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Nuclear Powered Aircraft
For
Antisubmarine Warfare

December 1, 1950

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SUMMARY

A study was made of nuclear powered aircraft suitable for anti-submarine warfare. Preliminary design details are given for two of these aircraft, one powered by modified turbo-jets, the other by modified turbo-props. The aircraft have gross weights of 395,000 pounds, carry crews of twenty (including relief personnel), and would be able to remain on search missions for a number of days. The turbo-jet aircraft was designed for flight speeds between 120 and 350 knots, the turbo-prop aircraft for speeds between 100 and 238 knots. Two other configurations are discussed briefly.

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INTRODUCTION

Nuclear energy propulsion offers the possibility of obtaining aircraft flight endurances substantially greater than those possible with present chemically fueled aircraft. This factor made it desirable to investigate the possibility of using nuclear power in aircraft suitable for antisubmarine warfare.

A brief discussion of the nuclear power plant is given in the text, and a preliminary analysis is presented of two aircraft using nuclear power plants. One of these applications is a turbo-jet aircraft with a speed range of 120 to 350 knots; the other is a turbo-prop aircraft with a speed range of 100 to 250 knots. These speed ranges were chosen for the respective power plants to obtain comparable climb performance for each aircraft. The turbo-jet aircraft has a military load capacity of 21,000 pounds; the turbo-prop aircraft has a military load capacity of 27,100 pounds. These carrying capacities provide for torpedoes, bombs, and sonobuoys, although no attempt has been made to resolve the weight allowances into these components.

Some consideration was also given to two other aircraft configurations.

The results of this investigation are detailed in three-view drawings, performance estimates, and weight analyses.

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NUCLEAR POWER PLANT UNCLASSIFIED

The basic components of the aircraft nuclear power plant used in this study are shown in Fig. 1. These components are a reactor heat source, an engine (to convert reactor heat energy into mechanical energy (thrust)), and a circulation system (for transferring heat from the reactor to the engine).

The reactor consists of a core (containing fissionable material) surrounded by a shield (used to protect the crew from radiation). The shield used in this investigation was designed to decrease the radiation dosage to a value of 1/20 roentgen per hour in the crew compartment with a distance of 50 feet separating the crew and the reactor. An indication of the magnitude of this radiation dosage may be obtained by considering the allowable dosage of 300 milliroentgen per week for civilian personnel in Atomic Energy Commission installations, and that of 1 roentgen per hour for military personnel in present NEPA bomber studies (which assume the crew to make a restricted number of 25-hour missions). By comparison, it may be seen that antisubmarine flights of several days duration could be made without subjecting the crew to a dosage in excess of that established for NEPA aircraft studies.

Flight range considerations differ from those of conventional aircraft. The endurance of a nuclear powered aircraft is not primarily a function of fuel consumption, but is determined by crew radiation tolerances. As a consequence, the aircraft may maintain any speed in its flight spectrum for the entire flight. The range is a simple function of flight speed and endurance.

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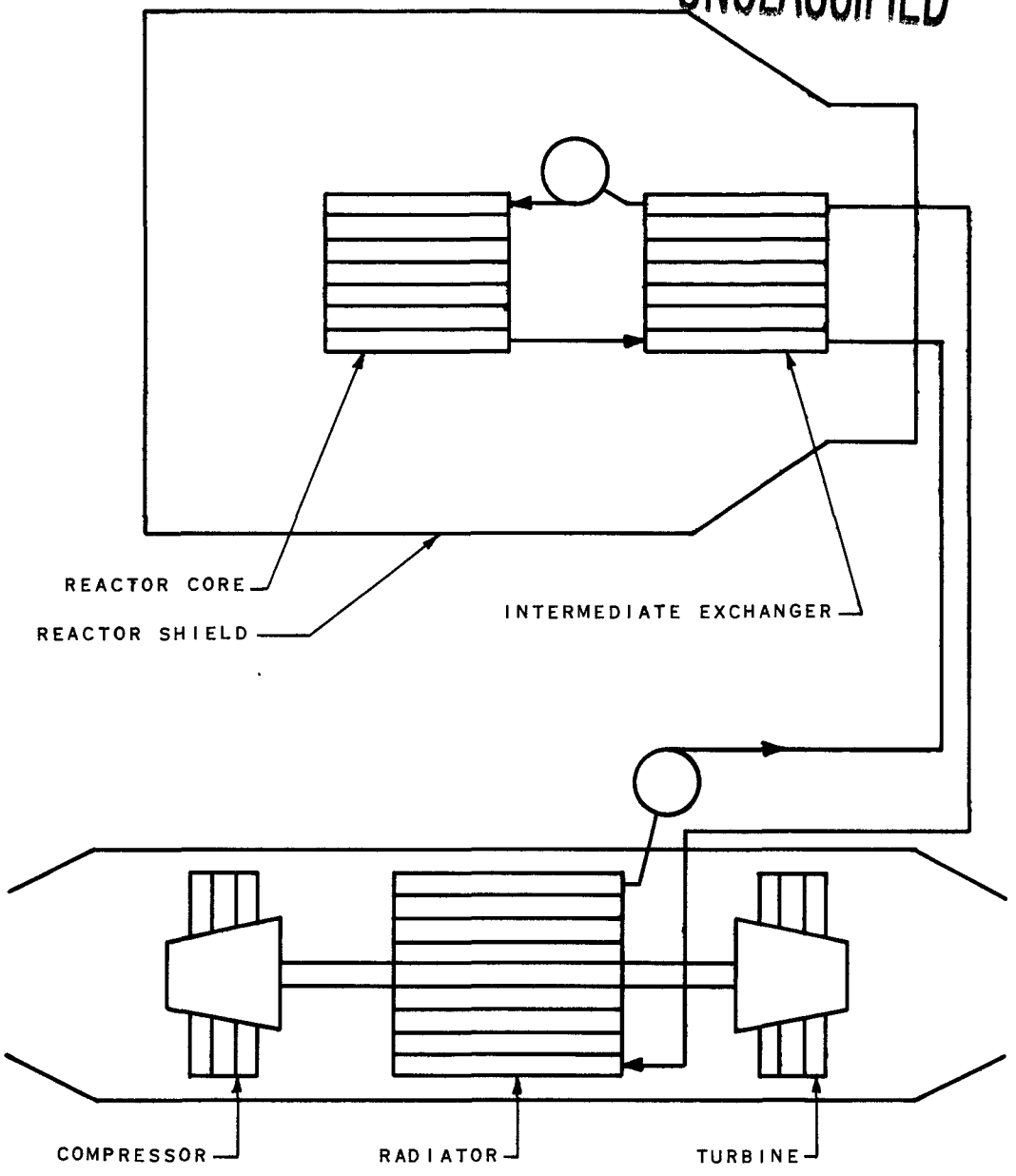

