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T-33A PERFORMANCE EVALUATION

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Project Engineer

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Project Pilot



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AIR FORCE FLIGHT TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

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ABSTRACT

The T-33A aircraft is a tandem two place single engine turbojet powered aircraft which is utilized as a basic trainer and as a combat readiness trainer throughout the Air Force. The standard configuration includes two 230 gallon tip tanks. This performance evaluation was required as a result of a recent command review of the T-33A Flight Manual. The total flight time required for the two aircraft tested was 31:45 hours during the period 3 December 1960 to 17 January 1961. Indications were that the performance data as presented in the Flight Manual was not accurate. Aircraft engines in service presumably had suffered thrust deterioration as a result of many years of service. Thus, the purpose of this test was to evaluate the performance of a representative T-33A aircraft with an average thrust engine and to determine the cause for the variation in performance between aircraft. To this end, the most representative, instrumented T-33A possessed by the USAF Experimental Flight

Test Pilot School was selected. For comparison purposes additional tests were performed on an aircraft having a low thrust engine.

Test results show a 10 percent variation in installed thrust which could cause even larger percentage variations in take-off and climb performance. The cruise and endurance performance is relatively unaffected by the thrust variations and engine life. The greatest cause of thrust variation is not attributed to the deterioration of the engine with service life, but rather to the broad thrust limits allowed after overhaul of the engine and to variations of climb rpm in flight. Low exhaust gas temperatures (below 685 degrees C) may indicate a low thrust engine; however, positive correlation of this point was not established.

The installation of a standard travel pod reduces the climb performance slightly and has a negligible effect on the take-off and cruise performance. However, the cruising speed with the travel pod must



be reduced from that of the standard tip tank configuration by .03 Mach number at all altitudes to achieve the same performance.

With a few exceptions the test and Flight Manual performance data compare favorably for the representative aircraft tested. The Flight Manual take-off data is optimistic by 16 to 24 percent, while the descent data examined is pessimistic by approximately 75 percent. The Flight Manual cruise and climb performance compares favorably at low altitudes, but is slightly optimistic at high altitudes. Insufficient descent and landing data is presented in the Flight Manual.

The T-33A aircraft, having been designed and built under early design standards and specifications, does not have cockpit features which are consistent with modern specifications. If it is to be used to train pilots to fly modern aircraft, certain changes should be made as noted in the recommendations section of this report. In addition, certain cockpit

features also noted constitute a flight hazard and should be corrected.

The Flight Manual places sideslip restrictions on the aircraft when carrying a travel pod. A qualitative investigation of the sideslip characteristics of the T-33A aircraft with travel pod installed was performed at the request of Sacramento Air Materiel Area. Full rudder sideslips in both the power approach and cruise configurations show no adverse characteristics attributable to the travel pod. Therefore, it is recommended the sideslip restrictions for the aircraft with travel pod installed be the same as for the aircraft with tip tanks installed.

An engine thrust evaluation, designed to show the variation in engine thrust caused by changing some of the critical engine components as allowed by the overhaul specifications, is being conducted. This data is not available at this time and the results of these tests will be reported in an addendum to this report.

*This report
has been
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26 MAY 1961

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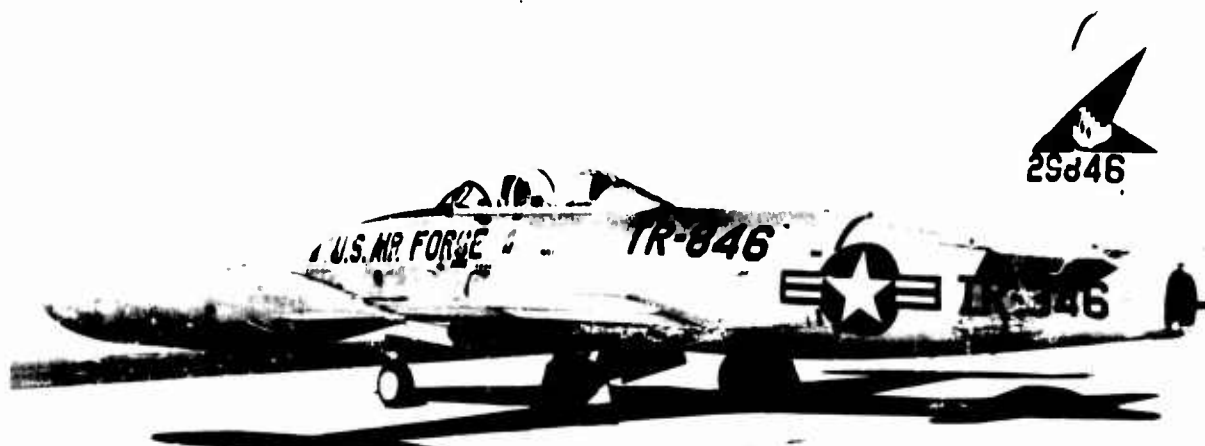
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INTRODUCTION

This report represents the results of performance tests conducted on T-33A-5, USAF No. 52-9846. The flight program was conducted at the Air Force Flight Test Center, Edwards Air Force Base, California, and consisted of 15 flights and 28:30 flight hours during the period from 3 December 1960 to 17 January 1961. Two additional flights for a total of 3:15 hours were flown on T-33A, USAF No. 51-8954 which had low installed static thrust.

The T-33A aircraft, manufactured by the Lockheed Aircraft Company, is a two place tandem cockpit, single turbojet powered aircraft that is utilized by Air Training Command as a basic trainer

and by other Air Force commands as a combat readiness trainer. At the beginning of the test the test air frame had accumulated 2180 flight hours, and the engine had 66 total flight hours since last overhaul. The aircraft and engine total flight hours are considered representative of the aircraft presently in service throughout the Air Force.

The aircraft was flown with two 230-gallon centerline tip tanks installed. The gross weight with full fuel was 15,280 pounds with a mid-center of gravity location. Three missions were flown with an external travel pod which adds 30 pounds when empty.

The data from the program was obtained to check the Flight Manual data and to determine any decay of performance while carrying an external travel pod. An investigation was also conducted to determine engine performance variation with engine life. Thrust stand runs were conducted on seven different T-33A aircraft which had 66 to 326 engine hours since last overhaul.

An engine producing low gross thrust was removed and tested in the power plant test cell. Since overhaul tolerances on the J33-A-35 engine allow

a wide variation in size of various critical components, the test engine was overhauled and is being tested at the high and low values allowed by the engine specification. This is being done to determine the probable variation in thrust of the engines in service. Results of these tests will be reported in an addendum report when available.

All test data gained during the program was provided to Lockheed Aircraft Corporation as it became available. Final plots were forwarded to the contractor on 3 February 1961.

TEST RESULTS

■ cockpit evaluation

Because of the service life of the T-33A aircraft and its projected utilization time, only safety of flight items and other discrepancies which can be easily accomplished to conform with HIAD are considered.

Safety of Flight Items

The present ejection system is unsatisfactory. It does not provide ground level escape at take-off and landing speeds, and it does not provide positive seat separation at any altitude. The extreme tight fit of the SA-17 parachute in the present ejection seat may prevent or delay pilot separation from the seat during ejection. In view of recent ejection fatalities attributed to the failure of the seat to separate, it is recommended that a positive automatic seat separation device be provided immediately and that a ground level ejection system be incorporated in the aircraft as soon as possible.

The locations of the starter, ignition, airstart, fuel sequence, battery generator and de-icing switches are unsatisfactory. Their secluded locations and illogical groupings are such as to cause undue effort and motions to perform normal and emergency

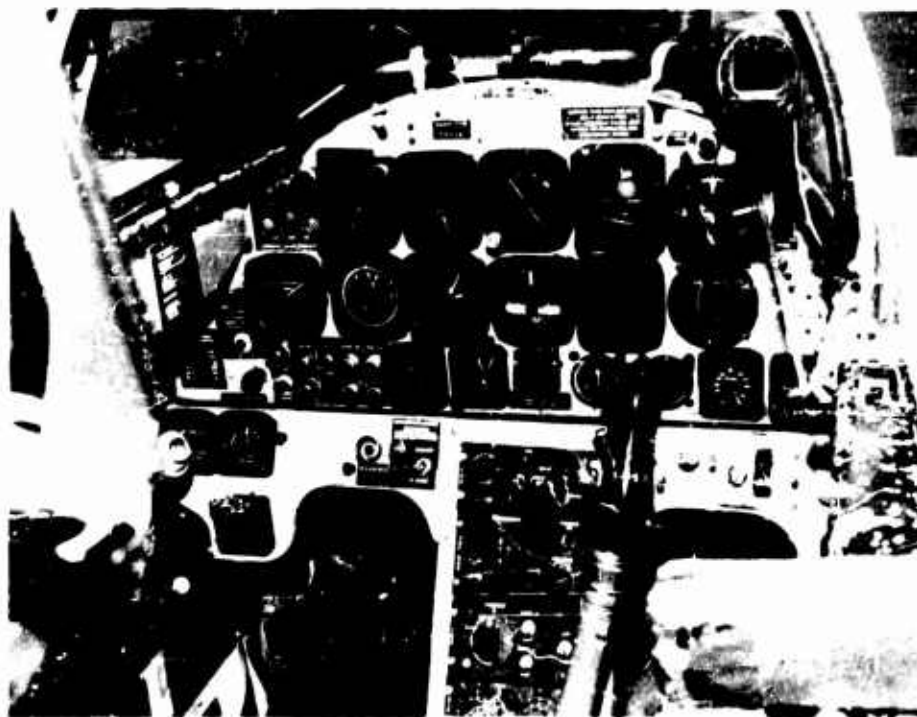
procedures. These switches are located in separate parts of the cockpit and are positioned such that they are obscured by the canopy rails, throttle and flap switch, making their identification and actuation difficult. Identification and operation of these switches during night or heavy weather is more difficult. For instance the engine normal starting sequence, in addition to the throttle movement, requires four switch actuation motions in various locations in the cockpit. The airstart sequence is equally as complicated with regards to motions and can be dangerous during periods immediately after take-off or during darkness. It is recommended that these switches be grouped according to function in an easily accessible location in the cockpit, and that the number of switch actuations be reduced to a minimum especially for emergency procedures.

The T-33A aircraft having been designed and built according to early design standards and specifications does not have cockpit features that are consistent with modern specifications. If this aircraft is to be used to train pilots to fly modern aircraft the cockpit lights and color coding of the controls should be consistent with present day HIAD specifications. In this light the following discrepancies are noted:

1. A large number of cockpit indicator and warning lights are incorrectly color coded. Red lights should be reserved for warning of catastrophic events such as fire warning, canopy unsafe, etc. Amber lights should be used for warning of items requiring corrective action by the pilot such as fuel sequencing, electrical power failure, etc. Green lights are used to signify satisfactory operation of the system concerned. The following cockpit lights should be changed from red to amber:

- a. Tip tank low pressure warning light.
- b. Main wing tank low pressure warning light.
- c. Leading edge tank low pressure warning light.
- d. Fuselage tank reserve low warning light.
- e. Fuel filter ice warning light.
- f. ATO indicator light.
- g. Turn and slip indicator warning light.
- h. Gyro instrument warning light.

2. The ejection seat handles, canopy jettison "T" handle, tip tank jettison handles and the bomb salvo button background are improperly color coded. HIAD C, 2-2.5.10.1 requires that they be painted orange-yellow with black stripes.



3. The fuselage tank switch indicator light should be changed from amber to green.

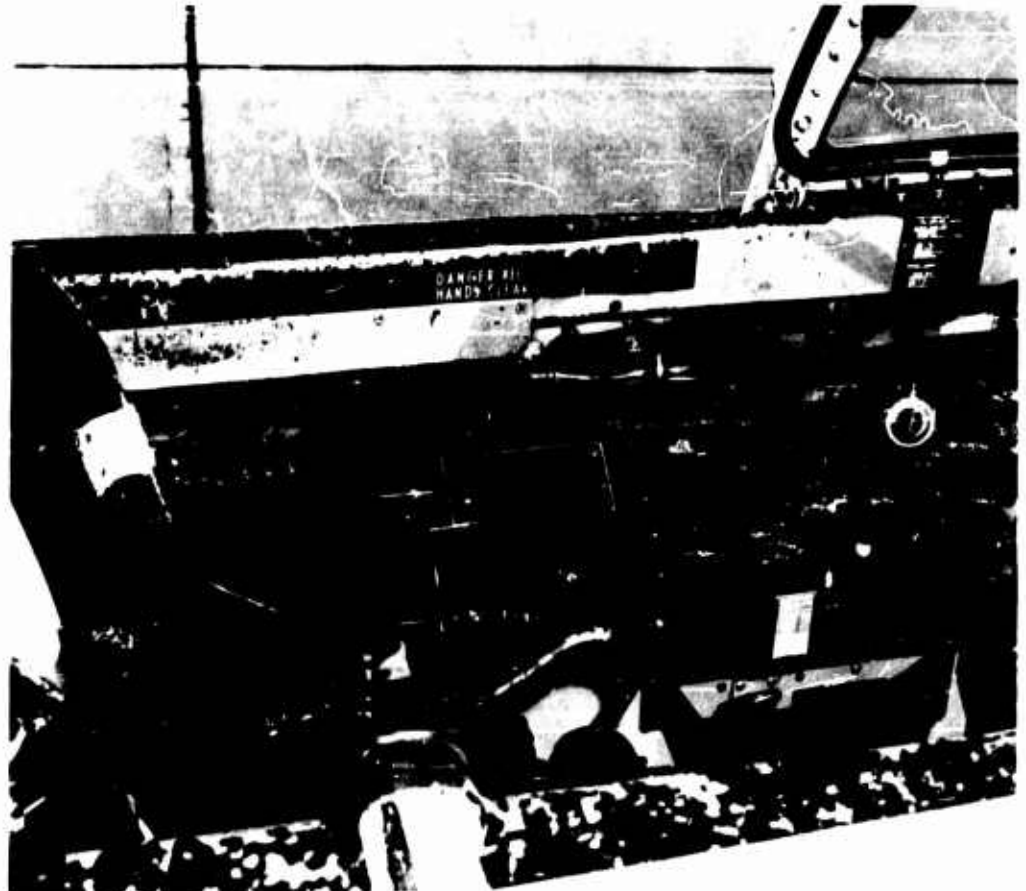
4. The provision for a master caution light and a caution panel, instead of the various advisory lights scattered throughout the cockpit, would greatly facilitate the pilot identification of a situation. The installation of a panel would reduce the time involved to identify the light, especially at night time.

5. The present fire, overheat and canopy warning lights should be replaced with the rectangular legend lights presently utilized in more modern aircraft. This type of light provides positive identification of the malfunctions but will not blind

the pilot during night or instrument conditions as does the present light. The take-off trim position light should also be replaced with this type of light.

6. The movement of the front cockpit interphone control box forward to the vacant position just aft of the throttle quadrant would facilitate pilot switch actuation.

7. The fuel overboard vent light is not dimmable and, therefore, tends to blind the pilot if illuminated at night or during instrument conditions. This light is frequently actuated at the start of steep descents utilized during instrument flying conditions. The light should be replaced with one that is dimmable.



■ ground handling

Visibility during all ground handling operations from the front cockpit is satisfactory while the rear cockpit forward visibility is restricted.

Directional control is provided by asymmetric braking and results in a turning radius that is considerably larger than that found for a similar aircraft equipped with nose wheel steering. A complete stop after a sharp turn can often result in a cocked nose wheel. Brake pedal forces and deflections are satisfactory.

Idle power is sufficient to maintain the proper taxi speed once the aircraft is rolling. The use of brakes in turning a sharp corner will require the addition of power to obtain the original taxi speed.

Taxiing the aircraft with the canopy open can result in a rapid directional oscillation of the canopy which is transmitted to the cockpit instrument panels. The vibrations and noise associated with this oscillation are annoying. The vibration can be eliminated by changing the canopy position or placing the canopy in the fully closed position.

■ take-off performance

The take-off sequence is initiated by stabilizing at 80 percent and releasing brakes after engine instruments are checked for satisfactory operation; power is then immediately increased to military. All take-offs were made using 30 degree flaps. Directional control is maintained with brakes up to 50 knots IAS at which time the rudder becomes effective. Directional control is then maintained with rudder and ailerons when required. Nose wheel lift-off is initiated at 85 knots and the aircraft rotated to the take-off attitude at 10 knots below take-off airspeed.

The aircraft can be lifted off the runway at an indicated speed of 107 knots but is subject to air-

frame buffet and reduced control effectiveness. The recommended Flight Manual speeds of 120 knots for normal take-off and 115 knots for minimum ground roll are satisfactory.

The gear was left in the extended position until passing through an altitude of fifty feet at which time the gear retraction cycle was initiated. The flap retraction was initiated at 140 knots and the aircraft allowed to accelerate while maintaining a slight climb angle.

The Flight Manual take-off data for the T-33A is optimistic for both the ground roll and the total distance to clear 50 feet. The ground roll distance for sea level standard day conditions at a brake release weight of 14,900 pounds and a lift-off indicated airspeed of 120 knots results in a ground run of 3890 feet. The Flight Manual data indicates a ground run of 2900 feet under the same conditions. The Flight Manual total distance to clear a 50 foot obstacle at an indicated airspeed of 135 knots is 4450 feet. Test value to clear a 50 foot obstacle at the same indicated airspeed is 5180 feet or more than 16 percent in excess of the value given in the Manual.

Ground roll distances and total distance to 50 feet with the external travel pod installed are identical to the standard configuration. No extra allowance need be given when planning a take-off with this configuration.

Take-off performance with a low thrust engine results in take-off distances that are slightly greater than those required with an average thrust engine. Ground roll with the low thrust engine is increased by 150 to 200 feet and the distance to 50 feet is increased by 150 to 300 feet, depending on the speed at take-off and at 50 feet.

Take-off data is presented in Figure 1, Appendix I and is summarized in the following table:

**TAKE-OFF
PERFORMANCE**

Sea level standard day — Gross wt — 14,800 pounds — Flaps 30° —
2-230 Gal. tip tanks

Indicated Airspeed Take-off — Knots	Ground Distance Feet	Indicated Airspeed 50 ft — Knots	Total Distance Feet
110	3320	140	4570
120*	3000	135	8100
130	4300	145	2000

*Recommended

■ **climb performance**

The climb performance of the T-33A aircraft is adequate for its mission. The military and normal rated power climb performance contained in the Flight Manual is slightly conservative at altitudes below 35,000 feet but is optimistic above this altitude. Acceleration and climb tests indicate that climbing the aircraft at speeds higher than the Flight Manual recommended schedule will require the same time and fuel to reach any given altitude but will give slightly better range. Partial fuel loads in the tip tanks (60 gallons) increase the rate of climb by 350 feet per minute over that for the aircraft with full tip tanks. The addition of the standard travel pod does not greatly reduce the climb performance if the climb schedule recommended in the Flight Manual is used. Climbing the aircraft at higher than Flight Manual recommended speeds with the travel pod installed results in a rate of climb reduction of approximately 150 feet per minute at all altitudes. Low installed thrust does not significantly reduce the climb performance if

the low and high thrust engines can be operated at the same (100 percent) engine speed. However, engines in the field operate at speeds that vary by as much as 2 percent causing a 300 to 500 feet per minute variation in climb performance.

The climb is entered after an acceleration from take-off to the initial climb schedule. The aircraft's nose is rotated upward at approximately ten knots below the desired climb speed and the schedule maintained by initially reducing the indicated airspeed two knots per thousand feet.

Acceleration and sawtooth climb tests, flown to determine the best climb schedule, indicate that the aircraft should be climbed at higher speeds than are recommended in the Flight Manual. However, initial climb tests were flown at too high a speed and a slightly slower schedule, lying between the test and Flight Manual schedule, is recommended.

The following table summarizes the data presented in Figures 2 thru 4, Appendix I for the three climb schedules flown:

CLIMB SCHEDULES

Altitude — Ft	Flight Manual — V, Recommended — V,	Test — V,
SL	270	260
5,000	260	264
10,000	250	270
15,000	240	260
20,000	230	253
25,000	220	248
30,000	210	227
35,000	200	211
40,000	190	194
41,000	180	188
42,000	180	187

Test climbs flown at the higher speed schedule indicate that greater range is obtained for the aircraft with tip tanks installed. There is no significant change in the time to climb or fuel used but the increased speed gives a 10 nautical mile increase in range when climbing to 40,000 feet. This climb schedule should be used as an alternate if maximum range is desired. Since the recommended Flight Manual climb schedule is easy to follow and results in comparable performance, no change in the Flight Manual schedule is proposed. Climb data for all configuration and schedules tested is presented in Figures 5 through 9, Appendix I. The following table summarizes the test data obtained with 2-230 gallon tip tanks installed and compares it with the data from the Flight Manual.

**MILITARY POWER CLIMB PERFORMANCE
WITH TWO 230 GALLON TIP TANKS**

Altitude — Ft	Rate of Climb Ft/Min	Time to Climb from SL — Min	Distance Traveled Nautical Miles	Fuel used from SL — Lbs
FLIGHT MANUAL CLIMB SCHEDULE				
10,000	2670	3.3	18.0	240
20,000	1880	7.5	37.0	485
30,000	1180	14.2	74.0	770
40,000	400	27.3	150.0	1130

RECOMMENDED CLIMB SCHEDULE				
10,000	2670	3.3	17.0	240
20,000	1880	7.5	40.0	485
30,000	1180	14.2	80.0	770
40,000	400	27.3	100.0	1125

FLIGHT MANUAL DATA *				
10,000	2500	3.5	18.0	
20,000	1800	8.4	38.0	
30,000	1110	15.8	78.0	
40,000	440	28.4	184.0	

*Flight Manual data at the standard weight obtained during test.

Climbs performed with 60 gallons in each tip tank resulted in a 350 feet per minute increase in rate of climb over the full tip tank condition at altitudes up to 30,000 feet. Above this altitude, the difference reduces to 250 feet per minute at 43,000 feet. This data is presented in Figure 5, Appendix I.

The addition of a standard external travel pod reduces the climb performance by less than 100 feet per minute at all altitudes when the Flight Manual climb schedule is used. Climbing at higher than Flight Manual speeds with the travel pod does not improve the range like it does for the aircraft without a travel pod. Therefore, the Flight Manual recommended climb schedule should always be used when the travel pod is carried. The following table summarizes the climb performance for the

configuration with 2-230 gallon tip tanks and the external travel pod, Figure 8, Appendix I. The Flight Manual data shows no difference in performance when carrying the travel pod, thus causing it to be very optimistic at high altitude. The service ceiling when carrying the travel pod is 42,300 feet while the Flight Manual data indicates a value of 44,700 feet.

The thrust of engines in service can be low because of low full throttle rpm in flight or because of low rated thrust after overhaul. Engines that are trimmed to produce rated rpm on the ground generally operate at rpms from zero to one percent higher during flight. This, in addition to the variations in rated thrust after overhaul can cause significant changes in the climb performance. Figure 9,

**MILITARY POWER CLIMB PERFORMANCE
WITH TIP TANKS AND TRAVEL PODS**

Altitude — Ft	Rate of Climb Ft/Min	Time to Climb from SL — Min	Distance Traveled Nautical Miles	Fuel used from SL — Lbs
FLIGHT MANUAL CLIMB SCHEDULE				
10,000	2000	3.0	14.0	200
20,000	1600	7.5	37.0	490
30,000	1100	14.6	73.0	770
40,000	340	28.7	157.0	1170
TEST CLIMB SCHEDULE (HIGHER SPEED)				
10,000	2520	3.5	17.0	240
20,000	1720	8.1	43.0	520
30,000	1010	15.6	85.0	830
40,000	280	33.0	125.4	1320
FLIGHT MANUAL DATA *				
10,000	2000	3.5	16.0	
20,000	1600	8.4	38.0	
30,000	1110	15.8	76.0	
40,000	410	28.4	154.0	

* Flight Manual data at the standard weight obtained during test.

Appendix I, shows the climb performance corresponding to that presented in Figure 5 (previously tabulated), but with no correction for off-standard engine operation. This data shows the engine speed of the low thrust aircraft, which operated at 99.5 percent on the ground, to be somewhat improved in the air. However, the increase in engine speed of the primary test aircraft over that obtained on the ground is from 100 to approximately 101 percent. The resulting effect on the climb performance is about 15 percent through the altitude range checked. When this data is corrected for non-standard engine operation the reduction in climb performance of the low thrust aircraft is hardly noticeable. It is more apparent at high altitudes but is less than 50 to 100 feet per minute.

Normal rated power climbs at 96 percent rpm on the Flight Manual climb schedule produced climb performance that was greater than Flight Manual data at 10,000 and 20,000 feet, and less than the Flight Manual data at 30,000 and 35,000 feet. The total time to climb from sea level to 35,000 feet was 2.4 minutes less than the value given in the Flight Manual and covered a distance that was 16 nautical miles shorter. The service ceiling of 41,500 feet given by the Flight Manual is very optimistic as compared to the 38,300 feet value estimated from the test data. The following table summarizes the test and Flight Manual data for normal rated power climb with 2-230 gallon top tanks (Figure 7, Appendix I).

NORMAL RATED CLIMB PERFORMANCE WITH TIP TANKS

Altitude — Ft	Rate of Climb Ft/Min	Time to Climb from SL — Min	Distance Traveled Nautical Miles	Fuel used from SL — Lbs
FLIGHT NORMAL CLIMB SCHEDULE*				
10,000	2200	4.0	17.0	240
20,000	1400	8.0	44.0	510
30,000	710	19.2	94.5	820
35,000	390	29.0	145.0	1020

FLIGHT MANUAL DATA*

10,000	1900	4.5	21.0
20,000	1220	11.0	52.0
30,000	600	21.3	110.0
35,000	400	31.2	161.0

*Flight manual data at standard
weights obtained from test.

The climb charts presented in the Flight Manual are difficult to interpret and require an excessive amount of time to obtain the presented data. It is recommended that the two charts be combined into a single chart similar to that presented in the Flight Manual for later model aircraft.

Level flight performance

The addition of a travel pod and the variation of installed thrust from engine to engine has only a minor effect on the level flight performance of the T-33A aircraft.

Maximum Level Flight Speed:

The maximum level flight speed¹ is reduced by as little as five knots indicated airspeed at mid-altitudes (25,000 feet) when the travel pod is carried. At extreme high and low altitudes the travel pod can cause as much as 15 knots reduction in maximum speeds. Thrust variations between aircraft cause less reduction in maximum speed than does the travel pod. The maximum speed data is presented in Figure 10, Appendix I, and is summarized in the following table.

**MAXIMUM SPEED -
GROSS WEIGHT 12,500 POUNDS
TIP TANKS**

Altitude — Ft	Mach No.*	True Airspeed V _t — Kts	Calculated Airspeed V _c — Kts
10,000	.716	465	386
20,000	.734	480	391
30,000	.753	491	393
40,000	.764	498	396
TIP TANKS AND TRAVEL POD			
10,000	.702	446	358
20,000	.722	464	364
30,000	.741	479	377
40,000	.755	485	387
*Mach number is the ratio of speed to the speed of sound at the same altitude.			

Cruise performance:

The cruise performance of the T-33A aircraft is unaffected by either the addition of a travel pod or by the variations in rated thrust of the engine installed in different aircraft. However, if the standard travel pod is to be carried, the cruise speed must be reduced by about .03 Mach number (approximately 10 knots at 35,000 feet) to achieve comparable performance.

A comparison of the test data found in Figures 11

through 28, Appendix I, with that contained in the Flight Manual shows the Flight Manual to be essentially correct at altitudes up to 30,000 feet. Above this altitude the Flight Manual is about 3 to 4 percent optimistic. This would cause a pilot planning a maximum range cross country mission to be 30 to 40 miles short when cruising at high altitudes. A summary of the cruise performance found in Appendix I is presented in the following table.

CRUISE PERFORMANCE WITH TIP TANKS

Altitude Ft	Weight Lbs	Recommended Cruise Mach No.	Specific Range NM/Lb	Fuel Flow Lbs/Hr	Range Factor $\frac{NM \times Lb}{Lb \cdot Hr}$
10,000	13,700	.450	.144	1000	1000
25,000	13,400	.550	.222	1030	2360
36,000	12,700	.550	.285	1310	3830
42,000	12,500	.600	.324	1200	4090

CRUISE PERFORMANCE WITH TIP TANKS AND TRAVEL POD

Altitude Ft	Weight Lbs	Recommended Cruise Mach No.	Specific Range NM/Lb	Fuel Flow Lbs/Hr	Range Factor $\frac{NM \times Lb}{Lb \cdot Hr}$
10,000	11,000	.410	.140	1000	1770
25,000	13,425	.525	.200	1000	2000
36,000	12,600	.520	.280	1200	3000

Other unpublished data obtained by students and staff of the USAF Experimental Flight Test Pilot School has been presented on the level flight performance summary plot in Figure 11, Appendix I, this data shows excellent correlation with the test data.

To facilitate the translation of the test data to numbers familiar to the pilot, Figures 12 through 14, 17 through 19, and 22 through 24, Appendix I, have been equipped with double scales, giving specific range as nautical miles per gallon, fuel flow as gallons per hour, and engine speed as percent rpm. While this representation of fuel flow is convenient, it is not correct since the engine performance depends on the heat content per pound of fuel and not per gallon. The fuel density of JP-4 is allowed to vary from 6.249 to 6.675 under military specification; thus, it is possible to have plus or

minus 2.5 percent variation in cruise performance from any data which is quoted in terms of volumetric fuel flow or fuel quantities (NM/Gal or Gal/Hr). Since JP-4 in recent years runs closer to 6.35 lb/gal, this value has been used to create the volumetric fuel flow scales found in this report.

Endurance Performance:

The endurance performance¹ of the T-33A aircraft is best at about 25,000 feet and 170 knots IAS. The performance above 25,000 feet is only slightly reduced but below this altitude the performance is reduced significantly. The speed for best endurance is about 151 knots IAS at low altitude and increases to 179 knots IAS at 42,000 feet. The endurance performance is found in Figures 12 through 15, Appendix I, and is summarized in the following table.

¹Endurance, defined as the maximum flight time possible with a given quantity of fuel is directly proportional to the endurance parameter $\frac{W}{W/S}$

W/S

**ENDURANCE PERFORMANCE WITH TIP TANKS
WITH OR WITHOUT TRAVEL POD**

Altitude Ft	Weight Lbs	Mach No.	Calibrated Airspeed Knots	Fuel Flow Gal/Hr	Endurance Min/10 Gal	Endurance Parameter $W/S/W_{10} \sqrt{\sigma}$
10,000	13,780	.275	151	282.0	2.38	0.29
25,000	13,400	.417	170	200.0	3.00	0.57
36,000	12,700	.548	176	184.3	3.26	0.37
42,000	12,500	.634	178	182.5	3.20	0.23

NOTE: Even though the maximum endurance can be obtained at 25,000 feet climbing to this altitude is not practical unless it is necessary to loiter for an extended period of time.

Range:

The maximum range of the T-33A aircraft with tip tanks installed is attained at .68 Mach number and at as high an altitude and power setting as possible. This results in a cruise climb which begins at 41,000 to 42,000 feet and ends at 46,000 to 47,000 feet with a fuel reserve of 150 gallons. The distance traveled with the cruise climb technique is 1032 miles, including the distance covered during a military power climb. An additional 200 miles

may be obtained by using a 175 knot IAS idle power descent from the end of cruise to 10,000 feet. About 75 gallons of fuel are consumed during this type of descent. A cruise mission of this sort was flown at a reduced power setting (98 percent rpm). The data for this mission is presented in Figure 27, Appendix I, and is summarized in the following table.

**RANGE MISSION -
CRUISE CLIMB
CONSTANT $W/S = 61,000$
TEST RESULTS**

	TIME Min	FUEL USED Gal	DISTANCE Miles
Taxi, take-off and accelerate to climb speed	5.0	40	—
Military power climb to cruise altitude 41,000 feet	27.0	175	151
Cruise climb at 0.68 Mach number	137.4	271	881
Idle power descent 175 knots starting at 46,000 feet	40.0	70	200
Fuel remaining at the end of descent to 10,000 feet	—	70	—
TOTAL	214.0	613	1232

Because of air traffic control restrictions it is often impossible to use cruise climb techniques. When the aircraft is flown at constant altitude, a different technique must be used to realize the maximum performance possible at that altitude. As for cruise climb, the best range for constant altitude cruise is obtained at the highest altitude attainable to start the cruise. At 35,000 feet the total range including climb is reduced by 8 percent from that obtained by cruise climb techniques at higher altitudes.

The cruise climb is accomplished by holding the desired Mach number and allowing the altitude to increase as fuel is consumed. For cruise at constant altitude, the Mach number for optimum cruise reduces as fuel is used so that the power must be reduced to hold the proper Mach number at each gross weight. The amount of the decrease in in-

dicated speed with fuel used may be found in Appendix A, Part 9 of the Flight Manual which contains the nautical miles per gallon data. The reduction for cruise at 30 to 35,000 feet amounts to about 5 knots in IAS for each 150 gallons of fuel used. It is recommended for ease of flight planning that a small table be added to the Nautical Miles Per Gallon of Fuel charts in Appendix I of the Flight Manual. The table should show the indicated airspeed for maximum range of each 100 gallons of fuel remaining for the specified altitude.

A constant altitude cruise mission was flown using the technique outlined above. The results confirmed the test data yielding a total range of 950 miles with a 150 gallon fuel reserve. This data is presented in Figure 28, Appendix I, and is summarized in the following table.

**RANGE MISSION -
CONSTANT ALTITUDE 35,000
TEST RESULTS**

	TIME Min	FUEL USED Gal	DISTANCE NM
Taxi, take-off and accelerate to climb speed	8.8	53	—
Military power climb to cruise altitude, 35,000 feet	19.0	142	112
Cruise at maximum range Mach numbers corresponding to gross weight	191.0	402	800
230 knots MS descent, speed brakes, 60 percent rpm	7.2	24	60
Fuel remaining at the end of descent to 5000 feet	—	102	—
TOTAL	195.4	613	1042

**■ directional stability evaluation
with travel pod**

At the request of Sacramento Air Materiel Area an investigation was made of sideslips with the standard travel pod installed.

Steady state sideslips in the cruise configuration were performed out to full rudder deflection and at indicated airspeeds from 190 to 300 knots. The aircraft exhibited positive static directional stability at all speeds and degrees of sideslip tested. Increas-

ing rudder force and deflection were required for increased sideslip angles. Dynamic lateral-directional stability was tested under the same speeds and the aircraft was observed to damp in approximately 4.5 cycles. No adverse characteristics were noted for this configuration.

Steady state sideslips in the power approach configuration were performed out to full rudder de-

flection at 145 and 165 knots IAS. The aircraft exhibited positive static directional stability throughout the entire range of sideslips tested. Excessive buffeting and slight oscillations were encountered when over half rudder deflections were applied. Past experience has shown that uncontrollable gyrations can result when a large degree of sideslip in the power approach configuration is initiated by a rapid movement of the rudder to full deflection.

It is recommended that the sideslip restriction with the travel pod installed be the same as that with tip tanks installed. It is further recommended that the sideslips for all power approach configurations be restricted to one half rudder deflection.

■ descent

The .6 Mach number descent performance contained in the Flight Manual is significantly in error. Test data shows the time to descend from 35,000 feet at .6 Mach number with speed brakes retracted is 15.5 minutes and the distance traveled is 101 nautical miles. This is almost 72 percent greater time and 84 percent greater distance than that given in the Flight Manual. In addition, the Flight Manual

labels the .6 Mach number descent as giving maximum range. Tests show that descents at any constant indicated airspeed between 160 and 190 knots give better range from any altitude below 40,000 feet.

The Flight Manual calls for the use of speedbrakes above 35,000 feet when performing the .6 Mach number descent. This results in a decrease in range. The speed brakes should not be extended above 35,000 feet during .6 Mach number descents if maximum range is desired. Maximum range is obtained at 175 knots indicated speed with idle power and speed brakes retracted. In this configuration from 35,000 feet it is possible to travel 115 miles in 29.6 minutes with 360 pounds (57 gal.) of fuel used.

Two descents were made at 250 knots IAS with the speed brakes extended. The first was made with idle power and the second with 85 percent rpm to provide pressurization and defogging. The descent performance is approximately the same above 35,000 feet and differs by 2000 feet per minute at lower altitudes with the 85 percent rpm giving the lower rate of descent. It is recommended that data for these descents be included in the Flight Manual.

The following table summarizes descent data presented in Figures 29 and 30, Appendix I.

DESCENT DATA Gross weight 11,000 pounds at 35,000 feet			
	TIME FROM 35,000 FT TO 0 FT	DISTANCE TRAVELED	FUEL USED
175 knots, idle rpm	29.6 min	115 NM	360 lb
250 knots, speed brakes, idle rpm	6.0 min	31 NM	85 lb
250 knots, speed brakes, 85 percent rpm	6.4 min	44 NM	270 lb
250 knots, idle rpm	14.0 min	82 NM	195 lb
Mach 0.6, idle rpm	15.5 min	101 NM	210 lb
Mach 0.6, Flight Manual idle rpm	8.9 min	34 NM	111 lb

Engine-out descents made while holding constant indicated airspeeds of 160 and 175 knots show the Flight Manual values to be conservative. The table below compares the engine-out descent data presented in Figure 31, Appendix I, with that shown in the Flight Manual.

ENGINE-OUT DESCENT
Gross weight 12,220 pounds at 40,000 feet

	TIME FROM 40,000 feet to SL	DISTANCE TRAVELED
160 knots	30.5 min	186 NM
175 knots	27.0 min	164 NM
160 knots Flight Manual Data	—	94 NM

The Flight Manual recommended speed provides adequate rpm for restarting the engine and decreases the time to descend without greatly decreasing the distance traveled. This increases the probability that battery power will be available at low altitude. The only instances where a pilot should reduce speed slightly is where the glide distance to a runway is marginal and an airstart is not contemplated.

■ Landing performance

The recommended procedures and techniques in the T-33A Flight Manual are satisfactory for normal traffic pattern, approach and landing.

