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REPORT OF USATECOM PROJECT NO. 4-4-0240-02
FLIGHT EVALUATION OF THE T63-A-5 TURBO SHAFT ENGINE INSTALLED IN A UH-13R HELICOPTER

January 1964

Project Engineer	Project Pilot
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SUMMARY

This report presents the results of a 12.5 hour flight evaluation of the T63-A-5 turbo shaft engine installed in a modified UH-13R helicopter. This flight program was conducted during the period of 2 December 1963 through 18 December 1963 at the engine manufacturer's flight test facility in Indianapolis, Indiana.

Test results from climb, level flight, power and autorotational descents revealed that the T63-A-5 engine was generally satisfactory in all steady-state flight conditions.

Quantitative and qualitative test data obtained during transient flight conditions revealed that engine acceleration time from flight idle power settings from 70 percent and above to military power is satisfactory at all altitudes. Engine acceleration time from a flight idle setting less than 70 percent was unsatisfactory. Also, the engine acceleration characteristics are unsatisfactory at all altitudes and power settings. The acceleration rate varied excessively from a very low rate of acceleration (lag) at the initiation of the power application to a very high rate of acceleration at the termination of the power application. In addition, the change in rate of acceleration occurred within a very short period of time (approximately one second).

The standard fuel control and power turbine governor combination installed on the test engine was unsatisfactory. Entry into autorotation and rapid decelerations above 14,000 feet were not possible because of design limitation of these controls. Rapid decelerations and attempts to enter into autorotation above 14,000 feet caused the power turbine speed to quickly exceed its maximum limit. Another design limitation of the fuel control makes it difficult to achieve realistic autorotational landings. The ground idle gas producer (N_1) speed of 62 percent is too high. At this N_1 speed the engine is producing approximately 30 residual horsepower. Application of the collective pitch to effect the autorotational landing permits this residual horsepower to be transmitted to the rotor.

Identification photo not available at time of publication.

PART I - GENERAL

REPORT OF
USATECOM PROJECT NO. 4-4-0240-02
FLIGHT EVALUATION OF THE T63-A-5 TURBO SHAFT ENGINE INSTALLED IN A UH-13R HELICOPTER

A. REFERENCES

A list of references will be found in Part III, Annex A.

B. AUTHORITY

1. Test Directive

The test directive was received by message AMCPM-LHT-11-1108, dated 20 Nov 1963. This message constituted authority to conduct approximately 20 hours of flight testing on the UH-13R helicopter equipped with a T63-A-5 engine.

2. Purpose of Test

The precise purpose of this program was to obtain information from Army test pilots on the operation of the T63-A-5 engine accompanied by engineering documentation of the results. This was to be accomplished in accordance with the approved plan of test presented in Annex D, Part III and the following areas outlined in the test directive:

a. Evaluation of the high altitude fuel control which is now being developed.

b. Evaluation of engine acceleration time at varying flight idle settings.

c. Evaluation of the inability to obtain zero horsepower during autorotation.

C. DESCRIPTION OF MATERIEL

1. Engine

The T63-A-5 engine is a free turbine, turbo shaft power plant being developed for the U. S. Army's Light Observation Helicopter (LOH).

The gas producer section is composed of a combination six stage axial flow-one stage centrifugal flow compressor directly coupled to a two stage gas producer turbine. The power turbine section is composed of a two stage free turbine which is gas coupled to the gas producer turbine. The engine contains an integral reduction gear box which provides an integral spline output drive at the front of the gear box. The engine has a single combustion chamber.

2. Helicopter

The UH-13R is a two-blade, single rotor, skid type, four passenger helicopter which had been modified into the UH-13R configuration to serve as a test-bed for the T63 engine development program. Major change to the UH-13R consisted of replacing the standard reciprocating engine with the T63 turbine. Due to the location of the engine power takeoff gearing on the T63, an offset gear box was installed aft of the engine to obtain straight line drive shafting back to the tail rotor. This gear box also reduced shaft speed in accordance with tail rotor requirements. Engine and main transmission mounts were modified to accommodate the test engine and the relocated transmission. Modified mounts were constructed of tubular steel. Dynamic components (i.e., main rotor head and blades and the tail rotor blades) were not modified.

The cabin of the UH-13R was standard except that two of the three rear seats were removed for test instrumentation and various cockpit engine controls were modified to accommodate turbine engine operation.

D. BACKGROUND

The U. S. Army is presently preparing to evaluate three light observation helicopters which will be powered by the T63-A-5 turbo shaft engine. The U. S. Army Materiel Command requested the U. S. Army Test and Evalution Command to conduct a flight evaluation of the T63-A-5 engine installed in the UH-13R helicopter.

E. TEST OBJECTIVES

The primary purpose of this program was to obtain U. S. Army test pilot comments with engineering documentation of the T63-A-5 engine operating characteristics before the start of the LOH evaluation. This was to be accomplished by utilizing the plan of test originally written for the evaluation of the T63/T65 engines (see Annex D, Part III). The test directive authorized approximately 20 hours of flight time. At the start of this program, only 17.5 hours of airframe time remained before an extensive teardown inspection was due on the test helicopter. Another limiting factor which caused this program to be modified was the calendar time remaining before the start of the LOH evaluation. As a result of these two conditions the flight program was shortened to 12.5 hours and approximately 75 percent of the plan of test was accomplished.

F. FINDINGS

1. General

An evaluation of engine handling qualities must include consideration of the airframe in which the engine is installed, since engine handling qualities are directly affected by airframe characteristics. In this evaluation a modified UH-13R was used as a test-bed airframe. It is probable that variations in airframe characteristics between the test-bed airframe and the LOH airframe will produce variations in engine handling characteristics. This evalutation will, therefore, specify those engine handling qualities which would probably be affected by a change in airframe and/or cockpit controls and linkage.

During this evaluation two fuel controls were evaluated. The fuel control to be used on the LOH is referred to in this report as the standard fuel control. One flight was accomplished with a modified fuel control installed. This fuel control was modified internally to permit entry into autorotations at altitudes above 15,000 feet, which was not possible with the standard fuel control. This modified fuel control is referred to in this report as the altitude control.

The test-bed airframe-engine combination did not have provision for installing a power turbine governor electrical beep switch and a collective pitch-power turbine governor coordinator. On the test-bed it was possible to install the electrical beep switch or the coordinator, but not both. To obtain level flight performance data at various power turbine (N_2) speeds it was necessary to install the electrical beep switch. One flight was flown with the coordinator installed to check for N_2 droop characteristics during transient flight conditions.

2. Engine Handling Qualities

Evaluation of engine handling qualities can be divided into two broad areas. In the first area are those qualities associated with steady-state flight conditions during which time the pilot is not manipulating the engine controls (i.e., cruise, continuous climb or descent, etc.). The second area consists of those qualities associated with transient flight conditions during which time the pilot is manipulating the engine controls to produce a desired response. Each engine ground and flight condition evaluated will be discussed relative to the two broad areas outlined above.

a. Starting

The engine starting cycle, using an external electrical power unit, was accomplished with the battery and generator "OFF" and utilizing fuel boost pump pressure. With the collective pitch in the full down position, the throttle was checked in the idle cut-off position and the power turbine (N_2) governor was set at the low speed stop using the electrical beep switch on the collective pitch stick. The engine starter button was then engaged and as engine compressor (N_1) speed accelerated to approximately 15-16 percent, the throttle was rotated to the ground idle detent (30 degree position). Engine light-off was instantaneous and the engine accelerated quickly to a stabilized N_1 speed of 60-62 percent. Throttle was maintained in the ground idle detent; and in accordance with the engine contractor procedures, the starter button remained engaged until the engine had accelerated to 58.5 percent N_1 speed at which time it was disengaged. This procedure was easily accomplished. Primary instruments monitored were the N_1 speed and the turbine outlet temperature (TOT limit is 843 degrees Centigrade for 6 seconds during starting). In this evaluation no excessive TOT readings were observed during engine starts. All engine starts were accomplished with free air temperature below standard-day temperature.

The T63-A-5 engine during the starting cycle has the characteristic of producing a loud tone similar to that emitted by a fog horn. This noise was apparently caused by air column resonance in the compressor discharge scroll and air tube combination. The engine manufacturer has eliminated this noise by connecting a 35 inch length of No. 10 hose to the anti-icing valve port and the accessor bleed port on the compressor scroll. One start was made with this hose disconnected for test purposes and no adverse effects were noticed. The fog horn noise would be disconcerning if it occurred without warning and pilots engaged in flight test of the T63-A-5 engine should be advised of this characteristic.

b. Run-up Characteristics

The external electrical power unit was disengaged after the engine had stabilized at ground idle speed and battery and generator switches were turned "ON". The twist grip throttle was then rotated to the full open position (90 degree position), and the engine was permitted to accelerate to the operating speed range. Because of the small twist grip travel range (90 degrees) and low throttle control force gradient, the pilot had a tendency to open the throttle too rapidly, thereby causing a high rate of engine acceleration which was difficult to control. This was an airframe discrepancy that should be watched for in the LOH evaluation. A twist grip incorporating high control force gradients and large travel range (approximagely 100 degrees) would be desirable.

Following engine stabilization at flight operating speed, the electrical beep switch was then actuated to adjust the power turbine/rotor (N_2 / N_r) speed to the high and low limits of the beep range to assure the adequacy of this range for flight. The beep switch was then actuated to adjust the N_2 / N_r speed to the speed desired for lift-off. Response of N_2 / N_r speed to beep switch actuation was satisfactory but initial lag following actuation of the beep switch made it difficult for the pilot to select precise N_2 / N_r speeds. This also was an airframe discrepancy that may not be present in the LOH models.

Total time for engine start and run-up was approximately two minutes and was satisfactory.

c. Engine Handling Qualities During Lift-off

Engine handling qualities during lift-off were briefly evaluated at the beginning and end of each test flight. Lift-off handling qualities were evaluated using a standard fuel control with only the electrical beep switch installed, a standard fuel control with only the N_2 coordinator installed, and an altitude control with only the electrical beep switch installed. The purpose of the coordinator was to maintain N_2 / N_r speed with a specific pre-selected range. No quantitative data was obtained during lift-off, however the following qualitative observations were made.

(1) Standard and Altitude Control with Electrical Beep Switch

In this configuration lift-off using a nominal rate of collective pitch application was satisfactory. Transient engine response was such that no difficulty was encountered in adjusting the power as required to bring the helicopter to a hover. Setting N_2 / N_r speed at 100 percent with the collective pitch full down prior to lift-off resulted in a steady-state N_2 / N_r droop to 95 percent as power was applied to obtain lift-off. To regain an N_2 / N_r speed of 100 percent following lift-off it was necessary to actuate the beep switch. This would be undesirable, particularly in turbulent air or where the helicopter was at high gross weights requiring power output near the maximum rated for the engine.

Engine response when performing a jump takeoff was unsatisfactory in this configuration. Jump takeoffs were performed using an initial torque setting of 10 psi (approximately 70 percent N_1 speed) with N_2 / N_r speed set at 100 percent. Collective pitch was then applied in approximately one second to obtain a jump takeoff. Engine transient response was such that the pilot had difficulty in judging the amount of power which was being obtained. This was caused primarily by a lag of approximately one second in N_1 and torque response followed by a very rapid increase of both parameters to a peak value which momentarily exceeded the steady-state value which had been commanded by the pilot. In addition, a transient N_2 / N_r droop to approximately 92 percent was obtained as power was applied. This was unsatisfactory as it was disconcerting to the pilot and was below the minimum rotor speed or 94 percent specified for the test-bed helicopter. An unsatisfactory degree of helicopter yawing was also obtained due to the pilot's inability to apply directional control at a rate compatible with the sudden response of the test engine.

(2) Standard Control with Coordinator

In this configuration engine response was superior to that obtained with the beep control except that the pilot did not have the beep capability to make small adjustments in N_2 / N_r speed. Using an initial N_2 / N_r speed of 100 percent no apparent transient droop was obtained as collective power was applied at a nominal rate. A negligible steady-state N_2 / N_r droop of approximately 1/2 percent was observed as power stabilized at a hover.

No jump takeoffs were executed using the power turbine coordinator, however comparable data obtained in flight at 1000 feet mean sea-level indicated that jump takeoff engine response using the coordinator would be superior to that obtained using the beep control alone. Collective stick application from 10 psi torque to 70 psi torque in approximately one second resulted in a transient N_2 / N_r droop from 100 percent to 95 percent. This was within the minimum rotor speed limit; however, lag followed by very rapid engine response as described in c (1) caused pilot difficulty in rapidly estimating the power which was being obtained as a result of the collective pitch application. Yawing of the helicopter, due to engine response, was again observed.

(3) Qualitatively, lift-off characteristics are adversely affected by:

(a) Lag in engine response followed by very rapid response.

(b) Engine tendency to overshoot desired power levels.

(c) Large transient N_2 / N_r droop.

(d) Large steady-state N_2 / N_r droop using the beep control alone.

To afford the pilot maximum flexibility in engine handling, incorporation of beep and coordinator should be considered.

d. Engine Handling Characteristics During Hovering Flight

Hovering flight is essentially a transitory maneuver insofar as engine handling is concerned since continuous pilot manipulation of engine controls is necessary to maintain a desired hovering attitude. Engine transient handling qualities during hovering flight are further subdivided into small transient responses (steady hovering) and large transient responses (changing hovering position or attitude) corresponding to the magnitude of the pilot input.

(1) Standard and Altitude Control With Electrical Beep Switch

In this configuration small transient engine response to pilot control manipulation was satisfactory. A compressor (N_1) speed of approximately 90 percent was required to hover, and at this power setting small power corrections could be accomplished quickly and precisely with very little use of the beep control to maintain desired N_2 / N_r speed. Rapid hovering maneuvering (forward, sideward, rearward, turning, etc.) was used to evaluate large transient response characteristics. In the power range required to sustain hovering flight without ground contact (approximately 80 percent to 100 percent N_1 depending on the severity of the maneuver), transient engine response was satisfactory and desired transient power levels were quickly and precisely obtained. When large steady-state collective power adjustments were used to accomplish a maneuver, rapid manipulation of the beep control was required to modulate N_2 / N_r speed in order to maintain approximately the desired speed of 100 percent. This characteristic was unsatisfactory since it required continuous pilot attention.

(2) Standard Control With Coordinator

In this configuration small transient engine response was unchanged from that obtained with the beep control and was satisfactory.

Large transient engine response was evaluated during rapid hovering maneuvering flight. Engine response to large collective power manipulations was satisfactory except that the pilot did not have the capability to select a desired N_2 / N_r speed other than that which had been pre-set by the coordinator. This was particularly apparent when large, quick collective power applications were used to initiate or terminate a maneuver. This type of power application produced a large transient N_2 / N_r speed droop of approximately 5 percent which the pilot could not immediately correct.

(3) Qualitatively, hovering engine handling qualities are adversely affected by:

(a) Large steady-state N_2 / N_r speed droop using the beep switch only.

(b) Inability of the pilot to select a range of N_2 / N_r speeds using the coordinator only.

e. Steady-State Flight Engine Characteristics

Steady-state engine handling characteristics were qualitatively evaluated during climb to-, cruise at- and descent from test altitudes of 5000, 10,000, 15,000 and 20,000 feet. Both the standard fuel control and the altitude fuel control were used during the climbs.

(1) Climb Characteristics

Engine handling qualities in a steady-state climb condition were generally satisfactory. Observed engine oil pressure on all climbs was lower than the minimum limit of 90 pounds per square inch (psi) by 5 - 10 psi. This was unsatisfactory but may have been caused by the oil pressure adjustment on the particular test engine. During climbs made at maximum continuous power and normal rated power, an initial torque pressure setting of 74 psi and 63.5 psi was maintained respectively until the helicopter climbed through an altitude where maximum continuous turbine outlet temperature (TOT) was reached. Power was then adjusted by collective pitch in order to maintain maximum allowable TOT throughout the remainder of the climb. No difficulty was encountered in maintaining either limit torque pressure or limit TOT. Using a standard fuel control with electric beep switch, N_2 / N_r speed tended to droop with increasing altitude. Due to lag in the rate of beep switch operation, the pilot had some difficulty in maintaining precise N_2 / N_r climb speeds.

One climb was made using the altitude control with electric beep switch. The pilot observed that N_2 / N_r speed was increasing as the helicopter climbed through 14, 000 feet mean sea-level and an attempt was made to beep N_2 / N_r speed down to the desired level. Actuation of the beep switch resulted in a decrease in compressor (N_1) speed from 100 percent to 94 percent with no apparent change in N_2 / N_r speed observed. Further experimentation with the beep switch produced a reduction of 2 1/2 percent in N_2 / N_r speed and a 6 percent reduction in N_1 speed at 21, 500 feet mean sea-level. The apparent reaction of compressor (N_1) speed to beep switch actuation was not fully explained by contractor personnel at the time of this report. Test day temperatures when this incident occurred were extremely low. Ambient temperature at 21, 500 feet was approximately -50 degrees Centigrade. It is possible that the extreme temperatures affected operation of the governing mechanism or of the N_1 and N_2 / N_r speed indicators. However, further investigation should be conducted to ascertain that this was the cause of the phenomena.

One maximum continuous power climb was made using a standard fuel control with power turbine governor coordinator only. As altitude increased during the climb, N_2 / N_r speed tended to droop. Droop obtained at peak altitude was within 2 1/2 percent of the N_2 / N_r speed set at the initiation of the climb. Since the beep control was not installed, the pilot had no means by which to maintain precise desired N_2 / N_r speed. This was unsatisfactory since optimum climb performance depends upon the ability to maintain desired rotor speeds.

(2) Cruise Characteristics

Steady-state engine cruise characteristics were evaluated while performing a series of speed-power runs at 5, 000, 10, 000, and 15, 000 feet to obtain engine performance data. Engine cruise characteristics were evaluated using a standard fuel control with electrical beep switch only, standard fuel control with coordinator only, and an altitude control with beep switch only.

There was no change in steady-state cruise characteristics as a result of changing engine configuration (i.e. switching from the electrical beep switch to the coordinator or from the standard control to the altitude control). In all configurations power once set, remained constant except for small random N_1 oscillations with a magnitude of ± 1 percent around the selected N_1 cruise settings between 80 percent and 90 percent. These oscillations were not of sufficient magnitude to be disturbing to the pilot. In addition, considering the tactical mission of the LOH and the relatively short periods of steady-state cruise which the mission implies, no significant effect upon cruise planning should result due to this characteristic.

As previously stated, operation of the electrical beep switch was satisfactory except for the lag in the rate of beep switch operation which caused difficulty in selecting desired N_2 / N_r cruise settings quickly. The coordinator when installed, operated satisfactorily in maintaining a pre-selected N_2 / N_r speed through a nominal range of cruise power settings. As previously discussed, however, use of the coordinator alone restricts the pilot to use of a single N_2 / N_r speed. This would be unsatisfactory in actual tactical use, particularly when operating at the extremes of the flight envelop. The capability to select an N_2 / N_r speed to suit the particular flight condition would be desirable. A coordinator coupled with an improved electrical beep control would combine the advantages of both; and this combination should be considered for the Light Observation Helicopter.

In all engine configurations the pilot experienced difficulty in making small cruise power collective adjustments within a compressor speed (N_1) range between 80 percent and 90 percent. This was due to a lag of approximately two seconds in engine response following collective pitch control movement. The lag was caused by a 20 rpm hysteresis designed into the N_2 / N_r governor. An N_2 / N_r speed change of approximately 20 rpm, therefore, was required to produce an N_1 speed change signal. Following engine response additional pilot attention was required because observed N_1 speed fluctuated around the adjusted setting for approximately two to three cycles before stabilizing. Total effect of these characteristics was an excessive degree of pilot attention required to perform small precise power changes, which was considered unsatisfactory. Increased sensitivity of the N_2 / N_r speed governor and faster power stabilization would eliminate this deficiency.

(3) Descent Characteristics

Engine handling characteristics during steady-state descent were qualitatively evaluated while descending from various test altitudes ranging from 20,000 feet mean sea-level to 1000 feet mean sea-level. Stabilized airspeed during the descents ranged from approximately 30 mph IAS to 80 mph IAS. Stabilized engine power ranged from compressor (N_1) speeds of 65 percent to 80 percent. Descent characteristics were evaluated using the standard and altitude fuel controls equipped with either the electric beep control or the power turbine governor coordinator.

Steady-state descent characteristics were not affected by changing the type fuel control (standard or altitude) or by changing from the electric beep control to the power turbine governor coordinator. Engine descent characteristics were satisfactory except for lag in engine response and compressor (N_1) oscillations of approximately 2 percent following small power adjustments which caused pilot difficulty in stabilizing at desired power settings as described under Cruise Characteristics, Section e (2). Lag was particularly apparent when descending at low power settings (65 percent to 70 percent) and improved at higher descent power settings (75 percent to 80 percent) but was generally unsatisfactory. Lag also appeared to vary as a function of altitude. For a given descent power lag was less apparent at low altitudes than at high altitudes.

Electric beep control operation was unsatisfactory due to lag as described in Section e (2). The power turbine governor coordinator operated satisfactorily, but in order to afford the pilot maximum flexibility in selecting desired N_2 / N_r speeds, both an improved beep control and the coordinator should be considered for installation on the Light Observation Helicopter.

(4) Autorotation Characteristics

Steady-state autorotation characteristics were qualitatively evaluated during a series of autorotations from various altitudes down to 1000 feet mean sea-level. Autorotations were accomplished using the standard fuel control with either electrical beep switch or coordinator and with the altitude fuel control using the electrical beep switch. Stabilized air speed during the autorotations was approximately 50 mph IAS.

Steady-state autorotation characteristics were generally satisfactory with all fuel control configurations except in "needles split" (N_2 and N_r) autorotation, where a continuous oscillation of approximately 2 percent was observed in compressor (N_1) and power turbine (N_2) speed. This oscillation did not affect the autorotational characteristics of the helicopter but it was distracting to the pilot, particularly in cases where the "split" between rotor (N_r) and power turbine (N_2) speed was small.

Using the altitude fuel control with the electrical beep switch, it was not possible to maintain a steady-state "split needle" (N_2 and N_r) condition as the helicopter autorotated through approximately 5000 feet mean sea-level even though collective pitch was maintained in the full down position. This was apparently caused by two factors. First, as altitude decreased, increasing aerodynamic drag of the rotor caused rotor speed (N_r) to decrease. Second, minimum power attainable with the altitude control was such that at approximately 5000 feet sufficient power was developed to cause the power turbine (N_2) to join with the decreasing rotor (N_r). From 5000 feet down to 1000 feet MSL the pilot was unable to obtain "needles split" autorotation. This was unsatisfactory since the pilot was unable to determine whether true autorotation was being obtained. Further evaluation will be required to determine whether true autorotation can, in fact, be obtained at low altitudes using an altitude fuel control.

f. Transient State Flight Engine Characteristics

Transient state engine characteristics were evaluated in a series of "needles joined" engine accelerations during entry into and recovery from autorotation, during "full-on" autorotations, during low level tactical flight, and during attempts to induce compressor stall or surge.

(1) Accelerations

Engine acceleration characteristics were quantitatively and qualitatively evaluated at 1000, 5000, 10, 000 and 15, 000 feet mean sea-level. The technique used was to stabilize at a desired compressor (N_1) speed ranging from 65 percent to 85 percent and a desired power turbine speed (N_2) ranging from 97 percent to 102 percent. Various stabilized airspeeds ranging from 20 mph IAS to 70 mph IAS were selected as necessary over the power range tested. With the twist grip throttle locked in the full open position collective pitch was then applied at a rate estimated to be the maximum rate at which collective pitch would normally be applied in service use. Use of this rate resulted in collective pitch application from the minimum power position in approximately one second. This rate of application was nominally maintained throughout the acceleration evaluation.

Results show that acceleration characteristics of the test engine were generally unsatisfactory. This was caused primarily by three engine characteristics:

(a) Total time required for the engine to accelerate to a power setting at or near maximum power was satisfactory, but engine acceleration rate varied excessively from a very low rate of acceleration (lag) at the initiation of the power application to a very high rate of acceleration at the termination of the power application. In addition, the change in rate of acceleration occurred within a very short period of time (approximately one second). This change was such that the pilot could not use the collective pitch control as a power positioning device. That is to say, he was unable to accurately estimate by "feel", the particular acceleration rate and final steady-state power which would result from positioning the collective pitch control at a selected displacement.

(b) Apparent torsional overshoot and instability were observed as engine acceleration peaked at or near maximum power. Engine torque pressure was used as a primary power reference during the accelerations. On numerous accelerations torque pressure peaked well above the maximum allowable torque before stabilizing at the steady-state level. The overshoot and stabilization occurred after the collective pitch control had been applied and the control was being held fixed in position. Following the peak overshoot, observed torque pressure oscillated around the steady-state value at a frequency of approximately one cycle per second. Amplitude of the oscillation was approximately 4 - 5 psi and the oscillation continued for a period of time such that excessive pilot attention was required to determine final steady-state value.

(c) Excessive transient and steady-state N_2 / N_r droop and run-out was observed when using the standard and altitude fuel control with electrical beep. Excessive transient N_2 / N_r droop and run-out was observed when using the standard fuel control with the power turbine governor coordinator. Transient droop was such that it was extremely disconcerting to the pilot, particularly when N_2 / N_r speed drooped below and accelerated above the minimum and maximum allowable rotor speeds respectively. Steady-state droop and run-out was such that excessive manipulation of the beep control was required to maintain N_2 / N_r speed near desired levels.

Figure number (1) shows a typical pilot reaction to the engine acceleration characteristics using a standard control with coordinator at 5000 feet. Examination of the curves shows that following collective pitch application in approximately one second there was a significant lag in torque response. This was followed by a rapid change in the rate of acceleration within one second to a peak acceleration rate of 40 psi per second. This was accompanied by an excessively large N_2 / N_r transient droop from an initial value of 101 percent to a minimum value of 89 percent or 5 percent below the minimum allowable rotor speed. Approximately one second later torque pressure peaked at a maximum value of 96 psi. This was in excess of two seconds after the collective pitch control had reached a static position. Further examination of the curve shows that torque pressure then declined and oscillated around a steady-state value of 88 psi. Pilot reaction, upon interpreting the large N_2 / N_r droop and the excessive torque pressure accompanied by torque oscillation, was to reduce collective pitch control in a very rapid "panic" type movement.

