RL10

LIQUID ROCKET

INSTALLATION HANDBOOK

RL10 LIQUID ROCKET ENGINE

INSTALLATION HANDBOOK

MARCH 1966

Pratt & Whitney Aircraft EAST HARTFORD, CONNECTICUT DIVISION OF UNITED AIRCRAFT CORPORATION

RECORD OF REVISIONS

ASSIGNED TO (JOB TITLE) LOCATION

REV. NO.	INSERTION DATE	BY	REV. NO.	INSERTION DATE	BY	REV. NO.	INSERTION DATE	BY
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Pratt & Whitney Aircraft

RL10 Installation Handbook

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INTRODUCTION

The RL10 liquid-propellant rocket engine has been designed and developed to provide a powerplant for upper-stage space vehicles. The engine can be used for multiengine installations on an interchangeable basis. It produces 15,000 pounds of thrust under vacuum conditions and has, in its present form, a growth potential of 20,000 pounds thrust at either manned or unmanned ratings. Other versions, utilizing the same basic operating cycle, can be designed to produce almost any desired thrust level. The RL10 meets the performance and installation requirements of specific vehicles. For other applications it is important that all details of the vehicle mission and engine installation and performance considerations be coordinated with Pratt & Whitney Aircraft to achieve optimum match between the vehicle and powerplant. Proper coordination of engine characteristics with the requirements of a specific vehicle and mission applications will ensure that the engine performs at its maximum capability. This Handbook presents basic information and data on the several versions of the RL10 engine and provides sufficient data to enable the vehicle designer to determine and evaluate the effect of various modifications.

Pratt & Whitney Aircraft is actively engaged in a program of research and development on liquid-propellant rocket engines. Knowledge gained from this program may result in changes to individual components. Consequently, the information and data included in this Handbook must be considered subject to change as development of this type of engine progresses. RL10 Information Letters and revisions to Handbook pages will be issued as often as warranted.

Exact details on a given engine model built to a particular designation are contained in the applicable Engine Specification and Installation Drawing. These data may give information which differs in detail from data quoted herein as required to reflect the selected configuration.

For additional information and clarification one of the following field offices should be contacted.

Pratt & Whitney Aircraft
Eastern Field Engineering
400 Main Street
East Hartford, Connecticut 06108

or

Pratt & Whitney Aircraft
Western Field Engineering
Webb-McCulloch Building
6151 West Century Boulevard
Los Angeles, California 90045

GENERAL DESCRIPTION

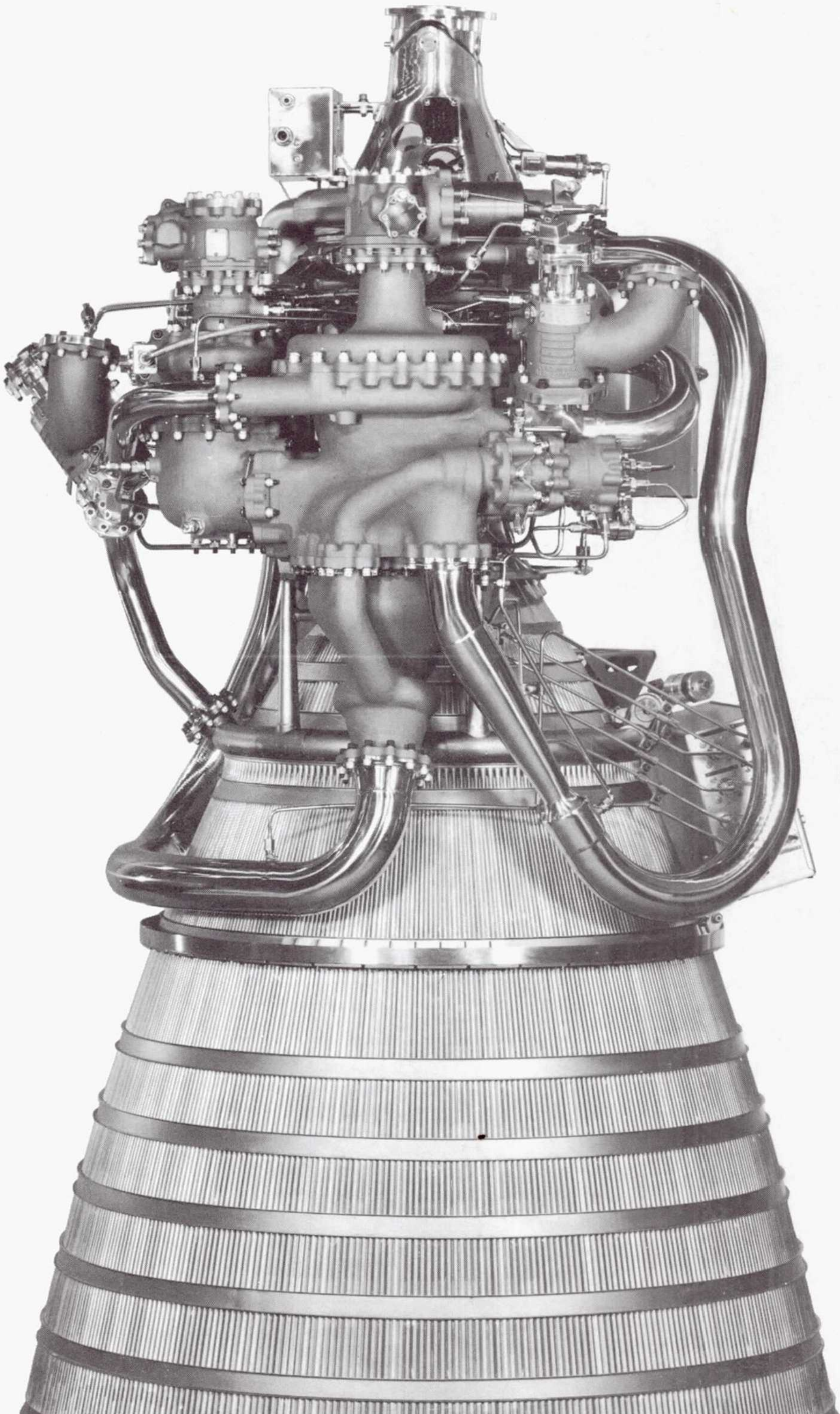
The RL10 liquid rocket engine is designed as a powerplant for upper-stage space-vehicle applications. The use of liquid hydrogen and liquid oxygen as propellants allows this engine to produce a very high specific impulse. Its high expansion ratio and unique regenerative operating cycle, which eliminates the need for a gas generator, further improve its performance. Incorporated in the design of the RL10 engine are such features as multiple-start capability and dry lubrication with hydrogen cooling of all moving parts, thus permitting the vehicle to coast in space between engine firings. The engine is equipped with a gimbal mount to permit thrust vector control.

The RL10 engine utilizes a regeneratively-cooled thrust chamber and a turbopump-fed propellant flow system. Pumped fuel, after cooling the thrust chamber, is expanded through the turbine which drives the propellant pumps. The fuel is then injected into the combustion chamber. The pumped oxidizer is supplied directly to the propellant injector through the propellant utilization (mixture ratio control) valve.

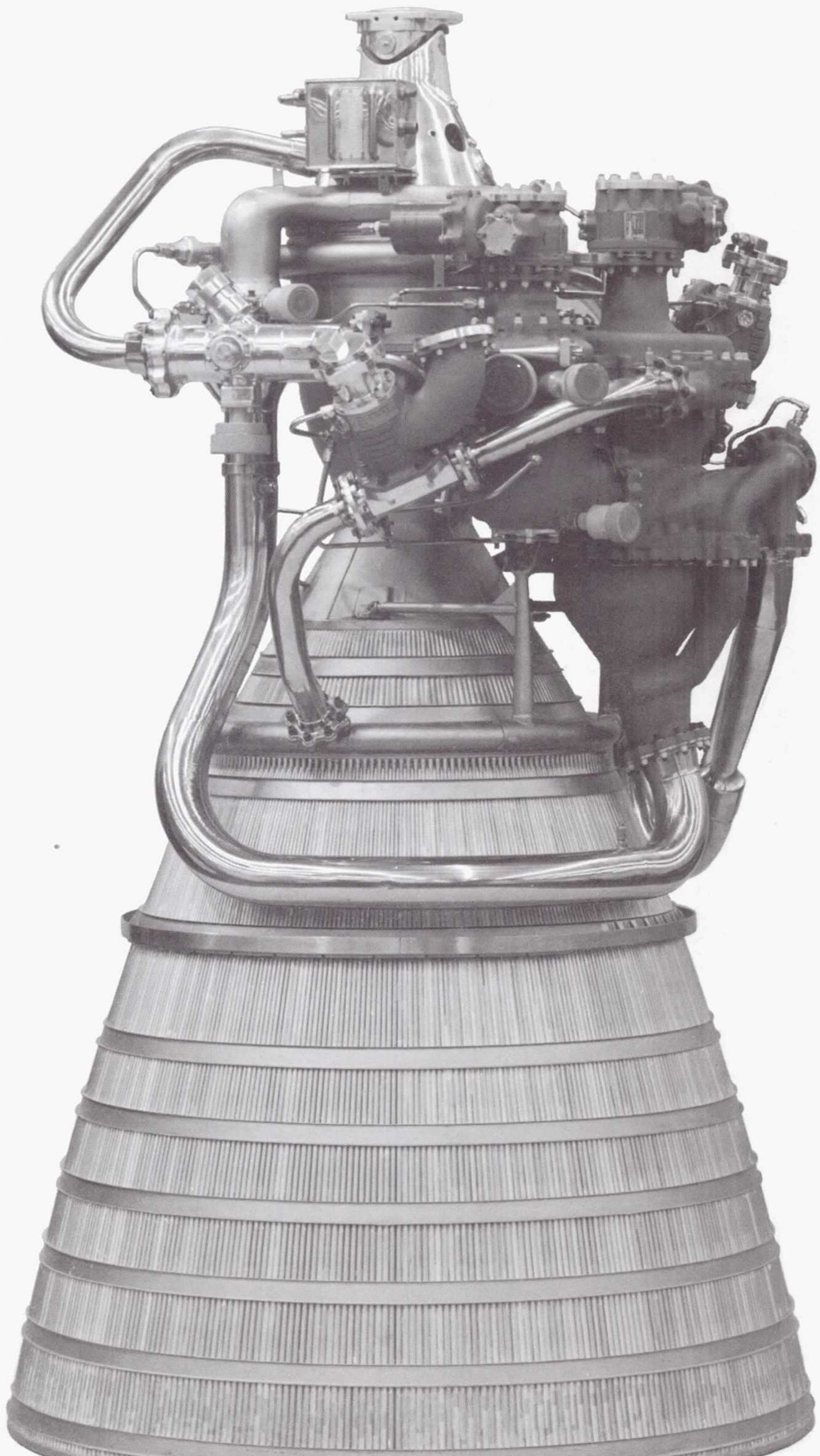
Thrust control is achieved by regulating the amount of fuel bypassed around the turbine as a function of combustion chamber pressure in order to vary turbopump speed and thereby control engine thrust. Ignition is accomplished by means of a spark-igniter recessed in the propellant injector face. Starting and stopping are controlled by pneumatic valves. Vehicle-supplied helium pressure to these valves is supplied through engine-mounted solenoid valves which are controlled by electrical signals from the vehicle.

Liquid hydrogen is attractive as a fuel because of its ability to produce a high specific impulse in combination with easily used oxidizers and its excellent capacity to absorb heat. Liquid hydrogen is currently available in commercial quantities at relatively low cost. It is storable and transportable either by vacuum-jacketed tank trucks, railroad cars, or transfer lines. It is also non-toxic and non-corrosive, as are the products of combustion with oxygen. While normal safety measures must be observed with its use, those who have had substantial experience with handling hydrogen prefer to work with hydrogen rather than RP fuels. At the Pratt & Whitney Aircraft test facility, liquid hydrogen is carried through vacuum-jacketed lines for distances up to 1800 feet and is stored with losses below one percent per day.

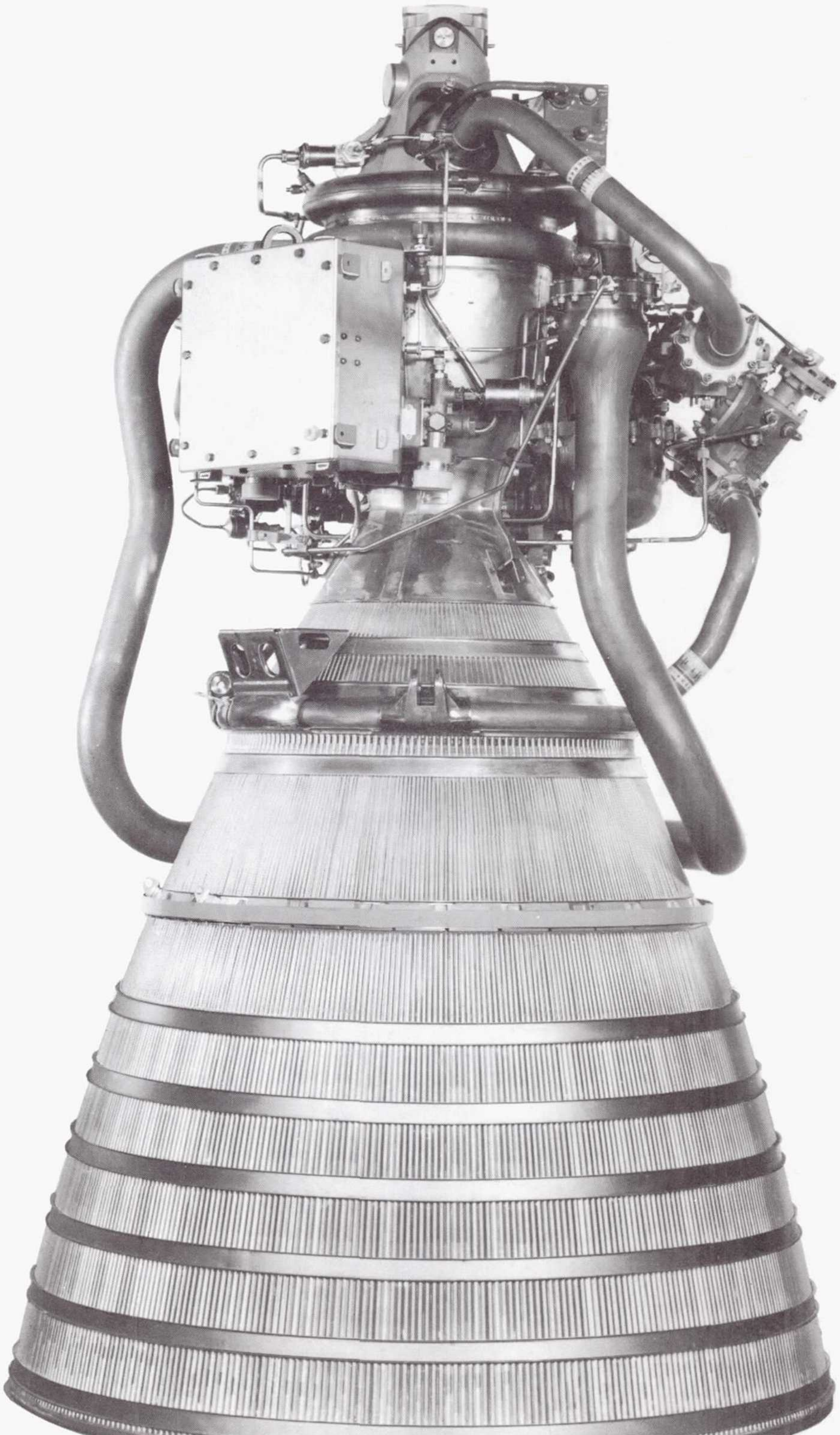
Several models of the RL10 engine have been produced to meet the requirements of specific vehicles and/or missions. The same basic engine cycle and operational modes are utilized for all models but each has installation and/or performance features which preclude complete interchangeability. Section 2 contains specifications for each of the developed models of the RL10 engine and pertinent features peculiar to each configuration. Specific differences in the component systems of each model are covered in other sections of this handbook.