Landing distances published for a "Hard Stop" in the Flight Manual are satisfactory in that it represents the minimum short field distances possible with the aircraft. Additional data should be included in the Flight Manual to reflect the landing distances with normal techniques and moderate braking.

The Flight Manual recommended procedure for a minimum run landing includes the immediate retraction of flaps. Test data indicates that there is no noticeable difference under any type of braking whether the flaps are left down or retracted. The landings on a wet or icy runway should be made with the flaps down since the aerodynamic drag will be greater than the increase of the braking force on this type of low friction surface. If no barrier is available on the landing runway it is to the pilot's advantage to leave the speed brakes extended during the ground roll. Landings were made using light, moderate and heavy braking with flaps full down (100 percent). The table on page 16 summarizes the landing performance presented in Figure 35, Appendix I.

LANDING PERFORMANCE
Sea Level — Standard Day — Average Gross Wt 11,000 lb —
Flaps 45° — 2-230 Gallon Tip Tanks

Indicated Airspeed at Touchdown Knots	Ground Roll Ft	Indicated Airspeed at 50 Ft — Knots	Total Distance Ft
MODERATE TO HEAVY BRAKING			
110	5600	130	8190
105	4700	120	6730
100	3800	110	5130
95	2130	105	4150
LIGHT TO MODERATE BRAKING			
110	7000	125	8770
105	6000	120	8040
100	4750	110	6300
95	2850	105	4800

When very light braking is utilized the ground roll is significantly increased. With a very light braking and a touchdown speed of 100 knots a 5900 foot ground roll will result.

■ engine performance

One of the objectives of this test program was to investigate the variations and the causes for variations of installed thrusts, and to check for possible deterioration in thrust with engine life. There is no correlation of thrust with total engine life and only a small amount of correlation exists between thrust and time since last overhaul. One engine (S/N A-085176) having low installed thrust and 269 hours of operating time was removed and checked for rated thrust. The thrust deterioration was found to be less than 100 pounds since overhaul. This is fairly reasonable considering that further inspection revealed a malfunctioning fuel control and excessive compressor and turbine deformations that approached the maximum limits.

The J33-A-35 Engine installed in the T-33A-5 aircraft is rated at 4600 pounds thrust uninstalled. When installed in the aircraft this value drops by approximately 800 pounds. The military power thrust varies considerably from engine to engine. The highest installed thrust measured on the seven aircraft tested was 4275 pounds and the lowest was 3880 pounds. The exhaust gas temperatures (EGT) varied from 676 degrees to 720 degrees C. There is some correlation between low thrust and low exhaust gas temperatures but positive correlation was not established. All high thrust engines had high EGT (above 690 degrees C); however, some low thrust engines had high EGT's as well. Thus, an engine having military power EGT that is less than 685 or 690 degrees centigrade might be suspected of having low thrust and should be checked unless the take-off and climb performance indicates otherwise.

The large variation in engine thrusts and consequently aircraft performance is attributed not to

thrust deterioration but to engine trim and the broad thrust limits allowed after the engine is overhauled. Engines trimmed to 100 percent rpm on the ground do not always operate at the same speed in flight. As much as one percent increase in engine speed was experienced in flight during these tests and caused significant variations in climb performance.

Because of the long service life of the J33-A-35 engine numerous overhauls have been accomplished. This has caused considerable variation in the thrust output between engines, especially since the only requirement for an acceptable engine is that it produce 4600 pounds of uninstalled thrust at exhaust gas temperatures which are less than 715 degrees centigrade. J-33 engines have been known to produce 5200 pounds of thrust without exceeding the temperature limits. This constitutes a 13 percent deviation from the rated thrust which can cause a greater percentage deviation in take-off and climb performance. In addition, there is no mandatory overhaul cycle for the engine. This allows some thrust deterioration in addition to the broad range of thrust ratings allowed above the 4600 pound value. If accurate performance figures are to be presented in the Flight Manual it is first necessary to limit the maximum as well as the minimum allowable thrust. It is recommended that thrust after overhaul be required to fall between 4600 and 4800 pounds, and that the engine trim be checked periodically on the ground and in flight to insure that the 100 percent rpm has not varied significantly. This would limit the percentage variation in aircraft performance to a reasonable value.

The specific fuel consumption (pounds of fuel per hour per pound of thrust) is 1.20 and does not vary by more than 2 percent between aircraft.

The tabular summary of the installed thrust data presented in Figures 45 through 51, Appendix I, along with engine overhaul data obtained from maintenance records, is presented in the following table.

ENGINE HISTORY AND PERFORMANCE

Sea Level Standard Conditions

Aircraft and Engine Serial No.	Engine Time Since Overhaul Hrs.	Nozzle Diameter in Area Sq.	Uninstalled Thrust at Last Overhaul — lbs	Installed Thrust — lbs	Installed EGT °F	Average Specific Fuel Consumption lbs/hr/lb
52-0046 A-000033	00	122.1	4000	4100	800	1.20
51-0054 A-000170	200	120.0	4000	3930	800	1.22
52-0041 A-004320	70	—	4700	3940	870	1.22
53-5541 A-070000	107	110.0	4000	4200	800	1.20
53-0121 A-000110	204	—	4000	4120	710	1.20
55-4340 A-004032	320	120.0	4000	3900	800	1.22
57-0040 A-002030	70	122.2	4000	4270	720	1.21

During the ground static thrust runs the exhaust gas temperature system was calibrated. Significant errors exist in this system except in the limit EGT range. In most instances the indication is 10 to 20 degrees lower than the actual temperature. A good part of this problem is attributed to the reading accuracy of the indicator face. A more accurate and more readable instrument (EGT Indicator Type MJ-4) is available in Air Force stock and should be installed to provide better EGT indication.

■ weight

The engine start gross weight of the test aircraft was 15,280 pounds which compared favorably with the representative weight of 15,100 pounds given in the Flight Manual. The take-off center of gravity was exactly half way between the fore and aft limits.

Since the T-33A aircraft has a fuel counter system installed in the standard production aircraft, this

system was calibrated and used for these tests. The calibrations showed this system to have less than 1/10 of one percent error for all fuel flow rates. However, this figure can be misleading because the counters are a subtractive type which indicate gallons remaining. It must be presumed that the aircraft are filled to the same level each time prior to flight. However, if the refueling crew is hurried and sufficient time is not allowed for the fuel to equalize itself between the baffles in the tanks it is possible to be short by 30 or 40 gallons. Even during controlled conditions it was not possible to fill the tanks to the same level each time, and the total fuel capacity varied by as much as 10 gallons (60 to 65 pounds).

The capacity of the fuel system was checked against a calibrated truck and by weighing the aircraft before and after the refueling operation. The fuel capacities of the individual tanks compare favorably with those given in the Flight Manual. A tabular summary of this data follows.

TANKS FUEL CAPACITY

	Test*	Flight Manual
Leading Edge	107.4	100.0
Main Wing	100.1	100.0
Tip Tanks	400.0	401.0
Fuselage	95.5	97.0
	621.0	626.0

*The number for each tank was not checked.

The normal fuel density figure for JP-4 used in preparation of the Flight Manual is 6.5 pounds per gallon. Present day fuel densities for JP-4 can run from 6.249 to 6.675 pounds per gallon. This can cause a 2 to 2.5 percent variation in aircraft weight, thus causing some variation in performance. Likewise, if the fuel density has been reduced it is anticipated that some change in the heat content of the fuel has been experienced. Thus, if the heat content has been reduced the aircraft performance per pound of fuel is reduced resulting in less range available. Because of this discrepancy in fuel density and heat content of the fuel, specific range and fuel flows quoted in terms of gallons, as in the Flight Manual, can be in error. Therefore, it is recommended that this fact be explained in the Flight Manual and that the Flight Manual figures be based on a more representative fuel density. The fuel density used throughout this report to convert from gallons to pounds is 6.35 pounds per gallon; however, this figure may not be representative Air Force wide and should be checked before it is accepted as the basis for the Flight Manual.

■ airspeed calibration

The position error calibration of the standard system of the T-33A aircraft is not consistent. Numerous calibration tests flown during the test pro-

gram show poor repeatability and correlation with each other. The data presented in Figure 32, Appendix I, shows plus or minus 2 knots variation from the mean with no apparent variations due to Mach effects. The variation in position error is attributed to the fact that the standard airspeed system utilizes a flush source which is very sensitive to small amounts of sideslip. Since the T-33A does not have rudder trim it is not possible to trim to a zero sideslip condition.

The trend of the calibration is the same as that given in the Flight Manual except that the correction is more negative at high speed and more positive at low speed.

The airspeed calibration is the same with gear, gear and flaps, and gear flaps and speed brakes extended; however, the values do not agree with those given in the Flight Manual. The Flight Manual data should be changed to agree with the information given in Figures 32 and 33, Appendix I.

An airspeed calibration in ground effect was obtained as part of the take-off and landing tests. Theodolite data was used to determine the true airspeed. This information was corrected to equivalent and compared to the indicated airspeed noted in the cockpit. This data is presented in Figure 34, Appendix I.



CONCLUSIONS

The T-33A aircraft satisfactorily performs its mission as a basic trainer and as a combat readiness trainer. However, certain cockpit discrepancies make it unlike any aircraft in the present Air Force inventory. If this aircraft is to be used to train pilots to fly modern day aircraft, its cockpit features should more closely conform to modern standards.

The Flight Manual data for the T-33A aircraft with tip tanks installed is in general agreement with the test results; however, some discrepancies exist. The Flight Manual take-off performance is very optimistic and must be changed. The Flight Manual climb and cruise performance at low and medium altitudes are satisfactory but are optimistic above 35,000 feet for the climb and above 25,000 for the cruise. There is insufficient descent data presented in the Flight Manual and that which was checked is in error. The landing performance given in the Flight Manual is satisfactory but does not represent the distances for normal braking conditions.

The installation of a standard travel pod does not affect the cruise performance of the aircraft if the

cruise speed is reduced by .03 Mach number. The climb performance with the travel pod is reduced by approximately 150 feet per minute at all altitudes. The take-off and landing performance is not affected by the installation of the travel pod.

Undue sideslip restrictions have been placed upon the aircraft when carrying a travel pod. These restrictions need not be more stringent than those for the aircraft without the travel pod. However, for both configurations the aircraft should be limited to one half rudder deflection sideslips in the power approach configuration.

There is considerable thrust variation between J33-A-35 engines installed in T-33A aircraft. This is caused by broad overhaul tolerances and by the fact that there is no mandatory overhaul cycle on the engine. Installed military power thrust varies from 3880 pounds to 4275 pounds or by 10 percent. However, the specific fuel consumption is relatively constant for all engines. This results in variations in take-off, climb and maximum speed performance but has little effect on the cruise performance.



RECOMMENDATIONS

A. The following safety of flight items are of sufficient urgency to require immediate action:

1. Provide the ejection system with a positive pilot-seat separator (page 2).
2. Modify the ejection seat to give a ground level ejection capability at take-off and landing speeds (page 2).
3. Re-locate the normal starting and airstart switches to a more accessible position where they may be easily identified and actuated. Reduce the number of switch actuations to complete a given operation to a minimum (page 2).

B. The following recommendations are made to prevent excessive thrust variations which cause significant performance differences between T-33A aircraft in service.

1. Engine trim of all aircraft in service should be periodically checked both on the ground and in flight to insure that the 100 percent rpm does not vary significantly. One percent can account for as much as 140 pounds of thrust accompanied

by a 400 feet per minute change in the rate of climb at sea level (page 17).

2. It is recommended that a maximum allowable thrust limit be established at 4800 pounds in addition to the 4600 pounds minimum thrust presently required so that the aircraft performance will more realistically conform to that which is published in the Flight Manual (page 17).

3. It is further recommended that a realistic overhaul cycle be established to prevent abnormal thrust deterioration which results from excessively long periods of operation between overhauls (page 17).

C. It is recommended that the Flight Manual be changed to reflect the results of this report. Specific areas which require attention are:

1. The take-off data must be revised (page 5).
2. The climb presentation should be simplified and the data should be changed to agree with flight test results. Include travel per climb data

in the Flight Manual (pages 8 through 11).

3. Change the high altitude level flight data. Revise the cruise climb instructions to reflect a constant Mach number climb and required rpm cruise. Include instructions for cruising with a travel pod. Include a table on each specific range chart to show the proper cruise airspeed for each 100 gallons of fuel remaining (pages 11 through 14).

4. Correct .6 Mach number descent data contained in the Flight Manual and add 175 knots and 250 knots idle and 85 percent rpm descent data to the Flight Manual (page 15).

5. Include additional landing data for operational (light to moderate) braking conditions. The distance required when clearing an obstacle should be included in the landing presentation (page 16).

6. It is recommended that all Flight Manual data be based on a more realistic fuel density which represents the Air Force wide average value (page 19).

7. No additional sideslip restrictions need be imposed upon the aircraft when carrying a travel pod. However, it is recommended that the aircraft be restricted to half rudder deflection sideslips in the power approach configuration both with and without the travel pod (page 15).

D. The following recommendations should be accomplished to improve the cockpit of the T-33A aircraft and to make it more compatible with the cockpits of modern day aircraft. These corrections can be accomplished by using agencies with a minimum of effort.

1. Replace the following warning lights (presently color coded red) with amber filters (page 3):

- a. Tip tank low pressure
- b. Main wing tank low pressure
- c. Leading edge tank low pressure
- d. Fuselage tank reserve low
- e. Fuel filter ice
- f. ATO indicator
- g. Turn and slip indicator
- h. Gyro instrument

2. Change the color of the fuselage pump indicator from amber to green (page 4).

3. Color code the following items orange-yellow with black striping (page 3):

- a. Ejection seat handles
- b. Canopy jettison "T" handle
- c. Tip tank jettison handles
- d. Bomb salvo button background

4. Replace the present fire, overheat, canopy warning and take-off trim indicator lights with rectangular legend lights of the type utilized in later model aircraft (page 4).

5. Provide a dimmable fuel overboard vent light (page 4).

6. Install a more accurate exhaust gas temperature indicator to prevent possible over-temperature conditions that can inadvertently occur with the present indicators (page 18).

E. The following items should be accomplished if future Technical Order modifications are programmed:

1. Provide a master caution panel to replace the various warning lights scattered throughout the cockpit (page 4).

2. Move the front cockpit interphone control box forward (page 4).

APPENDIX I

references

1. Flight Test Engineering Manual, Air Force Technical Report No. 6273 (Revised May 1951)
2. Standardization of Take-off Performance Measurements for Airplanes. AFFTC Technical Note R-12
3. Flight Manual, USAF Series T-33A Aircraft, TO IT-33A-1, 15 January 1960, Changed 1 June 1960
4. Pilots Handbook for Performance Flight Testing
AFFTC TN 59-46, December 1959. Revised September 1960
5. Aerodynamics Handbook for Performance Flight Testing AFFTC TN 60-28 July 1960
6. Air Force Standard Aircraft Characteristics Performance Substantiation Report for the T-33A Aircraft, LR 9723, 25 June 1954
7. Model Specification USAF Model J33-A-35 Turbojet Engine, No. 219C. Revised 1 December 1953
8. Performance Flight Tests of the Lockheed T-33A Airplane TN FTDSP 53-BJ
9. An Evaluation of Selected Performance Data Contained in T.O. IT-33A-1, Test Pilot School Memorandum Report (Unpublished)

symbols and notations

b	Wing Span	ft
e	Airplane Efficiency Factor	—
F _c	Gross Thrust	lbs
F _n	Net Thrust	lbs
M	Mach Number	
MAC	Mean Aerodynamic Chord	ft
P _a	Ambient Pressure	"Hg
T _a	Ambient Temperature	°K
T ₁₂	Compressor Inlet Total Temperature	°K
T ₁₄	Turbine Discharge Temperature (EGT)	°K
W	Gross Weight	Lbs
W _f	Fuel Flow	lbs/hr
V	True Airspeed	kts
IAS or V _i	Indicated Airspeed	kts
CAS or V _c	Calibrated Airspeed	kts
n	Normal Load Factor	g
N	Engine Speed	RPM
dh/dt	Rate of Climb	ft/min
(dh/dt) _a	Rate of Climb while accelerating	ft/min
dV/dH	Climb Schedule Accelerating	kts/ft
δ _a	Pressure Ratio	P _a /29.92
δ ₁₂	Compressor Inlet Pressure Ratio	P ₁₂ /29.92
Δ	An Incremental Change of the Variable which it precedes	
θ _a	Temperature Ratio	T _a /288
θ ₁₂	Compressor Inlet Temperature Ratio	T ₁₂ /288

subscripts

a	Ambient Condition
s	Standard Day Conditions
t	Test or Stagnation (total) conditions

■ data analysis methods

Take-Off Performance:

The take-off performance data presented in this report was measured by AFFTC Photo Theodolite Facilities and was reduced to sea level standard day no wind conditions in accordance with the exponential methods presented in Reference 2. The test and standard thrust were obtained from the static thrust run data at appropriate values of corrected rpm, $N/\sqrt{\theta_a}$.

Static Thrust Runs:

The static thrust measurements performed as part of this test were accomplished on the Edwards Thrust Stand Facility. The data was reduced to sea level standard day conditions through the use of the parameters FG/δ_a , $N/\sqrt{\theta_a}$, T_{14}/θ_a and $W_f/\delta_a\sqrt{\theta_a}$. Specific Fuel Consumption:

$$SFC = \frac{W_f}{a\sqrt{\theta_a}} / FG/\delta_a$$

Non-Steady State Energy Equations

Climbs, descents, accelerations and sawtooth climbs were reduced by non-steady state techniques with the equations being programmed to the IBM 704 computer. The computer utilizes an increment method of obtaining rates, where the method of incrementing is determined by the input cards. The equations used to compute the unaccelerated rate of climb is

$$\frac{dh}{dt} = 60 \left[\frac{2.8523}{32.172} \frac{V_{ts}}{\Delta t} \cdot \frac{\Delta V_t}{\Delta t} + \frac{\Delta H}{\Delta t} \sqrt{\frac{T_{at}}{T_{as}}} \right]$$

climb when accelerating was computed by the following expression

$$\left(\frac{dh}{dt} \right)_a = 60 \left[\frac{2.8523}{32.172} V_{ts} \left(\frac{\Delta V_t}{\Delta t} - \left[\frac{\Delta V_t}{\Delta H} \right] \frac{\Delta H}{\Delta t} \right) + \frac{\Delta H}{\Delta t} \sqrt{\frac{T_{at}}{T_{as}}} \right]$$

where $\left(\frac{\Delta V}{\Delta H} \right)$ is the acceleration with altitude required by the desired climb schedule

Thrust corrections were made to the climbs, accelerations and sawtooth climbs by means of slopes taken from the engine manufacturers model specification, Reference 7. The thrust corrections were converted into rate of climb by use of the equation

$$R/C_{\text{thrust}} = \frac{\Delta F_n V_{t_s} 101.33}{W_s}$$

Weight corrections were made by use of the following equations:

Effects of Induced Drag

$$\Delta R/C_{\text{ind drag}} = \frac{25.33 \sqrt{T_{a_s}}}{P_{a_s} M b^2 e}$$

$$\left[\frac{n_t^2 W_t^2 \frac{P_{a_s}}{P} - n_s^2 W_t^2}{W_s} \right]$$

Effect of weight alone

$$\Delta R/C_{\text{weight}} = \left[\frac{dh}{dt} + \Delta R/C_{\text{thrust}} \right] \frac{W_t - W_s}{W_t}$$

The standard rate of climb for accelerations and sawtooth climbs is

$$R/C_s = \frac{dh}{dt} + \Delta R/C_{\text{thrust}} +$$

$$\Delta R/C_{\text{ind drag}} + \Delta R/C_{\text{weight}}$$

for climbs

$$R/C_s = \left(\frac{dh}{dt} \right)_a + \Delta R/C_{\text{thrust}} +$$

$$\Delta R/C_{\text{ind drag}} + \Delta R/C_{\text{weight}}$$

for descents

$$R/D = \left(\frac{dh}{dt} \right)_a + \Delta R/D_{\text{ind drag}}$$

$$+ \Delta R/D_{\text{weight}}$$

Fuel flow corrections for climbs and accelerations were based on the slopes of the fuel flow curves presented in Figures 36, 38 and 40.

No corrections were made for engine overtemperature or undertemperature conditions nor were corrections made for the engine being overspeed or underspeed.

Level Flight Performance

Stabilized speed power data was obtained throughout the speed range by maintaining constant weight pressure parameter, W/δ . The data was reduced by the methods outlined in References 1 and 4.

Range

Two range missions were flown utilizing the cruise climb technique with and without the travel pod. Another was flown at constant altitude. The data was instrument corrected but not reduced to standard day conditions.

Landings

Landing data was obtained using the AFFTC Photo Theodolite Facilities. The data was reduced to sea level, standard day, no wind conditions according to the methods shown in References 1 and 5.

Airspeed Calibration

The calibration of the ships standard system was obtained by the tower fly-by, ground speed course and pacer methods. The T-37, F-104, T-33 and T-28 pacers were utilized. No effects of total head loss were noted and all of the error was assumed to be caused by the static system. The data reduction procedures used are outlined in References 1 and 4.

The position correction in ground effect was obtained during landings from photo theodolite data at the touchdown point.



performance plots

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FIGURE NO 1
TAKEOFF PERFORMANCE
T-33A - 5 AIRCRAFT
SEA LEVEL
WEIGHT 14900 LBS.
30° FLAP DEFLECTION

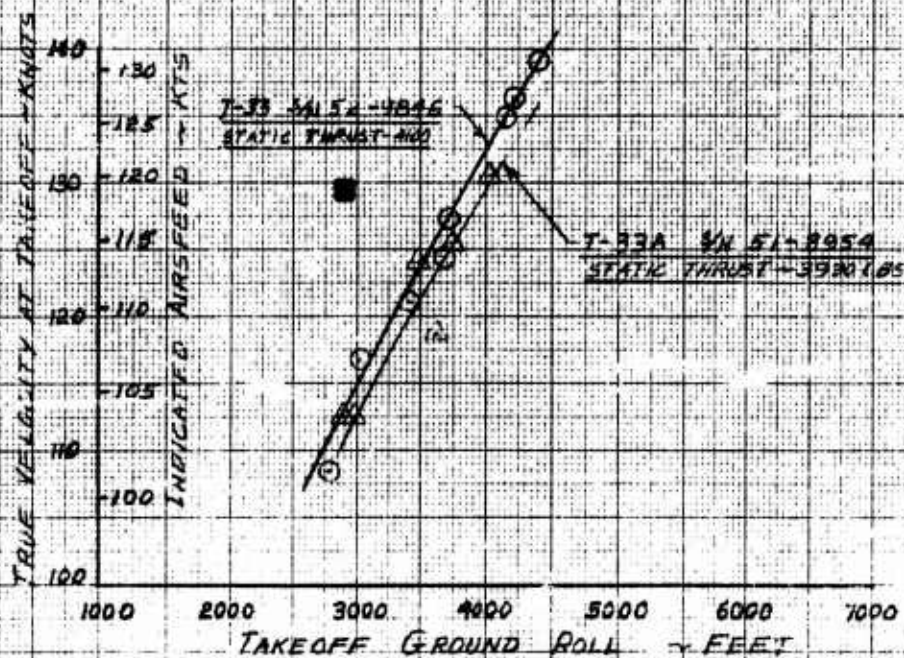
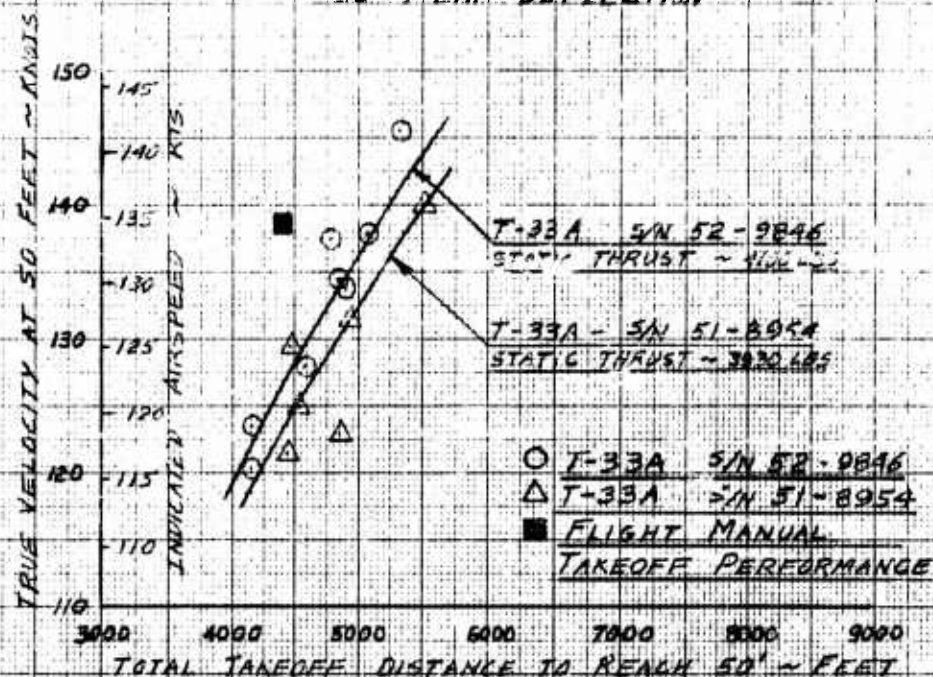


FIGURE NO. 2
CLIMB PERFORMANCE
LEVEL FLIGHT ACCELERATION METHOD
T33A USAF S/N 52-4846
J-33-A-35 ENGINE
2-230 GAL TIP TANKS INSTALLED
MILITARY POWER

SYMBOL	ALTITUDE-FT	WEIGHT-LB	METHOD
△	5000	15680	ACCELERATION
○	10000	14550	ACCELERATION
□	25000	14180	ACCELERATION
◇	35000	13900	ACCELERATION
◇	40000	13750	ACCELERATION
△	40000	13750	SAW TOOTH CLIMB
□	50000	13900	ACCELERATION

T-33A 51-8754

X+ RATE OF CLIMB CROSS PLOT DATA FROM TEST CLIMBS

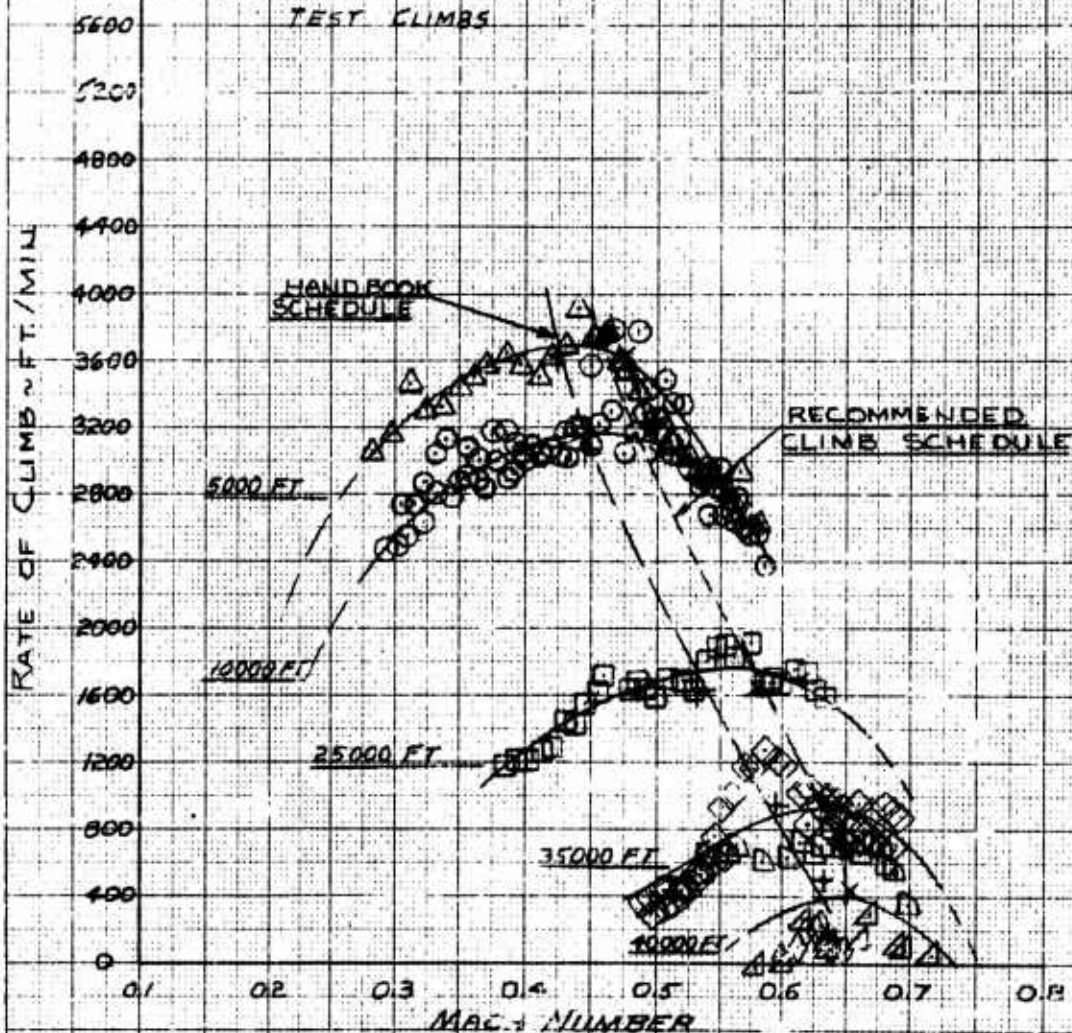
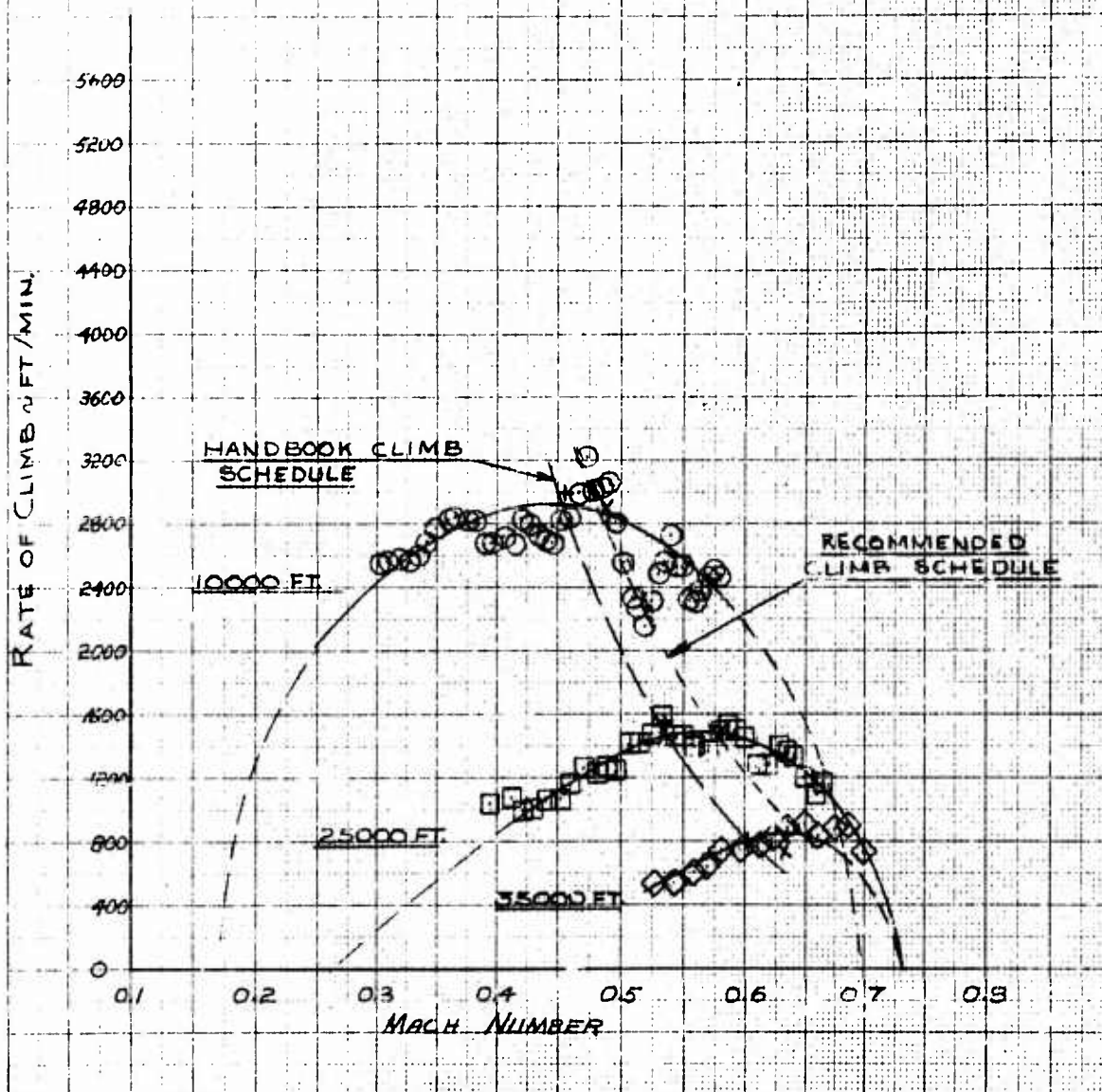
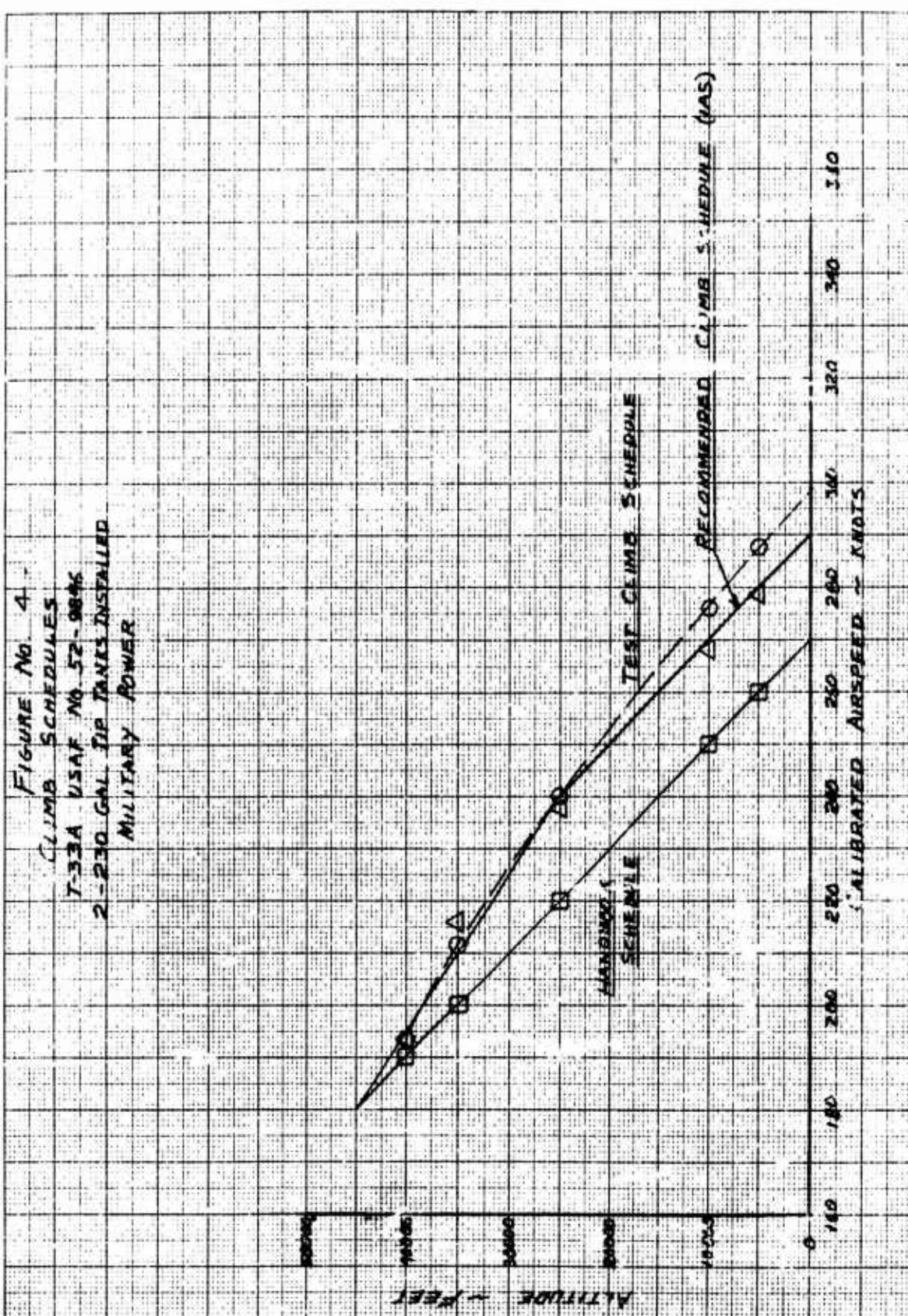


FIGURE NO. 3
CLIMB POTENTIAL
LEVEL FLIGHT ACCELERATION METHOD
T-33A USAF S/N 52-9846
J-33-A-35 ENGINE
TRAVEL POD AND 2-230 GAL TIP TANKS INSTALLED
MILITARY POWER

SYMBOL	ALTITUDE-FT.	WEIGHT-LES.
○	10000	14350
□	25000	14180
◇	35000	13900
+X	RATE OF CLIMB CROSS PLOT DATA FROM TEST CLIMBS	





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FIGURE NO 5
CLIMB PERFORMANCE
T-33A USAF NO. 52-9846
J-33-A-35 ENGINE
2-230 GAL. TIP TANKS INSTALLED
MILITARY POWER
TEST CLIMB SCHEDULE

