 0.002. The revised constants for the standard fuel consumption reduction method suggested in Report No. A.&.A.E.E./Res/215 have been incorporated.

The take-off and cooling results have been corrected to the full Tropical Summer Standard and will therefore cover the worst possible condition.

Since it is normal practice in Bomber Command to work in knots and nautical miles, certain basic speeds have been quoted in knots in brackets after the speeds in miles per hour and, similarly, distances in nautical miles after the distances in statute miles.

4.1 Position error correction. The results of the position error test of the port and starboard static vents, are given in Fig.3. At a mean weight of 56,500 lb. the position error correction of the port static vent varies from +2 mph at low speeds and +2.6 mph at 260 mph ASI, and does not meet the requirements of the A.P.I. The position error correction of the starboard static vent varies from +2.8 mph at 140 mph ASI to +1.0 mph at 260 mph ASI, and satisfies the requirements of the Mk.XIV bombsight.

The pitot error correction was not measured and has been assumed to be the same as that given in the 61st Part of this Report, with a similar head position. The position error correction (sum of port static vent and pitot corrections) is given in Fig.3.

4.2 Take-off trials. (For the full results see Table I and Fig.4) At a weight of 72,000 lb., the aircraft can be taken off in an unstick distance of 1050 yds. To achieve this distance, the aircraft must be "pulled off" at an ASI of 100-105 mph ASI. (85-90). Using a more normal squadron technique, the unstick distance is of the order of 1450 yds. at a take-off ASI of 120 mph (105). Both these distances refer to zero wind and Tropical Summer temperatures.

/4.3

4.3 Climb performance. (for the full results see Table II and Figs.5 to 7) The rate of climb, MS gear, radiator flaps closed at a take-off weight of 72,000 lb.,

At 2650 rpm, +7 lb/sq.in. boost, 220 ft/min. at FT height 8,400 ft.
At 2850 rpm, +9 lb/sq.in. boost, 340 ft/min. at FT height 8,400 ft.

The climb to 10,000 ft. takes 48.5 and 31.1 minutes, respectively.

At a take-off weight of 63,000 lb. the rate of climb with radiator flaps closed was :-

At 2650 rpm, +7 lb/sq.in. boost, MS gear, 370 ft/min. at FT height, 8,400 ft.
At 2850 rpm, +9 lb/sq.in. boost, FS gear, 330 ft/min. at FT height, 15,200 ft.

When in the target area, the service ceiling is 20,000 ft. (a weight of approximately 61,000 lb.). At this weight the aircraft has a comfortable cruising speed range of approximately 20 mph ASI at 18,000 ft.

A curve (in Figs.5 and 6) of fuel used to height is given for the three conditions quoted above.

4.4 Cooling trials. (For full results see Table III to V and Figs.8 and 9). The oil temperatures were corrected by the addition of 70% of the difference between the recorded and the tropical summer standard air temperatures. The radiator suitabilities were calculated from the following formula :-

$$S = \frac{T_n - T_s}{T_c - T_a}$$

where T_n = maximum permissible coolant temperature at engine outlet (125°C for climb and 115°C for cruising).
T_s = tropical standard air temperature
T_c = observed coolant 'out' temperature
T_a = actual air temperature.

In the following discussion the results on the starboard outer installation have been ignored for the reasons given in para.1.2 of the Introduction.

4.41 Cooling on the ground and during take-off. As soon as the engines were started, the aircraft was taxied from the dispersal point to the end of the runway and an engine check made at that point prior to the take-off. The distance from the dispersal point to the end of the runway was 2500 yds. and on no occasion was overheating encountered. The maximum coolant temperature noted after the engine check was 98°C with an air temperature of 36°C; the maximum oil temperature was 64°C.

The maximum coolant temperature noted during the take-off run, at 3000 rpm, +18 lb/sq.in. boost, was 101°C with an air temperature of 36°C, the corresponding oil temperature being 72°C. Radiator flaps were closed during the take-off.

