31st Part of Report No. A.& A.E.E./766,b.



AIRCRAFT AND ARMAMENT EXPERIMENTAL ESTABLISHMENT
BOSCOMBE DOWN

# A review of the performance and handling trials of ten production Lancaster Mk.III aircraft

by
C.S. Wills B.Sc.



A.& A.E.E. ref:- 3708/1/Eng.
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Date of tests:- See Appendix I.

Progress of issue of report

| Report No. | Title |
|---|---|
| 26th Part of A.& A.E.E./766,b | ND.405 - Performance and handling trials of a production aircraft. |
| 27th -do- | JA.870 - Handling tests with FN.82 tail turret and AGLT fitted. |
| 28th -do- | ND.537 - Performance and handling trials of a production aircraft. |
| 29th -do- | JA.918 - Oil cooling and radiator suitability trials. |
| 30th -do- | DV.179 - Tests of modified cabin and turret heating system. |

R & D

## Summary

Between January and October 1943, ten Lancaster III aircraft representing current production were briefly tested for performance and handling at full load.

The results have been reviewed to search for any signs of improvement or decay within the type.

No material change was found, but the one aircraft which was the sole representative from a daughter firm gave certain performance results which were inferior to the remainder.

## 1. Introduction.

As from January 1943, an agreed percentage of the output of Lancaster aircraft have been selected by the A.I.D. for brief performance and handling tests at full load by an A.& A.E.E. pilot and technical observer.

The results obtained have been issued separately for each aircraft after its trials (see Appendix I), but in this Part of the Report, an abstract of the results of the first ten Lancaster III to be so tested has been collected and presented for review.

The purpose of this review is to facilitate the search for any changes that may have occurred, or may occur, in the production of the type. It has been found, on the quantity production of other aircraft types, that occasionally serious deterioration can occur in the performance, or handling qualities of the type. This deterioration may arise from apparently insignificant changes in production methods, or in the operational limitations, but may escape notice in check flight tests made at light load.

## 2. Selection and condition of aircraft.

2.1. Selection. The ten aircraft were selected by D.G.A.I. branch of M.A.P. and were an agreed percentage of the type produced by each assembly plant.

Eight of these Lancasters were built by the parent firm at Plant A. Lancaster W.5008 was built by the daughter firm under the inspection of the same M.A.P. inspectors as at Plant A. Lancaster LM.322 was built by the parent firm at Plant B.

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2.2. Condition. All aircraft were received for test on delivery from the assembly plant to the R.A.F. airfield selected for the tests.

Details concerning the aircraft individually and their order of test are given in Appendix I, together with reference to the fuller description given in the initial parts of this report.

The first eight aircraft were tested under substantially identical conditions of all up weight, engine power rating and externalform but minor differences due to barrage cutters, de-icing paste etc. were noted.

The last two aircraft, JB.178 and JB.373 were flown at a take-off weight increased by 1,500 lb. and were fitted with a large pear shaped (H2S) blister at the ventral turret site. The effect of the change of weight has been allowed for, in the comparisons within this review.

The skinning of each aircraft was examined to check for defects likely to effect the test results, such as poor contours and bad riveting. In review the standard of the skinning appears to be maintained uniformly and satisfactorily for the aircraft type.

2.3. Loading. All flights were made at take-off weight within ±0.5% of the current maximum permissible take-off weight. These values were 61,500 lb. for the first eight aircraft and 63,000 lb. for JB.178 and JB.373.

The loadings were based on the computed tare weight and C.G. positions certified by the A.I.D. at the contractors' works.

The range of weights and C.G. positions covered in the course of the ten sets of trials for general handling were:-

All up weights: From 63,000 lb. to 54,000 lb.
C.G. position : From 58.5" to 50.5" aft of datum (flaps and undercarriage up).

The design limits for the C.G. range at the maximum permissible weight were, at the outset of these tests, from 48.5" to 58.0" aft of datum but a clearance issued during the period of tests extended the limits to cover from 45.0" to 62.0" aft of datum (flaps and undercarriage up).