FIG. 1 - SCHEMATIC OF NUCLEAR POWER PLANT

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The engines used in this investigation are essentially turbo-jet and turbo-prop units modified by adding radiators between the compressor and burner sections. This arrangement permits both running the engines with the heat supplied by the radiators, and augmenting this heat with chemical fuel. The reasons for chemical augmentation are twofold. The technique offers a safety factor in the event of reactor failure, and additional thrust may be obtained for take-off and high-performance conditions. A summary of preliminary power plant data for the turbo-jet and turbo-prop engines used in this investigation has been prepared.[1]

The circulation system consists of a liquid-metal circuit (sodium) together with the associated pumping system, for transferring heat from the reactor core to the intermediate heat exchanger; and another liquid-metal circuit (lithium) together with its pumping system, to transfer the heat from the intermediate heat exchanger to the engine radiator. The intermediate heat exchanger is placed within the shield to prevent radiation from escaping from the core circuit.

Cycle temperatures used in this analysis are based upon a reactor wall temperature of 1400°F., which corresponds to that being planned for a test-stand power plant, and is considered to be obtainable with currently available materials. This reactor wall temperature permits a turbine inlet temperature of approximately 1100°F. The chemical augmentation studies were based upon the thrust

[1] Memorandum: "Summary of Preliminary Power Plant Analysis for ASW-1 and ASW-3 Aircraft," September 29, 1950, from W. A. Spraker to M. W. Nesbitt.

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obtained by burning sufficient chemical fuel to raise the turbine inlet temperature to 1600°F. Cycle temperatures are among the important variables affecting thrust-weight values for this type of power plant. Any temperature increases obtainable with improved materials will result in substantially higher thrust-weight ratios.

It should be emphasized that the power-plant components discussed above are very similar to those presently being planned for use in a nuclear test-stand power plant.

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TURBO-JET AIRCRAFT (ASW-1)

Figure 2 presents a three-view drawing of a nuclear powered turbo-jet aircraft utilizing four modified XJ-53 engines. By using turbo-jet engines in this aircraft, a compact power-plant unit can be obtained. This unit can be removed as a package without disconnecting the engines and heat source. It is believed that this arrangement offers a high degree of airframe utilization by permitting the interchange of power-plant packages.

Figure 3 and Table 1 show the predicted performance of this aircraft at the design gross weight of 395,000 pounds. The endurance and cruising speeds are not specified, since they are not related, due to the uniqueness of the power plant. The aircraft may be operated at speeds varying from 130 to 340 knots at an altitude of 5000 feet.

Figure 4 shows the predicted performance of the aircraft with nuclear power and chemical augmentation.

Table 2 details the results of the estimated weight analysis for the aircraft. A weight allowance of 21,000 pounds has been assigned to torpedoes, bombs, and sonobuoys. No attempt was made to resolve this weight into these components. A 10,000-pound allowance was made for chemical fuel. In case of reactor failure, an additional 50,000 pounds of chemical fuel would be available in the reactor shield. Weight provisions have been made for nose and tail turrets mounting four 20-millimeter guns with ammunition.

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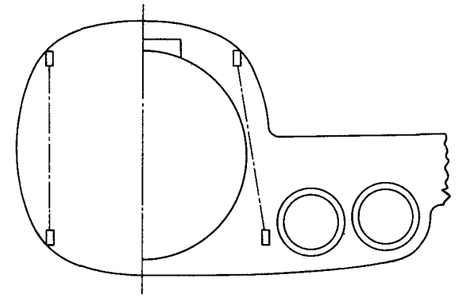

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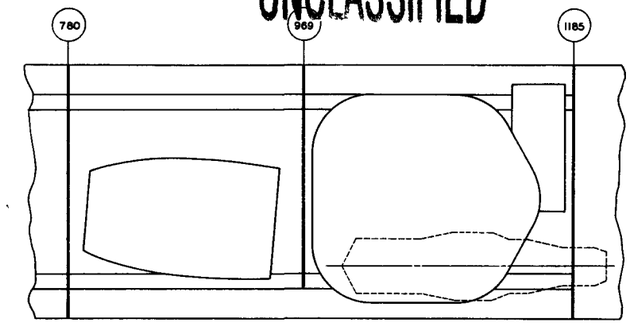