Figures (2) and (3) show the variation in engine acceleration characteristics at 5000 feet mean sea-level using the standard control with beep actuator (Figure 2) and the standard control with coordinator (Figure 3). Comparison of these curves with Figure (1) shows the same general characteristics except that using the beep control N_2 / N_r speed drooped 8 percent to a steady-state value of 96 percent. Acceleration rate, variation in acceleration rate, torque overshoot, and torsional oscillation were again unsatisfactory. The total time required to accelerate was 3 - 4 seconds for both fuel control configurations and was satisfactory.

Figures (4) and (5) show the acceleration characteristics of the test engine at 5000 feet using the altitude control with beep accelerating from an initial N_1 speed of 69 percent (Figure 4) and an initial N_1 speed of 64 percent (Figure 5). Total time required to accelerate to peak torque pressure was three seconds when initiating from 69 percent N_1 and four seconds when initiating from 64 percent N_1. Collective pitch application was completed in two seconds in both cases. Undesirable acceleration rate, torque overshoot, and torsional instability are again apparent. An initial N_2 / N_r speed of 99 percent was used in both tests; however, the acceleration from an N_1 speed of 69 percent produced a transient N_2 / N_r droop of 10 percent down to 89 percent while the acceleration from an N_1 speed of 64 percent produced an N_2 / N_r droop of 16 percent down to 83 percent. Transient droop in both cases resulted in rotor speeds well below the minimum of 94 percent. This was extremely disconcerting and was considered unsatisfactory.

Figure (6) shows an acceleration performed from an N_1 speed of 74 percent at 5000 feet mean sea-level using the altitude fuel control with the beep actuator. Examination of the curves shows that when accelerating from an N_1 setting of 74 percent, there is a significant reduction in transient N_2 / N_r droop over that obtained in accelerations from lower N_1 speeds (Figures 4 and 5). In addition, the torque overshoot characteristic appears to be improved. The varying rate of acceleration of torque, however, is unsatisfactory. The total time of three seconds required for the acceleration is satisfactory.

Figures (7) and (8) show acceleration characteristics at 10, 000 feet mean sea-level using a standard control with coordinator. Collective pitch application was made in approximately 2 1/4 to 2 1/2 seconds. Figure (7) shows an acceleration from an initial N_1 speed of 69 percent and Figure (8) shows an acceleration from an initial N_1 speed of 64 percent. Examination of the curves shows that at this altitude, total torque acceleration time from an initial N_1 speed of 64 percent was five seconds. This was marginally satisfactory. In addition, although steady-state N_2 / N_r droop was acceptable, large transient droop coupled with rapidly changing acceleration rate and torque overshoot was unsatisfactory in both accelerations.

Figure (9) shows an acceleration at 10, 000 feet using a standard control with coordinator. Collective pitch application was made in 1 1/2 seconds from an initial N_1 speed of 74 percent. Transient N_2 / N_r droop shows a significant reduction over that obtained from lower N_1 speeds (Figures 7 and 8). Steady-state N_2 / N_r droop was acceptable. Torque response was considerably improved. Total response time was 2 3/4 seconds which was satisfactory. The initial lag in torque response was decreased but the variation in acceleration rate was still marginally satisfactory. Torque overshoot was acceptable and damping of the torque oscillation appeared to be improved.

Figures (10) and (11) show acceleration characteristics at 15, 000 feet mean sea-level using a standard fuel control with beep actuator. Figure (10) shows a 1 1/4 second collective pitch application from an initial N_1 speed of 70 percent. Figure (11) shows a 1 1/4 second collective pitch application from an initial N_1 speed of 75 percent. In both accelerations initial N_2 / N_r speed was 99 percent. Examination of the curves shows that initiating the acceleration from the lower N_1 speed produced a significantly larger transient N_2 / N_r droop than when initiating from the higher N_1 speed. Transient N_2 / N_r droop from an initial N_1 speed of 70 percent was unsatisfactory since it resulted in an N_2 / N_r speed which was below the minimum allowable rotor speed of 94 percent. This was particularly significant considering the high test altitude since transient rotor blade stall could possibly occur. Total torque acceleration time was satisfactory in both cases, but prolonged engine lag followed by rapid acceleration was unsatisfactory. In addition, an unsatisfactory degree of torque overshoot was obtained when initiating from an N_1 speed of 70 percent (Figure 10).

Figure (12) shows an acceleration at 15, 000 feet mean sea-level from an intitial N_1 speed of 63 percent and an initial N_2 / N_r speed of 99 percent using an altitude control with beep actuator. Collective pitch was applied in two seconds. Examination of the curves shows that an excessively large transient N_2 / N_r droop of 17 percent was obtained which resulted in a minimum N_2 / N_r speed of 82 percent. N_2 / N_r speed recovered to a steady-state droop value of 94 percent, the minimum rotor speed. This characteristic was particularly unsatisfactory considering the high altitude and the possibility of rotor stall. Total time required to complete the acceleration was 6 1/4 seconds. This was excessive considering the tactical mission of the Light Observation Helicopter and the possibility that service use might include the requirement to operate at ground levels approaching 15, 000 feet. Comparison with Figure (5) indicates that the increased acceleration time is due to the increased altitude. In addition, variation in engine acceleration rate, torque overshoot and torque instability were also unsatisfactory during this acceleration.

Figure (13) shows a deceleration from an initial N_1 speed of 100 percent and an initial N_2 / N_r speed of 99 percent using an altitude control with beep actuator at 15, 220 feet mean sea-level. Collective pitch control was displaced in four seconds. Examination of the curves shows that N_2 / N_r speed over-ran 7 percent to a maximum transient value of 106 percent which exceeded the rotor limit by 2 percent. N_2 / N_r speed then stabilized at a steady-state over-run speed of 103 percent. Transient over-run was unsatisfactory but steady state over-run was acceptable. Time required for torque pressure to decrease to the minimum steady-state value was unsatisfactory considering the tactical mission of the Light Observation Helicopter. A significant lag in torque response was observed followed by a rapid decrease in torque. A more linear response would be desirable. No significant torque under-shoot was observed.

In summary, "needles joined" transient response characteristics of the test engine were generally unsatisfactory due to large variations in acceleration and deceleration rates, torque overshoot, apparent torsional instability, and large transient N_2 / N_r droop and over-run. These characteristics were observed with all fuel control configurations tested. Acceleration time was satisfactory at low altitudes and high initial N_1 speeds but appeared to deteriorate at high alitiudes and low N_1 speeds. Transient N_2 / N_r droop appeared to increase when initiating acceleration from low N_1 speeds. Use of both a beep actuator and a power turbine governor coordinator would be desirable to limit transient and steady-state N_2 / N_r droop and to provide the pilot with maximum flexibility.

(2) Entry Into Autorotation

Transient engine response characteristics during entry into autorotation were qualitatively evaluated using a standard control with beep actuator, a standard control with power turbine governor coordinator and an altitude control with beep actuator. Entries into autorotation were accomplished at alitiudes ranging from 20, 000 feet mean sea-level to 1000 feet mean sea-level. Airspeed during entry ranged from 30 to 60 mph IAS.

Using the standard control with beep actuator or coordinator, engine characteristics during entry into autorotation were satisfactory at altitudes up to approximately 14, 000 feet. A "split needle" N_2 / N_r condition was easily obtained by decreasing collective pitch only and N_1 and N_2 speeds during the entry were satisfactory. Above 14, 000 feet; however, engine characteristics during entry were unsatisfactory using the standard fuel control due to excessive N_2 run-out as collective pitch displacement was decreased. N_2 would have exceeded limits at altitudes above 14, 000 feet mean sea-level had entry into autorotation been continued. This was unsatisfactory. In order to obtain autorotation at the highest possible altitude using the standard control, an excessive amount of control manipulation was required. Entry into autorotation at 14, 000 feet was accomplished by beeping toward minimum N_2 / N_r speed while "juggling" the collective pitch control down so as to maintain an N_2 / N_r speed of 104 percent. This process resulted in the highest entry into autorotation obtained in the evaluation (14, 000 feet) using the standard control, but required excessive pilot attention.

Using the altitude fuel control with beep actuator, successful entry into autorotation was accomplished at 20, 500 feet mean sea-level. No difficulty was experienced in making this entry using a decreased collective pitch and a roll-off of the twist grip throttle to the ground idle position. Autorotation entry was again successfully accomplished at 15, 000 feet mean sea-level. Low level autorotation characteristics were unsatisfactory, however, due to the inability to maintain autorotation at altitudes below 5000 feet mean sea-level as described in Section e (4).

(3) Power Recovery from Autorotation

Power recovery from autorotation were qualitatively evaluated at altitudes ranging from 15, 000 feet mean sea-level to 30 feet above ground level (AGL) using the standard fuel control with the beep actuator and the altitude control with the beep actuator. Power recoveries were quantitatively evaluated at 1000 and 5000 feet mean sea-level using the standard control with beep actuator.

Time required to affect a power recovery from autorotation was satisfactory with all fuel control. Because of the rate at which the engine accelerated during the recoveries, marked yawing of the test-bed helicopter was observed at all altitudes. This was unsatisfactory. During a power recovery at 10, 000 feet from an initial N_1 speed of 60 percent the needles were joined with the twist grip throttle and the collective pitch was immediately applied. Rotor speed, at the initiation of collective pitch application, was 99 percent and decelerating. Needles were joined at an N_2 / N_r speed of approximately 98 percent. A resulting droop in N_2 / N_r speed to 88 percent was observed as pitch was applied. This was unsatisfactory.

Figure (14) shows a power recovery at 5000 feet mean sea-level using the altitude control with the beep actuator. Examination of the curves shows that from an initial N_r speed of 96 percent recovery was obtained in approximately three seconds. This was satisfactory. Minimum N_2 / N_r speed obtained was 98 percent following recovery initiation. Rate of torque build-up was such that marked yawing of the helicopter resulted. This was unsatisfactory.

Figure (15) shows a power recovery autorotation at 1000 feet using a standard fuel control with the beep actuator. Examination of the curves shows that, from an initial N_r speed of 100 percent and an initial N_2 speed of 94 percent, recovery was obtained in approximately two seconds. This was satisfactory. Minimum N_2 / N_r speed obtained following recovery was 100 percent. No difficulty was experienced in completing this power recovery except that rate of torque response caused considerable yawing of the helicopter.

Several power recoveries were executed near ground level. Power response was such that recovery could be affected at heights of approximately 30 feet AGL with no difficulty except in directional control due to yawing caused by the rate of increase of power.

In summary, power recovery engine characteristics appear to be satisfactory except that the rapid rate of power increase causes directional control difficulties. It appears that when executing power recoveries where rotor speed is decreasing and N_2 speed is low large transient N_2 / N_r droop will be obtained.

(4) Full-on Autorotations

Numerous full-on autorotations were executed at the contractor's test facility at touch-down airspeeds ranging from zero to 10 mph IAS. Autorotations were accomplished with the engine running at the ground idle position.

No difficulty was experienced in executing touch-down autorotations. During the execution of the autorotations it was observed that the helicopter appeared to be "floating" more than was normal. There seemed to be an excessive amount of rotor inertia. Discussion with the contractor and investigation of contractor data revealed that upon applying collective pitch to cushion the landing, approximately 20 to 30 residual horsepower was being delivered to the rotor by the engine. This was caused by a minimum compressor (N_1) speed which was sufficiently high so that residual power was obtained as collective pitch was applied. This characteristic, although not disturbing to the evaluation pilot, would tend to deceive pilots practicing autorotations into believing that they had more "cushion" than they would have were the engine actually dead. In this sense for training purposes, this characteristic was undesirable and unsatisfactory.

(5) Simulated Tactical Flight

A series of low level "nap of the earth" runs were made to evaluate the effect of engine handling characteristics upon the pilot while rapidly maneuvering the helicopter near ground level. Runs were made using a standard control with beep actuator. It was qualitatively determined that lag in engine response followed by rapid response torque overshoot tendencies, torque instability, large transient N_2 / N_r droop and over-run detracted from the pilot's ability to maneuver the helicopter to the maximum extent possible.

An excessive degree of pilot attention was required to monitor engine controls and instruments in order to assure the pilot that the engine remained within operating limits, particularly during maneuvers where relatively rapid large power changes were required. Incorporation of a power turbine governor coordinator coupled with an improved beep actuator (in order to eliminate lag in beep operation) would significantly enhance pilot capability during tactical flight. An improvement in engine transient response characteristics would be very desirable for this type of flying.

(6) Compressor Stall and Surge Characteristics

Attempts were made to induce compressor stall or surge at altitudes ranging from 5000 feet mean sea-level to 15,000 feet mean sea-level using both the standard and the altitude control equipped with either the electrical beep switch or the power turbine governor coordinator. Airspeed during the evaluation ranged from 20 knots IAS to 70 knots IAS. Technique employed was to induce very rapid changes in engine operating conditions through manipulation of the collective pitch control so as to vary air and fuel flow while the engine was in a transient state. To accomplish rapid collective pitch applications were made from minimum to maximum power followed by rapid pitch application back to the minimum power position. This procedure was also employed in a reversed sequence (i. e., from maximum to minimum to maximum power). Collective pitch application was made in approximately one half to one second in each direction and was timed so that the reversal in direction occurred as the engine was still in a transient state of response to the original application. (Example: Collective pitch was rapidly being lowered as the engine was rapidly accelerating).

No compressor stall or compressor surge was obtained at any of the flight conditions. No compressor speed (N_1) or transient torque instability was observed throughout the altitude-airspeed envelope investigated. Within the scope of the tests, compressor stall and compressor surge characteristics were considered satisfactory.

Contractor data indicated that compressor surge was obtained by rotating the twist grip throttle to ground idle in autorotation followed by a rapid power recovery where the twist grip throttle was rotated from ground idle to full open and the collective pitch was rapidly applied. Compressor surge was obtained by the contractor while using a type fuel control not used in this evaluation. Further investigation of compressor stall or surge characteristics, using the standard and altitude fuel control, should be made using the contractor technique outlined above.

g. Engine Shut-down

Engine shut-down was quickly and easily accomplished. After positioning the test-bed helicopter on the ground the cyclic control was locked in the neutral position and the collective pitch control was locked full down. On flights employing the electric beep control N_2 / N_r speed was then beeped down to the low speed stop. The twist grip throttle was then rotated from flight operating speed (full down) to the ground idle detent and the engine was allowed to stabilize at ground idle speed. The engine was then shut down by rotating the twist grip throttle to the idle cut-off detent. As the engine decelerated to a stop the fuel boost pump, battery and generator were deactivated. Total time required for shut-down was approximately one minute and was satisfactory.

3. Engine Performance

Engine performance tests were conducted in level flight at 5000, 10, 000 and 15, 000 feet and in climbing flight from 1000 feet to 20, 000 feet. In addition, engine ground run performance tests were conducted with the helicopter tied down.

The results of these tests are presented as referred values of shaft horsepower, turbine outlet temperature, gas producer rpm and fuel flow. Specific fuel consumption is presented as a function of referred shaft horsepower. A complete definition of these terms is presented in Annex B, Part III.

Time did not permit a detailed analysis of this data and, therefore, this data is presented with respect to the T63-A-5 Model Specification 580-E curves. No attempt was made to fair curves through the test data except where it was necessary to calculate standard-day shaft horsepower available versus altitude which is presented in Figure 34, Part II. All engine performance data obtained during this evaluation will be used as background data in the LOH program.

a. Ground Run Engine Performance

Engine performance characteristics were evaluated over a wide range of power by conducting ground run tests with the helicopter tied down. These tests were conducted at power turbine (N_2) speeds of 97 percent, 100 percent and 102 percent with the standard fuel control installed. The results are presented in Figures 16 through 21, Part II.

b. Level Flight Engine Performance

Engine performance characteristics were evaluated in level flight at 5000 feet with power turbine (N_2) speeds of 97 percent, 100 percent and 102 percent. Level flight performance data was also obtained at 10, 000 and 15, 000 feet with a N_2 speed of 100 percent. These tests were accomplished with the standard fuel control installed.

One flight was flown at 5000 feet to determine the effect on engine performance caused by using maximum permissible utility air bleed of 3 percent. Utility air bleed was simulated by disconnecting the anti-fog horn hose (described in Section f, Item 2(a), Part III.) and installing an orifice in the compressor scroll. This test was unsuccessful because the bleed orifice was the wrong size and utility air bleed obtained was less than . 05 percent, not the 3 percent desired. The data obtained during this flight was not used in this report.

Level flight performance was obtained at 10, 000 and 15, 000 feet with the standard fuel control installed and a power turbine (N_2) speed of 100 percent. An attempt was made with the altitude fuel control installed to obtain additional level flight performance data at 10, 000 and 15, 000 feet that could be compared with the performance data obtained with the standard fuel control. An oscillograph failure during this flight resulted in the loss of the fuel flow record. A complete compression, therefore, could not be accomplished.

All level flight performance tests were flown at a constant altitude and data points were taken at various stabilized N_1 speeds. The normal procedure is to stabilize at various airspeeds. Airspeed, however, is an airframe parameter and therefore the normal procedure was not used. The results of the level flight performance tests are presented in Figures 22 through 27, Part II.

c. Climb Engine Performance

Two climbs were flown from 1000 feet to 2000 feet to evaluate amximum engine performance characteristics. The techniques used to accomplish the climb tests is described in Section f, Section 2, Item e(1), Part III. Additional data points were obtained when climbs were required to perform other tests. The results of these tests are presented in Figures 28 through 33, Part II.

d. Standard-day Shaft Horsepower

Standard-day shaft horsepower available was calculated from test data curves of referred shaft horsepower versus referred turbine outlet temperature and referred shaft horsepower versus referred gas producer speed. Referred shaft horsepower and referred turbine outlet temperatures were corrected by the procedure outlined in Reference 3, Annex A, Part III.

A plot of standard-day shaft horsepower versus altitude is presented in Figure 34, Part II. The primary function of this plot is to determine engine critical altitudes. Engine critical altitude is that altitude at which a selected power setting cannot be maintained because an engine limit has been reached. Power available from the T63-A-5 engine is limited by torque, power turbine outlet temperature and gas producer speed. From Figure 34 the engine critical altitude for military power (250 SHP, 74 psi torque pressure) on a standard-day is 9100 feet. The engine critical altitude for normal rated power (212 SHP, 63.5 psi torque pressure) on a standard-day is 14,700 feet. These engine critical altitudes are based on a power turbine outlet temperature of 738 degrees Centigrade.

G. CONCLUSIONS

1. It is concluded that the T63-A-5 engine has satisfactory steady-state handling characteristics with the following exceptions:

a. Large steady-state N_2 / N_r droop when equipped with only the beep control.

b. Inability to select a specific N_2 / N_r speed when equipped with only a coordinator.

c. Lag in operation of the beep switch making precise N_2 / N_r speeds difficult.

d. Random (N_1) oscillations with a magnitude of ± 1 percent at cruise power settings between 80 and 90 percent.

e. Excessive pilot attention required to make small cruise power adjustments.

2. It is concluded that the T63-A-5 engine has unsatisfactory transient handling characteristics because of the following:

a. Engine acceleration time from an N_1 speed less than 70 percent to military power was unsatisfactory at all altitudes.

b. Engine acceleration rate varied excessively between start of power application and termination of power application which required excessive pilot attention to maintain power with engine design limits.

c. Torque overshoot and instability coupled with a large N_2 / N_r transient droop following a rapid acceleration.

d. Engine fuel control and power turbine design limitations that make rapid decelerations and entry into autorotation above 14,000 feet impossible without exceeding limits.

H. RECOMMENDATIONS

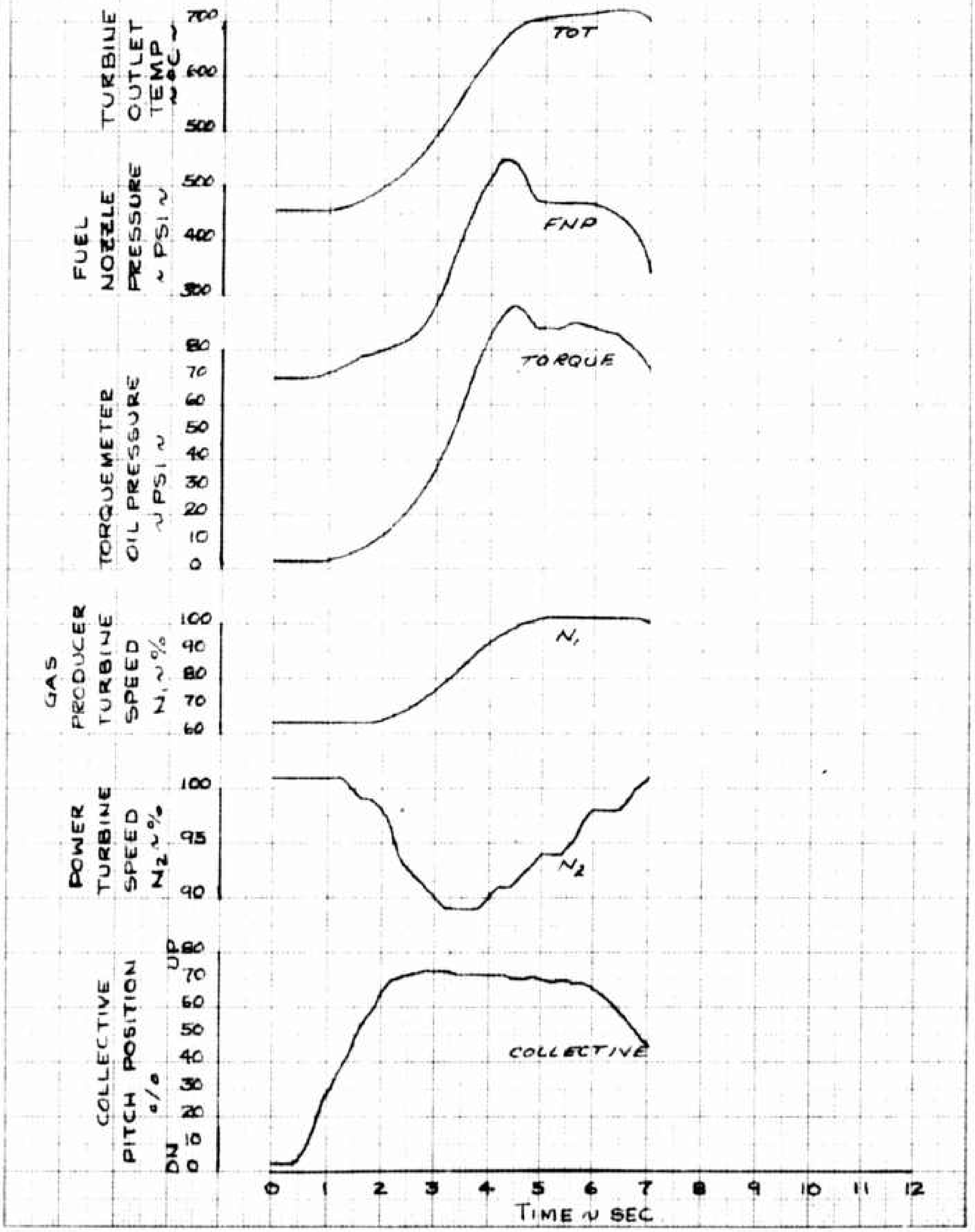
1. It is recommended that the data contained in this report be made available to all LOH test pilots and engineering personnel.

2. It is recommended that development work and flight testing of the fuel controls and power turbine governor combinations be continued.

