4-27-51
DATE

CONTRACT

MODEL

REPORT NO. 8472

PAGE NO. 1 OF 19

CHANCE VOUGHT

Engineering Department

CHANCE VOUGHT AIRCRAFT

DIVISION OF UNITED AIRCRAFT CORPORATION

DALLAS TEXAS

TITLE

STUDY OF SINGLE ENGINE VERSIONS OF F7U-3 AIRPLANE

SUBMITTED UNDER

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TABLES & FIGURES

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INTRODUCTION

In view of the questionable availability of satisfactory fully rated J46-WE-2 engines for the F7U-3, a study has been made of an installation of a single J57-P-1 power plant (with A/B) in the airplane.

A significant advantage of a single engine version of the airplane is the wide choice of alternate power plants that would be available. These are the J40-WE-10, J35-A-23, J67-W- , and J47-GE-21. All these engines currently have most active development programs scheduled. This report has been prepared to show both the characteristics and performance of the airplane with single engine installations.

SUMMARY

A discussion of the necessary modifications to the basic F7U-3 fuselage to accomodate single engine installations is given in Section I. Figure #1 is a three view of the modified airplane with the portion of the fuselage requiring redesign so indicated. Figure #2 is an inboard profile of the airplane without power plant installation. Each power plant, with a matched tail fairing, is on a separate transparent overlay, and can be compared individually by unfolding the inboard profile page and inserting it successively under each overlay.

Section II covers the assumptions made in arriving at the performance and weights shown. The comparative performance and weights are shown on Tables I and II respectively. Lapse rate vs speed curves for the various engines, at both sea level and 35,000 feet, are given in Figure #3. Figure #4 shows the wind required over the deck for catapulting each of the five single engine airplanes considered, as a function of gross weight.

Section III discusses each of the alternate power plants in some detail. Comparative engine characteristics are given in Table III. The desired airplane accessory provisions are shown in Table IV and the available pads on each engine, based on the latest information from the manufacturers is given in Table V.

Section IV covers the latest information on engine availability.

I. THE AIRPLANE

Because of the centerline firewall in the basic F7U-3, the aft fuselage must be redesigned to satisfy a single engine installation. Referring to Figures #1 and #2, the fuselage is unchanged from the basic F7U-3 forward of station #265 (between main and forward fuselage fuel cells), and the gun installation, engine ducts forward of station #265, and the main beam bulkhead forgings remain unchanged. With the exception of the items mentioned above, a new fuselage is required aft of station #265. This new fuselage is designed for aft engine removal, with engine accessory service access still provided on the bottom centerline of the fuselage. A new main fuel cell is required as well as two new side saddle tanks to replace the top centerline saddle tank on the present airplane.

34" main wheels are incorporated in place of the 30" wheels on the basic F7U-3. Since space provisions have been incorporated in the basic airplane for 34" wheels, this does not involve any change in the tail fairings. It is assumed that the main gear struts and supporting structure will be able to take the proportionately higher spin-up loads and bending moment imposed by the larger wheels, on the assumption that the take-off weight of the basic F7U-3 airplane will be reduced. Any reduction in take off weight of the basic F7U-3 should apply directly to the various single engine configurations.

In order to maintain the 25° catapult release attitude of the airplane without lengthening of the main landing gear and stay within acceptable limits of upsweep to the rear fuselage lines, the afterburner length of three of the power plants have been shortened. The J57-P-1 has been shortened 10.6", the J40-WE-10 has been shortened 21", and the J47-GE-21 has been shortened 8.6". The 35-A-23, with its short afterburner, must actually be lengthened 27" to keep the drag due to fuselage "tumble-home", in plan view, within acceptable limits. A slight bend has been incorporated in each afterburner near the exit, in order to pass the thrust line through the airplane CG. These minor changes are not considered to reflect any measurable change in airplane performance.

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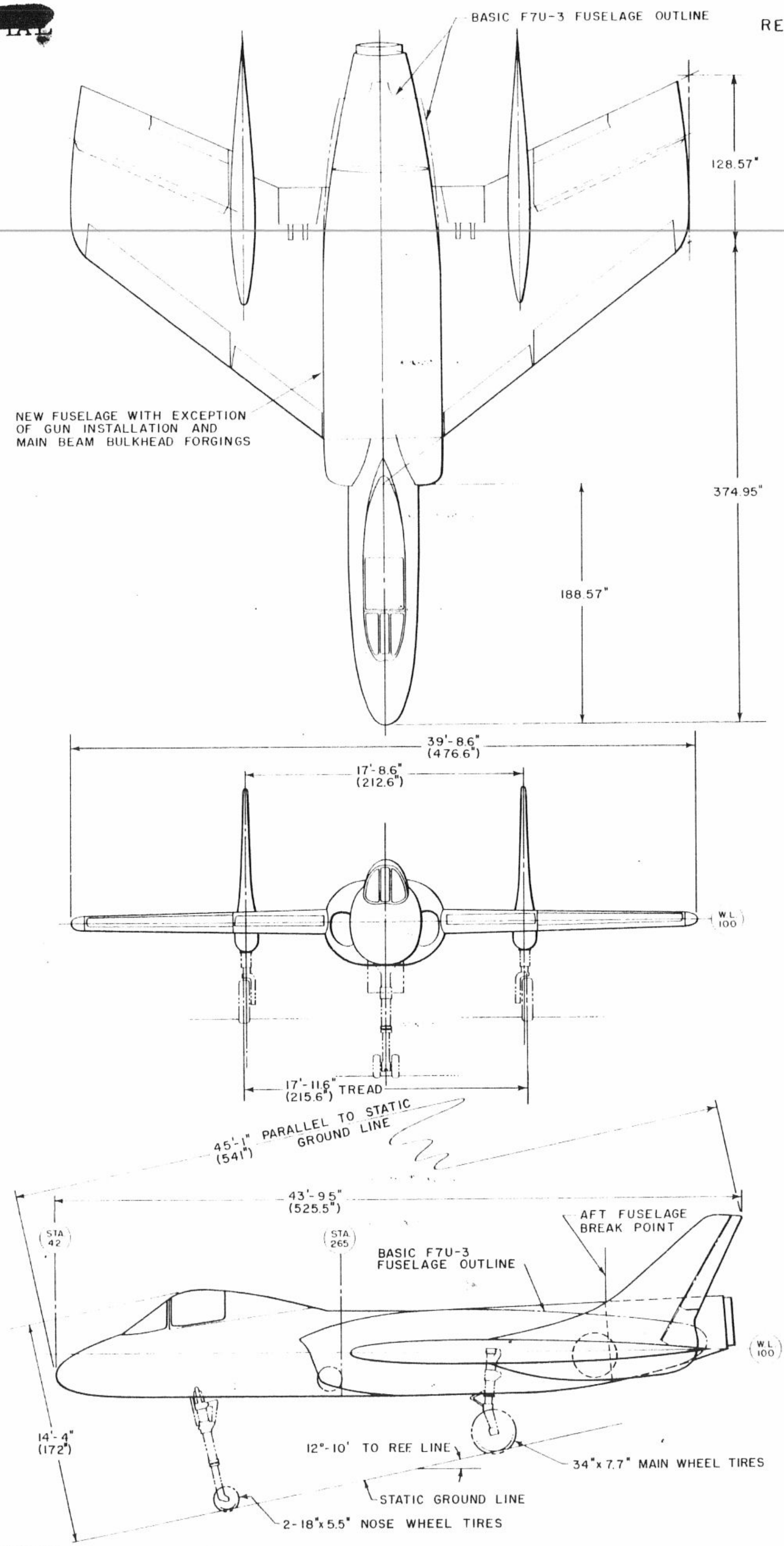