On one occasion the engines were maintained at 3000 rpm, +18 lb/sq.in. boost for 3 minutes after take-off, with 20° flap and undercarriage down, the speed attained being 150 mph ASI. With an air temperature of 37.5°C the maximum coolant temperature was 110°C and the oil 80°C. The radiator flaps on this occasion were open.

4.42 Cooling on climb (see Table IV and Figs.8 and 9). The radiator suitabilities on all climbs (radiator flaps closed), were above unity, the minimum suitability obtained being about 1.10 on the port outer installation.

The oil temperatures on all climbs were within the limitation, the maximum temperature of 95°C, was obtained at 72,000 lb., using 2850 rpm, +9 lb/sq.in. boost, occurred on all engines between 4000 and 5000 ft. in MS gear.

The oil...

The oil temperatures obtained in FS gear, under similar engine conditions, were 5 to 7°C below the limitation.

The oil temperatures, using 2650 rpm, +7 lb/sq.in. boost in MS gear were 2 to 5°C below the limitation.

Under standard Tropical Summer conditions, the rate of climb from a take-off weight of 72,000 lb., using 2650 rpm, +7 lb/sq.in. boost, would be 180 ft/min. This would be reduced by approximately 80 ft/min., if the radiator flaps were opened to bring the oil temperature within the standard 90°C limitation. In view of this low rate of climb, it was recommended that an investigation should be made into the possibility of increasing the oil temperature limitation to 95°C. This has now been agreed (see para. 2.4).

4.43 <u>Level flight (see Table V)</u>. The radiator suitabilities under all conditions tested were above unity, the minimum suitability obtained being about 1.07 on the port outer installation. At weights below approximately 67,000 lb. the coolant temperatures under tropical summer conditions will be within the standard 105°C limitation.

When flying under conditions of maximum range, in the area of operations, it is most unlikely that the standard limitation of 105°C will be exceeded.

The oil temperatures were within the limitation, the maximum temperature of 87°C was obtained on all installations at 5000 ft. at the high weights.

4.5 <u>Fuel consumption trials.</u> (For full results see Tables VI to XI and Figs. 10 to 17).

4.51 <u>Fuel consumption on climb.</u> Curves of rate of fuel flow against height are given in Fig. 10.

4.52 <u>Fuel consumption in level flight.</u> (see Tables VI to XI and Figs. 11 to 17). Under all conditions tested, the optimum specific air range was obtained using the maximum boost available and adjusting the rpm to give the optimum speed. The optimum speeds were above the corresponding minimum speeds for comfortable continuous cruising.

The optimum values of specific air range obtained (using cold air intakes), the corresponding air speeds and the approximate engine conditions required, are given in tabular form below :-

Height ft.	S/c gear	Weight lb.	Optimum SAR (ampg)	Optimum ASI (mph)	Engine conditions RPM	Engine conditions Boost (lb/in²)	Increase in speed for 3% loss of range (mph ASI)
20,000	FS	55,000	1.44	143	2500	+1.0	16
18,000	"	61,000	1.09	157	2500	+3.0	10
15,000	"	61,000	1.11	160	2400	+4.0	11
"	"	54,500	1.18	146	2200	+1.7	22
"	"	49,000	1.27	132	2100	+1.0	35
"	MS	54,500	1.21	145	2400	+0.7	19
10,000	"	70,000	0.98	168	2550	+5.0	14
"	"	64,000	1.06	164	2400	+3.7	16
"	"	54,500	1.25	154	2050	+1.2	18
"	"	47,000	1.37	141	1800*	0	22
8,000	"	70,000	0.98	169	2400	+5.2	14
5,000	"	70,000	1.01	170	2200	+5.5	15
"	"	62,500	1.10	164	2000	+3.7	17

* minimum rpm, with maximum boost available, the speed to suit the rpm.

/4.53

4.53 Procedure to obtain maximum range.

Climb. A comparison of two methods of climb is shown in Fig.5. The following table shows that a small gain is obtained by climbing at 2650 rpm, +7 lb/sq.in. boost, and this has the advantage of giving lower oil temperatures.