PART II

ENGINE	FIGURE NO. 1	HELICOPTER
T63-A-5 S/N 400029	ACCELERATION	UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG.
5000	50 MPH	-10°C	90° DEG	STD WITH COORDINATOR

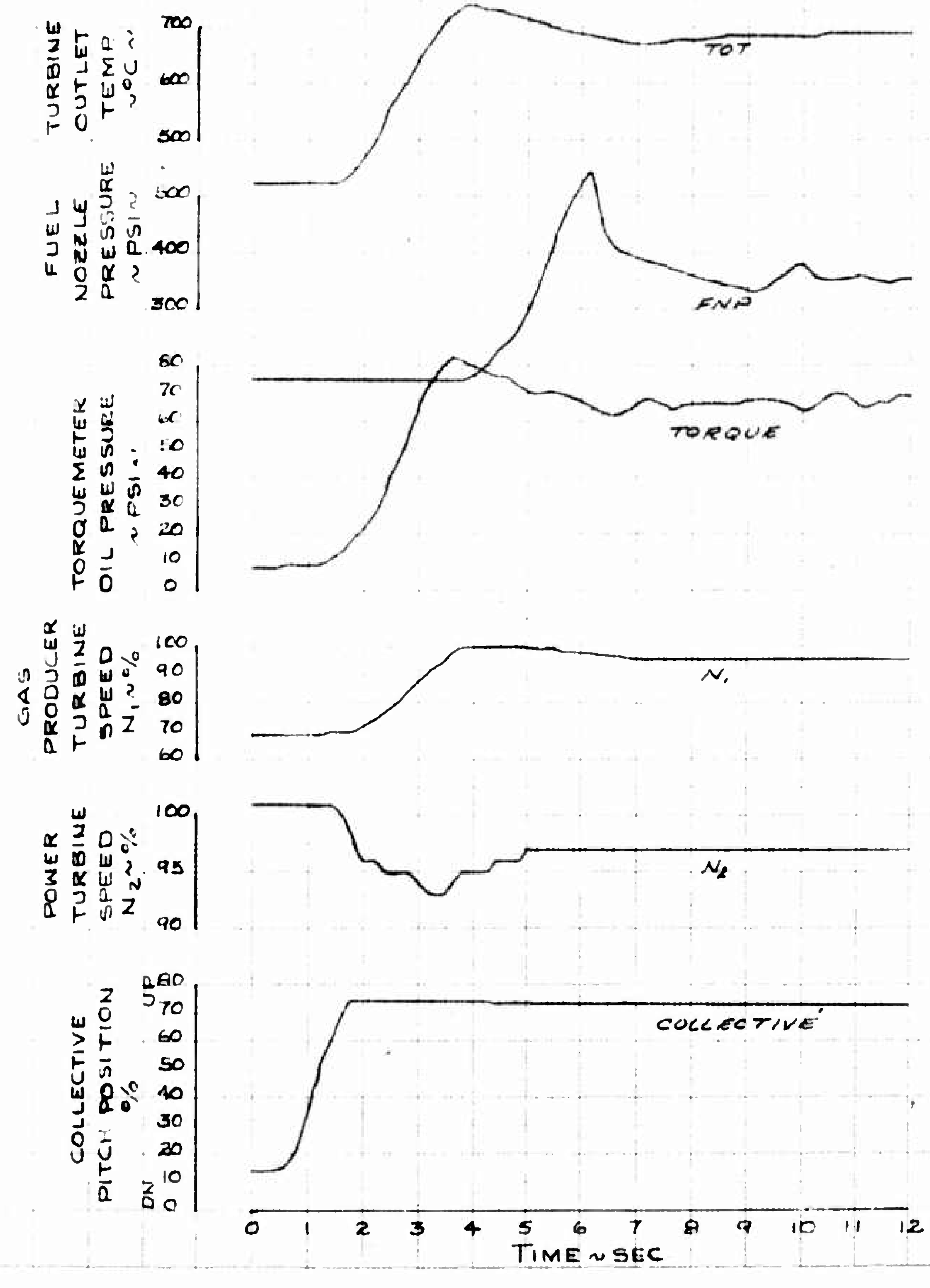


ENGINE
T63-A-5 S/N400029

FIGURE NO. 2
ACCELERATION

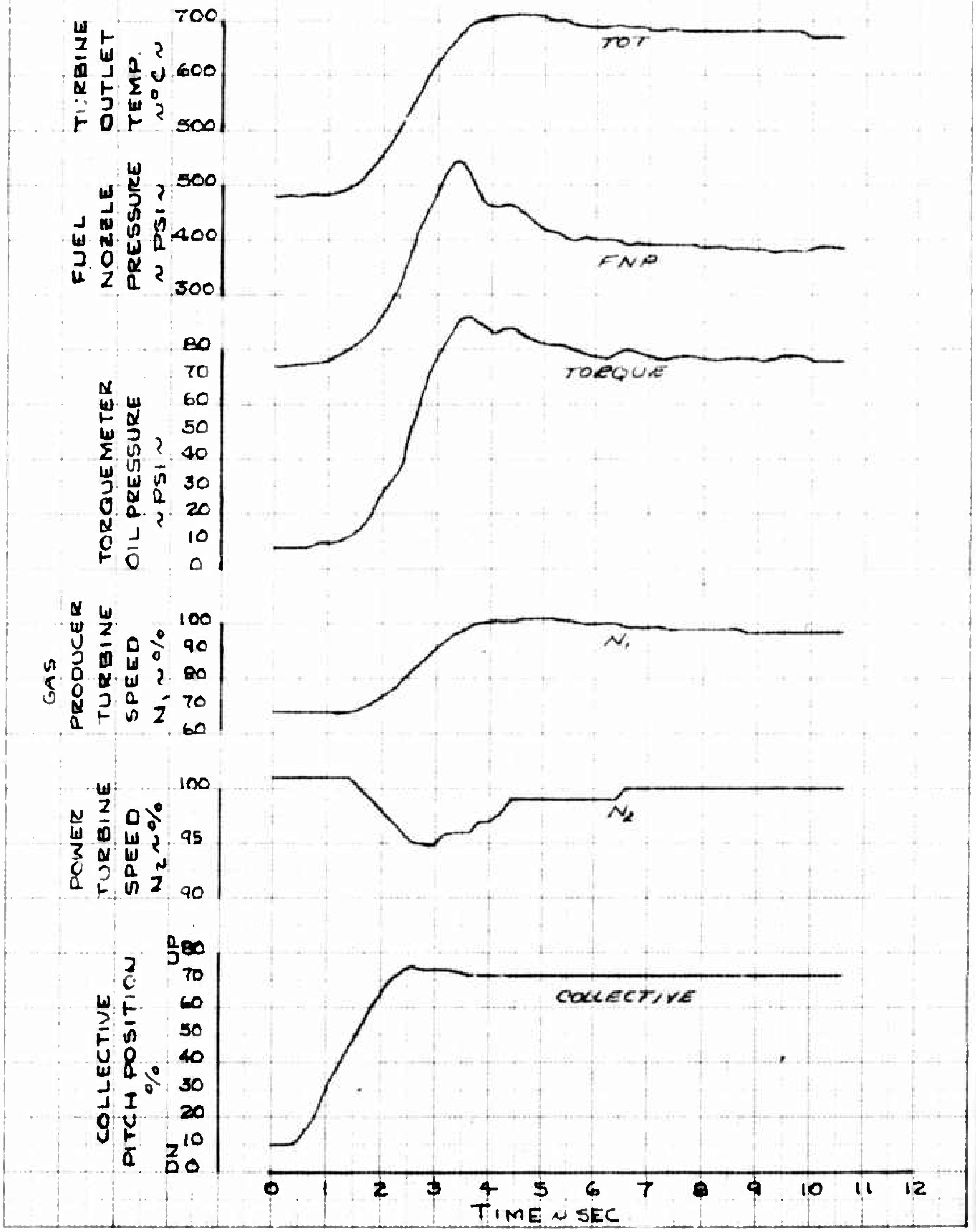
HELICOPTER
UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG
5000	59 MPH	7°C	90°	STD WITH BEEP SWITCH



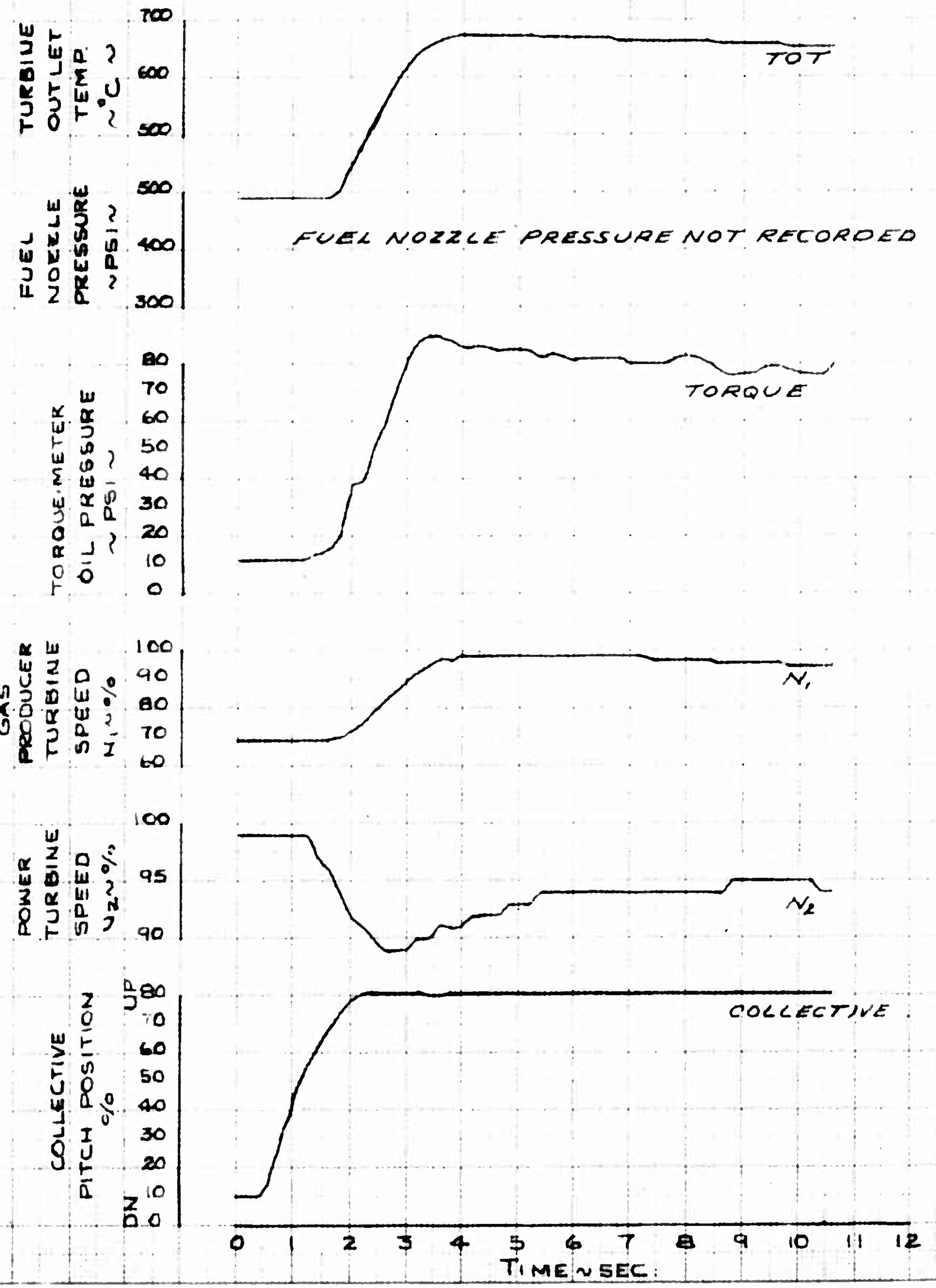
ENGINE	FIGURE NO. 3	HELICOPTER
T63-A-5 S/N 400029	ACCELERATION	UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG.
5000	63 MPH	-9°C	90 DEG	STD WITH COORDINATOR



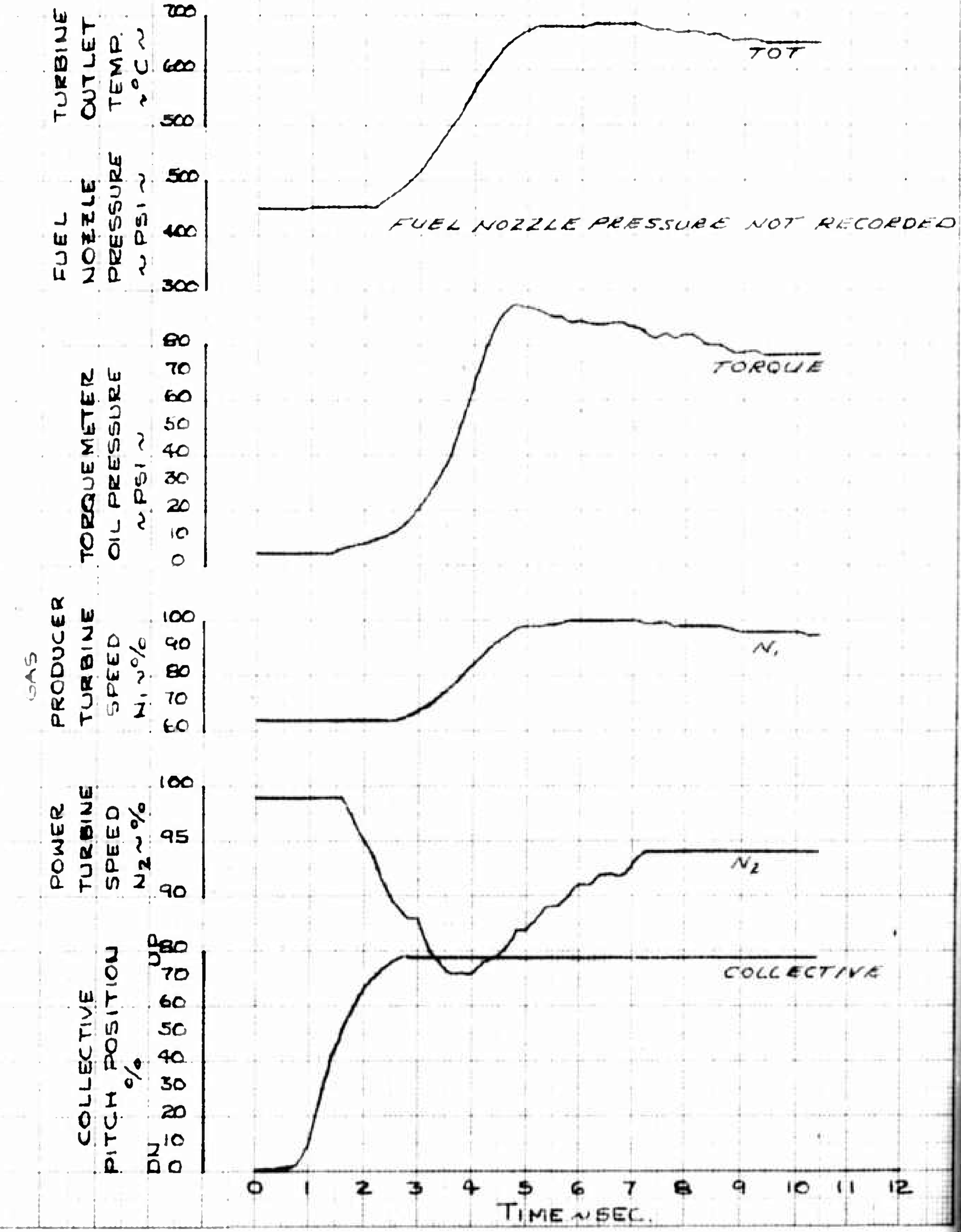
ENGINE	FIGURE NO. 4	HELICOPTER
T63-A-5 S/N 400029	ACCELERATION	UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG.
5000	45 MPH	-15°C	90 DEG	ALT WITH BEEP SWITCH



ENGINE	FIGURE NO. 5	HELICOPTER
T63-A-5 S/N400029	ACCELERATION	UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG
5000	51 MPH	-15°C	90 DEG	ALT WITH BEEP SWITCH

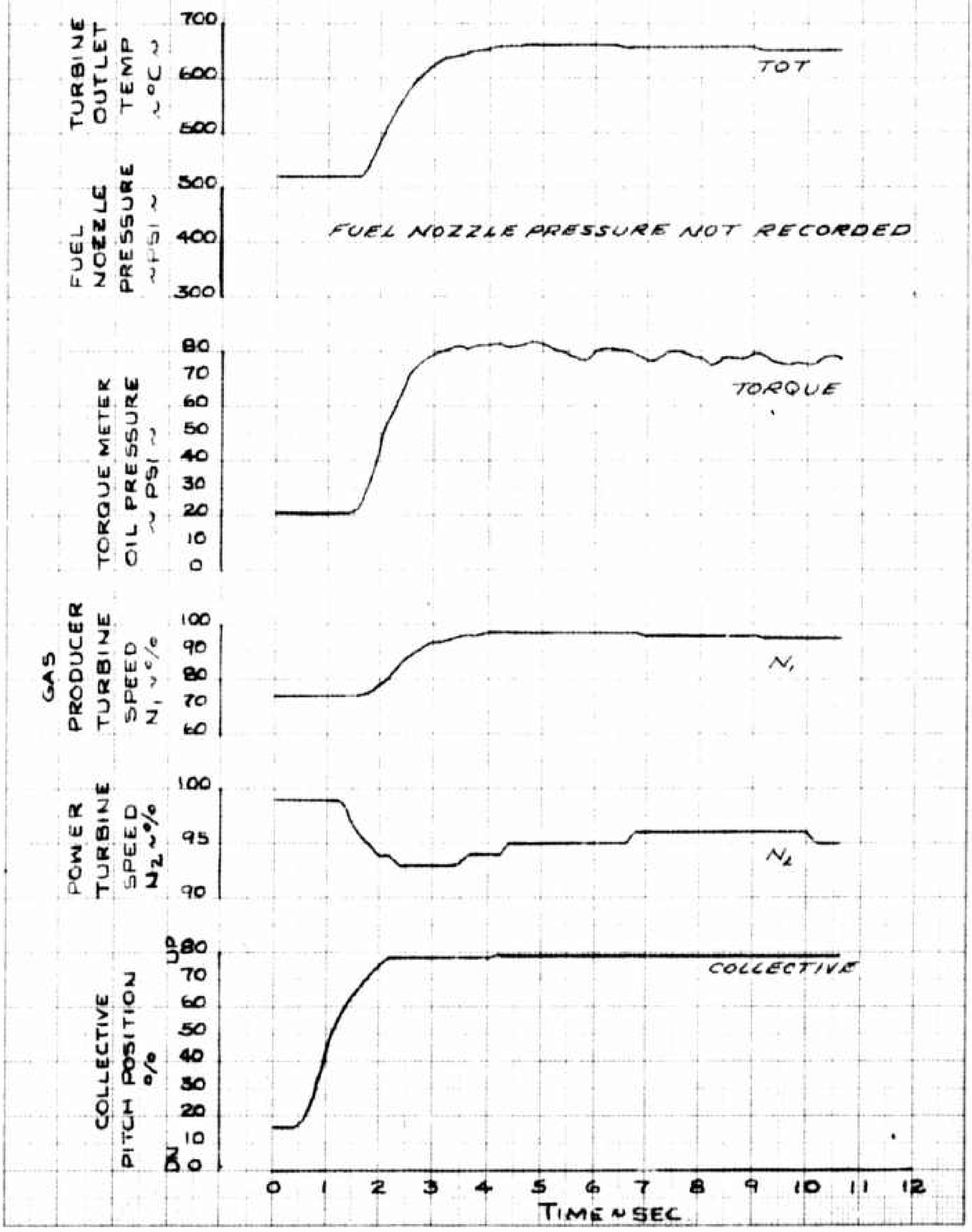


ENGINE
T63-A-5 S/N400029

FIGURE NO. 6
ACCELERATION

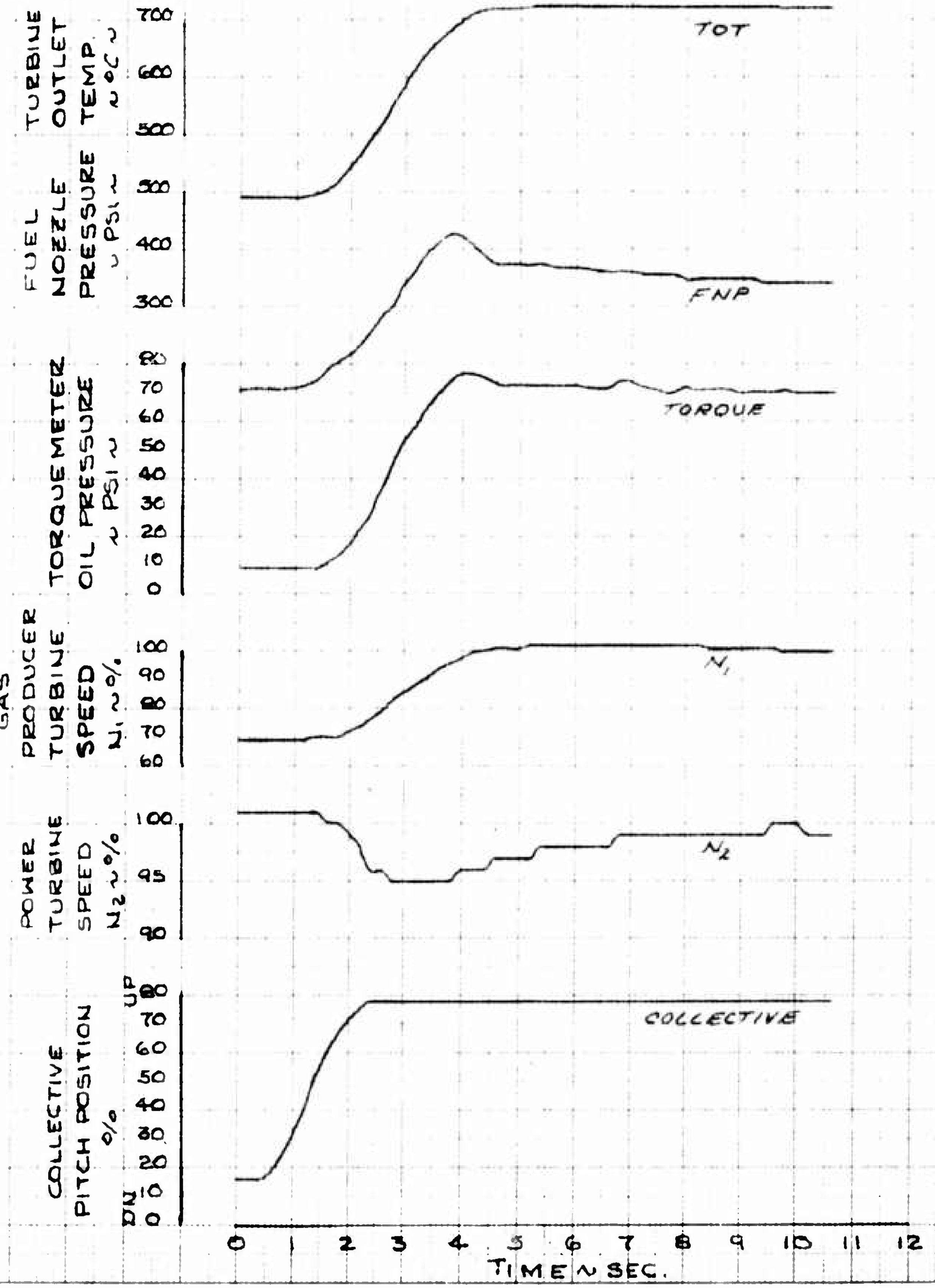
HELICOPTER
UH-13R S/N1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG.
5000	46 MPH	-14°C	90 DEG	ALT WITH BEEPSWITCH



ENGINE	FIGURE NO. 7	HELICOPTER
T63-A-5 S/N400029	ACCELERATION	UH-13R S/N1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG
10000	54 MPH	-19°C	90 DEG	STD WITH COORDINATOR