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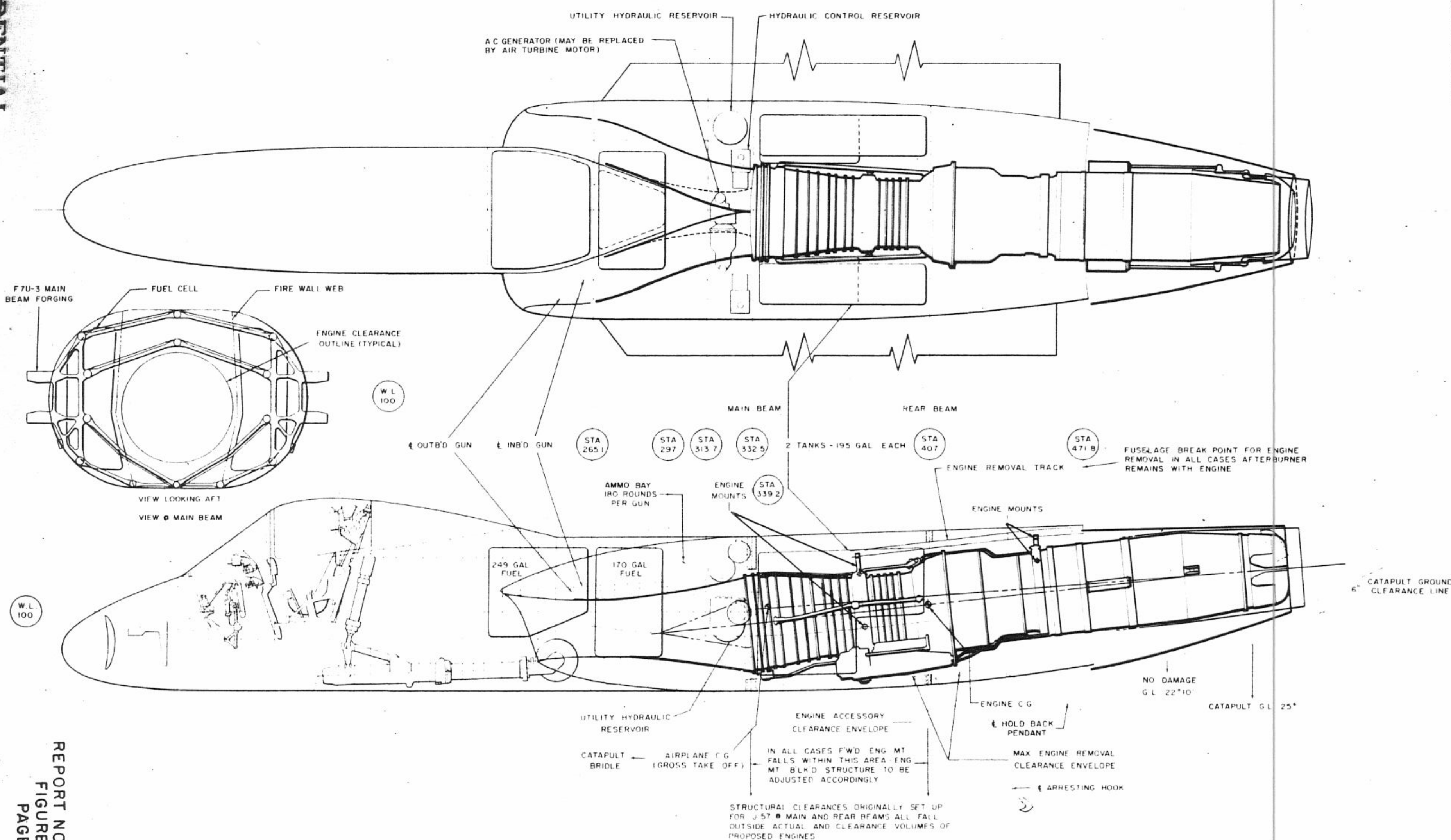

