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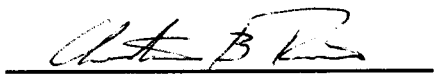
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Date 23 July 1993

PERFORMANCE OF THE SH-2F SEASPRITE HELICOPTER

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Christian B. Rice

August 1993

DEDICATION

This thesis is dedicated to my

wife Michele and

my daughter Courtney

DISCLAIMER

The technical data included in this thesis are actual flight test data collected during a limited scope flying qualities and performance evaluation of a United States Navy SH-2F helicopter. However, all enhancing characteristics and deficiencies attributed to the aircraft and its systems are the sole opinion of the author, and do not necessarily represent the official position of the Naval Air Test Center, the Naval Air Systems Command, or the United States Navy. Similarly, the recommended corrections to the documented deficiencies are presented by the author for the sole purpose of fulfilling the requirements of this thesis, and are not attributable to any of the aforementioned authorities.

ABSTRACT

This thesis summarizes the performance characteristics of the SH-2F Seasprite helicopter. Aircraft flight test data is presented including analysis and discussion of the test results. The aircraft performance was compared with the United States Navy's newest antisubmarine warfare and antiship surveillance and targeting helicopter, the SH-60B design specification to determine deficient performance characteristics. The significant deficiencies were single engine vertical climb performance and ASW and ASST mission tabulated performance (the ability of the aircraft to perform the mission as defined in the detail specification), which is related to mission fuel available. The deficiencies discovered during flight testing were analyzed to determine the most cost effective method to correct the deficient areas. An analysis of power required is the basis for the proposed correction of the deficiencies, and a recommendation of replacing the T58-GE-8F turboshaft engine with the T700-GE-401 turboshaft engine which corrects two of the three major deficiencies is made. Additionally, aerodynamic fairing of the main rotor and tail rotor hubs is also recommended which should further enhance the mission tabulated performance.

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INTRODUCTION

BACKGROUND

With the rising cost of new aircraft procurement combined with a decreasing budget, the United States Navy has determined that existing aircraft must continue to operate and have increased capabilities. The SH-2F Seasprite is one such case where an older U. S. Navy asset will be required to continue to operate, while increasing its capabilities, to keep the national defense budget manageable. The SH-2F is a small ship based Anti-Submarine Warfare (ASW) and Anti-Ship Surveillance and Targeting (ASST) helicopter currently operating from FF1052 and FFG7 class ships. The ASW mission is to track and destroy enemy submarine forces. The ASST mission involves identifying enemy naval forces, targeting and/or performing surveillance activities on these forces, and report these activities back to friendly forces.

PURPOSE

The purpose of this thesis is to summarize the performance characteristics of the SH-2F Seasprite for ASW and ASST missions. Additionally, it will provide cost effective, logical, and viable solutions to performance characteristics found to be deficient.

DESCRIPTION OF TEST AIRCRAFT

The SH-2F Seasprite helicopter, manufactured by Kaman Aerospace Corporation, has a single main rotor and an anti-torque tail rotor. The SH-2F is designed for ship and shore-based operations to detect, identify, track, and destroy enemy submarines. Additionally, it is designed to identify, and target surface ships over the horizon. Since the aircraft operates in a shipboard environment the size of the SH-2F was limited by the size of the landing and hangar area available on the FFG-7 and FF1052. The aircraft is powered by two General Electric T58-GE-8F turboshaft engines, each rated at 1350 SHP uninstalled (reference 1). The four bladed main rotor is driven through the combining and main gearboxes which are mounted between the engines. Cyclic and collective pitch control is obtained through blade flaps mounted on each main rotor blade. Aerodynamic action of the flaps changes the angle of attack of the main rotor blades in response to pilot inputs to the conventional flight controls. A major portion of the energy required to achieve rotor pitch changes is supplied by the aerodynamic action of the blade flaps rather than through pilot applied force. For this reason, the control forces are light. An inflight blade tracking system is designed to automatically adjust the tip path of the main rotor blades to reduce vibrations. The aircraft is equipped with retractable main landing gear and a full swivel

non-retractable tail wheel. The aircraft is shown in appendix A, figure 1, and a more detailed description can be found in the SH-2F Naval Aviation Training and Operations Manual (NATOPS) (reference 2).

SCOPE OF TESTS

The SH-2F was evaluated during three 2.0 hour ground and six 1.5 hour inflight periods. All flights were conducted in the Naval Air Station, Patuxent River local flying area under day visual meteorological conditions (VMC). A summary of test and test conditions is presented in appendix B, table I. The aircraft configuration was two pilots, one crewmember, one flight test engineer, full internal and auxiliary fuel (two 100 gallon auxiliary fuel tanks), and a ASQ-81(V)-2 magnetic detecting set. The average gross weight was 11,556 pounds, with an average center of gravity (CG) of 170.3 inches (aft CG). The test aircraft was representative of production SH-2F helicopters except for the addition of a sensitive airspeed boom with a sideslip vane and the following sensitive indicators in the cockpit: airspeed indicator, fuel counter, sideslip gauge, "g" indicator, and cockpit flight control position indicators. Photographs of the test aircraft and instrumentation are contained in appendix A, figures 2 and 3. The aircraft was originally tested against the requirements of MIL-D23222 (WEP) (reference 3), MIL-H-8501A (reference 4), and

the SH-2F detail specification (reference 5). To determine if the aircraft performance is in need of correction, it should be compared with the latest technology. For the purposes of this thesis, the SH-2F performance characteristics were compared to the requirements of the U. S. Navy's newest ASW and ASST aircraft, the SH-60B detailed specification (reference 6).

METHOD OF TESTS

Performance testing was conducted per "Helicopter Performance" (reference 7), "Rotary Wing Performance" (reference 8), and "A Summary of Helicopter Performance Flight Test Techniques" (reference 9). Flying qualities testing was conducted by the methods of "Helicopter Stability and Control" (reference 10). Hover performance was determined using the free flight hover method, using the aircraft radar altimeter to measure aircraft height above the ground. Level flight performance was evaluated using the constant W/sigma method. Climb and descent performance was evaluated using sawtooth test day techniques. Handling qualities ratings (HQR) were assigned using the Cooper Harper Handling Qualities Rating Scale (appendix C, table I, reference 11). Vibration assessment ratings (VAR) were assigned using the Subjective Vibration Rating Scale (included in appendix C, table II, reference 12). Deficiencies were assigned in accordance with

the definitions presented in appendix D. Normal cockpit instruments were used to measure all engine parameters. A Hewlett-Packard HP-41 calculator was used to maintain a constant W/sigma profile for level flight performance testing. Fuel flow data was obtained for the T58-GE-8F engine from the NATOPS Flight Manual (reference 2). Data were recorded on hand held cards and a portable voice tape recorder. Performance data were manually reduced on a Hewlett-Packard HP9845 computer using software written by Mr. J. McCue (as described in reference 8).

MISSION PROFILES

ANTI-SUBMARINE WARFARE

A typical anti-submarine warfare mission profile is outlined below. The ship or another source will identify a contact (submarine). That contact location is called a datum. The ASW pilot will proceed at V_h (maximum level flight airspeed) to the datum (approximately 30 to 40 nautical miles from the ship). The ASW pilot will drop sonobouys in a circular pattern around the datum at V_h. The radius of the sonobouy pattern will be determined by the time required for the helicopter to get to the datum, as compared to the distance the submarine can travel during the enroute time. Once the sonobouy pattern is complete, the ASW pilot will

perform MAD (magnetic anomaly detector) tracking patterns around the datum at V_{end} (maximum endurance airspeed) to locate the submarine. After the search is complete, the aircraft will travel back to the ship at V_{range} (airspeed for maximum range). For the SH-2F, the ASW mission weight is 13,500 pounds, consisting of a crew of three, full internal fuel (1,889 pounds), one full external 100 gallon auxiliary fuel tank (759 pounds), a full load of sonobouys (15 sonobouys, weighing a total of 465 pounds), and one MK 46 torpedo (529 pounds). The auxiliary fuel tank, torpedo, and sonobouys (totaling 1,753 pounds) can be jettisoned if required.

ANTI-SHIP SURVEILLANCE AND TARGETING

If there is a requirement for enemy ship targeting, identification, or surveillance, the ASST pilot will cruise out to the first pop-up point at V_{cruise} (airspeed corresponding to the higher value of 99 percent maximum specific range, (reference 13) at approximately 40 feet above ground level. The pilot will climb to approximately 1,500 feet above ground level and perform radar sweeps for 30 seconds to target, identify, or locate enemy ships. The first pop-up will be performed approximately 20 nautical miles from the mother ship. Pop-up maneuvers will be completed every 10 to 15 nautical miles during the ASST mission (this allows the pilot to keep surveillance on enemy tactics), with the maximum

distance from the mother ship being 60 nautical miles. The pilot will fly at V_{cruise} while transiting to and from the pop-up points in a zig-zag pattern to prevent disclosing information to enemy ships regarding the location of the mother ship. For the SH-2F, the ASST mission takeoff gross weight is 13,135 lbs, consisting of a crew of three, full internal fuel (1,887 lb usable), and two 100 gallon auxiliary fuel tanks (1,346 lb usable). The auxiliary fuel tanks are jettisonable.

MISSION PERFORMANCE REQUIREMENTS

The H-2 was developed in the early 1960's. If improvements to the aircraft are being considered, the newest technology should be used for correction of any deficient areas, additionally, to determine the adequacy of any proposed corrections, the aircraft performance should be compared with current technology specifications. The performance characteristics of the SH-2F will be compared to the detail specification for the SH-60B, reference 6, because the SH-60B is the newest technology helicopter in the United States Navy inventory that performs ASW and ASST missions. However, it is not logical to assume that the SH-2F with technology from the late 1950's and early 1960's will match the capabilities of the SH-60B and the technology of the 1970's. There will be some areas were the SH-2F will not meet the detail

specification requirements of the SH-60B. Additionally, some of the physical aspects of the two helicopters are significantly different; for example fuel capacity and maximum gross weight takeoff. The maximum gross weights for takeoff of the SH-2F and SH-60B are 13,500 lb (reference 2) and 21,700 lb (reference 13) respectively, a difference of 8,200 lb which is 65 percent of the maximum gross weight of the SH-2F. A comparison of the fuel loads of the SH-2F and SH-60B is presented in table I.

Table I

FUEL AVAILABLE FOR ASW AND ASST MISSIONS

MISSION	FUEL AVAILABLE (lb) SH-2F	FUEL AVAILABLE (lb) SH-60B
ASW	2536	3580
ASST	3209	3679

Notes: SH-2F configuration; full internal fuel and for the ASW mission, one 100 gallon auxiliary fuel tank (external), ASST mission, two 100 gallon auxiliary fuel tanks (both external). The SH-60B carries all fuel internally. Fuel available for the SH-2F is from reference 2. Fuel available for the SH-60B is from reference 13.

With such a large difference in fuel available for the mission, it is not likely that the SH-2F will be able to meet all of the SH-60B mission requirements. The SH-2F requires modification for correction of deficiencies, and a goal of meeting the performance parameters of new technology is

desired. Reference 6, the SH-60B detail specification spells out the ASW and ASST guaranteed tabulated performance as shown in table II below.

Table II

MISSION REQUIREMENTS

PARAMETER	ASW MISSION	ASST MISSION
V_h Maximum continuous power dash speed	125 KTAS	125 KTAS
Minimum rate of climb - dual engine	1500 fpm	1500 fpm
Vertical rate of climb - single engine (1)	450 fpm	450 fpm
Vertical rate of climb at sea level	550 fpm	550 fpm
In-ground-effect hover ceiling	Sea level, hot day	Sea level, hot day
Out-of-ground-effect hover ceiling	Sea level, hot day	Sea level, hot day

Note: (1) Aircraft gross weight without expendable stores and 20 minutes of fuel remaining for loiter, with a 30 knot wind over the deck at 95 % maximum rated single engine power with a temperature of 89.8 deg F at sea level.

The missions are defined in the SH-60B detail specification (reference 6) as follows:

ASW mission:

a. Engine start and take-off.

b. Climb on course from sea level to 5,000 ft PA at maximum continuous power (MCP).

c. Cruise at 5,000 ft PA at MCP to a point 70 nm from take-off.

d. Conduct an on-station search for the contact for 30 min at V_h (maximum level flight airspeed) at 5,000 ft PA.

e. Loiter on-station for 50 minutes at V_{end} (maximum endurance airspeed) at 5,000 ft PA.

f. Descend to sea level.

g. Conduct on-station combat for 40 minutes at V_h at sea level.

h. Climb on course from sea level to the best cruise altitude at maximum continuous power.

i. Return to the ship (70 nautical miles) at V_{range} and best range altitude.

j. Descend to sea level and land with ten percent mission fuel remaining.

ASST mission:

a. Engine start and take-off.

b. Climb on course from sea level to 1500 ft PA at MCP.

c. Cruise at 1,500 ft PA at V_{range} to a point 40 nm from take-off.

d. Loiter for 3.5 hours at V_{end} at 1,500 ft PA.

e. Cruise back to the ship (40 nm) at V_{range} at 1,500 ft PA.

f. Descend to sea level and land with ten percent mission fuel remaining.

DISCUSSION AND RECOMMENDATIONS

LEVEL FLIGHT PERFORMANCE

GENERAL

The level flight performance characteristics of the SH-2F were evaluated under the conditions presented in appendix B, table I, using a constant W/sigma method. Two target referred weights (W/sigma) were flown, corresponding to the ASW (13,500 lb) and ASST (13,135 lb) mission gross weights. The data were unreferred to sea level standard day conditions (15 deg C). Level flight characteristics are summarized in appendix B, table II. Generalized level flight data are presented in appendix E, figures 1 and 2. The maximum difference between the target and actual referred weights was 0.7 percent.

MAXIMUM LEVEL FLIGHT AIRSPEED

The maximum level flight airspeed data are presented in appendix E, figures 3 and 4. At ASW and ASST mission gross weights, V_h was determined to be 132 and 135 KTAS respectively. Maximum level flight airspeed was limited by the capabilities of the transmission and not the engine power available. Maintaining the test day V_h of 132 knots within 2

knots was easy, requiring small (± 1/4 inch) infrequent (every 2 to 3 seconds) longitudinal cyclic inputs (HQR 3). Since the search area increases with the square of the time required for the helicopter to get to the datum, a high maximum level flight airspeed is desirable. V_h of 132 KTAS will allow the ASW pilot to arrive at the datum early enough (40 nm in 18 minutes) to limit the search area to approximately 110 square nm. This is sufficiently small to be covered with the SH-2F range capabilities. The V_h of 132 KTAS for the ASW mission is satisfactory and exceeds the requirements of reference 6, V_h of 125 KTAS by 7 knots (6 percent).

MAXIMUM CRUISE AIRSPEED

The maximum cruise airspeed data are also presented in appendix E, figures 3 and 4. V_{cruise} for both the ASW and ASST configurations was determined to be 118 KTAS. Maintaining V_{cruise} within 2 knots was easy, requiring small (± 1/4 inch) infrequent (every 2 to 3 seconds) longitudinal cyclic inputs (HQR 3). Transiting 50 nautical miles to the targeting point will take 25 minutes. There is no specification requirement for V_{cruise} in reference 6.

MAXIMUM RANGE

Maximum specific range data also are presented in appendix E, figures 3 and 4. At ASW and ASST mission gross weights, allowing a 10 percent fuel reserve and a two minute start and warm-up period, the maximum ranges were 227 and 297 nm respectively at the maximum range airspeed, V_{range}, of 110 KTAS. Maintaining V_{range} within 2 knots was easy, requiring small ($\pm$ 1/4 inch) infrequent (every 2 to 3 seconds) longitudinal cyclic inputs (HQR 3). There is no specification requirement for V_{range} in reference 6.

ENDURANCE

Endurance related data for the ASW and ASST mission gross weights are also presented in appendix E, figures 3 and 4. With a fixed amount of fuel, an aircraft can stay up longest, if it operates at minimum fuel flow. Therefore, maximum endurance airspeed is the airspeed corresponding to minimum fuel flow. At ASW and ASST mission gross weights, allowing a 10 percent fuel reserve and a two minute start and warm-up period, the maximum endurance was 2.3 and 3.4 hours respectively at the maximum endurance airspeeds, V_{end}, of 75 and 70 KTAS respectively. Varying airspeed within 10 knots about V_{end} decreased endurance by less than 5 minutes for both missions. Maintaining V_{end} within 2 knots was easy, requiring

small (± 1/4 inch) infrequent (every 5 seconds) longitudinal cyclic inputs (HQR 3). There is no specification requirement for maximum endurance in reference 6.

FORWARD FLIGHT CLIMB AND DESCENT PERFORMANCE

CLIMB PERFORMANCE

The forward flight climb performance was evaluated at 55 percent dual engine torque, as limited by the operators manual (reference 2), under the test day conditions presented in appendix B, table I. The data are presented in appendix E, figure 5. The maximum rate of climb was 2275 feet per minute at an airspeed of 65 KCAL, and a gross weight of 12,183 pounds. Varying airspeed ± 5 knots about the best rate of climb airspeed resulted in a decrease in the rate of climb of only 75 feet per minute. There is no specific requirement in reference 6 for forward flight climb performance.

DESCENT PERFORMANCE

As presented in appendix B, table I, the forward flight descent performance was evaluated under test day conditions with minimum power used to keep the engine torques matched and the N_r at 106 percent. The data are presented in appendix E, figure 6. At 12,183 pounds, the maximum glide airspeed was 85

KCAL, with a corresponding rate of descent of 1800 feet per minute. The minimum rate of descent was 1675 feet per minute at 66 KCAL. Varying airspeed from 60 to 80 KCAL resulted in a maximum rate of descent of 1750 feet per minute. The maximum glide airspeed of 85 KCAL will allow the ASW/ASST pilot to glide 2.3 nautical miles following a dual engine failure at 3,000 feet. At the minimum rate of descent airspeed of 66 KCAL the ASW/ASST pilot will have approximately one-and-one-half minutes to descend to sea level, following a dual engine failure at 3,000 feet, allowing sufficient time to complete emergency procedures and make a mayday call. There are no specific forward flight descent performance requirements spelled out in reference 6.