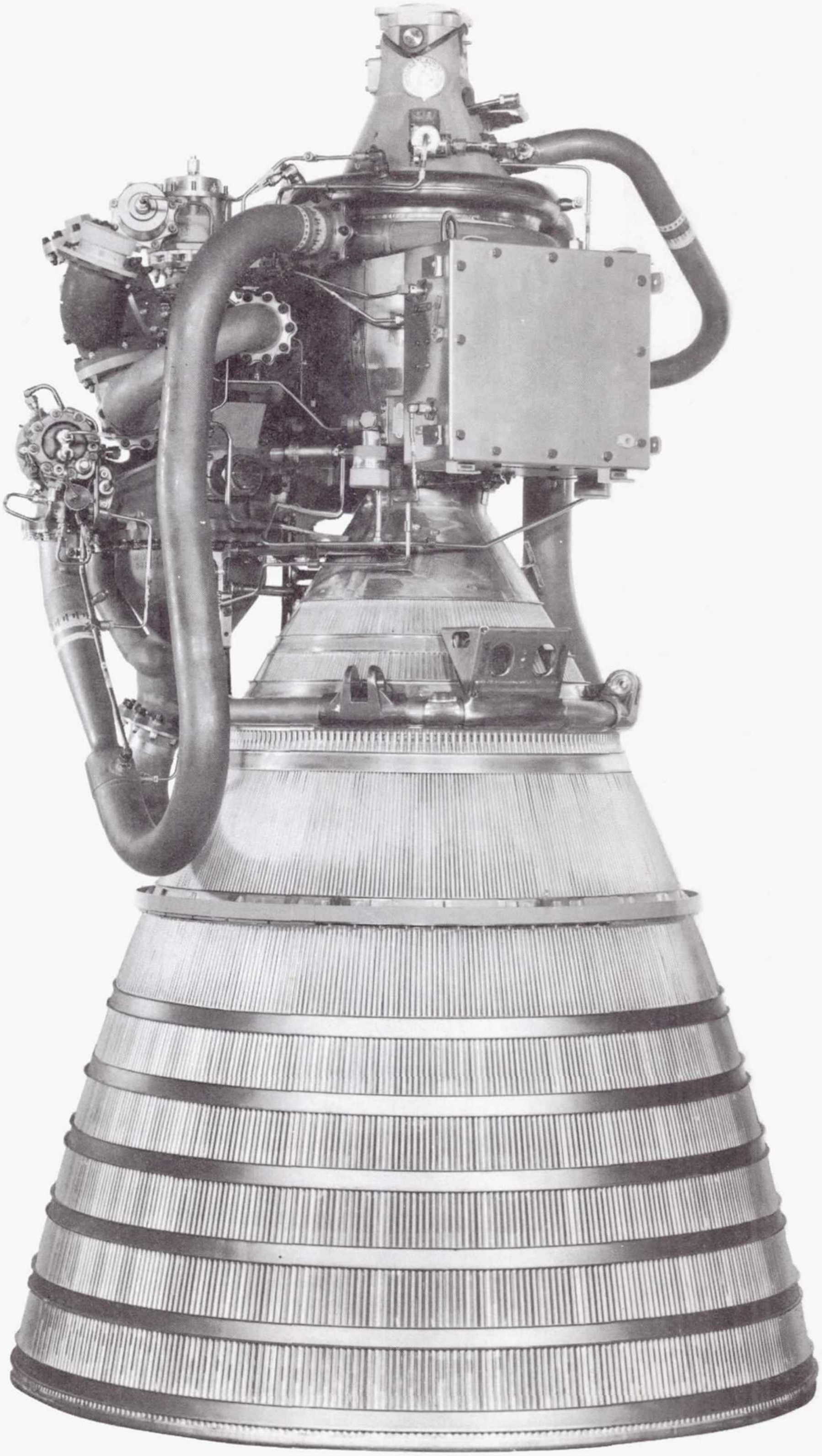
RL10A-3C ROCKET ENGINE
TOP VIEW



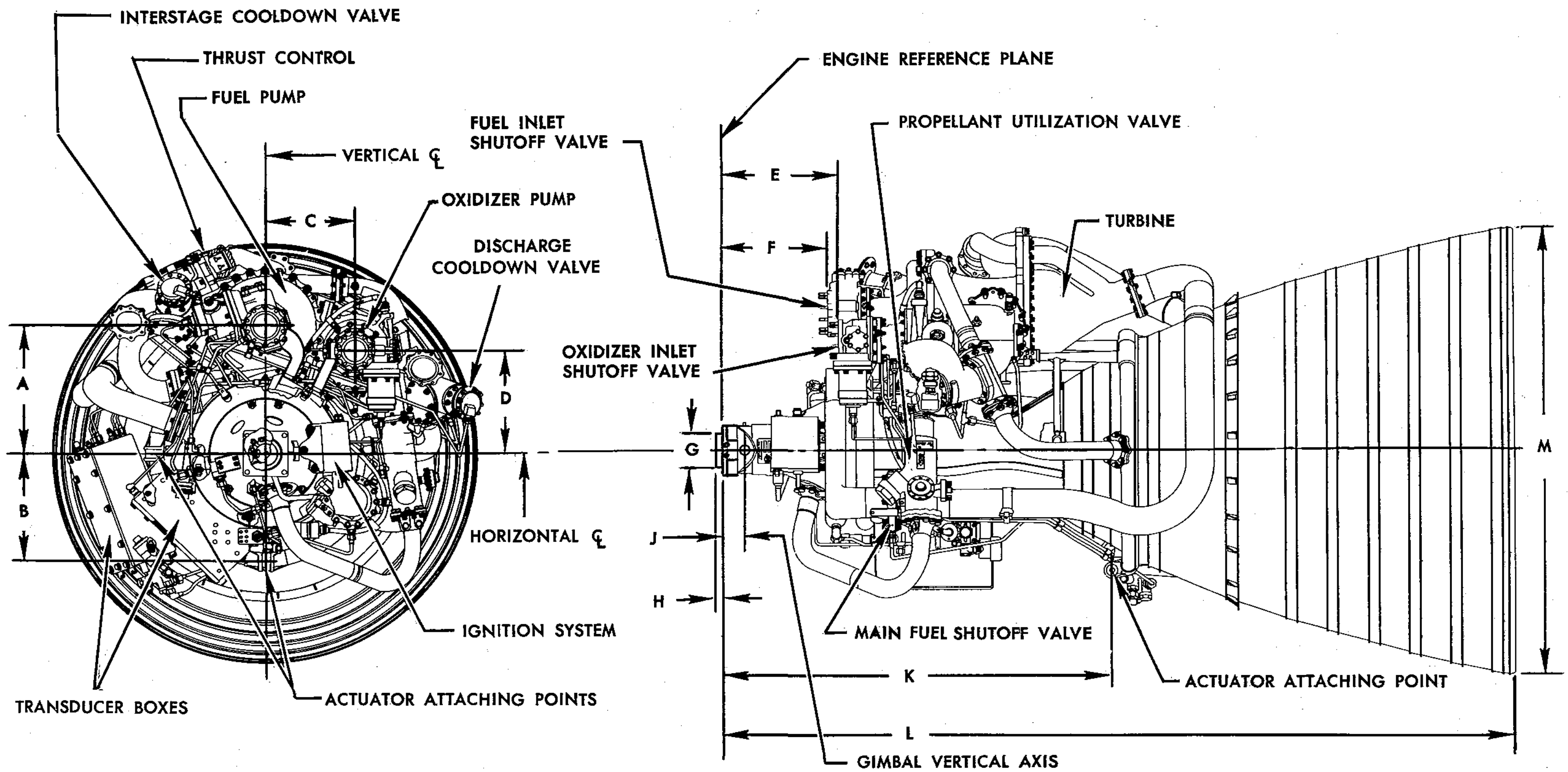
RL10A-3C ROCKET ENGINE
LEFT SIDE VIEW



RL10A-3-1 ROCKET ENGINE
BOTTOM VIEW



RL10A-3-1 ROCKET ENGINE
RIGHT SIDE VIEW

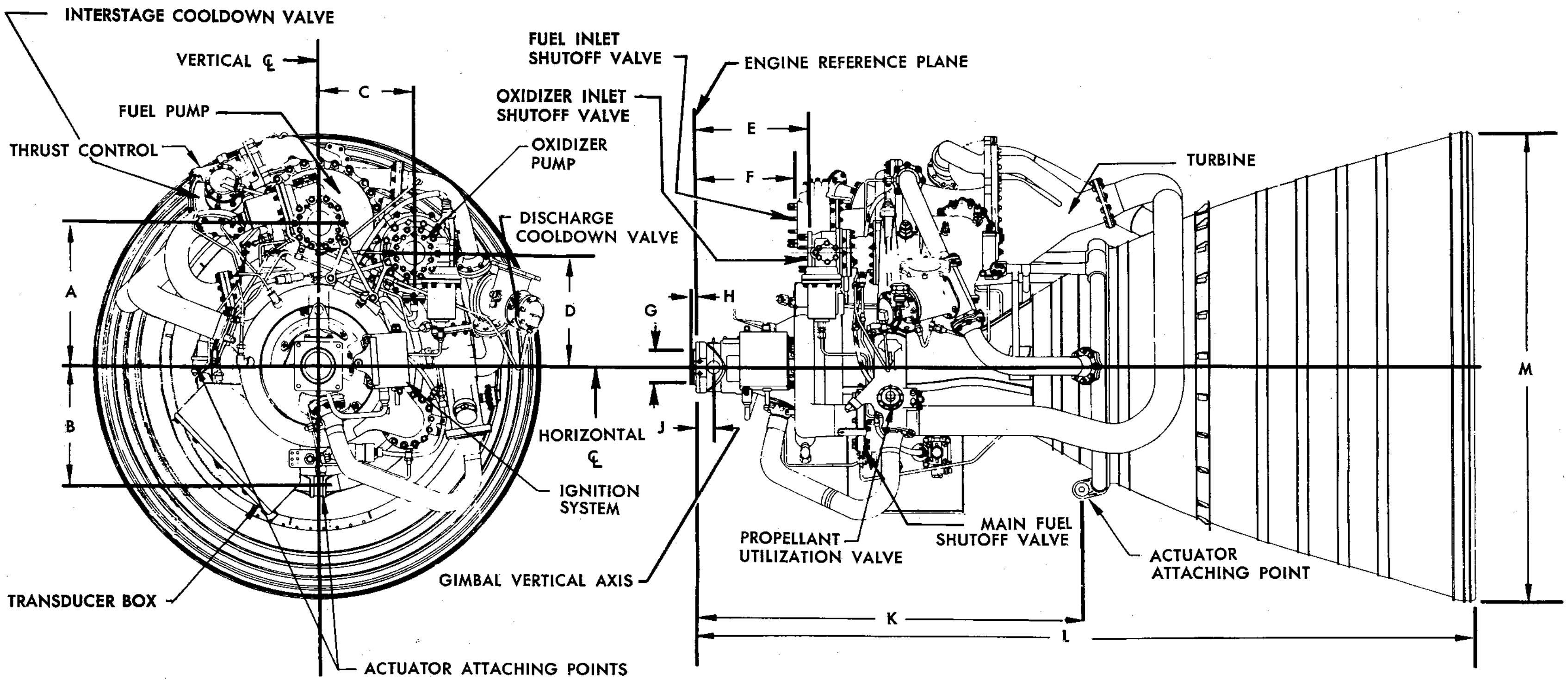


A — 11.750	D — 9.419	G — 2.876	K — 32.874
B — 10.172	E — 9.603	H — 0.240	L — 67.48
C — 8.128	F — 8.738	J — 1.500	M — 38.67

DIMENSIONS ARE NOMINAL IN INCHES AT ROOM TEMPERATURE

INST. 30496
DATE 9-1-61
REV. 9-15-65

RL10A-3
OUTLINE INSTALLATION DRAWING

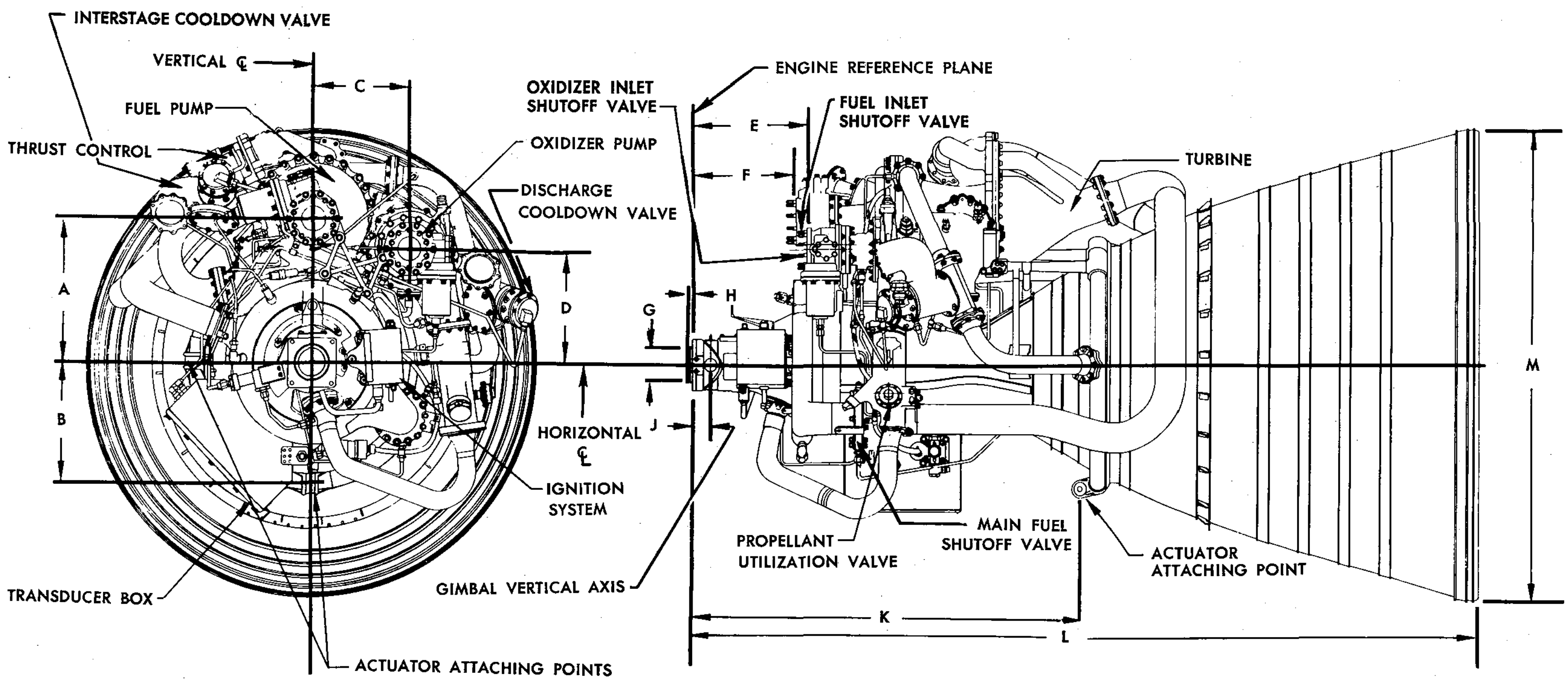


A — 11.750	D — 9.419	G — 2.876	K — 32.874
B — 10.172	E — 9.603	H — 0.240	L — 70.10
C — 8.128	F — 8.738	J — 1.500	M — 39.54

DIMENSIONS ARE NOMINAL IN INCHES AT ROOM TEMPERATURE

INST. 35359
DATE 4-1-65
REV. 3-1-66

RL10A-3-3
OUTLINE INSTALLATION DRAWING



A — 11.750	D — 9.419	G — 2.876	K — 32.874
B — 10.172	E — 9.603	H — 0.240	L — 67.48
C — 8.128	F — 8.738	J — 1.500	M — 38.67

DIMENSIONS ARE NOMINAL IN INCHES AT ROOM TEMPERATURE

INST. 35378
DATE 4-1-65
REV. 3-1-66

RL10A-3-1
OUTLINE INSTALLATION DRAWING

ENGINE SPECIFICATIONS

Engine Model	Specifications	Curve Number
RL10A-3	2272B	T-1545
RL10A-3-1	2272D	T-1702
RL10A-3-3	2265A	T-1703

The above specifications and curves present the estimated performance of the several versions of the RL10 rocket engine. The performance data presented is based on an altitude of 200,000 feet or above with propellants supplied at specific conditions, rated loading of the accessory drive, and includes total operating ventage rates.

PRATT & WHITNEY AIRCRAFT
Division of United Aircraft Corporation
East Hartford, Connecticut 06108
United States of America

Model — RL10A-3
Spec. No. — 2272B

SUMMARY OF
RL10A-3 LIQUID ROCKET ENGINE SPECIFICATION

ESTIMATED VACUUM PERFORMANCE

Thrust Rating	15000 ± 300 lb
Specific Impulse, Nominal	427 sec
Specific Impulse, Minimum (3σ)	420 sec
Mixture Ratio, Nominal (Factory Setting)	5.0 ± 2.0%
Acceleration Time (From Start to 90% Maximum Thrust)	2 sec maximum
Start Impulse (0 to 95% Thrust and 540° R)	(Centaur) 2750 ± 1000 lb-sec; (Saturn) 3350 ± 1000 lb-sec
Shutdown Time (From Removal of Start Signal to 5% Rated Thrust)	0.15 sec nominal
Shutdown Impulse, Nominal	1300 ± 250 lb-sec
Nominal Running Time	470 sec
Number of Starts During Service Life	20
Service Life	2820 sec
Thrust Vectoring (Gimbal Range)	± 4.0° (square pattern)
Geometric Thrust Axis Location (From Gimbal Point)	± 1/16 in.