P. AND W. J-57-P-1

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FIGURE NO. 2
PAGE NO. 7

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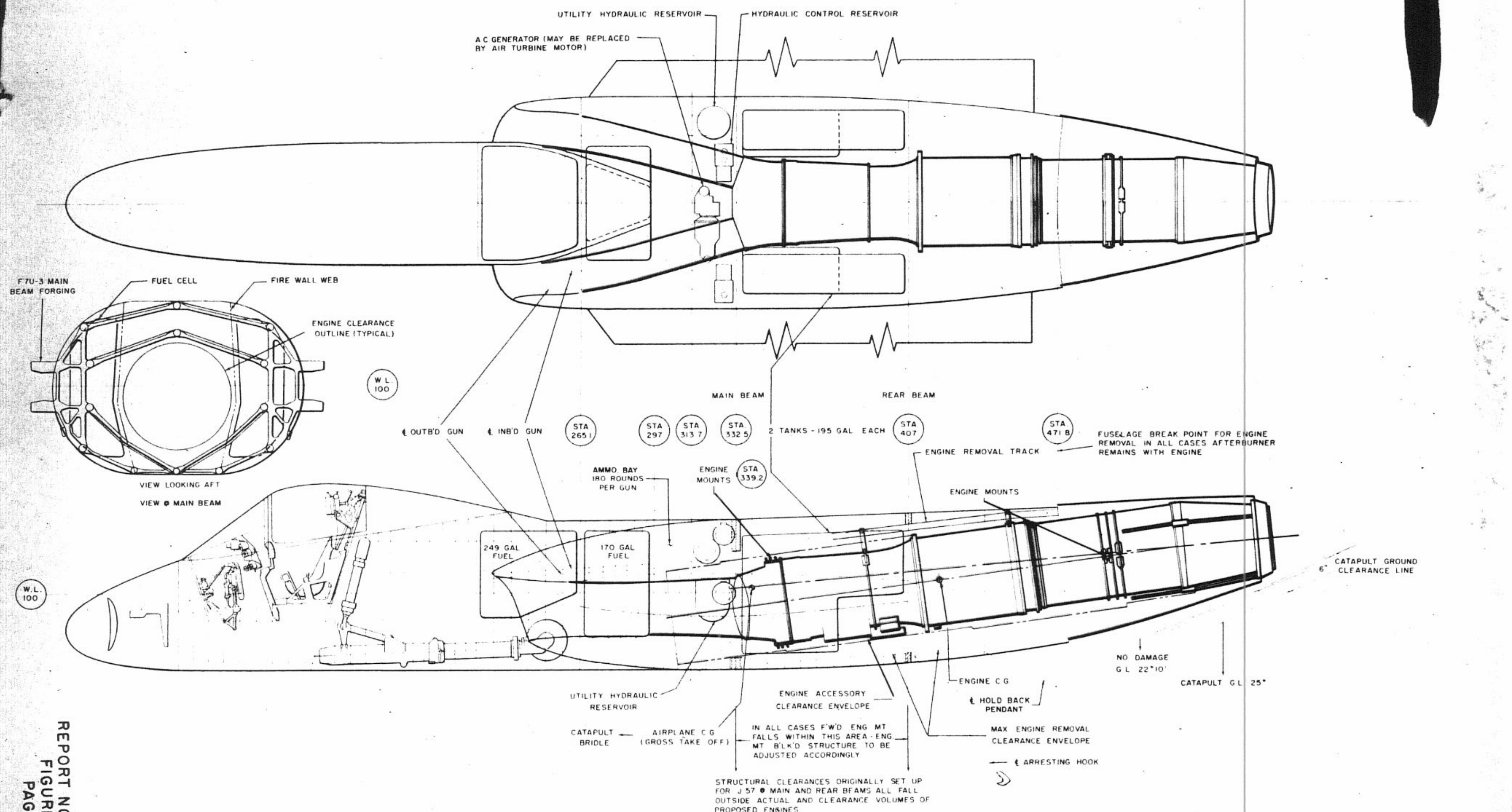
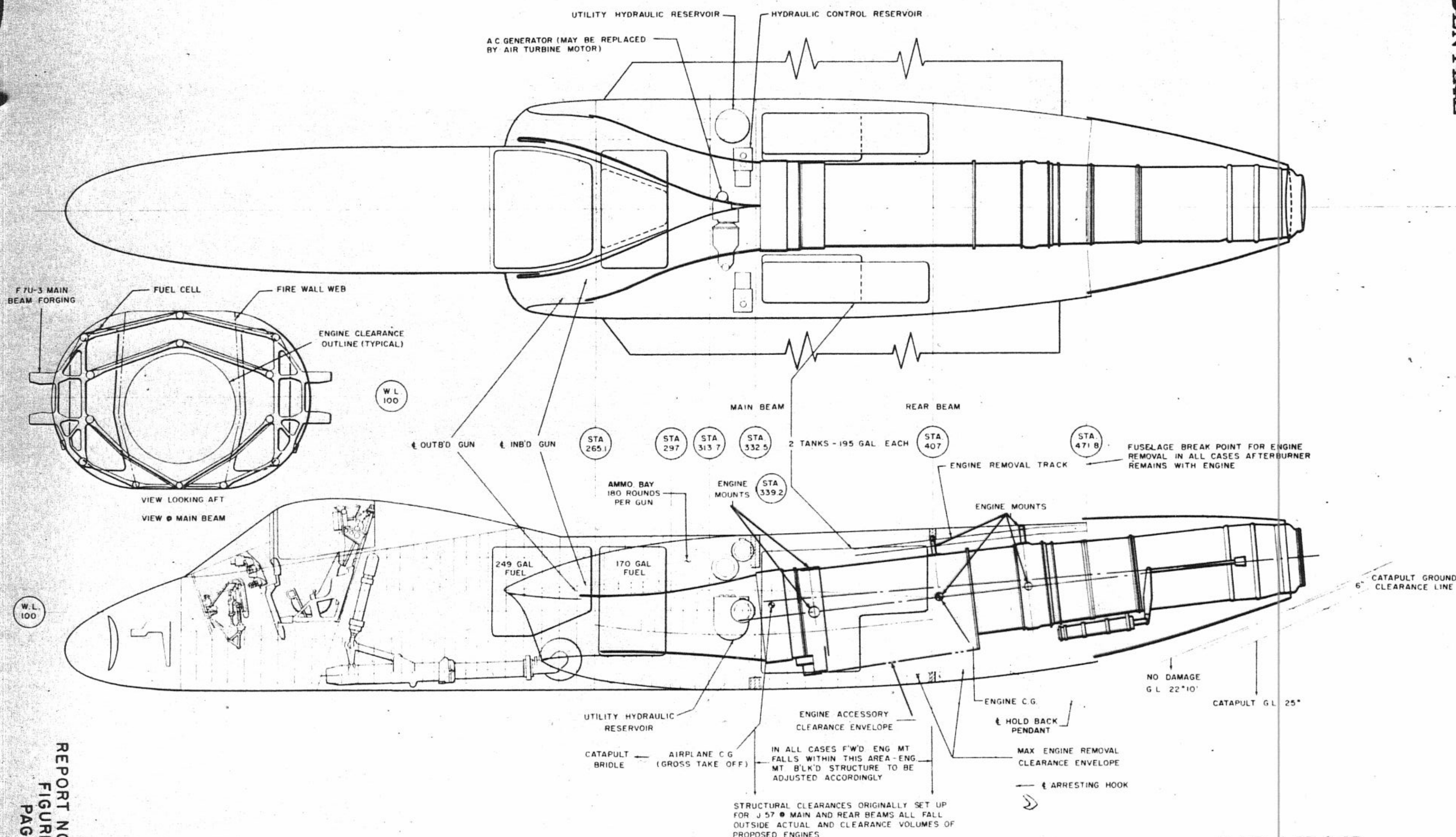