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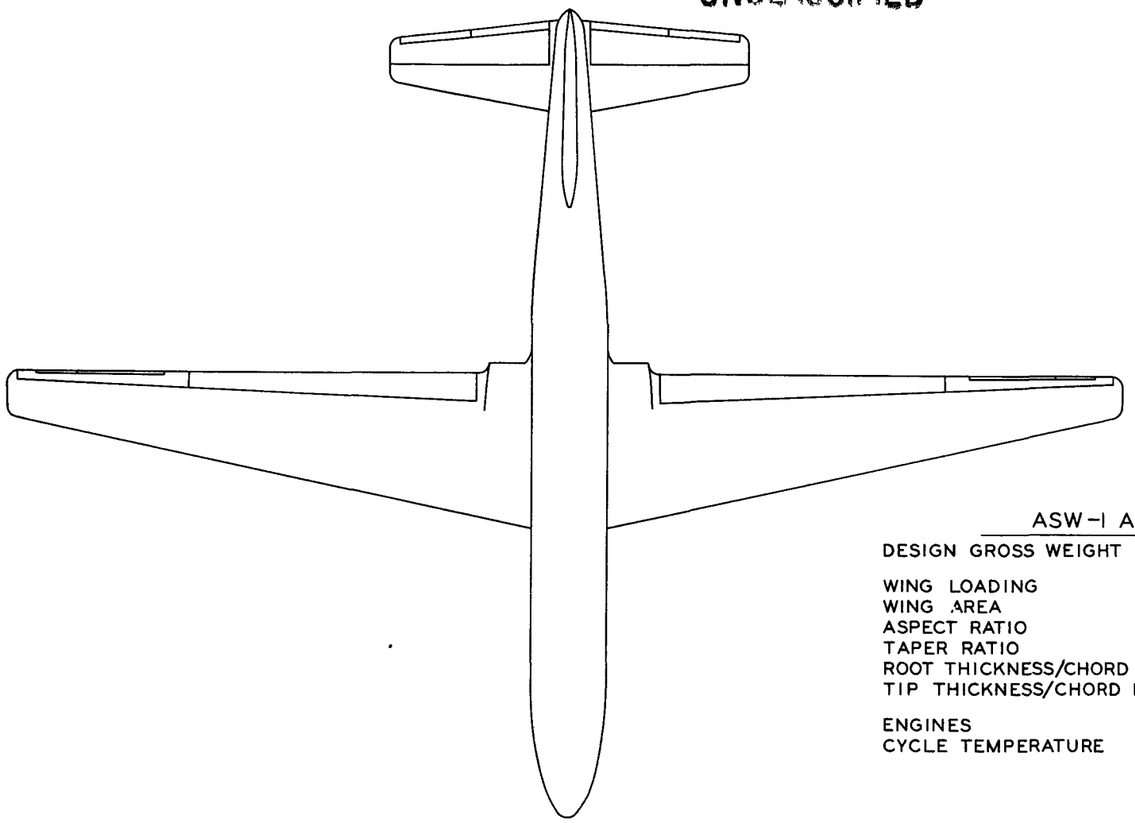
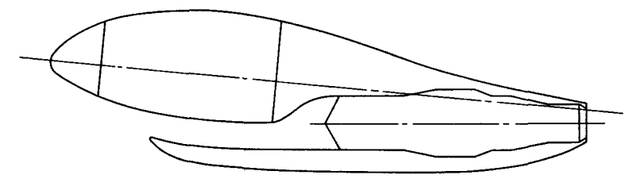


ASW-1 AIRCRAFT

DESIGN GROSS WEIGHT	395,000 LB
WING LOADING	70.2 LB /FT^2
WING AREA	5630 FT.^{2}
ASPECT RATIO	11.0
TAPER RATIO	.25
ROOT THICKNESS/CHORD RATIO	.22
TIP THICKNESS/CHORD RATIO	.17
ENGINES	4 XJ-53
CYCLE TEMPERATURE	1400°F. REACTOR WALL 1100°F. TURBINE INLET



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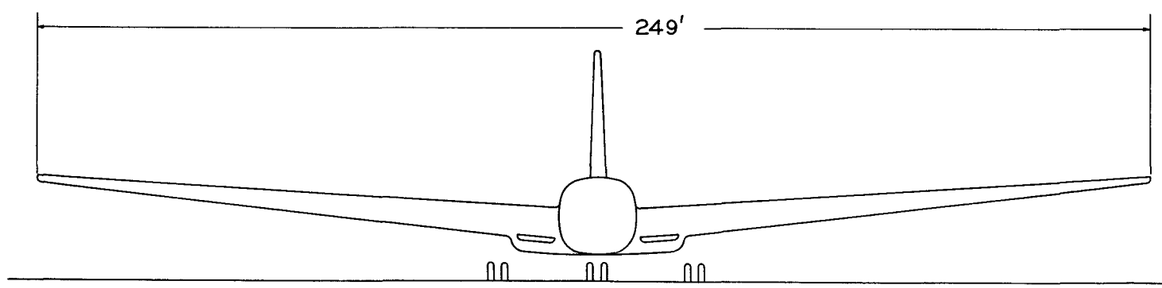