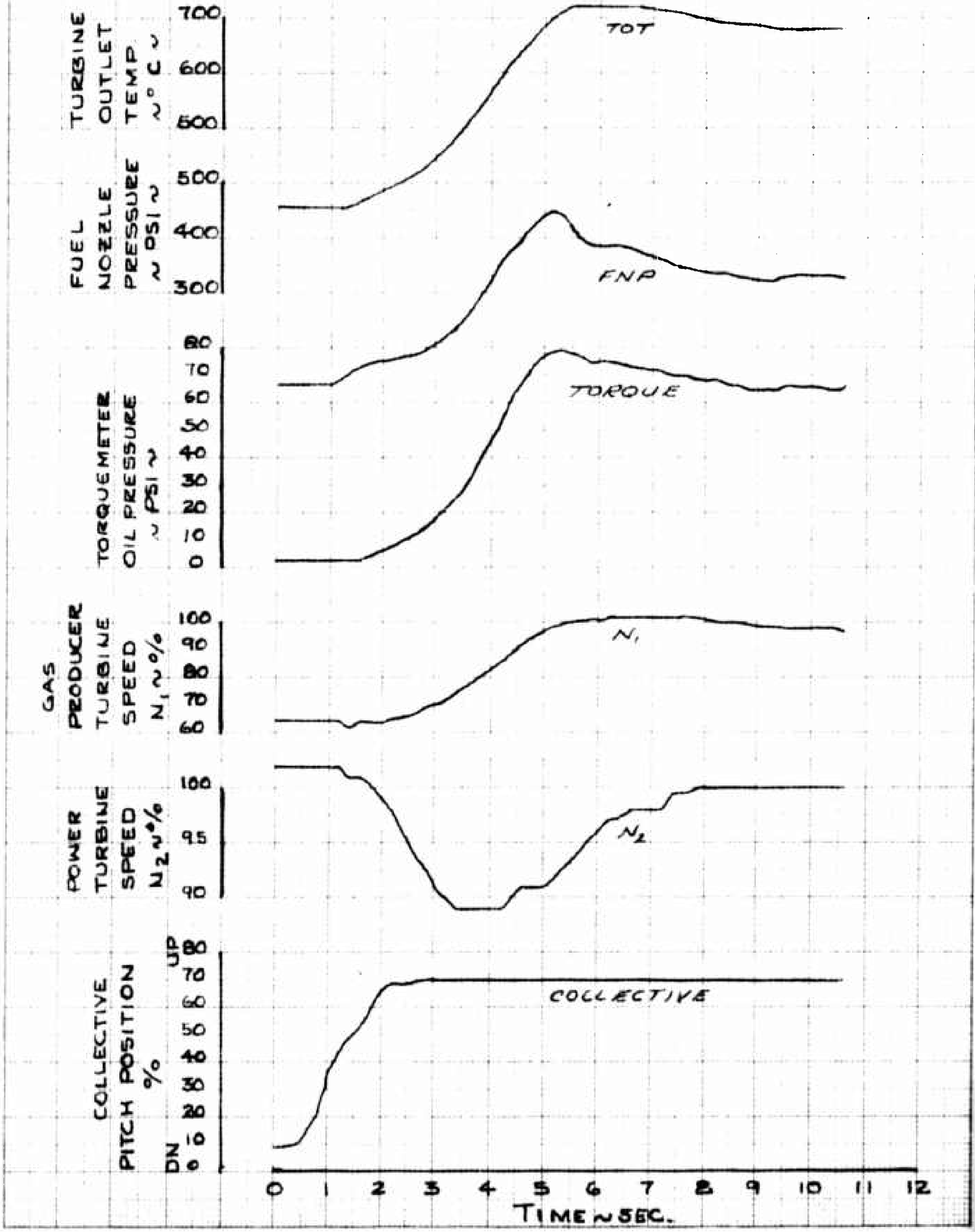


ENGINE
T63-A-5 S/N400029

FIGURE No. 8
ACCELERATION

HELICOPTER
UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG.
10000	20 MPH	-14°C	90 DEG	STD WITH COORDINATOR

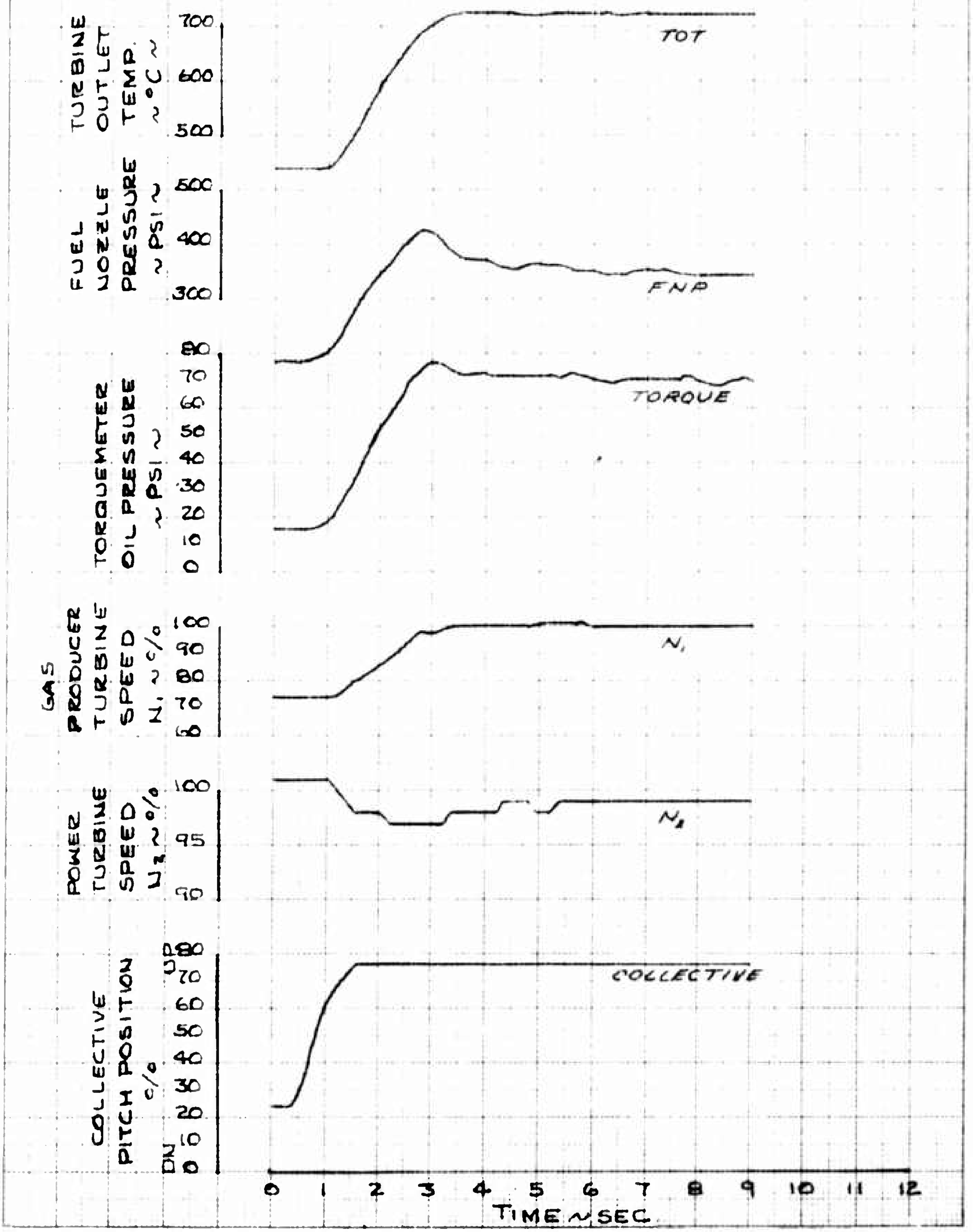


ENGINE
T63-A-5 S/N400029

FIGURE NO. 9
ACCELERATION

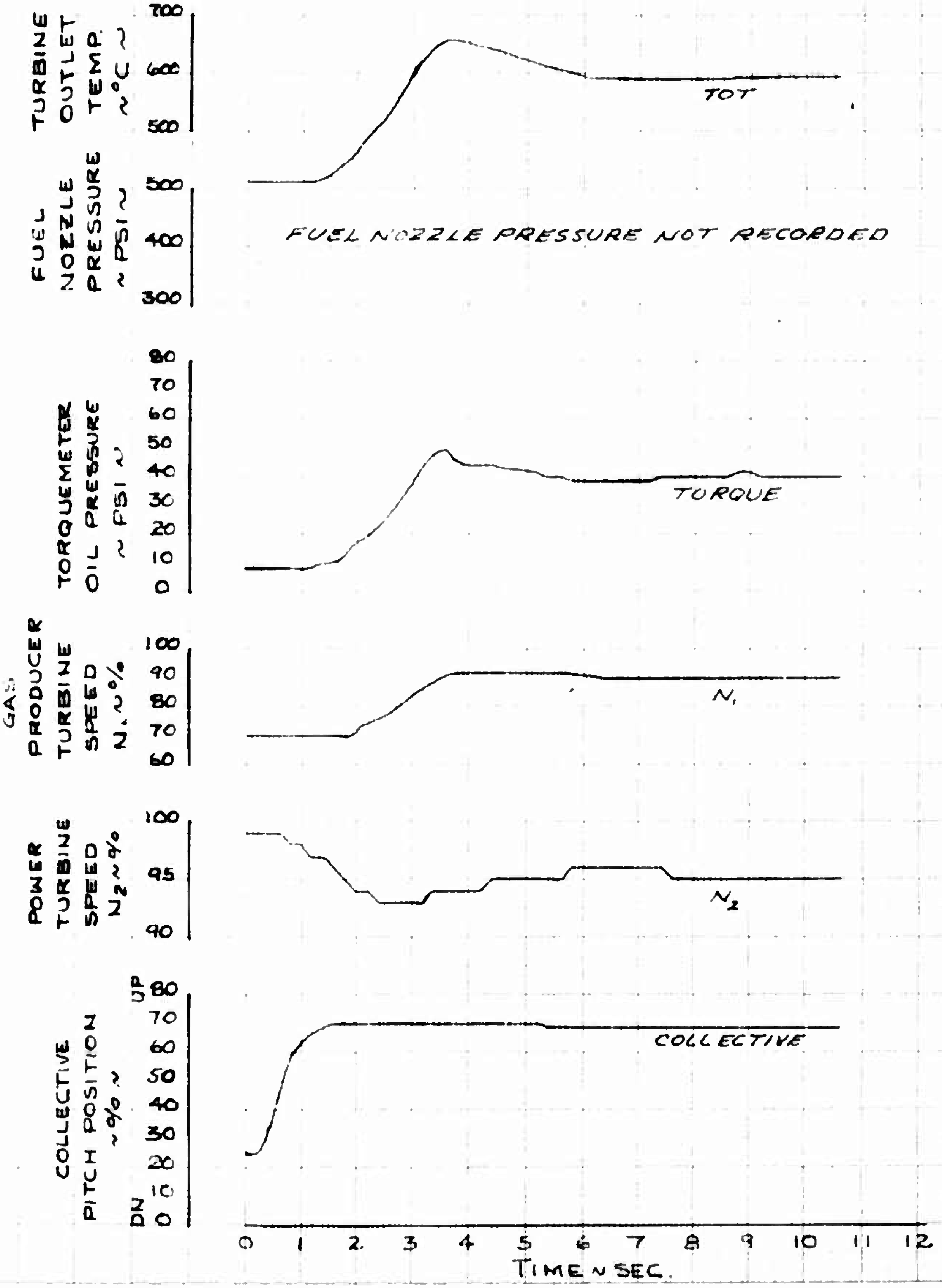
HELICOPTER
UH-13R S/N1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG
10000	50 MPH	-19°C	90 DEG	STD WITH COORDINATOR



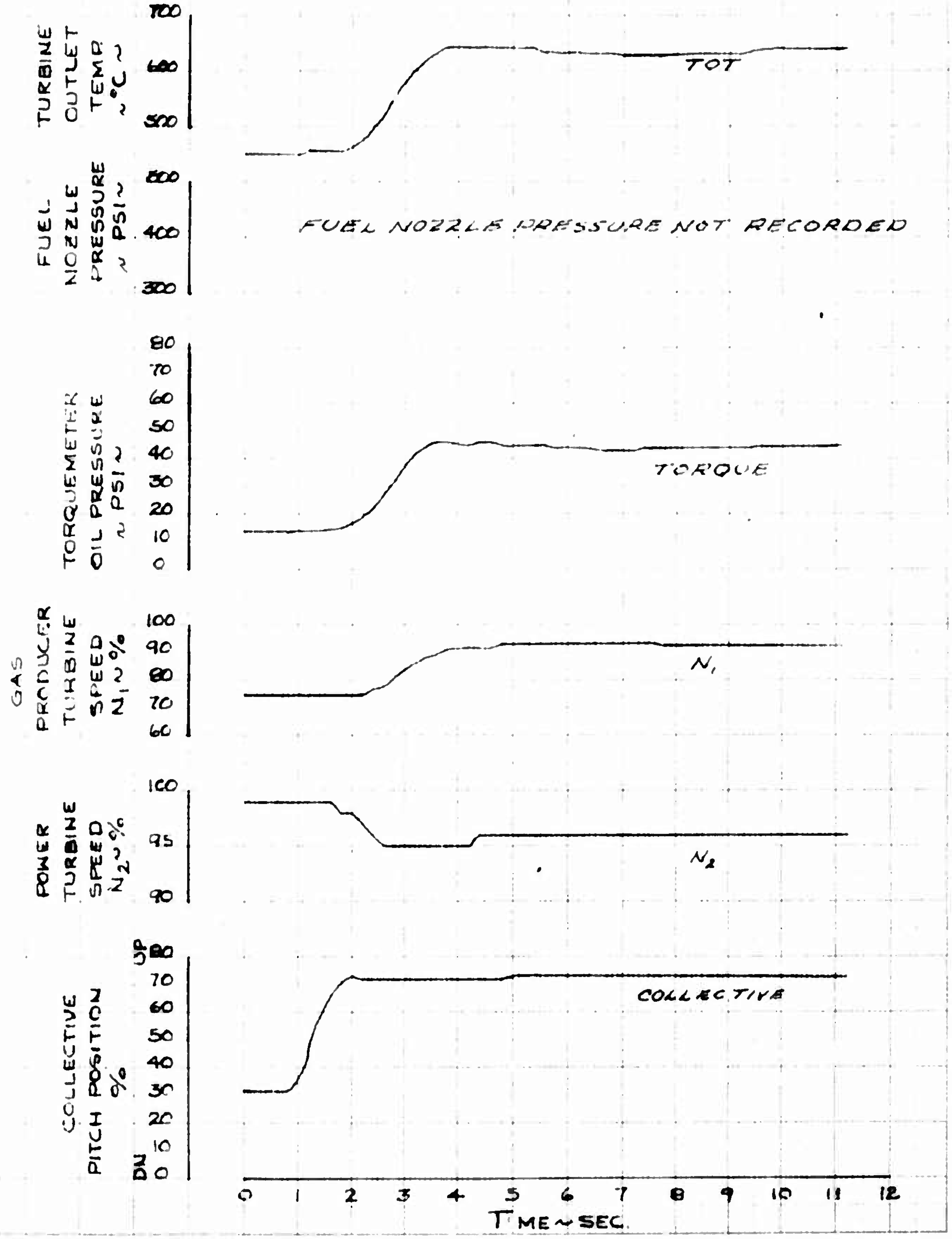
ENGINE	FIGURE NO. 10	HELICOPTER
T63-A-5 S/N 400029	ACCELERATION	UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG
15000	49 MPH	-11°C	90 DEG	STD WITH BEEP SWITCH



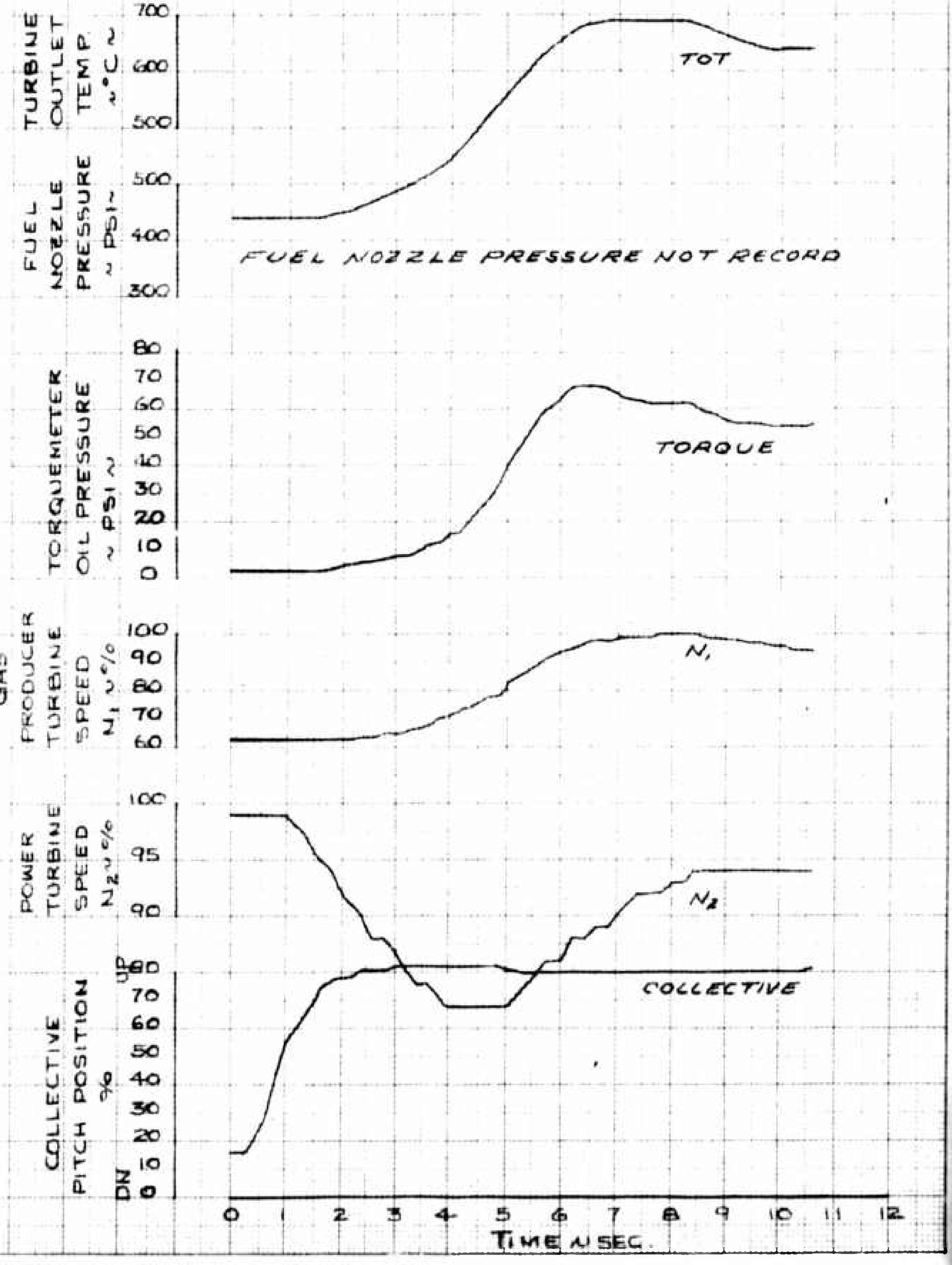
ENGINE	FIGURE NO. 11	HELICOPTER
T63-A-5 S/N 400029	ACCELERATION	UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG.
15000	54 MPH	-11°C	90 DEG	STD WITH BEEP SWITCH



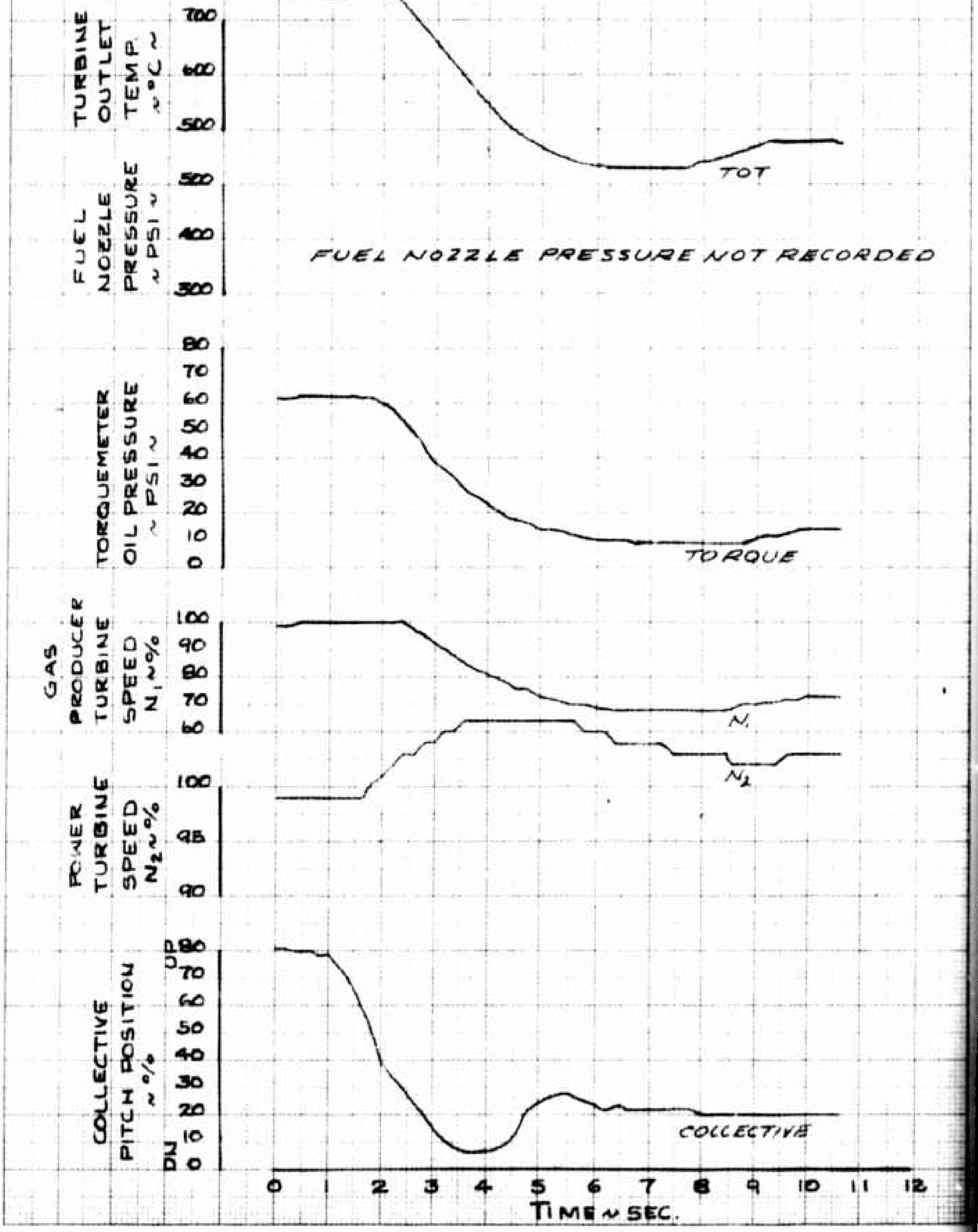
ENGINE	FIGURE NO. 12	HELICOPTER
T63-A-5 S/N400028	ACCELERATION	UH-13R S/N1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG.
15000	46 MPH	-29°C	90 DEG	ALT WITH BEEP SWITCH



ENGINE	FIGURE No. 13	HELICOPTER
T63-A-5 S/N400029	DECELERATION	UH-13R S/N1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG
15000	54 MPH	-29°C	90 DEG	ALT WITH BEEP SWITCH

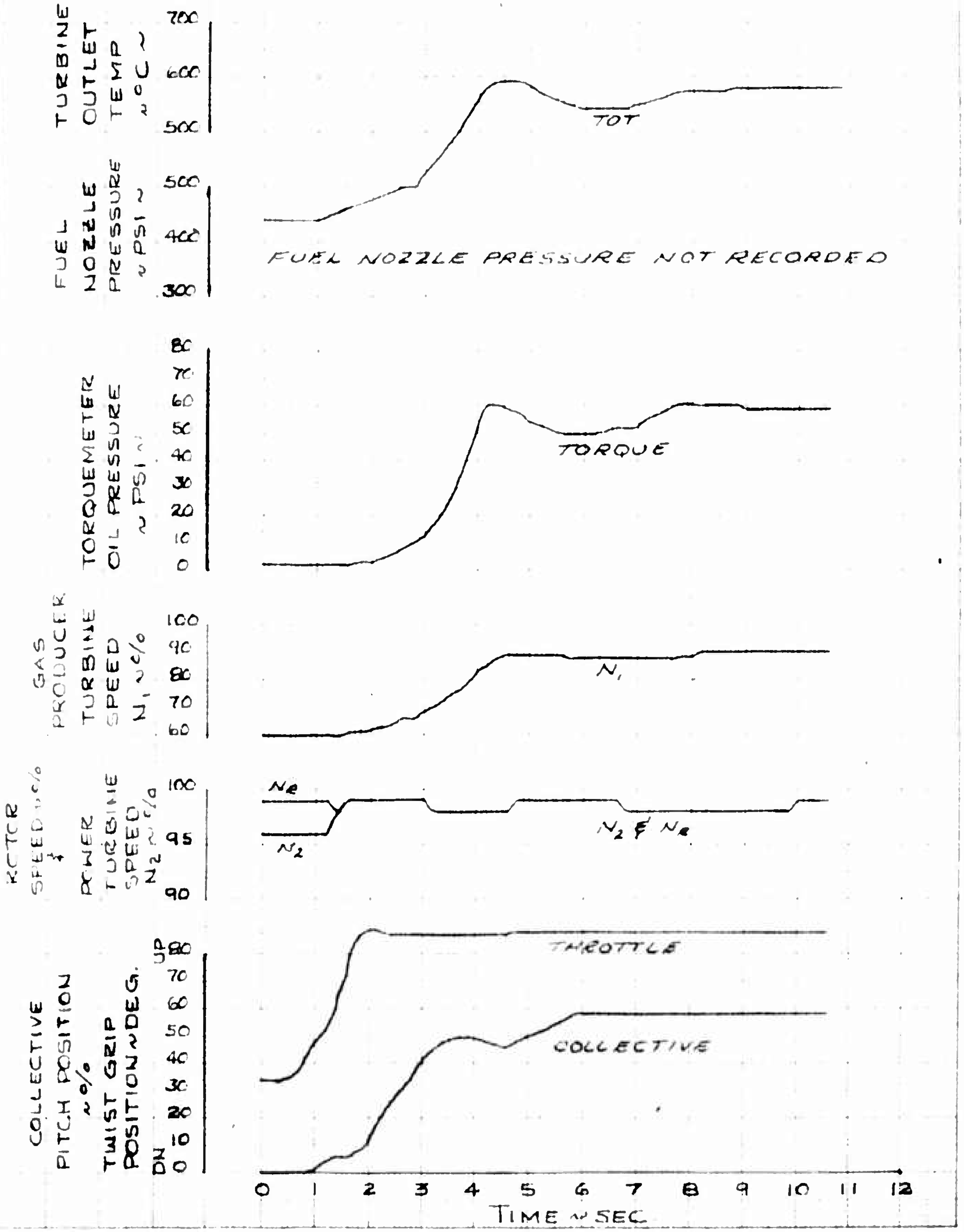


ENGINE
T63-A-5 S/N 400029

FIGURE NO 14
RECOVERY FROM
AUTOROTATION

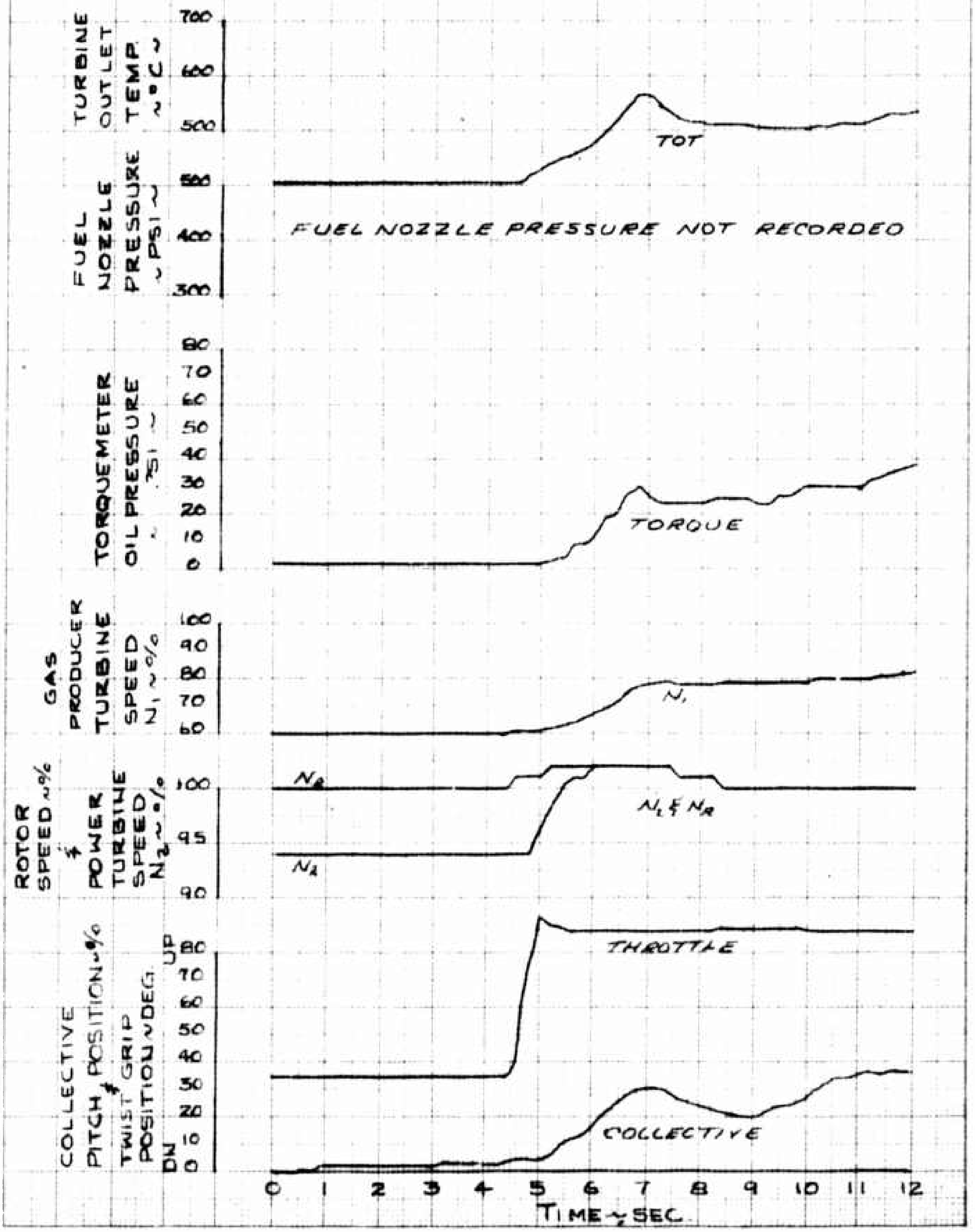
HELICOPTER
UH-13R S/N 1833

ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG
5000	50 MPH	-15°C	30 DEG TO 90 DEG	ALT WITH BEEP SWITCH