WEST. J40-WE-10



ALLIS. J-35-A-23

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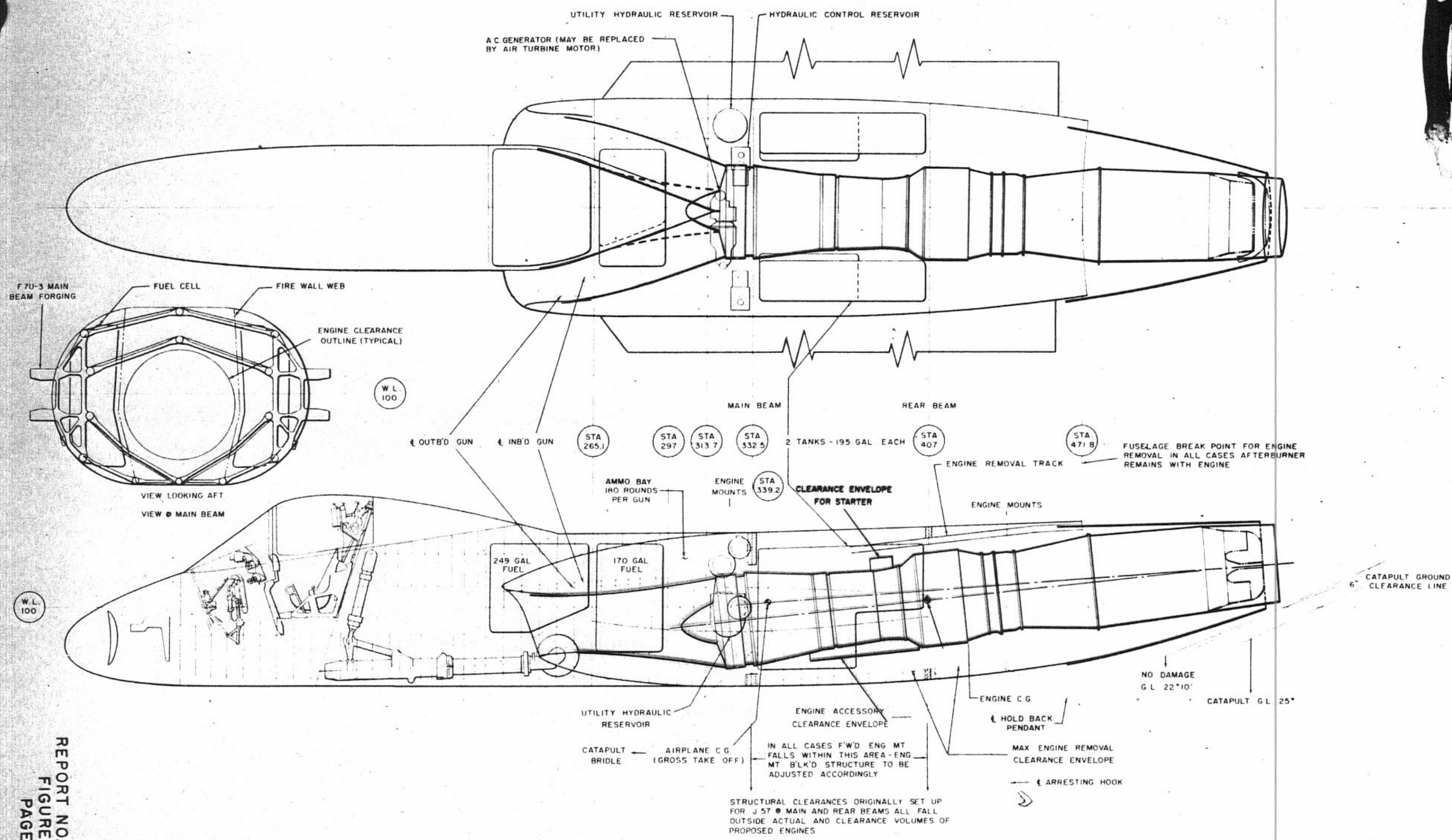

WRIGHT J-67-W

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FIGURE NO. 2
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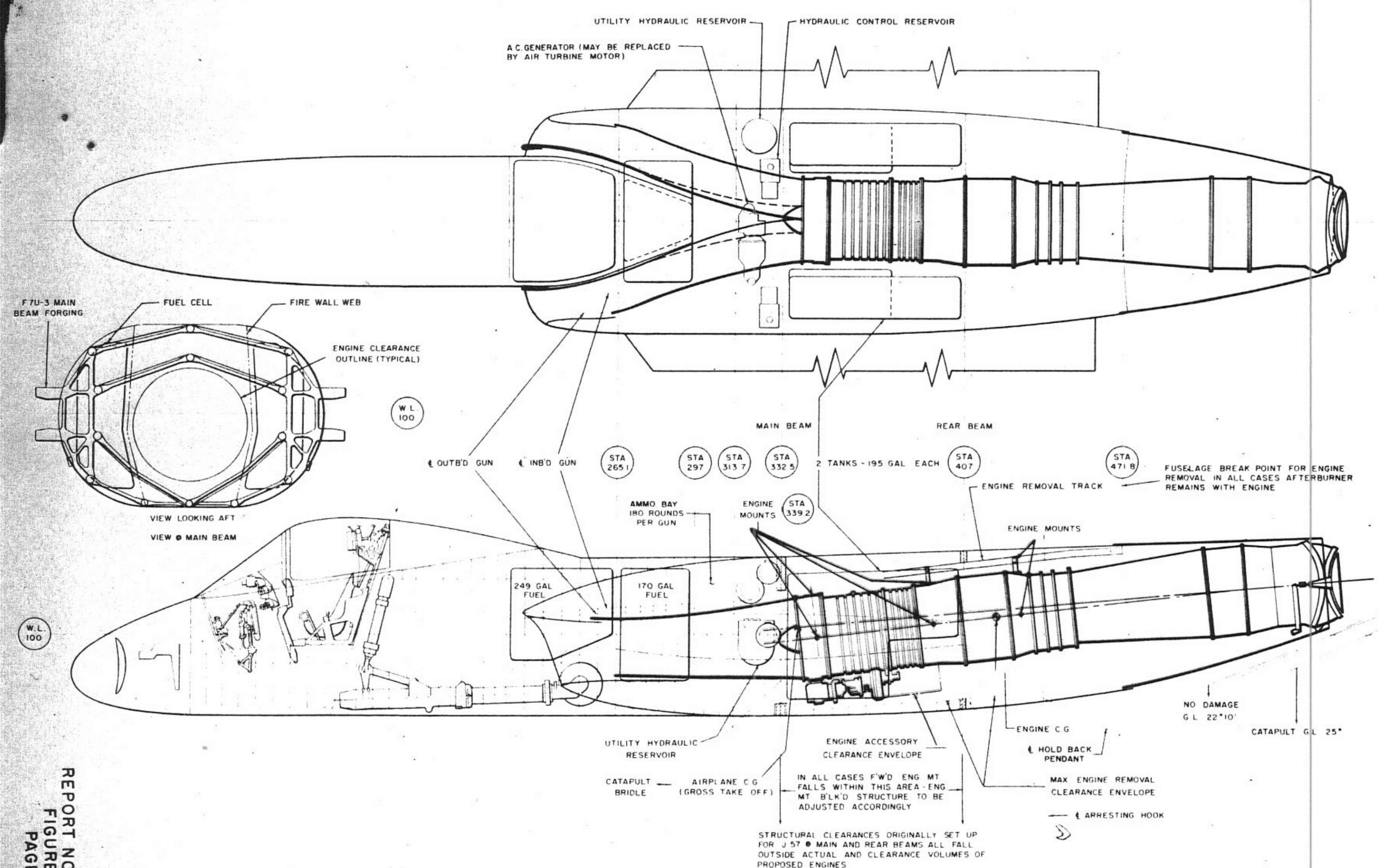
UTILITY HYDRAULIC RESERVOIR
HYDRAULIC CONTROL RESERVOIR
A.C. GENERATOR (MAY BE REPLACED BY AIR TURBINE MOTOR)
F7U-3 MAIN BEAM FORGING
FUEL CELL
FIRE WALL WEB
ENGINE CLEARANCE OUTLINE (TYPICAL)
W.L. 100
VIEW LOOKING AFT
VIEW @ MAIN BEAM
MAIN BEAM
REAR BEAM
℄ OUTB'D GUN
℄ INB'D GUN
STA 265.1
STA 297
STA 313.7
STA 332.5
2 TANKS - 195 GAL EACH
STA 407
STA 471.8
FUSELAGE BREAK POINT FOR ENGINE REMOVAL IN ALL CASES AFTERBURNER REMAINS WITH ENGINE
ENGINE REMOVAL TRACK
AMMO BAY 180 ROUNDS PER GUN
ENGINE MOUNTS
STA 339.2
ENGINE MOUNTS
249 GAL FUEL
170 GAL FUEL
W.L. 100
6" CATAPULT GROUND CLEARANCE LINE
NO DAMAGE G.L. 22°10'
CATAPULT G.L. 25°
ENGINE C.G.
℄ HOLD BACK PENDANT
UTILITY HYDRAULIC RESERVOIR
ENGINE ACCESSORY CLEARANCE ENVELOPE
CATAPULT BRIDLE
AIRPLANE C.G. (GROSS TAKE OFF)
IN ALL CASES F'W'D ENG MT FALLS WITHIN THIS AREA - ENG MT B'LK'D STRUCTURE TO BE ADJUSTED ACCORDINGLY
MAX ENGINE REMOVAL CLEARANCE ENVELOPE
℄ ARRESTING HOOK
STRUCTURAL CLEARANCES ORIGINALLY SET UP FOR J-57 @ MAIN AND REAR BEAMS ALL FALL OUTSIDE ACTUAL AND CLEARANCE VOLUMES OF PROPOSED ENGINES