2.4. Engine limitations and detail. The engine limitations in force at the period of the tests are given in Appendix II, they were effectively the same for all the aircraft tested, with the exception that +12 lb/sq.in. boost only was available for take-off with ED.726, ED.861 and ED.989. The change of type, from Merlin 28 to Merlin 38 as in JB.373 is not material in the comparison of the results, since the later type differed only in having strengthened components, but was subject to the same limitations, and power output rating, at the time of the tests.

The carburettors were "fully automatic" Stromberg type PD/16B1.

3. Scope of review.

3.1. Performance. The climb and level speed performance is compared mutually between the ten aircraft where possible.

The climbs were initiated immediately after take-off at full load and maintained approximately to the service ceiling using the appropriate best climbing speeds, with the radiator shutters fully open. The radiator thermostatic control was rendered inoperative.

Maximum climbing power was used throughout the climbs except for the first stage of the climbs to 12,000 ft. in M.S. gear supercharger on the last four aircraft tested. In those cases maximum rich cruising power was used (2650 rpm +7 lb/sq.in. boost).

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The level speeds were measured on each aircraft at height intervals of 2,000 ft. (approximately) between 6,000 ft. and 20,000 ft. at maximum weak cruising power. For the first three aircraft, tests were also made in level flight at the all-out level power ratings (5 minute limit) of 3000 rpm at +9 lb/sq.in. and +12 lb/sq.in. boost. (These tests were discontinued following a request from Bomber Command.)

For comparison, representative values of climb and level speed performance are taken at selected heights in the MS and FS gear ranges, from the performance figures previously given in the individual reports and corrected to common conditions. These corrected values are given in Tables I and II.

Where a set of comparable values on several aircraft are available, say the rate of climb at 2,000 ft., the mean is given also, This mean may be taken as representative for the current type, and against this any single value may be judged for normality.

From these mean values generalised pictures of climb and level speed performance have been drawn (Figs. 1 & 2) which may be taken as representative of the contemporary production of English built Lancaster III operating at 61,500 lb. take-off weight. The scatter between results for the individual aircraft for service ceiling, rates of climb and cruising speeds are also indicated (Figs. 1 & 2).

3.2. Handling. The results of the general handling tests which included stalls, dives and asymmetric powered flight are reviewed collectively.

4. Review of results.

4.1. Performance. A summary of the meaned results is given below. These are abstracted from the selection of performance results arranged for review in Table I and II.

The performance results given in this review have been corrected

(a) to standard I.C.A.N. atmospheric conditions.
(b) to a common take-off weight of 61,500 lb. for climb performance and to a mean weight approximating to 95% of the take-off weight, i.e. 58,500 lb. for cruising performance.
(c) to the full nominal boost appertaining to the condition of test, in cases where such boost was not maintained below the appropriate full throttle height.
(d) for position error according to best data available at the time of test from similar aircraft tested at A.& A.E.E. or R.A.E. with identical pitot-static head or static vent installations.

For (a) (b) and (c) the methods of correction are as given in Report No. A.& A.E.E./Res/170 using a supercharger constant C = 0.002.

4.11. Climb - MS gear at max. climbing power, i.e. 2850 rpm + 9 lb/sq.in. boost. - Mean of six aircraft.

Rate of climb: 850 ft/min. at 2,000 ft. falling to 830 ft/min at 9,000 ft.
Full throttle height: 9300 ft.
Time to reach 12000 ft: 15.3 minutes.

4.12. Climb in MS gear at max. rich cruising power, i.e. 2650 rpm + 7 lb/sq.in. boost. Mean of four aircraft.

Rate of climb: 655 ft/min. at 2,000 ft. falling to 635 ft/min. at 9,000 ft.
Full throttle height: 9600 ft.
Time to reach 12000 ft: 19.4 minutes.

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4.13. <u>Climb in FS gear at max. climbing power, i.e. 2850 rpm + 9 lb/sq.in. boost. Mean of ten aircraft.</u>

Rate of climb: Constant from 12,000 ft. to the full throttle height. 590/ft.min.
Full throttle height: 15,800 ft.
Time from 12,000 ft. to 20,000 ft. 16.7 minutes.
Service ceiling: 23,200 ft.