DESCRIPTION AND DIMENSIONS

Installation Drawing No. 2044001
Performance Curve No. T-1545

Type — Regeneratively-cooled turbopump-fed liquid-oxygen, liquid-hydrogen rocket engine

Maximum Engine Diameter (at room temperature)	38.8 inches
Maximum Engine Length (at room temperature)	67.6 inches
Maximum Radial Projection from Centerline	20 inches
Fuel Specification, Liquid Hydrogen	Preliminary Specification MIL-P-27201
Oxidizer Specification, Liquid Oxygen	MIL-O-25508A
Helium Specification, Gaseous Helium	Bureau of Mines Type A
Nozzle Area Ratio	40:1
Approximate Center of Gravity	See Installation Drawing

GUARANTEED DRY WEIGHT

Including Standard Equipment, Shall Not Exceed	297.3 lbs

Additional details on page 2

STANDARD EQUIPMENT

Included in Engine Dry Weight

Propellant Control System (Including Thrust Control, Mixture Ratio and Propellant Utilization Valve, Propellant Shutoff Valves, Solenoid-actuated Helium Shutoff Valves)

Engine Gimbal

Fuel and Oxidizer Pumps

Ignition System

Accessory Drives	No. of Drives	AND Type Designation	Rotation Drive End	Torque Rating lb-in.		Rotational Speed	IG Accessory Load	IG Overhung Moment
				Ts	Tc			
Fluid Power Pump	1	AND 20000 Type X-A	Counter-Clockwise	20	20	11,400 rpm	14 lbs	80 in. lb

STANDARD EQUIPMENT

Not Included in Engine Dry Weight

	Saturn	Centaur
Instrumentation Kit, excluding pressure transducers, but including turbopump torque check adapter, probes, sensors, mounting provisions for all instrumentation (including transducers)	33.3	20.3

Brackets required for equipment provided by vehicle contractor.

Nonpropulsive propellant vents.

NOTES

Unless otherwise specified, engines will be supplied with the standard equipment listed above.

The engine requires an estimated 0.044 lb of helium/engine start for pneumatic valve actuation.

The Installation Drawing must be used only to determine the configuration of necessary parts and details of drives.

For special arrangements, consult Pratt & Whitney Aircraft for written recommendations.

The above ratings are based on the use of specified propellants and fluids at the following conditions:

	Centaur	Saturn S-IV
Liquid Hydrogen at	38.8°R, 38.4 psia*	38.5°R, 33 psia*
Liquid Oxygen at	176.6°R, 59.8 psia*	163.5°R, 48.5 psia*
Gaseous Helium at 300°R to 600°R, 470 ± 30 psia		

The engine thrust chamber external temperature limits for starting or restarting are 300°R minimum and 570°R maximum.

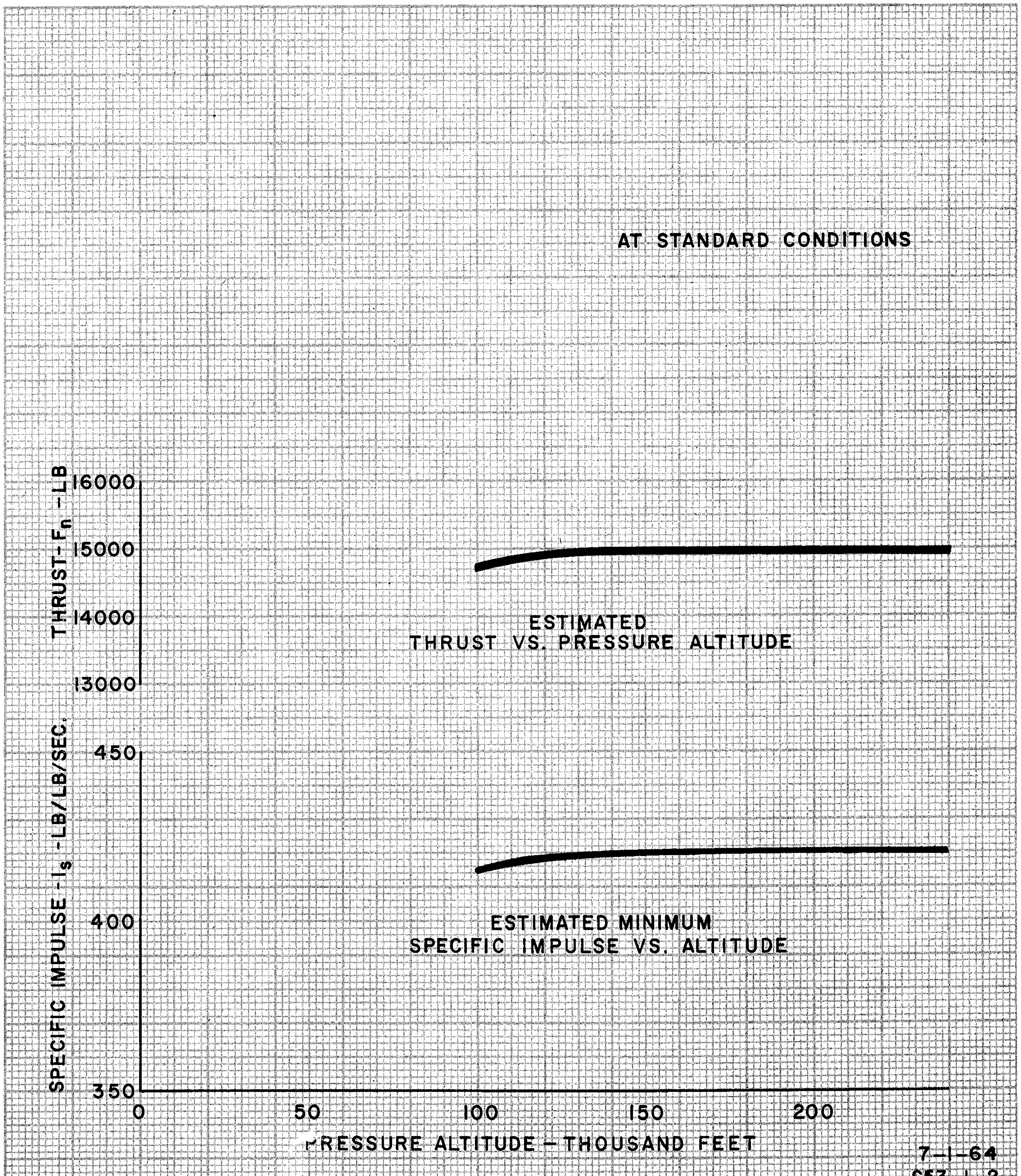
To start and shut down the engine, the solenoids must be maintained between 395°R and 620°R.

*For a particular installation, fuel and oxidizer inlet conditions should be coordinated with Pratt & Whitney Aircraft.

Printed in the United States of America

Subject to change without notice

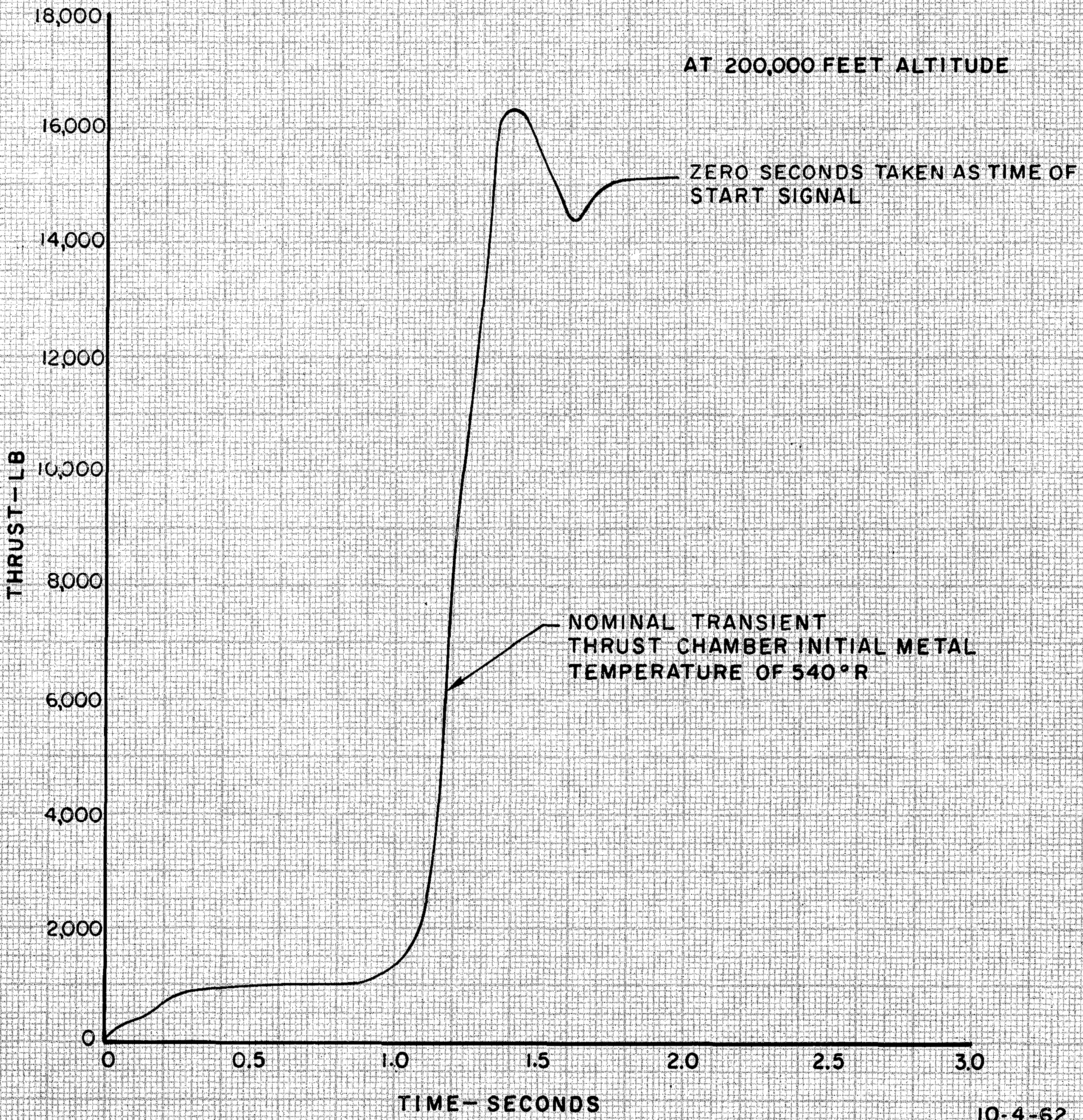
RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED PERFORMANCE
ARDC MODEL ATMOSPHERE - 1959



RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED STARTING TRANSIENT THRUST VS. TIME
ENGINES DESIGNATED FOR USE IN CENTAUR

STANDARD PROPELLANT CONDITIONS AT ENGINE INLET:

	FUEL	OXIDIZER
TEMPERATURE	38.8 °R	176.6 °R
TOTAL PRESSURE	38.4 PSIA	59.8 PSIA



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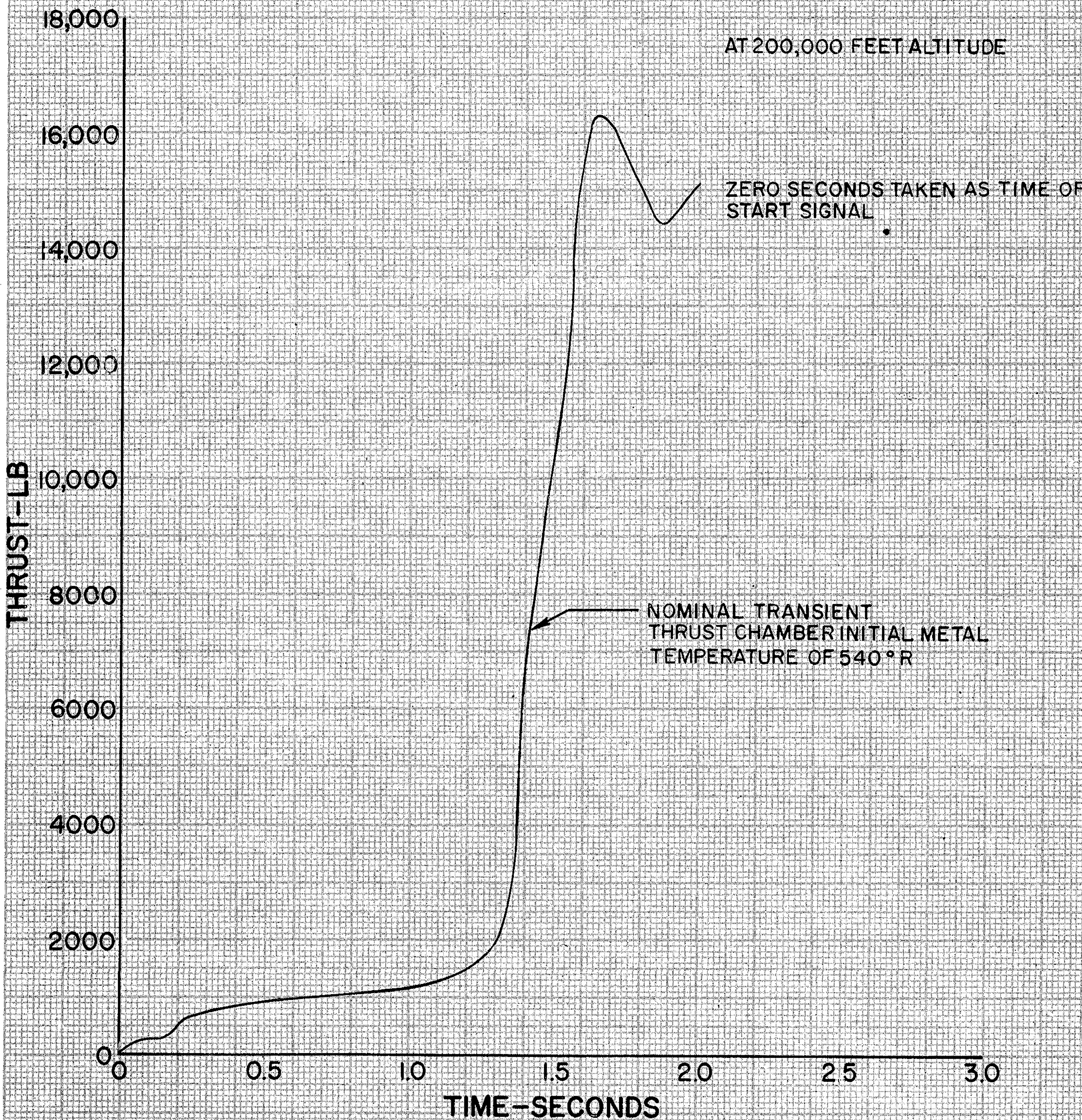
RL10A-3 LIQUID ROCKET ENGINE

ESTIMATED STARTING TRANSIENT THRUST VS. TIME

ENGINES DESIGNATED FOR USE IN SATURN

STANDARD PROPELLANT CONDITIONS AT ENGINE INLET:

	FUEL	OXIDIZER
TEMPERATURE	38.5 °R	163.5 °R
TOTAL PRESSURE	33 PSIA	48.5 PSIA



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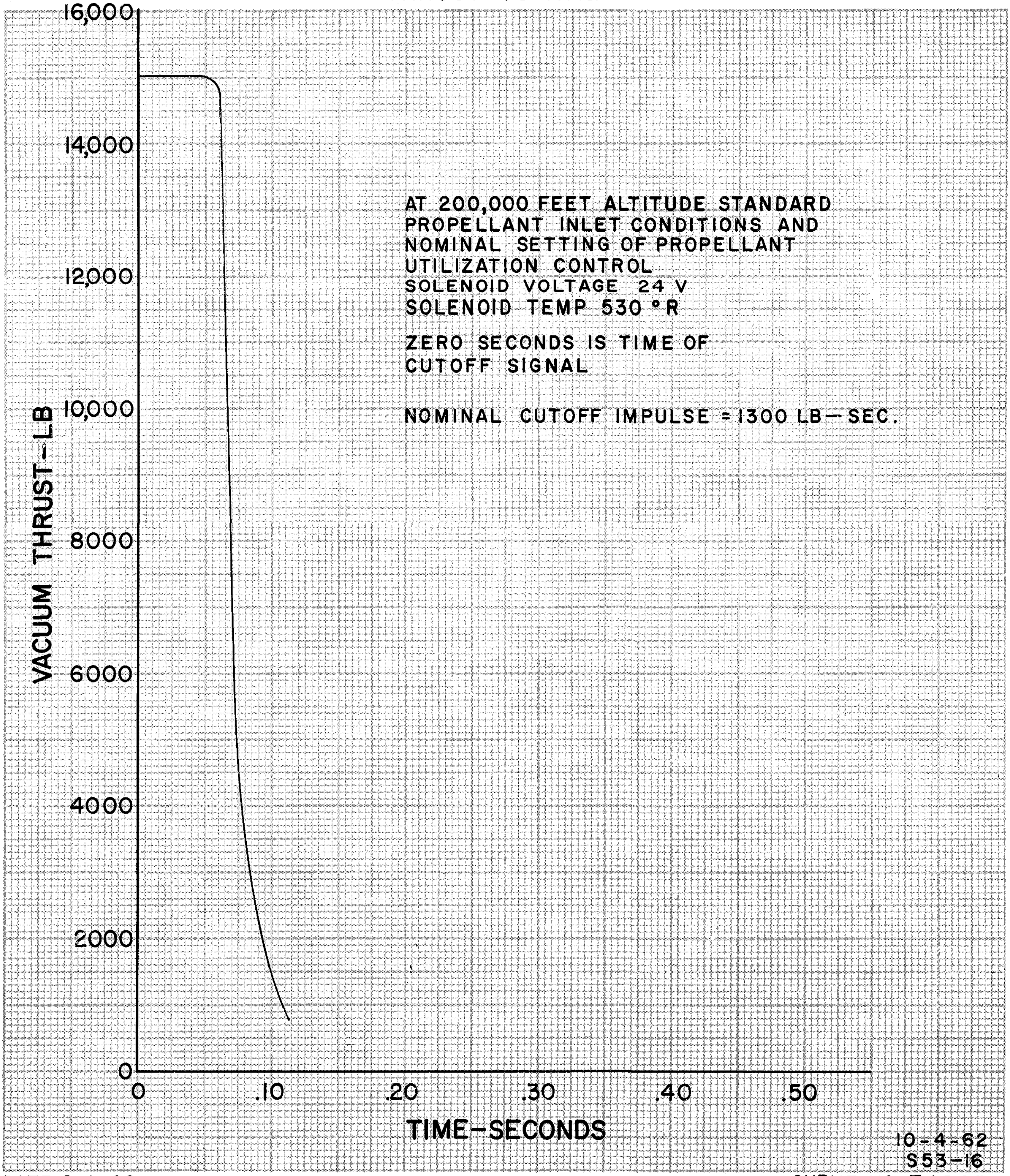
RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED SHUTDOWN TRANSIENT
THRUST VS TIME



PRATT & WHITNEY AIRCRAFT
Division of United Aircraft Corporation
East Hartford, Connecticut 06108
United States of America

Model — RL10A-3-1
Spec. No. — 2272D
Rev. 2

SUMMARY OF
RL10A-3-1 LIQUID ROCKET ENGINE SPECIFICATION

ESTIMATED VACUUM PERFORMANCE

Thrust Rating	15000 ± 300 lb
Specific Impulse, Nominal	433 sec
Specific Impulse, Minimum (3σ)	428 sec
Mixture Ratio, Nominal (Factory Setting)	5.0 ± 2.00%
Acceleration Time (From Start to 90% Rated Thrust)	2 sec maximum
Start Impulse (0 to 95% Thrust and 540° R)	1800 ± 1000 lb-sec
Shutdown Time (From Removal of Start Signal to 5% Rated Thrust)	0.15 sec nominal
Shutdown Impulse, Nominal	1180 ± 150 lb-sec (based on 380 sec run duration)
Mission Start Capability	3 minimum
Nominal Running Time (Cumulative)	470 sec
Service Life	4000 sec
Thrust Vectoring (Gimbal Range)	± 4.0° (square pattern)
Geometric Thrust Axis Location (From Gimbal Point)	± 1/16 in.

DESCRIPTION AND DIMENSIONS

Installation Drawing No. 2074901
Performance Curve No. T-1702

Type — Regeneratively-cooled turbopump-fed liquid-oxygen, liquid-hydrogen rocket engine

Maximum Engine Diameter (at room temperature)	38.8 inches
Maximum Engine Length (at room temperature)	67.6 inches
Maximum Radial Projection from Centerline	20 inches
Fuel Specification, Liquid Hydrogen	Preliminary Specification MIL-P-27201
Oxidizer Specification, Liquid Oxygen	MIL-O-25508A
Helium Specification, Gaseous Helium	Bureau of Mines Type A
Nozzle Area Ratio	40:1
Approximate Center of Gravity	See Installation Drawing

GUARANTEED DRY WEIGHT

Including Standard Equipment, Shall Not Exceed	291.2 lb

Additional details on page 2

STANDARD EQUIPMENT
Included in Engine Dry Weight

Propellant Control System (Including Thrust Control, Mixture Ratio and Propellant Utilization Valve, Propellant Shutoff Valves, Solenoid-actuated Helium Shutoff Valves)

Engine Gimbal

Fuel and Oxidizer Pumps

Ignition System

Accessory Drives	No. of Drives	AND Type Designation	Rotation Drive End	Torque Rating lb-in. Ts	Tc	Rotational Speed
Fluid Power Pump	1	AND 20000 Type X-A	Counter-Clockwise	20	20	11,340 rpm

STANDARD EQUIPMENT
Not Included in Engine Dry Weight

Instrumentation Kit, excluding pressure transducers, but including turbopump torque check adapter, probes, sensors, mounting provisions for all instrumentation (including transducers). 15.1 lbs

Brackets required for equipment provided by vehicle contractor.

Nonpropulsive propellant vents.

NOTES

Unless otherwise specified, engines will be supplied with the standard equipment listed above.

The engine requires an estimated 0.044 lb of helium/engine start for pneumatic valve actuation.

The Installation Drawing must be used only to determine the configuration of necessary parts and details of drives.

For special arrangements, consult Pratt & Whitney Aircraft for written recommendations.

The above ratings, except for start impulse, are based on the use of specific propellants and fluids at the following steady state conditions:

- Liquid Hydrogen at 38.8°R, 38.4 psia total pressure*
- Liquid Oxygen at 176.6°R, 59.8 psia total pressure*
- Gaseous Helium at 300°R to 600°R, 440 to 500 psia

Start impulse rating is based on the following starting conditions:

- Liquid Hydrogen at 40°R, 49 psia total pressure*
- Liquid Oxygen at 180°R, 95 psia total pressure*

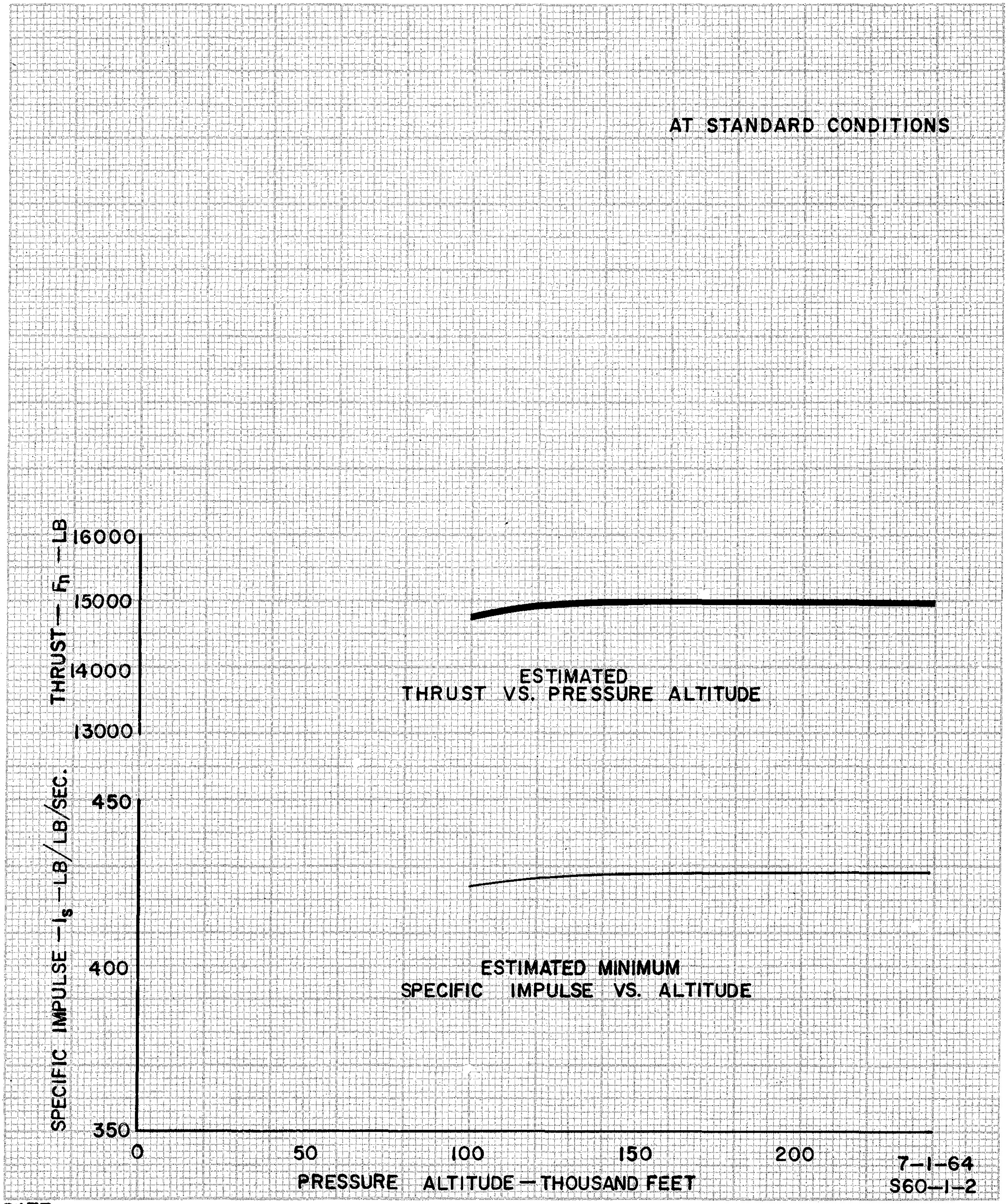
The engine thrust chamber external temperature limits for starting or re-starting are 300°R minimum and 570°R maximum.

To start and shut down the engine, the solenoids must be maintained between 395°R and 620°R.

*For a particular installation, fuel and oxidizer inlet conditions should be coordinated with Pratt & Whitney Aircraft.

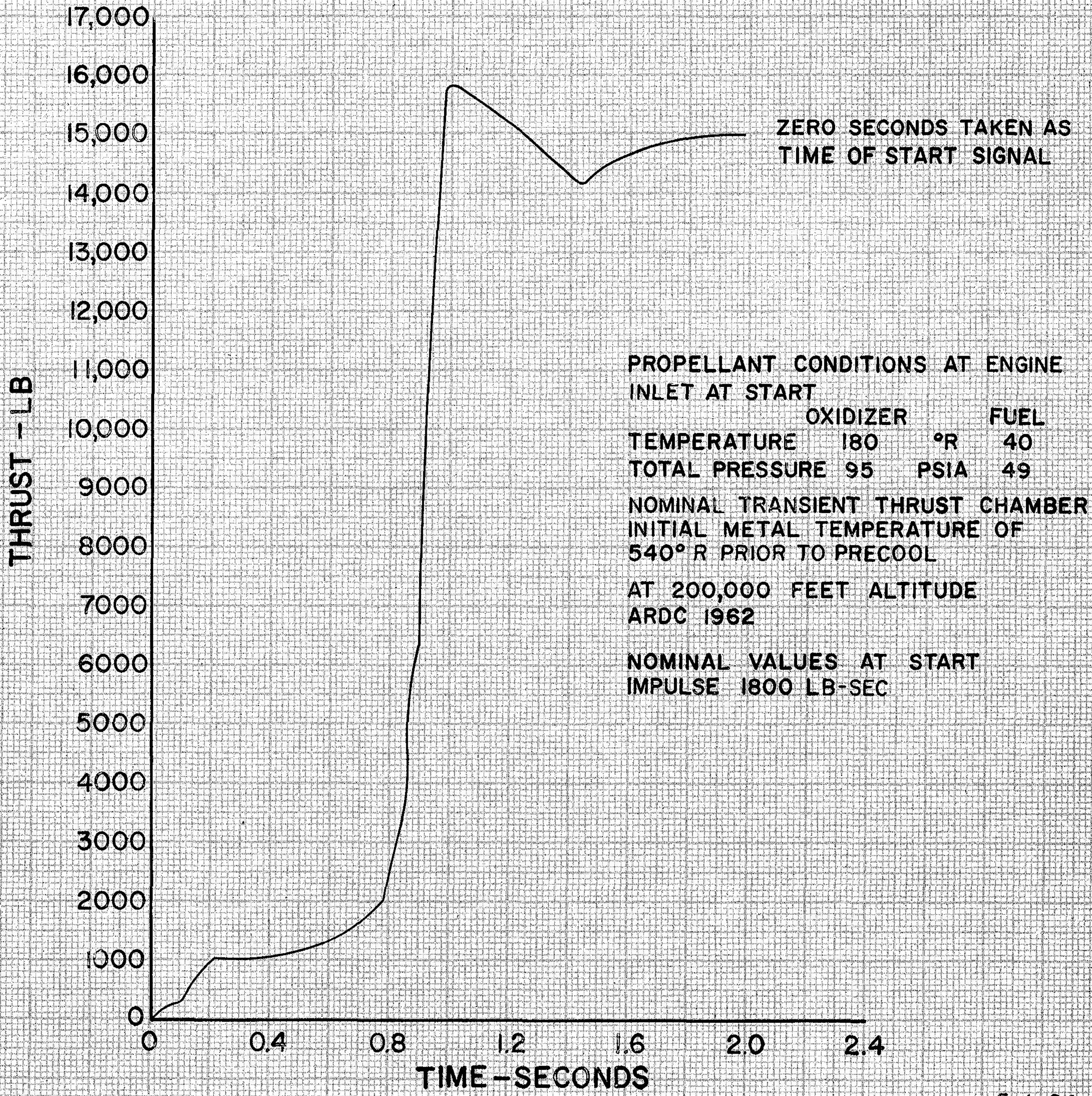
Printed in the United States of America

RL10A-3-1 LIQUID ROCKET ENGINE
ESTIMATED PERFORMANCE
ARDC MODEL ATMOSPHERE – 1962

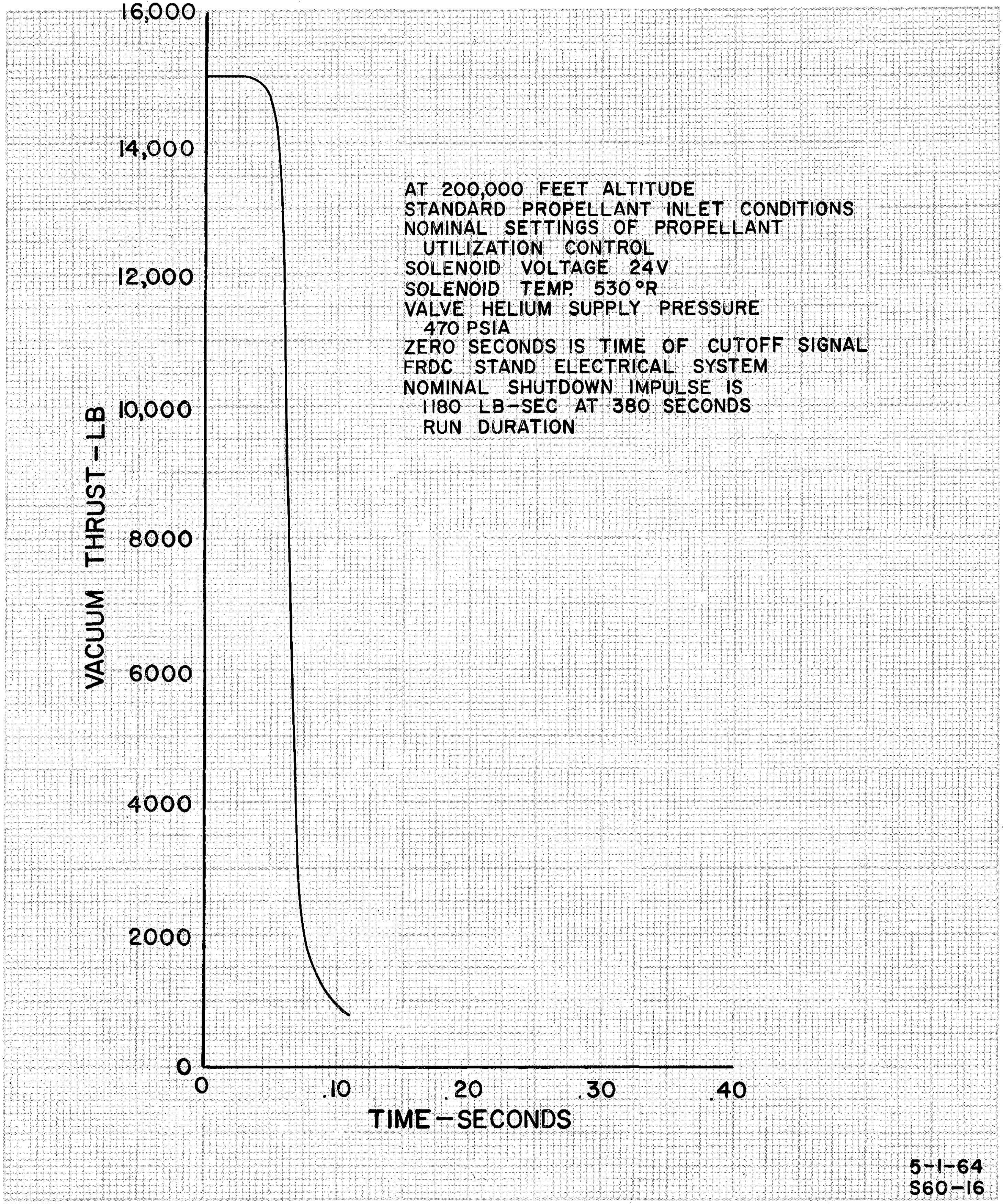


RL10A-3-1 LIQUID ROCKET ENGINE

ESTIMATED STARTING TRANSIENT
THRUST VS TIME



RL10A-3-1 LIQUID ROCKET ENGINE
ESTIMATED SHUTDOWN TRANSIENT
THRUST VS TIME



PRATT & WHITNEY AIRCRAFT
Division of United Aircraft Corporation
East Hartford, Connecticut 06108
United States of America

Model — RL10A-3-3
Spec. No. — 2265A
Rev. 1

SUMMARY OF
RL10A-3-3 LIQUID ROCKET ENGINE SPECIFICATION

ESTIMATED VACUUM PERFORMANCE

Thrust Rating	15000 ± 300 lb
Specific Impulse, Nominal	444 sec
Specific Impulse, Minimum (3σ)	439 sec
Mixture Ratio, Nominal (Factory Setting)	5.0 ± 2.00%
Acceleration Time (From Start to 90% Rated Thrust)	2 sec maximum
Start Impulse (To 2 sec from Start and 540°R)	14,200 ± 4000 lb-sec
Shutdown Time (From Removal of Start Signal to 5% Rated Thrust)	0.15 sec maximum
Shutdown Impulse	1180 ± 150 lb-sec (based on 380 sec run duration)
Mission Start Capability	3 minimum
Nominal Running Time per Start	450 sec
Service Life	4000 sec
Thrust Vectoring (Gimbal Range)	± 4.0° (square pattern)
Geometric Thrust Axis Location (From Gimbal Point)	± 1/16 in.