G.E. J47-GE-21

II. PERFORMANCE AND WEIGHTS

(a) Performance

The comparative performance of the five single engine versions of the F7U-3 airplane is shown in Table I. Qualifying notes on sources of engine data and installation loss estimates are given on the face of the table. The lower thrust of the J35-A-23 and J47-GE-21 is somewhat compensated for by the fact that these two installations have boundary layer removal ducts, whereas the three larger thrust engines do not. This is covered in detail in Section III.

It will be noted that the performance of the airplane with a J57-P-1 is not significantly different from the basic airplane with two J46-WE-2 engines. The low altitude performance is slightly lower and the high altitude performance is slightly better. The radius of action, however, is significantly improved with the J57-P-1. In comparing the relative performance of the airplane with one J57-P-1 engine and the airplane with 2 J46-WE-2 engines it should be kept in mind that the J57-P-1 is a new engine with a considerable development program already planned for it.

The performance of the airplane is approximately the same with each of the other single engine installations considered (with the exception of the radius of action with a J67-W-   ), thus assuring a maximum availability of power plants for the airplane at no significant change in overall performance. The considerable increase in radius of action with a J67-W-   results from the low engine weight, low specific fuel consumptions and lower afterburner boost ratio, based on the limited preliminary information available on the engine at this time.

For general comparison purposes the lapse rate vs speed is shown for the five power plants considered on Figure 3. Curves are shown for both sea level and 35,000 feet. Figure #4 shows wind required across deck as a function of take-off weight for each of the airplanes considered. The H4-1 and H8 are the only catapults shown, since the C10 is not critical.

(b) Weights

The weights of the five single engine airplanes considered are shown in Table II. It will be noted that the "basic" F7U-3 used as a base for both weight and performance calculations weighs 29,286 pounds. Any reduction in weight of the basic F7U-3 airplane will be reflected directly in the single engine versions.

PERFORMANCE COMPARISON - SINGLE ENGINE VERSIONS OF THE F7U-3 AIRPLANE

ENGINES	Two J46-WE-2		P-7 J57-P-1	J40-WE-10	J35-A-23	J67-W	J47-GE-21
	Spec.						
Sea Level static thrust, combat, lbs.	12200		15000	13750	13000	14000	13050
" with A/B prov.			9220	9300	w A/B 9400		wt 9834
WEIGHT, lbs. No A/B prov. Dry			9500	9500	9700		9400
with A/B			15000	13700	14350		13050
Take-off	29286		30275	29593	29965	29082	29425
Combat (60% fuel)	25698		26687	26005	26377	25494	25837
Landing (40% fuel)	23904		24893	24211	24583	23700	24043
FUEL LOAD, lbs.	8970		X 8970	8970	8970	8970	8970
ENGINE WGT inc A/B			4070	3968	II 4300		# 4045
PERFORMANCE — SFC, dry wt "prov			(.795) .82	.95	.99		.92
wt A/B			no A/B 1.96	2.5	2.0		1.90
Take-off Weight							
Radius of Action, Na. Mi.	460		515	490	470	550	490
Stalling speed, power-off, Knots	116		118	117	117.5	115.5	116.5
Stalling speed, combat power, kts.	105		106	106	107	104.5	106
Required wind over the deck, kts (1)							
H4-1 Catapult	33		36.5	35	37.5	34.5	36.5
H8 Catapult	30		33	31.5	34	30.5	33
C10 Catapult	None		None	None	None	None	None
Combat weight and Thrust							
Vmax at sea level, knots/MN	614/.931		(2) 595/.902	611/.926	609/.923	603/.914	606/.918
Vmax at 10000 ft., knots/MN	600/.942		595/.934	596/.935	590/.926	591/.928	591/.928
Vmax at 35000 ft., knots/MN	543/.945		543/.945	540/.939	535/.93	540/.939	538/.935
Max rate of climb at sea level, ft/m	17800		14550	16000	13900	13730	13630
Max rate of climb at 35000 ft.ft/min	5700		6260	5330	4210	6040	4960
Ceiling for 500 fpm rate of climb,ft	48300		49700	49000	47800	49200	48700
Time to climb to 35000 ft., min.	3.3		3.7	3.6	4.3	3.8	4.1
Landing Weight							
Stalling speed, power-off, knots	105		107.5	106	106.5	104.5	105.5
Mark V arresting gear limit -10 kts. (3)	103.5		101.5	102.5	102	103.5	102.5
Mark VII arresting gear limit-10kts. (3)	120		120	120	120	120	120

(1) Includes 5 knot margin
(2) 607/.920 neglecting engine cut-off limit.
(3) [illegible]

Notes - F7U-3 Single Engine Performance

Engine Ratings:

Estimated Development of the J57 Engine, Pratt and Whitney Installation Memo Report No. 149, dated April 11, 1950, revised March 23, 1951.

Allison Model Specification No. 286-D, USAF Model J35-A-23 Turbo-Jet Engine, dated April 29, 1949, revised December 4, 1950.

Westinghouse Model Specification XJ40-WE-10 Turbo-Jet Engine, dated June 7, 1950.