Climb to (height) ft.)	Case (1) Climb at 2650 +7 lb/sq.in. boost		Case (2) Climb at 2850 +9 lb/sq.in boost, and level out at most economical speed.	
	Fuel used	Dist. travelled	Dist. on amount of fuel in (1)	Fuel to travel same dist. as (1)
5,000	86 gall.	63 miles	55 miles	94 gall.
10,000	192 gall.	147 miles	130 miles	200 gall.

Level flight. The tests show that this aircraft engine combination obeys the maximum boost - minimum rpm law. Fig.17 shows the variation of the optimum airspeed and specific air range with weight at various heights.

Typical bombing sortie. The following procedure is suggested:-

Climb at 2650 rpm, +7 lb/sq.in. boost to 5000 ft. at 160 mph ASI (140) with radiator flaps closed.
Level out and fly at maximum obtainable boost adjusting the rpm to give an airspeed of 170 mph ASI (150). At regular intervals the rpm should be reduced to maintain the same airspeed.

After 700 gallons of fuel (about 3½ hours flying) have been used, the rpm should be reduced to give an airspeed of 165 mph ASI (145) and this airspeed maintained until 1300 gallons of fuel have been consumed (about 6½ hours flying).

At this point the aircraft would be climbed to 18,000 ft. at an airspeed of 160 mph ASI (140) with radiator flaps closed, using 2650 rpm, +7 lb/sq.in. boost in MS gear to approximately 11,000 ft. and thereafter 2850 rpm +9 lb/sq.in. boost in FS gear. The airspeed for cruising at 18,000 ft. should be 155 mph ASI (135).

As soon as convenient after bombing descend to 10,000 ft. and cruise at this height at an airspeed of 150 to 155 mph ASI (130-135). At regular intervals the rpm should be reduced to maintain this airspeed until the minimum rpm, at which the engines could be synchronised, had been reached. Thereafter the aircraft should be flown at the same engine conditions allowing the airspeed to increase as the weight decreased.

At engine rpm at or below 2000 it may be found desirable to increase the engine speed to 2650 rpm, at intervals of say 1 hour, as a safe guard against piston ring gumming.

4.6 Range estimation.

4.61 From fuel consumption trials para.4.5. Assuming the aircraft to take-off at 72,000 lb. with 3154 gallons of fuel and 6,000 lb. of bombs, the radius of action curve has been calculated using the procedure suggested in para. 4.53 above.

The estimated radius of action curve is shown in Fig.18 and gives a still air range of 3540 statute miles (3070), if the bombs are dropped half way.

/4.62

4.62 <u>From range flights</u> (for full results see Tables XII and XIII, and Figs. 19 - 21). Two long range flights were made to simulate a bombing sortie of the Tiger Force, This was necessary to cover the complete weight range since the saddle tank fitted to this aircraft was a 'mock-up'.

The first flight was made from a take-off weight of 72,000 lb. to cover the outward journey to the point at which the bombs would be released from 18,000 ft.

The second flight was made from a take-off weight of 55,250 lb. to cover the return journey from the point immediately after the bombs had been released.

Tables XII and XIII give the observations taken on the two flights, corrected for instrument errors only, with the calculated weight and specific air range at each stage, and Figs. 19 and 20 show a graphical plot of the progress of the two flights.

Fig. 21 shows the radius of action achieved under the conditions of tests, giving a still air range of 3500 statute miles (3040). Making an approximate correction to standard ICAN +19°C atmosphere gives a still air range of 3470 statute miles (3010). The total time for such a flight will be about 18½ hours.

The specific air ranges obtained during the range flight are 1-5% lower on those obtained at the same weights during the fuel consumption trials; the larger discrepancies occuring at the higher weights. No adequate explanations can be given for this, and it was seen that higher powers had to be used to maintain the same ASI despite the slightly colder atmospheric conditions obtained on the range flight.

A complete record of oil and coolant temperatures, obtained during the two long range flights are given in Tables XII and XIII. These results show that the radiator suitability, based on the standard 105°C limitation, is above unity at weights below about 69,000 lb., the minimum suitability being 0.96 on the SO installation. On the 115°C limitation the radiator suitability is above unity at all weights. The oil temperatures are within limitations throughout by at least 5°C in level flight and are on the 95°C limitation during the climb to the bombing altitude.