HOVER PERFORMANCE

GENERAL

The hover performance of the SH-2F helicopter was evaluated under the conditions presented in appendix B, table I, in 3 to 7 knot winds over a dry concrete runway. Generalized in ground effect (IGE) and out of ground effect (OGE) hover performance is presented in appendix E, figures 8 and 9. Power required versus pressure altitude plotted with military power available unreferred to standard day (15 deg C at sea level) and hot day (35 deg C at sea level) conditions

(reference 14) is presented in appendix E, figures 10 through 13. The IGE/OGE transition height was determined to be 35 feet above ground level as shown in appendix E, figure 14. There are no specific hover performance requirements spelled out in reference 6.

IN GROUND EFFECT HOVER

Standard and hot day hover ceiling data are presented in appendix E, figure 15. In the ASW configuration (a gross weight of 13,500 lb) with a five percent power margin for maneuvering and engine degradation (reference 15), the aircraft had adequate power to hover IGE on standard days at a pressure altitude of 9,000 feet and 2,500 feet on hot days. In the ASST configuration with a 5 percent power margin, the aircraft had sufficient power to hover IGE at 10,000 feet pressure altitude under standard day conditions and 3,750 feet pressure altitude under hot day conditions. The IGE hover performance exceeds the requirements of reference 6 and will allow the ASW/ASST pilot to hover over the ship deck during take off and landing. The IGE hover performance of the SH-2F is satisfactory for the ASW and ASST missions.

OUT OF GROUND EFFECT HOVER

Standard and hot day OGE hover ceiling data are presented in appendix E, figure 16. In the ASW configuration (a gross weight of 13,500 lb) with a 5 percent power margin, the maximum OGE hover ceiling was 8,000 ft PA under standard day conditions and 1,500 ft PA under hot day conditions. In the ASST configuration (a gross weight of 13,135 lb) with a 5 percent power margin, the maximum OGE hover ceiling was 8,900 and 2,600 ft PA under standard and hot day conditions respectively. The OGE hover performance will allow the ASW/ASST pilot to hover along side ships during HIFR (helicopter inflight refueling) operations, and meets the requirements of reference 6. The OGE hover performance of the SH-2F is satisfactory for the ASW and ASST missions.

SINGLE ENGINE HOVER

Single engine hover performance data are presented in appendix E, figure 10. The maximum gross weight for an IGE hover at sea level with a 5 percent power margin was 10,200 pounds under standard day conditions. Engine power was limited by the turbine gas temperature limit. The maximum gross weight takeoff weight for the ASW mission is 13,500 lb. If the pilot jettisons all stores, the gross weight of the aircraft will immediately be reduced by 1,753 lb, to 11,747

lb, and the aircraft will still exceed the maximum single engine hover maximum gross weight of 10,200 lb by 1,547 lb. In the event of an engine failure immediately after clearing the ship deck, the ASW/ASST pilot will not have the capability to perform a hovering landing at gross weights above 10,200 pounds (approximately the gross weight of the aircraft with all external stores jettisoned and 10 percent fuel remaining). Following a single engine failure during initial takeoff, with more than 10 percent of the total fuel in the internal tanks, inadequate power will be available to maintain hovering flight after jettisoning all external stores, resulting in an uncontrolled descent and impact with the ship or water. Reference 6 indicates a requirement for a single engine vertical rate-of-climb of 450 fpm. (Power for a vertical climb is more than the power required for hover, reference 16.) If the SH-2F does not have sufficient power to hover single engine, the requirement for a single engine vertical rate-of-climb will not be met. The single engine vertical rate-of-climb of the SH-2F fails to meet the requirements of reference 6. The limited single engine hovering capability of the SH-2F is a serious deficiency which must be corrected prior to aircraft deployment. It is recommended that an engine upgrade be considered that would allow the aircraft to hover on single engine after jettisoning all external stores.

VERTICAL CLIMB PERFORMANCE

The vertical climb performance was evaluated under test day conditions as presented in appendix B, table I. The data are presented in appendix E, figure 7. Under test day conditions, at 12,946 pounds, the maximum vertical rate-of-climb was 1,750 feet per minute at 63 percent dual engine torque. Reference 6 states the requirement for vertical rate-of-climb at sea level, 89.8 deg F, zero wind at ASW mission gross weight (13,500 lb for the SH-2F) to be 550 fpm. The main transmission has a maximum shaft-horsepower limit of 2,200 hp (reference 2). Under the conditions defined in reference 6, the power required to hover is 2,115 hp (reference 2), which allows 85 hp for vertical climb. Reference 16 defines that for low rates of climb, the following equation can be used to determine the horsepower increment required to climb vertically,

$$\text{delta HP} = (\text{gross weight(lb)})(\text{rate-of-climb(fpm)})/66{,}000$$

Using this equation, the SH-2F will have a vertical climb rate of 415 fpm using the 85 horsepower available for the vertical climb at 13,500 lb gross weight. The vertical climb performance of the SH-2F failed to meet the requirements of reference 6, by 135 fpm or 25 percent and was limited by the main transmission and not engine power available. The

vertical climb performance of the SH-2F is deficient, however, since the aircraft has a vertical climb capability of 415 fpm under the conditions defined in reference 6, this is considered to be a annoying deficiency. To correct this deficiency would require a modification or redesign of the main transmission, and is not likely to be cost effective.

GUARANTEED TABULATED PERFORMANCE

GENERAL

The ASW mission guaranteed performance data are shown in appendix B, table III. The performance data for comparison with reference 6 were obtained from reference 2, the operator's manual. The SH-60B detail specification indicates the use of maximum continuous power for a number of the legs of both the ASW and ASST missions. Since the SH-2F was transmission limited in a number of these situations (for example, the forward flight climb torque setting limit was 55 percent when the maximum continuous torque was 65 percent) the author used the limitations as defined in the operators manual, reference 2, vice MCP to determine power required. Power required and fuel flow data were obtained from references 1 and 2.

ASW Mission

The SH-2F comparison with the SH-60B detail specification ASW mission is presented in appendix B, table III, and the fuel used calculations are presented in appendix B, table IV. The T58-GE-8F powered SH-2F failed to meet the requirements of reference 6 by requiring 1,250 more pounds of fuel (49 percent) than were available for the mission. The excess fuel required to meet the ASW mission requirements of reference 6 is a serious deficiency which must be corrected as soon as possible.

ASST Mission

The SH-2F comparison with the SH-60B detail specification ASST mission is presented in appendix B, table V, and the fuel used calculations are presented in appendix B, table VI. The SH-2F failed to meet the requirements of reference 6 by requiring 642 more pounds of fuel (20 percent) than were available for the mission. The excess fuel required to meet the ASST mission requirements of reference 6 is a serious deficiency which must be corrected as soon as possible.

ENGINE ASSESSMENT

ENGINE FAILURES

The flying qualities of the SH-2F were qualitatively evaluated following simulated single and dual engine failures at 80 KCAL under the conditions presented in appendix B, table I. Engine failures were simulated by retarding the respective engine condition lever to 92 percent N_f (free power turbine speed). Level flight was possible with one engine operational with no significant change in aircraft trim and flying qualities. A simulated dual engine failure while in level flight required lowering the collective lever full down in less than the 1/2 second to prevent N_r (main rotor speed) from dropping below 92 percent (HQR 7). The rapid N_r decay will not provide the ASW/ASST pilot sufficient time to lower the collective and enter an autorotation. This is a significant deficiency which should be corrected as soon as possible. It is recommended that an engine vibration monitoring system be installed in the aircraft to warn the pilot of impending engine problems. This would allow the pilot to take appropriate action prior to an engine failure.

STATIC DROOP

The static rotor speed droop characteristics were tested under the conditions presented in appendix B, table I. The data are presented in appendix E, figure 17. N_r was set at 106 percent, which is the standard rotor speed for normal operations as defined in reference 2, with the collective full down. With the collective in a full down position the power setting was 13 percent dual engine torque. The SH-2F exhibited an increase in rotor speed (negative static droop) as indicated by the rotor speed increasing with increasing power to a maximum of 108.2 percent (2.2 percent over the normal operating speed) at 30 percent dual engine torque. At 59 percent dual engine torque, the rotor speed was 107 percent (1 percent over normal rotor speed). The over-canceling static droop compensation will require the ASW/ASST pilot to set N_r at 104 to 105 percent on deck prior to take off, increasing pilot workload. The static droop characteristics of the SH-2F are annoying and should be avoided in future designs. It is recommend that an automatic droop compensation device be designed for the engine control unit to maintain main rotor speed at a constant level.

TRANSIENT DROOP

The transient droop characteristics were evaluated under the conditions presented in appendix B, table I, concurrently with climb and descent performance tests. The data are presented in appendix E, figure 18. Collective increases and decreases from 8 to 3 seconds were evaluated. N_r for level flight was set at 106 percent, the normal rotor operating speed (reference 2). With increasing rates of collective application, the minimum transient drops in N_r was 104 percent with no apparent change in aircraft flying qualities. Rotor speed increased to a maximum of 107.5 percent with a 6 second collective reduction, again with no adverse aircraft response. The duration of the maximum transient droop was 1 second, after which the rotor speed returned to 106 percent. No rotor speed limitations were approached. The transient droop characteristics of the SH-2F are satisfactory for the ASW/ASST mission.

RECOMMENDATIONS FOR CORRECTION OF DEFICIENCIES

GENERAL

To correct the deficiencies discovered during testing of the SH-2F the author attempts to provide viable solutions that meet the requirements set forth by Mr. Nicolai (reference 17) including "Reduced Life Cycle Cost" and "Reduced Energy Consumption". Suppose that the author determined that the best solution to correct the deficiencies would be to re-engine the SH-2F; the engine must be more efficient in terms of specific fuel consumption and be available in the U. S. Armed Forces supply system (i.e., available off-the-shelf, to re-engine the SH-2 was chosen as an example.) Every effort will be made to provide corrections to the deficiencies that meet the intent of, as Mr. Nicolai states it, a "design for mankind".

OPTIONS

The viable approach to finding viable solutions to the deficiencies is to explore the options available and determine the most practical options that meet the requirements. The hover, range, and endurance deficiencies presented in this thesis are a function of the power required in the hover and level flight conditions (reference 18). In the case of the

single engine hover performance, the power required exceeds the power available. The range and endurance deficiencies are the result of too much power required for a given fuel load or inadequate fuel specifics. To correct the deficiencies with single engine hover performance, range, and endurance, the options of table III are available.

Table III

OPTIONS FOR CORRECTING THE DEFICIENCIES

OPTIONS	DEFICIENCIES		
	OEI Hover Performance	Maximum Range	Maximum Endurance
Reduce power required	■	■	■
Increase power available	■		
Improve fuel specifics		■	■
Increase fuel available		■	■

Note: The shaded blocks indicate applicable options for correcting the deficiencies.

After reviewing table III, it appears that the most elegant solution for correcting the deficiencies would be to reduce the power required for each of the deficient flight conditions. Increasing the power available would improve the OEI hover performance if any corresponding gross weight increases are not excessive when compared to the additional

power available. Improving the fuel specifics is a likely candidate to correct the range and endurance deficiencies if any weight penalties are offset by the improved fuel specifics. To correct all three deficiencies indicated, increasing the power available would have to be coupled with improving the fuel specifics. Increasing the fuel available would obviously improve the range and endurance of the aircraft, but would have a negative impact on OEI hover performance due to increased gross weight, and possibly forward flight performance if the additional fuel is carried externally. Of the options presented in table III, the following are worthy of further investigation: decreasing the power required, increasing the power available, and improving the fuel specifics.

REDUCING THE POWER REQUIRED

GENERAL

Power required is the sum of the following elements: induced, profile, and parasite power, H-force, and miscellaneous power requirements (reference 18). Mr. Prouty defines the components of power required as follows:

The induced power is that associated with producing rotor thrust.

Profile power is used to overcome friction drag on the

blades.

Parasite power is needed to overcome the drag of all of the aircraft components except the rotor blades.

H-force is the drag on the rotor blades in the plane of the rotor disc. In forward flight the advancing blade H-force acts aft and on the retreating blade acts forward.

Miscellaneous power used for the tail rotor, gearbox losses, hydraulic pumps, electrical generators, and other accessories.

Table IV identifies the elements of power required and the influence of each element on hovering or forward flight.

Table IV

The Elements of Power Required

Hovering and Forward Flight

Element of Power Required	Hovering Flight	Forward Flight
Induced	▒	▒
Profile	▒	▒
Parasite		▒
H-force		▒
Miscellaneous	▒	▒

Note: The shaded area are the elements of power required that are applicable in the respective flight condition.

By reviewing table IV it is obvious that the elements of power required that are applicable to both hovering and forward flight are induced power, profile power, and miscellaneous power requirements. In order to correct the deficiencies in hover performance, range, and endurance by reducing the power required, a reduction in induced, profile, or miscellaneous power is required.

INDUCED POWER

As stated previously, induced power is the power required to produce rotor thrust. In a hover, the thrust requirement is the same as the gross weight of the helicopter, and as the helicopter proceeds into forward flight the induced power requirement decreases with increasing airspeed. To reduce the induced power requirement the SH-2 would require a new or different rotor system. If the rotor system had a larger diameter, a reduction in induced power would result (reference 18), however, size of the rotor system of the SH-2F is limited to the current design by the size of the flight deck available on the FFG-7 (FFG - Guided Missile Frigate) Oliver Hazard Perry and FF1052 (FF - Frigate) Knox class ships. Thirty-two of the FF1052 class ships had to be modified from 1972 to 1976 by increasing the flight deck and hangar space to accommodate the SH-2F. The FFG-7 class ships were also modified beginning in 1985 to accommodate the SH-60B by increasing the overall

length of the ships by eight feet (reference 19). Increasing the rotor diameter would require additional modifications to the FF1052 Knox class ship, which would not meet the requirements of a "design for mankind". Additionally, increasing the rotor diameter would have negative effects on the maximum forward flight airspeed due to compressibility effects. Since hover performance is usually one of the first design requirements determined to size the helicopter (reference 16) an assumption that the main rotor diameter is maximized is likely to be correct.

PROFILE POWER

Profile power is the power required due to the profile drag of the main rotor blades. The rotor blades of the SH-2F are not very clean designs due to the draggy blade flap mechanisms. A new rotor system would probably provide a reduction in the profile power, however, significant redesign would be involved. If a clean rotor blade were used with no blade flap, it would require a redesign of the flight control system as well as the rotor system since the flight control system controls the blade motion through the blade flap. Another option for reducing the profile power would be to decrease the rotational speed of the rotor system, but as indicated in reference 19, the profile power requirements do not increase dramatically until the beginning of blade stall,

at airspeeds above 120 knots. A lower rotational speed would reduce the friction drag on the blades, however, it would also have a negative effect on the autorotation qualities of the helicopter. As described earlier, the autorotation characteristics of the SH-2F are deficient currently due to rapid N_r decay and reducing the rotational speed of the rotor system would only exacerbate the situation.

MISCELLANEOUS POWER

Miscellaneous power requirements come from a number of sources; tail rotor, generators, hydraulic pumps, gearbox losses, etc. The miscellaneous power requirements are defined in reference 1 as follows: a 21 horsepower loss to accessories (hydraulic pumps, generators, etc.), a 50 horsepower nominal requirement to power the tail rotor, a three percent loss through the engine speed decreaser gearboxes (one per engine), and a three percent loss through the combining gearbox. (The combining gearbox takes power from both engines and combines the inputs to the main rotor gearbox.) Under a maximum continuous power condition, the total miscellaneous power requirements total 203 horsepower. If significant reductions in the miscellaneous power requirements are made, the resulting increase in power available would be a step in the right direction, but not sufficient for corrections to the deficiencies presented in

this thesis. (For example a 25 percent reduction in the miscellaneous power required would provide only 51 horsepower that could be applied the performance deficiencies.)

SUMMARY

It is apparent that a reduction in the power required (induced and profile) could be the solution to the performance deficiencies of the SH-2F, however, a new rotor system would be costly in terms of redesigning both the flight control system and the rotor system. In terms of flight testing, a new rotor and flight control system would require flying qualities, performance, reliability, and maintainability testing. The redesign of the rotor and flight control systems would be time consuming and could be a technically risky endeavor with a significant flight test effort required. Additionally, a new rotor and flight control system are certainly not available as off-the-shelf items, and given the limited number of SH-2F aircraft currently in the U.S. Navy Fleet (104 SH-2F helicopters in the U. S. Navy, reference 19), it would not be cost effective. A new rotor and flight control system does not meet the requirements as the best "design for mankind".

INCREASE POWER AVAILABLE AND IMPROVE FUEL SPECIFICS

The only way to increase the power available is to re-engine the aircraft. The T58-GE-8F engines installed in the SH-2F were first designed in the late 1950's and therefore have late 1950's technology and are no longer produced. The T58-GE-8F engine was an excellent design for the era during which it was deployed, however, it does not have the fuel specifics of current technology engines. A new engine must have improved fuel specifics and greater power to provide an effective solution for the performance deficiencies. Additionally, the new engine must be cost effective for the Navy. This would imply that it would not require extensive training for the mechanics, it would be supportable logistically, and that it be common with another aircraft in the U. S. Armed Forces, ideally the Navy. Rotor and Wing International magazine, reference 20, provided a listing of available engines and applications. From the available possibilities, a practical solution would be the T700-GE-401 turboshaft engine. The T700-GE-401 engine is currently available in the Navy (it powers the H-60 series helicopters, reference 20), providing a ready source of trained mechanics and a working logistics system. A comparison between the T58-GE-8F and the T700-GE-401 engines is presented in table V.

Table V

A COMPARISON BETWEEN THE

T58-GE-8F AND T700-GE-401 TURBOSHAFT ENGINES

	T58-GE-8F	T700-GE-401
Weight (lb) (1)	308	438
Installed maximum shaft HP (2)	1350	1690
Fuel Flow at V_{end} (lb/hr) (3)	480	396
Drive output	REAR	FRONT
Maximum turbine gas temperature (deg C) (2)	690	867
Cost (4)	$73,800	$540,153

Notes: (1) Engine weights for the T58 and T700 from references 21 and 22 respectively.
(2) T58 installed maximum shaft horsepower and temperature from reference 2, T700 data from reference 23. Horsepower and temperature limits shown are 30 minute limits.
(3) Fuel flow for the SH-2F at V_{end} at 13,500 lb gross weight, 105% fuel flow to account for engine degradation is shown in appendix E, figures 3 and 4 for the T58 engine, T700 data under the same conditions is from reference 24.
(4) Engine cost data is in 1993 dollars from reference 25.