As stated previously, these results are corrected for the full nominal boost (+9 lb/sq.in.). During the tests, the controlled value of the boost at 15,800 ft. was low by ½ lb/sq.in. This fall off in boost appeared in general to be progressive with height. The observed mean full throttle height was in consequence higher than the corrected full throttle height by 600 ft.

4.14. <u>Level speeds</u>. The number of aircraft whose results contribute to the mean is shown in the brackets against the mean speed.

| | MS gear | FS gear |
|---|---|---|
| Max. true air speed at max. weak cruising power. (2650 rpm +4 lb/sq.in.) | 239 mph (10) at 14500 ft. F.T.H. | 243 mph (10) 20700 ft. F.T.H. |
| Max. true air speed at max. all-out level power. 3000 rpm, +12 lb/sq.in. (5 min.rating) | 272 mph (3) at 8000 ft. F.T.H. | 278 mph (2) at 15,000 ft. F.T.H. |
| Max. true air speed at 5 min.rating of 3000 rpm + 9 lb/sq.in. | 269 mph (3) at 11,500 ft. F.T.H. | 269 mph (3) at 18,400 ft.F.T.H. |

4.2. <u>Review of handling characteristics</u>. The aircraft were individually subjected to a routine schedule of tests designed to check the normality of handling qualities in all normal phases of flight. The tests in addition to general handling, covered the stall, dive, and asymmetrically powered cases. The effect of a substantial change (up to 6") in C.G. position was noted in each flight and was obtained by crew movement. The corresponding details of all-up weight and C.G. positions have been given in the individual reports. These tests generally were made at an all up weight within 7% of the maximum permissible for take-off.

As already indicated in the conclusions issued on each of these ten aircraft the handling characteristics were considered to be normal for the type in all respects but some detailed features are reviewed below.

4.21. <u>Stalling characteristics</u>. The stalling speeds are grouped below according to the similarity of their respective airspeed indicator system. The airspeeds have been corrected to an aircraft weight of 60,000 lb.

| | | Stalling speeds I.A.S. mph — Flaps and undercarriage UP | Stalling speeds I.A.S. mph — Flaps and undercarriage DOWN |
|---|---|---|---|
| (a) | Aircraft with similar under nose pitot static heads ED.453, W.5008 | 105, 101 | 87, 85 |
| (b) | Aircraft with similar static vents, but no $H_2S$ blister. ED.726, ED.861, ED.989 | 118,113,112 | 97,91,97 |
| | LM.322, JA.684, JA.914 | 112,108,107 | 91,91,86 |
| (c) | As for (b) but with $H_2S$ blister. JB.178 | 111 | 96 |
| (d) | Static vent repositioned to RAE instruction Note 726 (+$H_2S$ blister) JB.373 | 111 | 95 |

There is some physical difficulty in attaining the stalled condition with the flaps and undercarriage up, on most Lancaster III as tested. The precise position of the control column varies between the aircraft, and inspection of other Lancaster III at A.& A.E.E. has shown that in some cases the rearward movement of the control column is restricted slightly by the forward edge of the pilots seat when the latter is at the top of its travel.

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In no case was any vicious tendency reported either in the stall or in the recovery. The juddering of the airframe which normally occurs within 10 mph of the stall varies in degree between aircraft and in some cases could not be felt. The absence of judder is therefore no guarantee that the aircraft is not approaching the stalled condition.

4.22. Dive. In this test each aircraft was put into a dive at 12,000 ft. or less, with the throttle approximately one third open, and in trim for level flight at cruising power.

The maximum permissible diving speed of 360 mph IAS was generally attained within a height loss of some 4,000 ft. The maximum speed reached on certain of the aircraft exceeded 360 mph by as much as 23 mph in one dive, owing to the tendency of the aircraft to maintain acceleration during the initial stages of a recovery.

The typical feature of increasing nose heaviness with speed (when trimmed for level flight at cruising power) was noted in all dives, which made it desirable to retrim the elevator to tail heavy to reduce the load otherwise required on the control column.