ENGINE	FIGURE NO 15	HELICOPTER
T63-A-5 S/N 400029	RECOVERY FROM AUTOROTATION	UH-13R S/N 1833

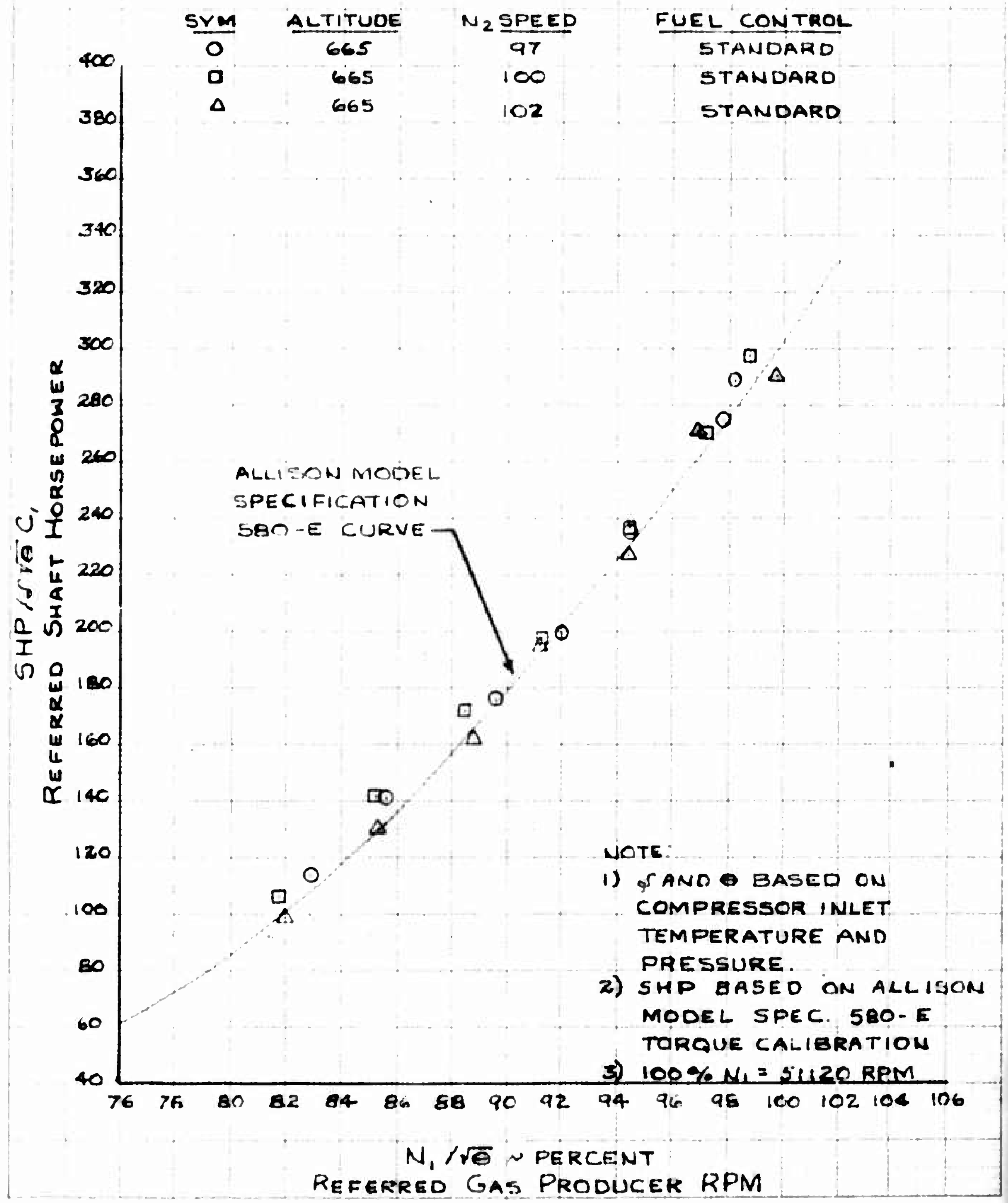
ALT	AIRSPEED	OAT	THROTTLE POSITION	FUEL CONTROL CONFIG.
1000	52 MPH	12°C	30 DEG TO 90 DEG	STD. WITH BEEP SWITCH



ENGINE
T63-A-5 S/N 400029

FIGURE NO. 16
ENGINE CHARACTERISTICS
GROUND RUN

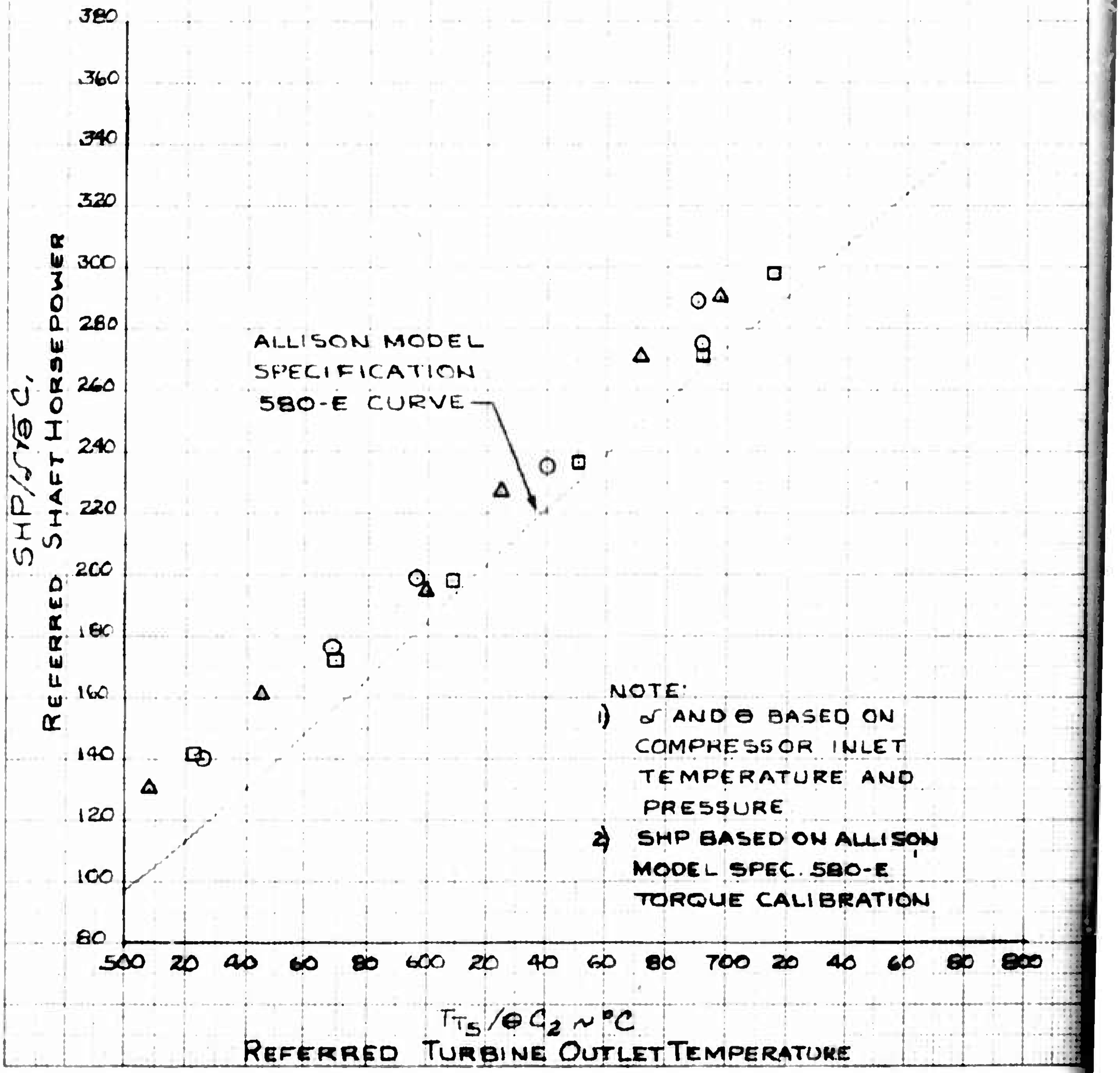
HELICOPTER
UH-13R S/N 1833



NOTE:
1) δ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE.
2) SHP BASED ON ALLISON MODEL SPEC. 580-E TORQUE CALIBRATION
3) 100% N_1 = 51120 RPM

ENGINE T63-A-5 S/N400029	FIGURE NO. 17 ENGINE CHARACTERISTICS GROUND RUN	**HELICOPTER** UH-13R S/N1833

SYM	ALTITUDE	N_2 SPEED	FUEL CONTROL
○	665	97	STANDARD
□	665	100	STANDARD
△	665	102	STANDARD



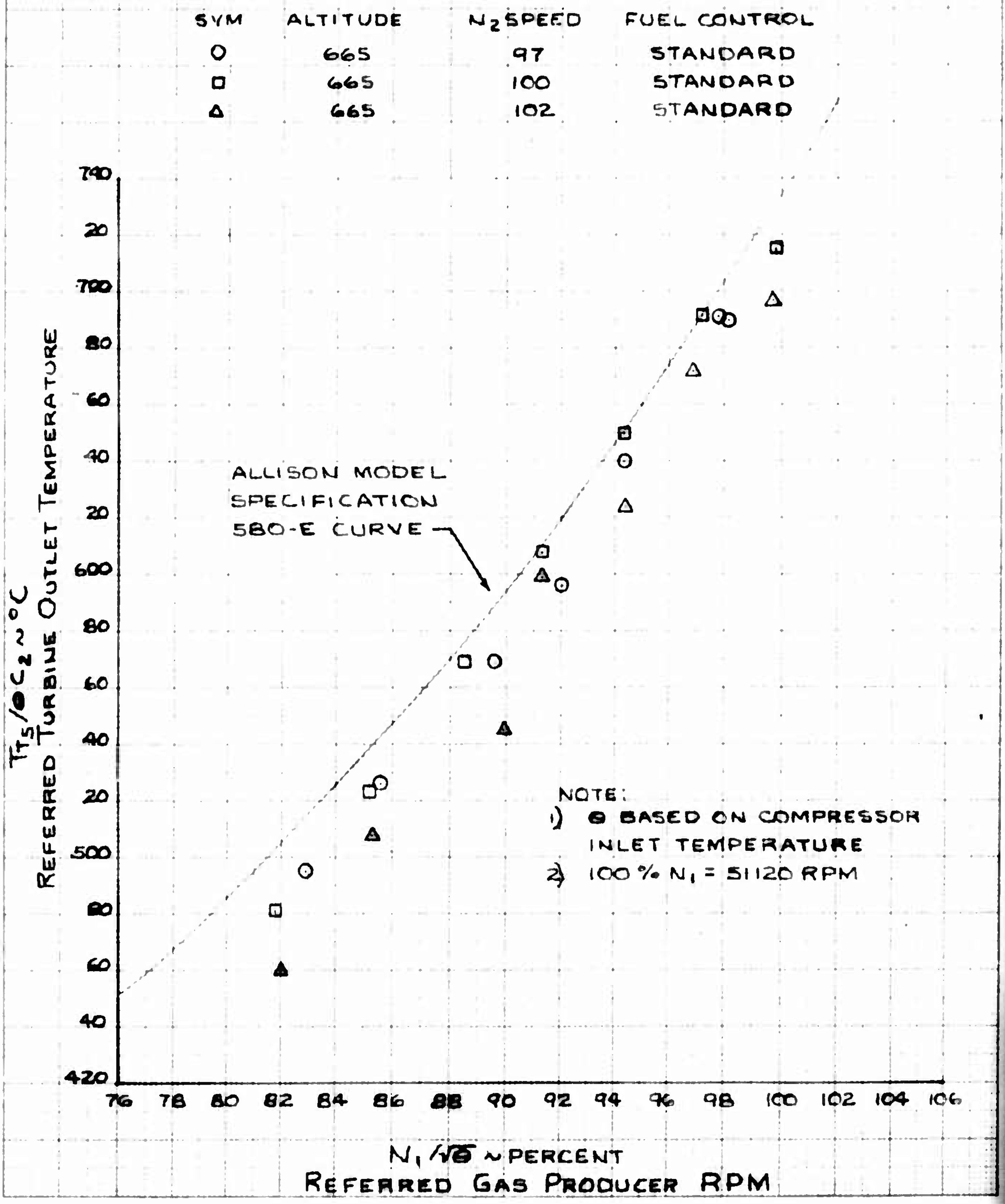
NOTE:

1) δ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE
2) SHP BASED ON ALLISON MODEL SPEC. 580-E TORQUE CALIBRATION

ENGINE
T63-A-5 S/N 400029

FIGURE No. 18
ENGINE CHARACTERISTICS
GROUND RUN

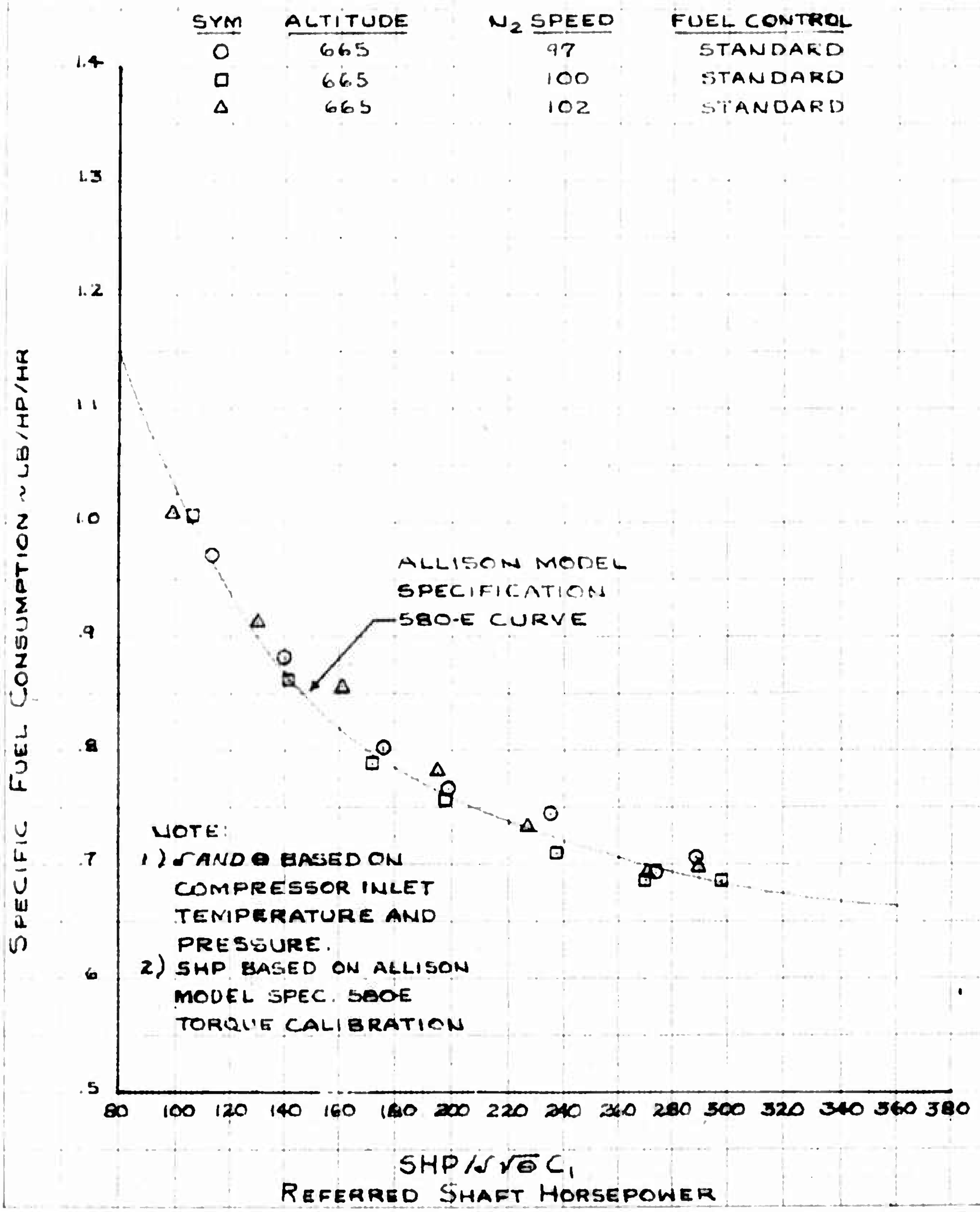
HELICOPTER
UH-13R S/N 1833



ENGINE
T63-A-5 S/N400029

FIGURE NO. 19
ENGINE CHARACTERISTICS
GROUND RUN

HELICOPTER
UH-13R S/N 1833

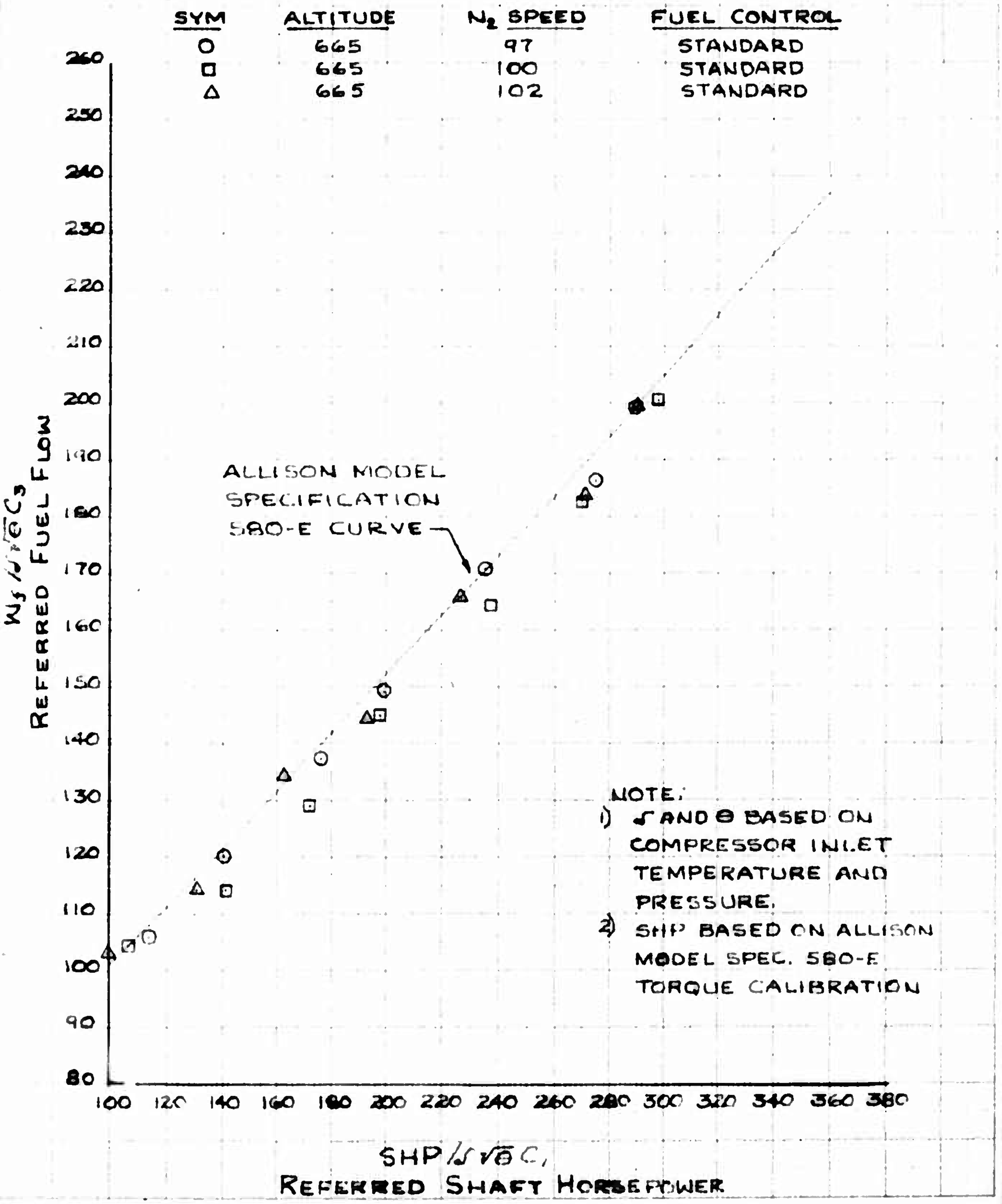


NOTE:
1) δ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE.
2) SHP BASED ON ALLISON MODEL SPEC. 580E TORQUE CALIBRATION

ENGINE
T63-A-5 S/N 400029

FIGURE NO 20
ENGINE CHARACTERISTICS
GROUND RUN

HELICOPTER
UH-13R S/N 1833

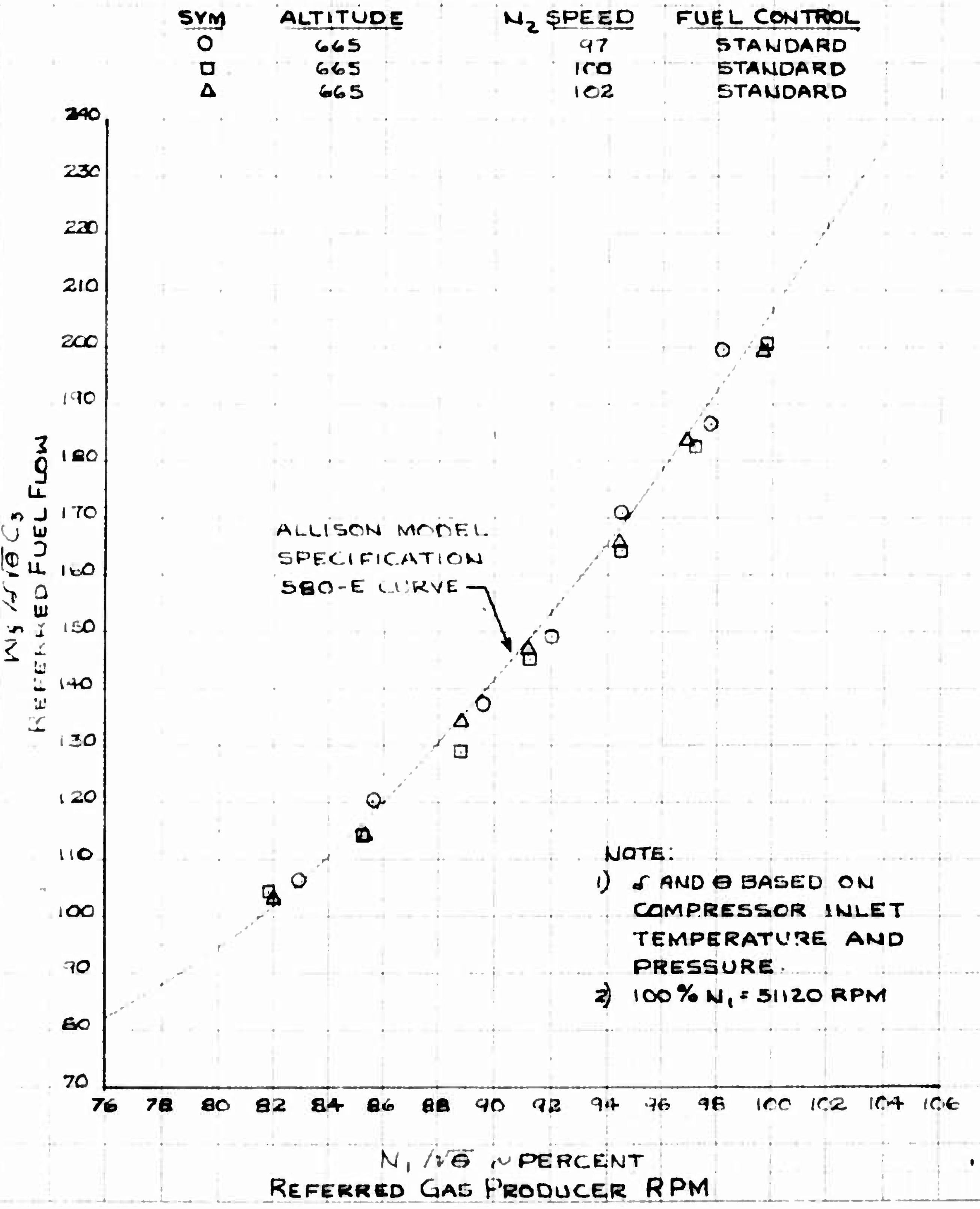


NOTE:
1) δ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE.
2) SHP BASED ON ALLISON MODEL SPEC. 580-E TORQUE CALIBRATION