4.7 <u>Miscellaneous.</u>

4.71 <u>Oil consumption.</u> The careful measurement of oil required to top up the tanks after the two range flights, was made and are given below :-

	Oil used, galls.			
	PO	PI	SI	SO
First flight (fuel used 1880 galls.)	6.1	6.2	6.3	6.0
Second flight (fuel used 1660 galls.)	4.1	3.0	5.0*	3.0

Total for typical flight with 3154 galls. fuel approx.: 35 galls.

* A slight oil leak occurred during this flight on SI engine.

4.72 <u>Fuel specific gravity.</u> Measurement of the fuel specific gravity was made before and after each flight. The variation in specific gravity of one sample of fuel was measured over a range of temperatures of 8 to 35°C, and found to be -.00083 per °C rise in temperature.

The variation in specific gravity of the fuel as supplied was small, the maximum difference between any two samples being 0.5% of the average. The average specific gravity (corrected to 15°C) was 0.7295, the accuracy of measurement being ± .00025.

A number of samples of 100 Octane fuel were artificially weathered at the R.A.E. and the change in specific gravity for a 1% change in volume was found to be .0007.

/An attempt...

An attempt was made to determine the volume of fuel lost by evaporation by measuring the fuel specific gravity before and after each range flight. On the first flight where the aircraft was climbed slowly, the loss on this basis was 0.2%. On the second flight when the aircraft was climbed quickly to 18,000 ft., the loss was 1.5%. It can be assumed that the loss due to evaporation for typical Tiger Force operations will be negligible.

4.73 Meteorological data. Appendix III gives a summary of the air temperature and humidity at Mauripur during the tests.

5. Conclusions.

The tests show that it is practical to operate the Lancaster at a weight of 72,000 lb. in conditions of high air temperature.

5.1 Take-off. The aircraft can be taken off at 72,000 lb. in an unstick distance of 1050 yds. To achieve this distance the aircraft must be "pulled off" at an ASI of 100-105 mph (85-90 knots). Using a more normal squadron technique, the unstick distance is 1450 yds. at a take-off ASI of 120 mph (105 knots).

5.2 Climb. The rate of climb, MS gear, radiator flaps closed at a take-off weight of 72,000 lb. is

At 2650 rpm, +7 lb/sq.in. boost, 220 ft/min. at FT height 8,400 ft.
At 2850 rpm, +9 lb/sq.in. boost, 340 ft/min. at FT height 8,400 ft.

The service ceiling at a weight of 61,000 lb., approximately when in the target area is 20,000 ft. At this weight the aircraft has a comfortable cruising speed range of 20 mph ASI at 18,000 ft.

5.3 Cooling. The coolant and oil temperature, corrected to Tropical Summer standard are within the agreed limitation for Tiger Force Operations.

It is probable that these temperatures will be within the standard Merlin 24 limitations under the operational conditions.

5.4 Range. Two long range flights made to simulate a bombing sortie of the Tiger Force using the procedure determined from fuel consumption trials, (see para. 4.53) showed that the maximum still air range with 3154 gallons of fuel and 6000 lb. of bombs, is 3470 statute miles or 3010 nautical miles.

/Table I

TABLE I

Take-off trials

3000 rpm. +18 lbs boost 20° flap.

Run	Weight lb.	Air temp °C	Air pressure "Hg"	Component wind speed mph	Measured ground distance yds	Ground distance (yds) corrected to tropical atmospheric conditions and zero wind.
1	57850	31	29.8	13.5	385	530 ⌘
2	57850	31	29.8	13.5	648	850 ⌿
3	62950	35	29.5	11.0	670	800 ⌘
4	66500	36	29.8	13.0	680	860 ⌘
5	69600	34.5	29.6	17.5	710	990 ⌘
6	72000	35	29.8	14.5	808	1070 ⌘
7	72000	37.5	29.7	0	1000	1020 ⌘
8	72000	35	29.7	5.5	1110	1430 ⌿
9	72000	30	29.6	11.0	1230	1520 ⌿

⌘ "Pull off" (Tail down) Indicated airspeed 100 - 105 mph
⌿ "Fly off" (Tail up) " " 115 - 120 "

TABLE II

Climb performance. Corrected to ICAN +19°C

Take-off wt. 72000 lb. Standard rate of climb. Radiator flaps closed.