There was a tendency, thought to be common to the aircraft type, for the aircraft to become starboard wing low during the dive. This tendency varies from aircraft to aircraft but may require up to 2 divisions of aileron trimmer to trim at the maximum speed.

4.23. Two and three engine handling. In no case was any difficulty encountered on throttling back the outboard engine when initially in trim for level flight at weak cruising power (2650 rpm +4 lb/sq.in. boost).

For two engine handling case, the following conditions were prescribed for the test:-

The propeller of the port outer engine feathered and stopped.
The port inner engine throttled right back with the propeller windmilling.
The starboard engines were opened up to 2850 rpm +9 lb/sq.in. boost (max. emergency power, engine cut case).
Full rudder trim to starboard.
Wings held laterally level, aircraft maintaining constant course.

Under these conditions the following airspeeds in mph I.A.S. were as shown below for the various loads required at the foot pedals.

| | (a) A/c with pitot-static hd mph IAS | | (b) A/c with fuselage static vents mph IAS | | | | | | (c) A/c with $H_2S$ & static vent mph IAS | (d) |
|---|---|---|---|---|---|---|---|---|---|---|
| A/c numbers | ED.453 | W.5008 | ED.726 | ED.861 | ED.989 | LM.322 | JA.684 | JA.914 | (JB.178) | (JB.323) |
| A. No foot load | (190)* | 180 | 169 | 180 | 190 | 185 | 180 | 184 | 190 | 200 |
| B. Mod. foot load suitable for long periods | - | 156 | 150 | 170 | 170 | 160 | 160 | 166 | 170 | 176 |
| C. Max. foot load - short period only | - | 122 | 135 | 150 | 150 | 140 | 135 | 145 | 140 | 150 |

* This speed is of doubtful validity not being obtained under the conditions stated above but with both starboard engines windmilling and with only 6 divisions of rudder trim to port. (See 2nd Part of A.& A.E.E. Report No. 766,b)

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4.24. <u>Approach and landing</u>. In general the glide approach was made at 140 mph IAS with the engines throttled back. This speed gave ample control even at the maximum landing weights employed. No difficulty was encountered during the landing with the port outer propeller feathered during the tests on LM.322. (21st Part of this Report.)

5. <u>Discussion of results</u>.

In referring to the comparison of individual results against the mean as given in Table I, it should be remembered that those aircraft performance values falling below the mean are not necessarily 'subnormal'. Some scatter of the results is known to occur due to the combined effects of (a) errors of measurements, (b) legitimate differences in equipment such as de-icing paste, barrage cutters, $H_2S$ blister, and (c) variations in engine power output.

With reference to errors of measurement, rates of climb of heavy bomber aircraft are particularly subject to variation between results obtained from ceiling climbs made under apparently identical conditions. These variations in rates of climb are frequently of the order of ±5% from the mean. Such differences can arise from imperfect weather conditions or from an inability to maintain a precisely constant climbing speed. The latter, in turn depends upon the longitudinal stability of the aircraft in the climb and the skill of the pilot.

It may be noted that evidence obtained at A.& A.E.E. on Lancaster III JA.918 indicates that de-icing paste as applied by Bomber Command, did not cause any measurable change in speed in level flight.

A specific aeroplane may possibly be subnormal in any one of at least five aspects of performance such as rate of climb, level speed in MS or FS supercharger gear, or in ceiling height. A further, although admittedly imperfect, check for deterioration in the 'cleaness' of the aircraft with respect to the type, is obtainable by noting whether the one aircraft is consistently below the mean in more than one of these five aspects of performance as measured.

Referring to Tables I & II it will be seen that the only aircraft having a rate of climb substantially less than the mean is W.5008 which was 15% low in rate of climb in FS gear at maximum climbing power. The rate of climb in MS gear was also some 5% low. This feature is, however, offset somewhat by the fact that the service ceiling height attained was slightly in excess of the mean. It might also be noted as a guide to the variability of these rates of climb, that the results for JA.914 were 15% high in rate of climb in FS gear at 14,000 ft. compared with the mean of four aircraft.