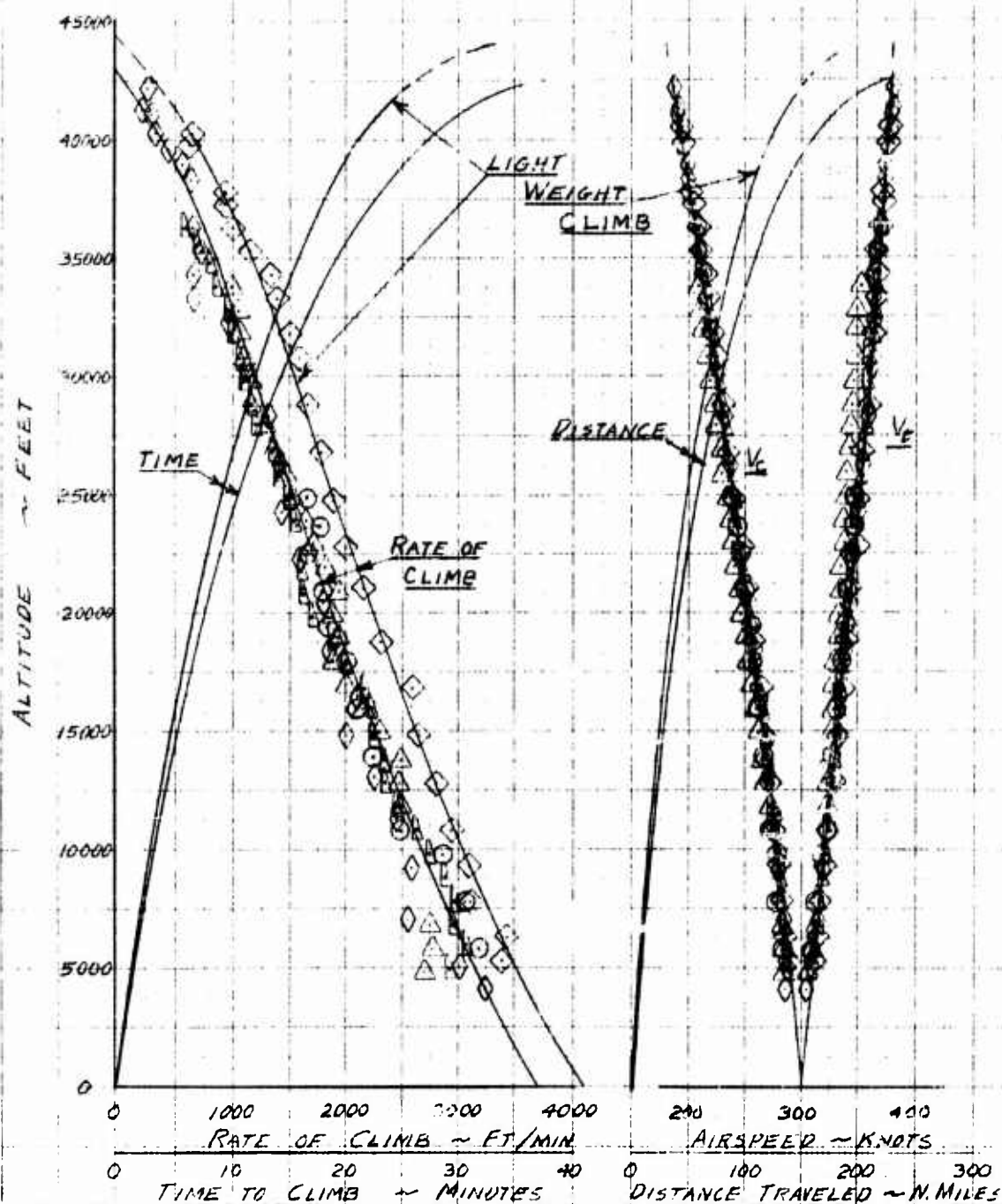


FIGURE NO. 5A

- NOTES 1) 2.0 MINUTES AND 350 POUNDS (55 GAL) OF FUEL USED
TO TAKE-OFF AND ACCELERATE TO CLIMB SPEED
2) B INDICATES CLIMB WITH LOW THRUST ENGINE
T-33A IN 51-8954 AT HEAVY WEIGHT

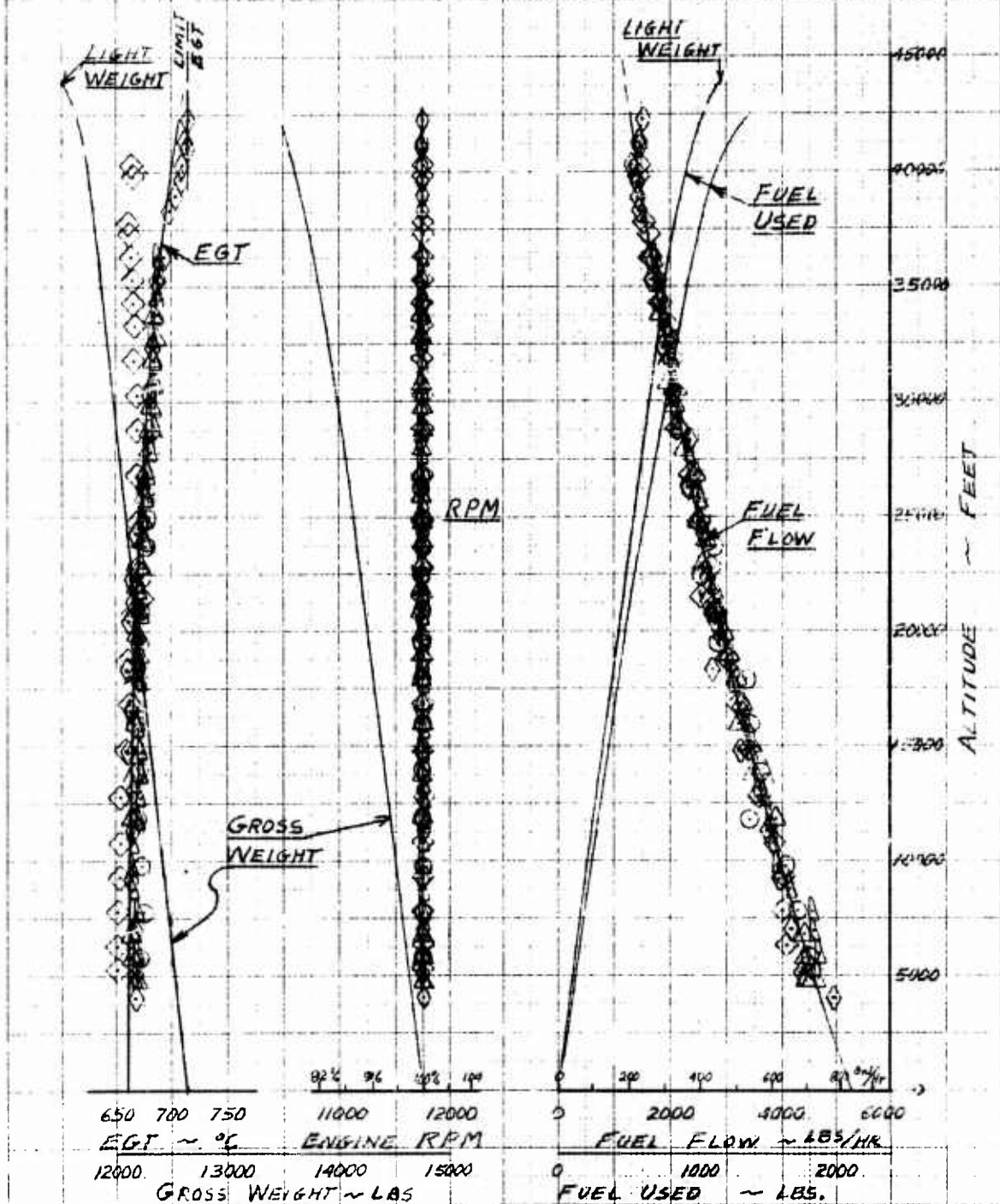


FIGURE NO. 6
CLIMB PERFORMANCE
T-33A USAF NO. 52-9846
J-33-A-35 ENGINE
2-230 GAL TIP TANKS INSTALLED
MILITARY POWER
FLIGHT MANUAL SCHEDULE

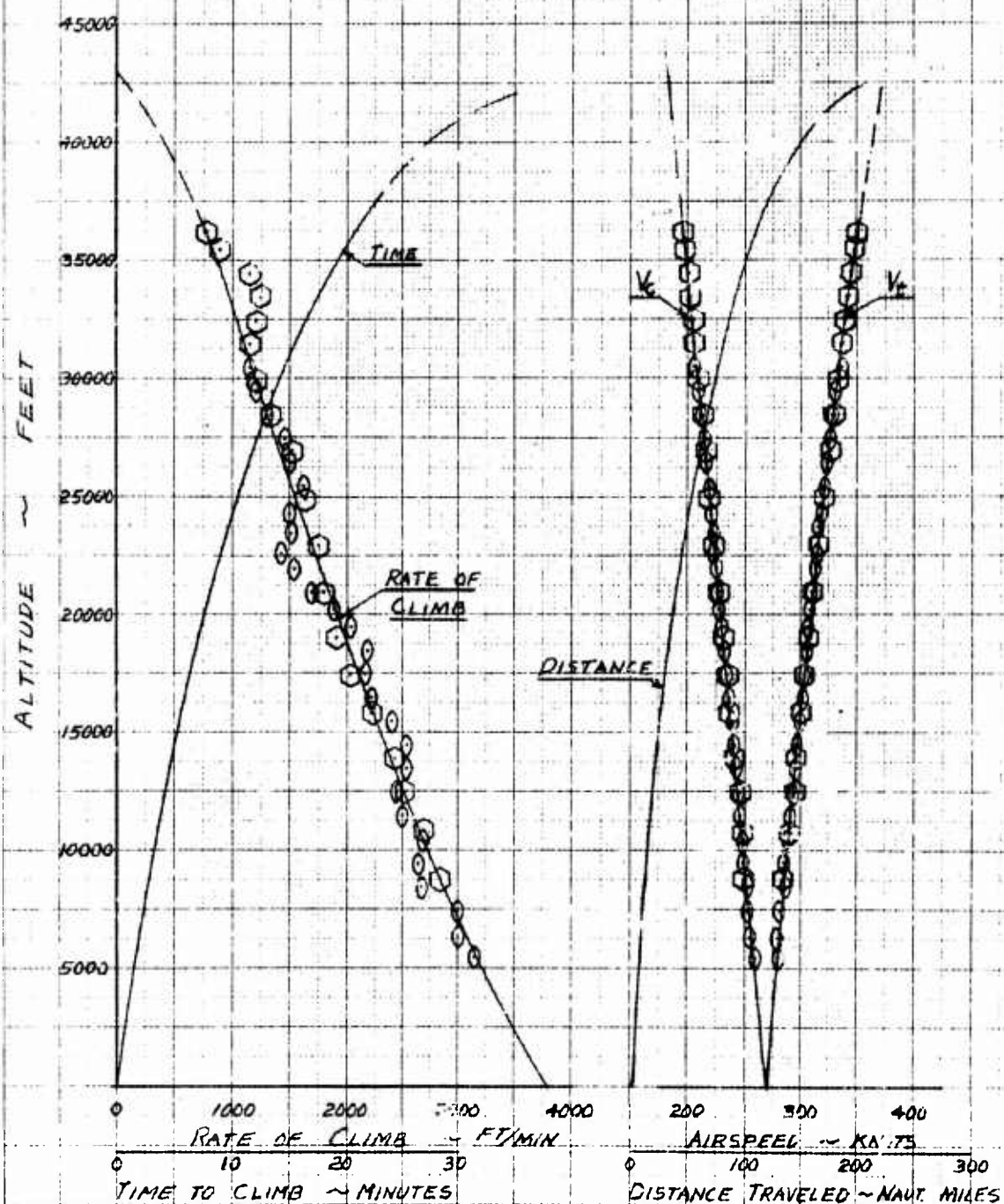


FIGURE No. 6A

NOTE: 2.0 MINUTES AND 350 POUNDS (55 GAL) OF FUEL USED TO TAKE-OFF AND ACCELERATE TO CLIMB SPEED

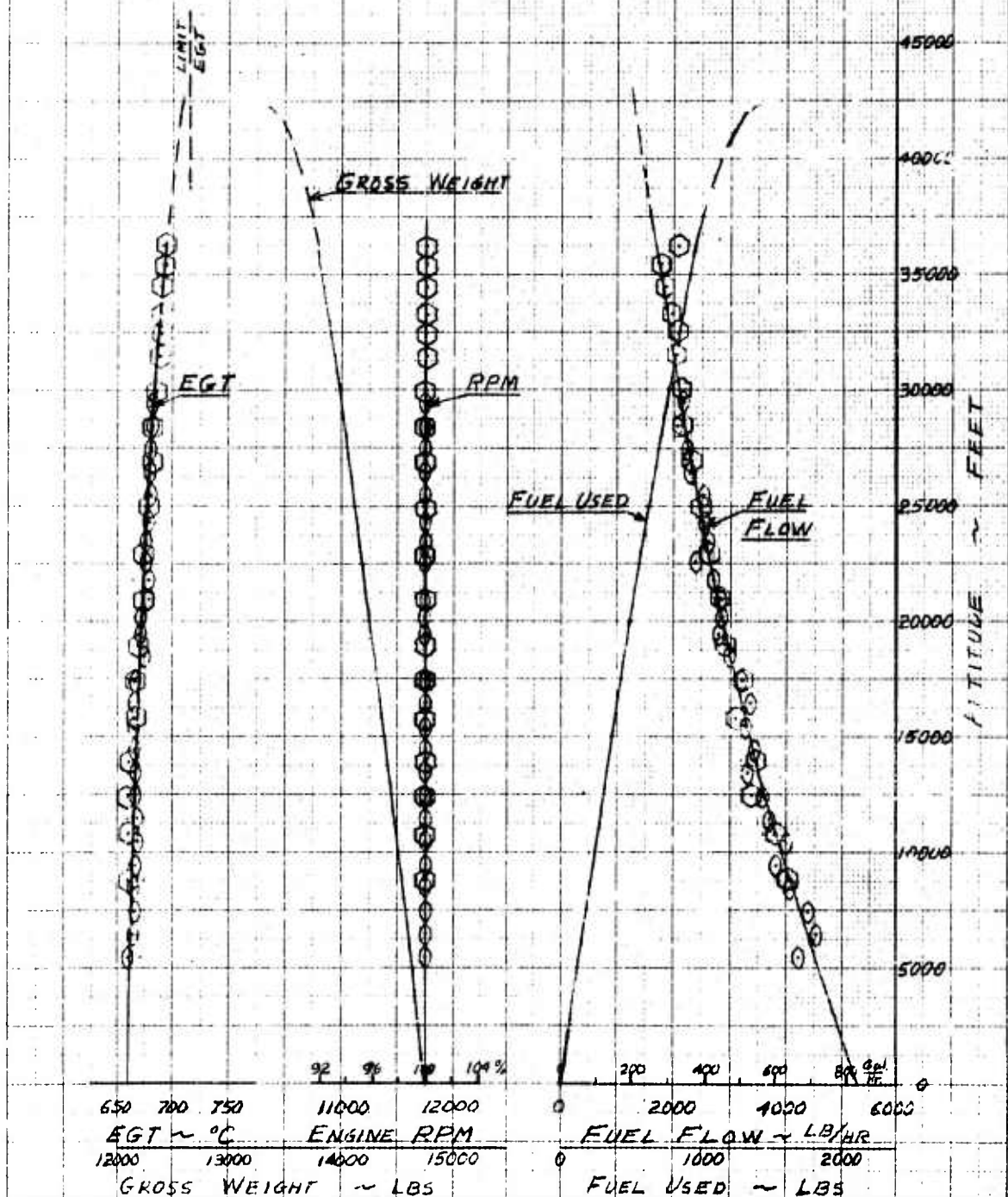


FIGURE NO. 7
 CLIMB PERFORMANCE
 T-33A USAF S/N 52-9846
 J-33-A-35 ENGINE
 2-230 GALT TANKS INSTALLED
 NORMAL RATED POWER (96% RPM)
 HANDBOOK SCHEDULE

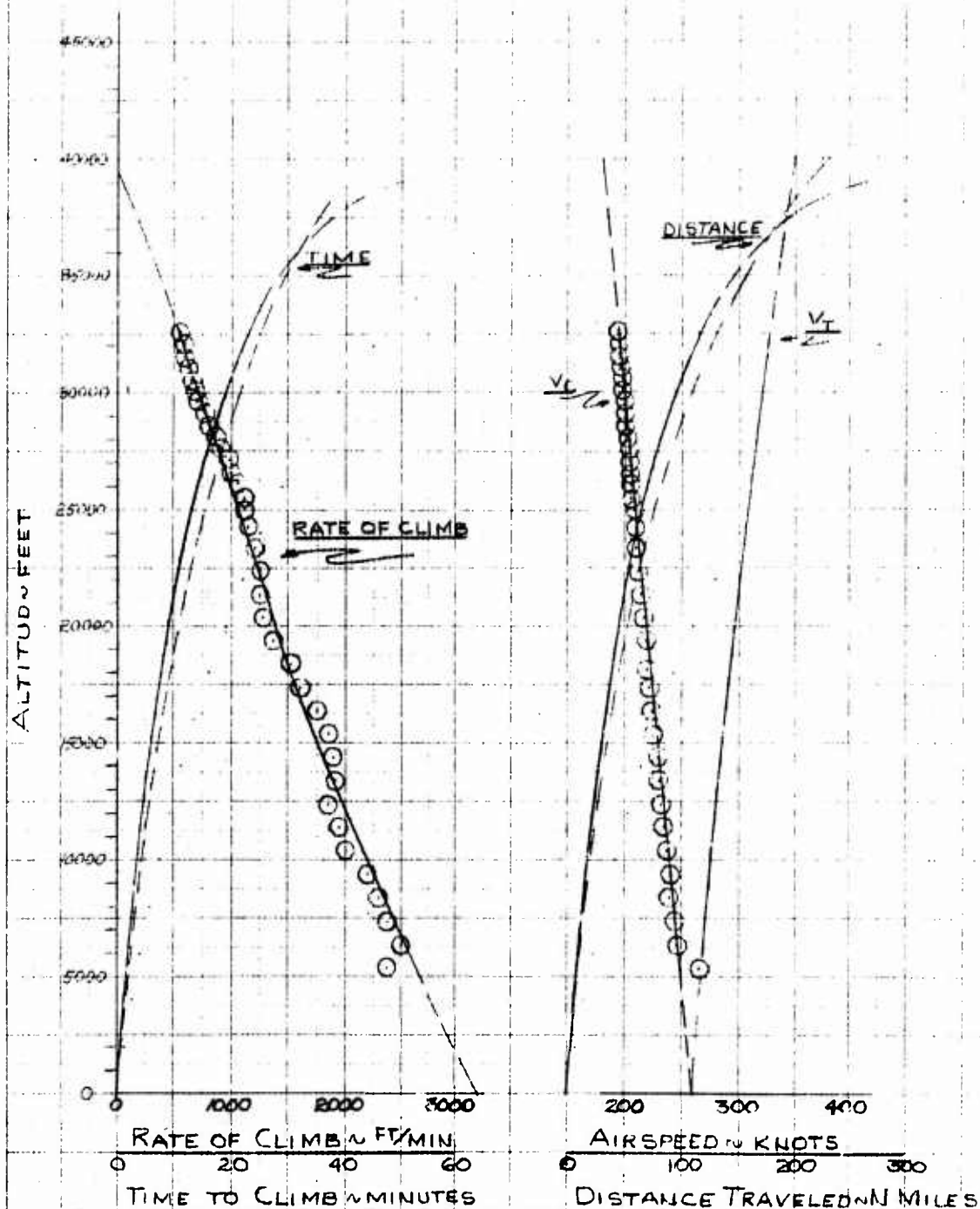


FIGURE NO. 7A

- NOTE 1) 2.0 MINUTES AND 350 POUNDS (55 GAL) OF FUEL USED
TO TAKE-OFF AND ACCELERATE TO CLIMB SPEED
2) DASHED LINE INDICATES HANDBOOK DATA

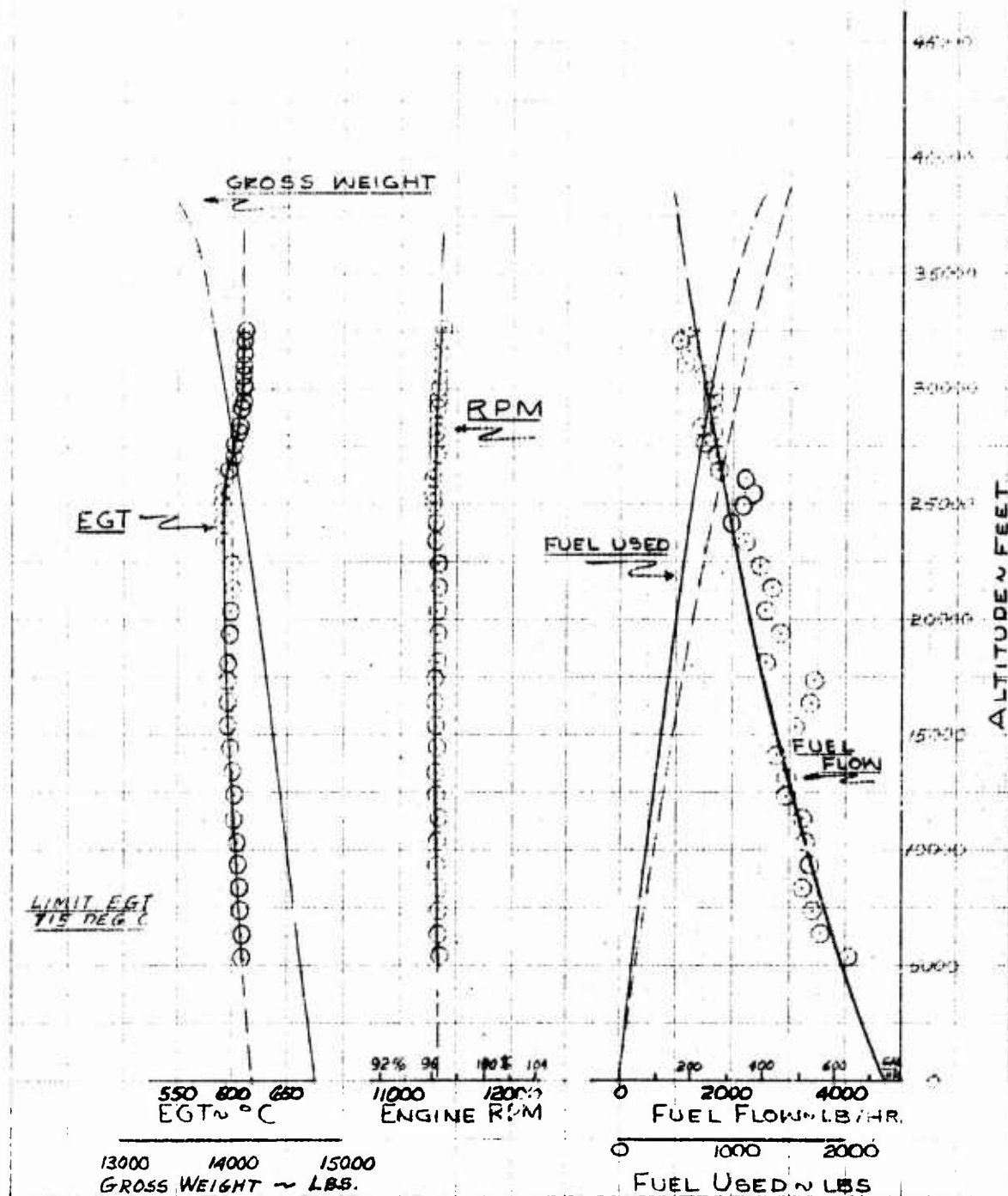


FIGURE NO 8
CLIMB PERFORMANCE
T-33A USAF NO 52-3446
J-33-A-35 ENGINE
TRAVEL POD AND 2-230 GAL TIP TANKS INSTALLED
MILITARY POWER

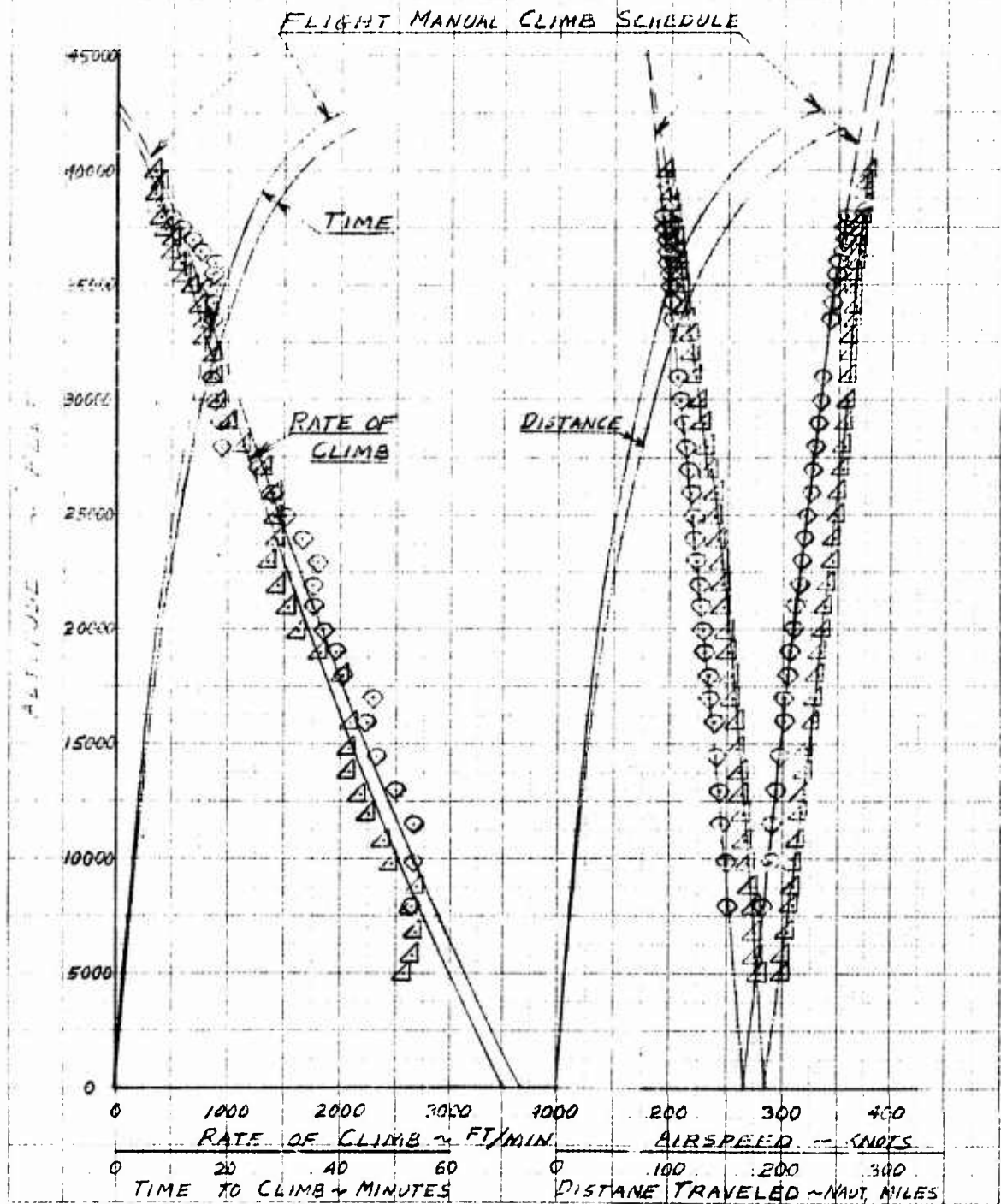


FIGURE NO 8A

NOTE: 2.0 MINUTES AND 350 POUNDS (55 GAL) OF FUEL USED TO TAKE-OFF AND ACCELERATE TO CLIMB SPEED

- FLIGHT MANUAL SCHEDULE
- △ TEST CLIMB SCHEDULE

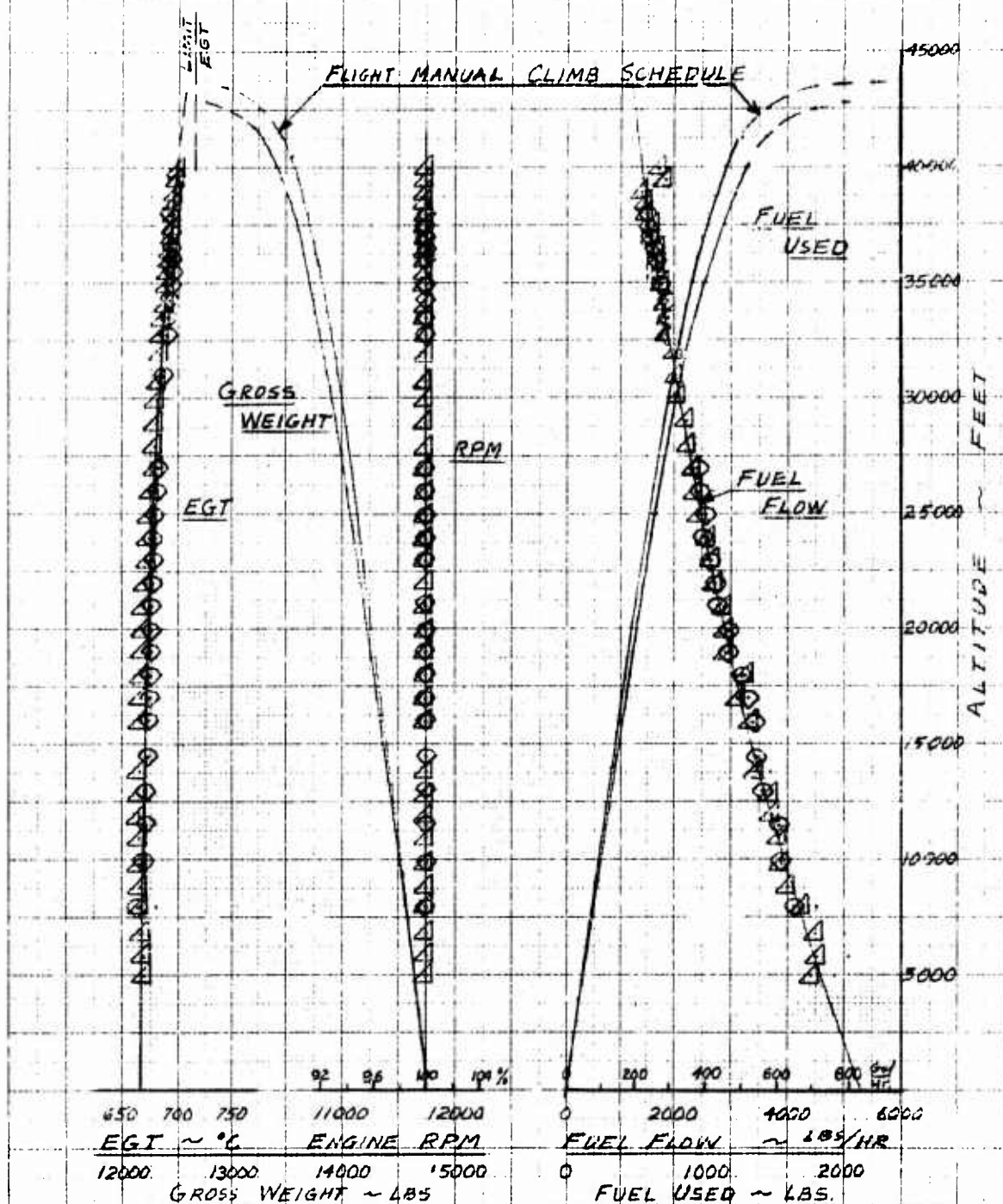


FIGURE NO. 9
CLIMB PERFORMANCE
T-33A USAF S/N 52-9846
U-33-A-35 ENGINE
2-250 GAL. TIPTANKS INSTALLED
MILITARY POWER
TEST CLIMB SCHEDULE

NOTE: DATA NOT CORRECTED FOR NONSTANDARD ENGINE PERFORMANCE

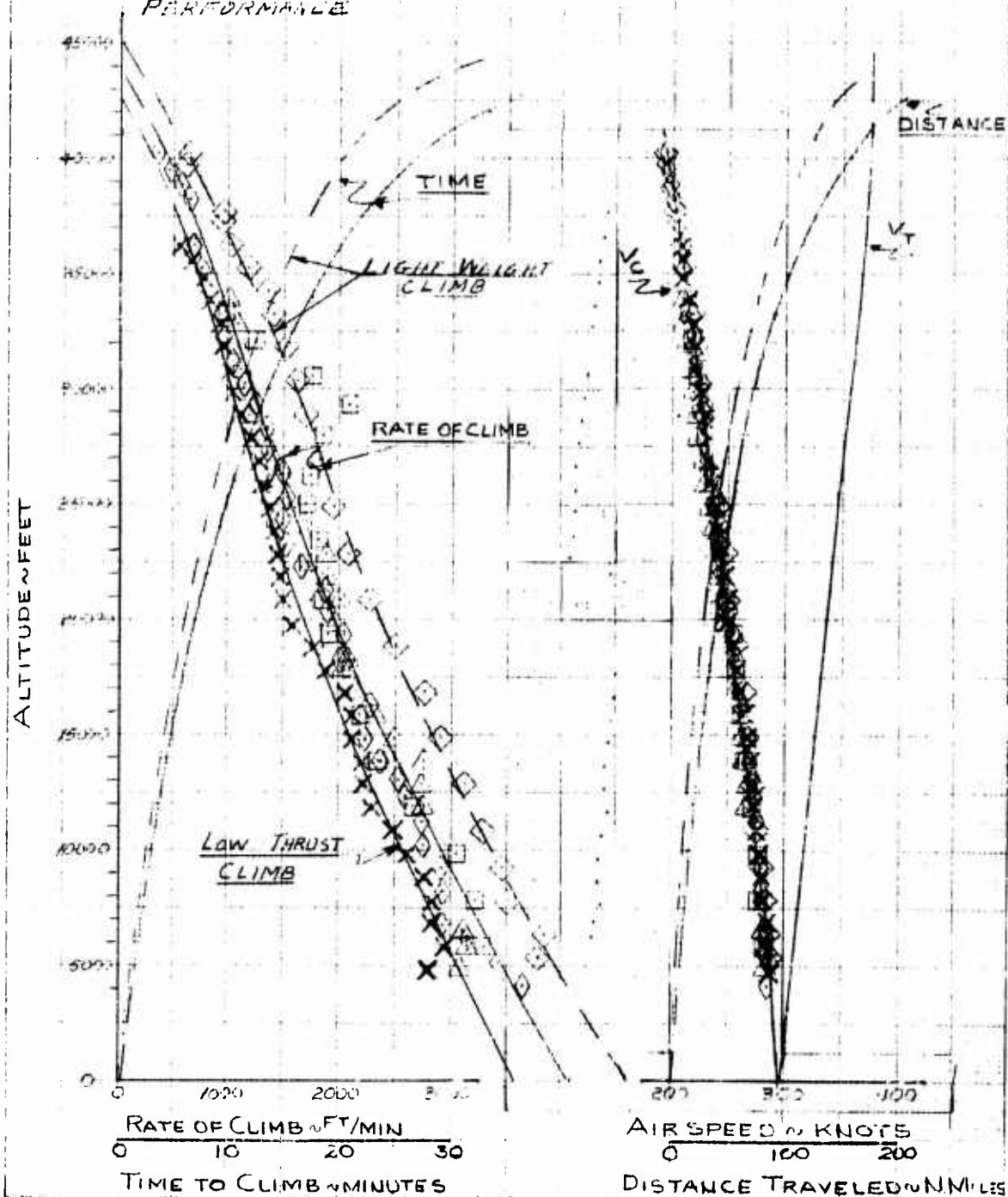
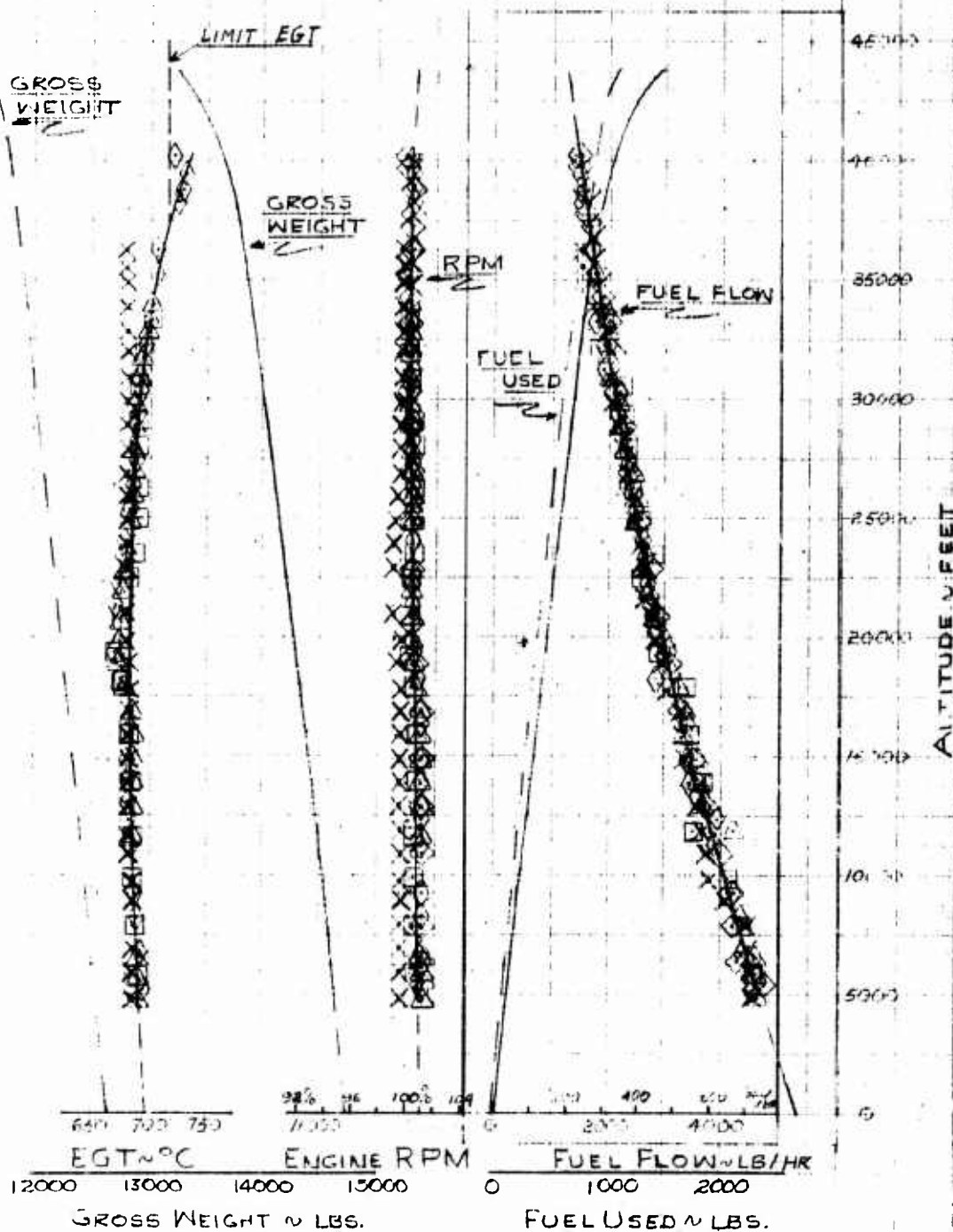