Estimated Average Performance of General Electric J47-GE-21 Turbo-Jet Engine with Reheat Afterburner, Bulletin No. R50GT106, dated November 2, 1950.

Duct Losses:

The air flows of the J35-A-23 and J47-GE-21 are such that the F7U-3 ducts (including boundary layer ducts) are useable; duct losses were estimated accordingly. To provide the greater airflows required by the J57-, J40, and J67 engines, the boundary layer ducts were eliminated and the losses were increased accordingly.

Weight:

The weight of each single engine version of the F7U-3 is based on a take-off weight of 30,275 lb. for the J57-P-1 airplane and reflects differences in engines. (In the "Study of Possible Improvements to the F7U Airplane", the take-off weight of the minimum change J57-P-1 airplane was quoted as 30,545 but this has been revised on the basis of a new engine spec.) The comparable take-off weight of a twin engine J46-WE-2 version of the F7U-3 would be 29,286 lb.

$C_{L_{max}}$ is 1.2 based on best estimates.

Drag vs Mach Number:

A low speed drag coefficient of .0171 lb/mph^2 was used. The variation of K_x with MN was taken from CVA Report 8478, Performance Data Report, dated June 19, 1950.

X Deduct 250# if titanium compressor can be put into production.

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CALCULATED

DATE

MODEL

SUBJECT:
TABLE II
F7U-3 SINGLE ENGINE VERSIONS

WEIGHT BREAKDOWN

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ENGINE TYPE	2/J46-WE2	1/J57P-1	1/J40WE10	1/J35A23	1/J67-W	1/J47GE21
	(1)	(2)	(3)	(4)	(5)	(6)
STRUCTURE	(8626)	(8888)	(8888)	(8888)	(8888)	(8888)
POWER PLANT	(5894)	(6724)	(6042)	(6414)	(5531)	(5874)
Engine	3783	4650	3968	4340	3457	3800
Fuel System	1721	1755	1755	1755	1755	1755
Accessories Etc.	390	319	319	319	319	319
EQUIPMENT	(4519)	(4416)	(4416)	(4416)	(4416)	(4416)
WEIGHT EMPTY	(19039)	(20028)	(19346)	(19718)	(18835)	(19178)
Fuel	8970	8970	8970	8970	8970	8970
U. L. Less Fuel	1277	1277	1277	1277	1277	1277
USEFUL LOAD	(10247)	(10247)	(10247)	(10247)	(10247)	(10247)
GROSS WEIGHT TAKE-OFF	(29286)	(30275)	(29593)	(29965)	(29082)	(29425)

NOTES:

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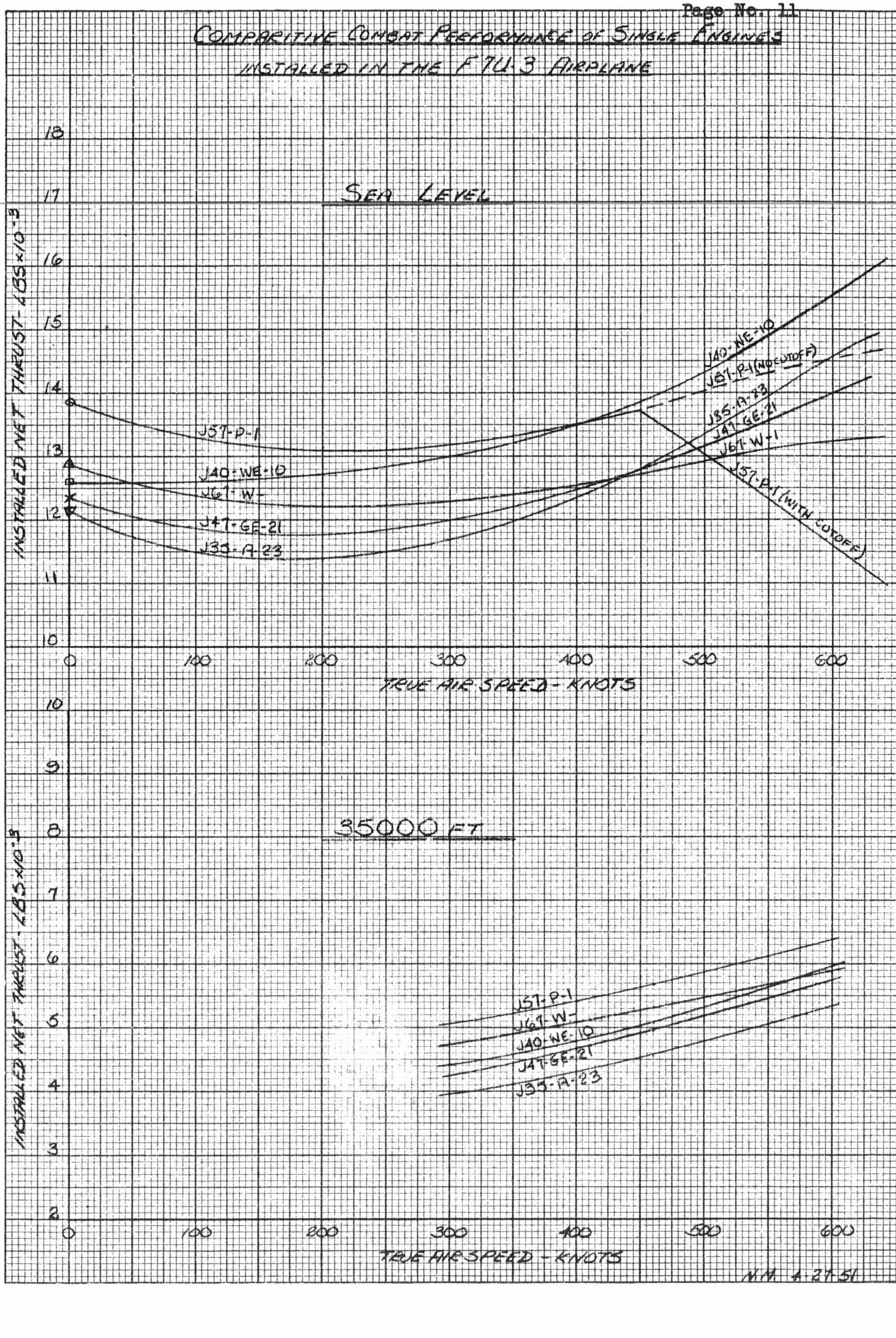
COMPARITIVE COMBAT PERFORMANCE OF SINGLE ENGINES
INSTALLED IN THE F7U-3 AIRPLANE
SEA LEVEL
INSTALLED NET THRUST - LBS×10⁻³
18
17
16
15
14
13
12
11
10
J57-P-1
J40-WE-10
J67-W-
J47-GE-21
J35-A-23
J40-WE-10
J57-P-1 (NO CUTOFF)
J35-A-23
J47-GE-21
J67-W-1
J57-P-1 (WITH CUTOFF)
0
100
200
300
400
500
600
TRUE AIR SPEED - KNOTS
35000 FT
INSTALLED NET THRUST - LBS×10⁻³
10
9
8
7
6
5
4
3
2
J57-P-1
J67-W-
J40-WE-10
J47-GE-21
J35-A-23
0
100
200
300
400
500
600
TRUE AIR SPEED - KNOTS
N.M. 4-27-51