DESCRIPTION AND DIMENSIONS

Installation Drawing No. 2111501
Performance Curve No. T-1703

Type — Regeneratively-cooled turbopump-fed liquid-oxygen, liquid-hydrogen rocket engine

Maximum Engine Diameter (at room temperature)	39.67 inches
Maximum Engine Length (at room temperature)	70.23 inches
Maximum Radial Projection from Centerline	20.25 inches
Fuel Specification, Liquid Hydrogen	Preliminary Specification MIL-P-27201
Oxidizer Specification, Liquid Oxygen	MIL-O-25508A
Helium Specification, Gaseous Helium	Bureau of Mines Type A
Nozzle Area Ratio	57:1
Approximate Center of Gravity	See Installation Drawing

GUARANTEED DRY WEIGHT

Including Standard Equipment, Shall Not Exceed	290.0 lbs

Date: 4-16-64
Rev: 2-1-66

Additional details on page 2

STANDARD EQUIPMENT
Included in Engine Dry Weight

Propellant Control System (Including Thrust Control, Mixture Ratio and Propellant Utilization Valve, Propellant Shutoff Valves, Solenoid-actuated Helium Shutoff Valves)

Engine Gimbal

Fuel and Oxidizer Pumps

Ignition System

Accessory Drives	No. of Drives	AND Type Designation	Rotation Drive End	Torque Rating lb.in. Ts	Torque Rating lb.in. Tc	Rotational Speed
Fluid Power Pump	1	AND 20000 Type X-A	Counter-Clockwise	20	20	12,000 rpm

STANDARD EQUIPMENT
Not Included in Engine Dry Weight

Instrumentation Kit, excluding pressure transducers, but including temperature and pressure probes, sensors, mounting provisions for all instrumentation (including transducers). 11.5 lbs

Brackets required for equipment provided by vehicle contractor.

Nonpropulsive vents.

NOTES

Unless otherwise specified, engines will be supplied with the standard equipment listed above.

The engine requires an estimated 0.044 lb of helium/engine start for pneumatic valve actuation.

The Installation Drawing must be used only to determine the configuration of necessary parts and details of drives.

For special arrangements, consult Pratt & Whitney Aircraft for written recommendations.

The above ratings are based on the use of specified propellants and fluids at the following conditions:

Liquid Hydrogen at 38.3°R, 30.0 psia*

Liquid Oxygen at 175.3°R, 60.5 psia*

Gaseous Helium at 300°R to 600°R, 440 to 500 psia

The engine thrust chamber external temperature limits for starting or re-starting are 250°R minimum and 570°R maximum.

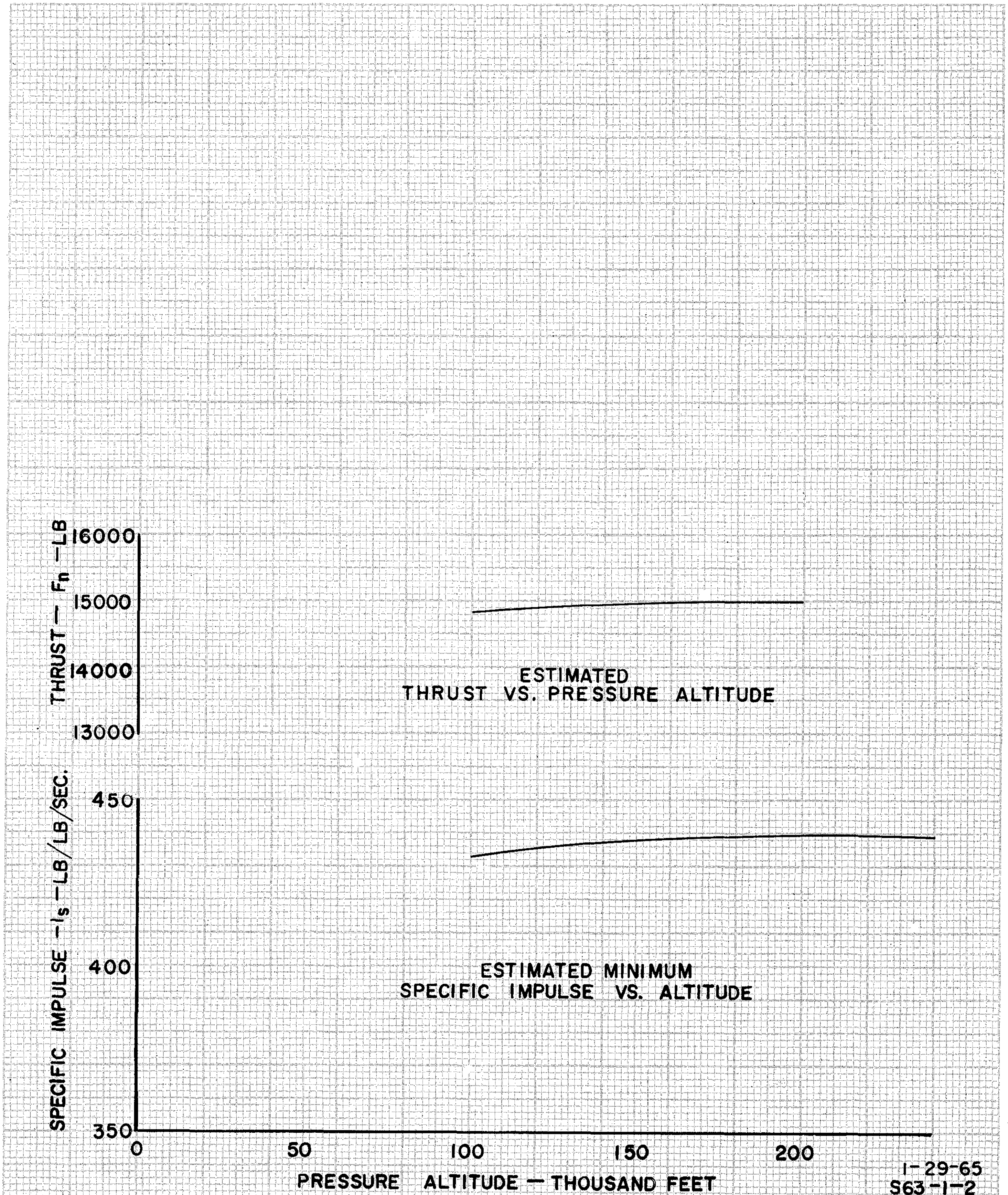
To start and shut down the engine, the solenoids must be maintained between 395°R and 620°R.

*For a particular installation, fuel and oxidizer inlet conditions should be coordinated with Pratt & Whitney Aircraft.

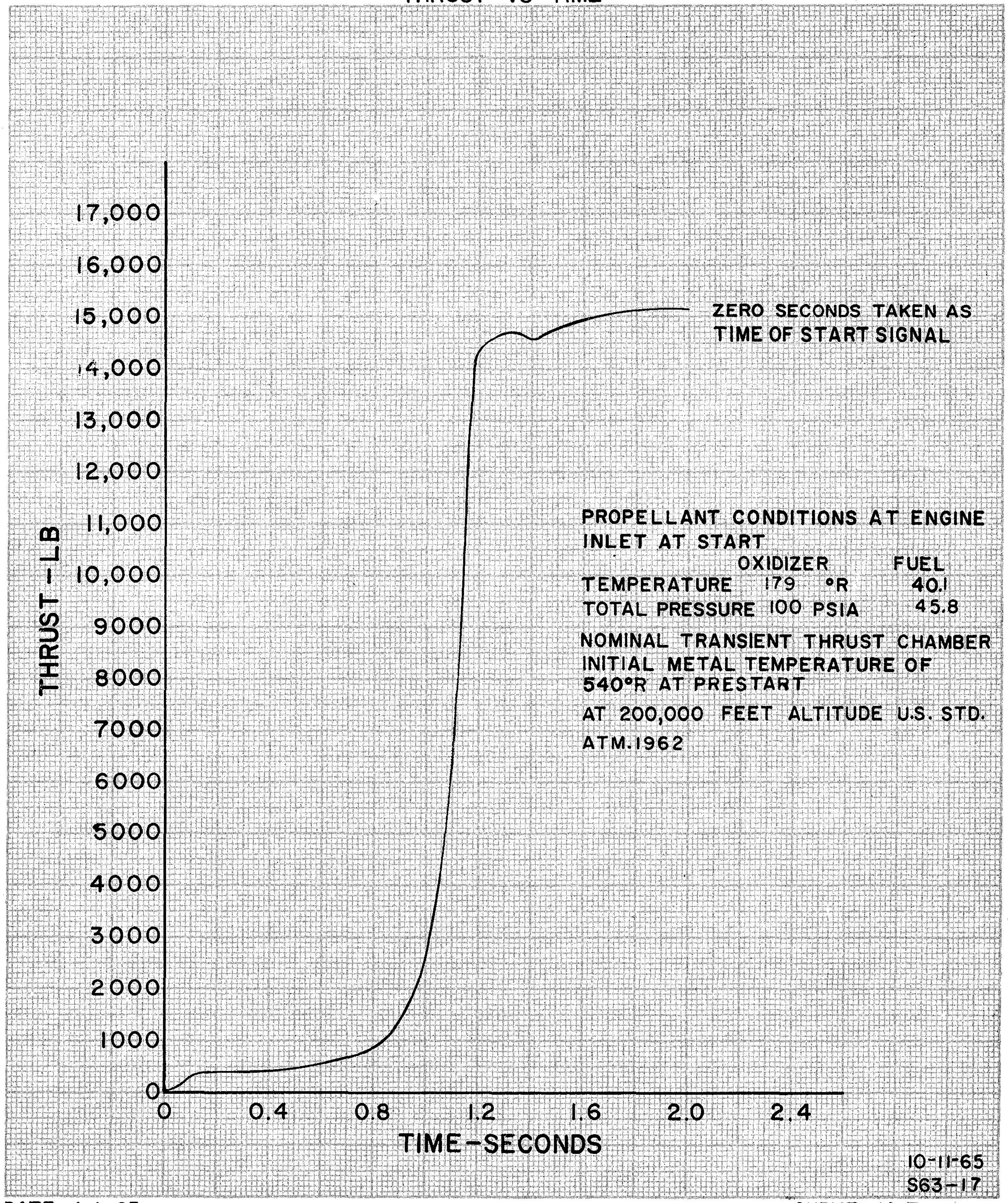
RL10A-3-3 LIQUID ROCKET ENGINE

ESTIMATED PERFORMANCE

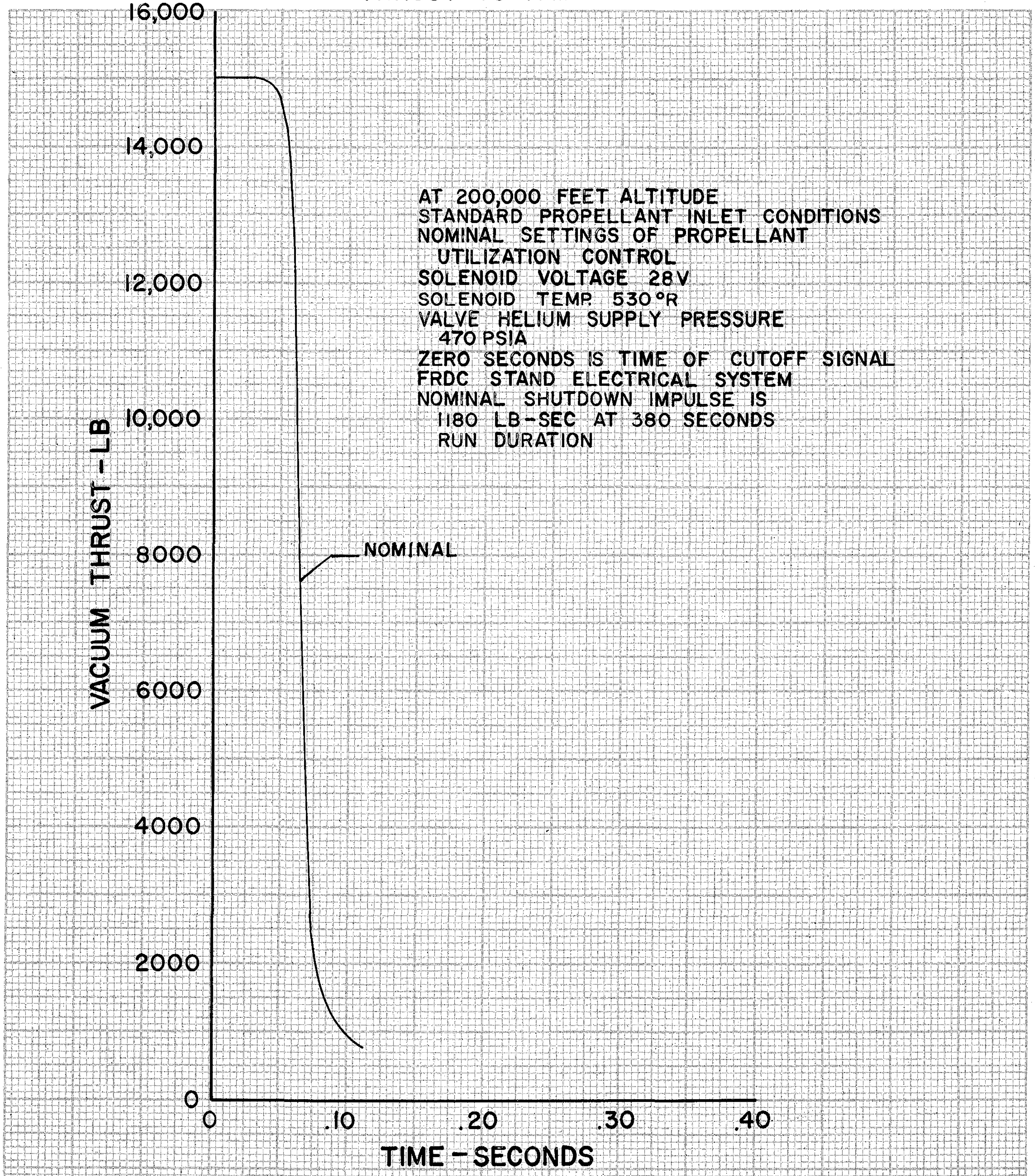
U.S. STANDARD ATMOSPHERE —1962



RL10A-3-3 LIQUID ROCKET ENGINE
ESTIMATED STARTING TRANSIENT
THRUST VS TIME



RL10A-3-3 LIQUID ROCKET ENGINE
ESTIMATED SHUTDOWN TRANSIENT
THRUST VS TIME



8-25-65
S63-21

PERFORMANCE CALCULATIONS

The performance of the RL10 engines at vacuum conditions is influenced by variations from specification values in the pressure and temperature of the propellants supplied to the pumps. The estimated effect of the variation of a single parameter on mixture ratio with the propellant utilization control at nominal setting are shown in:

Curves No. Inst. 30500, 30501, 30502, and 30503 for the RL10A-3 engines

Curves No. Inst. 35339, 35340, 35341, and 35342 for the RL10A-3-1 engines

Curves No. Inst. 35502, 35503, 35504, and 35505 for the RL10A-3-3 engines

The estimated mixture ratio resulting from the variation of more than one inlet parameter is determined from:

$$\frac{r}{r_{nominal}} = \left(\frac{r_{OPIP}}{r_{nominal}}\right)\left(\frac{r_{OPIT}}{r_{nominal}}\right)\left(\frac{r_{FPIP}}{r_{nominal}}\right)\left(\frac{r_{FPIT}}{r_{nominal}}\right)$$

where: OPIP is Oxidizer Pump Inlet Total Pressure in psia

OPIT is Oxidizer Pump Inlet Total Temperature in $^\circ R$

FPIP is Fuel Pump Inlet Total Pressure in psia

FPIT is Fuel Pump Inlet Total Temperature in $^\circ R$

The estimated effect of mixture ratio on thrust and specific impulse is shown in applicable Curves No. Inst. 30504, 35343, and 35506. These curves also give estimated thrust and specific impulse for propellants at specification inlet conditions and a varying mixture ratio produced by a varying propellant utilization valve setting.