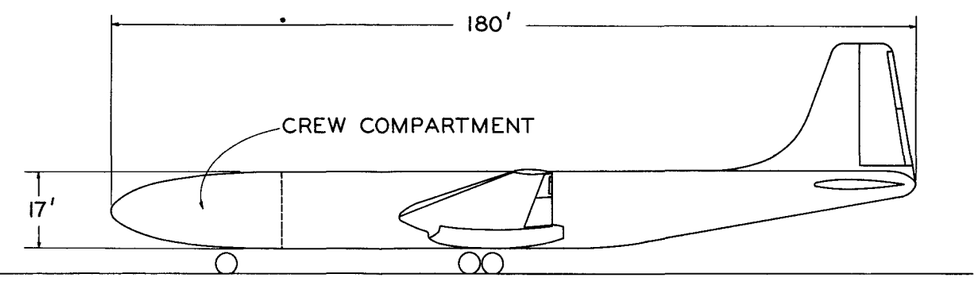

FIG. 2 - ASW-1 AIRCRAFT

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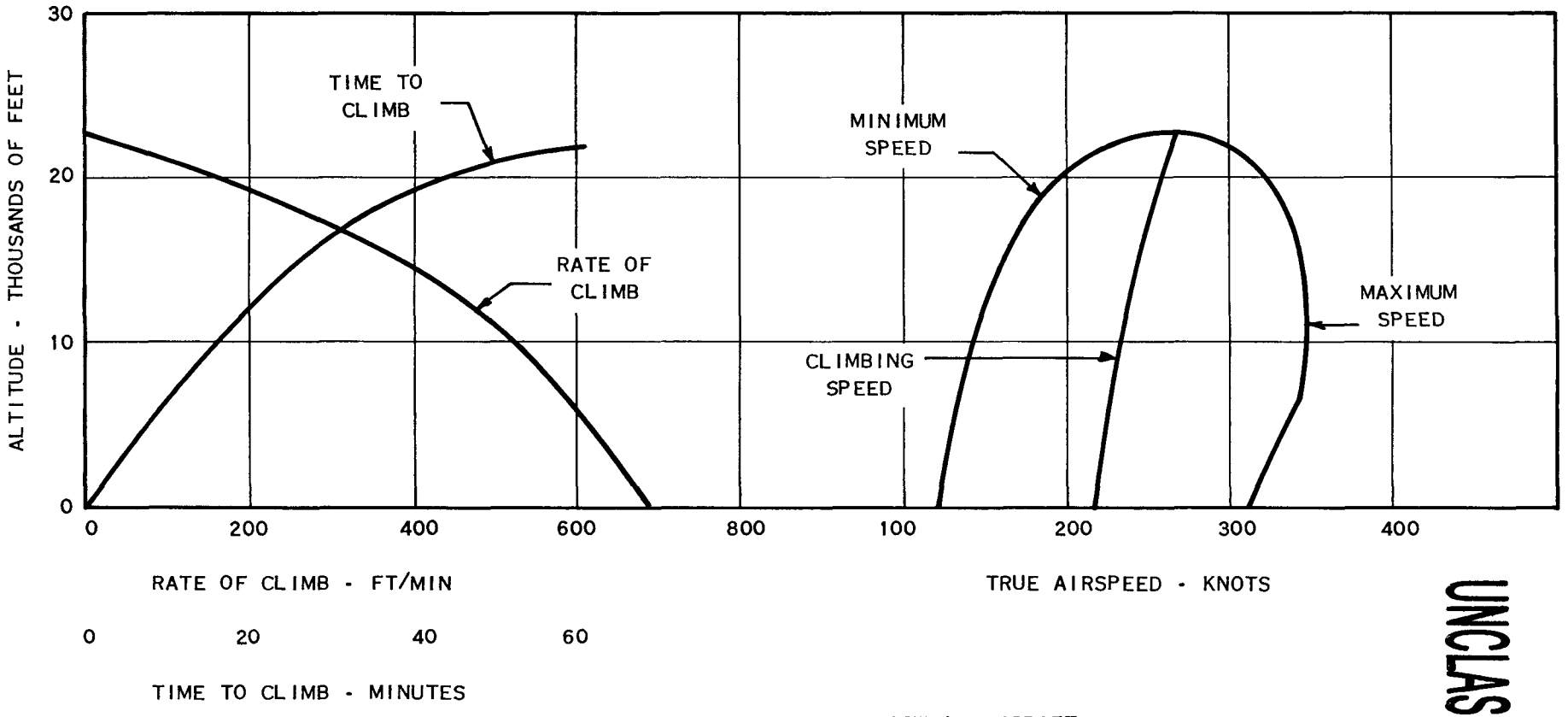

FIG. 3 - PERFORMANCE SUMMARY: ASW-1 AIRCRAFT
GROSS WEIGHT - 395,000 LB.
(4 XJ-53 TURBO-JET ENGINES:
NUCLEAR FUEL ALONE)

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TABLE 1

PERFORMANCE SUMMARY FOR TURBO-JET AIRCRAFT

Item	Nuclear Power Only	Nuclear Power with Chemical Augmentation
Take-off weight (lb.)	395,000	395,000
Fuel (lb.)	10,000	10,000
Military load (lb.)	21,000	21,000
Wing loading (lb/ft^2)	70.2	70.2
Take-off ground run at sea level (ft.)		4520
Take-off to clear 50-foot obstacle (ft.)		5570
Rate of climb at sea level (ft/min)	690	2240
Time to climb; sea level to 10,000 feet (min.)	17	5
Service ceiling (with 100-fpm. climb; ft.)	21,000	35,600
Max. speed at sea level (knots)	330	440