Height feet	Time Mins	Rate of climb ft/min.	ASI mph	Boost lb/in²	RPM
1000	2.7	360	160	+9	2850
2000	5.5	360			
3000	8.7	360			
4000	11.5	350			
5000	14.3	350			
6000	17.2	350			
7000	20.1	340			
8400⌘	24.2	340			
9000	26.2	290		+8.4	
10000	31.1	210		+7.6	
Take-off wt. 72000 lb.			160		
1000	4.2	240		+7	2650
2000	8.5	230			
3000	12.8	230			
4000	17.2	230			
5000	21.6	230			
6000	26.1	220			
7000	30.6	220			
8400⌘	36.1	220			
9000	40.2	200		+6.4	
10000	48.5	160		+5.6	
Take-off wt. 62950 lb.					
1000	2.5	410	160	+7	2650
2000	5.0	400			
3000	7.5	400			
4000	10.1	390			
5000	12.6	390			
6000	15.2	380			
7000	17.9	380			
8000⌘	20.5	370			
8400ø	22.0	370			
10000	25.9	360		9.0	2850
11000	28.7	360			
12000	31.5	350			
13000	34.4	350			
14000	37.3	340			
15200⌘	40.8	340			
16000	43.4	290		8.3	
17000	47.1	240		7.5	
18000	51.7	190		6.7	
19000	57.6	150		5.8	
20000	65.9	100		5.2	

⌘ Full throttle height. ø Supercharger gear change.

/Table II contd.

TABLE II (contd.)

Climb performance. Corrected to ICAN +19°C.

Radiator flaps closed.

Height	Weight 66500 lb				Weight 50650 lb.				Weight 57850 lb.			
	RPM	Boost lb/in²	ASI	R/C ft/min	RPM	Boost lb/in²	ASI	R/C ft/min	RPM	Boost lb/in²	ASI	R/C ft/min
1000	2650	+7.0	160	330	2650	+7.0	165	690	2650	+7.0	155	590
2000	↓	+7.0	↓	330	↓	+7.0	↓	680	↓	+7.0	↓	580
4000	↓	+7.0	↓	320	↓	+7.0	↓	670	↓	+7.0	↓	580
6000	↓	+7.0	↓	320	↓	+7.0	↓	660	↓	+7.0	↓	570
* 8400	↓	+7.0	↓	310	↓	+7.0	↓	640	↓	+7.0	↓	560
10000	↓	+5.6	↓	200	↓	+5.6	↓	520	↓	+5.6	↓	450
12000	↓	↓	↓	↓	↓	+4.2	↓	390	2650MS	4.2MS	↓	310
									2850FS	9.0FS	↓	550
14000	↓	↓	↓	↓	↓	+3.0	↓	250	2850	+9.0	↓	520
*15200	↓	↓	↓	↓	↓	↓	↓	↓	↓	+9.0	↓	500
16000	↓	↓	↓	↓	↓	↓	↓	↓	↓	+8.3	↓	450
18000	↓	↓	↓	↓	↓	↓	↓	↓	↓	+6.7	↓	340
20000	↓	↓	↓	↓	↓	↓	↓	↓	↓	+5.2	↓	220

* Full throttle height.