In level speed performance, ignoring those results which were measured on only three aircraft or less it is found that in MS gear at 2650 rpm +4 lb/sq.in. boost, W.5008, LM.322 and JB.178 were some 2% lower than mean level speeds quoted. In FS gear JB.178 was some 2% low at 16,000 ft. but average in speed at 20,000 ft. while ED.726 was approx. 1% low in speed at 16,000 ft. and 2% low at 20,000 ft. The speeds of W.5008 in FS gear were substantially identical with the mean values.

<u>Conclusions</u>.

It may be considered from this review that in the progress of these tests there was no material change in the performance or handling qualities of the type.

Lancaster III W.5008, which was the sole representative of the output of the subcontractors at Plant A, in this review was below the average of the remaining nine aircraft in rates of climb, (except toward the service ceiling) and in level flight at 2650 rpm +4 lb/sq.in. boost in MS gear. At 14,000 ft. it was 5 mph below the mean speed established by these ten aircraft.

TABLE I

Abstract of climb performance for 10 Lancaster III with T.O. weight of 61,500.
Radiator flaps open
Corrected for nominal boost below full throttle height.

| S/C Gear | RPM | Boost lb/sq.in. | Height ft | Item Measured | ED.453 | ED.726 | ED.861 | ED.989 | LM.322 | W.5008 | JA.684 | JA.914 | JB.178 | JB.373 | Mean of 10 values | Mean Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MS | 2850 | + 9 | 2000 | R/C:Ft/min | 840 | 860 | 810 | 860 | 920 | 820 | | | | | | 850 |
| | | | 9000 | -do- | 810 | 850 | 770 | 850 | 920 | 770 | | | | | | 830 |
| | | | | Full throttle height. (ft) | 9400 | 9400 | 9200 | 9000 | 9200 | 9700 | | | | | | 9300 |
| | | | 12000 | Time (mins) | 15.3 | 15.0 | 16.0 | 14.7 | 14.0 | 15.5 | | | | | | 15.1 |
| MS | 2650 | + 7 | 2000 | R/C:Ft/min | | | | | | | 630 | 700 | 620 | 690 | | 660 |
| | | | 9000 | -do- | | | | | | | 600 | 680 | 620 | 640 | | 632 |
| | | | | Full throttle height (ft) | | | | | | | 9800 | 9800 | 9000 | 9900 | | 9600 |
| | | | 12000 | Time (mins) | | | | | | | 20.0 | 18.0 | 20.6 | 19.0 | | 19.4 |
| FS | 2850 | + 9 | 14000 | R/C:Ft/min | 600 | 560 | 580 | 550 | 640 | 500 | 590 | 680 | 580 | 610 | 589 | |
| | | | | Full throttle height (ft) | 16400 | 16500 | 15600 | 15700 | 16200 | 16500 | 15500 | 15400 | 15100 | 15800 | 16020 | |
| | | | | Service Ceiling (ft) | 23100 | 23000 | 23900 | 23800 | 23300 | 22800 | 22800 | 23700 | 23000 | 22200 | 23160 | |
| | | | 12000 to 20000 | Time (mins) | 15.0 | 16.2 | 16.6 | 16.8 | 14.7 | 19.0 | 18.0 | 14.5 | 17.8 | 16.9 | 16.5 | |

TABLE II

Abstract of level speed performance for 10 Lancaster III aircraft
Corrected to mean weight of 58,500 lb. Radiator flaps closed.