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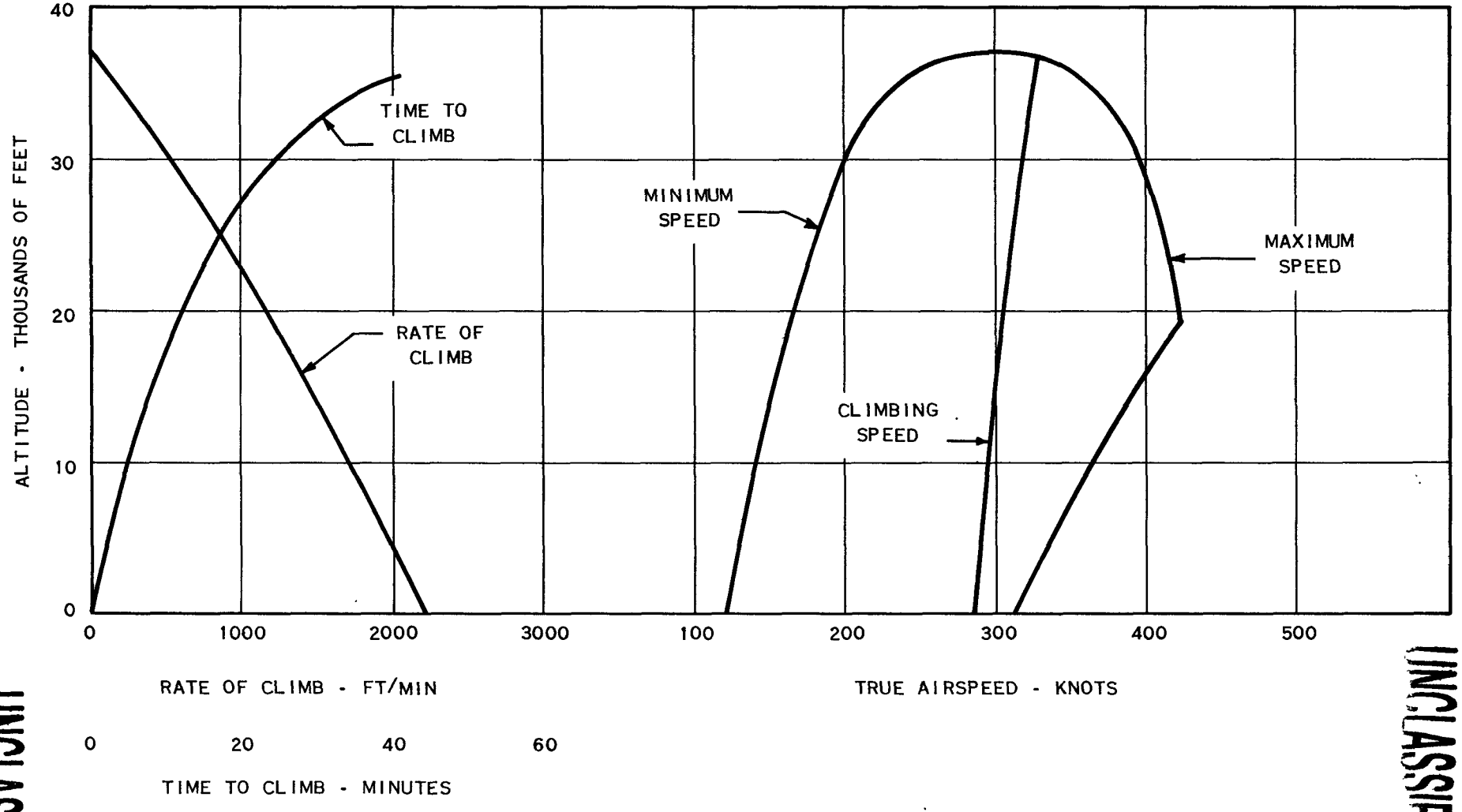

FIG. 4 - PERFORMANCE SUMMARY: ASW-1 AIRCRAFT
GROSS WEIGHT - 395,000 LB.
(4 XJ-53 TURBO-JET ENGINES;
NUCLEAR FUEL WITH CHEMICAL AUGMENTATION)

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TABLE 2

ESTIMATED WEIGHT ANALYSIS OF TURBO-JET AIRCRAFT

Airframe		116,900 pounds
Wing group	57,200	
Tail group	5,100	
Body group	32,100	
Nacelle group	3,000	
Landing gear group	19,500	
Power Plant		221,000
Reactor-shield assembly	160,000	
Engines and radiators	52,000	
Piping, etc.	2,500	
Auxiliary power units & pumps.	3,000	
Shield cooling assembly	3,000	
Chemical fuel system	500	
Fixed Equipment		20,600
Turrets (2), guns (4, 20 mm.), and ammunition	3,600	
Radar search unit	6,000	
Anti-icing equipment	1,320	
Crew furnishings	2,630	
Surface controls	1,390	
Reactor and engine controls	1,900	
Instruments	350	
Hydraulic, electrical, and communication systems	3,410	
Crew including food and water (2)		5,500
Pilots	(4)	
Navigators	(4)	
Engineers	(4)	
Radio-radar operators	(6)	
Gunner	(1)	
Cook	(1)	
Fuel		10,000
Bombs, Torpedoes, Sonobuoys, etc.		21,000
Design Gross Weight		395,000 pounds

TURBO-PROP AIRCRAFT (ASW-3)

Figure 5 is a three-view drawing of a nuclear powered turbo-prop aircraft with four XJ-57-P1 turbo-prop engines.

Figure 6 and Table 3 show the predicted performance of this airplane at the design gross weight of 395,000 pounds. As in the case of the turbo-jet aircraft, the endurance and cruising speeds are not specified, since they are not related. The aircraft may be operated at speeds varying from 105 to 220 knots at an altitude of 5000 feet.

Figure 7 shows the predicted performance with nuclear power and chemical augmentation.