The T58-GE-8F received certification in 1968, and the T700-GE-401 received certification in 1982 (reference 26), a difference of 14 years. The increased power available in the T700 is due to the fact that it is larger; the T700 is 42

percent heavier than the T58. Improvements in fuel specifics are largely based on increasing engine pressure ratios and turbine inlet temperatures, made possible by higher performance materials (reference 26). A detailed description of the T58 and T700 turboshaft engines can be found in reference 2 and 27 respectively. Re-engineing the SH-2F with T700 engines has two disadvantages: increased engine weight (130 pounds per engine) and the engine has a front drive which will require modification to the H-2 before installation (these modifications are beyond the scope of this thesis). The advantages of the T700 include increased power (a 25 percent increase) and improved fuel specifics (a 21 percent decrease). The T700 has been operating in the H-60 series helicopters since the mid 1980's and has proven reliability, maintainability, and operational capabilities. For the T700 to be a viable option for replacing the T58, the improved fuel specifics must be sufficient to overcome the weight penalty associated with the more powerful engine. Re-engineing the SH-2F is a viable option for correcting the performance deficiencies and should be investigated further.

PERFORMANCE GAINS FROM THE T700-GE-401 ENGINE

GENERAL

The SH-2F will have improved aircraft performance as a result of the increased power available and improved fuel specifics available in the T700 turboshaft engine. The following paragraphs will address performance predictions for the SH-2F powered by T700-GE-401 engines. The predictions are based on data gathered by the author during DT-II testing of the SH-2F while a student at USN Test Pilot School. The assumptions used to determine the predicted performance are as follows: (1) the aircraft maximum gross weight remained 13,500 lbs, with the increase of 260 lb of engine weight being offset by a reduction of 260 lb of mission fuel, (2) the power required was not affected by the T700 engine installation, (the power required is the same for the SH-2F as powered by T58-GE-8F engines) and (3) the fuel specifics of the T700 are based on reference 24.

SINGLE ENGINE HOVER

The single engine hover performance for the T700 powered SH-2F is presented in appendix E, figures 19 and 20, for standard day conditions. Power available for the T700 was taken from reference 23, "SH-60B T700-GE-401C Engine

Evaluation" (hot day power available was not available). On a standard day, the SH-2F will be able to hover in and out of ground effect at a maximum gross weight (13,500 lb) with one engine inoperative. To provide engine power for maneuvering and possible engine degradation (if the engine is dirty), a five percent power margin is necessary. This reduces the OEI out-of-ground effect hover gross weight to a maximum of 13,000 lb gross weight. Sufficient power will be available on a standard day to hover with OEI. In a worst case situation, if the aircraft gross weight is greater than 13,000 lb the pilot will be required to jettison the sonobouy load, or the external fuel tanks, but will be able to hover the aircraft. The T700 powered SH-2F single engine hover performance provides a increase of approximately 3,000 lb in OEI hover capability on a standard day at sea level. The T700 powered SH-2F has the capability to hover single engine out-of-ground effect under standard day conditions, at sea level.

SINGLE ENGINE VERTICAL CLIMB

The detail specification for the SH-60B states a requirement for single-engine vertical rate-of-climb of 450 feet per minute at sea level and 89.8 degrees F with a gross weight equivalent to 20 minutes of fuel for loiter at sea level with one engine inoperative, minus expendable loads. For the SH-2F, that gross weight is approximately 10,000 lb

(reference 2). The data collected by the author during flight testing of the SH-2F was limited to standard and hot day hover performance. The data available for the T700 engine was limited to standard and tropical day conditions and for these reasons, the single-engine vertical climb performance data will be presented under standard day conditions only. The predictions for OEI vertical climb performance are based on the equation presented earlier, from reference 16. At 11,747 lb (the gross weight of the aircraft minus all jettisonable loads) the power required to hover (based on figure 20 in appendix E) is approximately 1325 horsepower. The additional power increment to climb vertically at 450 fpm is 80 horsepower. The total power required to climb vertically at 11,747 lb gross weight is 1,405 horsepower. The power available from a single engine at sea level on a standard day is 1,690 horsepower. If the aircraft has a single engine failure after a maximum gross weight takeoff, sufficient power will be available for vertical climb rates exceeding 450 fpm, if the pilot jettisons the external loads to reduce the aircraft gross weight to 11,747 lb. The SH-2F when powered by T700-GE-401 engines for the purposes of this thesis meets the requirements of reference 6 for single engine vertical climb performance.

GUARANTEED TABULATED PERFORMANCE

ASW Mission

The ASW mission guaranteed performance data are shown in appendix B, table IV. The T700 powered SH-2F comparison with the SH-60B detail specification guaranteed tabulated performance is presented in appendix B, table III, and the fuel used calculations are presented in appendix B, table VII. The T700-GE-401 powered SH-2F failed to meet the requirements of reference 6 by requiring 1,026 more pounds of fuel (45 percent) than were available for the mission. The improved fuel specifics of the T700 provided an increased capability over the T58, including offsetting the 260 increase in engine weight, but still failed to meet the requirements of the SH-60B detailed specification for the ASW mission by 46 percent and is still considered to be a significant deficiency. The T700 provides a significant improvement in ASW mission performance and should be considered as a first step in the correction of this deficiency.

ASST Mission

The T700-GE-401 powered SH-2F comparison with the SH-60B detail specification guaranteed tabulated performance is presented in appendix B, table V, and the fuel used

calculations are presented in appendix B, table VIII. The T700 powered SH-2F exceeds the requirements of reference 6 by 77 lb of fuel (3 percent) for the ASST mission. The improved fuel specifics at the loiter condition for the SH-2F provided the capacity to meet the specification requirements, including the offset of 260 lb for the increase in engine weight. The performance characteristics of T700 powered SH-2F are satisfactory for the ASST mission.

Summary

Replacing the T58-GE-8F engine with the T700-GE-401 engine will correct the single engine vertical climb and the ASST mission fuel deficiency requirements as defined in the SH-60B detail specification. The T700-GE-401 fuel specifics are not enough of an improvement over the T58-GE-8F fuel specifics to meet the ASW mission requirements as defined in the SH-60B detail specification. It is significant to note that the SH-60B has 3,580 lb of fuel available for the specification ASW mission and the T700 powered SH-2F has 2,276 lb of fuel available for the mission, a difference of 1,304 lb or 36 percent.

CONSIDERATIONS

Meeting the detail specification for the SH-60B mission was a significant challenge. Providing additional power and improved fuel specifics corrected two of the three significate deficiencies. The final deficiency could be corrected by a combination of providing T700's to power the aircraft (improving fuel specifics) and a reduction in power required. In forward flight the most significant reductions in power required can be achieved by reducing the parasite drag, detailed by Keys and Wiesner in "Guidelines for Reducing Helicopter Parasite Drag" (reference 28). Keys and Wiesner present data that indicates the H-2 is considered to be cleaner in terms of parasite drag than the average production helicopter. Additionally, reference 28 indicates that the following areas can be improved to reduce the total parasite drag on helicopters in forward flight: basic fuselage, landing gear, main rotor hub, tails, tail rotor hub, protuberances, and roughness, leakage, cooling, and momentum losses. The SH-2F has a fairly clean basic fuselage, the angle of attack in cruise conditions is generally zero (reference 29) which can be a significant savings in terms of parasite drag (reference 16) and the corners on the fuselage are rounded which is desired for reducing parasite drag (reference 28). The data presented in reference 28 are substantiated by references 30 and 31. The main landing gear is retractable, but does not

have doors to cover the gear when retracted, and the tail landing gear is fixed. Fairings or doors to cover the main landing gear when retracted and a retractable tail landing gear would have to be carefully considered due to possible gross weight penalty. The SH-2F could benefit from the following areas in terms of reducing parasite drag; fairing the main rotor and tail rotor hubs, an aerodynamic cleanup of the protuberances on the fuselage, and reducing roughness, and leakage (i.e., flush seals around door and window openings). Significant improvement is most likely in efforts towards fairing the main and tail rotor hubs as indicated in "A General Review of Helicopter Rotor Hub Drag Data" by Mr. Sheehy (reference 32). Work in these areas would further improve the range and endurance of the SH-2F.

Reducing Fuel Required for the ASW Mission

To correct the ASW mission deficiency, a reduction in the fuel required is necessary. It follows that a reduction in fuel flow will result in a reduction in the fuel required for the mission. A reduction in the flat plate area of the aircraft would reduce the power required and thus the fuel flow. Parasite drag accounts for approximately 45 percent of the total power required under high speed conditions (reference 28), therefore, to reduce power required parasite drag should minimized. Since the bulk of the ASW mission

defined in reference 6 is flown at V_h, a reduction in the fuel flow at V_h will be examined. The three components that account for 80 percent of the parasite drag on conventional helicopters are the landing gear, the main rotor hub, and the fuselage. The main landing gear on the H-2 are retractable, and therefore are not significant contributors to the parasite drag. Twenty to 33 percent of the total drag of the aircraft comes from the main rotor hub and associated interference drag (reference 32), and the potential reduction in drag due to the main rotor hub is approximately 50 percent (reference 32). The potential reduction in drag due to the fuselage is roughly 5 percent of the total drag in forward flight (reference 28). These potential savings are based on conventional helicopters.

The potential drag savings can be used to estimate the reduction in power required by reducing the flat plate area and calculating the change in power required. The change in power required will provide a reduction in the fuel flow and therefore provide an indication of the levels of fuel saving that can be expected. Analysis of the author's flight test data (reference 29) indicates that the flat plate area of the SH-2F in the ASW configuration (MAD, two 100 gal auxiliary fuel tanks, landing gear retracted) is 47 square feet. The flat plate area changes are as follows: 9.4 to 15.5 square feet for the main rotor hub, and 2.1 square feet for the fuselage. The total potential reduction in flat plate area is 11.5 to 17.6 square feet. A reduction in flat plate area by

11.5 square feet (25 percent) results in a 12 percent reduction in fuel flow for an airspeed of 130 knots. A reduction in flat plate area by 17.6 square feet (37 percent) results in a 22 percent reduction in fuel flow for an airspeed of 130 knots.

Considering the 22 percent reduction in fuel flow (using the T700 engine) for an airspeed of 130 knots, the aircraft will still fall short of the ASW mission requirements of reference 6 by 526 lb of fuel or 23 percent of the mission fuel available. The 17.6 square feet reduction in flat plate area does improve the mission capability of the aircraft by providing an additional 500 lb of fuel for the mission (over the improvements provided by the T700 engine fuel specifics). A reduction in drag or flat plate area of approximately 40 square feet, or 85 percent of the total flat plate area would be required to allow the aircraft to meet the ASW mission requirements. It is not likely that a 85 percent reduction in the flat plate area of the aircraft is achievable.

CONCLUSIONS

GENERAL

The SH-2F presently has significant performance deficiencies in single engine vertical climb, and ASW and ASST mission fuel requirements. Providing increased power and improved fuel specifics corrects the single engine vertical climb and ASST mission fuel deficiencies, but does not correct the ASW mission fuel deficiency. The T700 powered SH-2F is an options for correcting two of the three deficiencies that meets the requirements of a design for mankind. Efforts to reduce the parasite drag on the fuselage in forward flight may provide the necessary improvements to reduce power required that would allow the T700 powered SH-2F to meet the ASW mission requirement of the SH-60B. These reductions in parasite drag also are likely to meet the requirements of a "design for mankind."

RECOMMENDATIONS

Replace the T58-GE-8F engines with the T700-GE-401 engines. Investigate the possible gains in forward flight performance by reducing the parasite drag on the fuselage and main and tail rotor hubs. These improvements in the SH-2F will provide a safer, more effective SH-2 for the U.S. Navy.