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MS | 2650 | + 4.0 | 8000 | TAS (mph) | 225 | 226 | 229 | 229 | 221 | 222 | 229 | 226 | 221 | 230 | 225.8 | |
| | | | 14000 | -do- | 235 | 239 | 240 | 241 | 235 | 233 | 238 | 241 | 239 | 242 | 238.3 | |
| | | | | Full throttle height (ft) | 14400 | 15200 | 14200 | 14200 | 15000 | 15200 | 14500 | 14300 | 13700 | 14100 | 14480 | |
| | 3000 | + 9 | - | Full throttle height (ft) | 11500 | 11500 | 11500 | | | | | | | | | 11500 |
| | | | F.T.Ht. | TAS (mph) | 267 | 268 | 271 | | | | | | | | | 268.7 |
| | 3000 | +12 | | Full throttle height (ft) | 8400 | 7500 | 8500 | | | | | | | | | 8130 |
| | | | F.T.Ht. | TAS (mph) | 272 | 270 | 273 | | | | | | | | | 271.7 |
| FS | 2650 | + 4.0 | 16000 | TAS (mph) | 236 | 232 | 236 | 237 | 232 | 234 | 237 | 237 | 230 | 235 | 234.6 | |
| | | | 20000 | TAS (mph) | 242 | 236 | 241 | 241 | 243* | 241 | 244 | 246 | 242 | 239 | 241.5 | |
| | 3000 | + 9.0 | | F.T.Ht. ft. | 18300 | 18300 | 18400 | | | | | | | | | 18330 |
| | | | | TAS (mph) | 271 | 267 | 272 | | | | | | | | | 270 |
| | 3000 | +12 | | F.T.Ht. ft. | 15000 | | 15000 | | | | | | | | | 15000 |
| | | | | TAS (mph) | 278 | | 277 | | | | | | | | | 277.5 |

* Estimated

/Appendix

## APPENDIX I

Detail of aircraft tested, order of test, relevant part of report and description.

| A/c No. | Date of Test (1943) | A.& A.E.E. Report No. | Brief description |
|---|---|---|---|
| ED.453 | 26 Jan - 1 Feb | 2nd/766,b | See 2nd/766,b: 4000 lb bomb doors; No under turret; 2 Navigation blisters on walls of pilots canopy. Gapped snow guards. Merlin 28 powerplant. 16 cable cutters. 6 fuel pump fairings under wings. De-icing paste to all leading edges. Under nose pitot-static head. Hamilton type A5/138 propellers, 13'1" diam. |
| ED.726 | 22nd March | 16th/766,b | As above, except static vent and large perspex nose (Mod.780) fitted. |
| ED.861 | 16th April | 18th/766,b | As for ED.726, except no barrage cutters, no de-icing paste applied. |
| ED.989 | 18th May | 20th/766,b | As for ED.726. |
| LM.322 | 19th May | 21st/766,b | As for ED.726 but no de-icing paste applied. |
| W.5008 | 31st May and 17th June | 12th/766,b | As for ED.453 except Marstrand tail wheel tyre and 4 fuel pump fairings only. |
| JA.684 | 24th June | 13th/766,b | As for ED.726 except: Marstrand tail wheel tyre. No de-icing paste. Monica and type 90 aerials added in vicinity of tail turret. |
| JA.914 | 23rd July | 15th/766,b | As for JA.684 except navigation blister on starboard side only. |
| JB.178 | 2nd Sept. | 17th/766,b | As for JA.914 except $H_2S$ blister added and barrage cutters deleted. |
| JB.373 | 3rd Oct. | 19th/766,b | As for JB.178 except Merlin 38's fitted. |

## APPENDIX II

Engine limitations for Merlin 28 & 38.
(as used for tests within this review.)

| | RPM | Boost lb/sq.in. | |
|---|---|---|---|
| Max. power for take-off | 3000 | + 12 | for ED.453, 726,861 |
| | | + 14 | for remainder. |
| " " " climb | 2850 | + 9 | |
| " " " weak cruising | 2650 | + 4 | |
| " " " all out level (5 minute rating) | 3000 | + 12 | |

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Chief Technical Officer.