Table 4 details the results of the estimated weight analysis for the ASW-3 aircraft. A weight of 27,100 pounds was allotted to torpedoes, bombs, and sonobuoys. A weight allowance of 10,000 pounds was made for chemical fuel. In case of reactor failure in this airplane, an additional 44,000 pounds of chemical fuel would be available in the reactor shield. Weight provisions have been made for nose and tail turrets mounting four 20-millimeter guns with ammunition.

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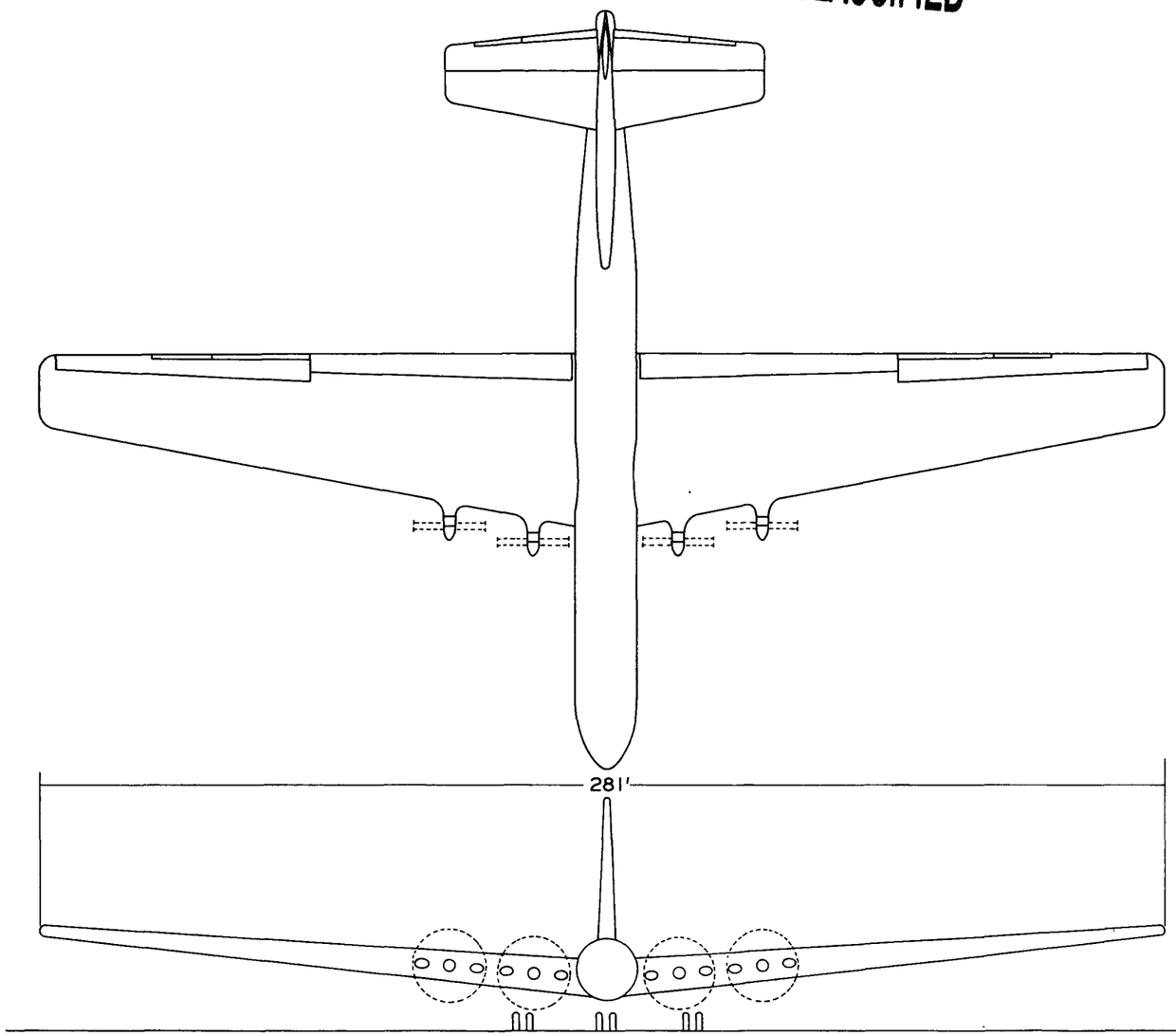

ASW-3 AIRCRAFT

DESIGN GROSS WEIGHT	395,000 LB.
WING LOADING	45 LB / FT^2
WING AREA	8780 FT.^{2}
ASPECT RATIO	9.0
TAPER RATIO	.4
ROOT THICKNESS/CHORD RATIO	.21
TIP THICKNESS/CHORD RATIO	.15
ENGINES	4 XJ-57
CYCLE TEMPERATURES	1400° REACTOR WALL 1100° TURBINE INLET
PROPELLERS	EIGHT BLADE CONTRA-ROTATING 18 FT DIAMETER