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APPENDICES

APPENDIX A

FIGURES

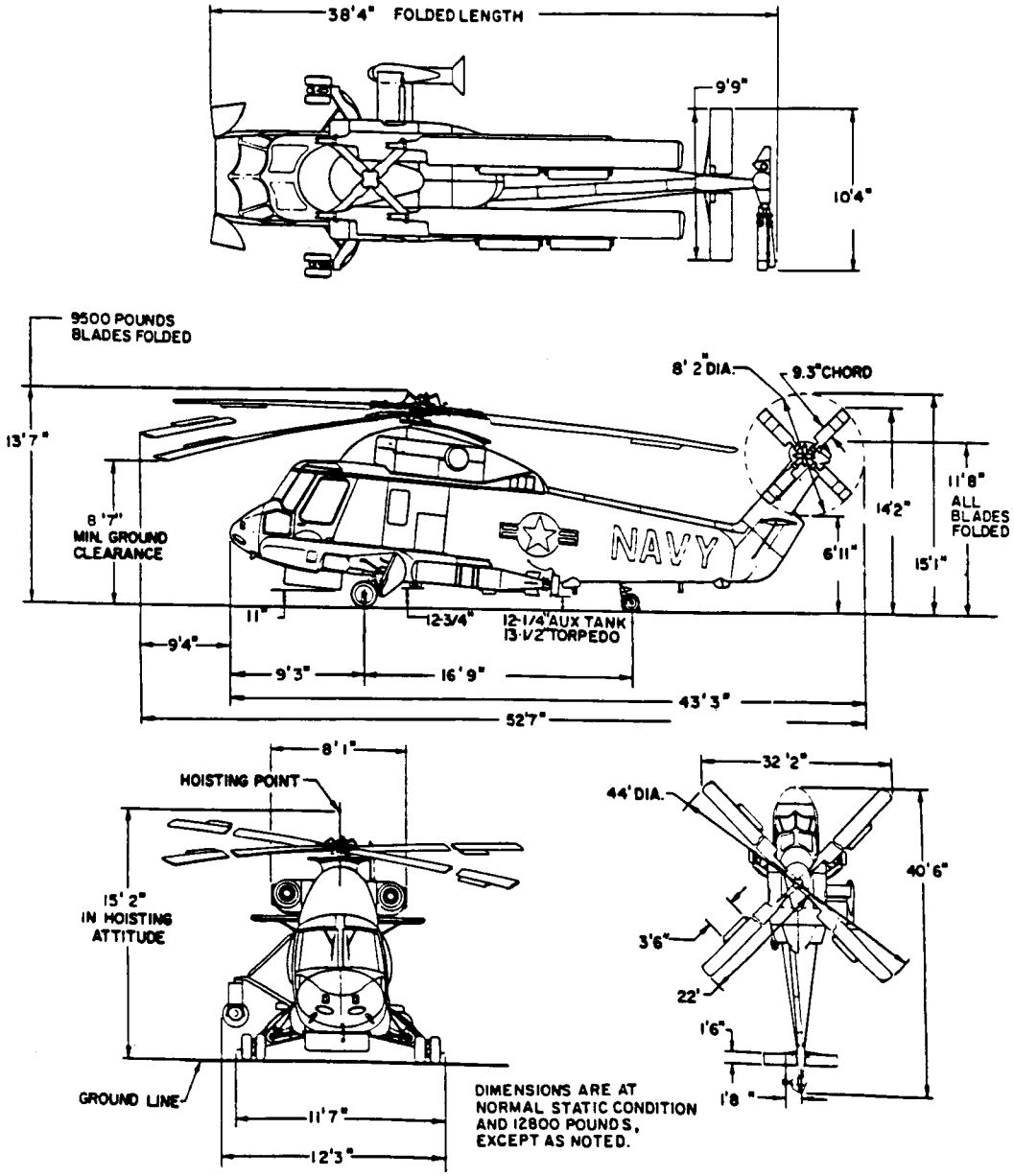


Figure 1

THREE VIEW DRAWING OF THE SH-2F HELICOPTER

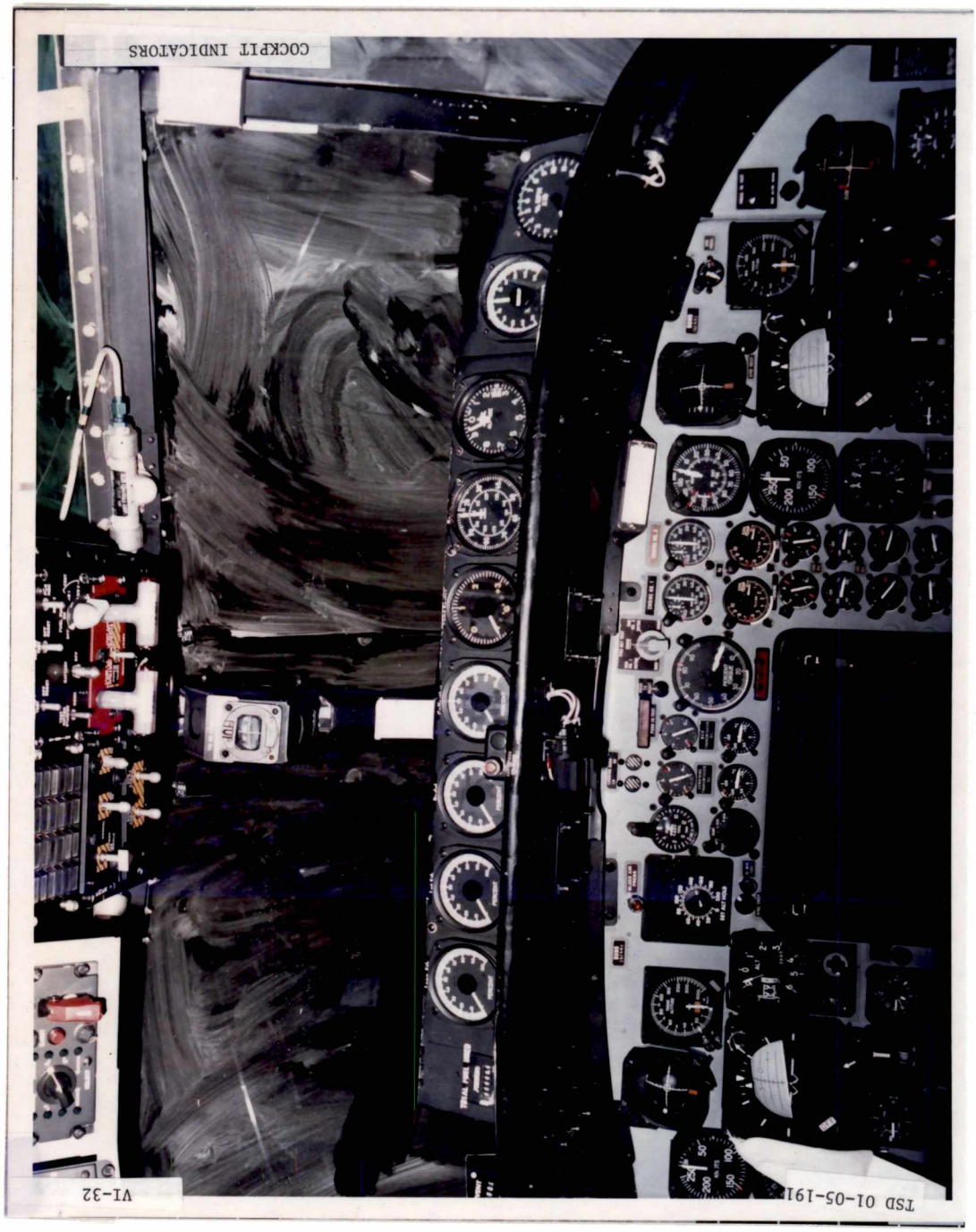


Figure 2

COCKPIT INSTRUMENTATION

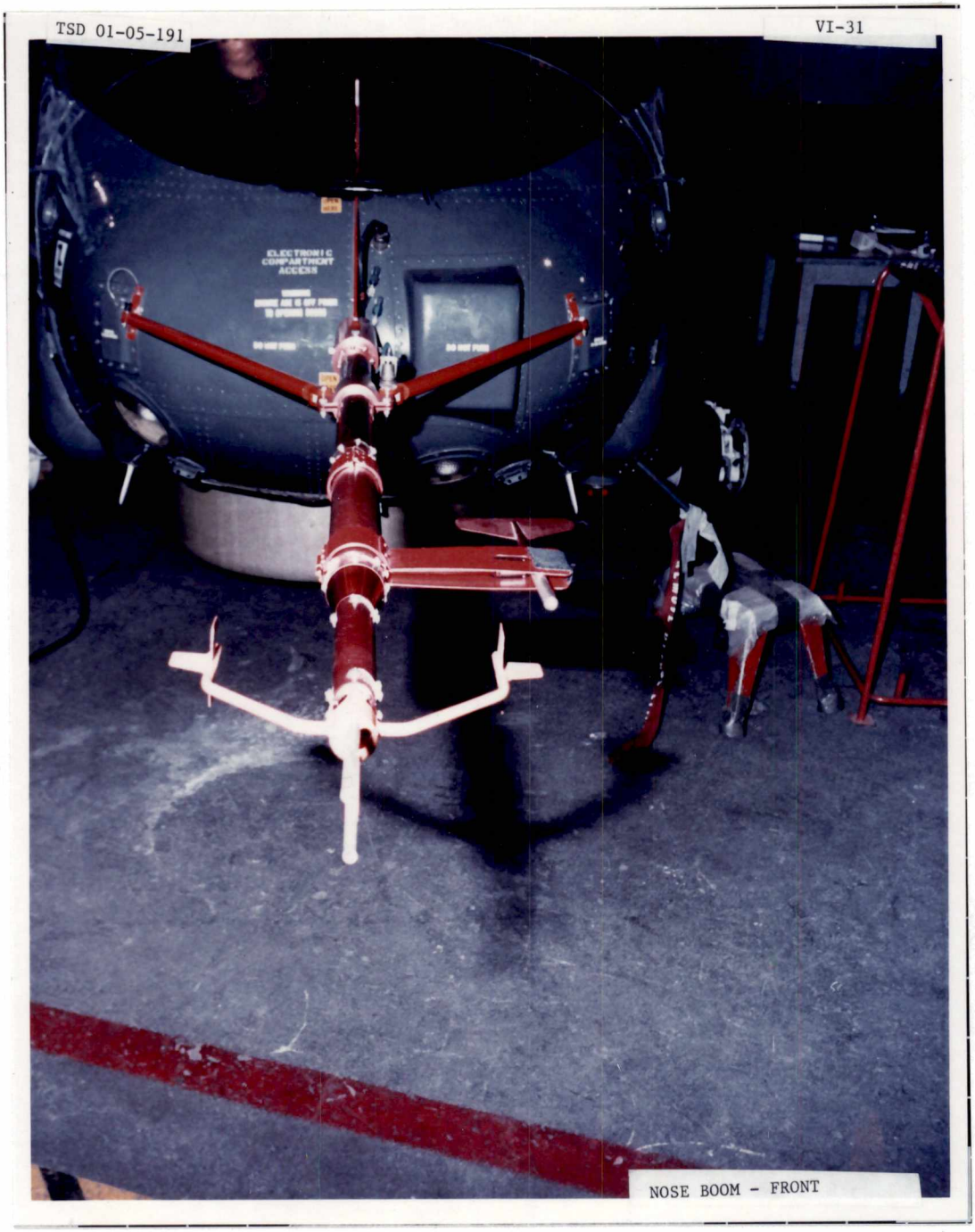


Figure 3

AIRSPEED/SIDESLIP BOOM

APPENDIX B

TABLES

Table I

TESTS AND TEST CONDITIONS

Test (1 - 4)	Airspeed (KCAS)	Average PA (ft)	Average OAT (deg C)	Average Gross Weight (lb)	Average CG (in)
Cockpit Evaluation	-	0	17	-	-
Mechanical Characteristics	0 - 130	3,000	17	11,556	170.3
Hover Performance (5)	0	100	20	12,833	173.8
Hover Ladder	0	50	20	12,833	173.8
Static Droop	0	45	20	12,946	175.7
Vertical Climb Performance	0	600	20	12,946	175.7
Level Flight Performance	45 - 130	3,000	17	10,683	169.3
Climb and Descent Performance	60 - 120	2,000	17	12,183	169.8
Transient Droop	90	2,000	17	11,770	171.4
Engine Assessment	0 - 120	2,000	17	11,556	170.1
N_r Decay for Single/Dual Engine Failures	80	1,000	18	11,083	169.8

Notes: (1) Configuration - two 100 gallon auxiliary fuel tanks, doors closed, MAD detection set.
(2) Landing gear - retracted during forward flight tests, extended during all other testing.
(3) BOOST - On, ASE - On.
(4) N_r - 106 %
(5) N_r - 102 %, 104 %, and 106 %

Table II

PERFORMANCE SUMMARY (T58-GE-8F ENGINES)

Parameter	ASW Configuration	ASST Configuration
V_h	132 KTAS	135 KTAS
V_{cruise}	118 KTAS	118 KTAS
Maximum Range	227 nm	297 nm
V_{range}	110 KTAS	110 KTAS
Maximum Endurance	2.3 hr	3.4 hr
V_{end}	75 KTAS	70 KTAS
Maximum Forward Flight Rate-of-Climb	2275 fpm at 65 KCAS	
Minimun Rate-of-Descent	1675 fpm at 66 KCAS	
Maximum Glide Airspeed	85 KCAS	
IGE Hover Ceiling	Hot Day Conditions - 10,050 ft PA Standard Day Conditions - 3,075 ft PA	
OGE Hover Ceiling	Hot Day Conditons - 9,025 ft PA Standard Day Conditions - 2,500 ft PA	
Single Engine Hover	10,200 lb Maximum Gross Weight Sea Level, Standard Day	

Table III

ASW MISSION FUEL REQUIREMENTS

	T58-GE-8F Engines			T700-GE-401 Engines		
Condition	W_f/eng (lb/hr)	Fuel Used per leg (lb)	Fuel Remain (lb)	W_f/eng (lb/hr)	Fuel Used (lb)	Fuel Remain (lb)
Maximum gross weight 13,500 lb			2,536			2,276
Engine Start & take-off, 5 min @ MCP (1100 SHP/engine)	679	113	2,423	584	97	2,179
Climb from sea level to 5,000 feet H_p @ MCP (931 SHP/engine, torque limited in forward flight climbs, average rate of climb: 1400 fpm)	605	79	2,344	519	68	2,111
Cruise @ 5,000 ft H_p, V_h, for 70 NM (MCP: 1100 SHP/engine, V_h is 125 KTAS from ref 60 Spec)	598	625	1,719	517	541	1,570
Search on-station @ 5,000 ft H_p for 30 min @ V_h, MCP (1100 SHP/engine)	594	594	1,125	517	517	1,053
Loiter on-station @ 5,000 ft H_p for 50 min @ V_{end}	384	640	485	332	554	499
Descend to sea level, no fuel used			485			499
Combat, on station @ sea level for 40 min @ V_h, MCP (1100 SHP/engine)	630	839	-354	584	779	-280

Table III

ASW MISSION FUEL REQUIREMENTS - Continued

ASW	T58-GE-8F Engines			T700-GE-401 Engines		
Condition	W_f/eng (lb/hr)	Fuel Used (lb)	Fuel Remain (lb)	W_f/eng (lb/hr)	Fuel Used (lb)	Fuel Remain (lb)
Climb from sea level to altitude for best cruise at MCP, on course	605	99	-453	491	85	-365
Return to ship @ Altitude for best range and V_{range}	448	543	-996	374	433	-798
Descend to sea level, no fuel used, no distance gained			-996			-798
Land on the ship with 10 % fuel remaining		254	-1,250		228	-1,026

Notes: The ASW mission is spelled out in reference 6, the SH-60B detail specification. SH-2F power required was taken form the SH-2F NATOPS manual (reference 2). Fuel flow for the T58-GE-8F engine was also taken from reference 2, for the T700-GE-401 eingine, fuel flow data was taken from reference 24. Power required for the T700 powered SH-2 was assumed to be the same as the power required for the T58 powered SH-2.

Table IV

MISSION FUEL REQUIREMENTS CALCULATION

ASW MISSION
SH-2F WITH T58-GE-8F ENGINES

Engine start, maximum continuous power (MCP) for 5 min.
ESHP/Engine = 1096 lb/hr (reference 1)
Fuel flow (W_f) = 679 lb/hr per engine
Fuel used = $2W_f$(5 min/60 min/hr) = 113 lb

Climb from sea level to 5,000 ft H_p at MCP.
Rate of climb at 13,500 lb gross weight (GW) = 1275 fpm
Fuel used = 75 lb
Time to climb = 5,000 ft/1275 fpm = 3.9 min
ESHP/engine = 55 % (reference 2 limit for climb power setting).
W_f for 55 % power = 605 lb/hr (reference 2)
Fuel used = $2W_f$(3.9 min/60 min/hr) = 79 lb
Distance traveled during climb at 70 knots (best climb airspeed) = 70 knots(3.9 min/60 min/hr) = 4.6 NM

Cruise at 5,000 ft H_p at MCP to a point 70 NM from the ship.
Distance to 70 NM point from ship = 70 NM - 4.6 NM = 65.4 NM
A/S limit (ref 2) = 125 KCAS
Time to travel 65.4 NM at 125 KCAS = (64.5 NM/125 NM/hr)60 min/hr = 31.4 min
W_f (from ref 2, GW = 13,000 lb) = 1195 lb/hr/2 engines = 598 lb/hr per engine
Fuel used = $2W_f$(31.4 min/60 min/hr) = 625 lb

On Station Search at 5,000 ft H_p at MCP for 30 min at V_h.
W_f (from ref 2, GW = 12,000 lb) = 1188 lb/hr/2 engines = 594 lb/hr per engine
Fuel used = $2W_f$(30 min/60 min/hr) = 594 lb
Average GW for this leg of the mission = 12,350 lb.

On-station loiter: V_{end} at 5,000 ft H_p for 50 min
Interpolated for V_{end} at 5,000 ft H_p from ref 2 for W_f.
W_f = [(778 - 758)/2 + 758]/2 = 384 lb/hr at 70 KCAS
Fuel used = $2W_f$(50 min/60 min/hr) = 640 lb

Descend to sea level, no fuel used, GW = 11,294 lb.

Combat on-station: 40 min at V_h, MCP at sea level.
W_f = (1259 lb/hr)/2 = 630 lb/hr (ref 2, average GW = 11,000 lb)
Fuel used = $2W_f$(40 min/60 min/hr) = 839 lb
V_h = 133 KCAS (ref 2)

Table IV - Continued

MISSION FUEL REQUIREMENTS CALCULATION

ASW MISSION
SH-2F WITH T58-GE-8F ENGINES

Climb to best cruise altitude at MCP.
GW = 11,000 lb since fuel load can no longer reduce the GW.
Best cruise altitude determined to be 10,000 ft H_p, cruise distance was taken into account (altitude limited by reference 6)
Rate of climb at 11,000 lb gross weight (GW) = 2030 fpm
Time to climb = 10,000 ft/2030 fpm = 4.9 min
ESHP/engine = 55 % (reference 2 limit for climb power setting).
W_f for 55 % power = 605 lb/hr
Fuel used = $2W_f$(4.9 min/60 min/hr) = 99 lb
Distance traveled during climb at 70 knots (best climb airspeed) = 70 knots(4.9 min/60 min/hr) = 5.7 NM

Cruise to back to the ship, 64.2 NM at V_{range}, 10,000 ft H_p.
V_{range} = 106 KCAS at 11,000 lb GW
W_f = 448 lb/hr per engine
Time to travel 64.2 NM at 106 KCAS = 64.2/106 = 0.61 hr = 36.3 minutes
Fuel used = $2W_f$(0.61 hr) = 543 lb

Descend to sea level, no fuel used, no distance gained.

Land on the ship with 10 % fuel reserve remaining.
10 % fuel reserve = 0.1(2536 lb mission fuel) = 254 lb

Total fuel available for the mission = 2,536 lb
Total fuel used for the mission = 3,788 lb
Mission fuel deficiency = 1,250 lb for the ASW mission.

Notes: Performance data taken from the NATOPS Flight Manual reference 2, unless otherwise indicated. The ASW mission is from the detail specification for the SH-60B, reference 6.

Table V

ASST MISSION FUEL REQUIREMENTS

ASST	T58-GE-8F Engines			T700-GE-401 Engines		
Condition	W_f/eng (lb/hr)	Fuel Used (lb)	Fuel Remain (lb)	W_f/eng (lb/hr)	Fuel Used (lb)	Fuel Remain (lb)
Maximum gross weight 13,135 lb			3,209			2,949
Engine Start & take-off, 5 min @ MCP (1100 SHP/engine)	679	113	3,096	584	97	2,852
Climb from sea level to 1,500 feet H_p @ MCP (931 SHP/engine, torque limited in forward flight climbs, average rate of climb: 1400 fpm)	605	21	3,075	519	17	2,835
Cruise @ 1,500 ft H_p, V_h, for 40 NM (MCP: 1100 SHP/engine, V_h is 125 KTAS from ref 60 Spec)	621	379	2,696	575	351	2,484
Loiter on-station @ 1,500 ft H_p for 3.5 hr @ V_{end}	380	2,660	36	270	1,887	597
Return to the ship @ 1,500 ft H_p for 40 NM @ V_{range}	510	357	-321	399	225	372
Descend to sea level, no fuel used			-321			372
Land on the ship with 10 % fuel reserve remaining		321	-642		295	77

Notes: The ASST mission is spelled out in reference 6, the SH-60B detail specification. SH-2F power required was taken form the SH-2F NATOPS manual (reference 2). Fuel flow for the T58-GE-8F engine was also taken from reference 2, for the T700-GE-401 eingine, fuel flow data was taken from reference 24. Power required for the T700 powered SH-2 was assumed to be the same as the power required for the T58 powered SH-2.

Table VI

MISSION FUEL REQUIREMENTS CALCULATION

ASST MISSION
SH-2F WITH T58-GE-8F ENGINES

Engine start, maximum continuous power (MCP) for 5 min.
ESHP/Engine = 1096 lb/hr (reference 1)
Fuel flow (W_f) = 679 lb/hr per engine
Fuel used = $2W_f$(5 min/60 min/hr) = 113 lb

Climb from sea level to 1,500 ft H_p at MCP.
Rate of climb at 13,000 lb gross weight (GW) = 1430 fpm
Time to climb = 1,500 ft/1430 fpm = 1.0 min
ESHP/engine = 55 % (reference 2 limit for climb power setting).
W_f for 55 % power = 605 lb/hr
Fuel used = $2W_f$(1.0 min/60 min/hr) = 21 lb
Distance traveled during climb at 70 knots (best climb airspeed) = 70 knots(1.0 min/60 min/hr) = 1.2 NM

Cruise at 1,500 ft H_p at MCP to a point 40 NM from the ship.
Distance to 40 NM point from ship = 40 NM - 1.2 NM = 38.8 NM
A/S limit (ref 2, GW = 13,000 lb) = 127 KCAS
Time to travel 38.8 NM at 127 KCAS = (38.8 NM/127 NM/hr) = 0.31 hr = 18.3 min
W_f = 621 lb/hr
Fuel used = $2W_f$(18.3 min/60 min/hr) = 379 lb

Loiter on station at 1,500 ft H_p for 3.5 hr at V_{end}
V_{end} = 70 KCAS, GW = 12,615 lb at the beginning of the loiter phase.
W_f = 380 lb/hr
Fuel used = $2W_f$(3.5 hr) = 2660 lb
Average GW for loiter leg = 11,267 lb

Return to ship, 40 NM at 1,500 ft H_p at V_{range}
GW = 11,000 lb
W_f = 510 lb/hr per engine
V_{range} = 114 KCAS
Time to travel 40 NM = 40 NM/114 KCAS = .35 hr = 21 min
Fuel used = $2W_f$(.35 hr) = 357 lb

Descend to sea level, no fuel used, no distance gained.

Land on the ship with 10 % fuel reserve remaining
Fuel available for the mission = 3209 lb
10 % reserve = 0.1(3209 lb) = 321 lb

Table VI - Continued

MISSION FUEL REQUIREMENTS CALCULATION

ASST MISSION
SH-2F WITH T58-GE-8F ENGINES

Total fuel available for the mission = 3,209 lb
Total fuel used for the mission = 3,851 lb
Mission fuel deficiency = 642 lb for the ASST mission.