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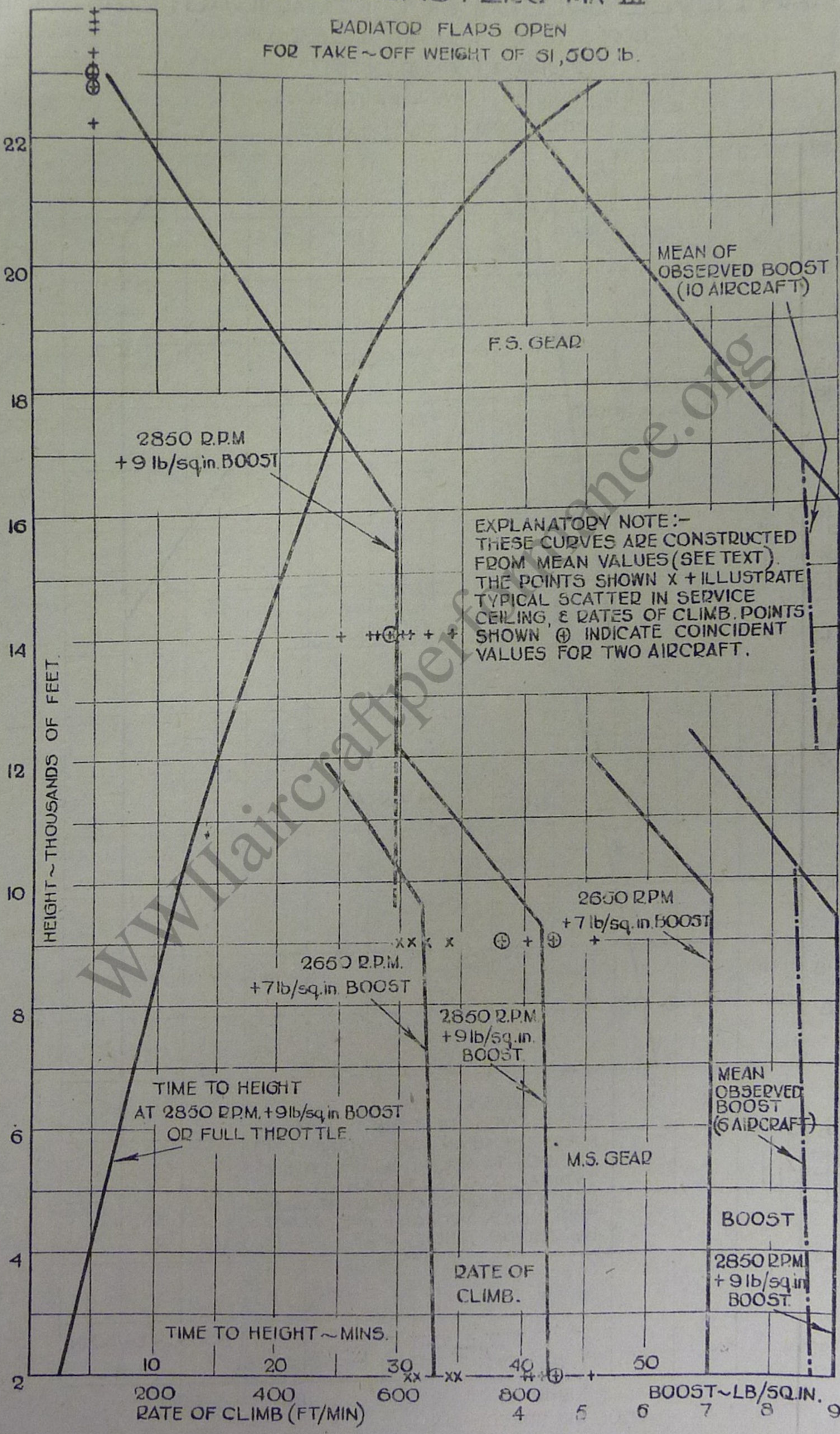
Commanding A.&A.E.E.,
Royal Air Force.