Where more exact calculations of the effect of propellant inlet conditions and utilization valve settings on engine performance are required, the regression equations given herein may be used.

TRIM REGRESSION EQUATIONS
FOR RL10 ENGINES

These regression equations are used for determination of the percent nominal mixture ratio, percent nominal thrust, and percent nominal specific impulse within a given range of inlet conditions and propellant utilization valve angles.

One general form equation is used for the three desired values. To obtain a particular item, the constants listed in Tables I, II, and III for the RL10A-3, RL10A-3-1, and RL10A-3-3 engines, respectively, must be used. The general form equation is as follows:

$$
\begin{aligned}
Y_r, Y_F, Y_I = {} & C_O + C_1 (FPIP) + C_2 (OPIP) + C_3 (FPIT) \\
& + C_4 (FPIT)^{1/2} + C_5 (OPIT) + C_6 (K) \\
& + C_7 (K)^{1/2} + C_8 (K)^{-1/2} + C_9 (FPIP)(K) \\
& + C_{10} \left[(FPIP)(K)\right]^{1/2} + C_{11} (K)/(OPIP) \\
& + C_{12} (FPIT)(K) + C_{13} (K/FPIT) \\
& + C_{14} \left[(OPIT)(K)\right]^{-1/2} + C_{15} \left[(FPIP)(K)/(OPIP)\right]^{1/2} \\
& + C_{16} (FPIP)(K)/(FPIT) + C_{17} \left[(FPIP)(K)(OPIT)\right]^{1/2} \\
& + C_{18} (K)/(OPIP)(FPIT) + C_{19} (K)/\left[(OPIP)(OPIT)\right] \\
& + C_{20} \left[(OPIT)(K)/(OPIP)\right]^{1/2}
\end{aligned}
$$

where:

Y_r = Percent nominal mixture ratio = $\dfrac{\text{mixture ratio}}{\text{nominal mixture ratio}} \times 100\%$

Y_F = Percent nominal thrust = $\dfrac{\text{thrust}}{\text{nominal thrust}} \times 100\%$

Y_I = Percent nominal specific impulse

= $\dfrac{\text{specific impulse}}{\text{nominal specific impulse}} \times 100\%$

K = Propellant Utilization Valve Angle Factor

The value of "K" is determined as a function of propellant utilization valve angle in the following equations:

$$K_1 = A_0 + A_1 \alpha + A_2 \alpha^2 + A_3 \alpha^3 + A_4 \alpha^4 + \Delta K \alpha$$

$$K_2 = B_0 + B_1 \alpha + B_2 \alpha^2 + \Delta K \alpha$$

where:

K_1 = Propellant Utilization Valve Angle factor for angles equal to or less than zero degrees.

K_2 = Propellant Utilization Valve Angle factor for angles greater than zero degrees.

α = Propellant Utilization Valve Angle in degrees.

ΔK = Individual engine variation from nominal propellant utilization valve angle factor. For nominal engine characteristics, the value of ΔK should be set to zero.

The values of the constants used in these equations are as follows:

Constant	RL10A-3S	RL10A-3C	RL10A-3-1	RL10A-3-3
A_0	9.4323	8.5861	9.3035	***
A_1	0.090828	0.090828	0.090828	***
A_2	0.00021357	0.00021357	0.00021357	***
A_3	-0.00001262	-0.00001262	-0.00001262	***
A_4	-0.0000001089	-0.0000001089	-0.0000001089	***
B_0	9.4323	8.5861	9.3035	***
B_1	0.095465	0.095465	0.095465	***
B_2	-0.00024019	-0.00024019	-0.00024019	***
ΔK	*	*	*	**

* Values available upon request for each engine

** Values to be provided for each engine on the P-60 form

*** To be supplied

The nominal inlet conditions are as follows:

	RL10A-3S	RL10A-3C	RL10A-3-1	RL10A-3-3
FPIP, psia	33	38.4	38.4	30.0
OPIP, psia	48.5	59.8	59.8	60.5
FPIT, °R	38.5	38.8	38.8	38.3
OPIT, °R	163.5	176.6	176.6	175.3

The regression equations defined by the constants in Tables I, II, and III are valid over the following range of the required propellant inlet conditions shown in Section 5, Inst. Curves No. 30505, 35346, 35347, 30506, 35348, and 35349:

	RL10A-3S	RL10A-3C	RL10A-3-1	RL10A-3-3
FPIP, psia	28.0 to 40.0	30.0 to 42.0	30.0 to 46.0	*
OPIP, psia	40.0 to 65.0	41.0 to 80.0	41.0 to 80.0	*
FPIT, °R	36.5 to 40.5	37.5 to 41.5	37.5 to 41.5	*
OPIT, °R	162.0 to 172.0	173.0 to 185.0	173.0 to 185.0	*

* To be supplied

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TABLE I - RL10A-3 REGRESSION EQUATION CONSTANTS

Constant	Percent Mixture Ratio		Percent Thrust		Percent Specific Impulse	
	Saturn	Centaur	Saturn	Centaur	Saturn	Centaur
C_0	569.25798	401.76414	93.152620	145.42012	62.886704	80.28710
C_1	-0.290155	-.38675408	0.	0.	.045548147	.04249788
C_2	0.2311698	.21605280	.054539698	.027877564	0.	0.
C_3	14.925431	8.8237498	.45972195	.34266203	-1.5189968	-.38217556
C_4	-151.81550	-76.820194	0.	0.	14.120808	0.
C_5	0.	0.	.12863454	0.	0.	0.
C_6	2.5402870	0	1.1920656	3.2255006	.57280947	0.
C_7	-24.665024	-50.506752	-9.7990853	-22.153724	0.	9.1634542
C_8	-385.18450	-437.09394	-176.94826	-121.22685	33.221892	71.393981
C_9	0.	0.	.0062183117	0.	0.	-.00280165
C_{10}	0.	5.3208642	0.	1.7726874	0.	0.
C_{11}	162.11991	376.66752	0.	169.65460	-55.985681	-85.769416
C_{12}	-0.063294	0.	-.011302331	-.034337026	0.	0.
C_{13}	0.	112.38630	0.	0.	-16.423958	-35.590925
C_{14}	4687.8142	4653.1916	2080.4271	1053.8834	-512.61698	-675.35881
C_{15}	0.	0.	0.	-5.07886	0.	0.
C_{16}	0.42640	0.	0.	0.	-.12899405	0.
C_{17}	0.	-.33862338	-.021234689	-.091392693	0.	0.
C_{18}	0.	0.	959.23560	-2363.1515	-681.6966	0.
C_{19}	-9228.9076	-46941.992	0.	-13758.492	7089.6080	9500.7129
C_{20}	-8.2948326	-8.270695	-1.5806411	0.	2.5337902	2.4668132

TABLE II - RL10A-3-1 Regression Equation Constants

Constant	Percent Mixture Ratio	Percent Thrust	Percent Specific Impulse
C_0	401.70126	145.36654	80.307585
C_1	-.38675408	0.	.042119788
C_2	.2160528	.027877564	0.
C_3	8.8237498	.34266203	-.38217556
C_4	-76.820194	0.	0.
C_5	0.	0.	0.
C_6	0.	2.976779	0.
C_7	-48.5203719	-21.282440	8.8030647
C_8	-454.98725	-126.18951	74.316636
C_9	0.	0.	-.00258561
C_{10}	5.1115999	1.7029694	0.
C_{11}	347.62231	156.57236	-79.155651
C_{12}	0.	-.031689264	0.
C_{13}	103.72008	0.	-32.846473
C_{14}	4843.6793	1097.0262	-703.00597
C_{15}	0.	-4.8791135	0.
C_{16}	0.	0.	0.
C_{17}	-.32530566	-.087798309	0.
C_{18}	0.	-2180.9265	0.
C_{19}	-43322.248	-12697.561	8768.103
C_{20}	-7.9454168	0.	2.3697959

TABLE III - RL10A-3-3 Regression Equation Constants

Constant	Percent Mixture Ratio	Percent Thrust	Percent Specific Impulse
C_0			
C_1			
C_2			
C_3			
C_4			
C_5			
C_6	VALUES		
C_7	TO BE		
C_8			
C_9	SUPPLIED		
C_{10}			
C_{11}			
C_{12}			
C_{13}			
C_{14}			
C_{15}			
C_{16}			
C_{17}			
C_{18}			
C_{19}			
C_{20}			

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ROCKET ENGINE SYMBOLS

The following symbols are used in rocket engine performance calculations:

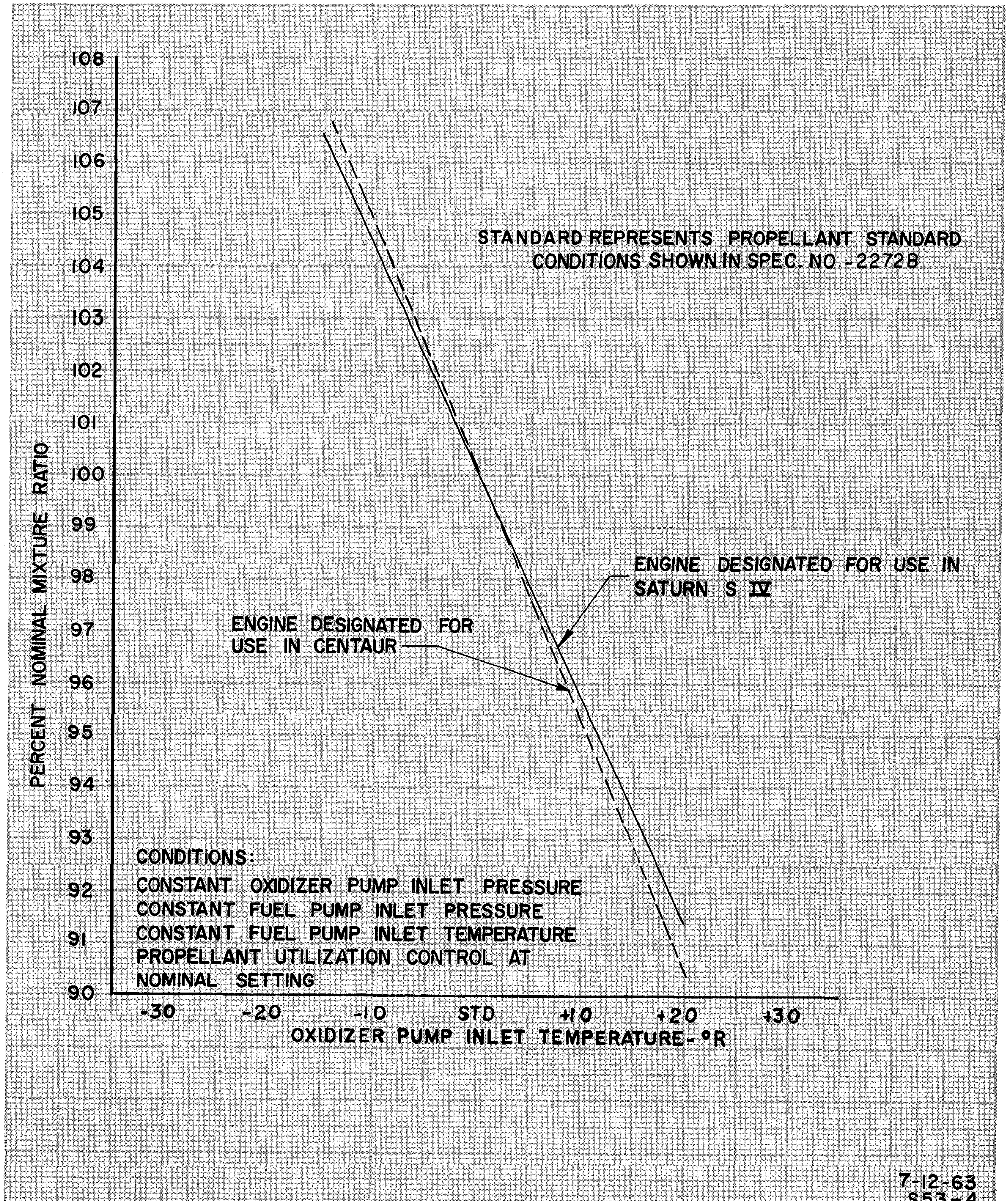
Symbol	Identity	Units
A_d	design area ratio	
A_e	nozzle exit area	in.^{2}
A_t	throat area	in.^{2}
C_s	stream thrust coefficient (ratio of actual to ideal vacuum thrust coefficient)	
C_f	thrust coefficient	
c	effective exhaust velocity	ft/sec
c*	characteristic velocity	ft/sec
D_e	nozzle exit diameter	in.
D_t	nozzle throat diameter	in.
ϵe	A_e/A_t	
F	thrust	
g	conversion factor between mass and weight	32.174 ft/sec^2
$\eta_c{}^*$	characteristic velocity efficiency	
Δh	turbopump head rise	ft
h_{sv}	turbopump suction head above vapor pressure	ft

Symbol	Identity	Units
I_s	specific impulse	sec or lb/lb/sec
L^*	characteristic chamber length	in.
M	Mach number	
N	turbopump speed	rpm
N_s	turbopump specific speed parameter	
S	turbopump suction specific speed parameter	
r	mixture ratio (oxidizer mass to fuel mass)	
P_{amb}	ambient pressure	psia
P_c	chamber pressure	psia
P_{se}	nozzle exit static pressure	psia
P_{te}	nozzle exit total pressure	psia
Q	volume flow rate	gal/min
T_c	combustion chamber temperature	$^{\circ}R$
V_c	combustion chamber volume (measured in chamber throat)	$in.^3$
v_e	actual exhaust velocity at discharge plane	ft/sec
$\dot{W}_f$	fuel flow rate	lb/sec
$\dot{W}_o$	oxidizer flow rate	lb/sec
$\dot{W}_p$	propellant flow rate	lb/sec
W_G	stage overall gross weight	lb
W_H	stage hardware weight	lb