ENGINE
T63-A-5 S/N 400029

FIGURE NO. 21
ENGINE CHARACTERISTICS
GROUND RUN

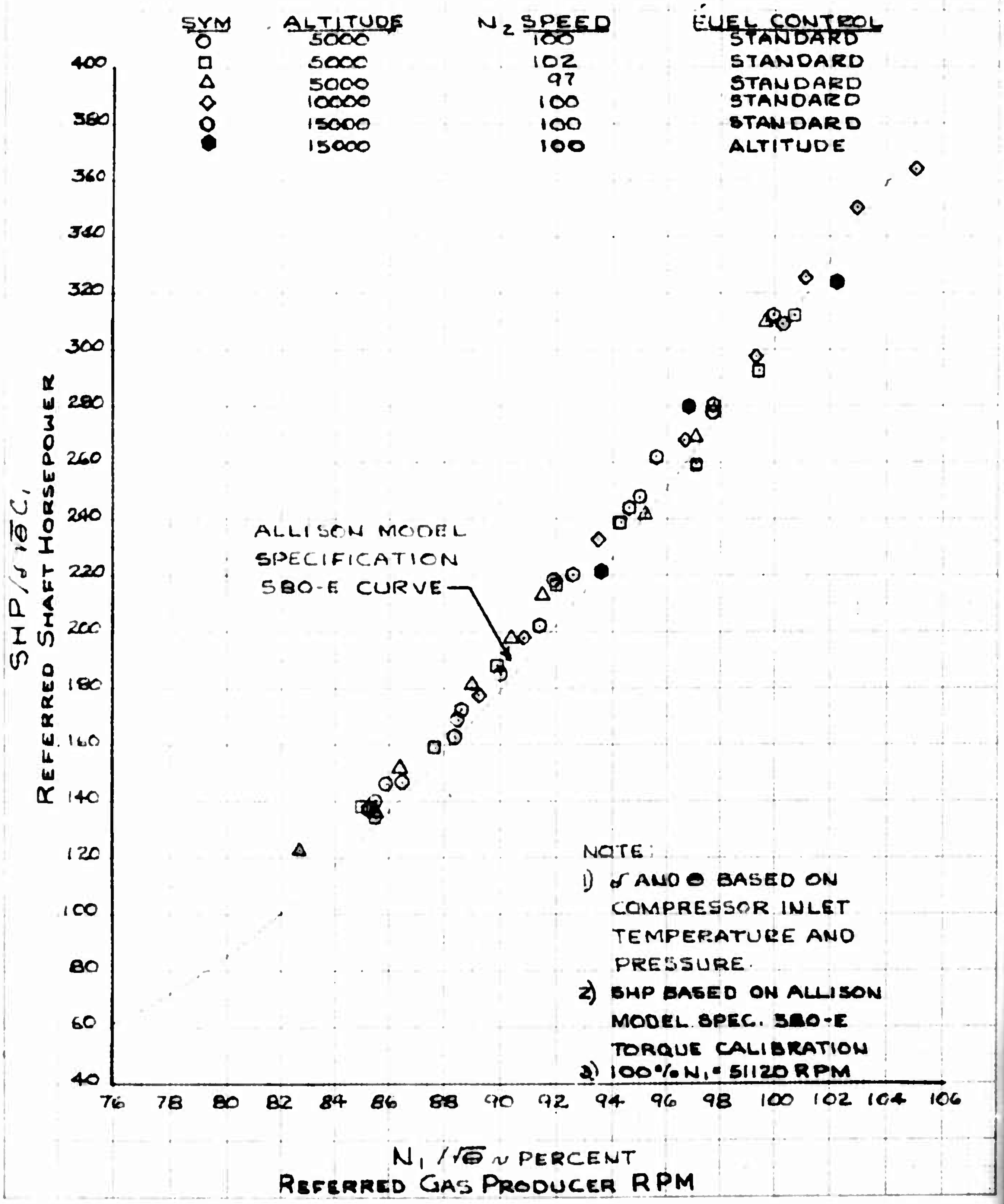
HELICOPTER
UH-13R S/N 1885



ENGINE
T63-A-5 S/N400029

FIGURE NO. 22
ENGINE CHARACTERISTICS
LEVEL FLIGHT

HELICOPTER
UH-13R S/N1833



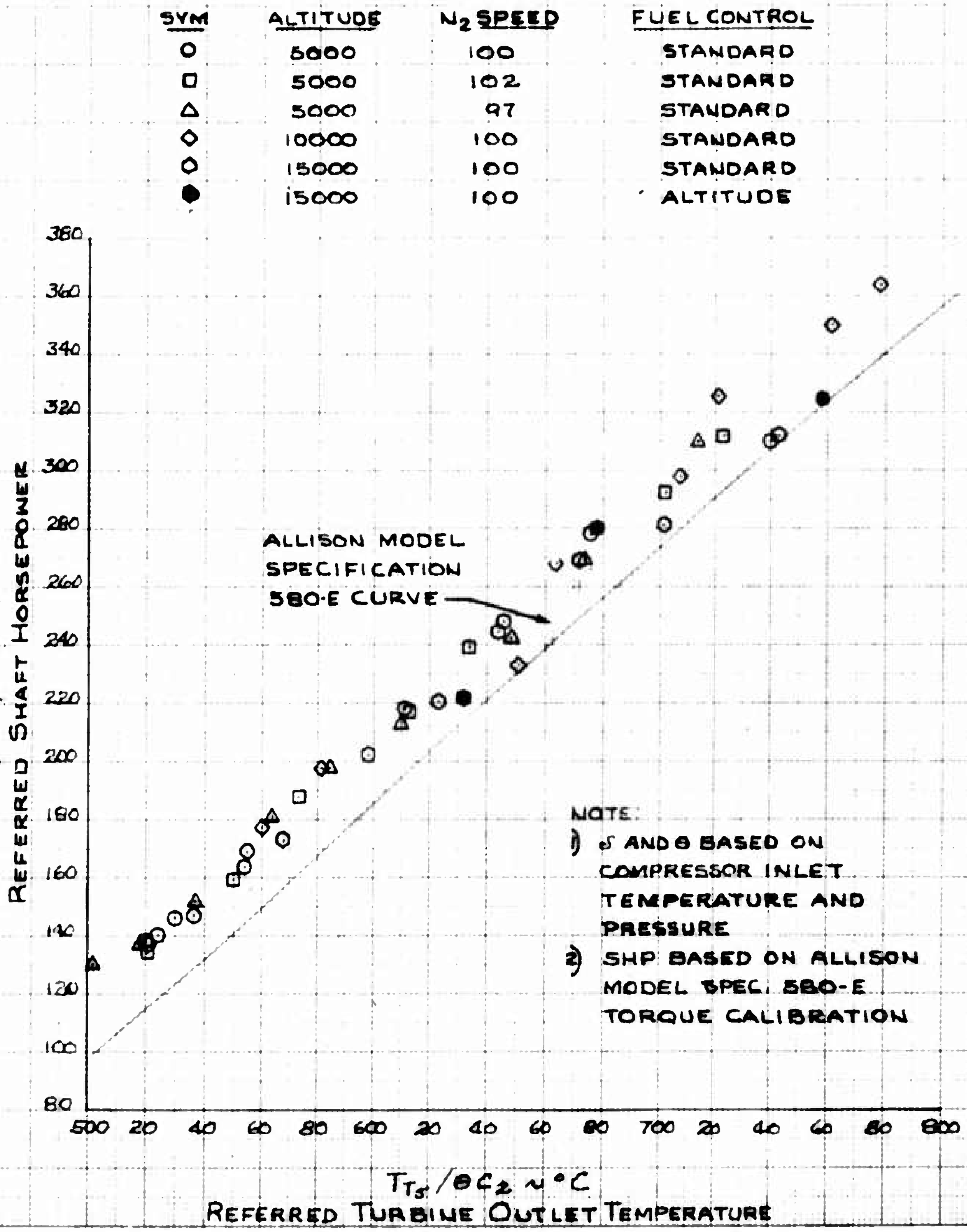
SYM	ALTITUDE	N_2 SPEED	FUEL CONTROL
○	5000	100	STANDARD
□	5000	102	STANDARD
△	5000	97	STANDARD
◇	10000	100	STANDARD
○	15000	100	STANDARD
●	15000	100	ALTITUDE

NOTE:
1) δ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE.
2) SHP BASED ON ALLISON MODEL SPEC. 580-E TORQUE CALIBRATION
3) 100% N_1 = 51120 RPM

ENGINE
T63-A-5 S/N400029

FIGURE NO. 23
ENGINE CHARACTERISTICS
LEVEL FLIGHT

HELICOPTER
UH-13R S/N 1833



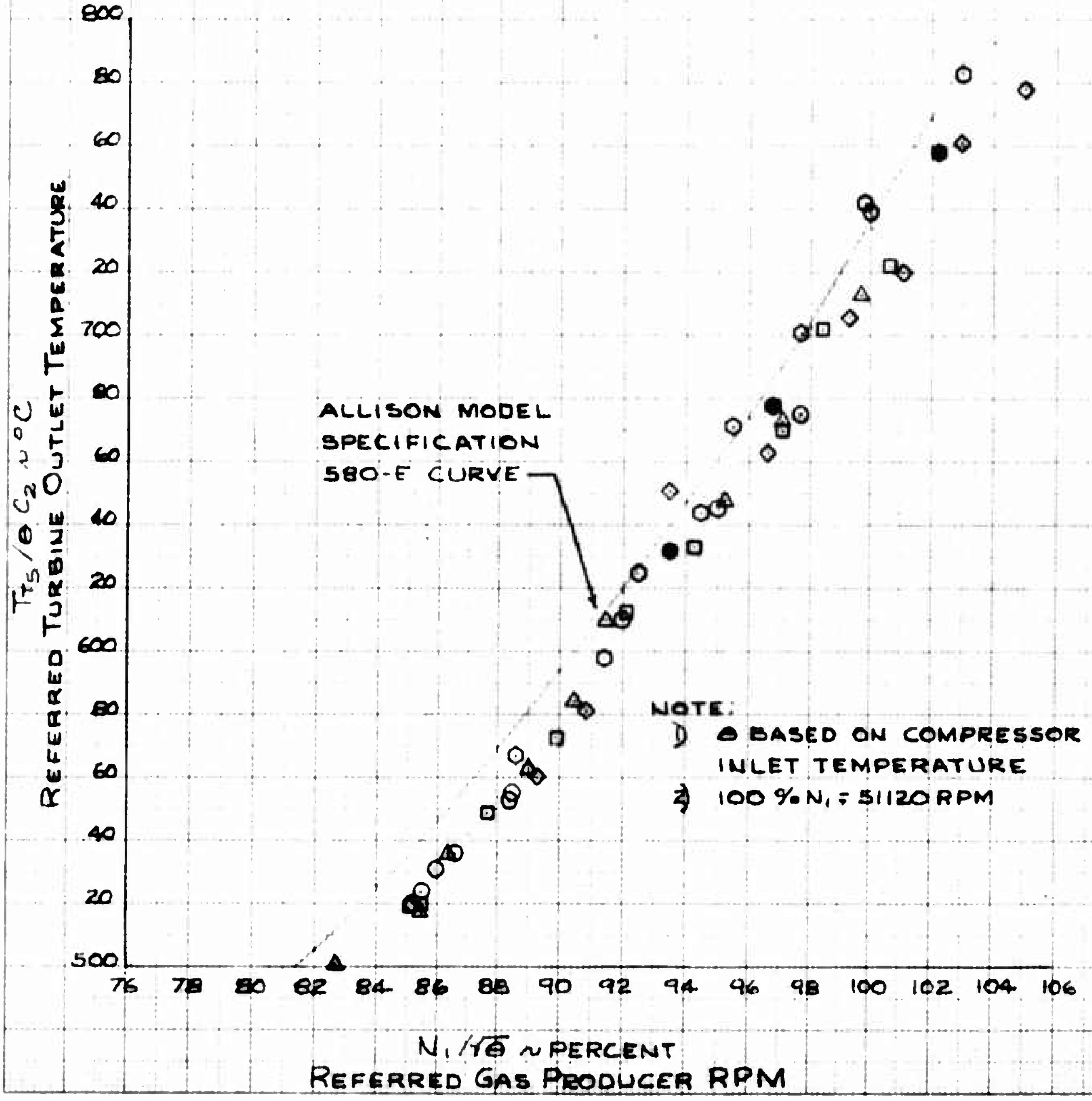
NOTE:
1) δ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE
2) SHP BASED ON ALLISON MODEL SPEC. 580-E TORQUE CALIBRATION

ENGINE
T63-A-5 S/N 400029

FIGURE NO. 24
ENGINE CHARACTERISTICS LEVEL FLIGHT

HELICOPTER
UH-13R S/N 1833

SYM	ALTITUDE	N_2 SPEED	FUEL CONTROL
○	5000	100	STANDARD
□	5000	102	STANDARD
△	5000	97	STANDARD
◇	10000	100	STANDARD
○	15000	100	STANDARD
●	15000	100	ALTITUDE

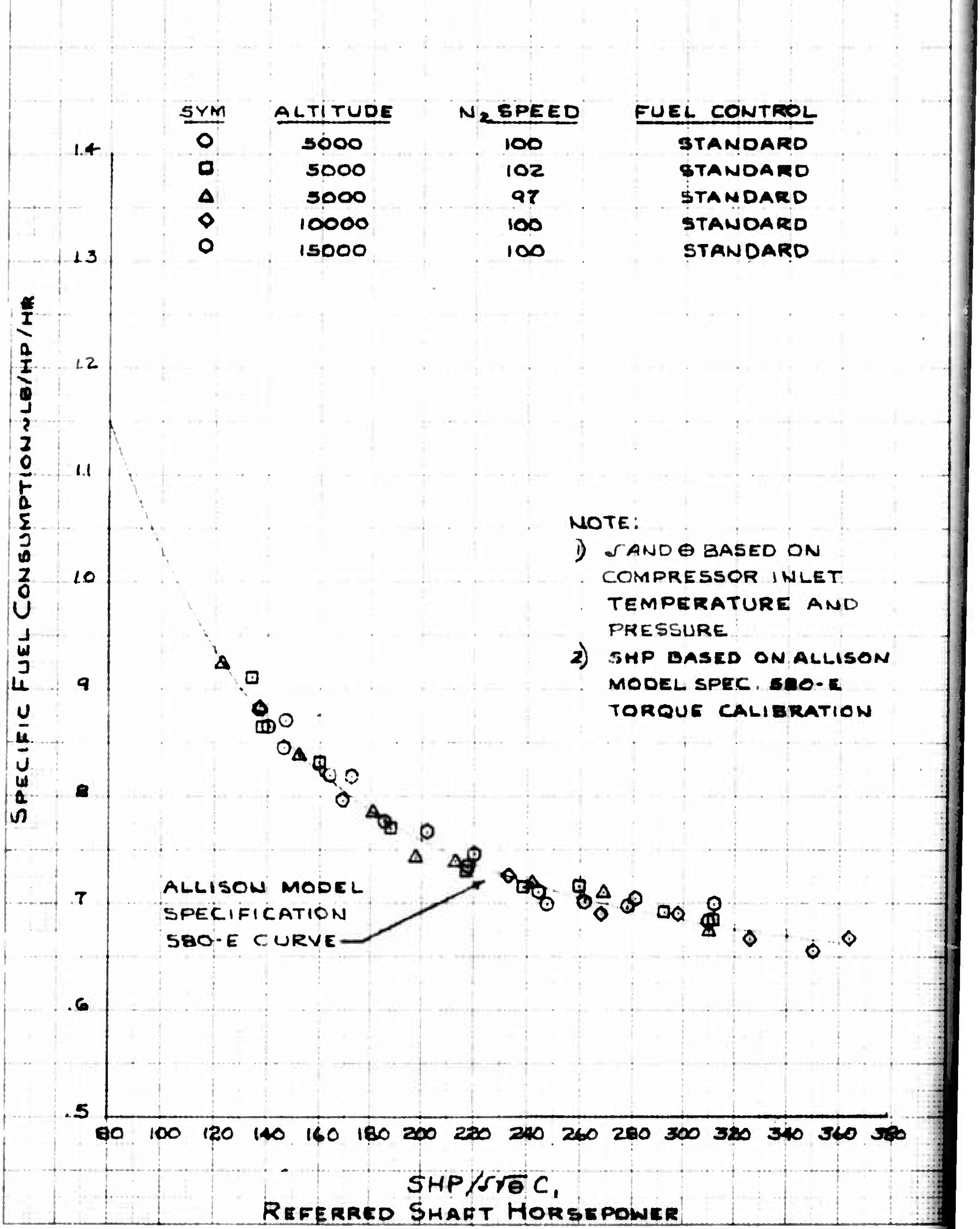


NOTE:
1) θ BASED ON COMPRESSOR INLET TEMPERATURE
2) 100 % N_1 = 51120 RPM

ENGINE
T63-A-5 S/N 400029

FIGURE NO. 25
ENGINE CHARACTERISTICS
LEVEL FLIGHT

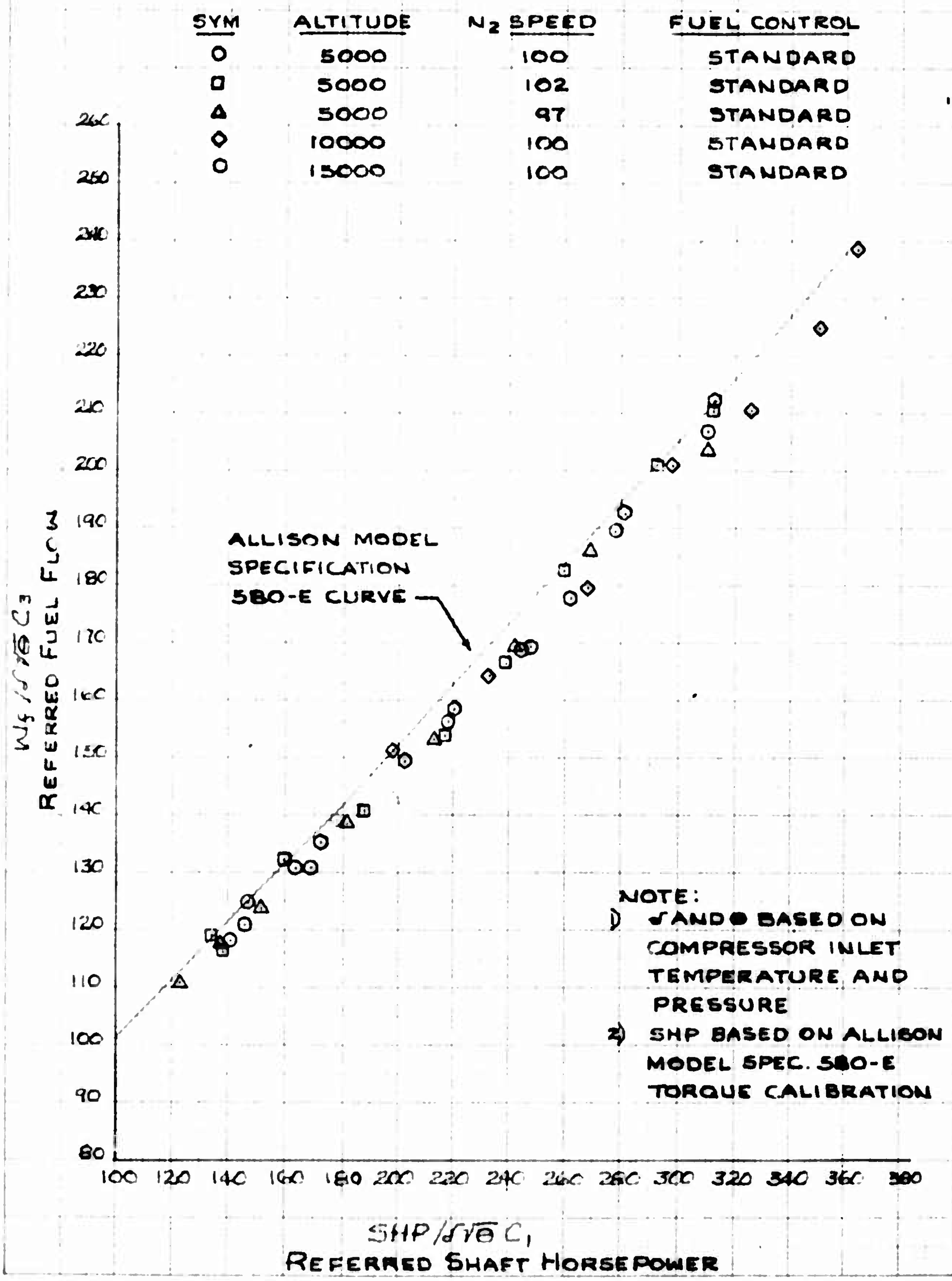
HELICOPTER
UH-13R S/N 1833



ENGINE
T63-A-5 S/N 400029

FIGURE NO. 26
ENGINE CHARACTERISTICS
LEVEL FLIGHT

HELICOPTER
UH-13R S/N 1835



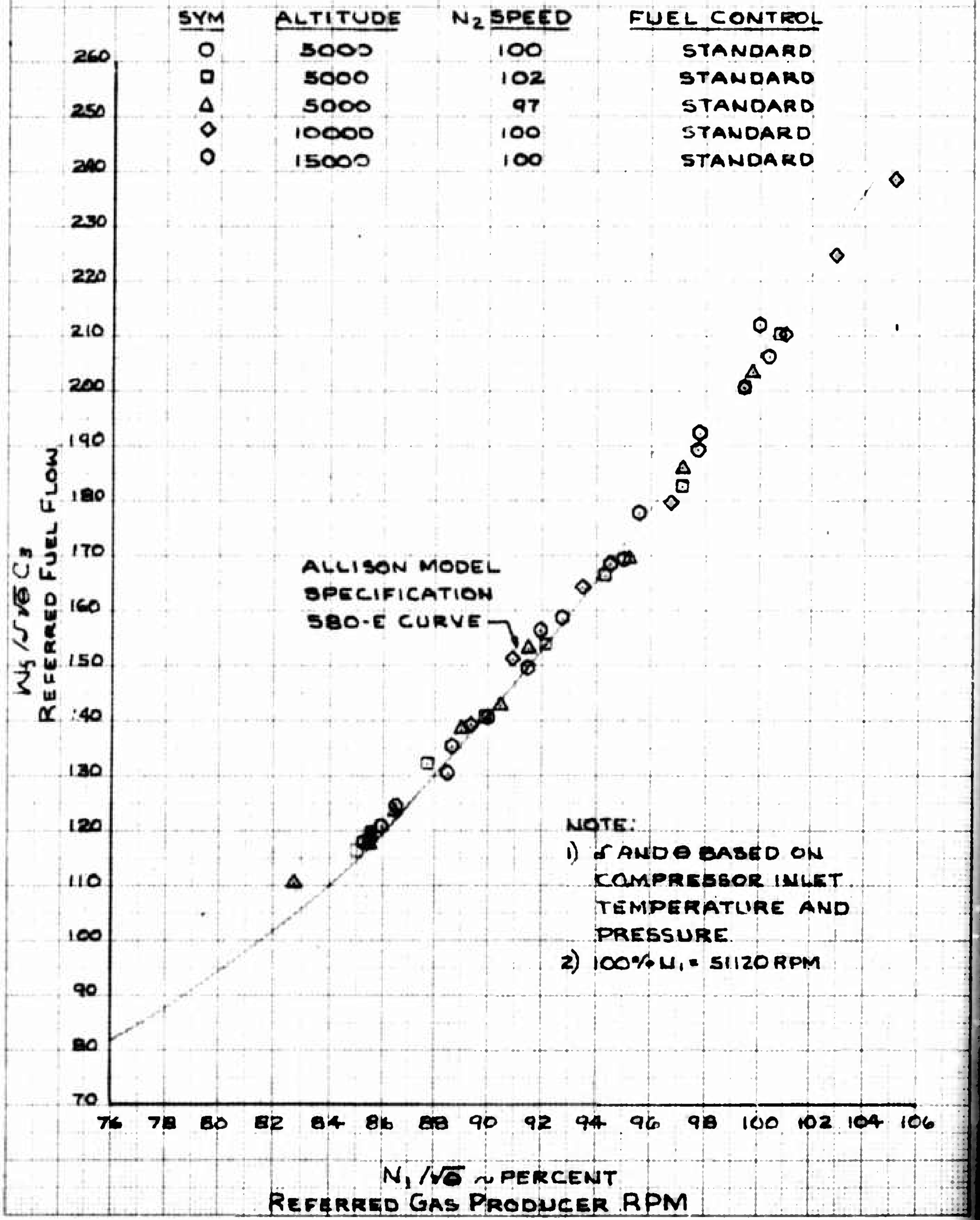
SYM	ALTITUDE	N_2 SPEED	FUEL CONTROL
○	5000	100	STANDARD
□	5000	102	STANDARD
△	5000	97	STANDARD
◇	10000	100	STANDARD
○	15000	100	STANDARD

NOTE:
1) δ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE
2) SHP BASED ON ALLISON MODEL SPEC. 580-E TORQUE CALIBRATION