FIGURE No 9A

- NOTE 1) 2.0 MINUTES AND 350 POUNDS (53 GAL.) OF FUEL USED IN TAKE-OFF AND ACCELERATE TO CLIMB SPEED
 2) DASHED LINE INDICATES CLIMB AT WEIGHTS EQUIVALENT TO HAVING 60 GAL IN EACH TITANK AT TAKE-OFF
 3) X INDICATES CLIMB WITH LOW THRUST ENGINE NT-33A S/N 51-8954



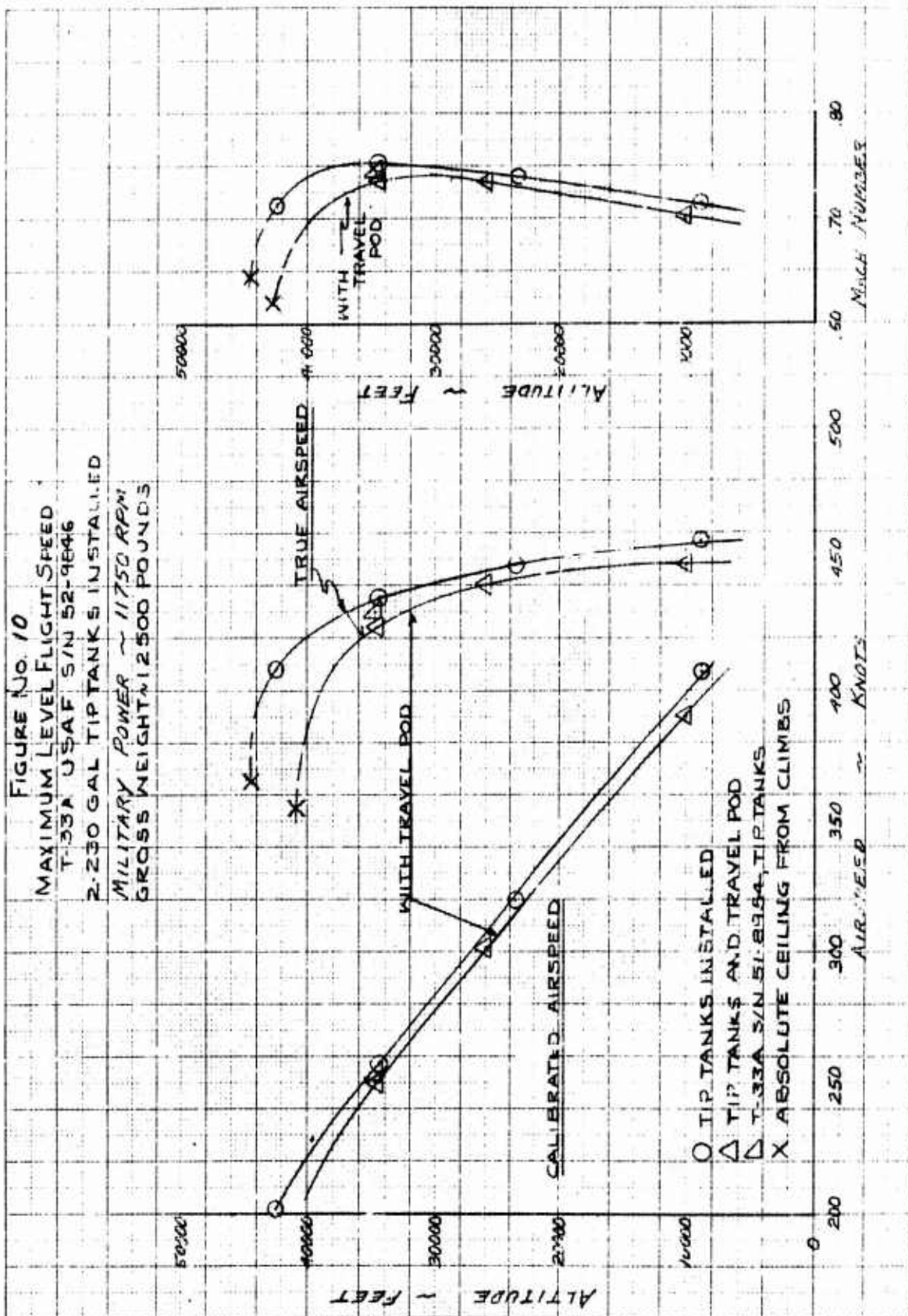


FIGURE NO. 11
 LEVEL FLIGHT PERFORMANCE SUMMARY
 RANGE FACTOR & MACH NUMBER
 VS
 WEIGHT PRESSURE PARAMETER

- T33A S/N 52-9846 TIP TANKS
- ▽ T33A S/N 52-9846 TIP TANKS & TRAVEL POD
- T33A S/N 51-8954 TIP TANKS, 1961
- △ T33A S/N 51-8954 TIP TANKS
- REF TN-FTDSP-53-6J, 1953
- ◇ T33A S/N 51-8954 TIP TANKS, STUDENT MEMORANDUM REPORT, 1958

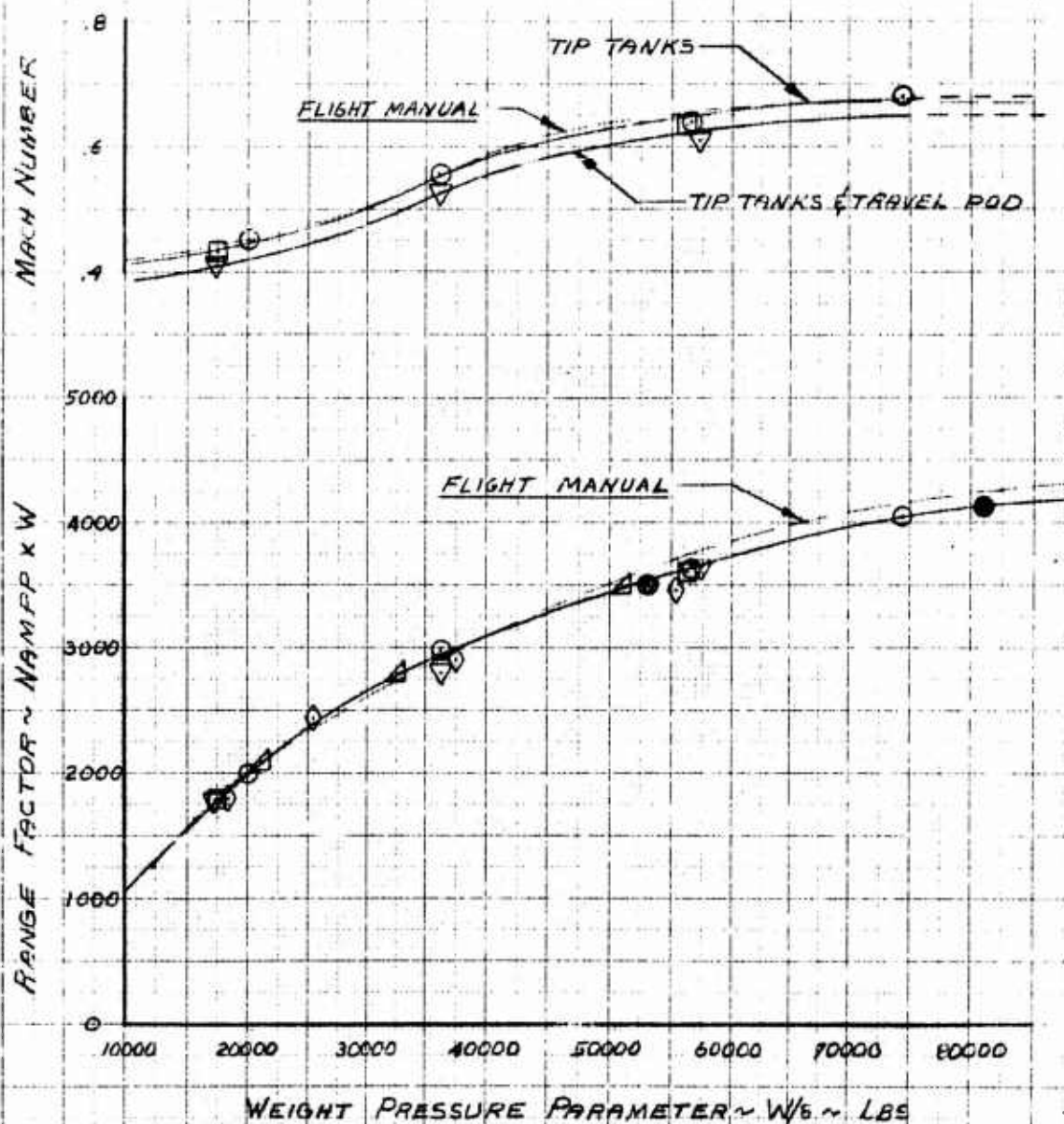


FIGURE NO 12
 LEVEL FLIGHT PERFORMANCE
 SPECIFIC RANGE
 T33A USAF NO 52-9846
 J33-A-35 ENGINE S/N A-C80032
 2-230 GAL. TIP TANKS INSTALLED

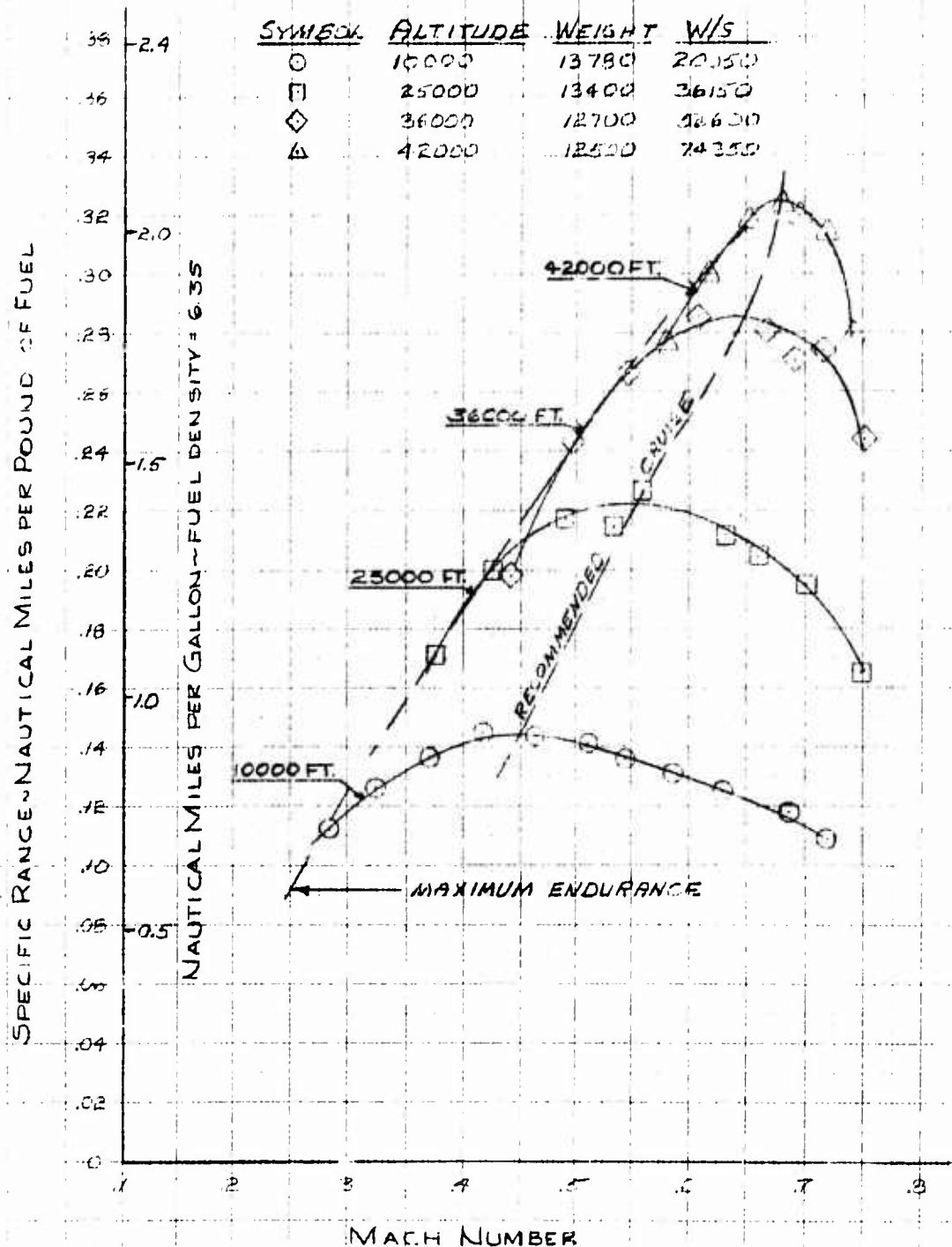


FIGURE No 13
 LEVEL FLIGHT PERFORMANCE
 ENGINE SPEED VS CALIBRATED AIRSPEED
 T23A USAF NO 52-9876
 J33A-35 ENGINE S/N A-080033
 2-230 GAL TITANKS INSTALLED

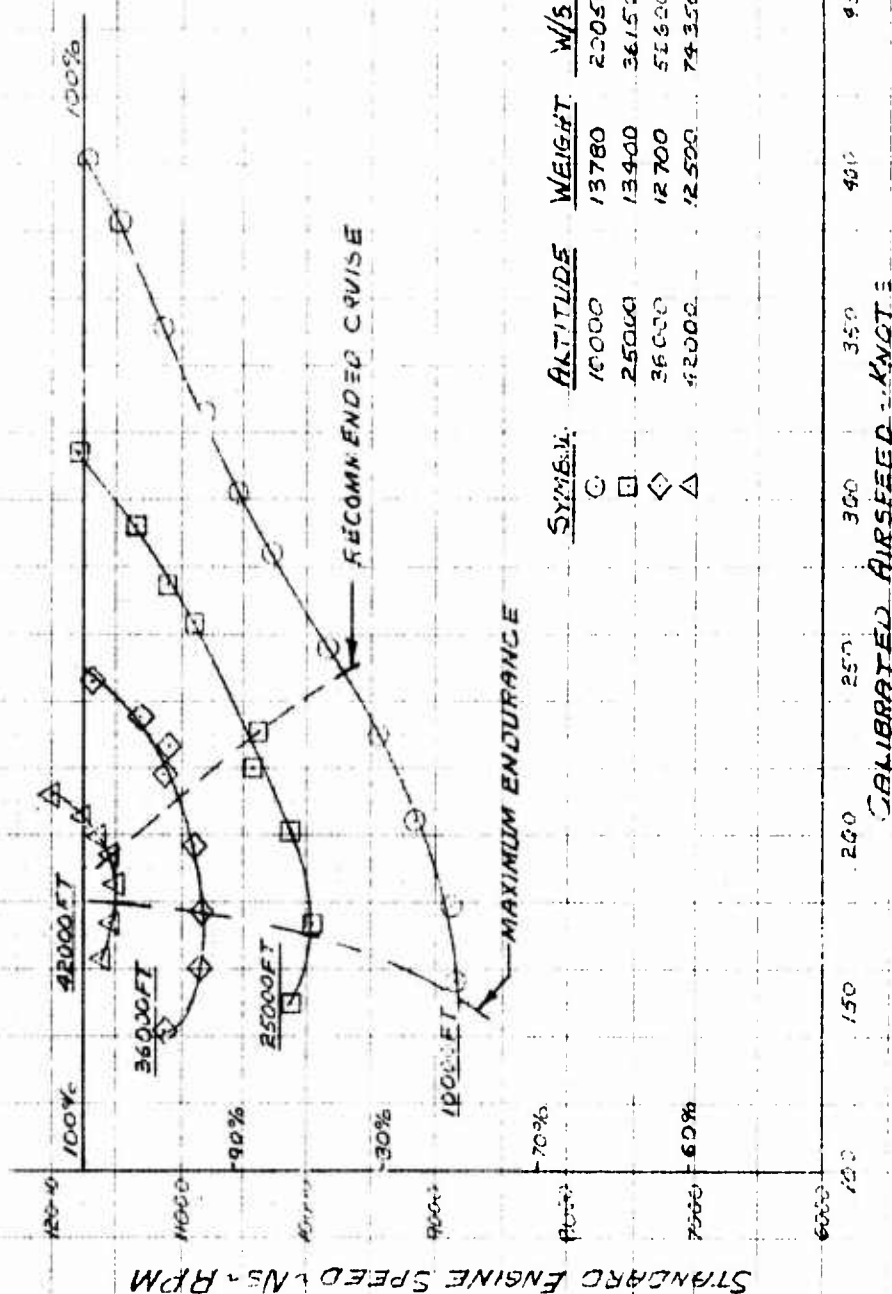


FIGURE NO 14

LEVEL FLIGHT PERFORMANCE

FUEL FLOW VS. CALIBRATED AIRSPEED

T-33A USAF S/N 52-9846

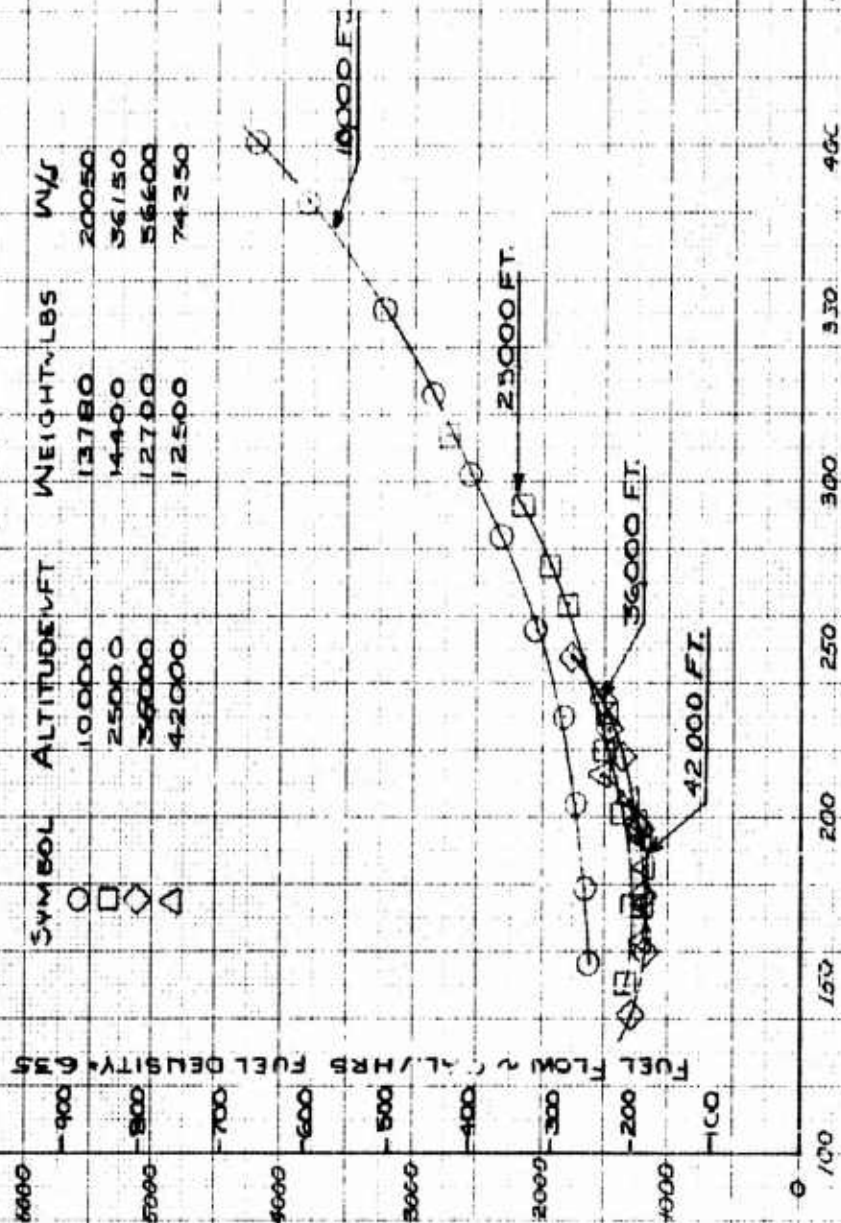
J33-A-35 ENGINE S/N A-08033

2-230 GAL. TIPTANKS INSTALLED

FUEL FLOW ~ GAL/HRB FUEL DENSITY ~ 6.35

STANDARD FUEL FLOW ~ W/GS ~ LBS/HR.

SYMBOL	ALTITUDE-FT	WEIGHT-LBS	W/GS
○	10000	13780	20050
□	25000	14400	36150
◇	36000	12700	56600
△	42000	12500	74250



CALIBRATED AIRSPEED ~ KNOTS

FIGURE No. 15
 LEVEL FLIGHT PERFORMANCE
 CORRECTED ENGINE SPEED VS MACH NUMBER
 T-33A USAF S/N 52-9846
 J33-A-35 S/N A-080033
 2-230 GAL TIPTANKS INSTALLED

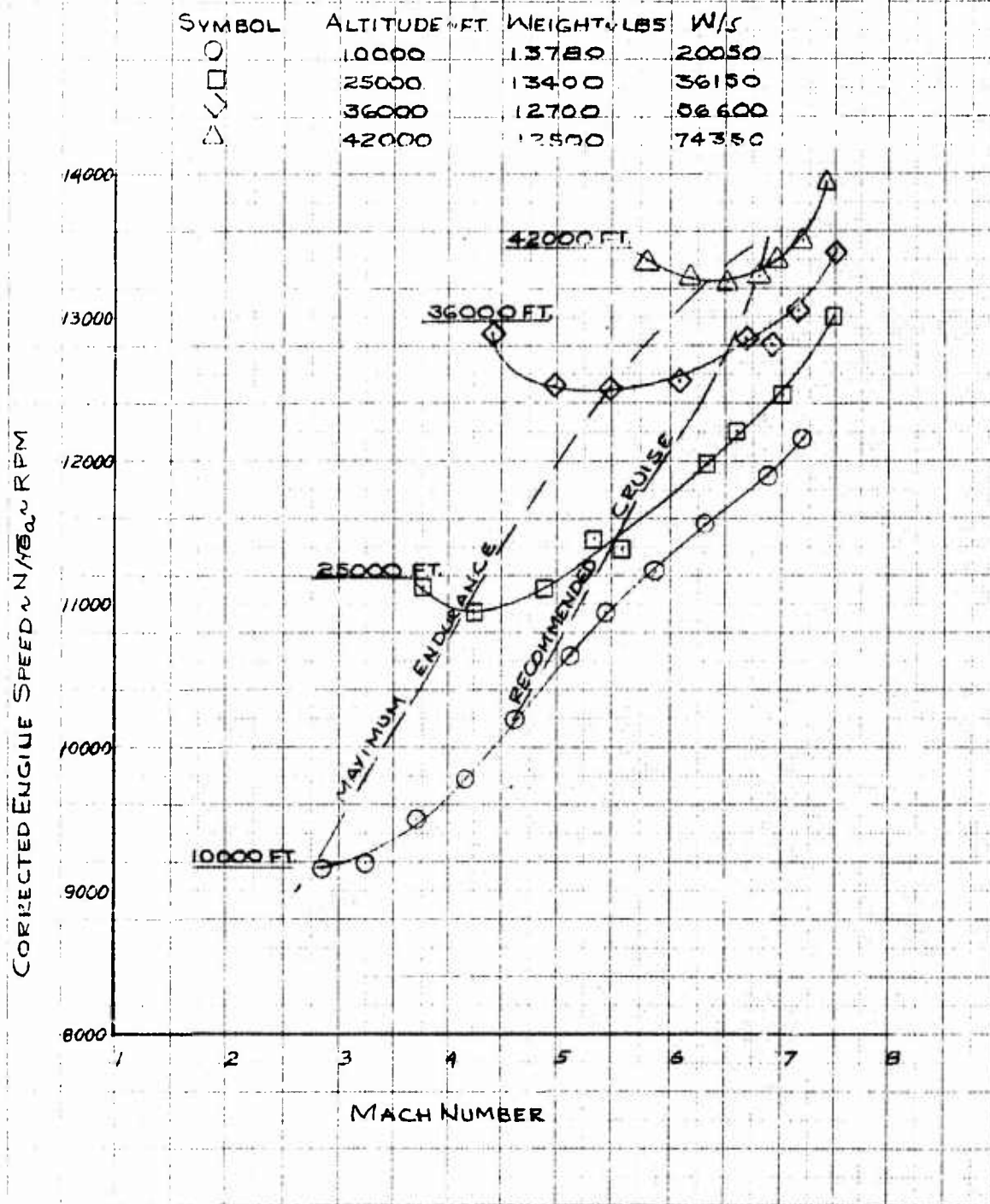


FIGURE NO. 16
 LEVEL FLIGHT PERFORMANCE
 CORRECTED FUEL FLOW VS MACH NUMBER
 T-33A USAF S/N 52-9846
 J 33-A-35 S/N A-08003
 2-230 GAL TIPTANKS INSTALLED

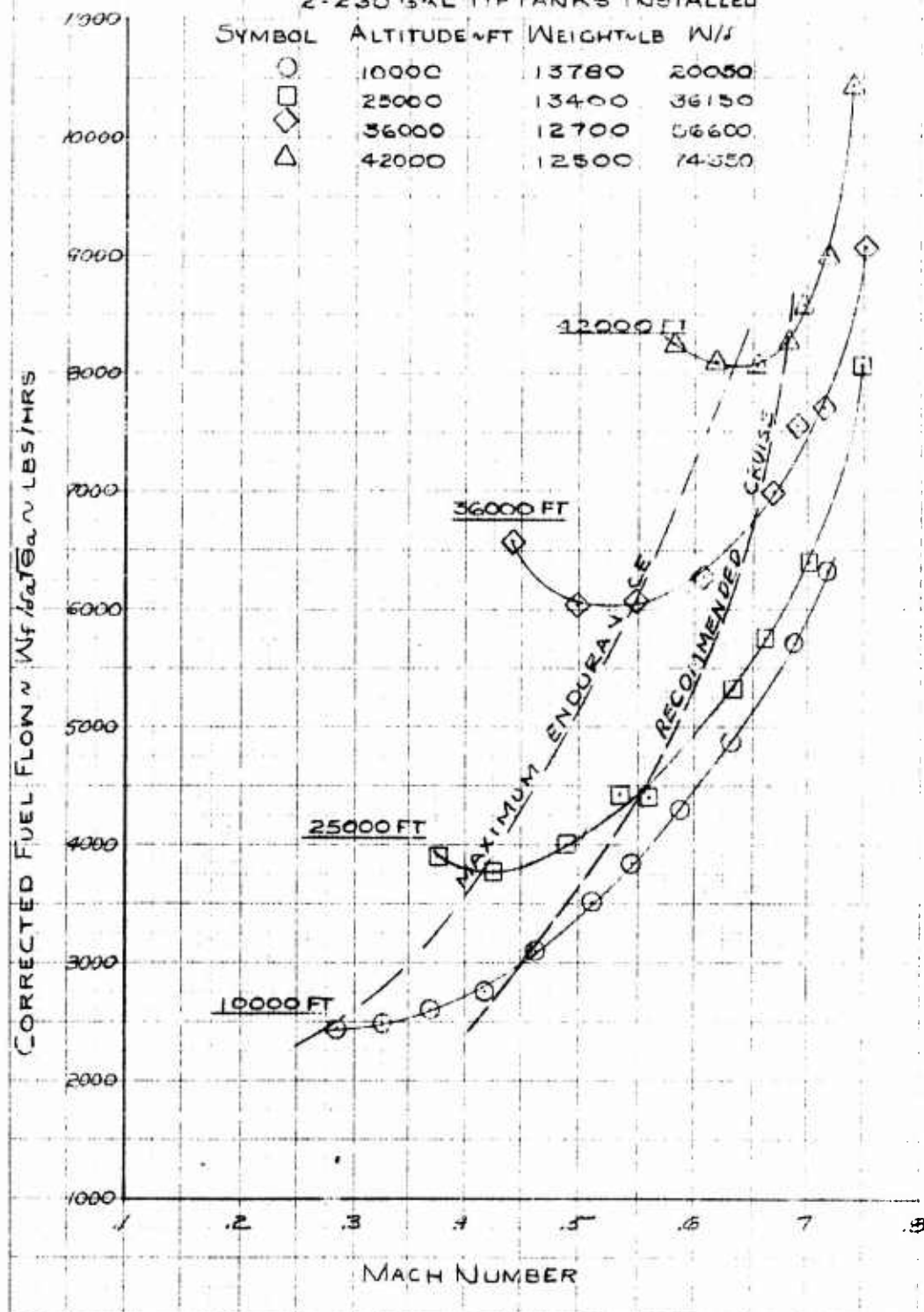


FIGURE NO 17
 LEVEL FLIGHT PERFORMANCE
 SPECIFIC RANGE
 T33A CORF NO51-8954
 T33-A-35 ENGINE SN A-085176
 2-220 GAL TIP TANKS INSTALLED

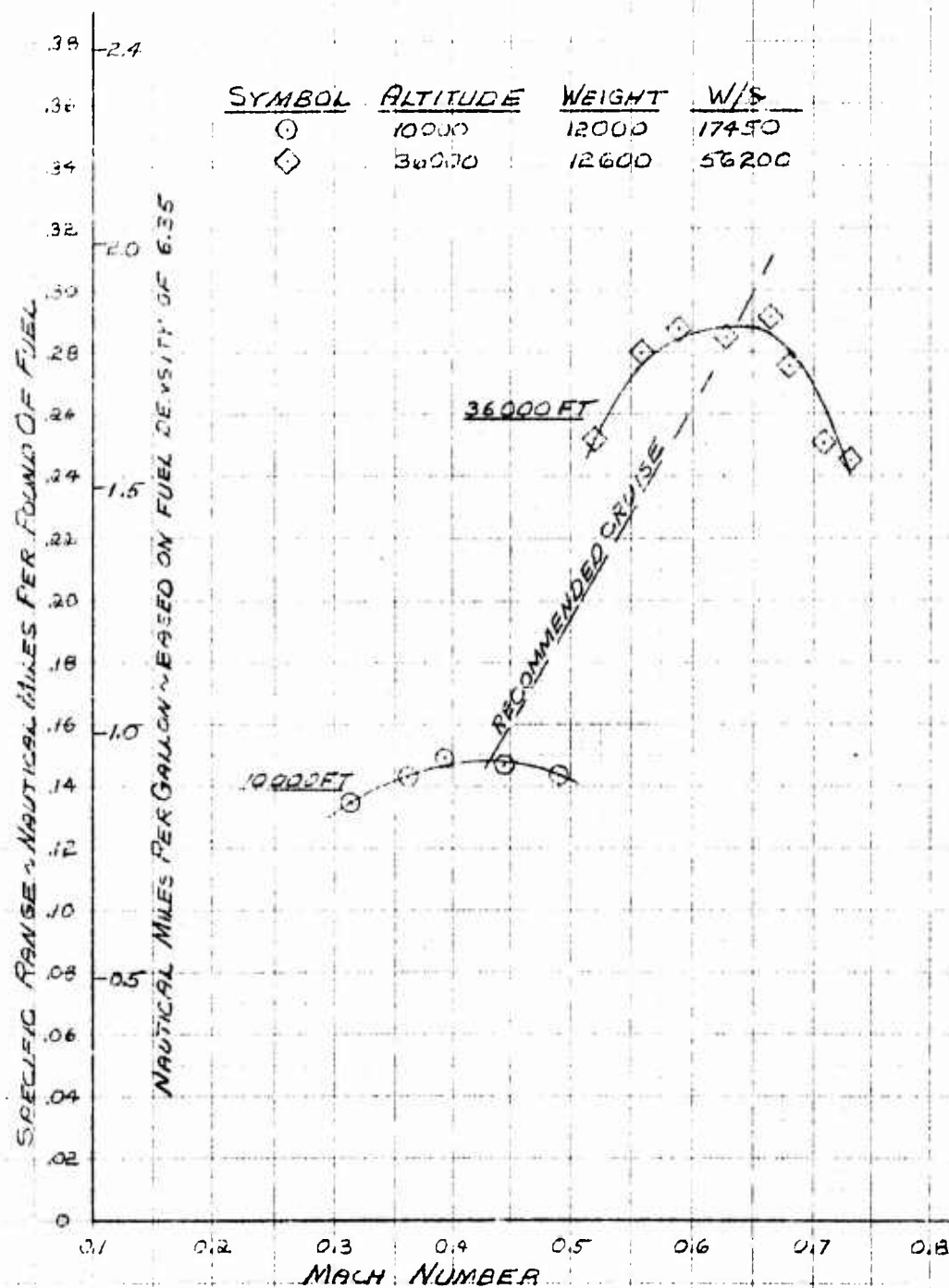


FIGURE NO 18
 LEVEL FLIGHT PERFORMANCE
 ENGINE SPEED VS CALIBRATED AIRSPEED
 T33A USAF NO. 51-8954
 J-33-A-35 ENGINE S/N A-085176
 2-230 GAL TIP TANKS INSTALLED

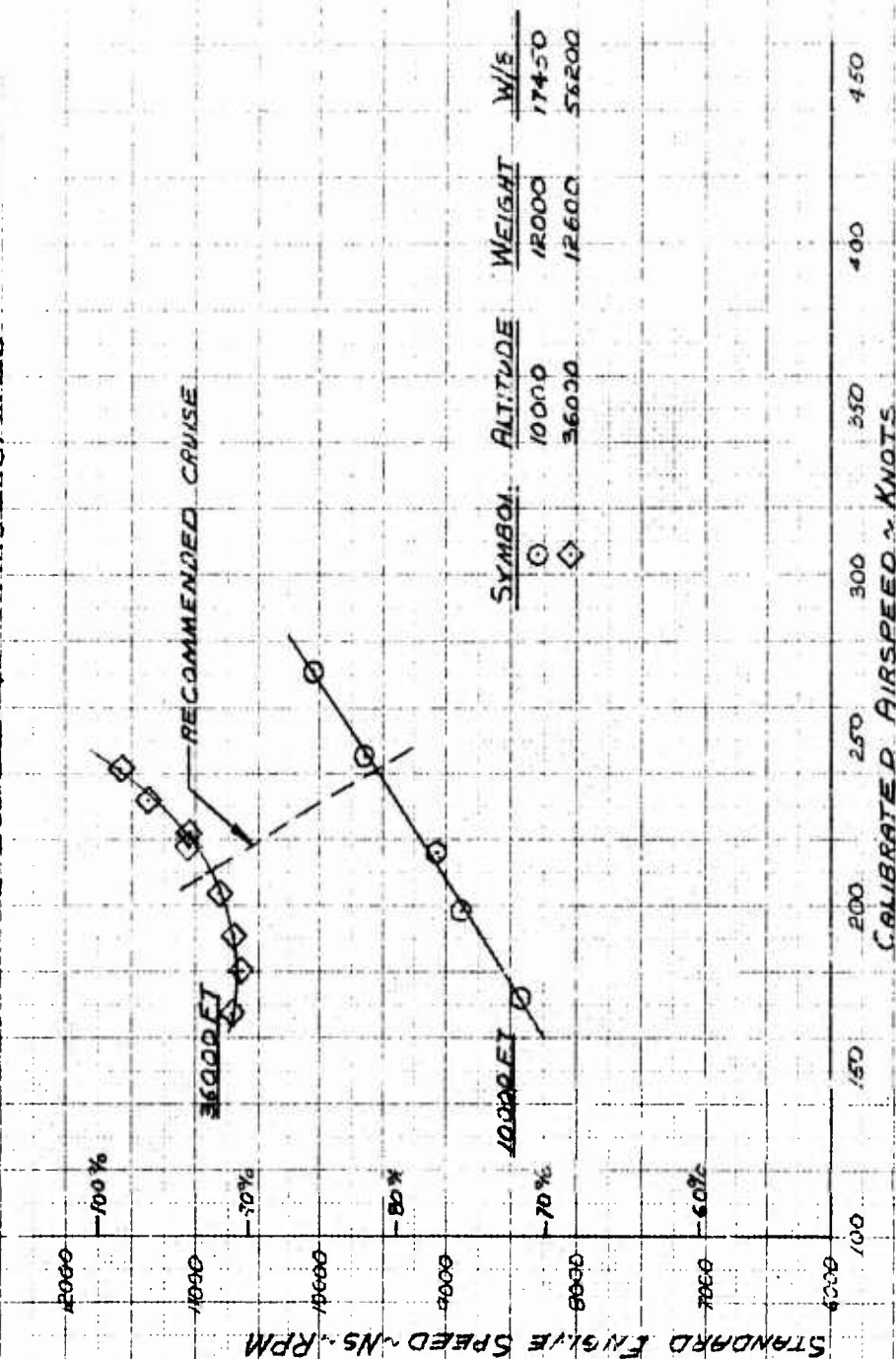


FIGURE NO 19
 LEVEL FLIGHT PERFORMANCE
 FUEL FLOW VS CALIBRATED AIRSPEED
 T33A USAF NO 57-8954
 J33-A-35 ENGINE S/N 085176
 2-230 GAL TIP TANKS INSTALLED