Notes: Performance data taken from the NATOPS Flight Manual reference 2, unless otherwise indicated. The ASST mission is from the detail specification for the SH-60B, reference 6.

Table VII

MISSION FUEL REQUIREMENTS CALCULATION

ASW MISSION
SH-2F WITH T700-GE-401 ENGINES

Engine start, maximum continuous power (MCP) for 5 min.
ESHP/Engine (transmission limit) = 1097 lb/hr (reference 1)
Fuel flow (W_f) = 584 lb/hr per engine
Fuel used = $2W_f$(5 min/60 min/hr) = 97 lb

Climb from sea level to 5,000 ft H_p at MCP.
Rate of climb at 13,500 lb gross weight (GW) = 1275 fpm (reference 2)
Time to climb = 5,000 ft/1275 fpm = 3.9 min
ESHP/engine = 55 % (reference 2, transmission limit for climb power setting).
W_f for 55 % power = 519 lb/hr
Fuel used = $2W_f$(3.9 min/60 min/hr) = 68 lb
Distance traveled during climb at 70 knots (best climb airspeed, reference 2) = 70 knots(3.9 min/60 min/hr) = 4.6 NM

Cruise at 5,000 ft H_p at MCP to a point 70 NM from the ship.
Distance to 70 NM point from ship = 70 NM - 4.6 NM = 65.4 NM
A/S limit (reference 2) = 125 KCAS
Time to travel 65.4 NM at 125 KCAS = (64.5 NM/125 NM/hr)60 min/hr = 31.4 min
W_f = 517 lb/hr per engine
Fuel used = $2W_f$(31.4 min/60 min/hr) = 541 lb

On Station Search at 5,000 ft H_p at MCP for 30 min at V_h.
W_f = 517 lb/hr per engine
Fuel used = $2W_f$(30 min/60 min/hr) = 517 lb
Average GW for this leg of the mission = 12,380 lb.

On-station loiter: V_{end} at 5,000 ft H_p for 50 min
Interpolated for V_{end} at 5,000 ft H_p from ref 2 for W_f.
W_f = 332 lb/hr at 70 KCAS
Fuel used = $2W_f$(50 min/60 min/hr) = 554 lb

Descend to sea level, no fuel used, GW = 11,568 lb.

Combat on-station: 40 min at V_h, MCP at sea level.
W_f = 584 lb/hr at 1097 SHP/engine
Fuel used = $2W_f$(40 min/60 min/hr) = 779 lb
V_h = 133 KCAS (ref 2)

Table VII - Continued

MISSION FUEL REQUIREMENTS CALCULATION

ASW MISSION
SH-2F WITH T700-GE-401 ENGINES

Climb to best cruise altitude at MCP.
GW = 11,300 lb since fuel load can no longer reduce the GW.
Best cruise altitude determined to be 10,000 ft H_p (data from ref 2), cruise distance was taken into account (altitude limited by reference 6)
Rate of climb at 11,300 lb gross weight (GW) = 1930 fpm (reference 2)
Time to climb = 10,000 ft/1930 fpm = 5.2 min
ESHP/engine = 55 % (reference 2 limit for climb power setting) = 931 HP
W_f = 491 lb/hr per engine for 931 HP at 5,000 ft H_p
Fuel used = $2W_f$(5.2 min/60 min/hr) = 85 lb
Distance traveled during climb at 70 knots (best climb airspeed, reference 2) = 70 knots(5.2 min/60 min/hr) = 6.1 NM

Cruise to back to the ship, 63.9 NM at V_{range}, 10,000 ft H_p.
V_{range} = 125 KTAS, ESHP = 825 HP/engine (reference 24) at sea level. V_{range} at 10,000 ft H_p is 111 KTAS
W_f = 373 lb/hr per engine
Time to travel 63.9 NM at 111 KCAS = 63.9/111 = 0.58 hr = 34.5 min
Fuel used = $2W_f$(0.58 hr) = 433 lb

Descend to sea level, no fuel used, no distance gained.

Land on the ship with 10 % fuel reserve remaining.
10 % fuel reserve = 0.1(2216 lb mission fuel) = 222 lb

Total fuel available for the mission = 2,216 lb
Total fuel used for the mission = 3,296 lb
Mission fuel deficiency = 1,080 lb for the ASW mission.

Assumptions: (1) The power required for the T700 powered SH-2F is the same as the power required for the T58 powered SH-2F. (2) Power required was determined using the performance charts in the operator's manual, reference 2. (3) Fuel flow was determined using the Corrected ESHP vs Corrected W_f curve in reference 24. The ASW mission is defined in reference 6.

Table VIII

MISSION FUEL REQUIREMENTS CALCULATION

ASST MISSION
SH-2F WITH T700-GE-401 ENGINES

Engine start, maximum continuous power (MCP) for 5 min.
ESHP/Engine (transmission limit) = 1097 lb/hr (reference 1)
Fuel flow (W_f) = 584 lb/hr per engine
Fuel used = $2W_f$(5 min/60 min/hr) = 97 lb

Climb from sea level to 1,500 ft H_p at MCP.
Rate of climb at 13,000 lb gross weight (GW) = 1430 fpm (reference 2)
Time to climb = 1,500 ft/1430 fpm = 1.0 min
ESHP/engine = 55 % (reference 2 limit for climb power setting).
W_f for 55 % power = 519 lb/hr (reference 2)
Fuel used = $2W_f$(1.0 min/60 min/hr) = 17 lb
Distance traveled during climb at 70 knots (best climb airspeed, reference 2) = 70 knots(1.0 min/60 min/hr) = 1.2 NM

Cruise at 1,500 ft H_p at MCP to a point 40 NM from the ship.
Distance to 40 NM point from ship = 40 NM - 1.2 NM = 38.8 NM
A/S limit (ref 2, GW = 13,000 lb) = 127 KCAS
Time to travel 38.8 NM at 127 KCAS = (38.8 NM/127 NM/hr) = 0.31 hr = 18.3 min
W_f = 575 lb/hr
Fuel used = $2W_f$(18.3 min/60 min/hr) = 351 lb

Loiter on station at 1,500 ft H_p for 3.5 hr at V_{end}
V_{end} = 71 KTAS (reference 24), GW = 12,615 lb at the beginning of the loiter phase.
W_f = 270 lb/hr
Fuel used = $2W_f$(3.5 hr) = 1887 lb
Average GW for loiter leg = 11,720 lb

Return to ship, 40 NM at 1,500 ft H_p at V_{range}
GW = 10,776 lb W_f = 399 lb/hr per engine
V_{range}(reference 24) = 125 KTAS
Time to travel 40 NM = 40 NM/125 KCAS = 0.32 hr = 19.2 min
Fuel used = $2W_f$(.32 hr) = 225 lb
Descend to sea level, no fuel used, no distance gained.

Land on the ship with 10 % fuel reserve remaining
Fuel available for the mission = 2889 lb
10 % reserve = 0.1(3209 lb) = 290 lb

Table VIII - Continued

MISSION FUEL REQUIREMENTS CALCULATION

ASST MISSION
SH-2F WITH T700-GE-401 ENGINES

Total fuel available for the mission = 2,889 lb
Total fuel used for the mission = 2,867 lb
Mission fuel surplus = 22 lb for the ASST mission.

Assumptions: (1) The power required for the T700 powered SH-2F is the same as the power required for the T58 powered SH-2F. (2) Power required was determined using the performance charts in the operator's manual, reference 2. (3) Fuel flow was determined using the Corrected ESHP vs Corrected W_f curve in reference 24.

APPENDIX C

RATING SCALES

Table I

COOPER-HARPER HANDLING QUALITIES RATING SCALE

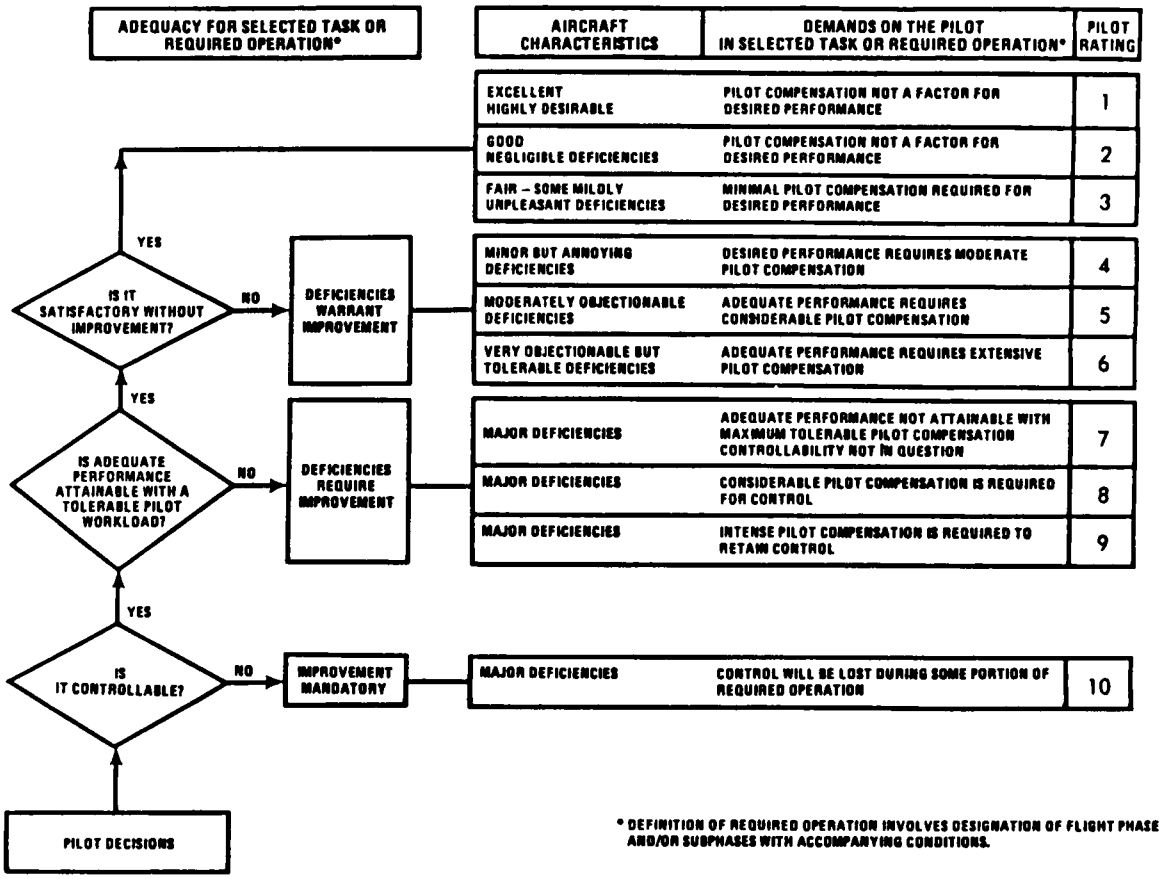


Table II

VIBRATION ASSESSMENT RATING SCALE

Rating	Term used for Deg	Description
0	No vibration	
1 2 3	Slight	Not apparent to experienced aircrew fully occupied by their tasks but noticeable if their attention is directed to it or if not otherwise occupied.
4 5 6	Moderate	Experienced aircrew are aware of the vibration but it does not affect their work, at least over a short period.
7 8 9	Severe	Vibration is immediately apparent to experienced aircrew even when fully occupied. Performance of primary task is affected or tasks can only be done with difficulty.
10	Intolerable	Sole preoccupation of aircrew is to reduce vibration level.

APPENDIX D

DEFINITION OF DEFICIENCIES

DEFINITION OF DEFICIENCIES

"Serious" indicates a deficiency, the correction of which is necessary because it adversely affects

a. Airworthiness of the aircraft.

b. The ability of the aircraft to accomplish its primary or secondary mission.

c. The effectiveness of the crew as an essential subsystem.

d. The safety of the crew or the integrity of an essential subsystem. In this regard, a real likelihood of injury or damage must exist. Remote possibilities or unlikely sequences of events shall not be used as a basis for safety items.

"Significant" indicates a deficiency, the correction of which will significantly improve the capability of the system undergoing evaluation.

"Annoying" indicates a deficiency that can be easily compensated for but should be corrected in future designs. It would not be cost effect to correct annoying deficiencies.

APPENDIX E

PERFORMANCE CURVES

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR RETRACTED/FUEL: JP-5

AVG GW: 10,683 lbs
CG: 169.3 INCHES (AFT)
ASE: ON
N_r: 106%
OAT: 17 DEG C
H_p: 3000 FT
METHOD: CONSTANT W/SIGMA(13,500 LB)

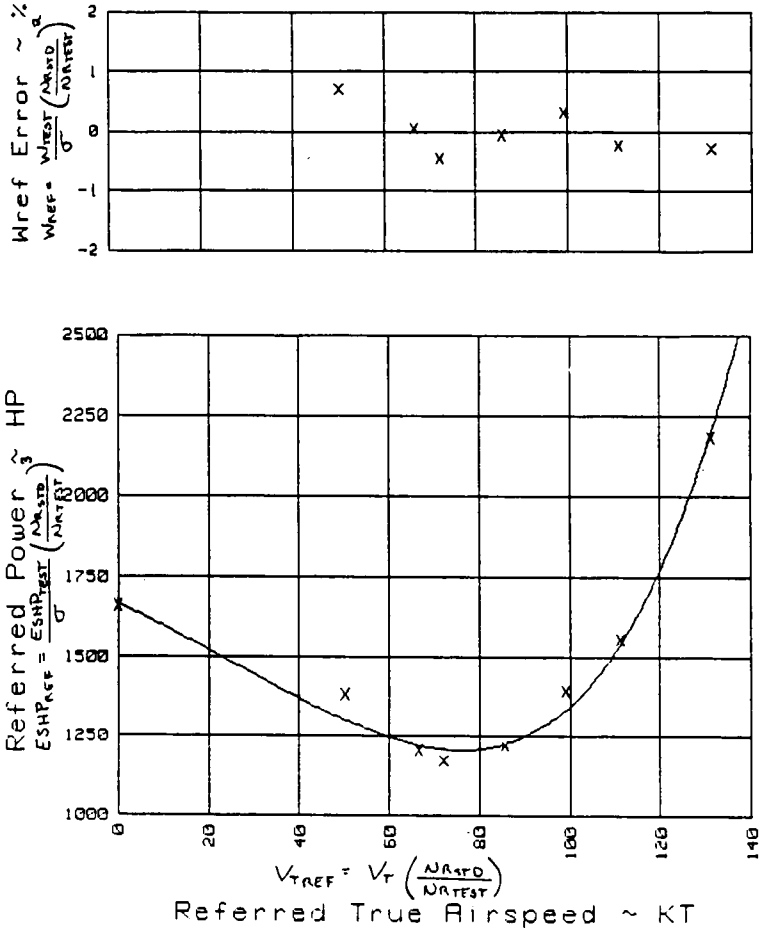


Figure 1

GENERALIZED LEVEL FLIGHT PERFORMANCE

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR RETRACTED/FUEL: JP-5

AVG GW: 10,683 lbs
CG: 169.3 INCHES (AFT)
ASE: ON
N_r: 106%
OAT: 17 DEG C
H_p: 3000 FT
METHOD: CONSTANT W/SIGMA(13,135 lb)

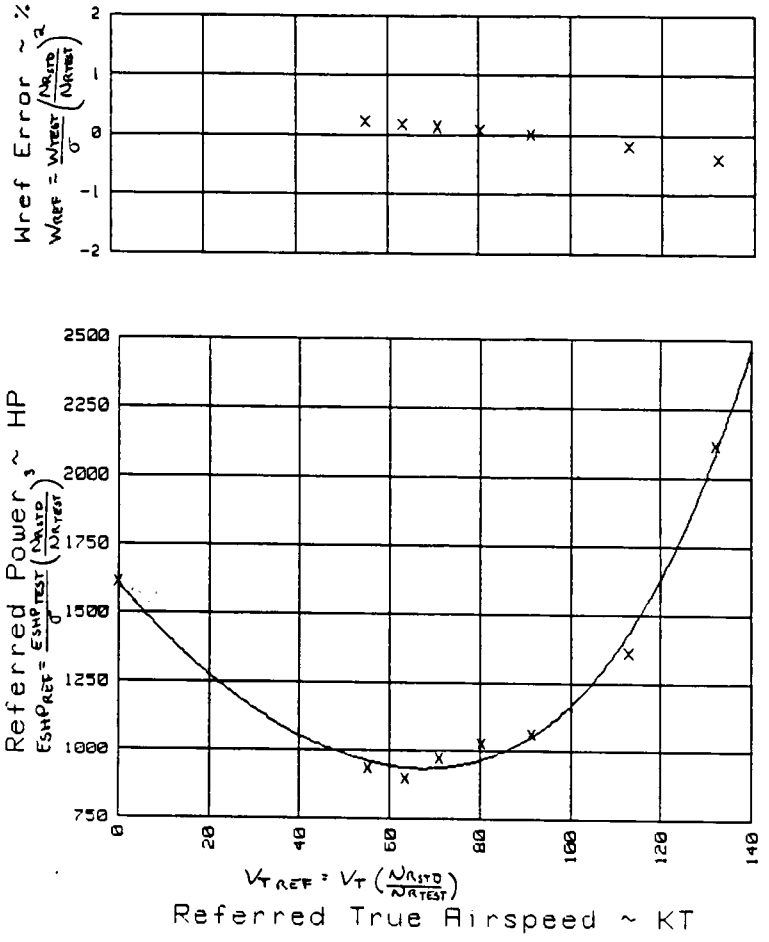


Figure 2

GENERALIZED LEVEL FLIGHT PERFORMANCE

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR RETRACTED/FUEL: JP-5

AVG GW: 10,683 lbs
CG: 169.3 INCHES (AFT)
ASE: ON
N_r: 106%
OAT: 17 DEG C
H_p: 3000 FT
METHOD: CONSTANT W/SIGMA(13,500 lb)