ENGINE
T63-A-5 S/N 400029

FIGURE NO. 27
ENGINE CHARACTERISTICS
LEVEL FLIGHT

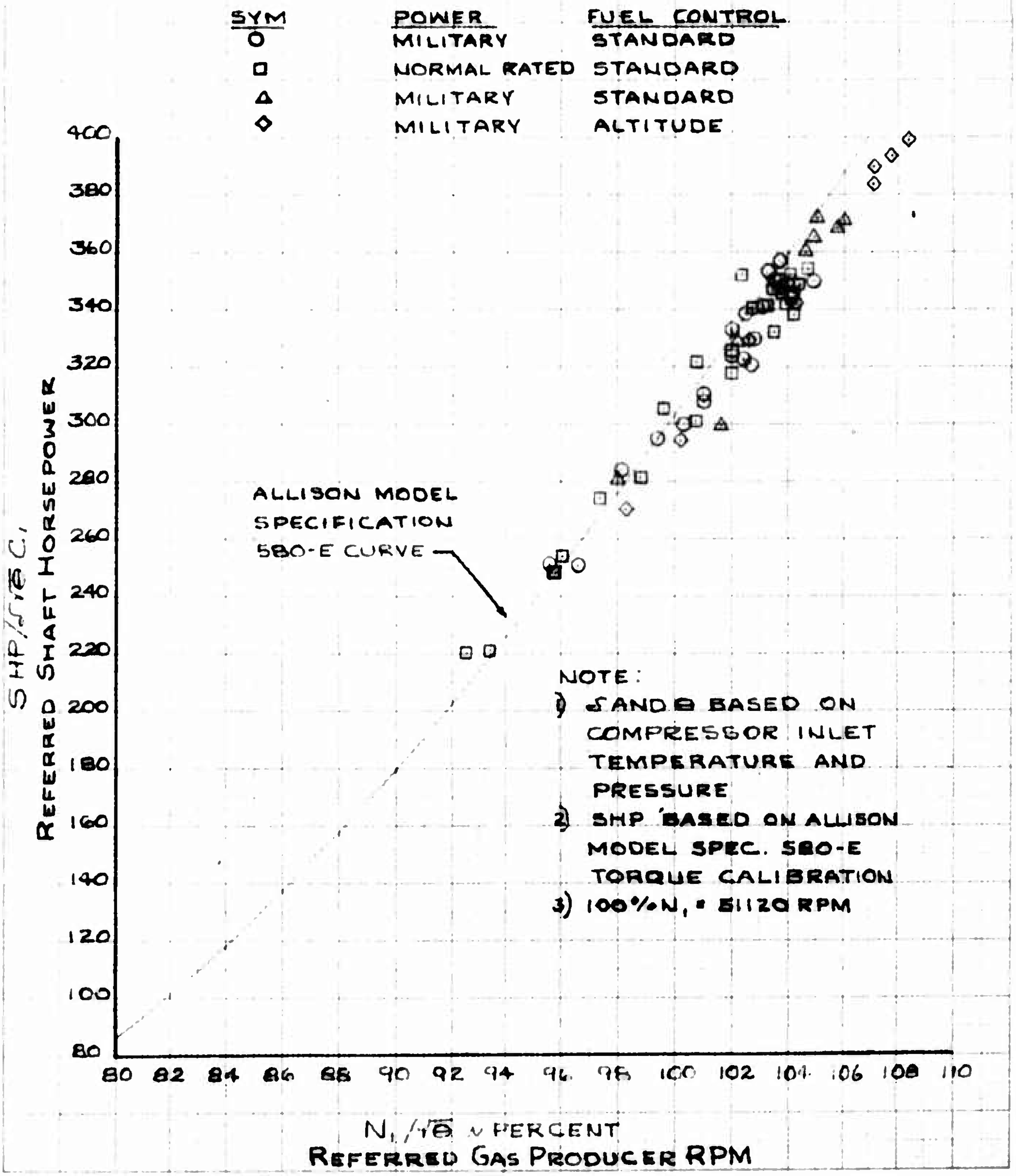
HELICOPTER
UH-13R S/N 1833



ENGINE
T63-A-5 S/N400029

FIGURE NO 28
ENGINE CHARACTERISTICS
CLIMB

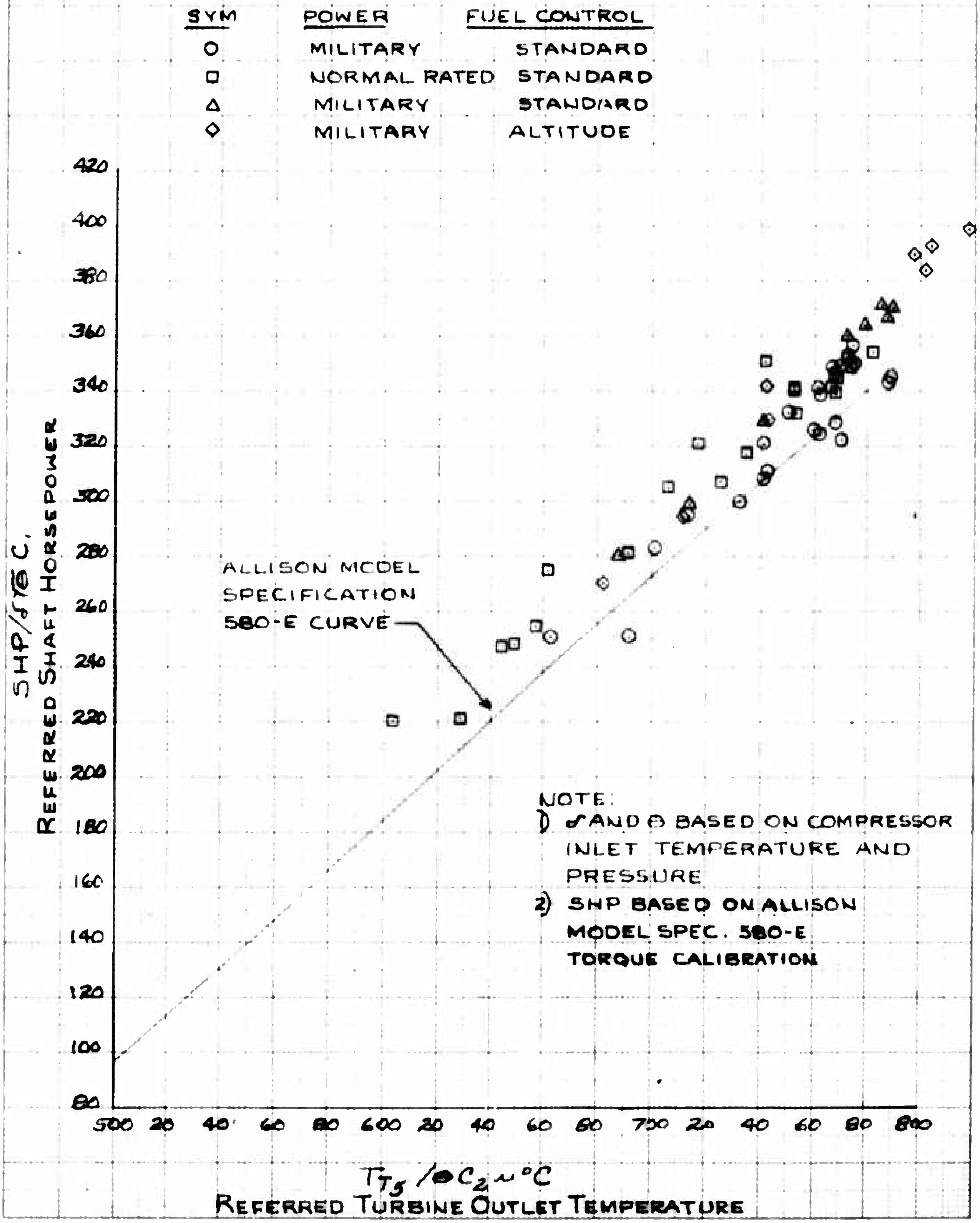
HELICOPTER
UH-13R S/N 1833



ENGINE
T63-A-5 S/N 400029

FIGURE NO. 29
ENGINE CHARACTERISTICS
CLIMB

HELICOPTER
UH-13R S/N 1833

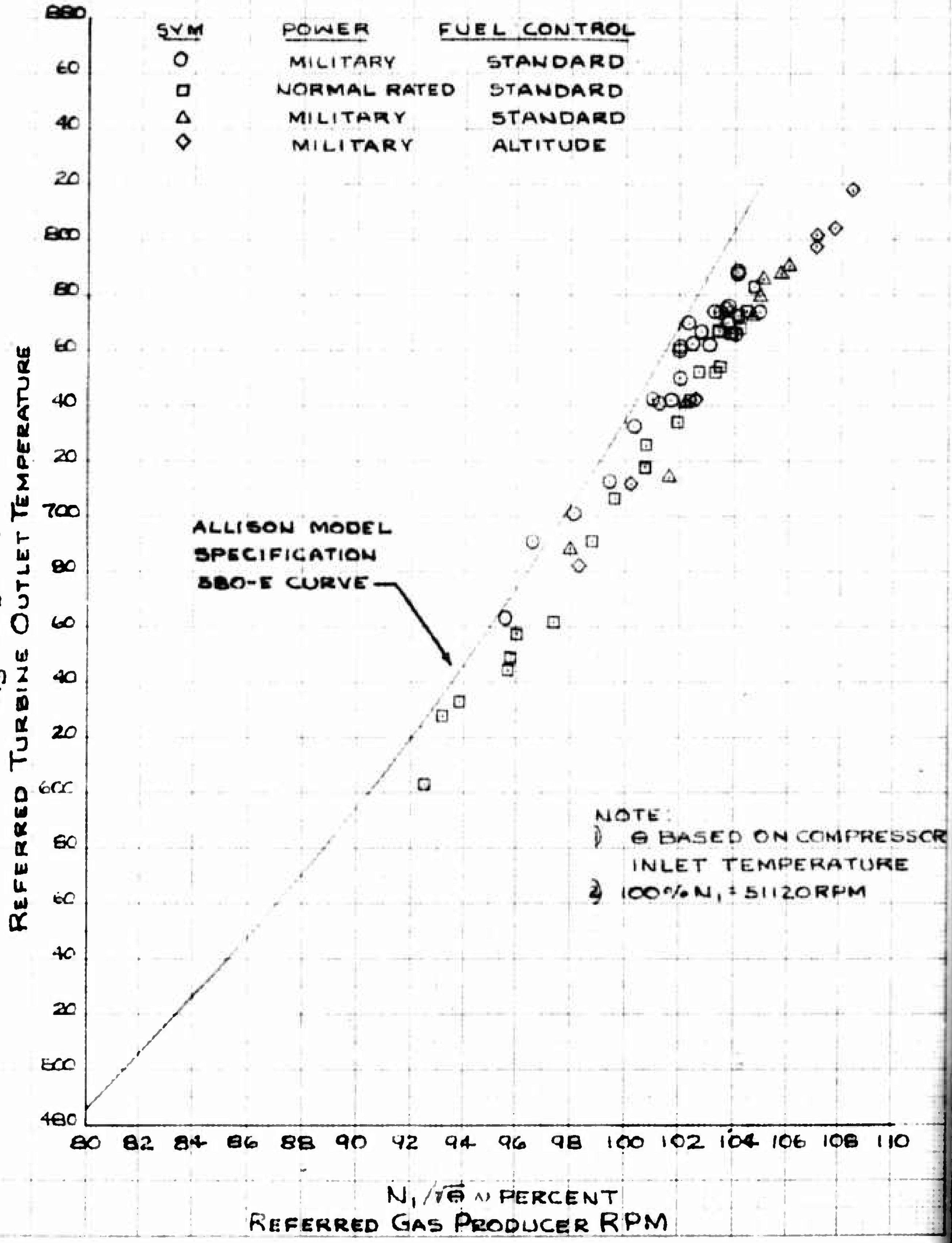


NOTE:
1) δ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE
2) SHP BASED ON ALLISON MODEL SPEC. 580-E TORQUE CALIBRATION

ENGINE
T63-A-5 S/N 400029

FIGURE NO. 30
ENGINE CHARACTERISTICS
CLIMB

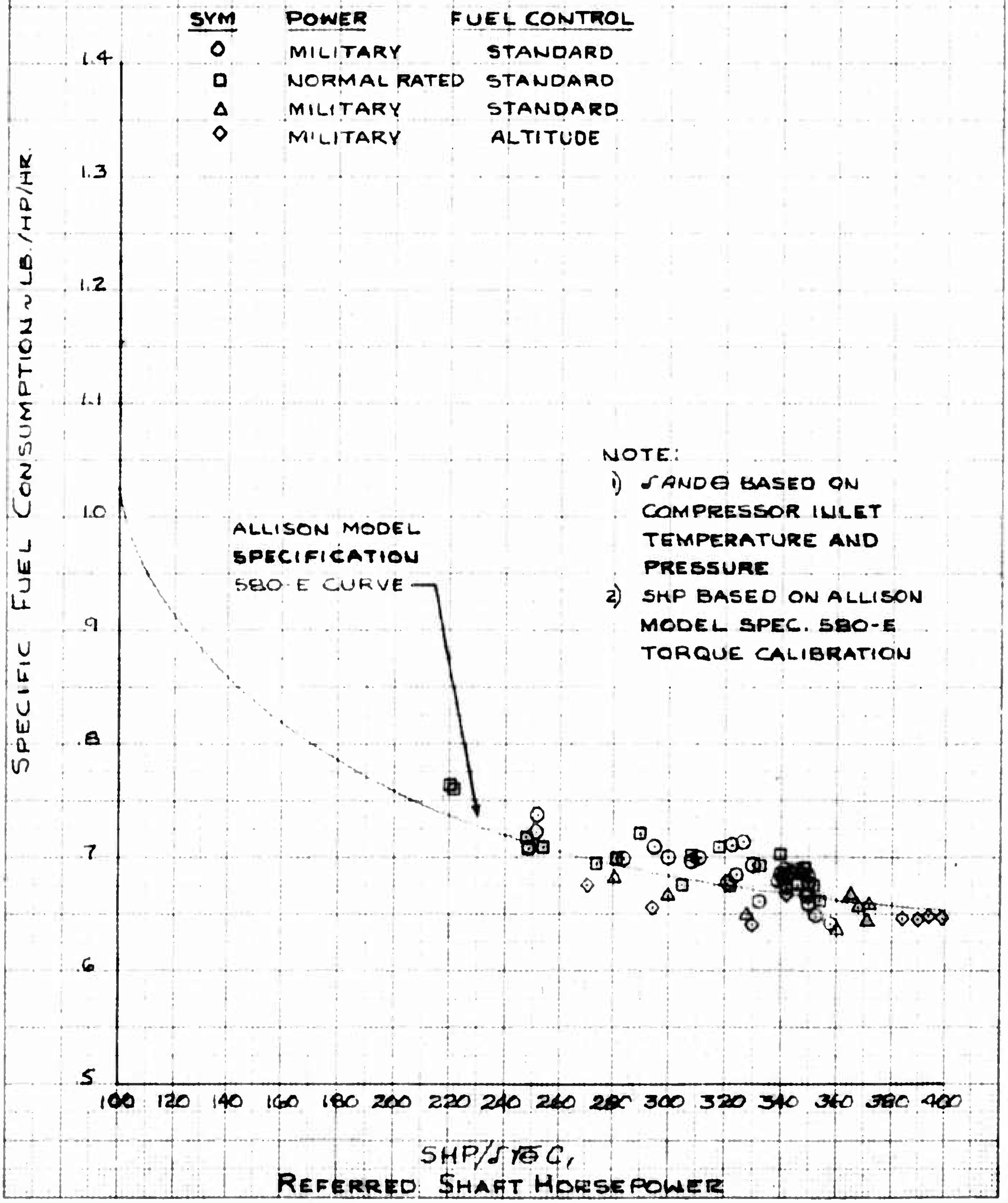
HELICOPTER
UH-13R S/N1833



ENGINE
T63-A-5 S/N 400029

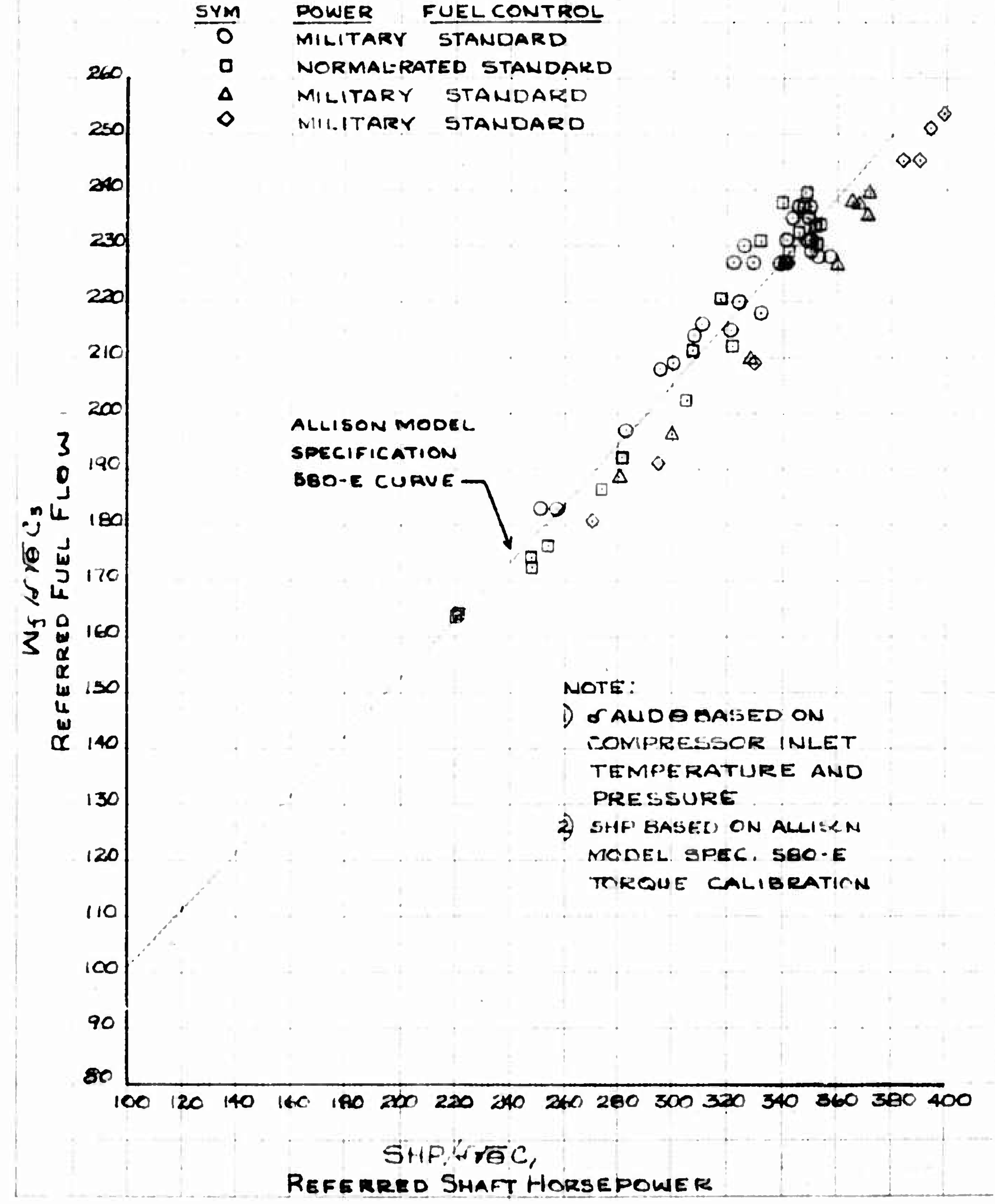
FIGURE NO. 31
ENGINE CHARACTERISTICS
CLIMB

HELICOPTER
UH-13R S/N 1833



NOTE:
1) √ AND θ BASED ON COMPRESSOR INLET TEMPERATURE AND PRESSURE
2) SHP BASED ON ALLISON MODEL SPEC. 580-E TORQUE CALIBRATION

ENGINE	FIGURE No. 32	HELICOPTER
T63-A-5 S/N400029	ENGINE CHARACTERISTICS CLIMB	UH-13R S/N 1833



ENGINE
T63-A-5 S/N 400029

FIGURE NO. 33
ENGINE CHARACTERISTICS
CLIMB

HELICOPTER
UH-13R S/N 1833

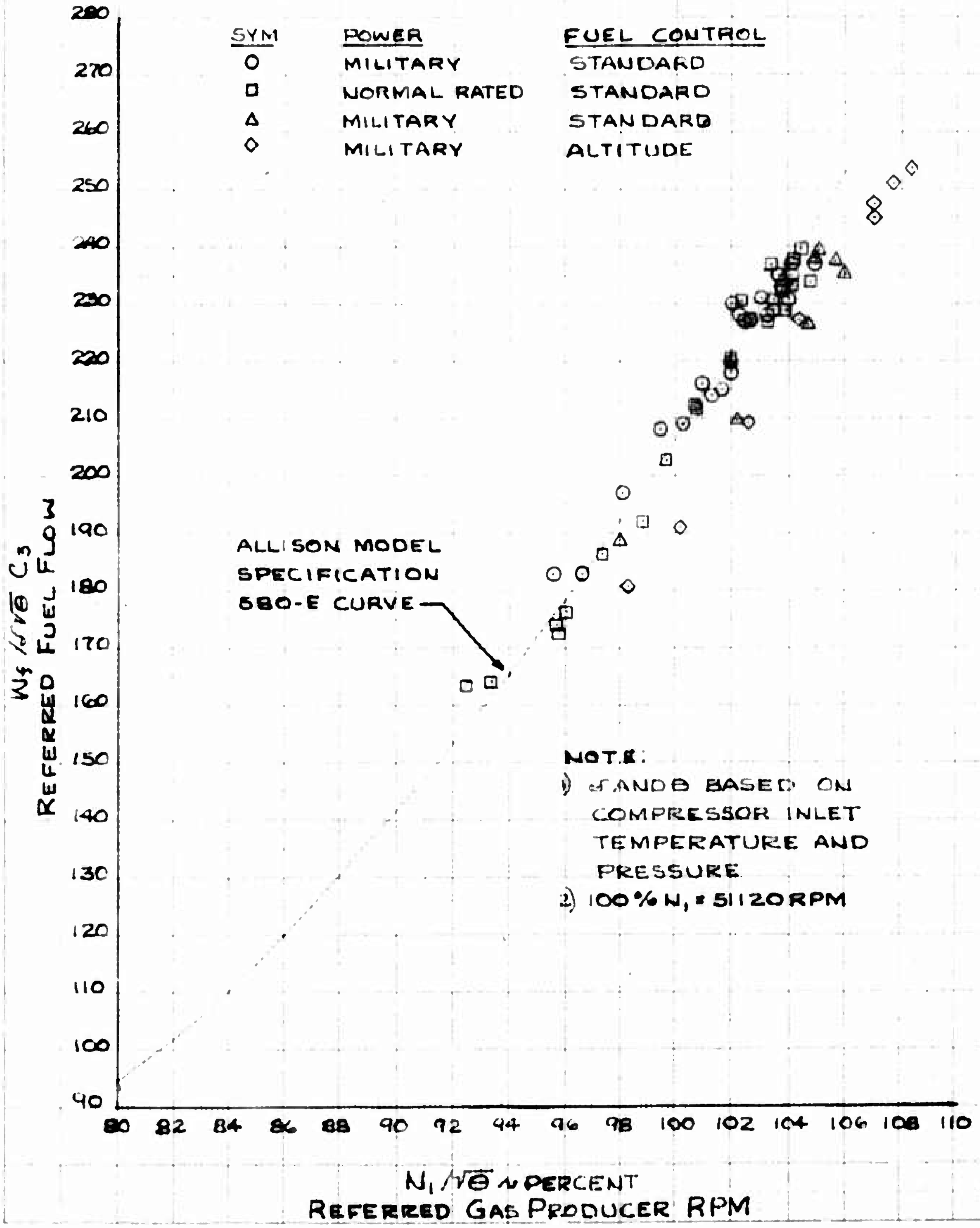
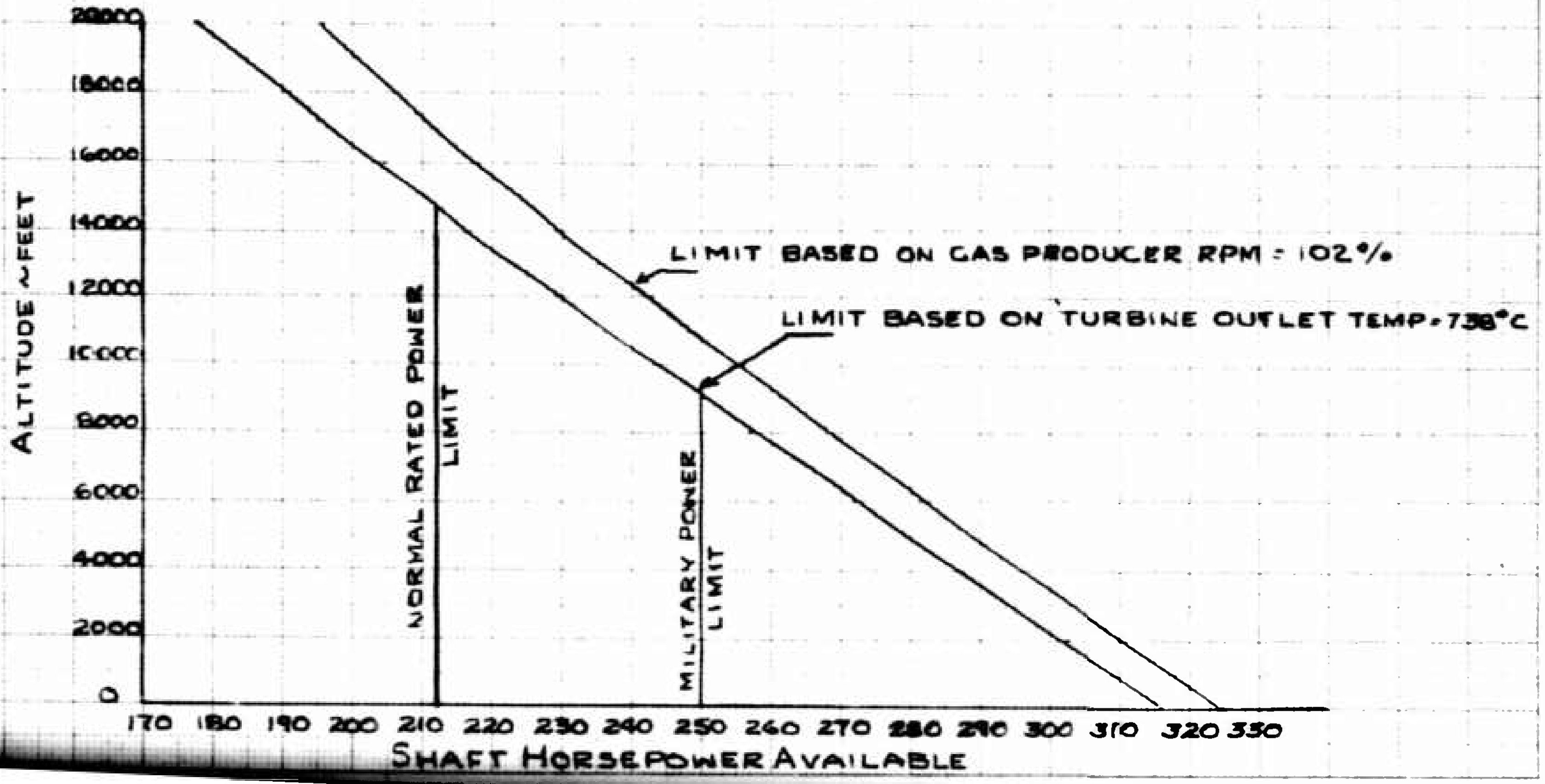


FIGURE No. 34
STANDARD DAY SHAFT HORSEPOWER AVAILABLE
T63-A-5 S/N 400029

NOTE.

1) SHP DETERMINED FROM CURVE OF $SHP/\sqrt{\theta C}$, VS. $T_{T_5}/\theta C_2$ AND $SHP/\sqrt{\theta C}$, VS $N_1/\sqrt{\theta}$ AS ESTABLISHED FROM TEST DATA
2) COMPRESSOR INLET TEMPERATURE = AMBIENT TEMP. + 1°C
3) COMPRESSOR INLET PRESSURE = AMBIENT PRESSURE X 1.003 ($P_{T_2}/P_A = 1.003$)
4) DATA CORRECTED FOR $N_2 = 100\%$
5) ACCESSORY AND ELECTRICAL LOAD ASSUMED = 3HP
6) ANTI-ICING AIR AND UTILITY BLEED AIR "OFF"



PART III

ANNEX A

REFERENCES

1. Allison Division of General Motors Corporation, Model Specification No. 580E, "T63-A-5 Gas Turbine Engine", dated 28 Nov 1963, Revised 24 June 1963.

2. Allison Division of General Motors Corporation, Publication No. 3W2, "Allison Operation Maintenance and Overhaul Handbook T63-A-5 Gas Turbine Engine", dated 1 Oct 1962, Revised 1 July 1963.