STANDARD FUEL FLOW ~ WTS ~ LBS/HR
 FUEL FLOW ~ GALL/HR - BASED ON FUEL DENSITY OF 6.35 LB/GAL

SYMBOL	ALTITUDE	WEIGHT	W/S
○	10000	12000	17450
△	36000	12600	56200

10000 FT

36000 FT

CALIBRATED AIRSPEED ~ KNOTS

FIGURE NO 20
 LEVEL FLIGHT PERFORMANCE
 CORRECTED ENGINE SPEED VS MACH NUMBER
 T33A USAF NO 51-8954
 J33-A-35 ENGINE S/N 4-085176
 2-2 2 GAL TIP TANKS INSTALLED

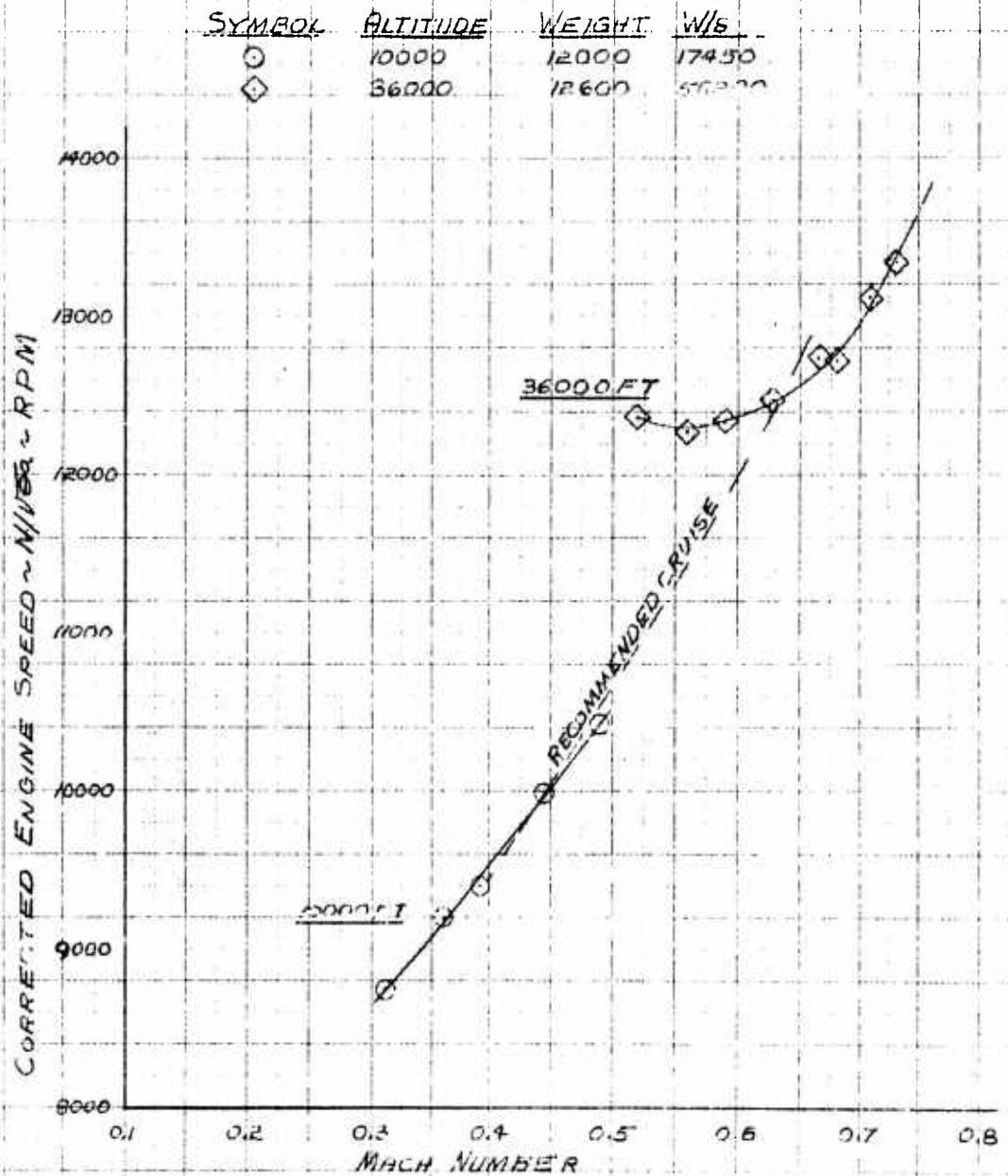


FIGURE No 21
 LEVEL FLIGHT PERFORMANCE
 CORRECTED FUEL FLOW VS MACH NUMBER
 T 33A UGAF NO 51-8954
 J 33-A-35 ENGINE S/N A-085176
 2-230 GAL TIP TANKS INSTALLED

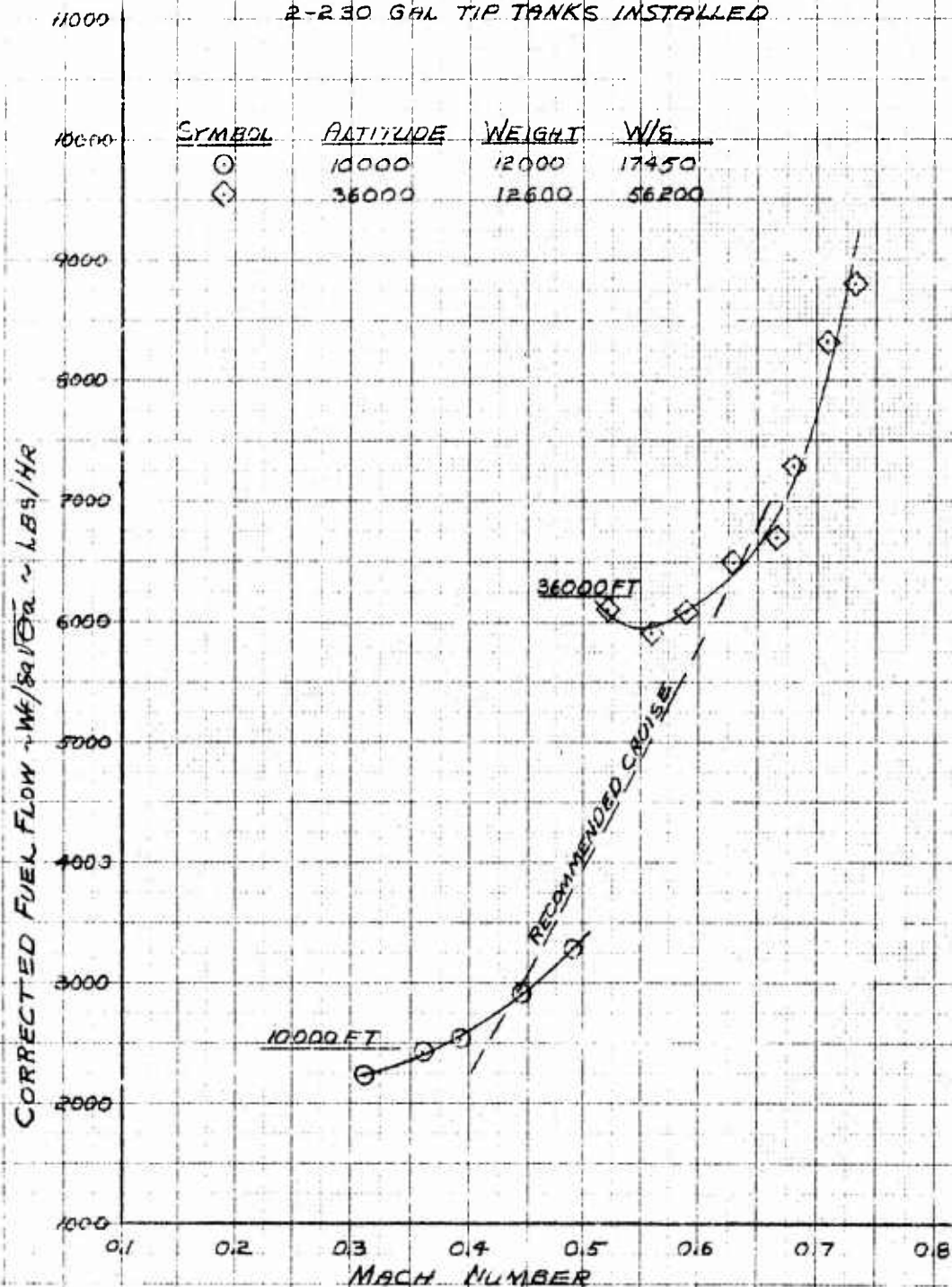


FIGURE NO. 22
LEVEL FLIGHT PERFORMANCE
SPECIFIC RANGE

T 33A USAF NO 52-9846
J33-A-35 ENGINE S/N A-080083
TRAVEL POD 4.10 2-250 GAL TIP TANKS INSTALLED

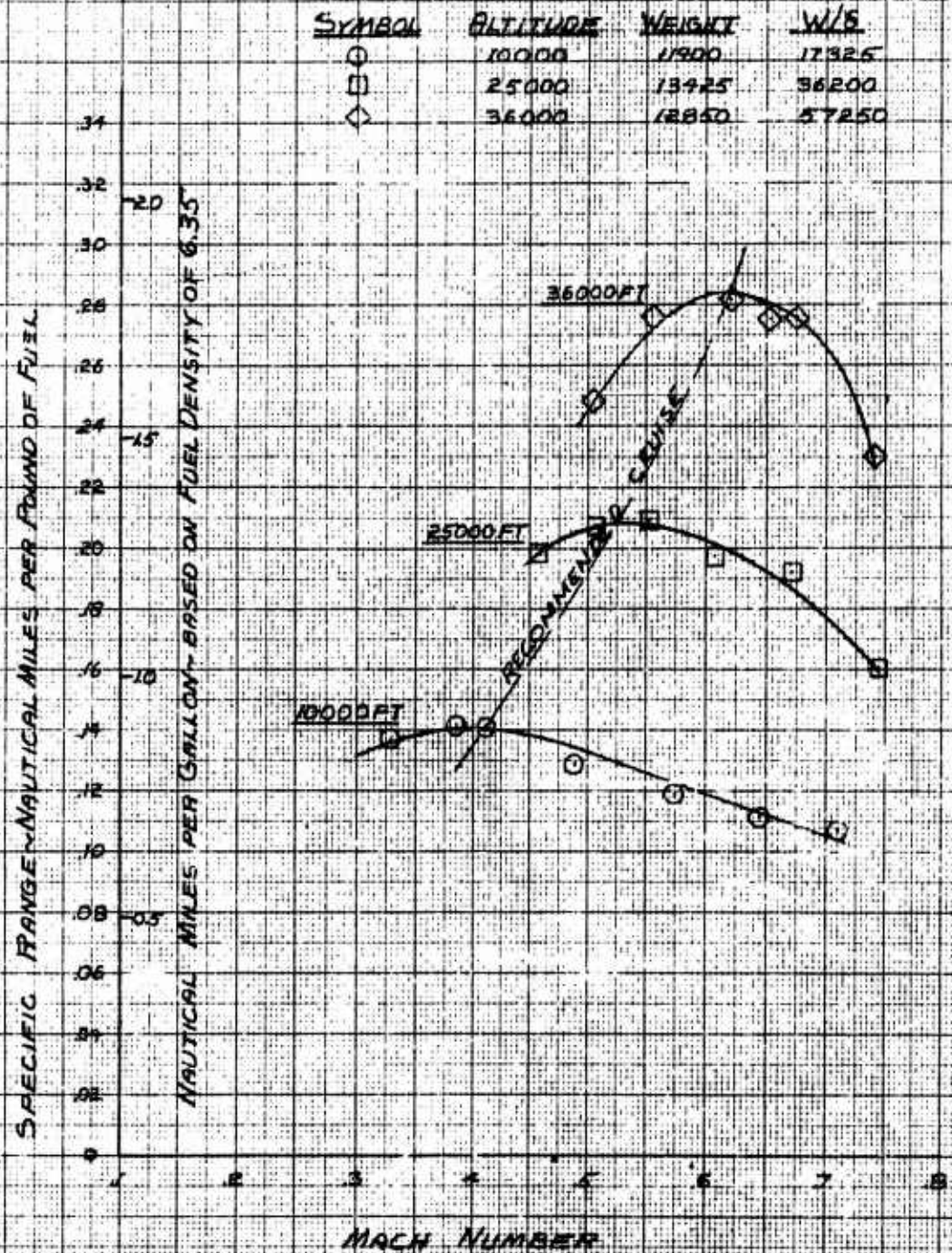


FIGURE No 23
 LEVEL FLIGHT PERFORMANCE
 ENGINE SPEED VS CALIBRATED AIRSPEED
 T33A USAF NO. 52-9496
 J33-A-35 ENGINE SNA-080033
 TRAVEL POD AND 2-230 GAL TANKS INSTALLED

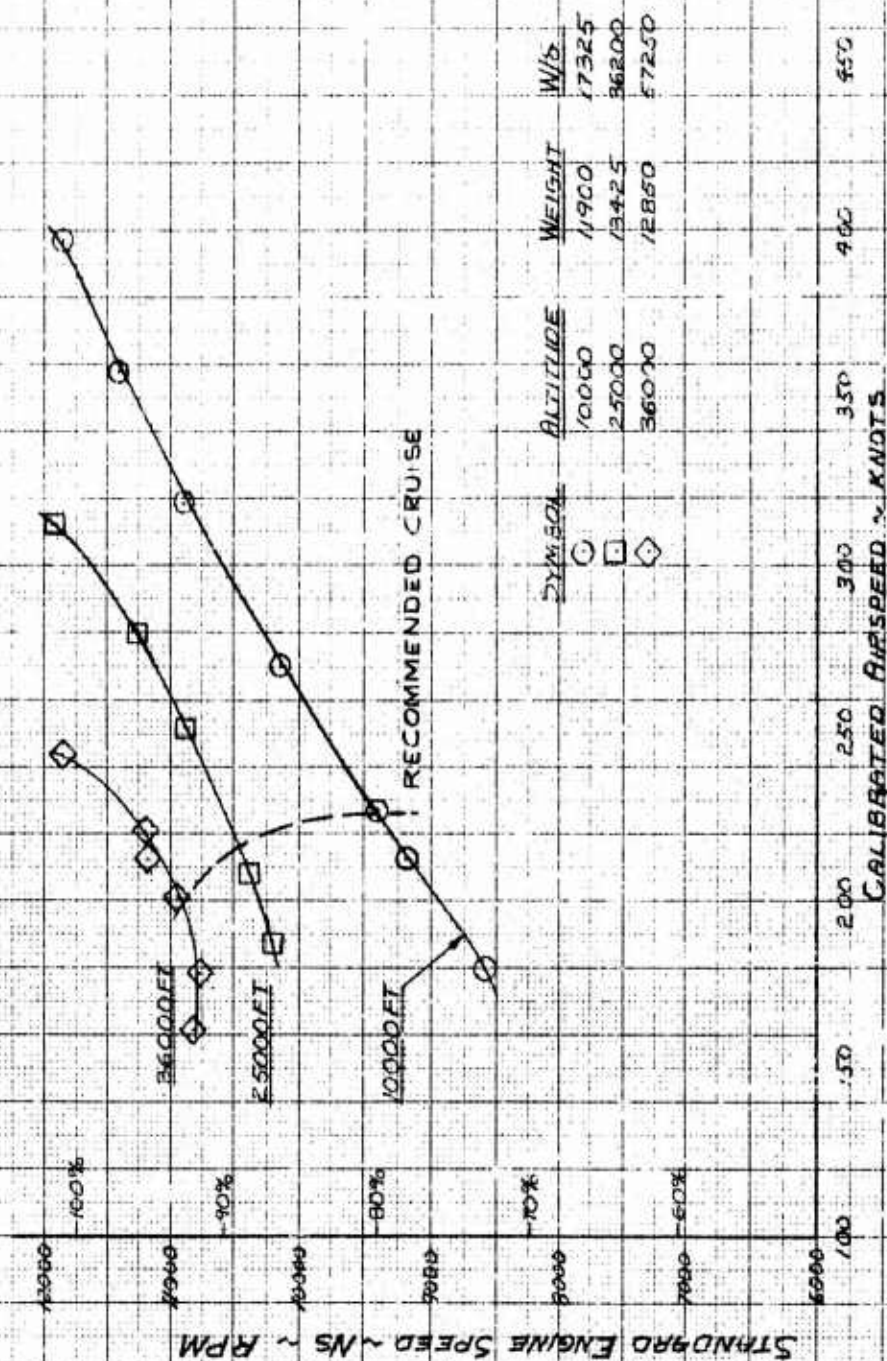


FIGURE NO. 24
 LEVEL FLIGHT PERFORMANCE
 FUEL FLOW VS. CALIBRATED AIRSPEED
 T-33A USAF S/N 52-9846
 J33-A-35 ENGINE S/N A-380033
 TRAVEL POD AND 2-230 GAL. TANKS INSTALLED

STANDARD FUEL FLOW ~ W_{50} ~ LB/HR
 FUEL FLOW ~ GAL/HR BASED ON FUEL DENSITY ~ 6.35

SYMBOL	ALTITUDE ~ FT	WEIGHT ~ LB	W/F
○	10000	11900	17325
□	25000	13425	36200
◇	36000	12850	57250

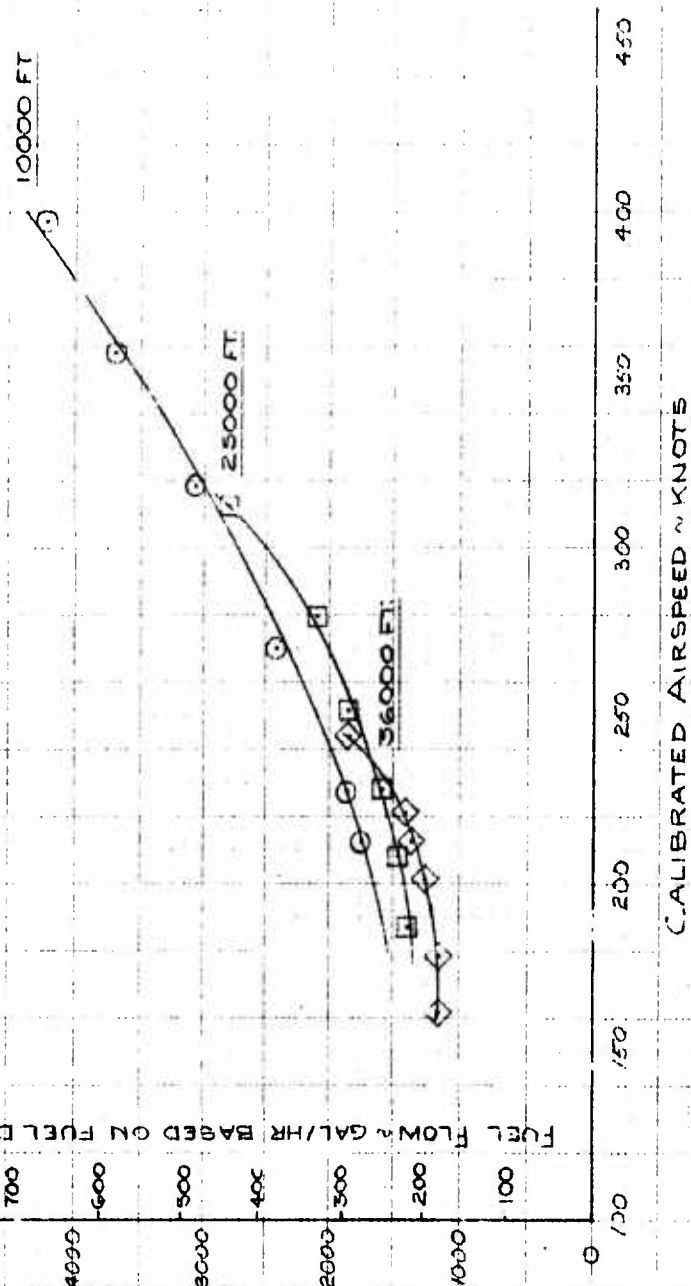


FIGURE No 25
 LEVEL FLIGHT PERFORMANCE
 CORRECTED ENGINE SPEED VS MACH NUMBER
 T33A USAF NO 52-9846
 J33-A-35 ENGINE S/N A-080033
 TRAVEL POD AND 2-230 GAL TIP TANKS INSTALLED

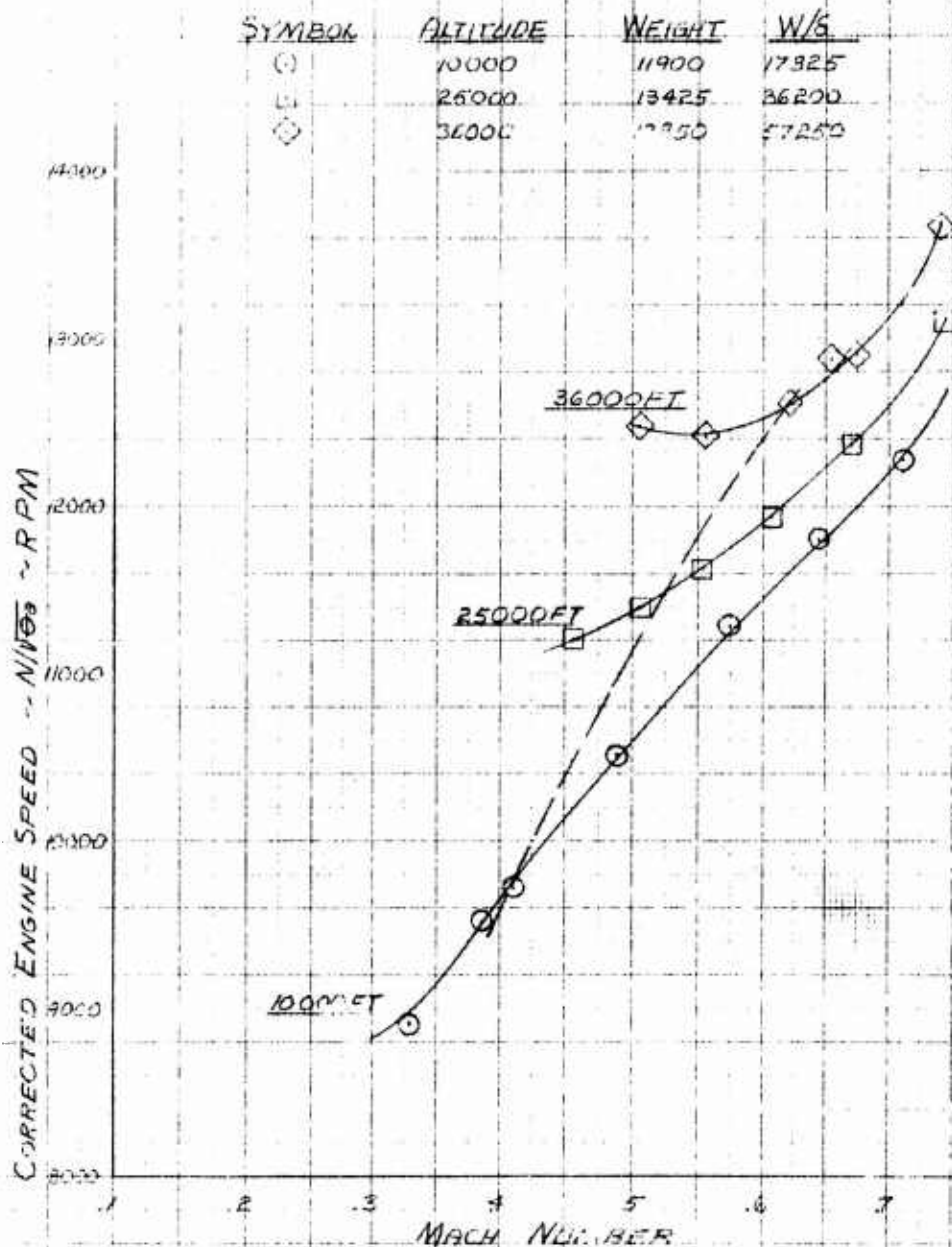
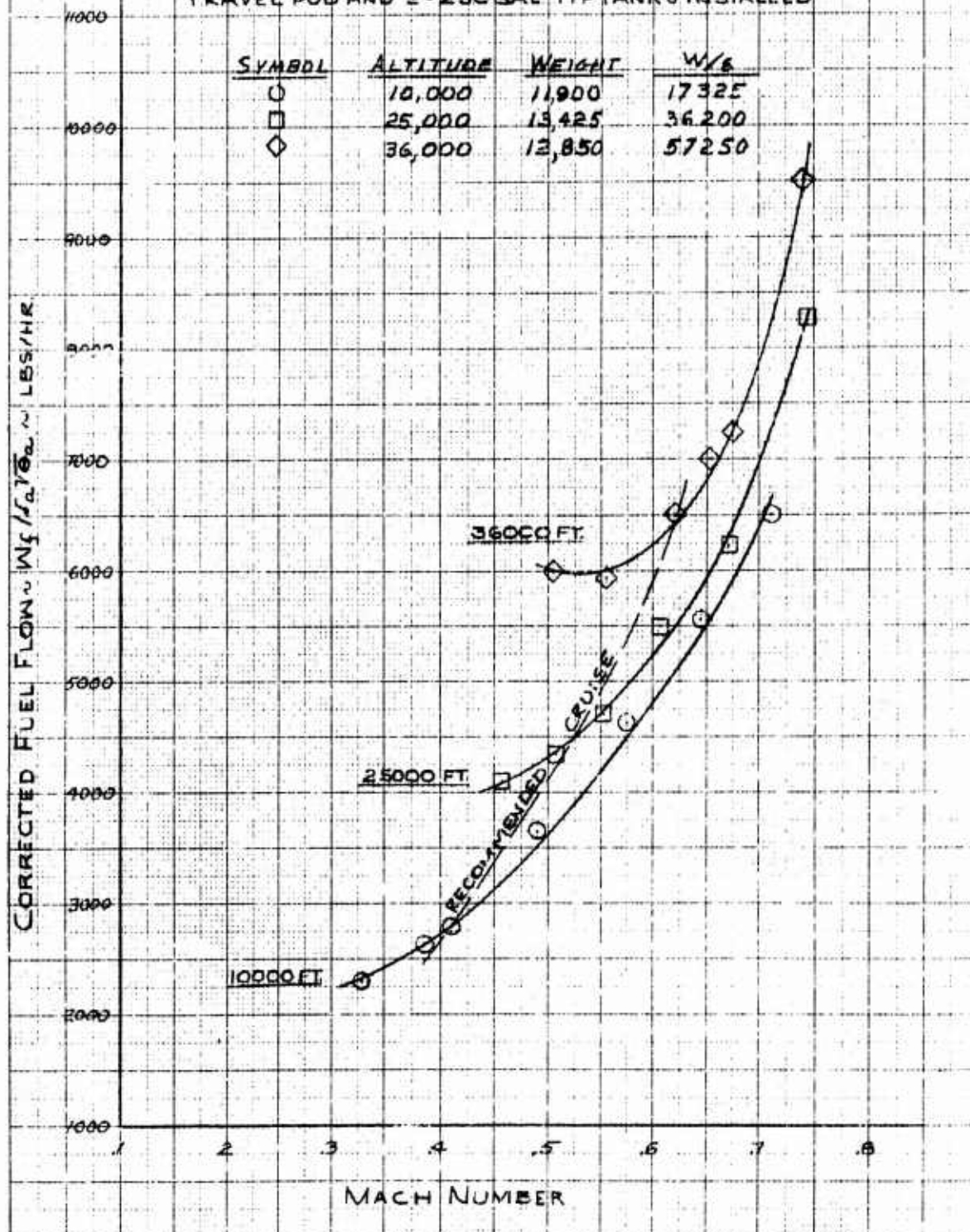


FIGURE NO. 26
 LEVEL FLIGHT PERFORMANCE
 CORRECTED FUEL FLOW VS MACH NUMBER
 T-33A USAF S/N 52-9846
 J83-A-35 ENGINE S/N 4-080033
 TRAVEL POD AND 2-230 GAL TIPTANKS INSTALLED



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FIGURE NO. 27
 RANGE MISSION
 T-33A USAF S/N 52-9846
 J33-A-35 ENGINE S/N A-02033

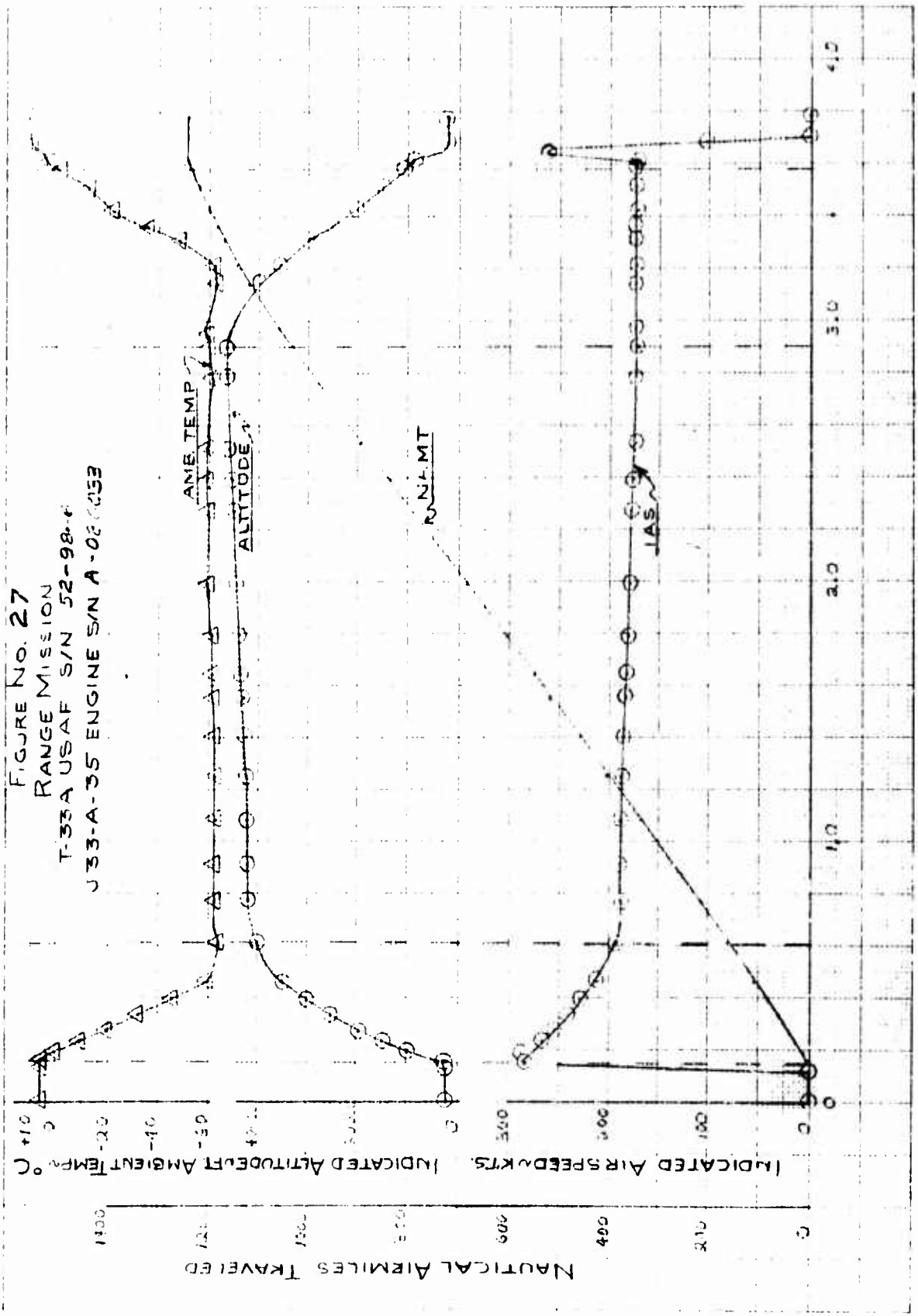
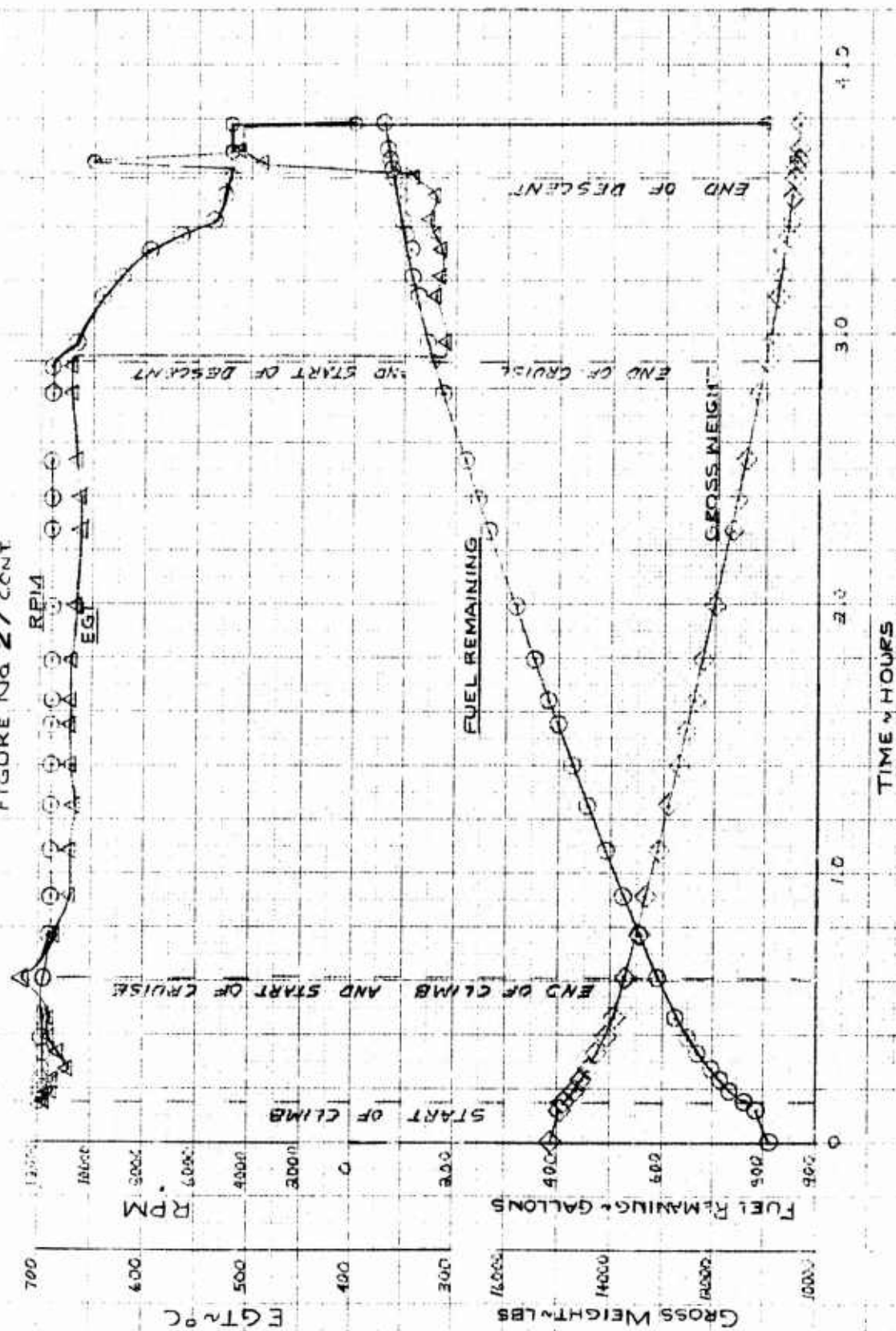