FIG. 4

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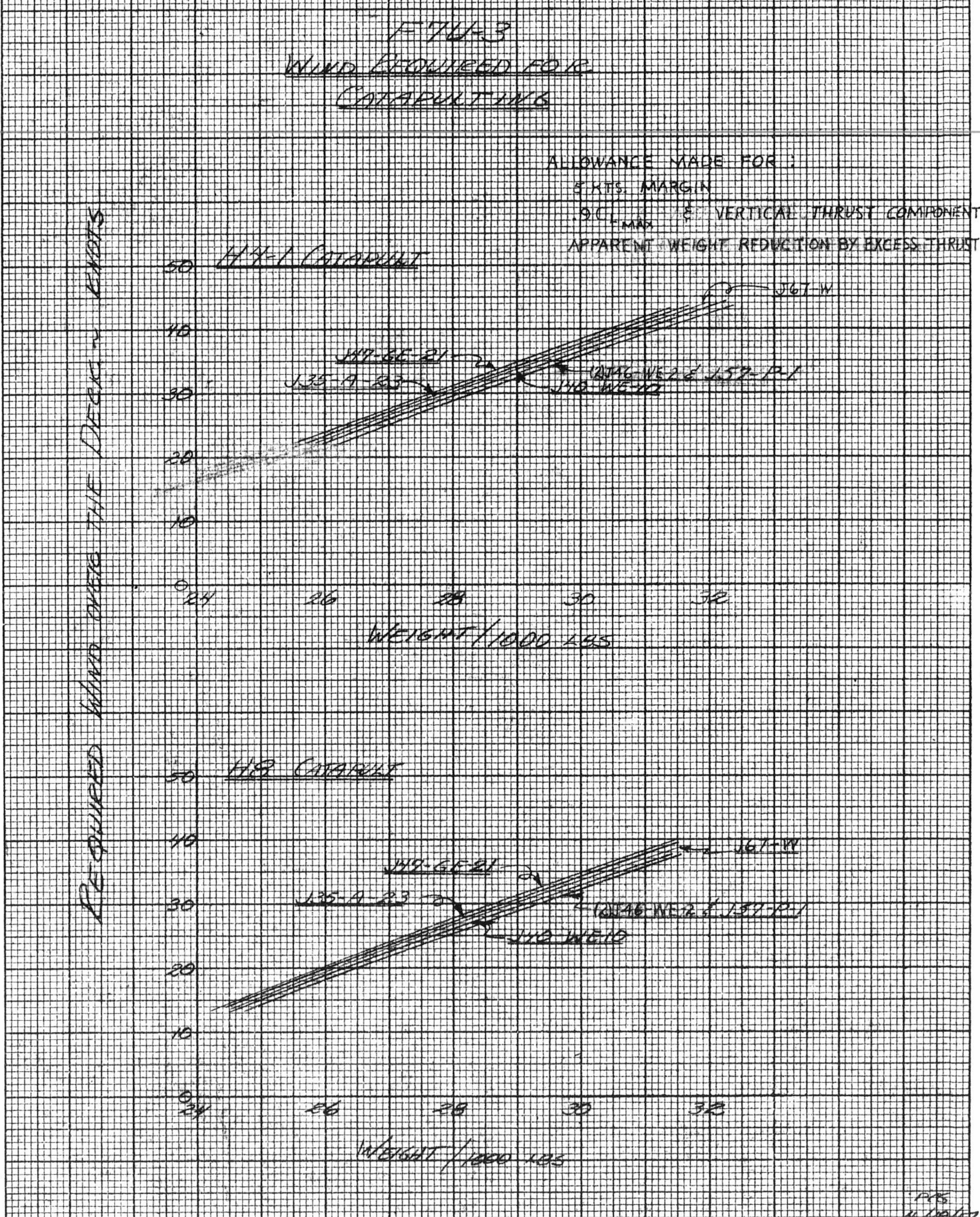

[redacted]

III. POWER PLANTS

The basic characteristics of the five single engines considered are shown in Table III with 2 J46-WE-2 engines shown for comparison purposes. The desired airplane accessory provisions are tabulated in Table IV, and the available accessory drives on each of the engines considered are shown in Table V. Each engine installation is covered individually in the balance of this section.

(a) J57-P-1

The high compression ratio of the J57-P-1 engine accounts for the superior high altitude performance and lower cruise SFC, the latter being reflected in the improvement in radius of action. From an operational standpoint, however, probably the most significant advantage of the high compression ratio is in maintaining dependable afterburner combustion at or near service ceiling.

From the airflow data in Table III it may be seen that the airflow for the J57-P-1 is higher than that for two J46 engines. As a result, it was necessary to remove the boundary layer ducts provided for the J46 installation in order to provide sufficient duct inlet area. It should be noted that the duct inlets will thus be identical to those on the interim F7U-3 with two J35-A-29 engines. This increases the duct pressure losses, particularly at high speed, and the airplane performance shown in Table I reflects these higher losses.

In order to satisfy the desired accessory requirements of the F7U-3 airplane, three of the presently proposed pads on the J57-P-1 engine would have to be changed. The two AND20002 Type XII E pads would have to be converted to Type XII F or K pads to accomodate the power control hydraulic pumps. The AND20002 Type XII D pad would have to be converted to a Type XII F pad for the DC generator. The AC generator could be driven by an air turbine motor if a constant speed drive were not provided on the engine.

(b) J40-WE-10

The J40-WE-10 is the longest of the engines considered, primarily due to the front-mounted accessories. Consequently it required the greatest reduction in afterburner length (21") to keep it within the airplane limits without lengthening of the main landing gear. The front-mounted accessories will not be as readily accessible for servicing as on the other engines where the accessories are on the bottom centerline under the compressor section. Similar to the J57-P-1, the airflows for the J40-WE-10 are higher than for the two J46 engines and therefore, the boundary layer ducts are removed. Here again the performance shown in Table I reflects the increased duct losses due to lack of boundary layer ducts.

One additional AND20002 Type XII K or F pad is required for a power control hydraulic pump to satisfy the requirements of Table IV on the J40-WE-10. This engine is the only one which provides a constant speed drive on the engine, permitting the AC generator to be mounted directly on the engine.