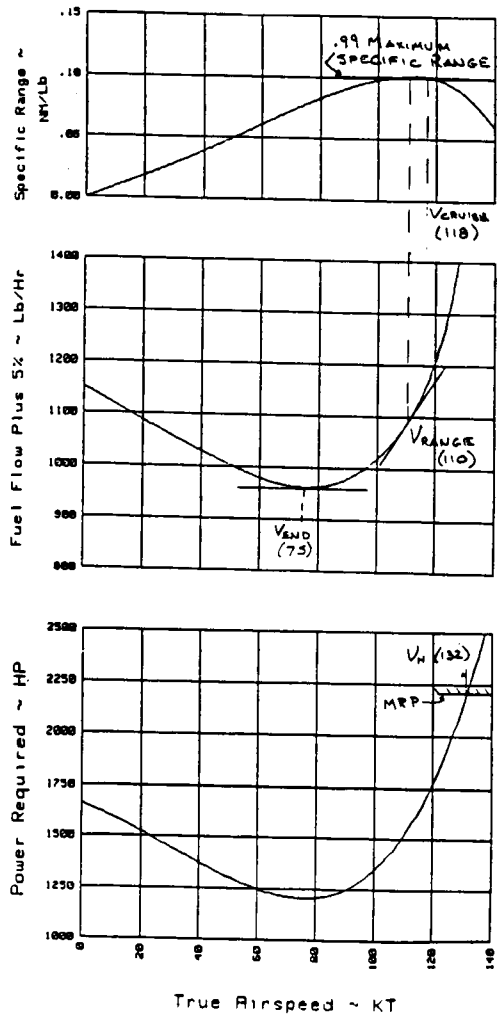


Figure 3

LEVEL FLIGHT PERFORMANCE

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR RETRACTED/FUEL: JP-5

AVG GW: 10,683 lbs
CG: 169.3 INCHES (AFT)
ASE: ON
N_r: 106%
OAT: 17 DEG C
H_p: 3000 FT
METHOD: CONSTANT W/SIGMA(13,135 lb)

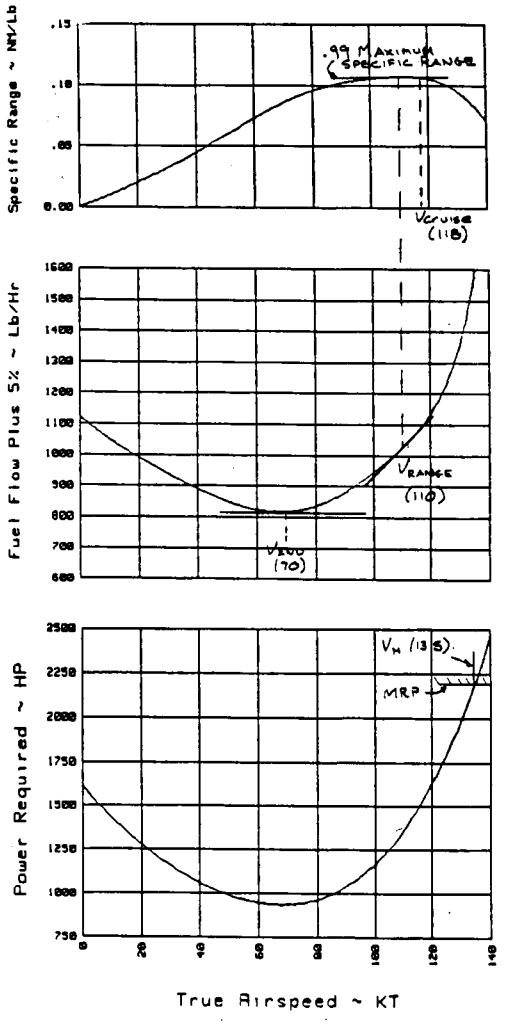


Figure 4

LEVEL FLIGHT PERFORMANCE

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F	AVG GW: 12,183 lbs
ENGINE S/N: #1 25295	CG: 169.3 INCHES (AFT)
#2 22636	ASE: ON
CONFIGURATION: 2 EXTERNAL 100	N_r: 106%
GAL AUX TANKS, MAD, DOORS CLOSED	OAT: 17 DEG C
BLEED AIR: NORMAL	H_p: 2000 FT
GEAR RETRACTED/FUEL:JP-5	METHOD:SAWTOOTH CLIMBS

Note: Data used to verify operators manual curve.

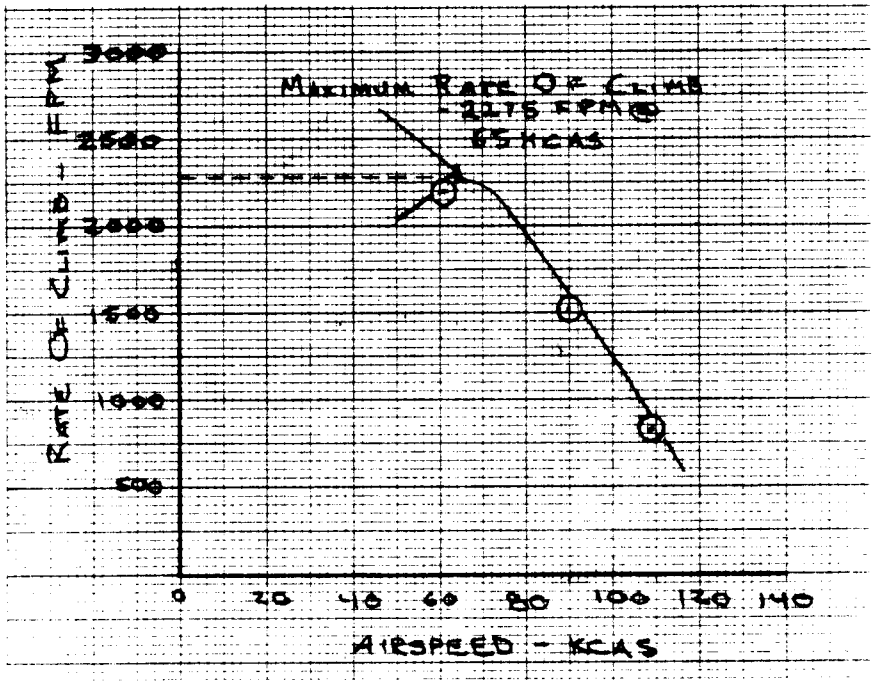


Figure 5

FORWARD FLIGHT CLIMB PERFORMANCE (TEST DAY)

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F	AVG GW: 12,183 lbs
ENGINE S/N: #1 25295	CG: 169.3 INCHES (AFT)
#2 22636	ASE: ON
CONFIGURATION: 2 EXTERNAL 100	N_r: 106%
GAL AUX TANKS, MAD, DOORS CLOSED	OAT: 17 DEG C
BLEED AIR: NORMAL	H_p: 2000 FT
GEAR RETRACTED/FUEL: JP-5	METHOD: SAWTOOTH DESCENTS

Note: Data used to verify operators manual curve.

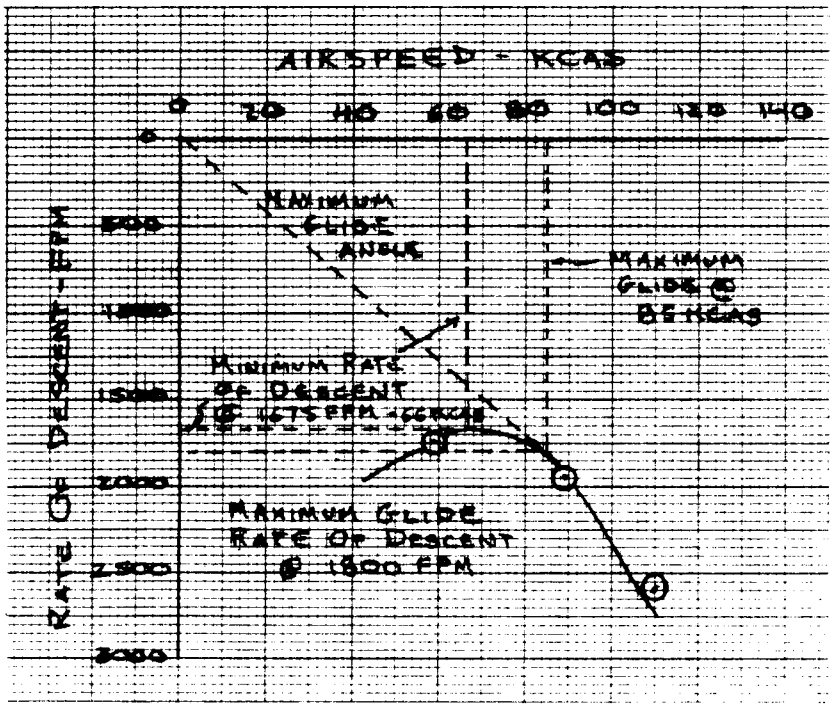


Figure 6

FORWARD FLIGHT DESCENT PERFORMANCE (TEST DAY)

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 12,946 lbs
CG: 175.7 INCHES (AFT)
ASE: ON
N_r: 106 %
OAT: 20 DEG C
H_p: 600 FT

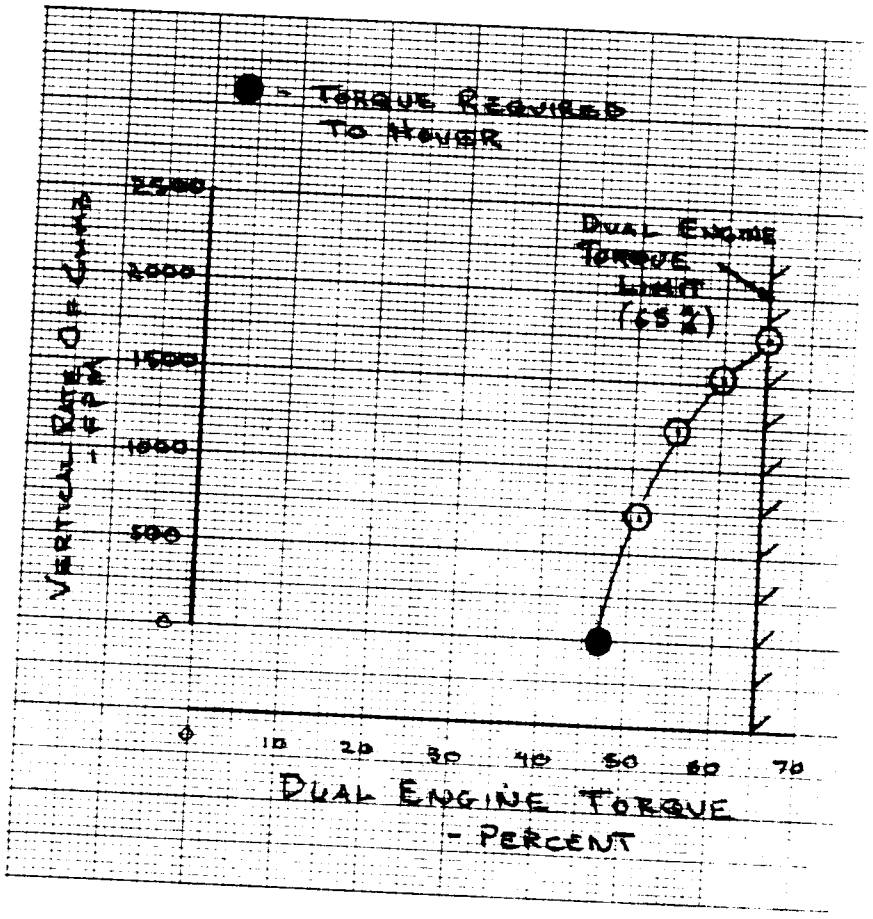


Figure 7

VERTICAL CLIMB PERFORMANCE (TEST DAY)

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 12,833 lbs
CG: 173.8 INCHES (AFT)
ASE: ON
N_r: 106 %
OAT: 20 DEGREES C
ALTITUDE: 20 FT AGL
METHOD:FREE HOVER
WINDS: 3 - 7 KNOTS

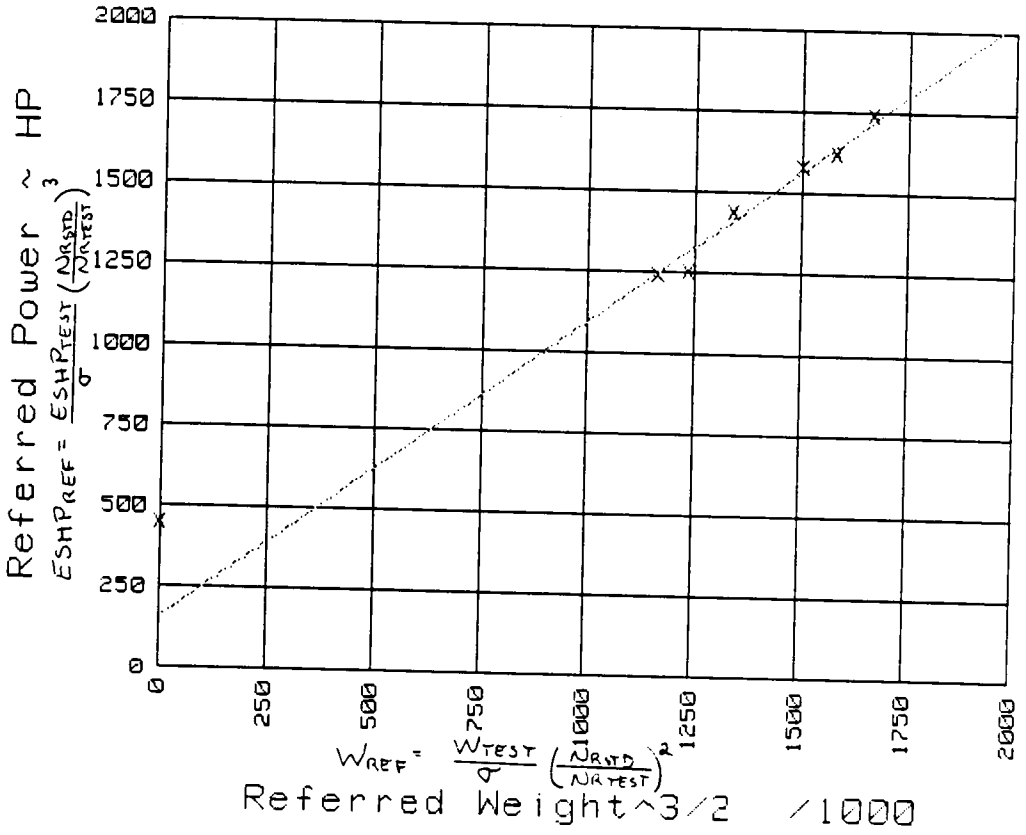


Figure 8

GENERALIZED IGE HOVER PERFORMANCE

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 12,833 lb
CG: 173.8 INCHES (AFT)
ASE: ON
N_r: 106 %
OAT: 20 DEG C
ALTITUDE: 20 FT AGL
METHOD:FREE HOVER
WINDS: 3 - 7 KNOTS

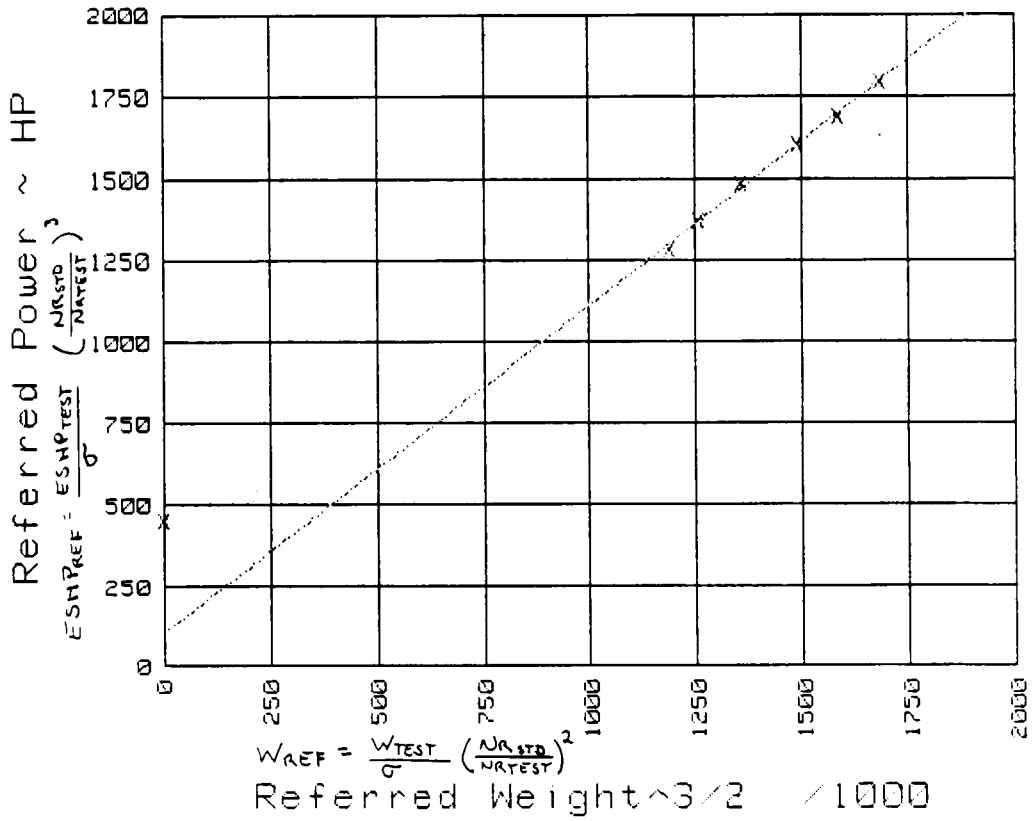


Figure 9

GENERALIZED OGE HOVER PERFORMANCE

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 12,833 lb
CG: 173.8 INCHES (AFT)
ASE: ON
N_r: 106 %