TABLE III

Cooling on the ground and during take-off

All results shown are the observed values

Air temp °C	RPM	Boost lb/in²	Oil pressure lb/in²				Oil temp. °C.				Coolant temp °C				Remarks
			PO	PI	SI	SO	PO	PI	SI	SO	PO	PI	SI	SO	
32	Idle	-	40	70	58	32≠	53	52	50	56≠	91	94	96	100≠	After run up
32	3000	+18	-	-	-	-	62	61	58	65≠	98	100	101	105≠	After TO ASI 130
32	Idle	-	65	73	72	41≠	63	55	58	78≠	93	94	96	107≠	After run up
32	3000	+18	75	85	80	60≠	75	72	74	79≠	101	99	101	108≠	At take-off
32	2650	+ 7	72	79	75	54≠	73	72	73	81≠	97	96	98	101≠	During circuit ASI 160
36	Idle	-	66	70	69	60*	64	52	56	64*	96	94	98	112*	After run up
36	3000	+18	70	75	72	60*	80	80	80	85*	100	100	108	108*	During idle
36	2650	+ 7	68	75	72	58*	78	78	78	84*	101	99	102	108*	During circuit ASI 175
34.5	Idle	-	52	71	65	62*	53	49	49	59*	88	87	87	96*	After run up
34.5	3000	+18	80	88	81	68*	72	68	67	78*	101	99	101	108*	At take-off ASI 120
35	2850	+ 9	68	74	72	51ø	82	78	78	103ø	105	101	103	110ø	During circuit ASI 170
37.5	3000	+18	70	80	75	60	80	80	78	78	105	102	108	110	Shutters open ASI 150 after 3 mins.

≠ Original engine

* Replacement engine with incorrect flap setting.

ø " " " " " " and faulty thrustat valve.

/Table IV.

TABLE VI

Fuel consumption and specific air range at 20,000 ft.
Cold air. Radr. flaps closed. FS gear. Mean wt. 55,000 lb.
Corrected to ICAN +19°C

RPM	Boost lb/in²	Std ASI mph	TAS mph	Total fuel flow gall/hour	Specific air range ampg
2650	3.4	163	236	216	1.09
2600	2.3	157	226	202	1.12
2550	1.6	150	216	190	1.13
2500	1.1	142	206	181	1.14
2450	0.7	131	193	174	1.12

TABLE VII

Fuel consumption and specific air range at 18000 ft.
Cold air. Radr. flaps closed. FS gear. Mean wt. 61,000 lb.
Corrected to ICAN +19°C.

RPM	Boost lb/in²	Std ASI mph	TAS mph	Total fuel flow gall/hour	Specific air range ampg
2650	4.7	170	235	226	1.04
2600	4.1	166	230	215	1.07
2550	3.4	161	224	206	1.08
2500	2.9	155	216	198	1.09
2450	2.4	146	205	190	1.07

TABLE VIII

Fuel consumption and specific air range at 15000 ft.
Cold air. Radiator flaps closed
Corrected to ICAN +19°C.

Mean weight lb.	S/C gear	RPM	Boost lb/in²	Std ASI mph	TAS mph	Total fuel flow gall/hour	Specific air range ampg
61000	FS	2650	7.3	187	246	252	0.98
↓	↓	2550	5.8	178	235	224	1.05
		2450	4.6	169	224	203	1.10
		2350	3.4	156	207	188	1.10
		2250	2.3	129	176	174	1.01
54500	FS	2650	7.3	192	252	252	1.00
↓	↓	2550	5.8	184	243	224	1.08
		2450	4.6	175	232	203	1.14
		2350	3.4	166	219	188	1.16
		2250	2.3	155	205	174	1.18
		2150	1.3	143	191	161	1.18
54500	MS	2650	2.7	176	233	203	1.15
↓	↓	2600	2.3	172	228	196	1.16
		2500	1.4	163	216	182	1.19
		2400	0.7	153	204	169	1.21
		2300	0.1	142	190	156	1.22
49000	FS	2650	7.3	196	258	252	1.02
↓	↓	"	4.0	180	238	216	1.10
		"	2.0	169	223	195	1.14
		"	0	149	198	174	1.13
		2600	6.6	192	252	237	1.07
		2500	5.2	185	244	213	1.14
		2400	3.9	178	235	195	1.20
		"	2.0	166	219	182	1.20
		"	0	146	194	165	1.17
		2300	2.8	169	224	181	1.24
		2200	1.8	159	211	167	1.26
		"	0	141	189	155	1.22
		2100	0.9	149	198	155	1.27
		2000	0.2	135	182	143	1.27

/Table IX

TABLE IX

Fuel consumptions and specific air range at 10,000 ft.
Cold air. Radiator flaps closed. MS gear
Corrected to ICAN +19°C.