FIG 1

# MEAN CLIMB PERFORMANCE OF 10 LANCASTERS Mk III




31ST PART OF REPORT No A.&A.E.E./766 b. | LANCASTERS Mk III | CURVE No 6156 | TRACED I.M.P. | DATE 14.3.44 | CHECKED | APPROVED

FIG. 2

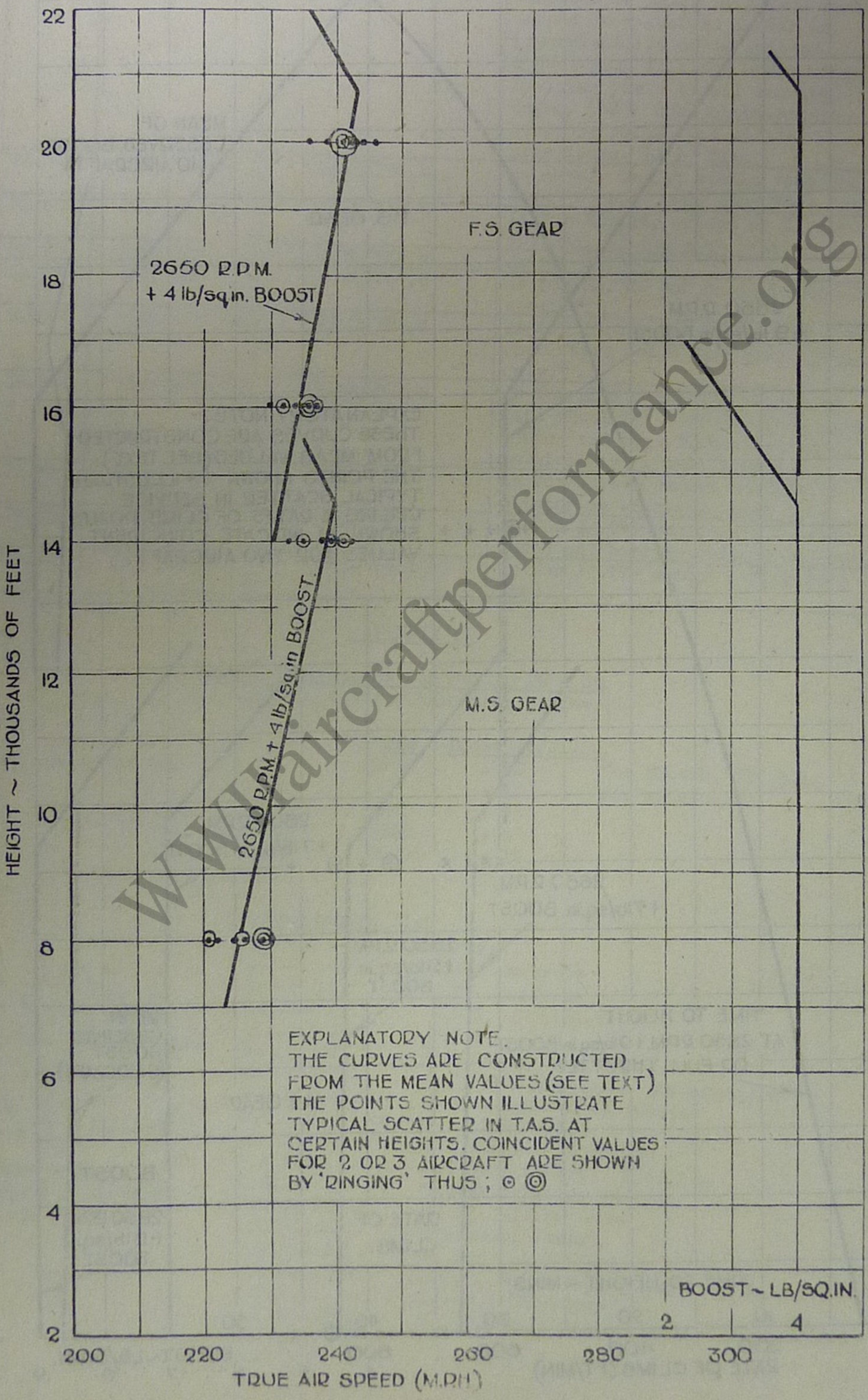
# MEAN LEVEL SPEEDS FOR 10 LANCASTERS Mk III

CORRECTED TO A WEIGHT OF 58,500 lb.

(RADIATOR FLAPS CLOSED)

WEAK CRUISING POWER LIMITATIONS.

2650 R.P.M. + 4 lb/sq.in BOOST.

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