FIGURE No 27 CONT



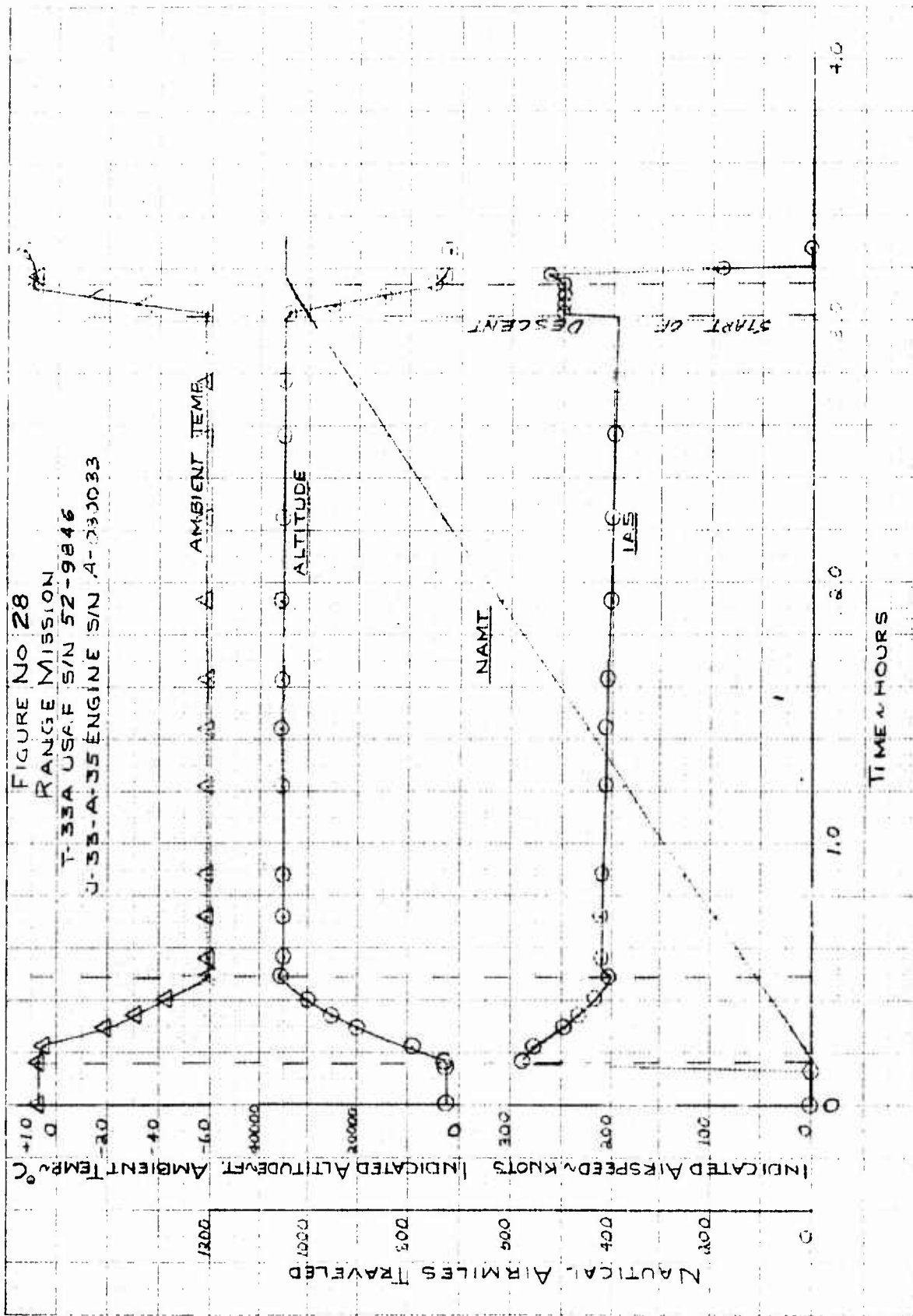


FIGURE No 20 CONT

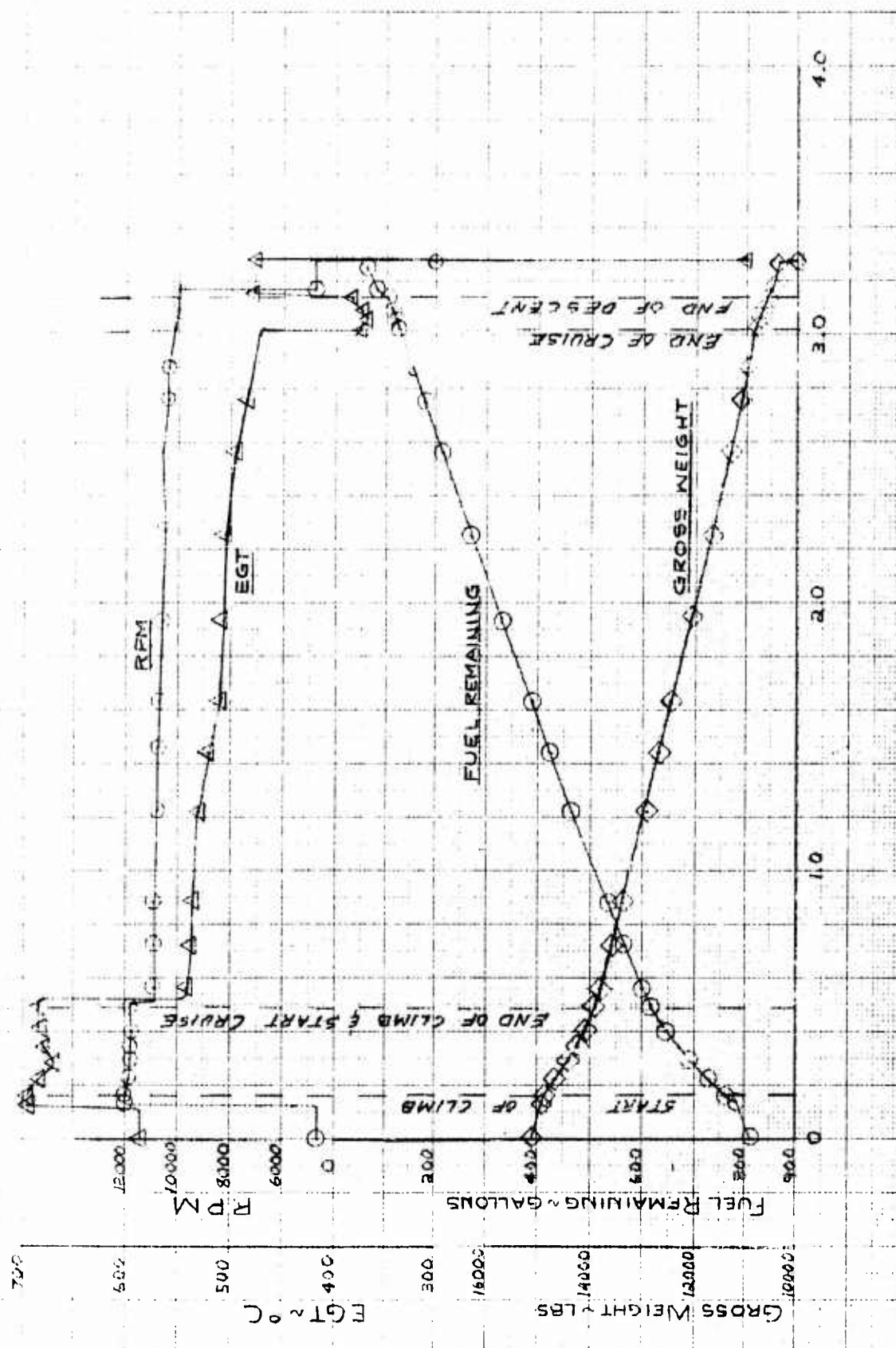


FIGURE No. 29
 DESCENT PERFORMANCE
 T-33A USAF S/N 52-9846
 2-230 GAL. TIPTANKS INSTALLED
 GROSS WEIGHT 11000 LBS

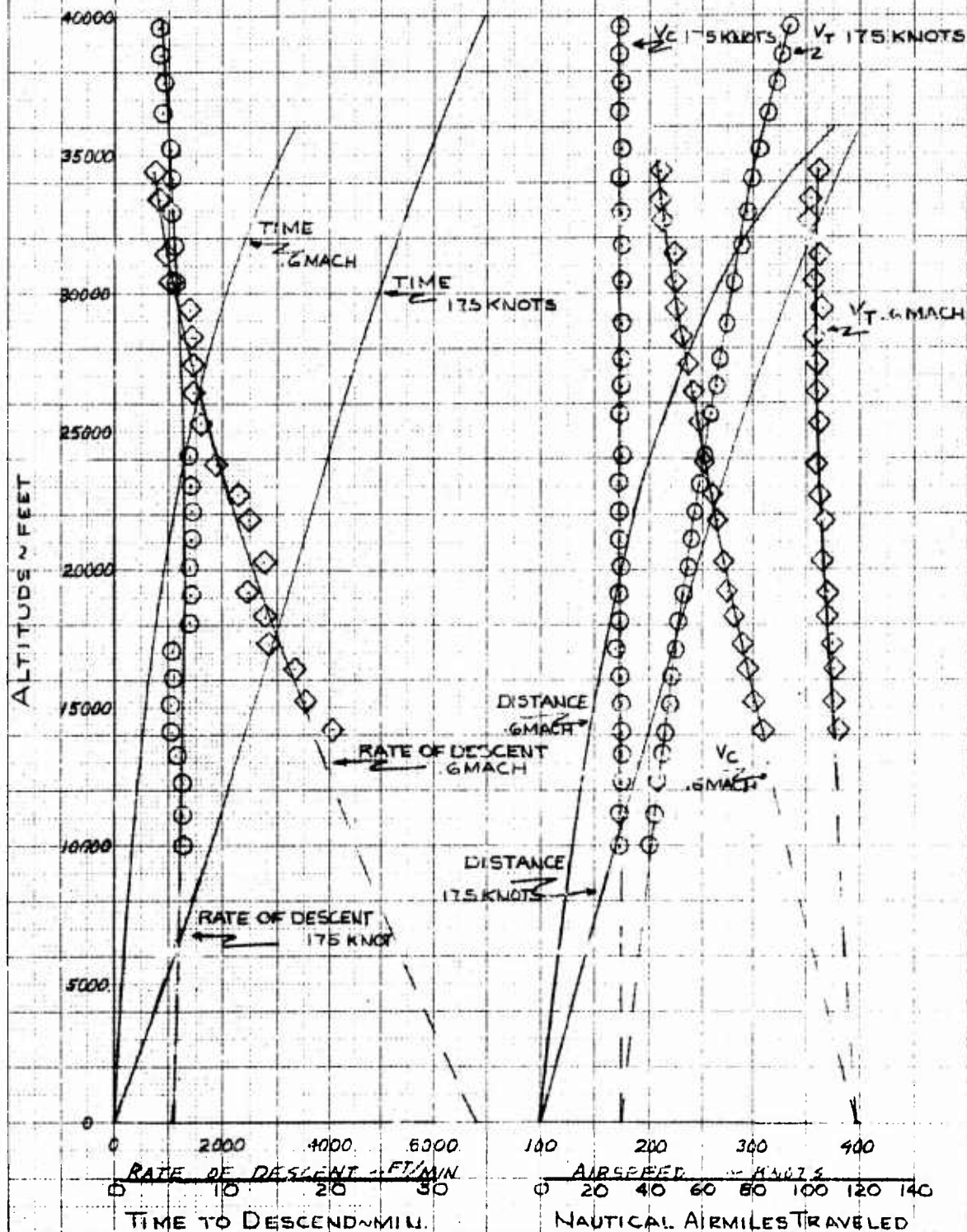


FIGURE NO. 29A

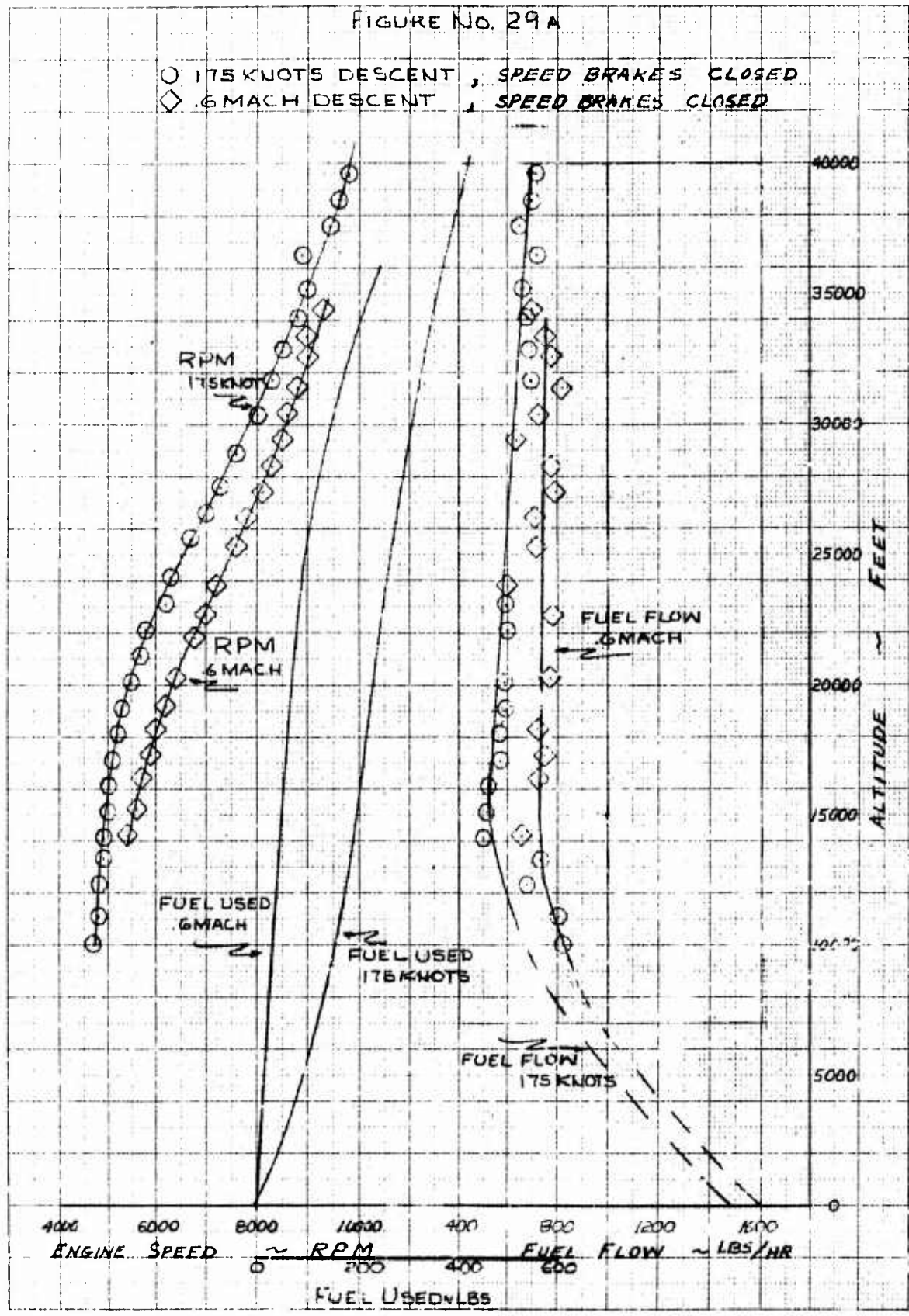


FIGURE NO. 30
 DESCENT PERFORMANCE
 F-33A USAF S/N 52-9846
 2-230 GAL TIPTANKS INSTALLED
 GROSS WEIGHT 11000 LBS

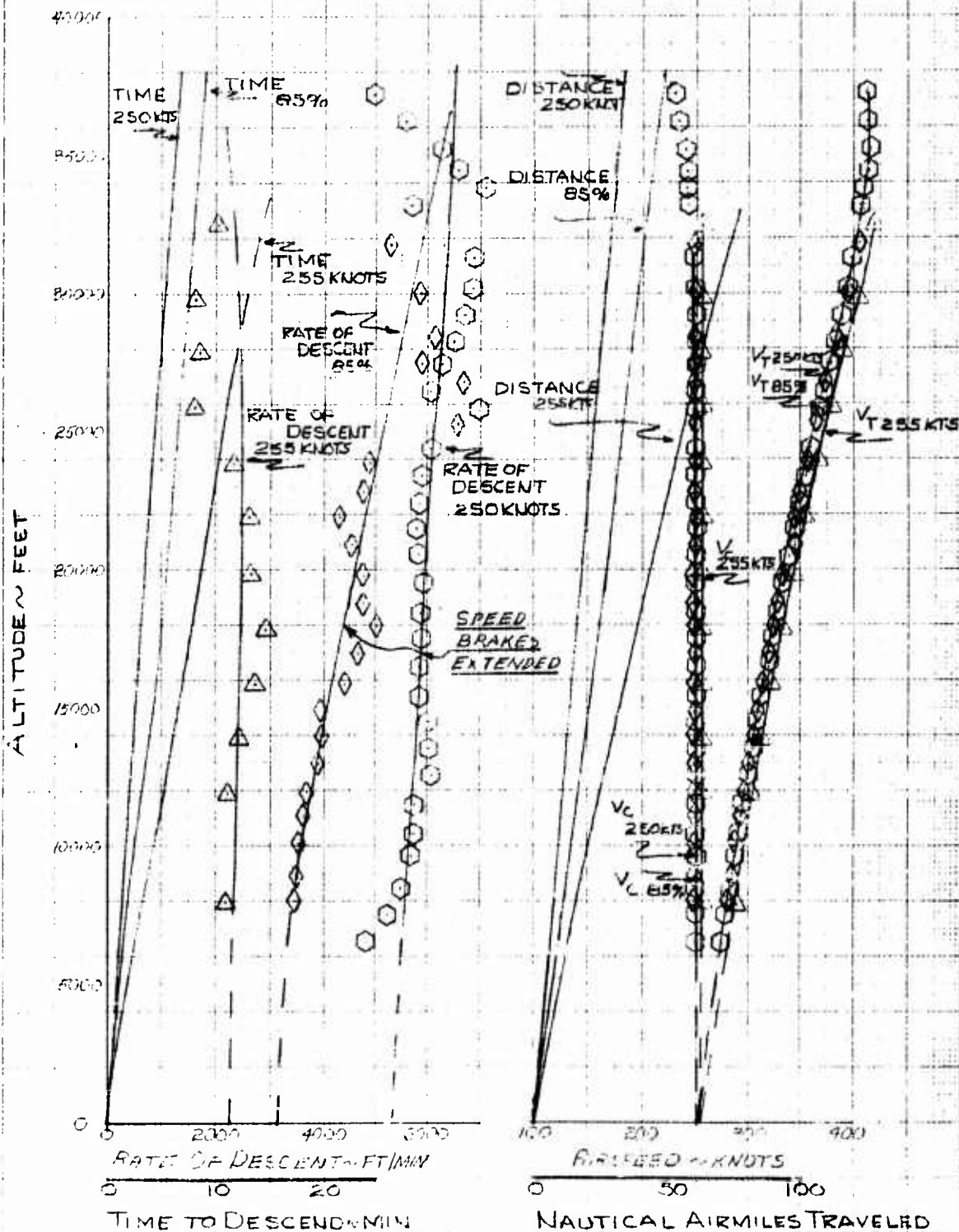


FIGURE NO. 30A

SYMBOL	SUBSCRIPT	TYPE OF DESCENT	CONFIGURATION
○	250 KNOTS	250 KNOTS IDLE RPM	SPEED BRAKES OUT
◇	85%	250 KNOTS 85% RPM	SPEED BRAKES OUT
△	255 KNOTS	255 KNOTS IDLE RPM	CLEAN

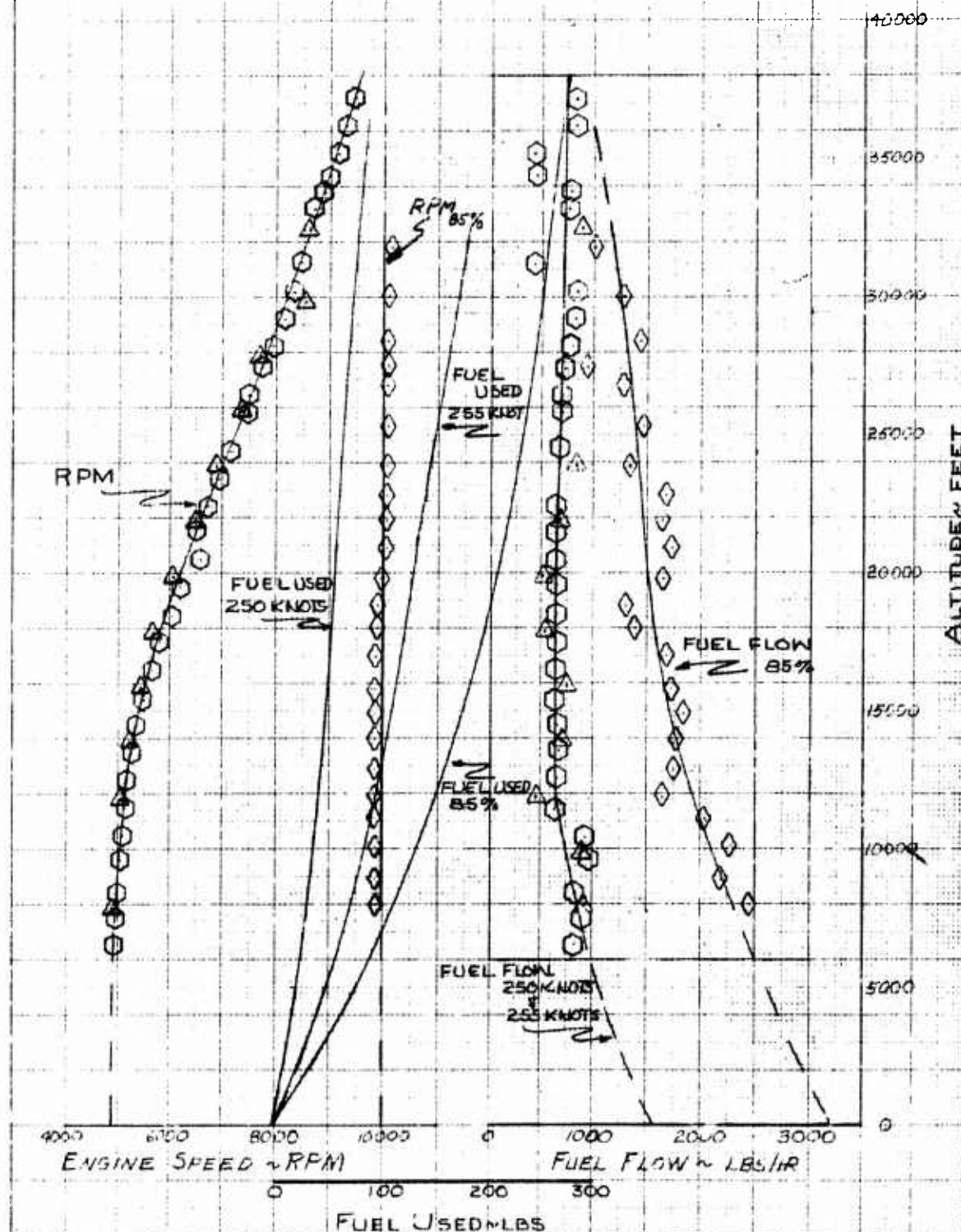


FIGURE No. 31
ENGINE OUT DESCENT
T-33A USAF S/N 52-9641
2-230 GAL TIPTANKS INSTALLED
GROSS WEIGHT 12,200 LBS

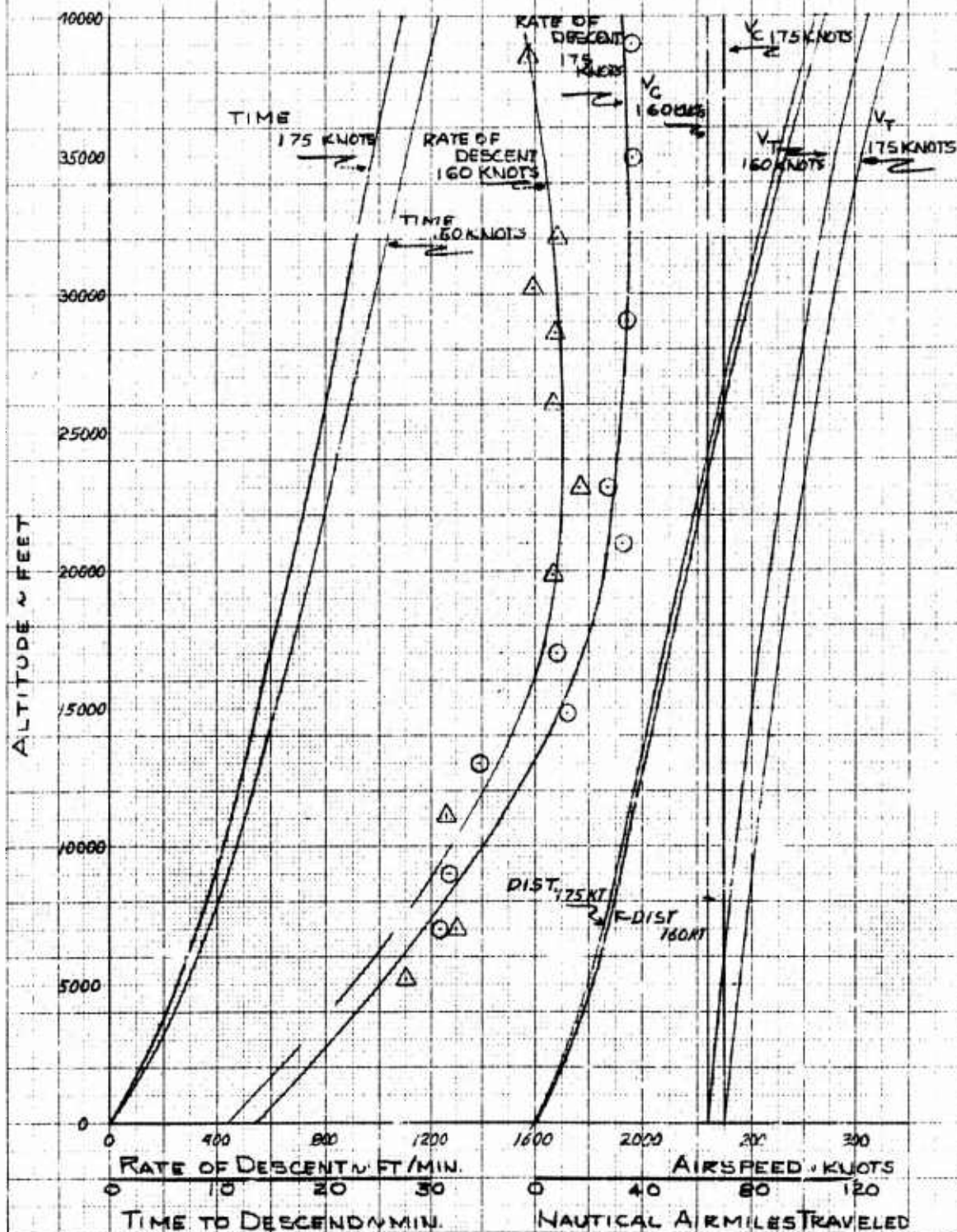
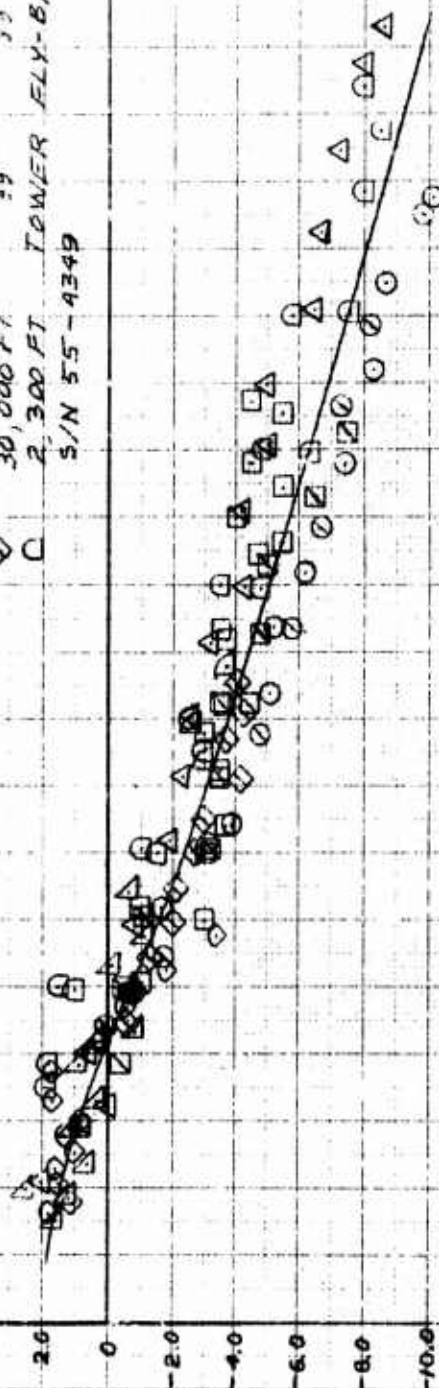


FIGURE NO. 32
AIRSPEED POSITION ERROR CALIBRATION
STANDARD AIRSPEED SYSTEM
CRUISE CONFIGURATION
T-33A USAF SIN 52-9846

ALTITUDE	METHOD OF CALIBRATION
2300 FT	TOWER FLY-BY
5000 FT	STABILIZED FACE WITH T-28
10000 FT	" " T-28
10000 FT	" " F-77
10000 FT	" " T-33
10000 FT	" " F-104
20000 FT	" " T-33
20000 FT	" " F-104
30000 FT	" " T-33
23000 FT	TOWER FLY-BY ON T-33A
S/N 55-4349	

CORRECTION TO BE ADDED - ΔV_k - KNOTS



INDICATED AIRSPEED ~ KNOTS

FIGURE NO. 3²
AIRSPEED POSITION ERROR (ALIGATION
STANDARD AIRSPEED SYSTEM
7-33A USAF NO 52-9846
CONFIGURATIONS AS NOTED

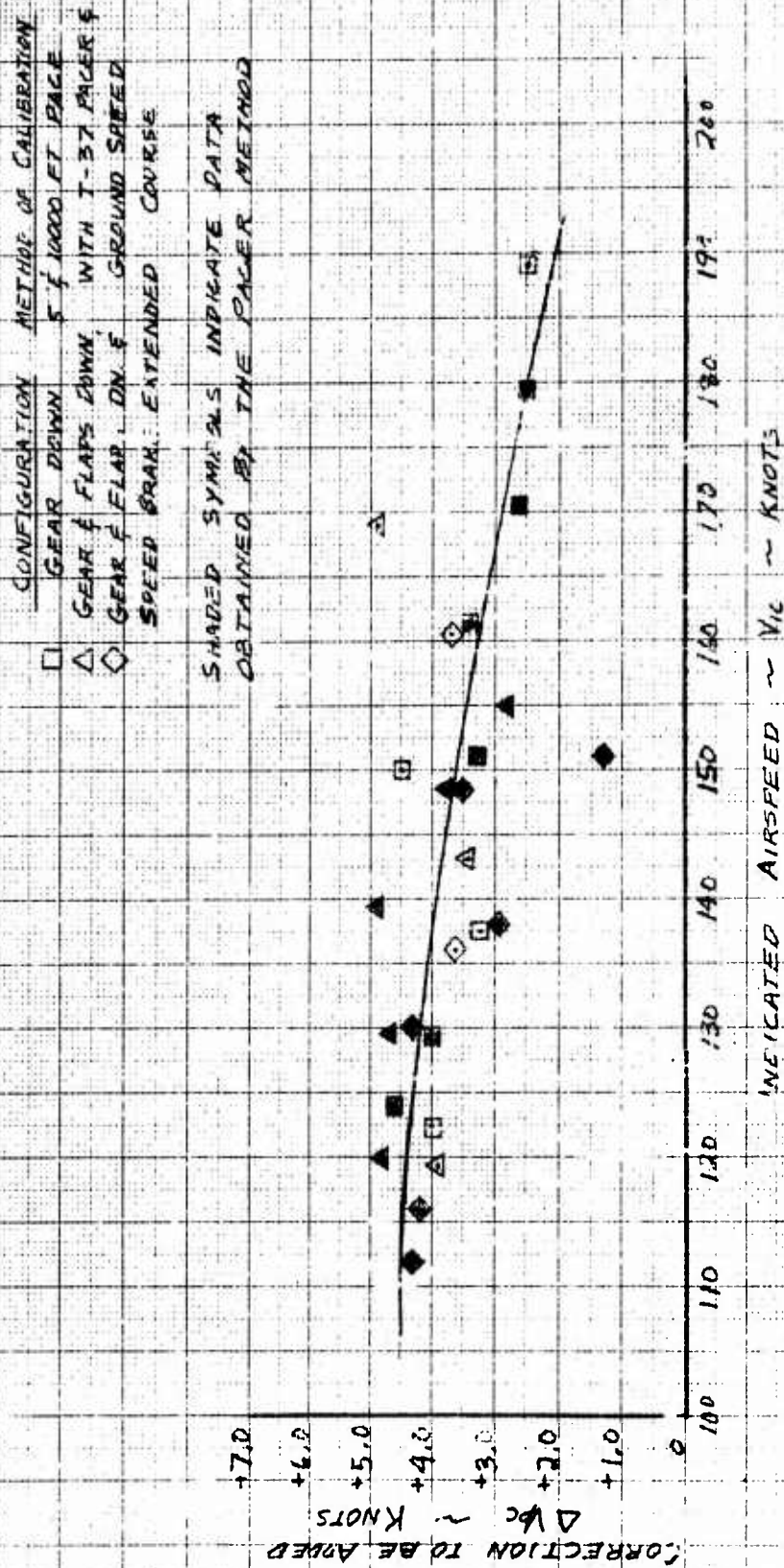


FIGURE NO 34
AIRSPEED CALIBRATION IN GROUND EFFECT
T-33A AIRCRAFT

DATA OBTAINED FROM TAKEOFF AND LANDING TESTS

- T-33A S/N 52-9846 TAKEOFF
- ⊙ T-33A S/N 52-9846 LANDING
- △ T-33A S/N 51-8954 TAKEOFF
- ⊡ T-33A S/N 51-8954 LANDING

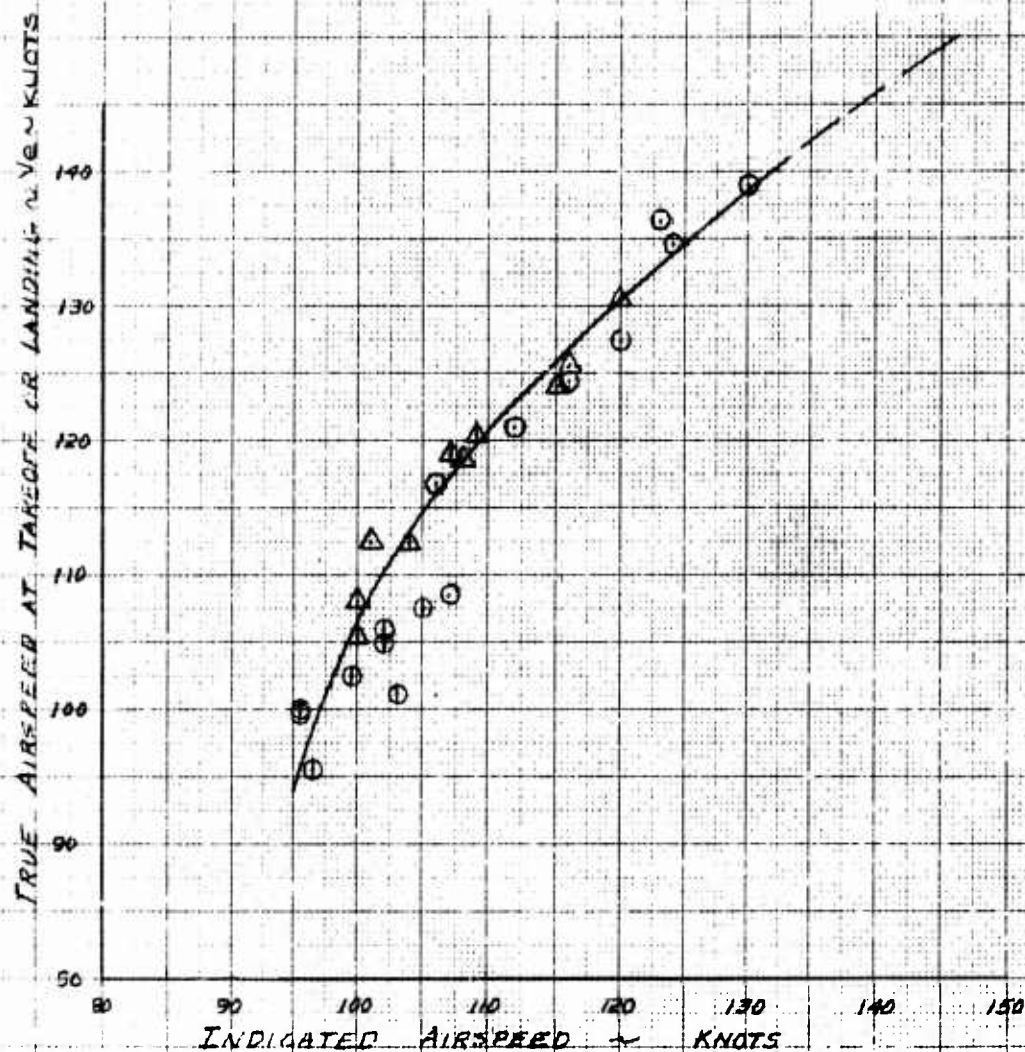


FIGURE NO. 35
 LANDING PERFORMANCE
 T-3A AIRCRAFT
 SEA LEVEL
 AVERAGE WEIGHT 11500 LBS.