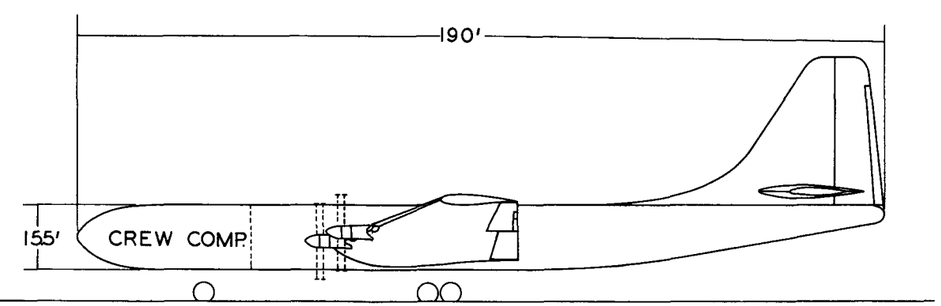

FIG. 5 - ASW-3 AIRCRAFT

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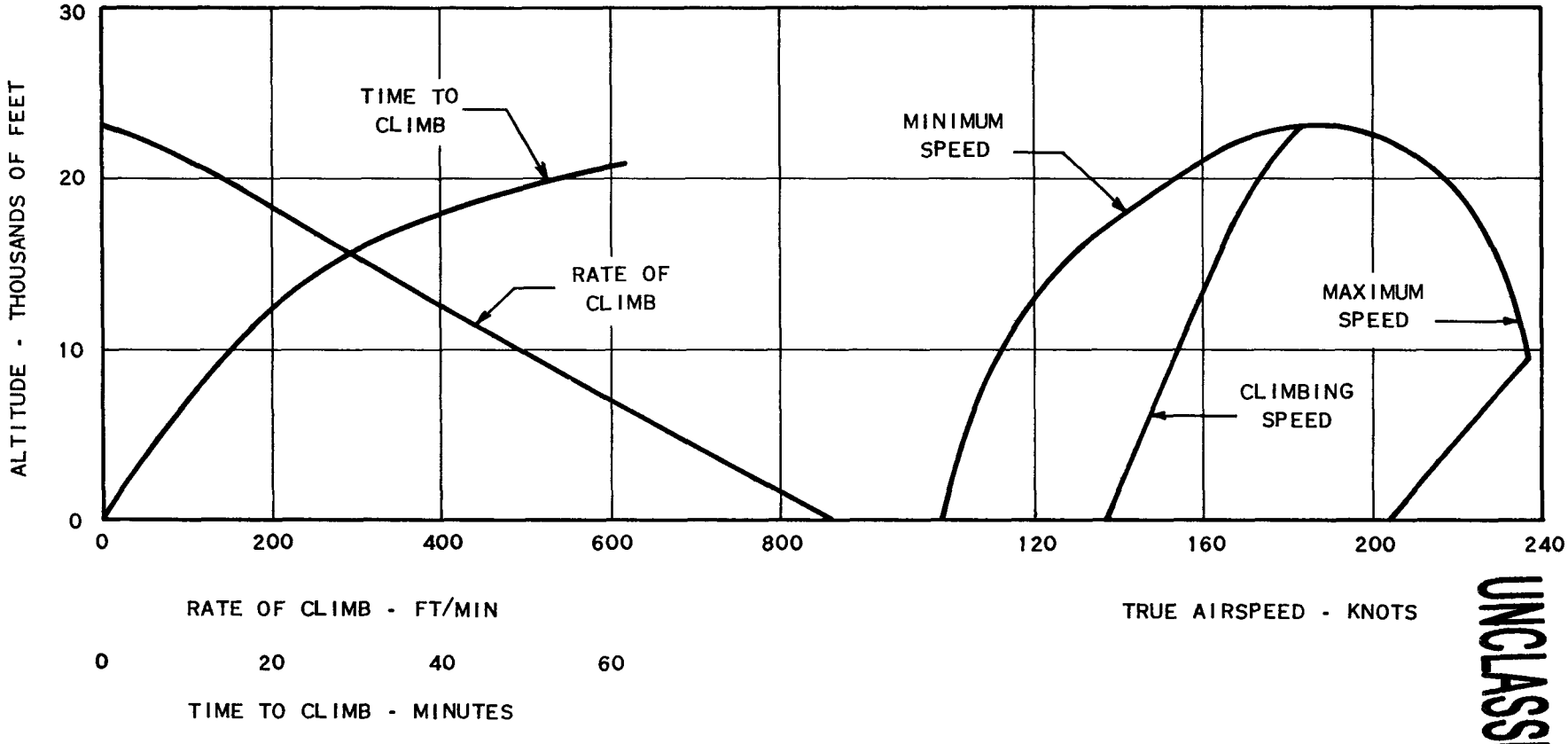

FIG. 6 - PERFORMANCE SUMMARY: ASW-3 AIRCRAFT
GROSS WEIGHT - 395,000 LB.
(4 XJ-57-P1 TURBO-PROP ENGINES:
NUCLEAR FUEL ALONE)

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TABLE 3

PERFORMANCE SUMMARY FOR TURBO-PROP AIRCRAFT

Item	Nuclear Power Only	Nuclear Power with Chemical Augmentation
Take-off weight (lb.)	395,000	395,000
Fuel (lb.)	10,000	10,000
Military load (lb.)	27,100	27,100
Wing loading (lb/ft^2)	45	45
Take-off ground run at sea level (ft.)		1600
Take-off to clear 50-foot obstacle (ft.)		2220
Rate of climb at sea level (ft/min)	860	2810
Time to climb; sea level to 10,000 feet (min.)	15	4
Service ceiling (with 100-fpm. climb); ft.	21,000	34,000
Max. speed at sea level (knots)	242	350