(c) J35-A-23

The J35-A-23 engine with afterburner is the shortest of the five engines considered, due to the use of a short afterburner. The location of the engine is dictated by balance considerations, and, in order to keep the "boat-tail" drag of this version comparable to the other engine studies, a segment of tailpipe has to be inserted in the afterburner. It will be noted in Table III that the airflow requirements of the J35-A-21 are nearly identical to those for two J46-WE-2 engines. Thus, the duct inlets and boundary layer ducts of the basic F7U-3 can be retained. The duct pressure losses are consequently kept to a minimum at high speeds, and the resulting overall reduction in installation losses tends to compensate for the lower thrust ratings of the engine.

One additional AND20002 Type XII E, F, J or K pad is needed on the J35-A-23 engine for either the utility pump or DC generator, to satisfy the requirements of Table IV. This might possibly be supplied by conversion or adaptation of the AND20007 Type XVII F pad which is presently supplied. The AC generator requirements can be satisfied by a constant speed engine pad, a Sundstrand system or an air turbine motor.

(d) J67-W-

The data available on this engine is not comparable to those available on the other four engines considered in this study. The available data indicate that the engine is basically similar to the J57-P-1 in performance, however, the combat thrust is 1000 pounds lower, due to the lower afterburner boost ratio. The current quoted weight for the J67-W- plus afterburner is significantly lower than that for the other four engines studied, thus just about balancing out the thrust difference. The airflow requirements are similar to those for the J57-P-1 and the J40-WE-10, requiring elimination of the boundary layer removal ducts, with the ensuing increase in duct pressure losses.

Changes in accessory drive provisions, if any, cannot be estimated at this time, since the basic engine accessory drive provisions are not known.

(e) J47-GE-21

The installation of the J47-GE-21 is very similar to the J35-A-23 except for the longer basic afterburner on the J47 engine. Like the J35-A-23 it will be noted that the airflow requirements for this engine are nearly identical to those for two J46-WE-2 engines. The duct inlets and boundary layer ducts of the basic F7U-3 can be retained, thus, reducing the duct pressure losses with this installation. This is reflected in the airplane performance shown in Table I.

[redacted]

The accessory situation on the J47-GE-21 is also similar to that on the J35-A-23 in that one additional pad is required for the utility pump on the DC generator. Here again the AND20007 Type XVII E pad which is supplied might be converted or adapted to satisfy this requirement. The AC generator requirement can be satisfied by a constant speed engine pad or an air turbine motor.

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TABLE III

Military Engine Designation	2 J46-WE-2	J57-P-1	J40-WE-10	J35-A-23	J67-W	J47-GE-21
Manufacturer	Westinghouse	Pratt & Whitney	Westinghouse	Allison	Wright	General Electric
S.L.Static Thrust & SFC						
Military Power	8160 - 1.01	9220 - 0.82	9275 - 0.95	(1)9400-0.965	(1)9700-0.805	9034 - 0.916
Combat Power	12200-2.50	15000 - 1.96	13700 - 2.50	(2)13000-2.25	(3)14000-1.75	13050 - 1.894
S.L. Static Airflow (#/sec)	141	167	160	150	160	142
35000' M = 0.95						
Combat Power & S.F.C.	6200 - 2.30	7160 - 2.055	6450 - 2.18	(2)5400-2.57	(3)6340-1.87	5970 - 2.10
Airflow (#/sec)	66	80.5	75	68	77	67
35000' M = 0.80						
Normal Power	2740 - 1.120	3220 - 0.965	3050 - 1.08	2590 - 1.155	(3)3360-0.95	2020 - 1.051
Airflow (#/sec)	58	73.5	67	60	70	59
Weight (4)	3783	4650	3968	4340	3457	3800
Diameter	29	41	42.5	37	40	37
Length	193	237	284	(5) 201	(6) 240	240

Notes:
1. Military thrusts for engines with afterburners not known exactly. Values shown are basic engine thrusts reduced by 3% and SFC's increased by 3% to account for losses in afterburner.
2. Combat performance of J35-A-23 engine does not include latest improvements to engine and is therefore somewhat conservative.
3. Performance of J67 estimated from data obtained informally from Wright Aero. Corp.
4. All weights represent engine including oil system and accessory pads for airplane accessories.
5. Length of J35-A-23 is for a short afterburner.
6. Length of J67-W afterburner is variable - can be adjusted within limits to fit different installations.

[redacted]

TABLE IV

AIRPLANE ACCESSORIES DESIRED

Accessory	Number	Manufacturer	AND Drive Pad Required
Power Control Hydraulic Pump	2	N. Y. Air Brake Hamilton Standard	AND 20002 Type XII K AND 20002 Type XII F
Utility Pump	1	N. Y. Air Brake Hamilton Standard	AND 20002 Type XII J or K AND 20002 Type XII E or F
D.C. Generator (400 amp)	1		AND 20002 Type XII E or F
*Alternator	1		Special Constant Speed Drive.

*The constant speed drive may be supplied in any of three ways:

1. On the engine similar to J40-WE-10.
2. Sundstrand system which requires an AND 20002 XII F pad on engine for the hydraulic pump, but which removes the need for a utility pump pad on the engine.
3. Air Turbine motor.

TABLE V

AIRPLANE ACCESSORY PADS PROPOSED OR SUPPLIED ON EACH ENGINE

Engine	Accessory	Number	AND Pad & Type	Continuous Torque Rating ("#)
J57-P-1	Starter	1	AND 20002, Type XII-B	4200
	Generator	2	AND 20002, Type XII-E	600
	Generator	1	AND 20002, Type XII D	500
	Hydraulic	1	AND 20002, Type XII J	600
J40-WE-10	Starter	1	AND 20002, Type XII F	1500
	Generator	1	AND 20002, Type XII E	600
	*Alternator	1	AND 20006, Type XVI D	
	*Generator	1	AND 20002, Type XII E	600
	Hydraulic	1	AND 20002, Type XII K	1000
	*Special constant speed drive pads			
J35-A-23	Starter	1	AND 20006, Type XVI-S	4200
	Generator	1	AND 20007, Type XVII F	4200
	Generator	1	AND 20002, Type XII F	1500
	Hydraulic	2	AND 20002, Type XII K	1000
J-67-W-	There is no specific information on the accessory pads on this engine available.			
J47-GE-21	Starter	1	AND 20006, Type XVI-S	4200
	Generator	1	AND 20007, Type XVII-E	4200
	Generator	1	AND 20002, Type XII F	1500
	Hydraulic	1	AND 20002, Type XII K	1000
	Hydraulic	1	AND 20002, Type XII J	600

IV. ENGINE AVAILABILITY

The following tabulation gives the current best estimate on the availability for installation in a prototype airplane of each of the five engines considered in this study:

Engine	Availability for Prototype Airplane
J57-P-1	July 1952
J40-WE-10	March 1953
J35-A-23	January 1953
J67-W	March 1953
J47-GE-21	March 1952

From this table it may be seen that the J47-GE-21 offers the earliest probable availability for prototype installation in an airplane, followed closely by the J57-P-1. The availability of the other engines is later but certainly in time to be realistically considered as alternate engines beyond the prototype installation.