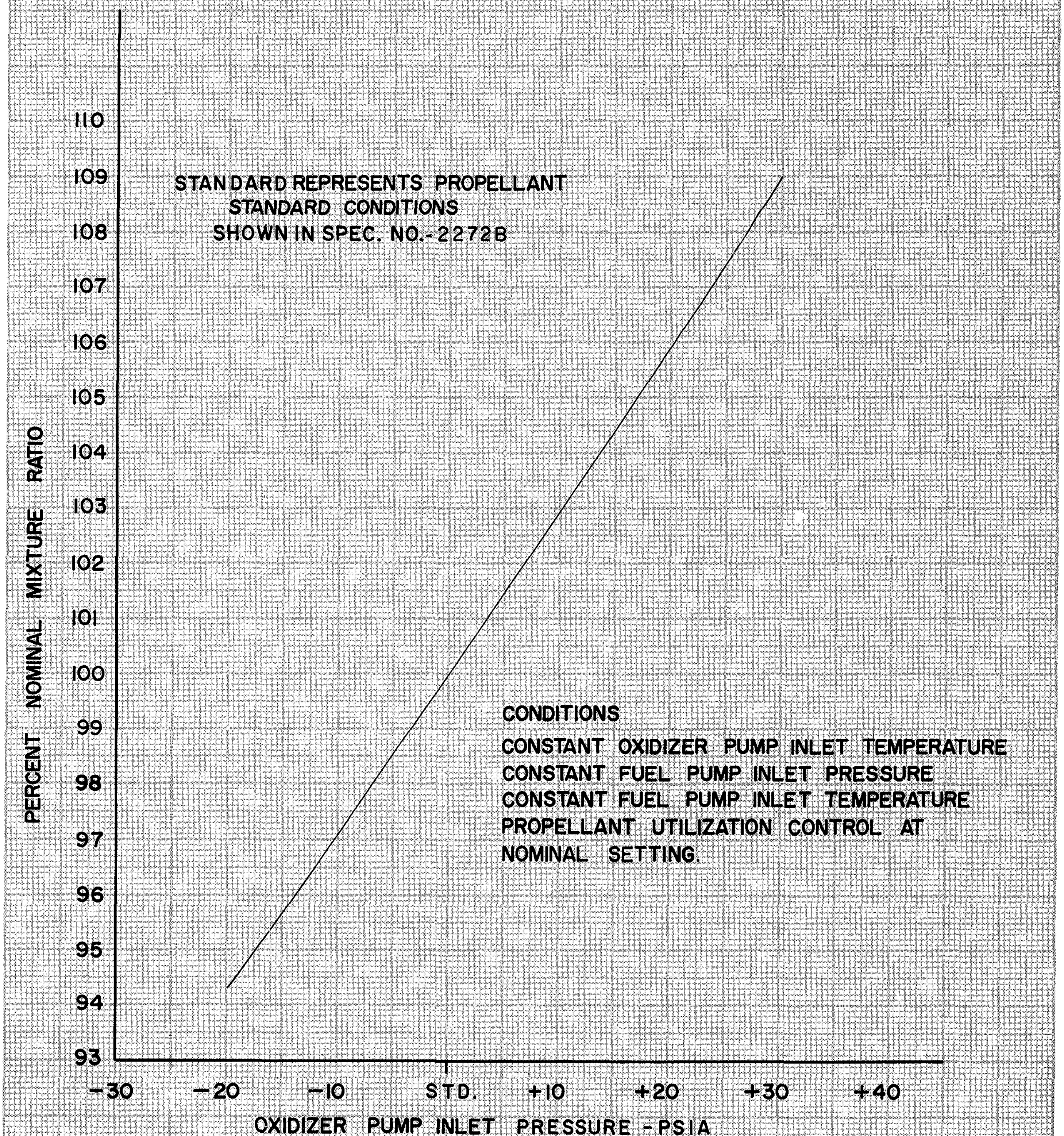
Symbol	Identity	Units
W_P	stage propellant weight	lb
W_{PL}	stage payload weight	lb
ρ_b	propellant bulk density	$lb/in.^3$ or lb/ft^3

RL10A-3 LIQUID ROCKET ENGINE

ESTIMATED EFFECT OF OXIDIZER PUMP INLET TEMPERATURE ON MIXTURE RATIO



RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF OXIDIZER PUMP INLET PRESSURE ON MIXTURE RATIO

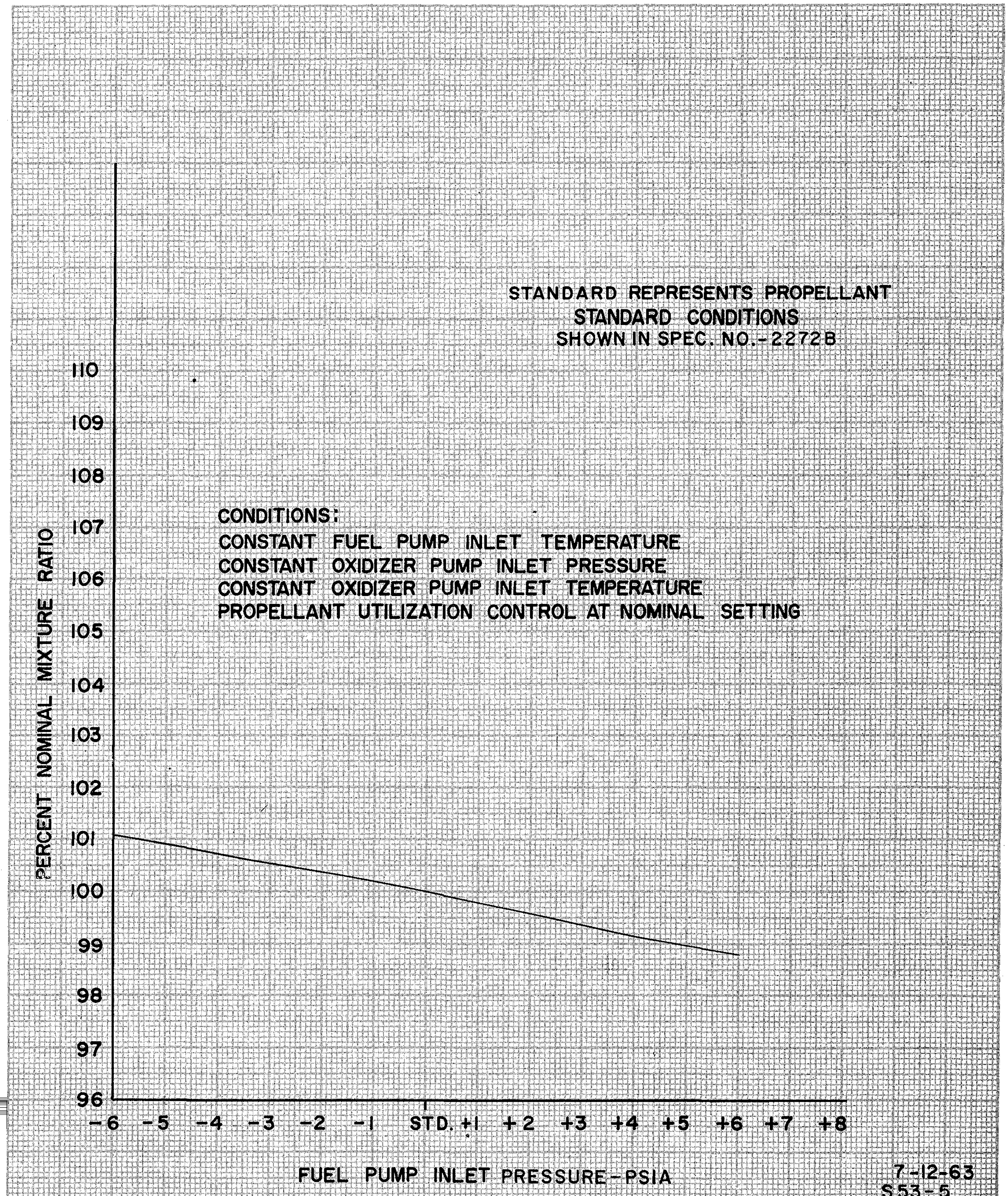


7-12-63
S53-3

DATE 8-3-61
REV 3-1-66

CURVE NO. INST. 30501

RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF FUEL PUMP INLET PRESSURE ON MIXTURE RATIO

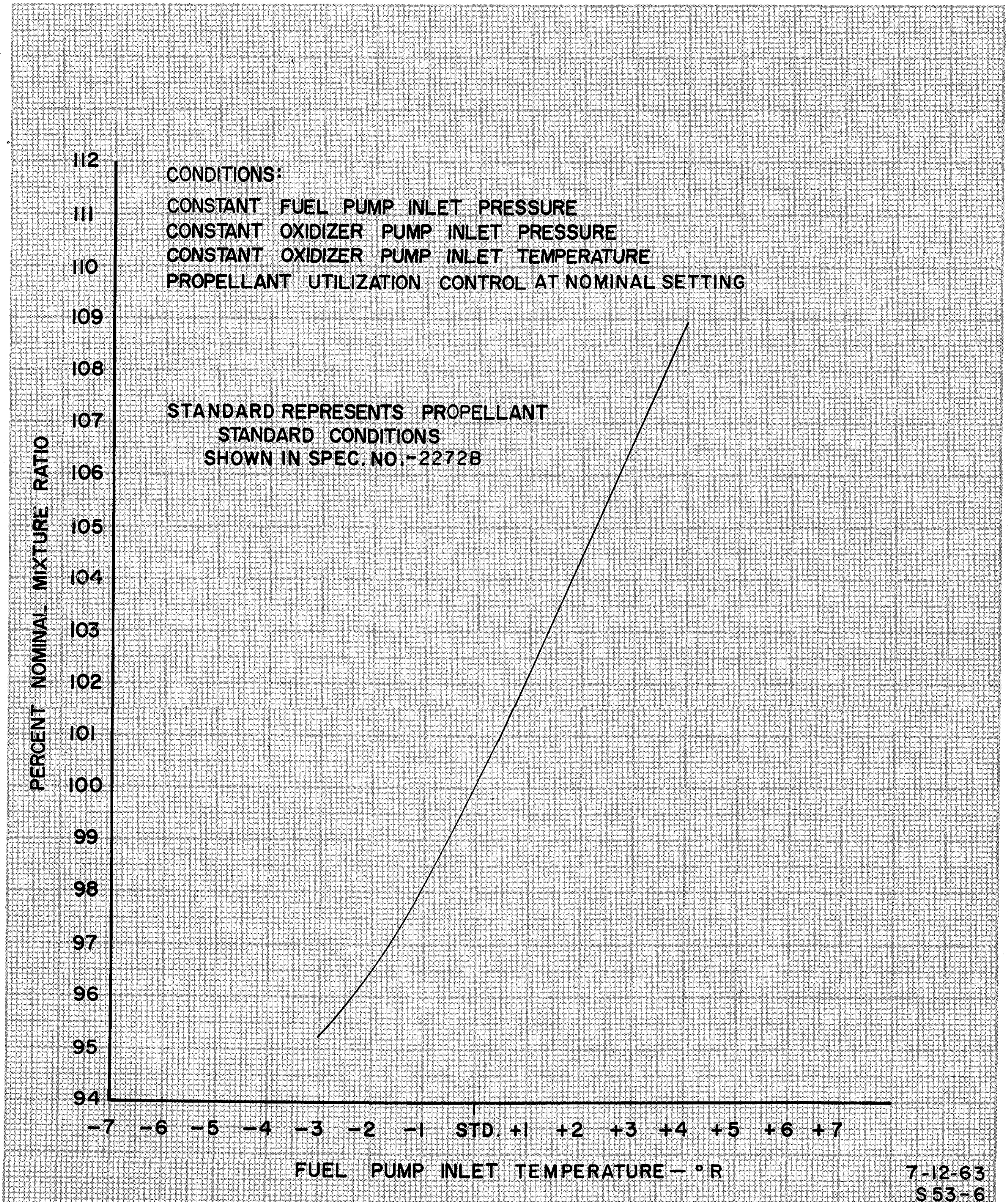


DATE 8-3-61
REV 3-1-66

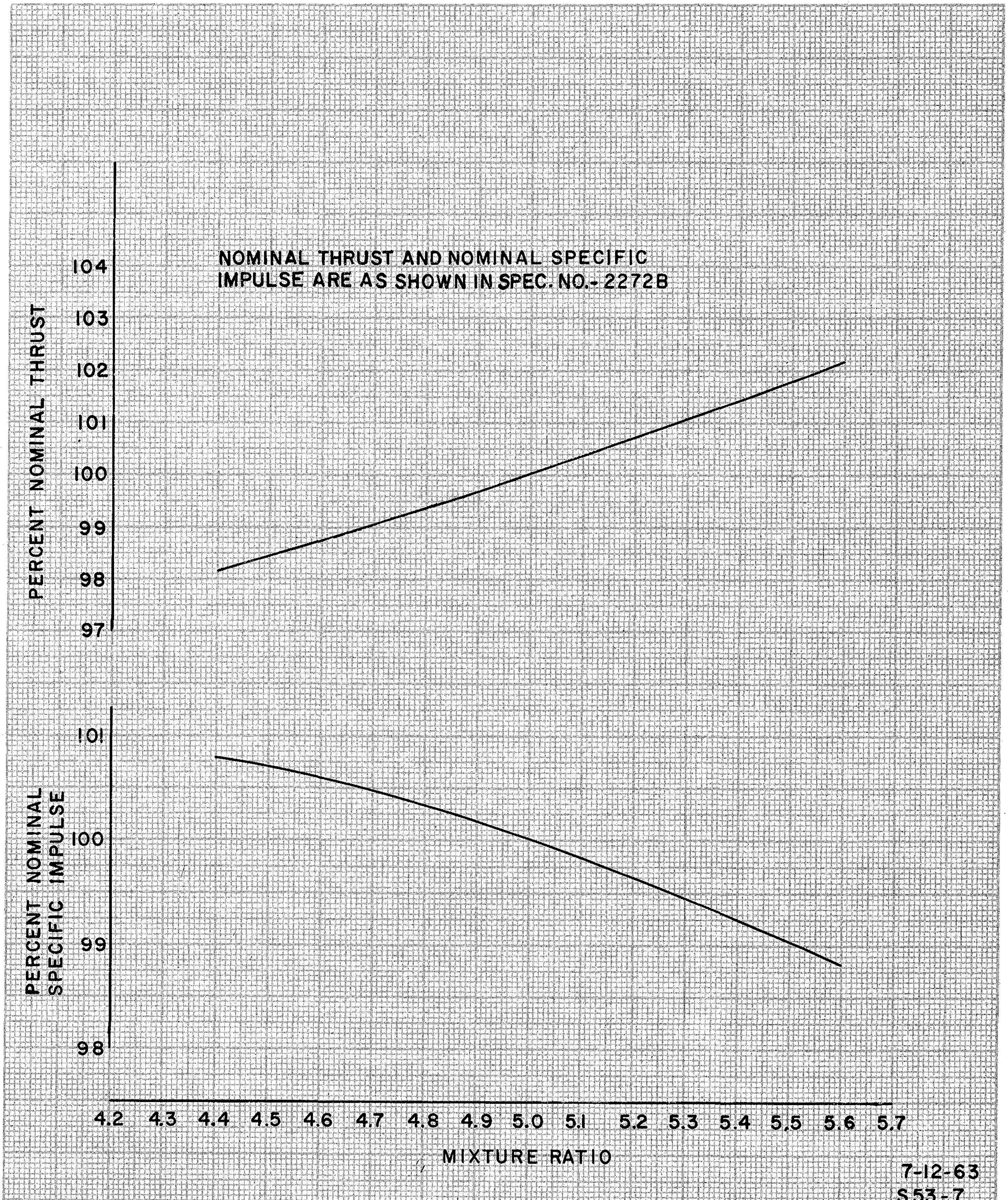
CURVE NO INST 30502

RL10A-3 LIQUID ROCKET ENGINE

ESTIMATED EFFECT OF FUEL PUMP INLET TEMPERATURE ON MIXTURE RATIO



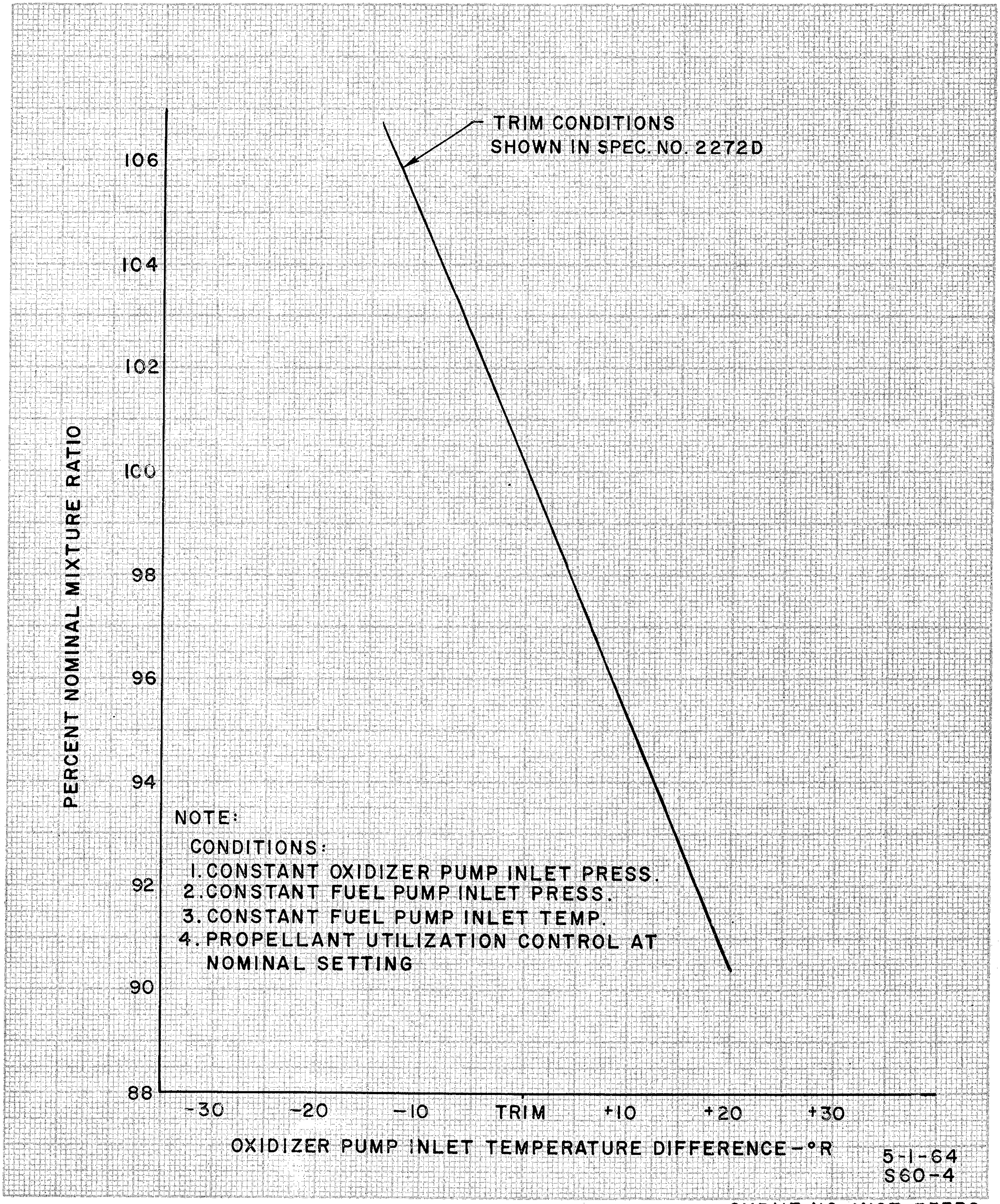
RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF MIXTURE RATIO ON THRUST AND SPECIFIC IMPULSE