METHOD:FREE HOVER

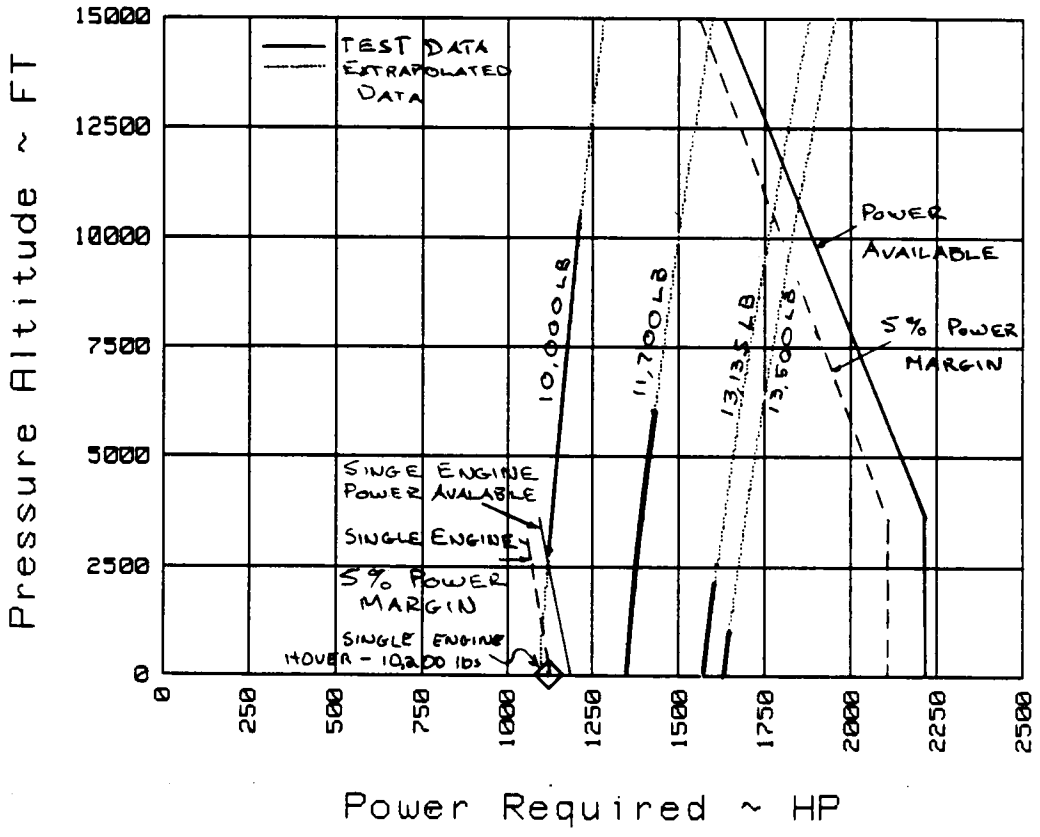


Figure 10

STANDARD DAY IGE HOVER CEILING WORKING PLOT

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 12,833 lbs
CG: 173.8 INCHES (AFT)
ASE: ON
N_r: 106 %

METHOD:FREE HOVER

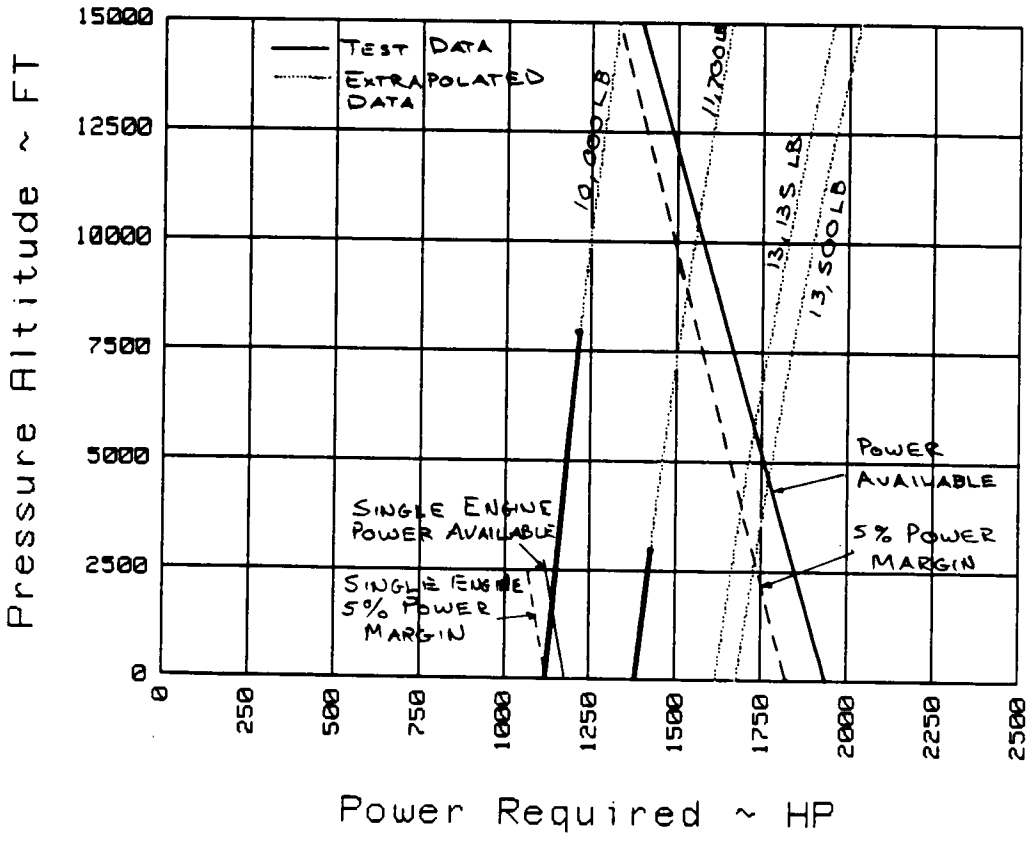


Figure 11

HOT DAY IGE HOVER CEILING WORKING PLOT

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 12,833 lb
CG: 173.8 INCHES (AFT)
ASE: ON
N_r: 106 %

METHOD:FREE HOVER

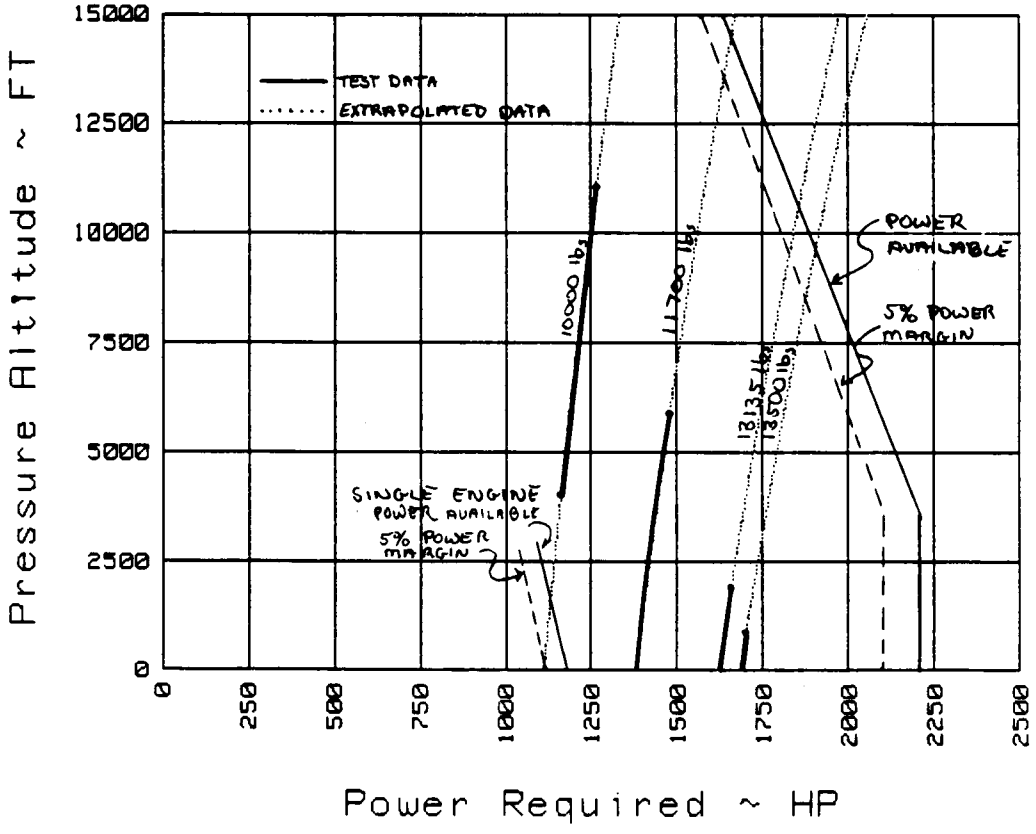


Figure 12

STANDARD DAY OGE HOVER CEILING WORKING PLOT

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 12,833 lb
CG: 173.8 INCHES (AFT)
ASE: ON
N_r: 106 %

METHOD:FREE HOVER

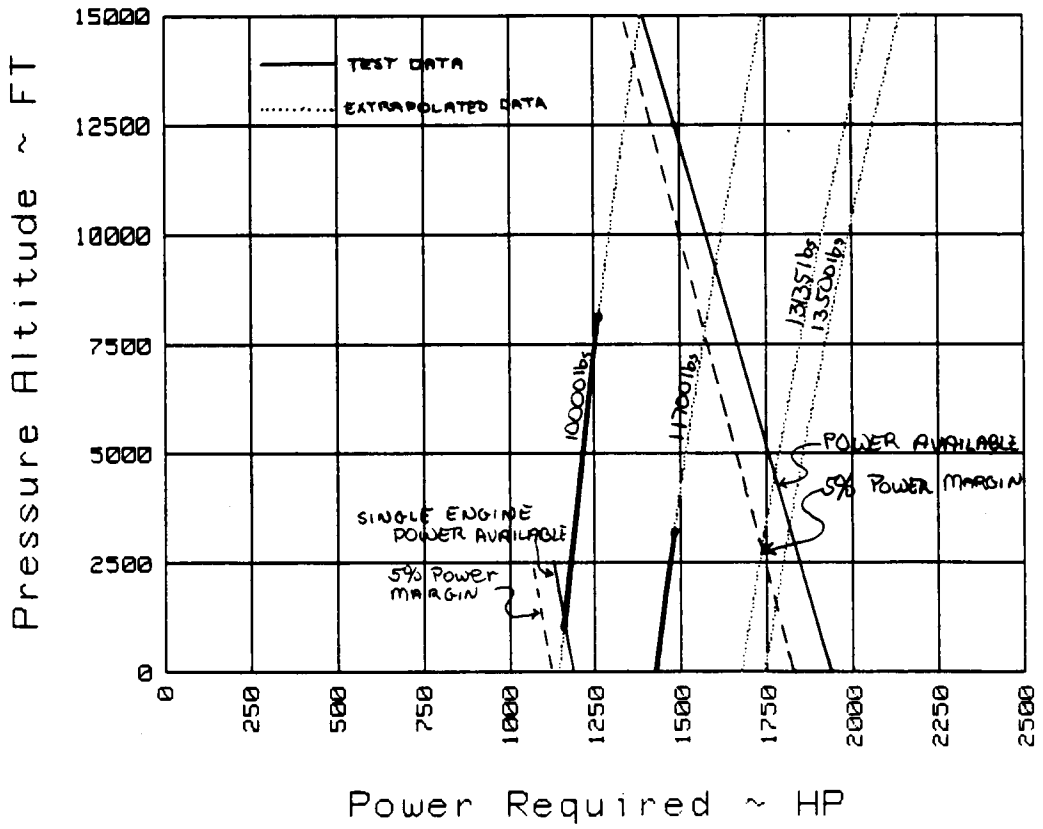


Figure 13

HOT DAY OGE HOVER CEILING WORKING PLOT

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F	AVG GW: 12,833 lb
ENGINE S/N: #1 25295	CG: 173.8 INCHES (AFT)
#2 22636	ASE: ON
CONFIGURATION: 2 EXTERNAL 100	N_r: 106 %
GAL AUX TANKS, MAD, DOORS CLOSED	OAT: 20 DEG C
BLEED AIR: NORMAL	ALTITUDE: 20 FT AGL
GEAR EXTENDED/FUEL:JP-5	METHOD:FREE HOVER