3. Allison Division of General Motors Corporation, Report No. AW. 0031-017A, "Basic Equations Used for Obtaining T63-A-5 ENGINE Performance".

4. Allison Division of General Motors Corporation, Experimental Flight Test Technical Report No. TR5305-12-509, "Allison T63-A-5 Engine Evaluation in Bell UH-13R Helicopter S/N 1833", dated 24 July 1963.

ANNEX B

ENGINE PERFORMANCE CALCULATION METHOD

The equations used to correct the engine performance from test conditions to U. S. standard conditions were obtained from Reference 3, Annex A, Part III and are as follows:

$$\begin{array}{ccccccc} \textcircled{1} & \textcircled{2} & \textcircled{3} & \textcircled{4} & \textcircled{5} & \textcircled{6} & \textcircled{7} \end{array}$$

$$SHP = \left[\delta\sqrt{\theta}C_1 \left(\frac{SHP}{\delta\sqrt{\theta}C_1} + \frac{\Delta SHP}{\delta\sqrt{\theta}C_1} + \frac{\Delta SHP}{\delta\sqrt{\theta}C_1} \right) \left(1 + \frac{C_{BL_1} \times \% W_{BL}}{100} \right) + HP_{EXT} \times C_{HP_1} \right] C_{ah_1}$$

$$T_{T_5} = \left[\theta C_2 \left(\frac{T_{T_5}}{\theta C_2} + \frac{\Delta T_{T_5}}{\theta C_2} + \frac{\Delta T_{T_5}}{\theta C_2} \right) \left(1 + \frac{C_{BL_2} \times \% W_{BL}}{100} + \frac{HP_{EXT} \times C_{HP_2}}{\delta\sqrt{\theta}} \right) \right] C_{ah_2}$$

$$W_f = \left[\delta\sqrt{\theta}C_3 \left(\frac{W_f}{\delta\sqrt{\theta}C_3} \quad \frac{\Delta W_f}{\delta\sqrt{\theta}C_3} + \frac{\Delta W_f}{\delta\sqrt{\theta}C_3} \right) \left(1 + \frac{C_{BL_3} \times \% W_{BL}}{100} + \frac{HP_{EXT} \times C_{HP_3}}{\delta\sqrt{\theta}} \right) \right] C_{ah_3}$$

NOTE: The circled numbers denote corrections that are explained on the following page.

① Inlet pressure and temperature corrections.

② Values at sea-level-static-standard-day calibrations at 100% N_2

③ Power turbine speed correction (N_2 /   ).

④ Ram pressure ratio corrections.

⑤ Air bleed corrections.

⑥ Horsepower extracted corrections (accessory and electrical load).

⑦ Correction factors for anti-icing air "ON."

The following is a brief description of the terms used in the above equations and the terms used to present performance data.

a. θ - Theta, a ratio of test condition temperature to standard-day, sea-level temperature. $\theta = T_{test} / 288.16$.

b. δ - Delta, a ratio of test condition pressure to standard-day, sea-level pressure. $\delta = P_{test} / 29.92$ in. Hg.

c. C_1 - Shaft horsepower correction. A function of ambient air temperature and pressure.

d. C_2 - Gas producer turbine outlet temperature correction. A function of ambient air temperature and pressure.

e. C_3 - Fuel flow correction. A function of ambient air temperature and pressure.

f. $SHP/\delta\sqrt{\theta}C_1$ - Referred shaft horsepower. This is output shaft horsepower corrected for inlet temperature and pressure conditions at sea-level, standard-day conditions $\delta\sqrt{\theta}C_1 = 1$.

g. $N1/\sqrt{\theta}$ - Referred gas producer turbine speed, or N1 referred. This is gas producer turbine speed corrected for inlet temperature. At sea-level, standard-day conditions $\sqrt{\theta} = 1$.

h. $W_f/\delta\sqrt{\theta}\,C_3$ - Referred fuel flow. This is fuel flow corrected for inlet temperature and pressure conditions. At sea-level, standard-day conditions $\delta\sqrt{\theta}\,C_3 = 1$.

i. $T_{t_5}/\theta C_2$ - Referred turbine outlet temperature, or T_{t_5} referred. This is turbine outlet temperature corrected for inlet temperature. At sea-level, standard-day conditions $\theta C_2 = 1$.

j. SFC - Special Fuel Consumption. This is obtained by dividing fuel flow by shaft horsepower (W_f / SHP) and has the units of pounds of fuel per hour per horsepower.

k. Cbl_1 - Shaft horsepower correction for compressor air bleed.

l. Cbl_2 - Turbine outlet temperature correction for compressor air bleed.

m. Cbl_3 - Fuel flow correction for compressor air bleed.

n. Wbl - Percent of total air bleed from compressor.

o. Chp_1 - Shaft horsepower correction for horsepower extracted to drive accessories and electrical load.

p. Chp_2 - Turbine outlet temperature correction for horsepower extracted to drive accessories and electrical load.

q. Chp_3 - Fuel flow correction for horsepower extracted to drive accessories and electrical load.

r. HPext - Amount of horsepower extracted to drive accessories and electrical load. In this evaluation, HPext was assumed to be 3 horsepower.

s. Cai_1 - Shaft horsepower correction for anti-icing air "ON" equals 0.968.

t. Cai_2 - Turbine outlet temperature correction for anti-icing air "ON" equals 1.020.

u. Cai_3 - Fuel flow correction for anti-icing air "ON" equals 1.036.

NOTE: The values for items 3, 4, 5, 11, 12, 13, 15, 16, 17, 19, 20 and 21 were obtained from curves presented in Reference 3, Annex A, Part III.

ANNEX C

INSTRUMENTATION

All instrumentation was installed and calibrated by the engine manufacturer. Prior to the start of this flight evaluation, engineering and instrumentation personnel from the U. S. Army Aviation Test Activity spot checked the calibration of several parameters. This was accomplished with the cooperation of the engine manufacturer's instrumentation personnel.

The following parameters were measured and recorded on an oscillograph:

*1. Gas producer turbine speed.

*2. Power turbine speed.

*3. Rotor speed.

4. Torquemeter pressure.

5. Governor sensing pressure.

6. Compressor discharge pressure.

7. Regulator sensing pressure.

8. Fuel nozzle pressure.

9. Cabin floor accelerometer.

10. Power turbine governor position.

11. Throttle position.
12. Collective pitch position.
13. Turbine outlet temperature.
14. Pylon damper position.

*15. Fuel flow.

NOTE: The calibration of the parameters marked with an * were spot checked by ATA personnel.

The following parameters were measured and recorded on a photo panel:

* 1. Altitude.

2. Airspeed.

* 3. Free air temperature.

4. Fuel inlet temperature.
5. Power turbine governor position.
6. Throttle position.
7. Fuel control sensing pressure.

* 8. Torquemeter oil pressure.

9. Engine fuel boost pressure.

*10. Gas producer turbine speed.

*11. Power turbine speed.

*12. Rotor speed.

13. Fuel nozzle pressure.

14. Engine oil pressure.

15. Collective pitch position.

*16. Turbine outlet temperature.

17. Oil inlet temperature.

*18. Compressor inlet temperature.

19. Battery voltage.

20. Compressor inlet pressure.

21. Starter current.

22. Generator load.

23. Oscillograph coordination counter number.

NOTE: The calibrations of the parameters marked with an * were sopt checked by ATA personnel.

ATA-TP-63-10 ANNEX D

TEST PLAN FOR THE EVALUATION OF THE T63/T65 GAS TURBINE ENGINE AS INSTALLED IN THE UH-13R HELICOPTER

AVIATION TEST ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA
TEST AND EVALUATION COMMAND
ARMY MATERIEL COMMAND
UNITED STATES ARMY

15 July 1963

TEST PLAN FOR THE
EVALUATION OF THE T63/T65 GAS TURBINE ENGINE
AS INSTALLED IN THE
UH-13R HELICOPTER

INTRODUCTION

The following test plan outlines evaluations of the Allison T63-A-5 and the Continental T65-T-1 gas turbine engines. These evaluations are being made to determine operation and performance characteristics of the engines as installed in a helicopter under various in-flight conditions. Each engine will be installed in a UH-13R helicopter for these tests.

The evaluations will be conducted by the U. S. Army Aviation Test Activity at each contractor facility. The results of these tests will be forwarded to the LOH Project Manager, AMC, Washington, D. C. through the TEC Headquarters, Aberdeen Proving Ground, Maryland.

TESTS TO BE CONDUCTED

The specific fuel consumption along with various other engine parameters will be determined at various engine inlet conditions. These tests will be conducted with the helicopter tied down at the following conditions:

Gas Producer Speed (N_1): 70% to maximum

Power Turbine Speed (N_2): Minimum, 100% and maximum

Altitude: That available at the contractor's facilities and in level flight at a constant pressure altitude at the minimum weight under the following conditions:

N_1	N_2	Altitude
As Required	Minimum	5000 ft
As Required	100%	5000 ft
As Required	Maximum	5000 ft
As Required	100%	10, 000 ft
As Required	100%	15, 000 ft

The airspeed range of interest is from zero (or the minimum) to the maximum.

The maximum power available at various altitudes will be determined by conducting continuous climbs from sea-level to the service ceiling or limit altitude of the helicopter at the following conditions:

Power: Military (30 min limit) and maximum continuous

Power Turbine Speed (N_2): Minimum, 100% and maximum

Gross Weight: Minimum

Airspeed: Approximately 45 knots CAS

Test Plan for the T63/T65 Gas Turbine Engine Evaluation as Installed in the UH-13R Helicopter

The minimum acceleration times from various power settings to maximum power will be determined. These tests will be conducted on the ground with the rotor unloaded and loaded and also in flight. The minimum time for power recovery from an autorotation will also be determined. These tests will be conducted at altitudes of approximately 5000 and 15, 000 feet.

The contractor demonstrated airstart airspeed-altitude envelope will be spot checked at various airspeed-altitude conditions corresponding to the extremes of the envelope.

An attempt will be made to induce compressor stall (surge) and torsional instability. These tests will be accomplished at altitudes of approximately 5000, 10, 000, and 15, 000 feet, a light gross weight and various airspeeds in climbing, level and descending flight. Collective inputs and reversals of various magnitudes and rates will be applied in an attempt to induce these phenomenon.

The effect of compressor bleed (for utility) on engine performance will be determined at 100 percent power turbine speed at an altitude of 5000 feet, minimum gross weight, airspeeds from 20 knots to V_{max} and using the maximum bleed available.

Power turbine response droop and lag characteristics will be evaluated throughout the airspeed envelope at an altitude of 5000 feet and a minimum gross weight. Collective inputs, pedal inputs, and changes in power settings will be made to evaluate these effects.

The effect of boost pump failure on engine operation will be evaluated by conducting a military rated power climb at 100 percent rotor speed with the boost pump inoperative. An attempt will be made to climb to at least 6000 feet during this test.

Test Plan for the T63/T65 Gas Turbine Engine Evaluation as Installed in the UH-13R Helicopter

CONCLUSIONS

This test plan will provide limited engineering data to evaluate both the T63 and T65 gas turbine engines. This evaluation will require approximately twenty (20) hours of engine operation and six (6) weeks of testing on each engine. Additional tests may be required to evaluate problem areas which are not known at this time.

TEST DATA

T63-A-5

TEST: GROUND RUN
FLT NO.: 1

CN	899	900	901	902	903	904	905
ALT	665	665	665	665	665	665	665
FAT	-1.5	-1.5	-2.5	-2.5	-2.5	-2.0	-2.0
Tt_2	.5	-1.5	-1.5	-1.5	1.5	1.5	2.0
Pt_2	29.09	29.09	29.09	29.09	29.09	29.09	29.09
Trp	32	40	50.5	57	67,5	78.8	83.
Tt_5	477	500	539	563	615	663	664
N_1	80.8	83.1	87.	89.3	92.3	95.5	96.
N_2	100.2	99.5	98.7	99.2	99.2	99.2	99.2
Wf	103.2	115.8	132.	143	165.	179.5	192.5

TEST DATA

T63-A-5

TEST: GROUND RUN
FLT NO.: 1

CN	906	907	908	090	910	911	912
ALT	665	665	665	665	665	665	665
FAT	-2.0	2.	-2.0	-2.0	-2.0	-2.0	-2.0
Tt_2	2.5	1.0	-1.0	-.5	-1.0	-1.0	-1.0
Pt_2	29.09	29.09	29.09	29.09	29.09	29.09	29.09
Trp	28.5	38.	46.5	55.	65.3	75.5	83.
Tt_5	461	494	530	568.	605	645	666
N_1	80.	83.1	86	88.8	91.8	94.4	96.0
N_2	101.5	103.6	103.3	101.5	103	102.1	102.1
Wf	102.5	113.2	126.7	141.5	159.3	176.6	194

TEST DATA

T63-A-5

TEST: GROUND RUN
FLT NO.: 1

CN	913	914	915	916	917	918	919
ALT	665	665	665	665	665	665	665
FAT	-2.0	-2.0	-2.0	2.0	-2.0	-3.0	-2.5
Tt_2	1.0	1.0	0	0	0	0	0
Pt_2	29.09	29.09	29.09	29.09	29.09	29.09	29.09
Trp	27.0	36.0	45.0	54.5	64.7	76.0	81.5
Tt_5	443	487	520	570	595	640	663
N_1	80.0	83.2	86.5	88.8	91.9	94.3	97.1
N_2	103.	101.7	101.5	101.5	101.6	101.7	101.7
Wf	100	110.5	129.3	143	159.3	176.6	191.2

TEST DATA

T63-A-5

TEST: SPEED POWER
FLT NO.: 2

CN	334	335	336	337	338	339	340	341	342
ALT	5000	5000	5030	5030	4990	5000	5020	5040	5020
FAT	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Tt_2	8.5	10.0	9.0	9.0	9.0	9.0	8.5	8.5	8.0
Pt_2	24.92	24.92	24.92	24.92	24.92	24.92	24.92	24.92	24.92
Trp	35.4	32.0	39.5	46.5	51.0	54.5	62.0	68.7	78.5
Tt_5	530.	520.	550.	575.	595.	619.	654.	678.	715.
N_1	84.5	82.0	85.5	88.1	89.5	91.5	94.1	96.	98.5
N_2	97.5	97.7	97.0	97.7	97.	97.5	97.	97.	97.7
Wf	102.5	97.1	107.9	120.	126.7	132.1	145.4	159.2	173.8

TEST DATA

T63-A-5

TEST: SPEED POWER
FLT NO.: 2

CN	325	326	327	328	329	330	331	332	333
ALT	5000	4985	5000	4990	5010	5040	5030	5010	5055
FAT	7.0	7.5	7.5	8.0	8.0	8.0	8.0	8.0	8.0
Tt_2	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.0	8.0
Pt_2	24.92	24.92	24.92	24.92	24.92	24.92	24.92	24.92	24.92
Trp	32.5	33.4	38.7	45.0	52.3	58.0	65.0	72.0	77.0
Tt_5	528.0	528.0	558.0	580.0	620.0	640.0	675.0	705.0	725.0
N_1	84.5	84.1	86.7	88.9	91.0	93.2	96.0	98.2	99.5
N_2	103.0	103.0	102.5	102.5	103.0	102.5	100.0	102.0	101.2
Wf	102.5	100.0	110.9	121.2	132.1	142.8	156.5	171.0	179.2

TEST DATA

T63-A-5

TEST: SPEED POWER
FLT NO.: 2

CN	313	314	315	316	317	318
ALT	5030	5010	5020	5020	5040	5040
FAT	7.0	7.0	7.0	7.0	7.0	7.5
Tt_2	8.0	8.0	8.5	8.5	10.0	7.5
Pt_2	24.9	24.92	24.92	24.92	24.92	24.92
Trp	42.0	36.5	34.9	34.9	36.8	46.5
Tt_5	562	545	535	535	545	550
N_1	87.4	85.5	84.5	84.5	85.2	88.8
N_2	100.5	101.0	101.0	101.0	100.5	99.8
Wf	113.1	107.9	102.5	102.5	105.0	121.2

CN	319	320	321	322	323	324
ALT	5040	5010	5030	4980	5010	5050
FAT	7.5	7.0	7.5	7.5	8.0	8.0
Tt_2	8.5	10.0	9.0	9.0	8.0	8.0
Pt_2	24.92	24.92	24.92	24.92	24.92	24.92
Trp	41.0	34.4	54.5	62.0	69.3	78.5
Tt_5	562	535	619	654	678	742
N_1	87.4	84.5	91.0	94.0	96.5	99.1
N_2	100.1	100.5	100.2	99.8	99.8	98.0
Wf	113.1	102.5	134.8	145.4	162.2	176.7

TEST DATA

T63-A-5

TEST: CLIMB
FLT NO.: 4

CN	365	366	367	368	369	370	371
ALT	1000	2000	3000	4000	5000	6000	7000
FAT	9.	8.5	11.5	10.5	9.0	6.0	4.0
Tt_2	8.5	8.5	10.5	8.5	7.0	5.0	3.5
Pt_2	28.71	28.71	28.71	25.96	25.0	24.1	23.2
Trp	72.	74.2	74.6	74.2	74.6	73.0	72.5
Tt_5	655	675	704	695	704	718	725
N_1	94.5	95.5	96.5	97.0	98	98.5	99
N_2	100	99	100.3	100.0	99.5	99.5	100.
Wf	176.8	176.8	176.8	173.8	176.8	170.9	170.9

CN	372	373	374	375	376	377	378
ALT	8000	9000	10000	11000	12000	13000	14000
FAT	2.0	1.0	0	-1.5	-3.5	-5.0	-8.0
Tt_2	2.0	1.0	0	-1.5	-3.5	-4.5	-7.0
Pt_2	22.3	21.4	20.5	19.7	18.9	18.1	17.35
Trp	69.0	71.	65.5	63.5	60.5	58.5	58.
Tt_5	722	730	722	740	743	734	730
N_1	99	99.5	99.	99.	99	98.5	98.5
N_2	100	100.3	100.5	100.5	100.3	100.3	100.3
Wf	162.2	159.2	151.0	148.1	147.0	142.8	134.9

TEST DATA

T63-A-5
(Cont.)

TEST:CLIMB
FLT NO.: 4

CN	379	380	381	382	383	384
ALT	15000	16000	16500	16990	17500	18000
FAT	-11.0	-13.0	14.5	-15.0	-16.5	-17.5
Tt_2	-10.0	-12.0	-13.0	-14.0	-15.0	-16.0
Pt_2	16.7	16.1	15.8	15.6	15.2	14.9
Trp	56.0	55.0	54.3	54.0	52.0	52.0
Tt_5	720	718	718	718	718	715
N_1	98.5	99.0	98.5	98.0	98.0	98.0
N_2	100.3	101.0	100.5	101.0	101.0	101.0
Wf	132.2	126.7	126.7	121.2	118.7	116.0

CN	385	386	387	388	389
ALT	18480	18980	19450	19970	20490
FAT	-18.5	-20.0	-21.0	-22.0	-24.0
Tt_2	-16.5	-16.5	-18.0	-18.0	-19.0
Pt_2	14.6	14.3	14.0	13.75	13.45
Trp	50.0	50.0	47.5	46.5	43.7
Tt_5	715	715	725	722	705
N_1	98.0	99.0	98.0	98.0	96.5
N_2	101.0	98.5	100.3	100.3	100.0
Wf	116.0	116.0	113.2	110.7	105.1

TEST DATA

T63-A-5

TEST: CLIMB
FLT NO.: 5

CN	421	422	423	424	425	426
ALT	1000	2010	3000	4000	5000	6000
FAT	15.0	13.0	10.0	8.0	8.0	5.5
Tt_2	15.0	13.0	10.0	8.0	7.5	6.0
Pt_2	28.7	27.7	26.75	25.8	25.0	24.0
Trp	63.5	61.2	62.5	64.0	62.5	61.2
Tt_5	622	642	640	645	650	655
N_1	92.5	93.0	93.0	94.5	94.5	94.5
N_2	100.0	100.5	100.0	99.6	99.6	99.6
Wf	162.2	156.5	151.0	153.8	148.1	145.4

CN	427	428	429	430	431	432
ALT	7010	8000	9000	10000	11000	12000
FAT	4.0	2.0	0	-1.5	-3.5	-5.0
Tt_2	4.0	2.0	0	1.5	-3.5	-5.0
Pt_2	23.15	22.3	21.4	20.5	19.7	18.95
Trp	63.5	62.5	65.0	62.5	62.7	59.8
Tt_5	655	682	690	704	693	707
N_1	95.5	96.5	97.0	97.7	97.4	98.3
N_2	99.6	99.6	99.6	99.6	99.6	99.1
Wf	148.1	147.0	148.1	148.1	142.8	142.8

TEST DATA

T63-A-5
(Cont)

TEST: CLIMB
FLT NO.: 5

CN	433	434	435	436	437	438
ALT	13000	14000	14990	16000	16990	17490
FAT	-6.0	-8.0	-11.0	-13.5	-16.0	-17.0
Tt_2	-6.0	-8.0	-11.0	-13.5	-16.0	-17.0
Pt_2	18.05	17.35	16.7	16.1	15.5	15.2
Trp	62.7	58.2	56.0	53.7	52.3	53.2
Tt_5	717	717	710	710	717	720
N_1	98.7	98.5	98.5	98.5	98.5	98.5
N_2	99.1	99.1	99.1	99.6	100.5	99.6
Wf	142.8	134.9	129.2	126.8	121.2	121.2

CN	439	440	441	442	443
ALT	18000	18500	18990	19470	19970
FAT	-18.0	-20.0	-20.0	-21.0	-22.0
Tt_2	-18.0	-20.0	-20.0	-21.0	-22.0
Pt_2	14.9	14.6	14.3	14.0	13.8
Trp	51.2	49.2	49.2	48.5	48.1
Tt_5	717	710	710	714	723
N_1	98.2	98.2	97.5	98.2	98.5
N_2	99.6	99.6	99.6	99.5	100.5
Wf	118.6	111.6	116.0	114.9	110.6

TEST DATA

T63-A-5

TEST: SPEED POWER
FLT NO.: 5

CN	452	453	454	455	456	457	458	459
ALT	15000	15000	14960	15000	14990	14990	14970	15010
FAT	-13.0	-13.0	-12.0	-12.0	-12.0	-12.0	-12.0	-12.0
Tt_2	-10.0	-9.0	-8.0	-9.0	-9.0	-10.0	-10.0	-10.0
Pt_2	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7
Trp	28.0	33.0	36.0	40.0	43.0	46.0	51.0	53.0
Tt_5	550	580	605	622	648	671	711	745
N_1	84.7	87.5	88.8	90.5	91.5	93.4	95.5	98.5
N_2	99.8	100.0	100.0	99.8	99.3	99.8	99.8	99.8
Wf	78.2	86.5	91.9	97.1	102.5	110.5	121.5	129.2

TEST DATA
T63-A-5

TEST: SPEED POWER
FLT NO.: 7

CN	569	570	571	572	573	574	575	576
ALT	10030	10020	9960	9960	10010	9920	9880	9900
FAT	-14.0	-14.0	-14.0	-14.0	-14.0	-14.0	-14.0	-14.0
Tt_2	-12.0	-12.0	-12.0	-12.0	-12.0	-12.0	-12.0	-12.0
Pt_2	20.35	20.35	20.35	20.35	20.35	20.35	20.5	20.5
Trp	45.0	51.5	57.5	62.5	68.0	71.0	38.0	34.0
Tt_5	600	610	650	665	700	715	536	516
N_1	89.0	92.0	94.5	96.2	98.0	100.0	86.0	85.0
N_2	101.5	102.0	102.0	102.00	101.5	101.0	102.0	102.0
Wf	112.0	122.5	137.0	143.7	153.0	162.0	104.0	96.0

TEST DATA

T63-A-5

TEST: CLIMB
FLT NO.: 7

CN	551	552	553	554	555	556	557	558
ALT	2000	4000	6000	8000	10000	12000	14000	14980
FAT	-8.0	-8.0	-8.0	-9.0	-13.0	-17.0	-18.0	-18.0
Tt_2	-8.0	-8.0	-8.0	-10.0	-14.0	-15.0	-17.0	-18.0
Pt_2	27.7	25.9	24.1	22.3	20.5	18.9	17.4	16.7
Trp	73.5	73.5	75.5	77.5	73.0	67.0	62.0	58.5
Tt_5	630	655	685	713	720	720	717	713
N_1	94.0	97.5	98.0	100.0	100.5	100.0	99.0	98.7
N_2	102.3	102.3	102.0	101.0	101.0	100.5	100.5	100.2
Wf	168.8	166.0	166.6	166.6	159.2	149.2	139.0	133.0

TEST DATA

T63-A-5

TEST: CLIMB
FLT NO: 8

CN	770	771	772	773	774	775	776	777
ALT	1950	4000	6000	8000	10000	11960	13990	15900
FAT	-13	-14	-15	-18	-20	-22	-26	-30
Tt_2	-14	-13	-15	-17	-19	-20	-23	-26
Pt_2	27.8	25.9	24.05	22.25	20.5	18.85	17.32	16.1
Trp	70.2	72.5	75.5	73.2	75.5	70.2	65	61.7
Tt_5	602	635	660	657	710	710	710	715
N_1	93.2	95.2	97.1	98.3	100.5	100.3	100.3	100.3
N_2	103	101.7	101.5	100.5	100	100.2	100.2	100.3
Wf	160.5	159.5	162.7	164	163.5	153	142.8	134

TEST DATA

T63-A-5

TEST: CLIMB
FLT NO: 8

CN	778	780	781
ALT	17900	20000	20850
FAT	-33	-37	-38
Tt_2	-29	-31	-30
Pt_2	14.9	13.7	13.2
Trp	56.5	51	50
Tt_5	640	745	749
N_1	100.3	99	99
N_2	100	101	101
Wf	123	145	145

TEST DATA

T63-A-5

TEST: SPEED POWER
FLT NO: 8

CN	794	795	796	811	812	813
ALT	14920	14920	14920	4980	4980	5080
FAT	-29	-29	-29	-14	-14	-14
Tt_2	-24	-24	-24	-12	-12	-12
Pt_2	16.7	16.7	16.7	24.9	24.9	24.8
Trp	35	45	53	57	57	58
Tt_5	560	600	670	380	330	365
N_1	87	90	95	89	89	93
N_2	99	99	99	99	99	99
Wf	145	145	145	145	145	145

PART IV

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