Mean weight lb.	RPM	Boost lb/in^2	Std ASI mph	TAS mph	Total fuel flow gall/hour	Specific air range ampg.
70000	2650	6.2	183	223	235	0.95
	2600	5.7	179	218	225	0.97
	2500	4.6	166	203	207	0.98
	2400	3.7	147	182	194	0.94
	2350	3.2	135	169	186	0.91
64000	2650	6.2	188	229	235	0.98
	"	4.0	175	213	214	0.99
	"	2.0	158	193	197	0.98
	2600	5.7	185	225	225	1.00
	2500	4.6	178	216	207	1.04
	2400	3.7	168	204	194	1.05
	"	2.0	151	186	180	1.03
	2300	2.9	156	191	180	1.06
	2200	2.2	133	168	168	1.00
54500	2650	6.2	198	241	235	1.02
	2600	5.7	196	238	225	1.06
	2500	4.6	191	232	207	1.12
	2400	3.7	185	224	192	1.16
	2300	2.9	178	216	180	1.20
	2200	2.2	169	206	168	1.22
	2100	1.5	160	195	156	1.24
	2000	0.9	149	182	146	1.24
47000	2650	6.2	207	251	235	1.07
	"	3.0	190	231	206	1.12
	"	1.0	176	214	189	1.13
	"	-1.0	153	186	172	1.08
	2600	5.7	204	248	225	1.10
	2500	4.6	199	242	207	1.17
	2400	3.7	193	235	192	1.22
	"	3.0	188	228	187	1.22
	"	1.0	171	209	173	1.20
	"	-1.0	150	183	158	1.15
	2300	2.9	186	226	180	1.26
	2200	2.2	179	217	168	1.29
	"	1.0	167	203	160	1.26
	"	-1.0	147	179	148	1.21
	2100	1.5	170	207	156	1.32
	2000	0.9	161	197	146	1.34
		-1.0	142	174	137	1.27
	1900	0.4	153	186	136	1.36
	1800	-0.1	141	173	127	1.36

TABLE X

Fuel consumptions and specific air range at 8000 ft.
Cold air. Radiator flaps closed. Mean wt. 70,000 lb.
Corrected to ICAN +19°C

RPM	Boost lb/in^2	Std ASI mph	TAS mph	Total fuel flow galls/hour	Specific air range ampg
2650	7.5	196	231	265	0.87
2550	6.6	186	220	236	0.93
2450	5.7	176	208	214	0.97
2350	4.8	161	192	197	0.97
2250	4.1	140	170	184	0.92

/Table XI

TABLE XI

Fuel consumptions and specific air range at 5000 ft.
Cold air. Radr. flaps closed. MS gear
Corrected to ICAN +19°C

Mean weight lb.	RPM	Boost lb/in^2	Std ASI mph	TAS mph	Total fuel flow galls/hour	Specific air range ampg
70000	2650	7.0	197	222	256	0.87
	2550	7.0	196	220	248	0.88
	2450	7.0	193	217	235	0.92
	2350	6.8	190	215	225	0.95
	2250	5.9	180	202	201	1.00
	2150	5.0	164	186	184	1.01
	2050	4.2	148	169	172	0.98
62500	2650	7.0	198	223	256	0.87
	"	5.0	184	207	218	0.95
	"	3.0	167	190	199	0.95
	"	1.0	143	163	183	0.89
	2500	7.0	196	221	239	0.92
	2400	7.0	195	220	230	0.95
	"	5.0	181	205	201	1.01
	"	3.0	164	186	186	1.00
	2300	6.4	192	216	216	1.00
	2200	5.5	183	206	194	1.06
	"	5.0	177	199	188	1.05
	"	3.0	160	183	176	1.04
	2100	4.8	173	195	178	1.09
	2000	4.2	163	184	169	1.10
	1900	3.4	152	172	157	1.09

/Table XII