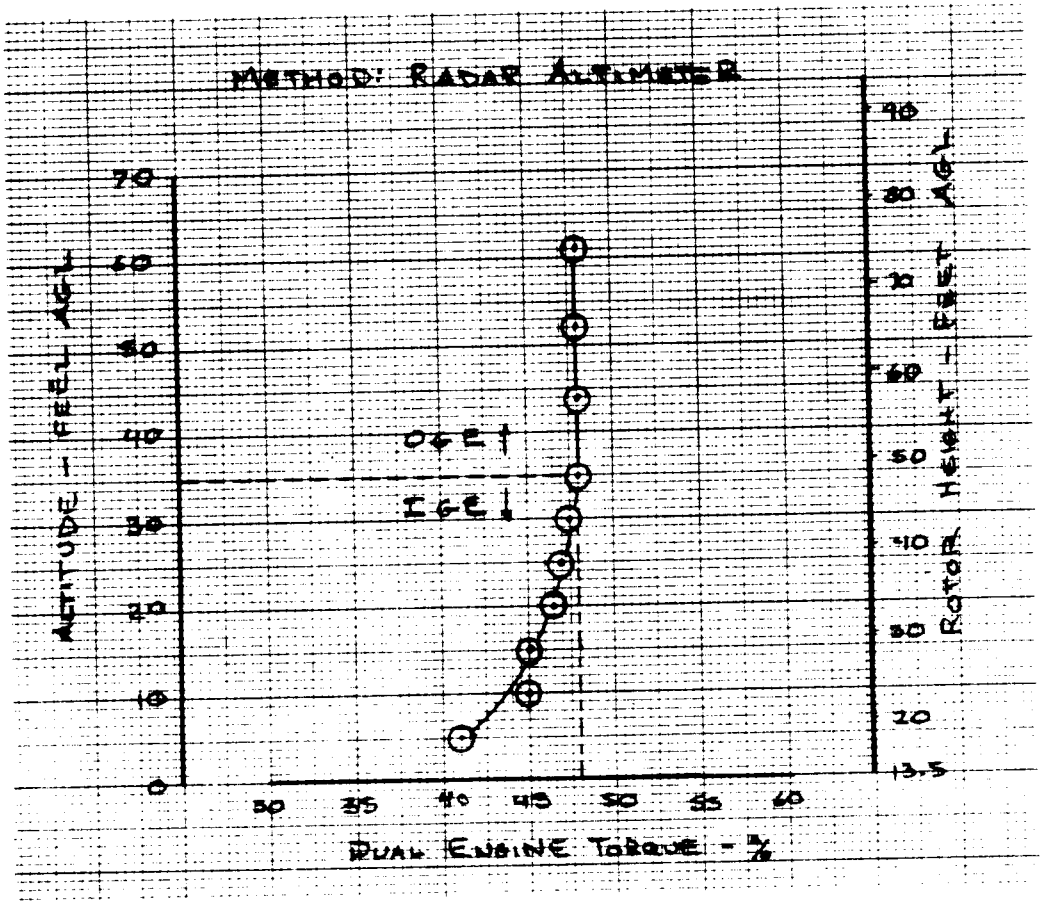


Figure 14

IGE/OGE TRANSITION DETERMINATION

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
EXTERNAL 100 GAL
AUX TANKS, MAD, DOORS CLOSED
AIR: NORMAL

FUEL: JP-5
GEAR: EXTENDED
ASE: ON CONFIGURATION: 2
N_r: 106 %
METHOD: FREE HOVER BLEED

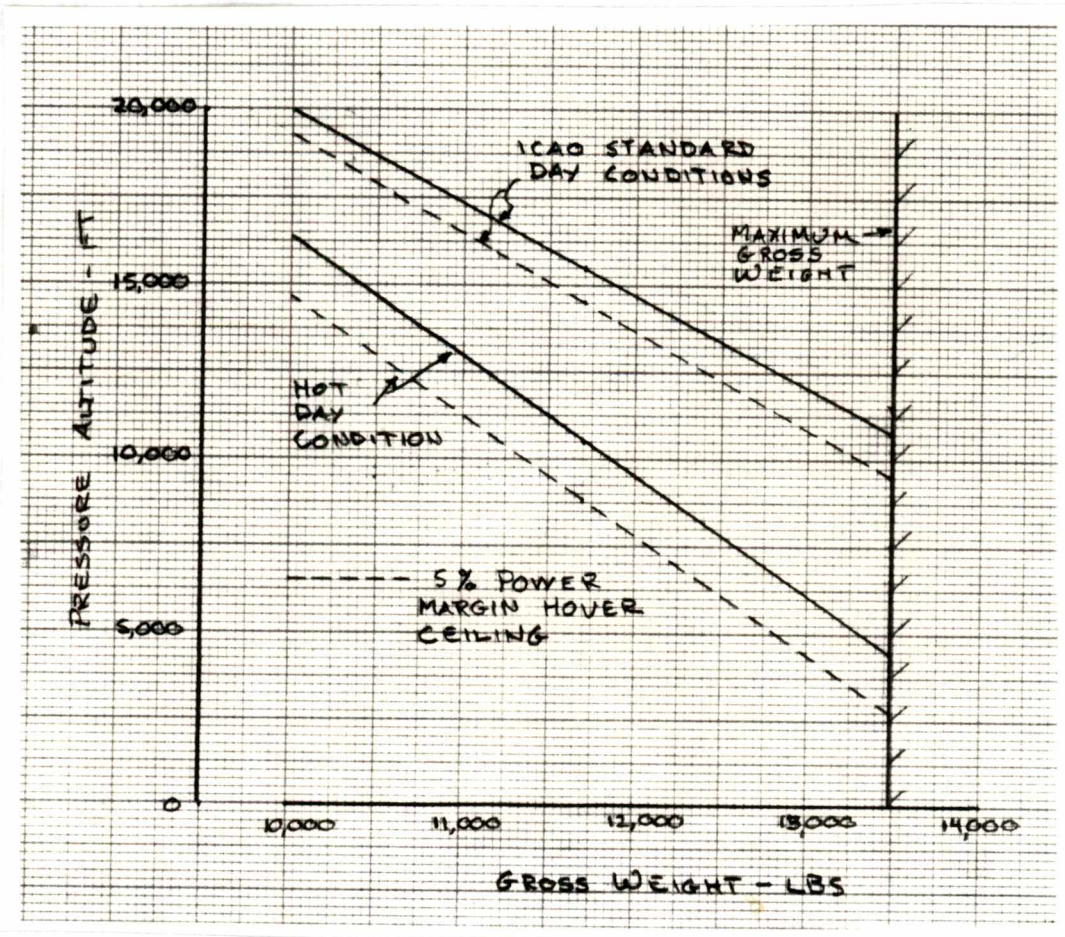


Figure 15

IGE HOVER CEILING

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL

FUEL: JP-5
GEAR: EXTENDED
ASE: ON
N_r: 106 %
METHOD: FREE HOVER

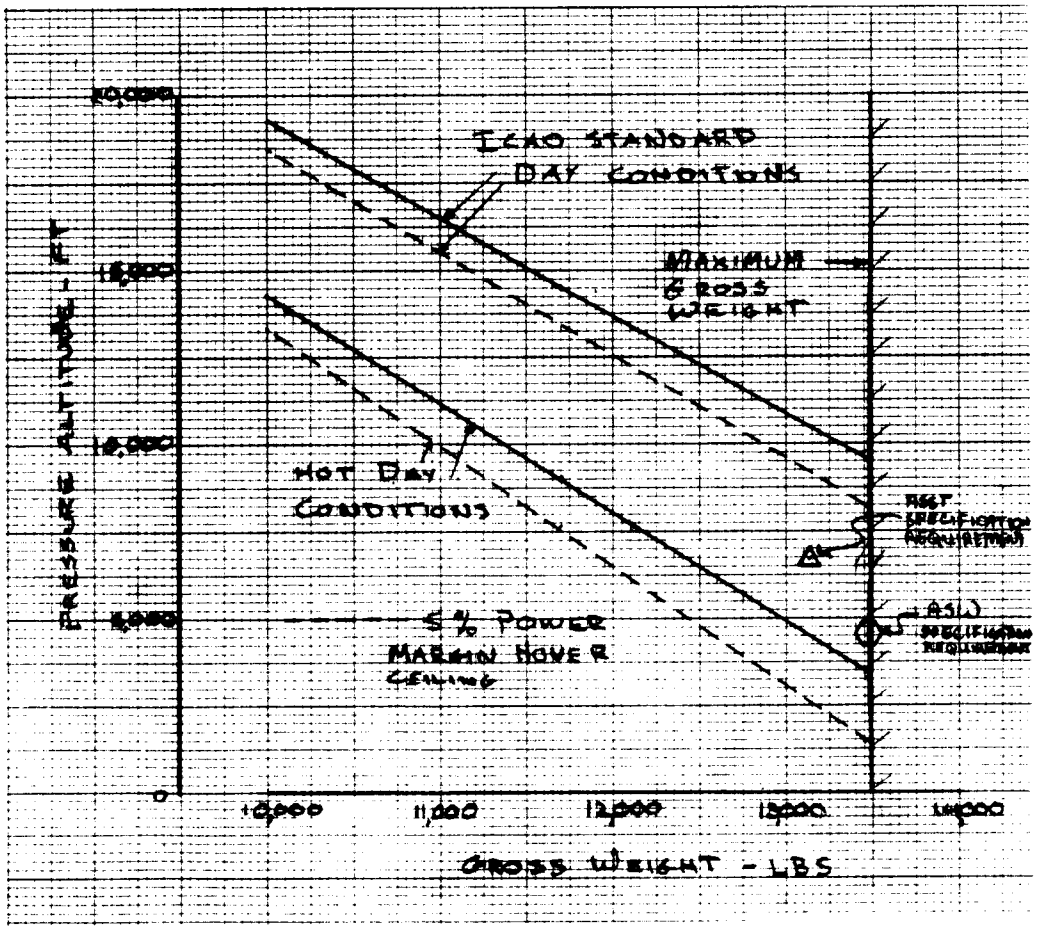


Figure 16

OGE HOVER CEILING

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 12,946 lb
CG: 175.7 INCHES (AFT)
ASE: ON
N_r: 106 %
OAT: 20 DEG C
ALTITUDE: 45 FEET AGL
METHOD:FREE HOVER

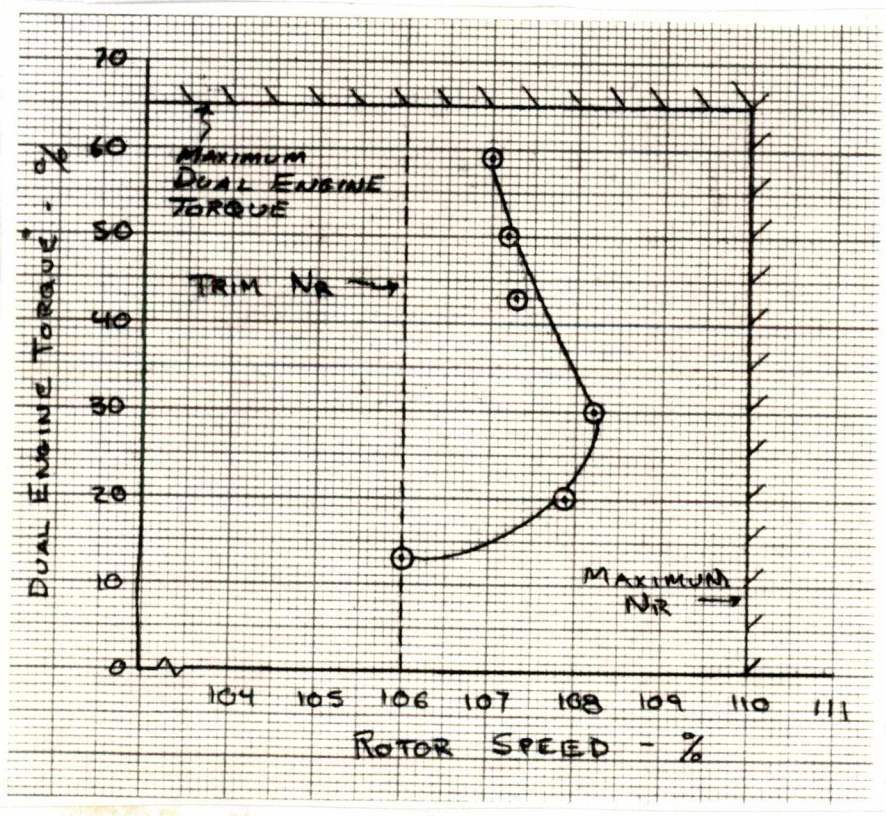


Figure 17

STATIC DROOP

MODEL SH-2F HELICOPTER
BuNo 161641

ENGINES (2): T58-GE-8F
ENGINE S/N: #1 25295
#2 22636
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: NORMAL
GEAR EXTENDED/FUEL:JP-5

AVG GW: 11,750 lb
CG: 171.4 INCHES (AFT)
ASE: ON
N_r: 106 %
OAT: 17 DEG C
H_p: 2000 FT
AIRSPEED: 90 KCAL
METHOD: 8 TO 3 SECOND COLLECTIVE PULLS

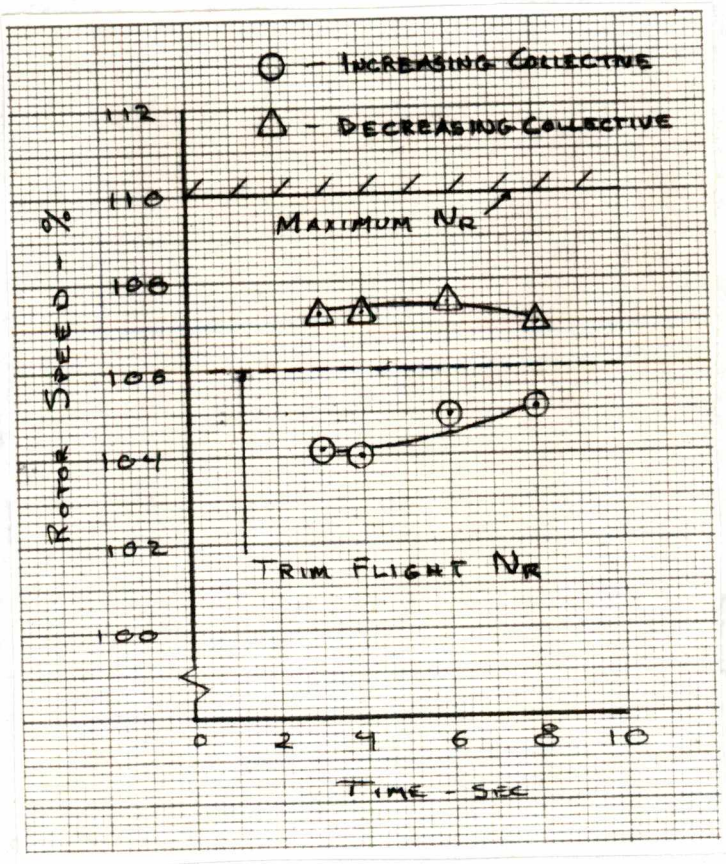


Figure 18

TRANSIENT DROOP

MODEL SH-2F HELICOPTER

ENGINES (2): T700-GE-401
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: OFF
GEAR: EXTENDED/FUEL: JP-5

AVG GW: 12,833 lb
CG: 173.8 INCHES (AFT)
ASE: ON
N_r: 106 %
METHOD: FREE HOVER

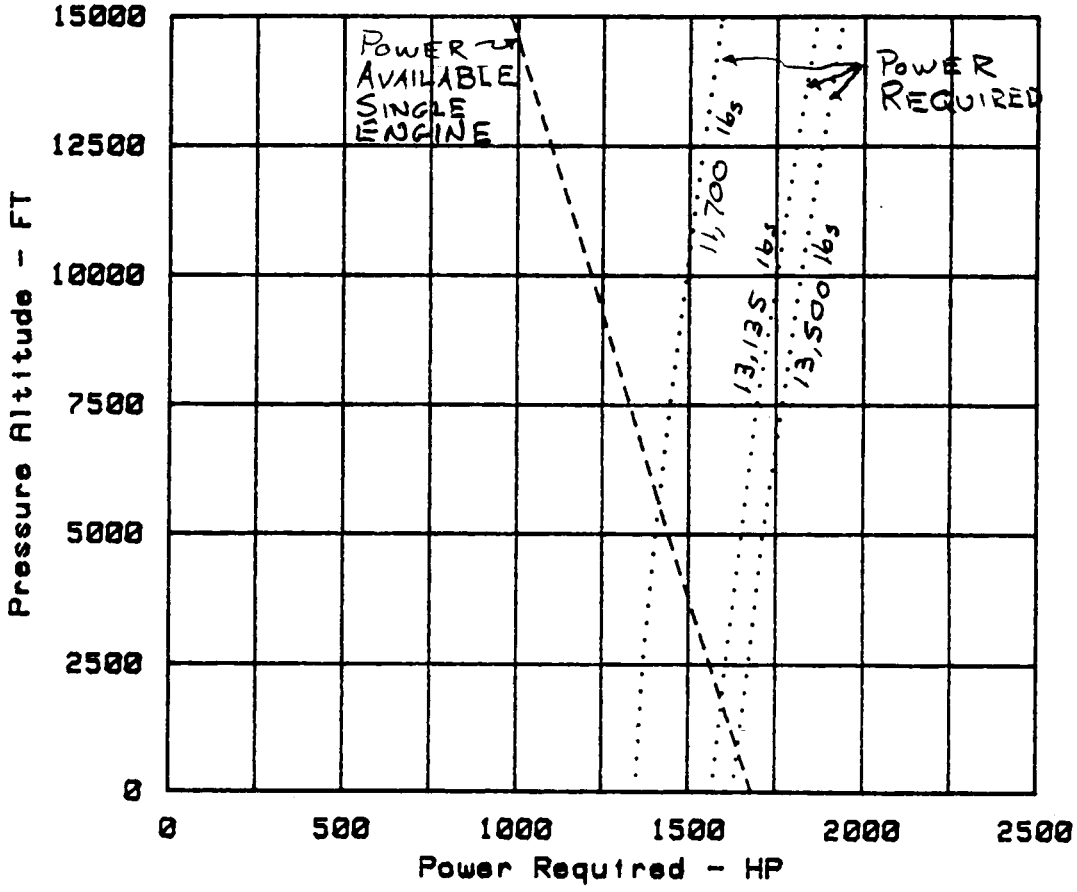


Figure 19

STANDARD DAY IGE SINGLE ENGINE HOVER CEILING WORKING PLOT

MODEL SH-2F HELICOPTER

ENGINES (2): T700-GE-401
CONFIGURATION: 2 EXTERNAL 100 GAL AUX TANKS, MAD, DOORS CLOSED
BLEED AIR: OFF
GEAR: EXTENDED/FUEL: JP-5

AVG GW: 12,833 lb
CG: 173.8 INCHES (AFT)
ASE: ON
N_r: 106 %
METHOD: FREE HOVER

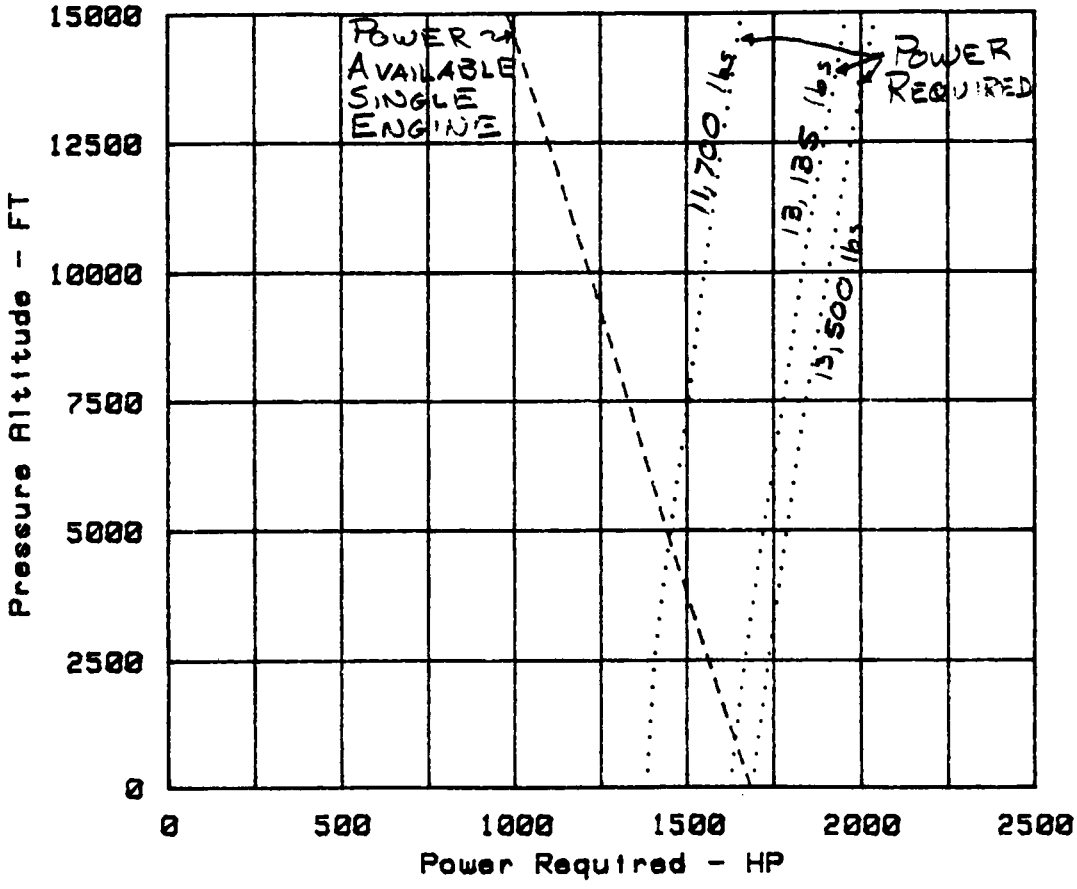


Figure 20

STANDARD DAY OGE SINGLE ENGINE HOVER CEILING WORKING PLOT

APPENDIX F

GLOSSARY

GLOSSARY

AGL - Above Ground Level
ASE - Automatic Stabilization Equipment
ASST - Antiship Surveillance and Targeting
ASW - Antisubmarine Warfare
Deg C - Degrees Celsius
Deg F - Degrees Fahrenheit
Delta HP - Change in horsepower
FF1052 - Frigate, Oliver Hazard Perry Class Ship
FFG7 - Guided Missile Frigate, Knox Class Ship
FPM - feet per minute
Front Drive Engine - is designed to deliver power from the front of the engine
GAL - gallons
HQR - Handling Qualities Rating
IGE - In-ground-effect
KCAL - Knots Calibrated Airspeed
KTAS - Knots True Airspeed
MAD - Magnetic Anomaly Detector
MCP - Maximum Continuous Power
N_r - Main rotor rotational speed
OEI - One Engine Inoperative
OGE - Out-of-ground-effect
PA - Pressure Altitude
Pop-Up - A quick climbing maneuver that allows the ASST pilot to perform over the horizon target and tracking radar sweeps.
Rear Drive Engine - is designed to deliver power from the rear of the engine.
Static Droop - Relative deviation of rotor speed at various stable (static) power settings.
Transient Droop - Relative deviation of rotor speed during power changes.
V_{cruise} - Maximum cruise airspeed
V_{end} - Maximum endurance airspeed
V_h - Maximum level flight airspeed
V_{range} - Maximum range airspeed

VITA

Christian Benjamin Rice was born in Tucson, Arizona on 10 November 1960. He received his primary and secondary education in South Carolina, Brazil, Colorado, California, Illinois, and Virginia, and graduated from Woodbridge High School, Virginia in June 1979. The following September he was admitted to Northern Virginia Community College, Woodbridge Virginia and completed two years of engineering study. In September 1981 he was admitted to Virginia Tech, Blacksburg Virginia, and in June 1984 he was awarded a Bachelor of Science degree in Aerospace and Ocean Engineering. In June 1984 he began working at the Rotary Wing Aircraft Test Directorate at the Naval Air Test Center, Patuxent River Maryland. After spending two years as a project engineer, he was selected to attend the U. S. Naval Test Pilot School in July 1986, as a member of Class 91. Mr. Rice graduated from Test Pilot School in June 1987, and returned to work at the Rotary Wing Aircraft Test Directorate. Since that time Mr. Rice has worked as a senior project engineer and a program manager. In September 1987 he entered the University of Tennessee Space Institute extension program and received a Master of Science degree in Aviation System in August 1993. The author plans to continue to work in developmental test and evaluation of aircraft and systems.