SHAPED SYMBOL INDICATES HANDBOOK DATA
 X INDICATES LANDINGS WITH FLAPS RETRACTED
 AFTER TOUCH DOWN

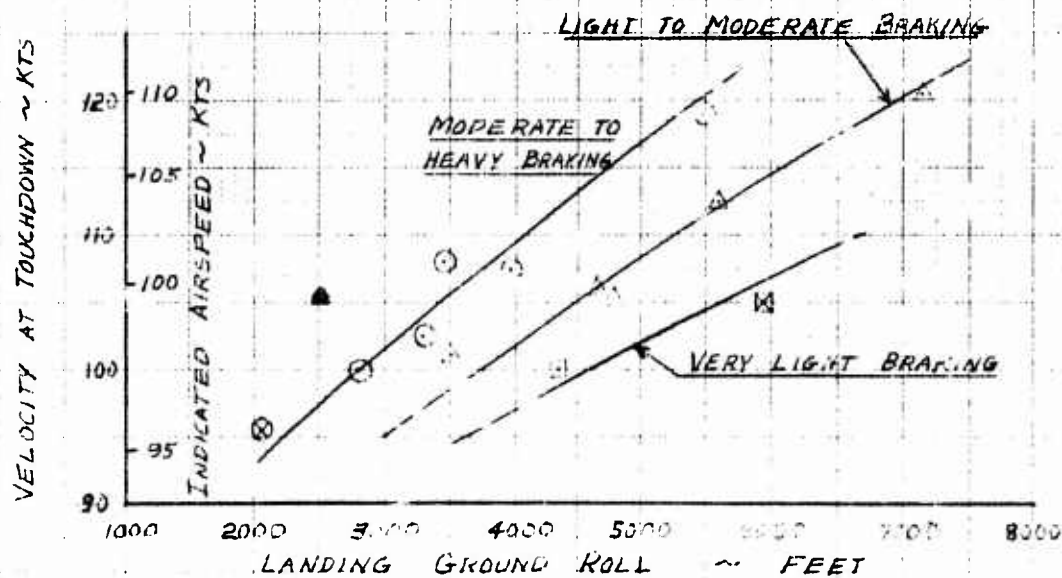
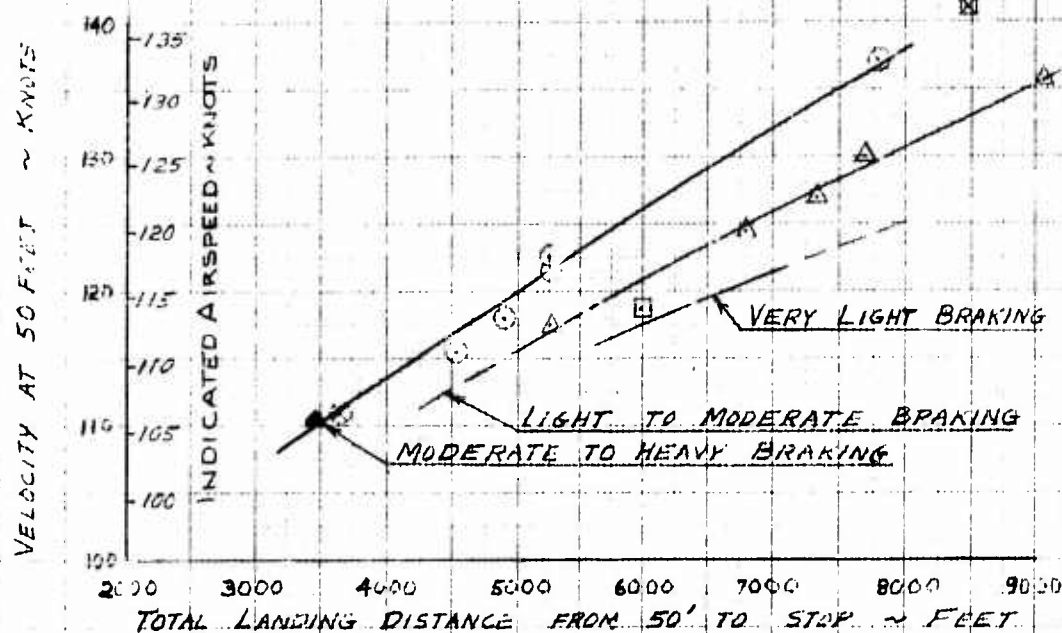


FIGURE NO 36

LEVEL FLIGHT PERFORMANCE

CORRECTED ENGINE SPEED VS CORRECTED FUEL FLOW

T-33A USAF S/N 52-9846

J33-A-35 ENGINE S/N A-080053

POWER FOR LEVEL FLIGHT

2-230 GAL TPTANKS INSTALLED

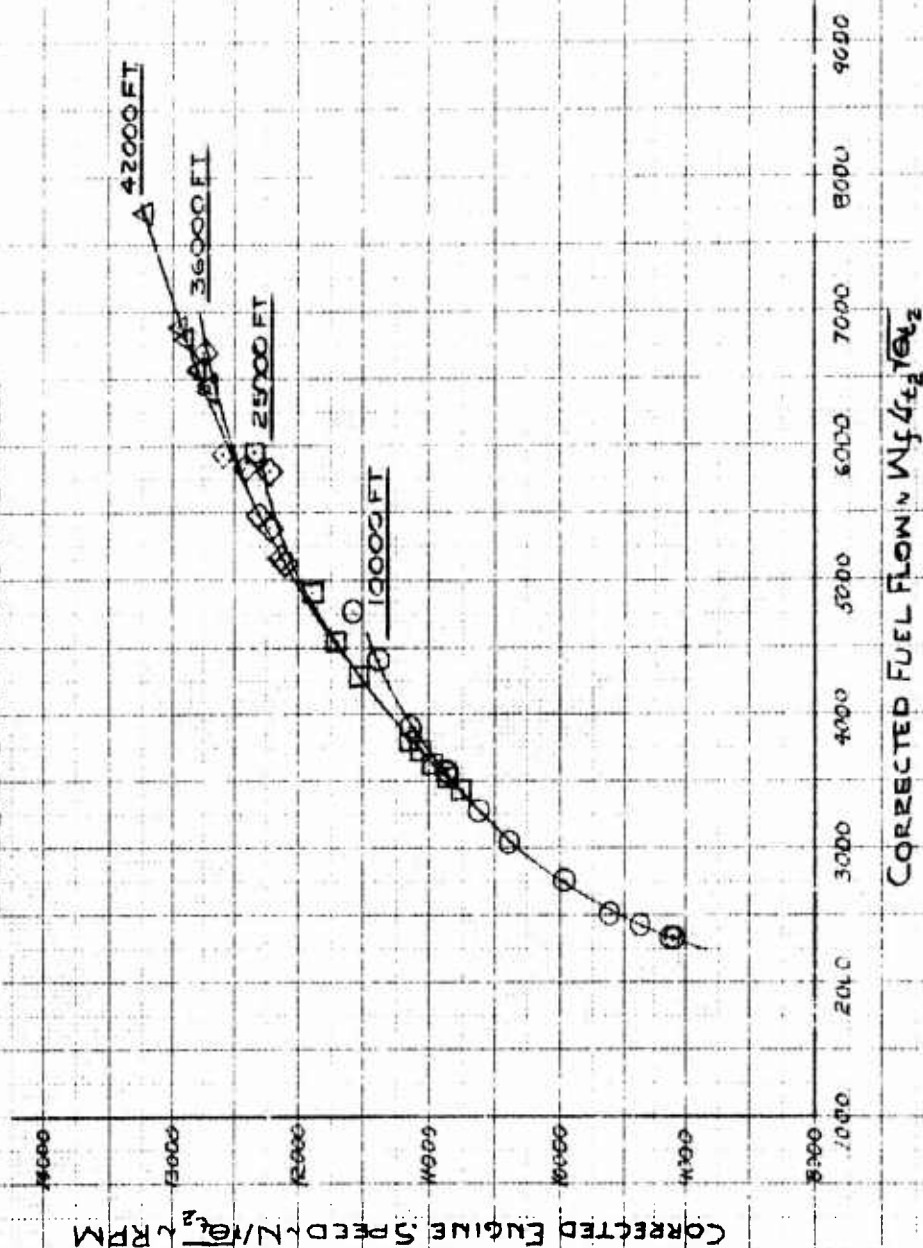


FIGURE No 37
LEVEL FLIGHT PERFORMANCE
CORRECTED EXHAUST GAS TEMPERATURE
VS

CORRECTED ENGINE SPEED
T-33A USAF S/N 52-9846
J-33-A-35 ENGINE S/N A-080033
POWER FOR LEVEL FLIGHT
2-230 GAL TIPTANKS INSTALLED

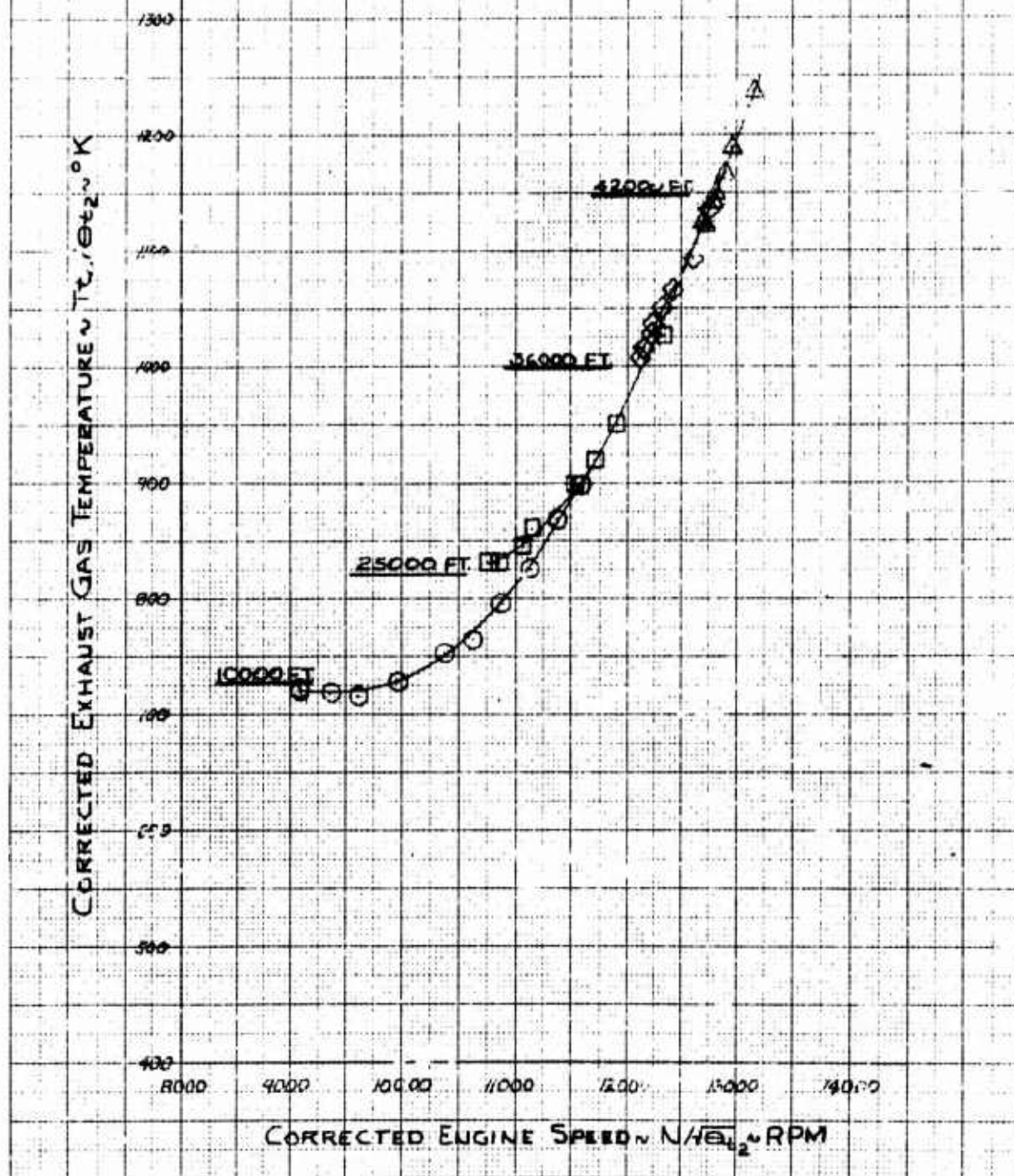


FIGURE No. 38

LEVEL FLIGHT PERFORMANCE

CORRECTED ENGINE SPEED VS CORRECTED FUEL FLOW
T-33A USAF S/N 52-9846

J33-A-35 ENGINE S/N A-080033
POWER FOR LEVEL FLIGHT

TRAVEL POD AND 2-230 GAL TPTANKS INSTALLED

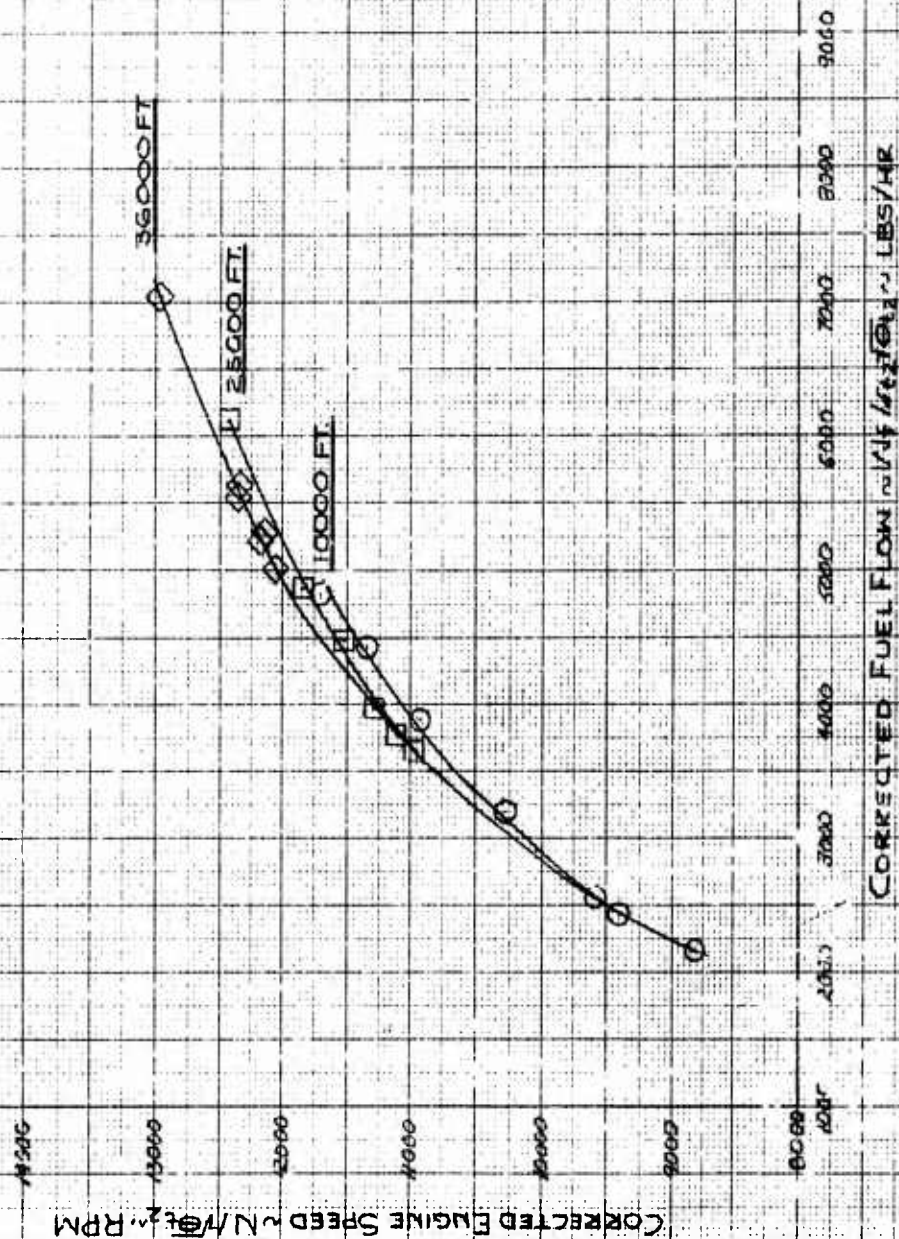


FIGURE NO. 39
 LEVEL FLIGHT PERFORMANCE
 CORRECTED EXHAUST GAS TEMPERATURE
 VS
 CORRECTED ENGINE SPEED
 T33A USAF NO. 52-9846
 J33-A-35 ENGINE S/N A-080033
 POWER FOR LEVEL FLIGHT
 TRAVEL POD AND 2-230 GAL. TIP TANKS INSTALLED

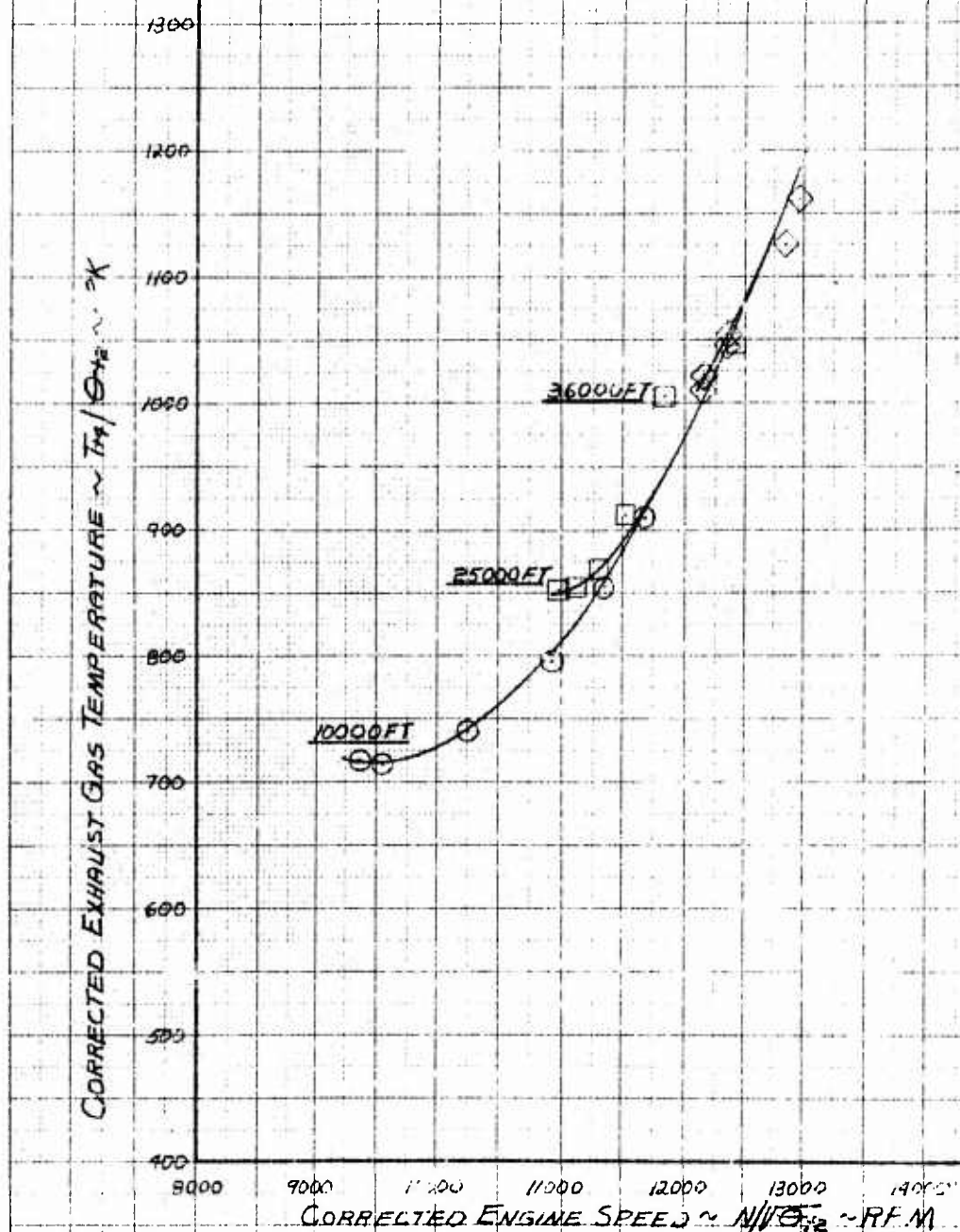


FIGURE NO. 40
 LEVEL FLIGHT PERFORMANCE
 CORRECTED ENGINE SPEED VS CORRECTED FUEL FLOW
 T33A USAF NO 51-8964
 J33-A-35 ENGINE SN A-085176
 POWER FOR LEVEL FLIGHT
 2-230 GAL TIA TANKS INSTALLED

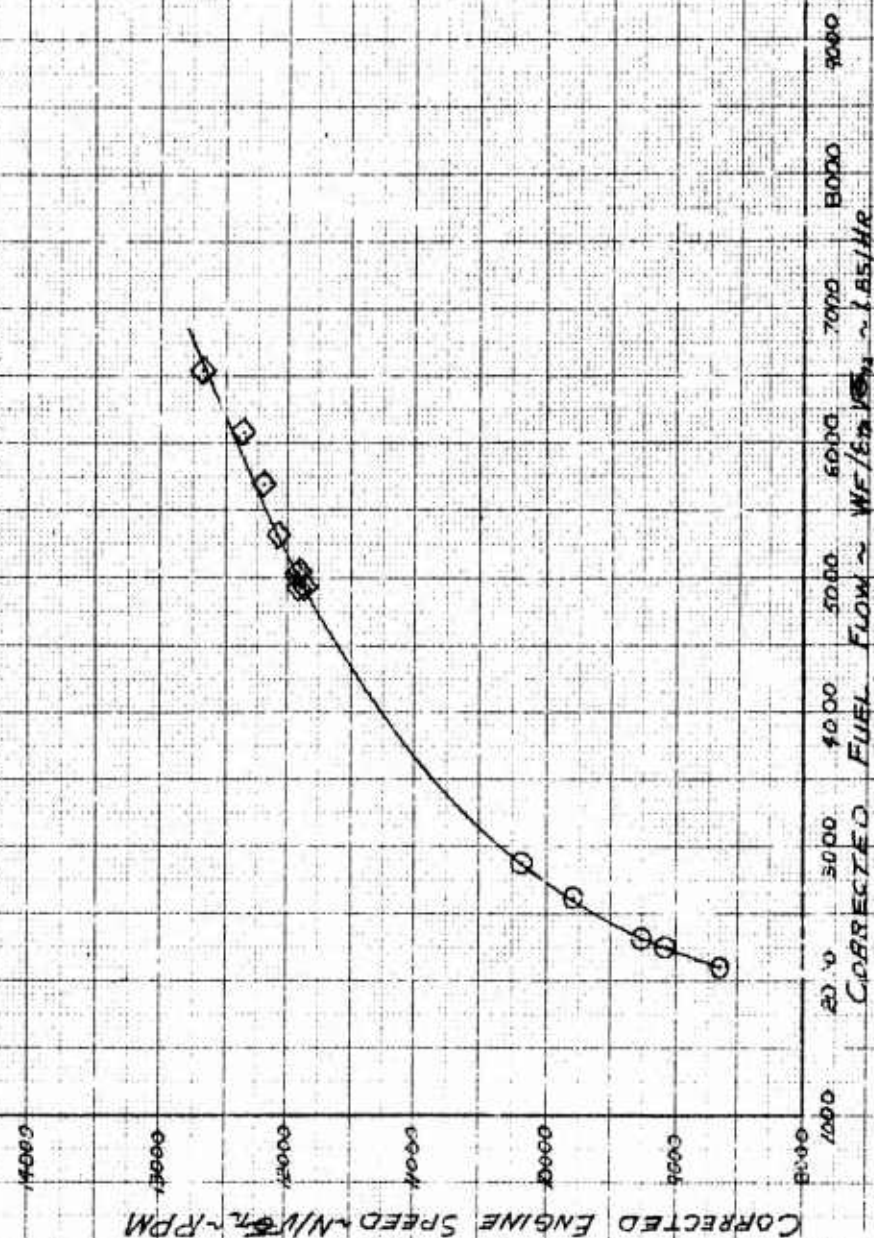


FIGURE NO. 41
 LEVEL FLIGHT PERFORMANCE
 CORRECTED EXHAUST GAS TEMPERATURE
 VS
 CORRECTED ENGINE SPEED
 T-33A USAF NO 51-8954
 J33A-35 ENGINE S/N A-095176
 POWER FOR LEVEL FLIGHT
 2-230 GAL. TIP TANKS INSTALLED

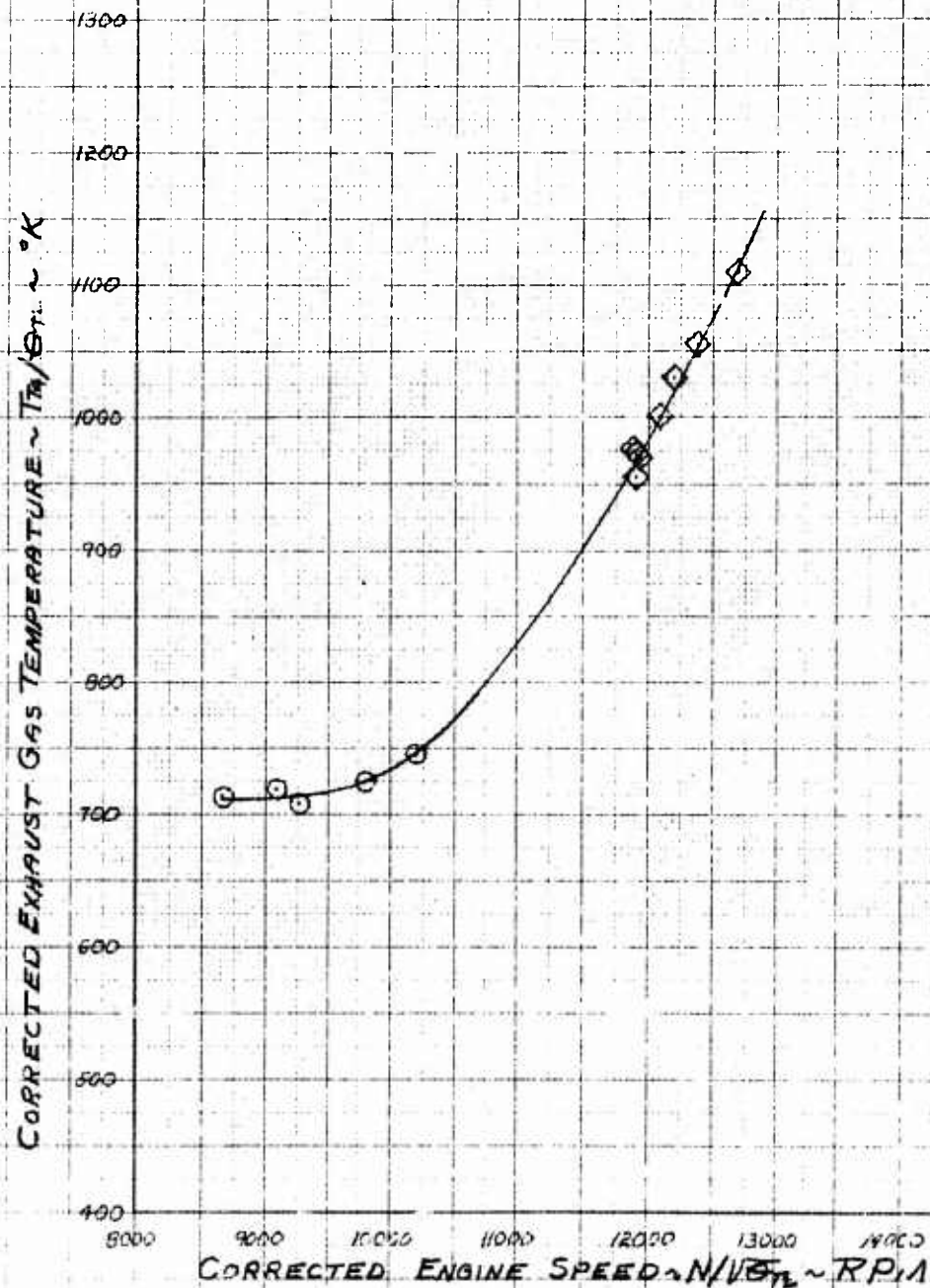


FIGURE NUMBER 4-2
INLET PRESSURE RECOVERY
F-33A-5 AIRCRAFT
J33-A-75 ENGINE

DATA OBTAINED FROM LOCKHEED AIRCRAFT CO.

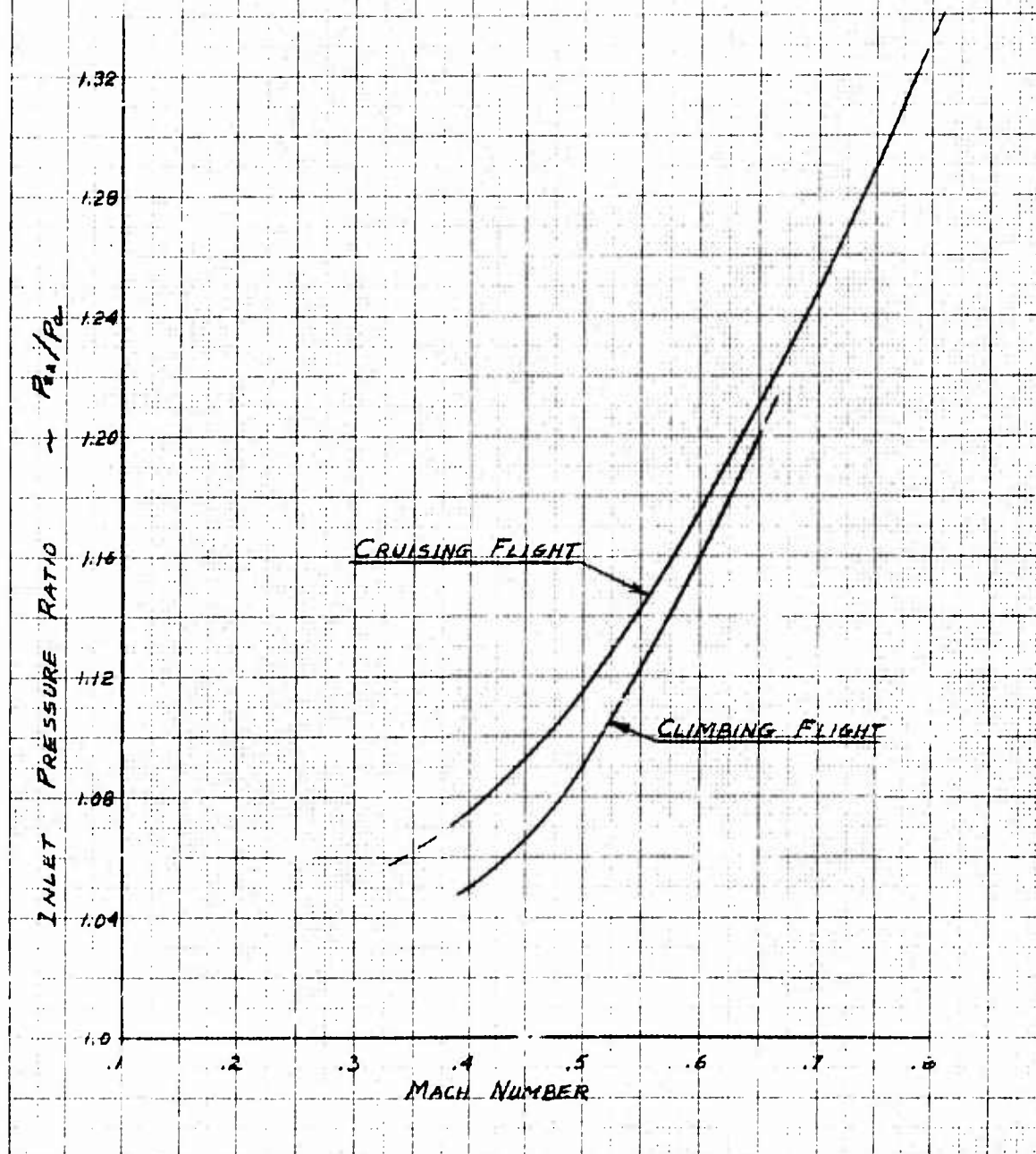


FIGURE No. 43
FUEL PRESSURE CALIBRATION
T-33A AIRCRAFT
J 33-A-35 ENGINE

NOTE: DATA OBTAINED DURING STATIC THRUST
CALIBRATIONS ON SEVEN DIFFERENT
T-33A AIRCRAFTS

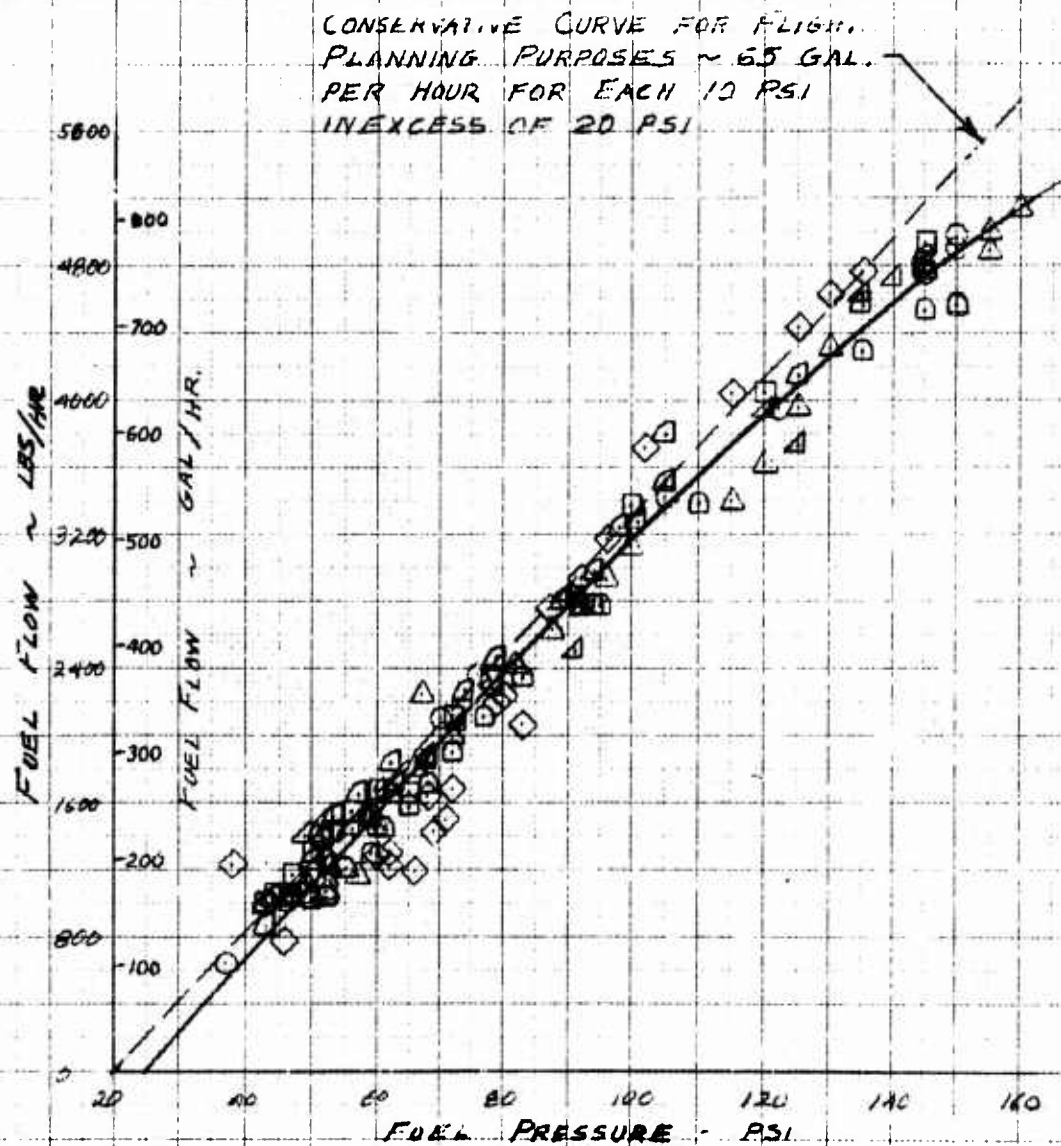


FIGURE NO. 44
EXHAUST GAS TEMPERATURE CALIBRATION
T-33A-5 AIRCRAFT
T-33-A-35 ENGINE

NOTE: DATA OBTAINED DURING STATIC THRUST CALIBRATIONS
ON SEVEN DIFFERENT T-33A AIRCRAFTS

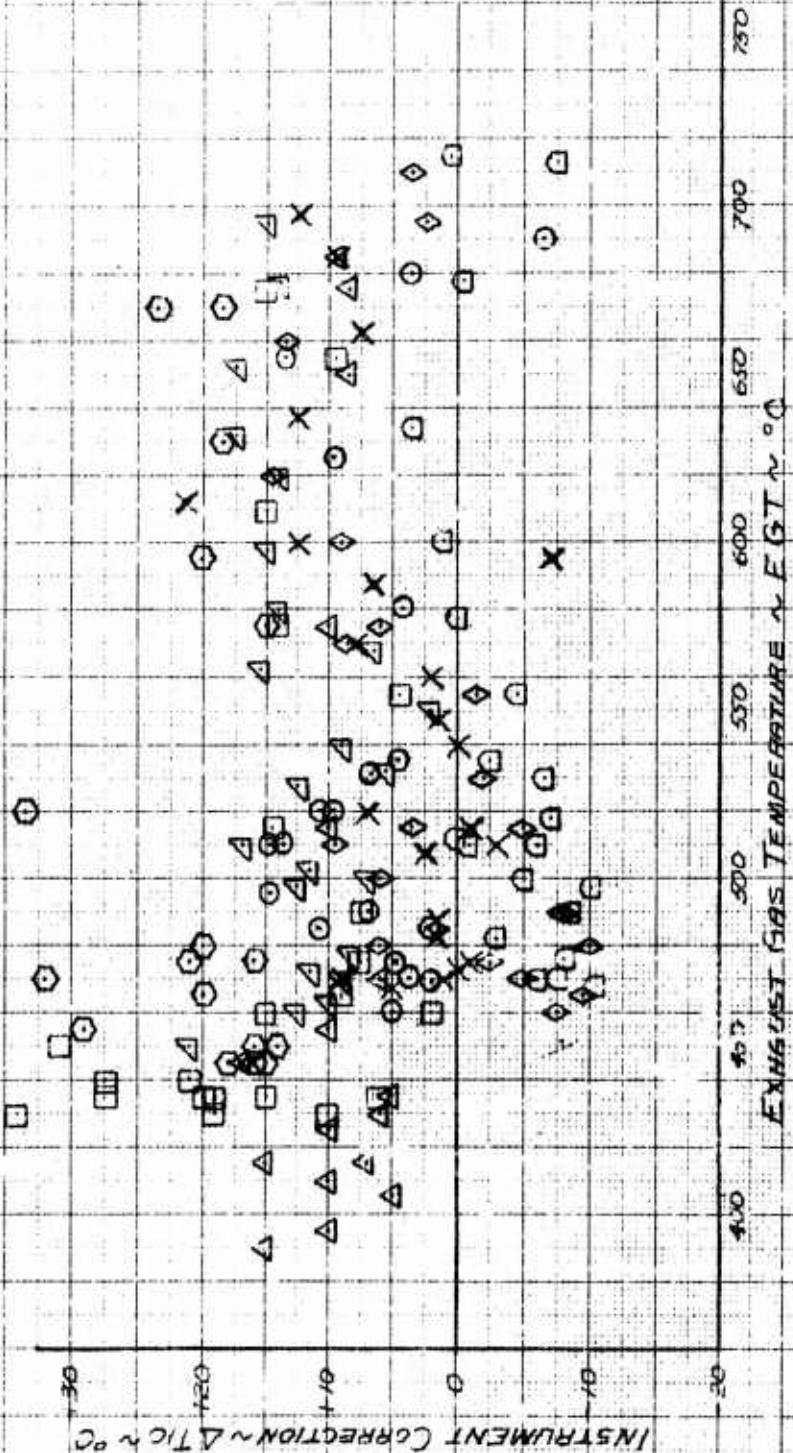


FIGURE No. 45
 T-33A USAF S/N 52-9846
 ENGINE TIME SINCE OVERHAUL 66 HOURS
 UNINSTALLED THRUST AT OVERHAUL 4890 LBS
 NOZZLE DIAPHRAM AREA 122.1 SQ. IN.
 J-33-A-35 ENGINE S/N A-030033

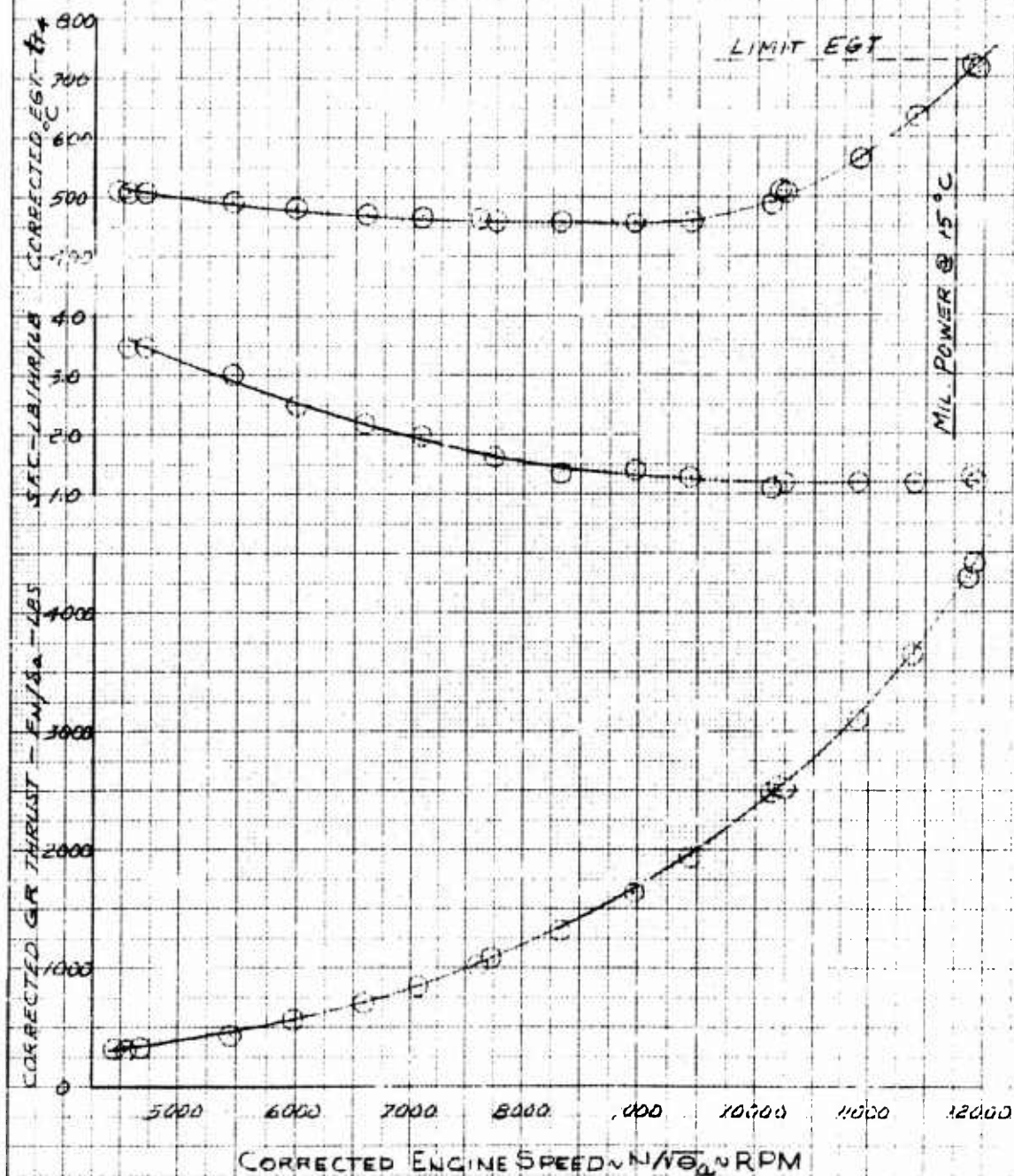


FIGURE NO. 46
 STATIC THRUST CALIBRATION
 T-33A USAF S/N 51-8954
 J-33-A-35 S/N A-085176
 ENGINE TIME SINCE OVERHAUL 269 HOURS
 UNINSTALLED THRUST AT OVERHAUL 4632 LBS
 NOZZLE DIAPHRAM AREA 120.8 SQ IN.