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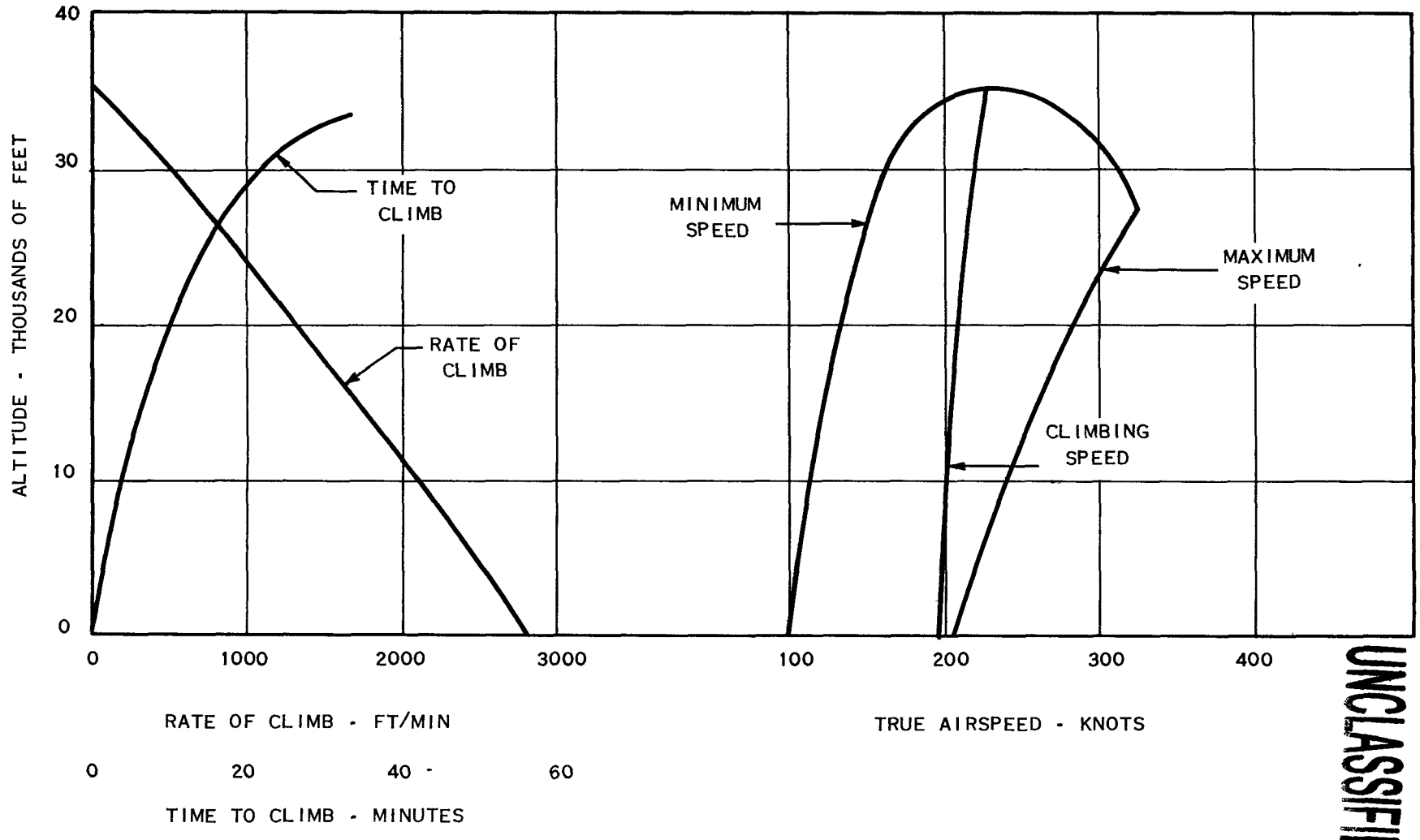

FIG. 7 - PERFORMANCE SUMMARY: ASW-3 AIRCRAFT
GROSS WEIGHT - 395,000 LB.
(4 XJ-57-P1 TURBO-PROP ENGINES;
NUCLEAR FUEL WITH CHEMICAL AUGMENTATION)

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TABLE 4

ESTIMATED WEIGHT ANALYSIS OF TURBO-PROP AIRCRAFT

Airframe		129,800 pounds
Wing group	68,300	
Tail group	8,500	
Body group	30,500	
Nacelle group	3,000	
Landing gear group	19,500	
Power Plant		202,000
Reactor-shield assembly	142,500	
Engines, propellers and radiators	48,000	
Piping, etc.	5,000	
Auxiliary power unit and pumps	3,000	
Shield cooling assembly	3,000	
Chemical fuel system	500	
Fixed Equipment		20,600
Turrets (2), guns (4, 20 mm.), and ammunition	3,600	
Radar search unit	6,000	
Anti-icing equipment	1,320	
Crew furnishings	2,630	
Surface controls	1,390	
Reactor and engine controls	1,900	
Instruments	350	
Hydraulic, electrical, and communication systems	3,410	
Crew including food and water (20)		5,500
Pilots	(4)	
Navigators	(4)	
Engineers	(4)	
Radio-radar operators	(6)	
Gunner	(1)	
Cook	(1)	
Fuel		10,000
Bombs, Torpedoes, Sonobuoys, etc.		27,100
Design Gross Weight		395,000

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[redacted]

TUG-TOW AIRCRAFT AND FLYING BOAT

Two other aircraft configurations were briefly considered in this investigation.

The tug-tow aircraft arrangement consists of an unmanned, remote[redacted]air-frames [redacted]ld be used for [redacted]nce of possibly 500 feet between the tug and tow would permit reductions in the reactor shield weights used in the above studies. It appears from a brief study that a modified B-36 could tow a Lockheed PO-1W as a second airplane. A total gross weight of 400,000 pounds for the two aircraft seems permissible.

A flying boat utilizing turbo-prop engines appears possible, with approximately the same gross weight as the land-based turbo-prop aircraft discussed previously. Such an application may have the added advantage that it could be landed at sea for rescue work.

[redacted]