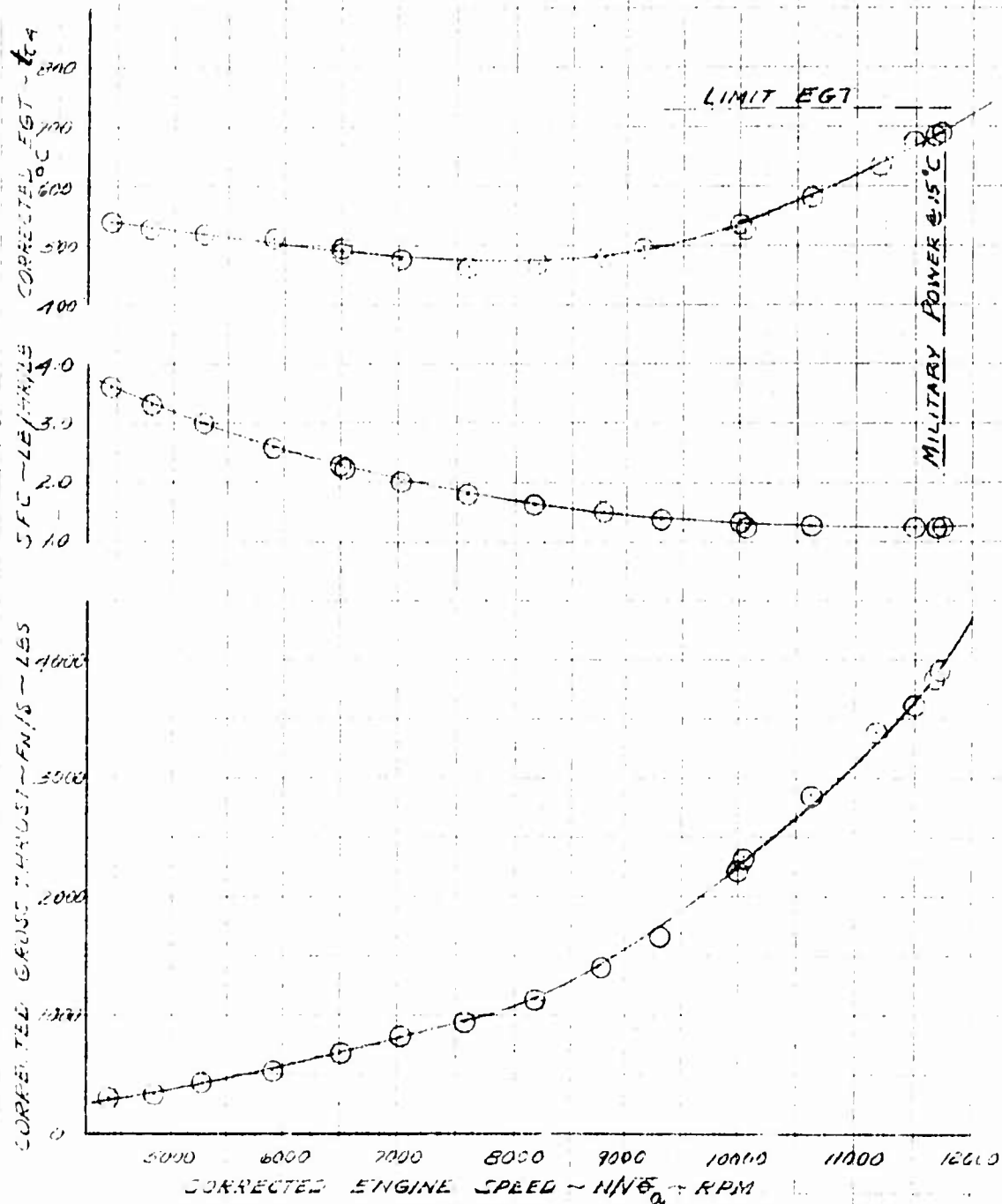


FIGURE No. 47
 STATIC THRUST CALIBRATION
 T-33A USAF S/N 52-9241
 J33-A-35 S/N A-064328
 ENGINE TIME SINCE OVERHAUL 79 HOURS
 UNINSTALLED THRUST AT OVERHAUL 4766 LBS
 NO NOZZLE DIAPHRAM INFORMATION

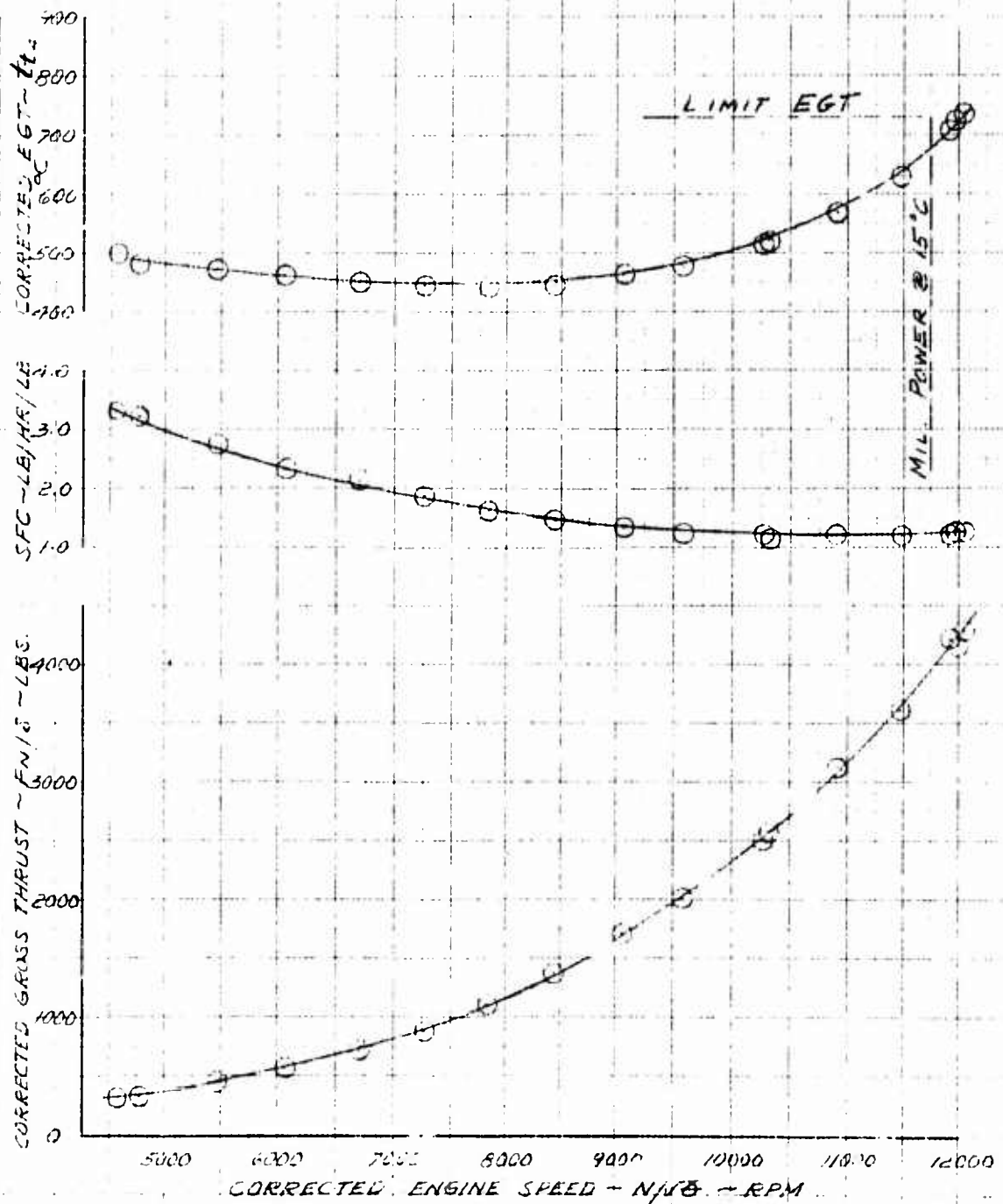


FIGURE No. 48
 STATIC THRUST CALIBRATION
 T33A USAF S/N 53-5541
 J-33-A-35 S/N A-079995
 ENGINE TIME SINCE OVERHAUL 197 HOURS
 UNINSTALLED THRUST AT OVERHAUL 4683 LBS
 NOZZLE DIAPHRAM AREA 119.5 SQ IN.

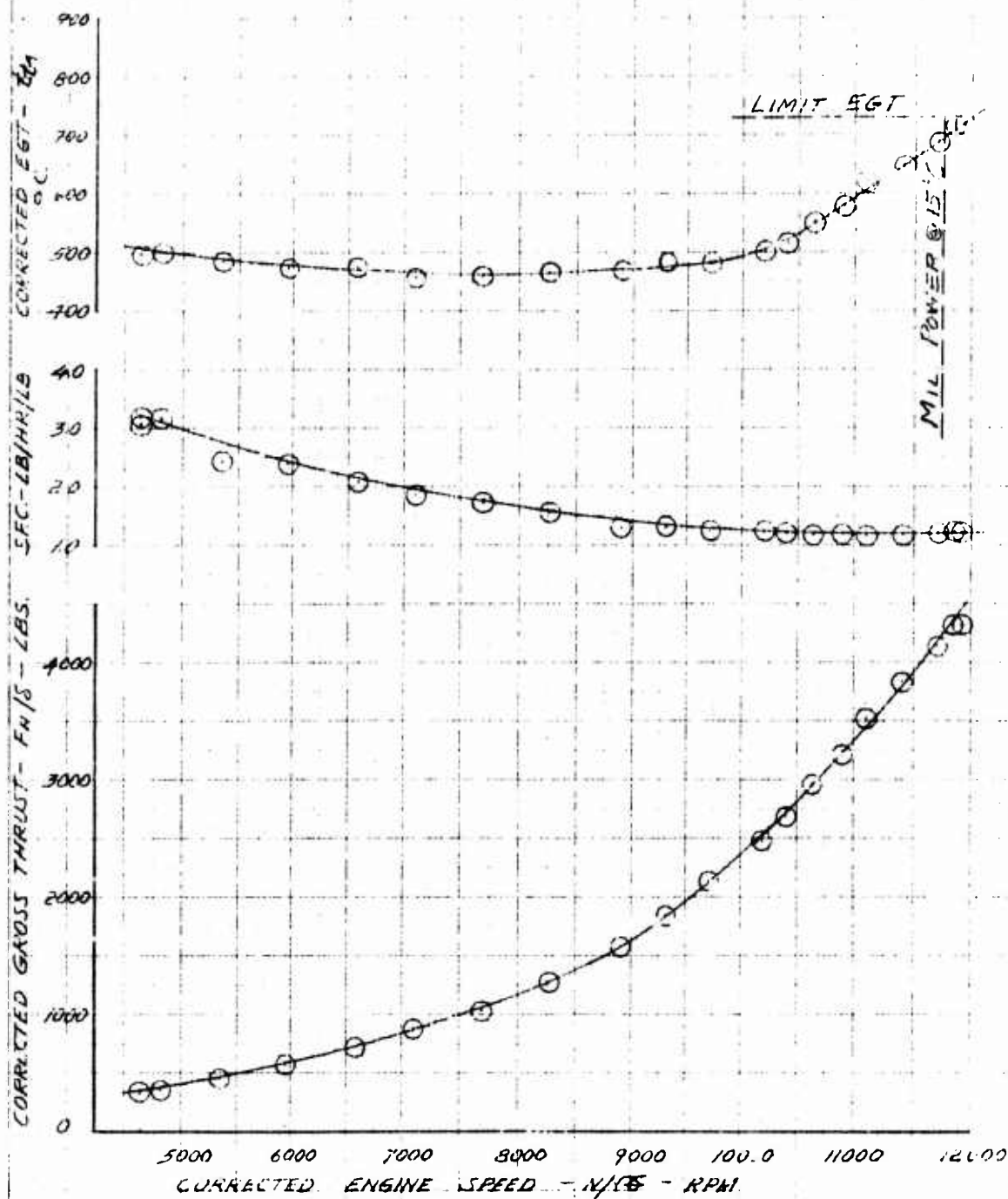


FIGURE No. 49
 STATIC THRUST CALIBRATION
 T-33A USAF S/N 52-6121
 J-33-A-35 S/N A-080110

ENGINE TIME SINCE OVERHAUL 254 HOURS
 UNINSTALLED THRUST AT OVERHAUL 4804 LBS
 NOZZLE DIAPHRAM AREA NOT AVAILABLE

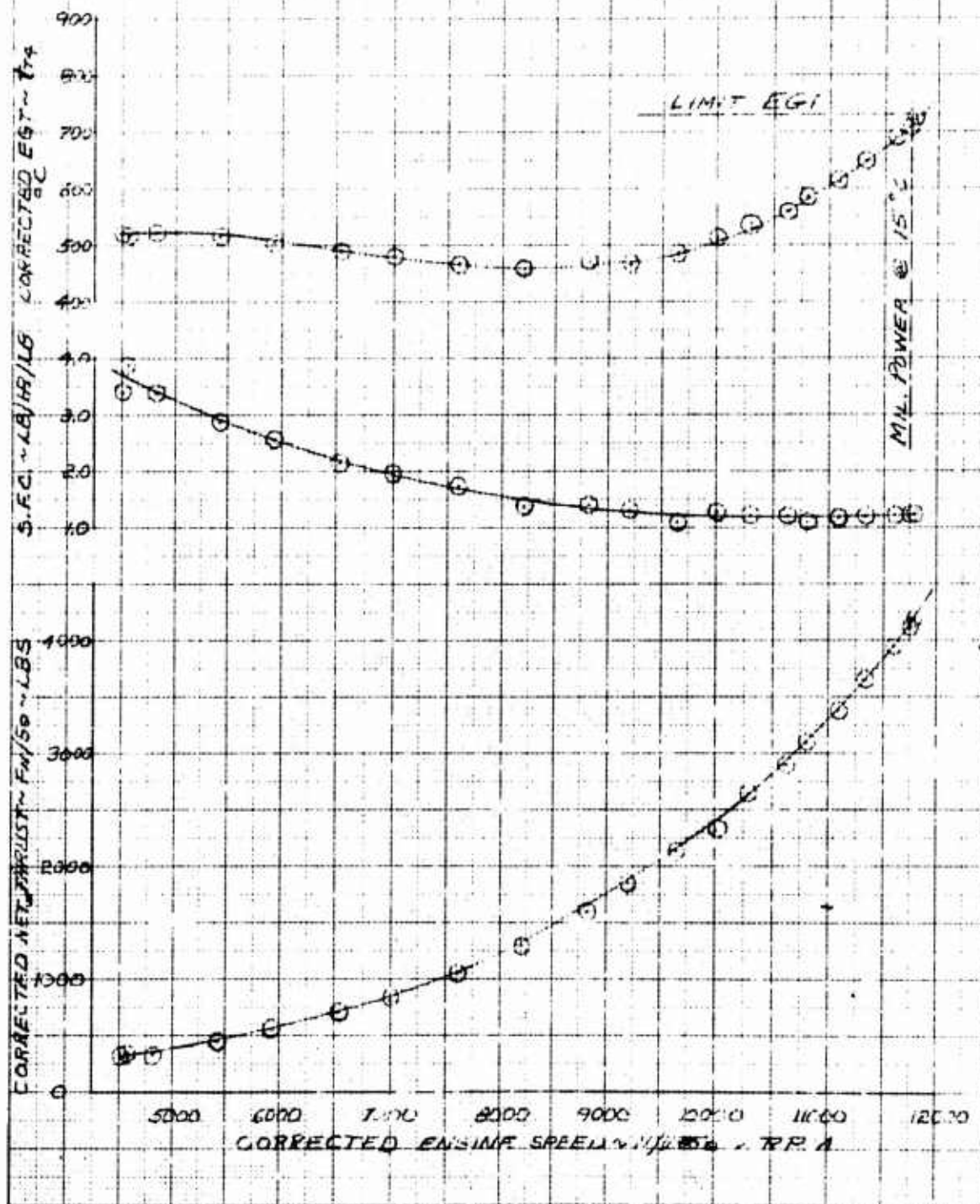


FIGURE No. 50
 STATIC THRUST CALIBRATION
 T-33A USAF S/N 55-4349
 J33-A-35 S/N A-084632
 ENGINE TIME SINCE OVERHAUL 326 HOURS
 UNINSTALLED THRUST AT OVERHAUL 4697 LBS
 NOZZLE DIAPHRAM AREA 120.5 SQ. IN.

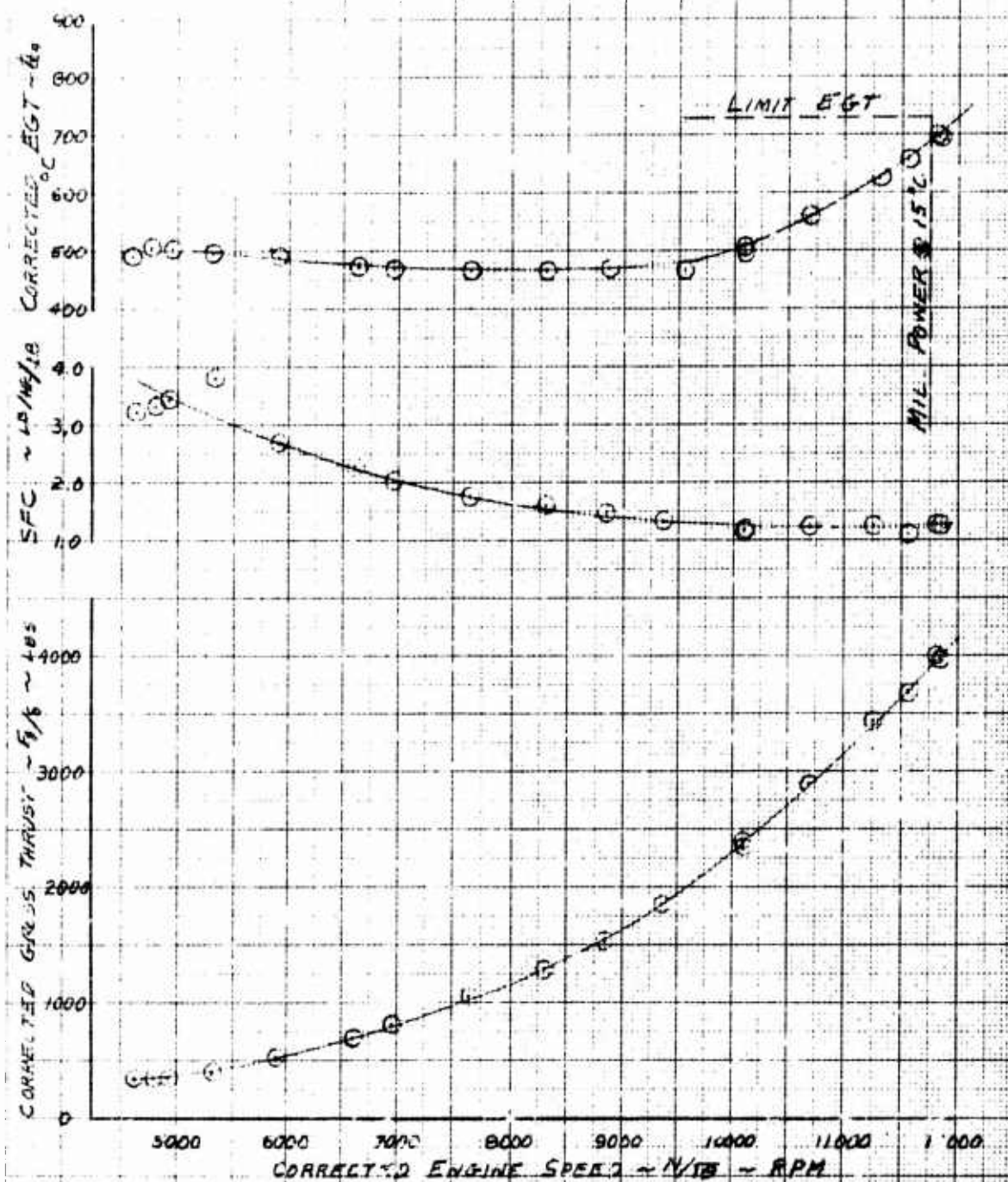
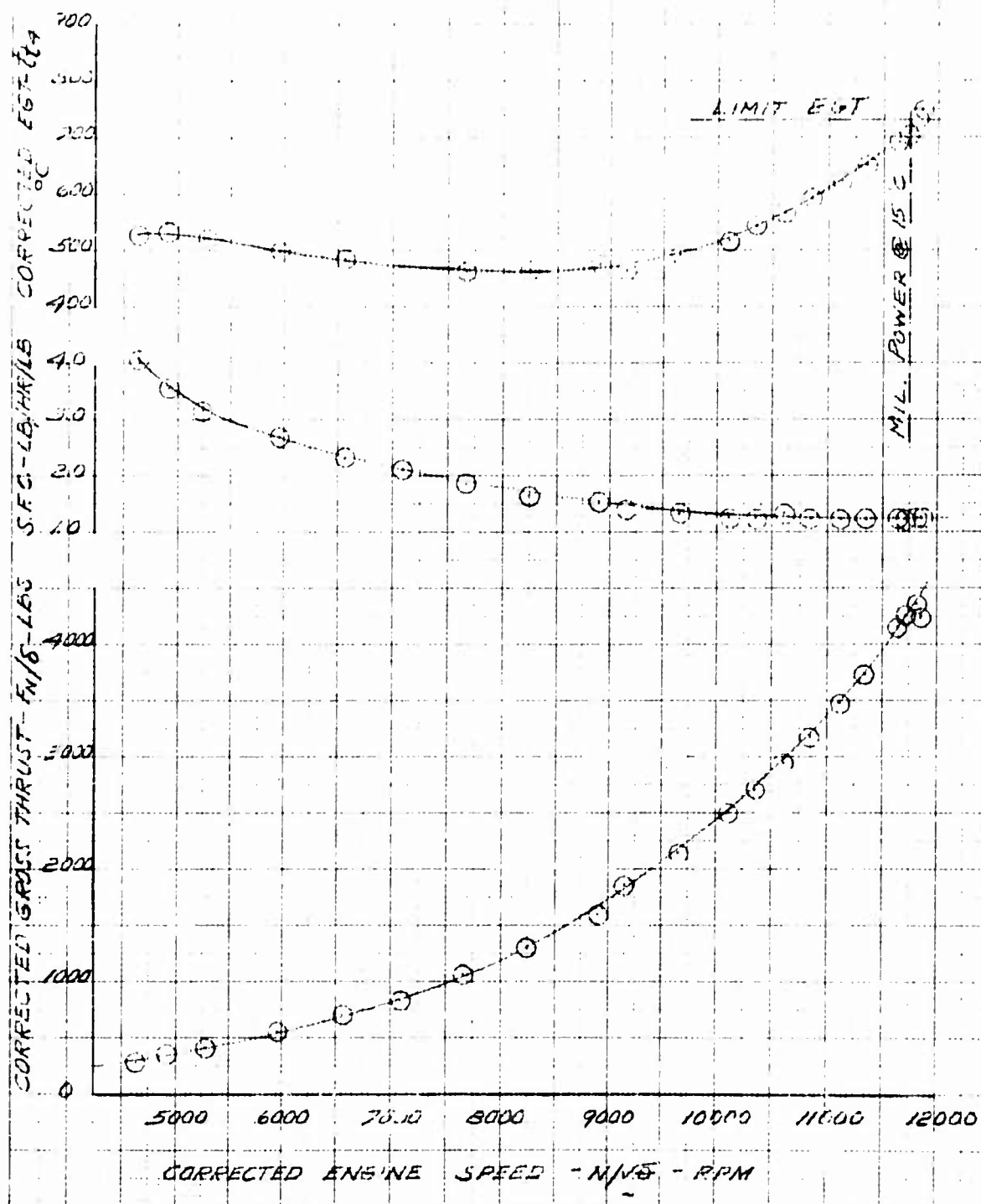
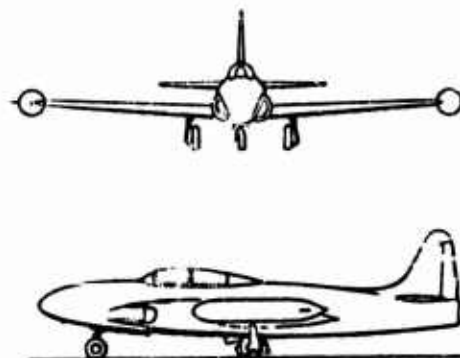
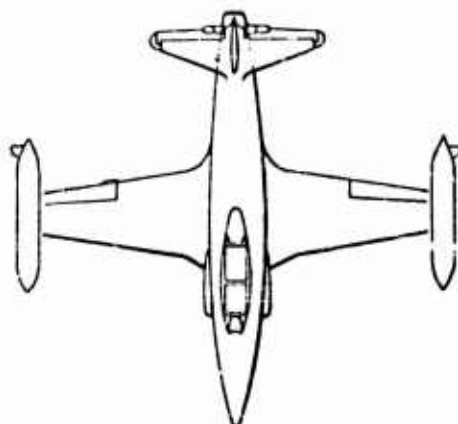


FIGURE NO. 51
 STATIC THRUST CALIBRATION
 T-33A USAF S/N 57-0549
 J33-A-35 S/N A-082939
 ENGINE TIME SINCE OVERHAUL 76 HOURS
 UNINSTALLED THRUST AT OVERHAUL 4927 LBS.
 NOZZLE DIAPHRAM AREA 122.86 SQ IN.





APPENDIX II

aircraft dimensions and design data:

General:

Length	37.72 ft
Height	11.67 ft
Span	37.54 ft
Tread	8.75 ft

Span, one flap	8.47 ft
Mean chord	1.81 ft
Deflection limit	45 degrees

Wing:

Area	234.8 sq ft
Span	37.54 ft
Aspect ratio	6.00 with tip tanks
Taper ratio	2.63
Dihedral	+3 degrees 49.8 min
Incidence root	+1 degree 0 min
Incidence tip	-0 degree 30 min
Airfoil section	NASA 65-213, $\alpha = 0.5$
MAC	80.6 in

Ailerons:

Total area including trim tabs	17.5 sq ft
Left trim tab area	0.46 sq ft
Right trim tab area	0.48 sq ft
Aileron total travel	± 20 degrees from horizontal
Aileron trim tab travel from trailing edge	± 20 degrees from horizontal

Speed Brakes

Total area	5.8 sq ft
Deflection	60 degrees ± 3 degrees or 45 degrees ± 3 degrees (depends on series of aircraft)

Wing Flaps:

Type	Split
Area, total	30.7 sq ft

■ **no asymmetric deflection
more than 4 degrees**

Horizontal Tail

Total area	45.5 sq ft
Span	15.7 ft
Elevator area including tabs	8.7 sq ft
Trim tab total area	0.55 sq ft
Spring tab total area	0.57 sq ft
Elevator deflection range	+26 degrees -16 degrees

Trim tab deflection range

1. From T. E. elevator	+20 degrees 20 minutes
2. From T. E. elevator	-25 degrees up
Spring tab deflection range	+10 degrees -22 degrees

Airfoil section NASA 65, 2-010
Symmetrical Section

Vertical Tail

Total area	22.5 sq ft
Rudder area including trim tab	5.3 sq ft
Total deflection	±30 degrees

Airfoil section NASA 65, 2-010
Symmetrical Section

Operating Limitations

1. **LOAD FACTORS**

2-230 gal centerline tip tanks	
Symmetrical pullout	Rolling pullout
+7.33g	+4.8g
-3.00g	

No tip tanks

Symmetrical pullout	Rolling pullout
+8.00g	+5.33g
-3.00g	

2. *Maximum Speeds*

With or without 2-230 gallon centerline tip tanks and/or
travel pod.
505 knots IAS or Mach 0.80 whichever is lower.

3. *Additional Limitations*

No intentional inverted spins
No intentional erect spin with gear and flaps down

No intentional erect spins with tip tanks removed or with
tip tanks installed and containing fuel.
Rate of roll limit—158 degrees per second with 2-230
gallon centerline tip tanks installed.

4. *Landing Gear*

Operation and down and locked—195 kts

5. *Flaps*

45 degrees down—175 kts

6. C. G. limits +23.8 percent to +32.0 percent MAC with
tip tanks installed +23.0 percent to +32.0 percent MAC
without tip tanks.

■ **flight control system**

Longitudinal control is provided by the elevator
which is powered by direct linkages to the control
stick in each cockpit. The elevator is divided into
two sections, one on each side of the rudder, and
is interconnected by a bar linkage. Spring tabs on
each side of the elevator are utilized to reduce the
longitudinal stick forces. Trim tabs on each elevator
section are electrically operated. The total elevator
deflection available is 26 degrees up and 16 degrees
down from neutral.

Lateral control is provided by hydraulic boosted
ailerons. The boost system reduces the stick forces
required by 1/15 that utilizing the Manual System.
Manual operation of the ailerons is available in
case of a malfunction of the hydraulic system. The
aileron trim system incorporates an electrically ac-
tuated tab on the left aileron and a small ground
adjustable tab on the right aileron. Total aileron
deflection is ± 20 degrees from the neutral position.

A conventional rudder is utilized and is powered
by direct linkages to the rudder pedals in each
cockpit. The rudder trim tab is ground adjustable
only. Total rudder deflection is ± 30 degrees from
the neutral position.

The wing flaps are of a split design and are ac-
tuated by two electric motors that are mechanically
interconnected by a flexible shaft. This feature pro-

vides for flap operation in case one motor fails; however, this unsymmetrical flap deflection causes the aircraft to roll toward the flap with the failed motor.

Two speed brakes, located beneath the rear cockpit, are hydraulically operated. The total deflection available is either 45 degrees or 60 degrees depending on the series of aircraft. The majority of aircraft in the inventory have two position speed brakes, i.e., either opened or closed. Some late model aircraft have continuously variable control allowing braking to be adjusted between full opened and full closed.

■ fuel system

The fuel system consists of a fuselage tank, four wing tanks and two external tip tanks. All wing and tip tanks feed into the fuselage tank which supplies fuel to the engine. The fuselage tank, main wing tanks, and leading edge tanks all incorporate a boost pump to transfer fuel under pressure. The tip tanks utilize engine air to force feed fuel into the fuselage tank. The sequence in which fuel is burned is manually controlled by the pilot by turning the boost pumps and/or pressurization on or off. In case of electrical failure the fuel from the fuselage tank and tip tanks are available for engine operation. Reference page 19.

■ power plant operation

The T-33A aircraft is powered by a J33-A-35 turbojet engine which is manufactured by the Allison Division of the General Motors Corporation. The engine is rated at 4600 pounds at military power (100 percent rpm). When installed in the T-33A this value is reduced by approximately 800 pounds for static conditions. Military power is rated at 11,750 rpm (100 percent) and normal rated power is 11,280 rpm (96 percent).

The engine utilizes centrifugal compression and has a single stage impeller which produces a compression ratio of 4.5 to 1. The compressor and auxiliary equipment is driven by a single stage turbine wheel.

■ weight and balance

Basic weight including 2-230 gallon tip tanks	9637 lbs
Two pilots	430
821 gallons of fuel (at 6.35 lbs/gal)	5213
Engine start weight	15,280
Center of gravity at engine start is 28.8 percent MAC and 25.2 percent MAC when empty.	

■ instrumentation

The test data was recorded by use of a photo panel recorder installed in the nose compartment. Instrumentation used during the program is listed below.

Photo Panel Recorder:

Airspeed indicator
 Altimeter
 Free air temperature indicator
 Tachometer
 Fuel remaining counter
 Stop watch

Cockpit Instruments:

Airspeed indicator
 Altimeter
 Tachometer
 Free air temperature indicator
 Fuel remaining counter
 Exhaust gas temperature indicator

ASTIA DOCUMENT NO. AD

Air Force Flight Test Center
USAF Experimental Flight Test Pilot School
Edwards Air Force Base, California
T-33A Performance Evaluation. By W. G. Schweikhard and
T. P. Stafford, Captain, USAF. May 1961. 91 Pages.
(AFFTC-TR-61-22)

The purpose of this performance test was to evaluate the performance of a representative T-33A aircraft with an average thrust engine and to determine the cause for the variation in performance between aircraft. To this end, the most representative, instrumented T-33A possessed by the USAF Experimental Flight Test Pilot School was selected. For comparison purposes additional tests were performed on an aircraft having a low thrust engine. With a few exceptions the test and Flight Manual performance data compare favorably for the representative aircraft tested. The Flight Manual take-off data is optimistic by 16 to 24 percent, while the descent data examined is pessimistic by approximately 75 percent. The

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Flight Manual cruise and climb performance compares favorably at low altitudes, but is slightly optimistic at high altitudes. Insufficient descent and landing data is presented in the Flight Manual.

The greatest cause of thrust variation is not attributed to the deterioration of the engine with service life, but rather, to the broad thrust limits allowed after overhaul of the engine and to variations of trim rpm in flight. Low exhaust gas temperatures (below 685 degrees C) may indicate a low thrust engine; however, positive correlation of this point was not established.

As a result of the qualitative investigation, it is recommended that the sidestep restrictions for the aircraft with travel pod installed be the same as for the aircraft with tip tanks installed.

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