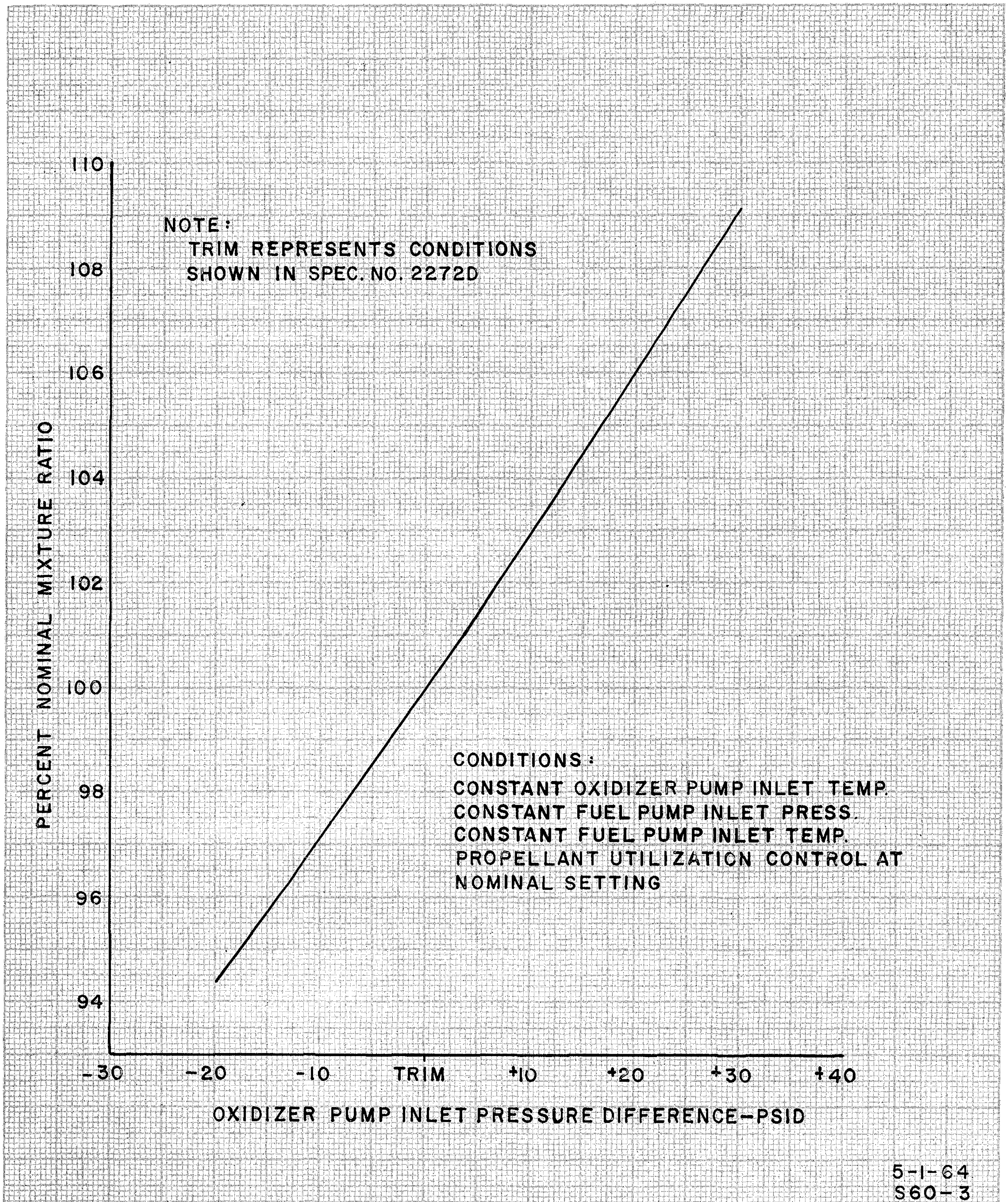
DATE 4-15-63
REV 3-1-66

CURVE NO. INST 30504

RL10A-3-1 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF OXIDIZER PUMP INLET TEMPERATURE ON MIXTURE RATIO



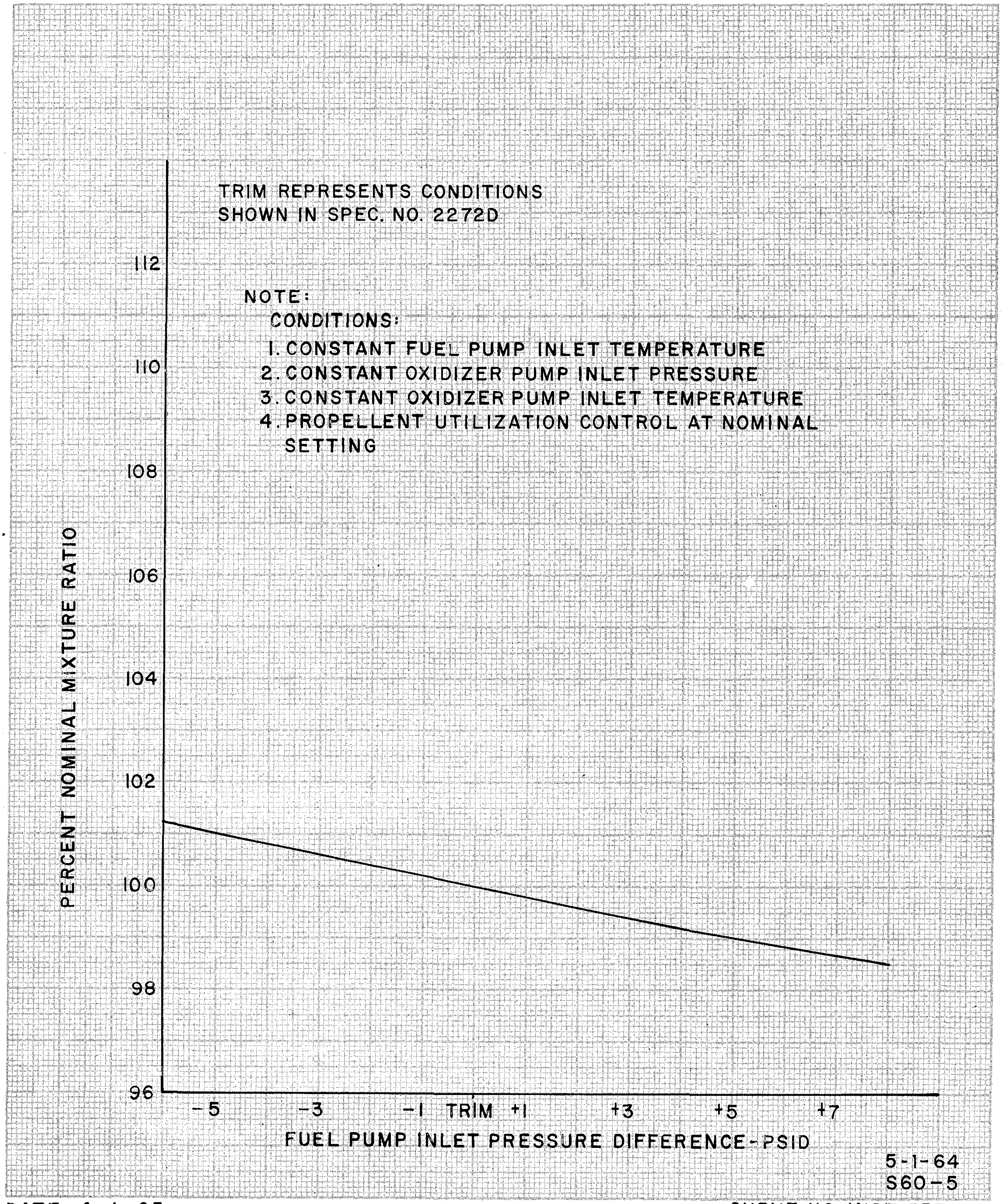
RL10A-3-1 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF OXIDIZER PUMP INLET PRESSURE ON MIXTURE RATIO



DATE: 4-1-65

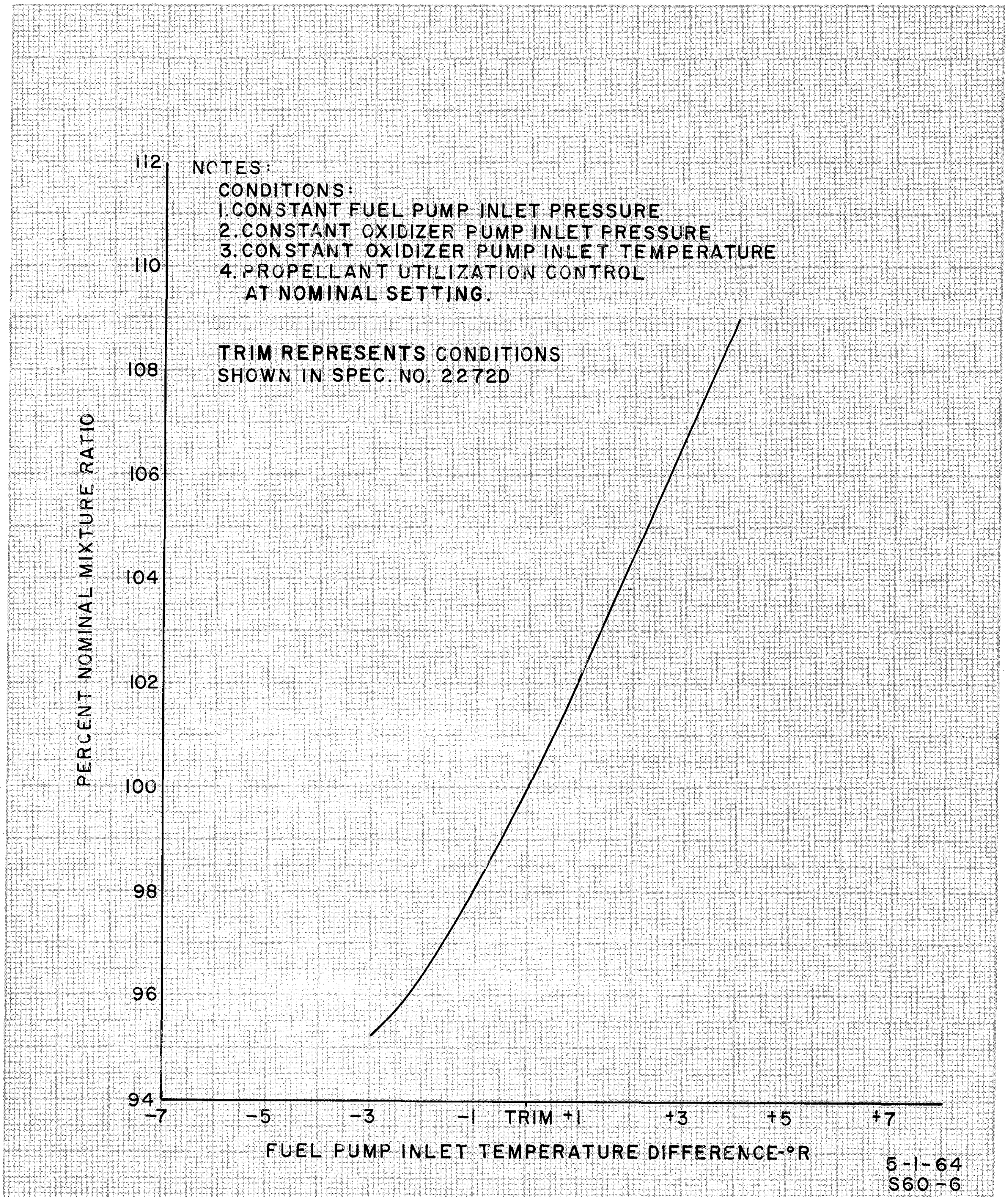
CURVE NO. INST. 35340

RL10A-3-1 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF FUEL PUMP INLET PRESSURE ON MIXTURE RATIO



RL10A-3-1 LIQUID ROCKET ENGINE

ESTIMATED EFFECT OF FUEL PUMP INLET TEMPERATURE ON MIXTURE RATIO



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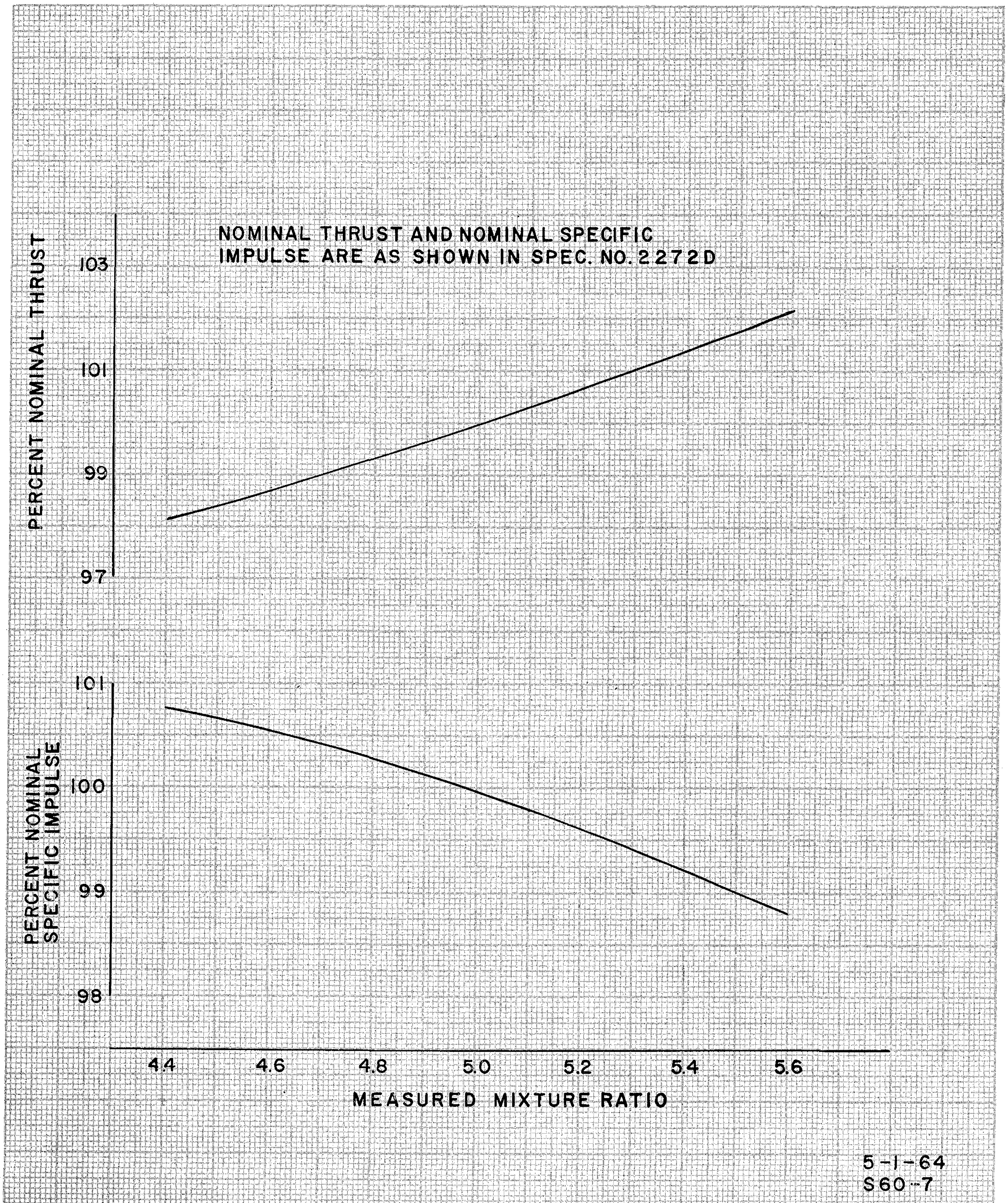
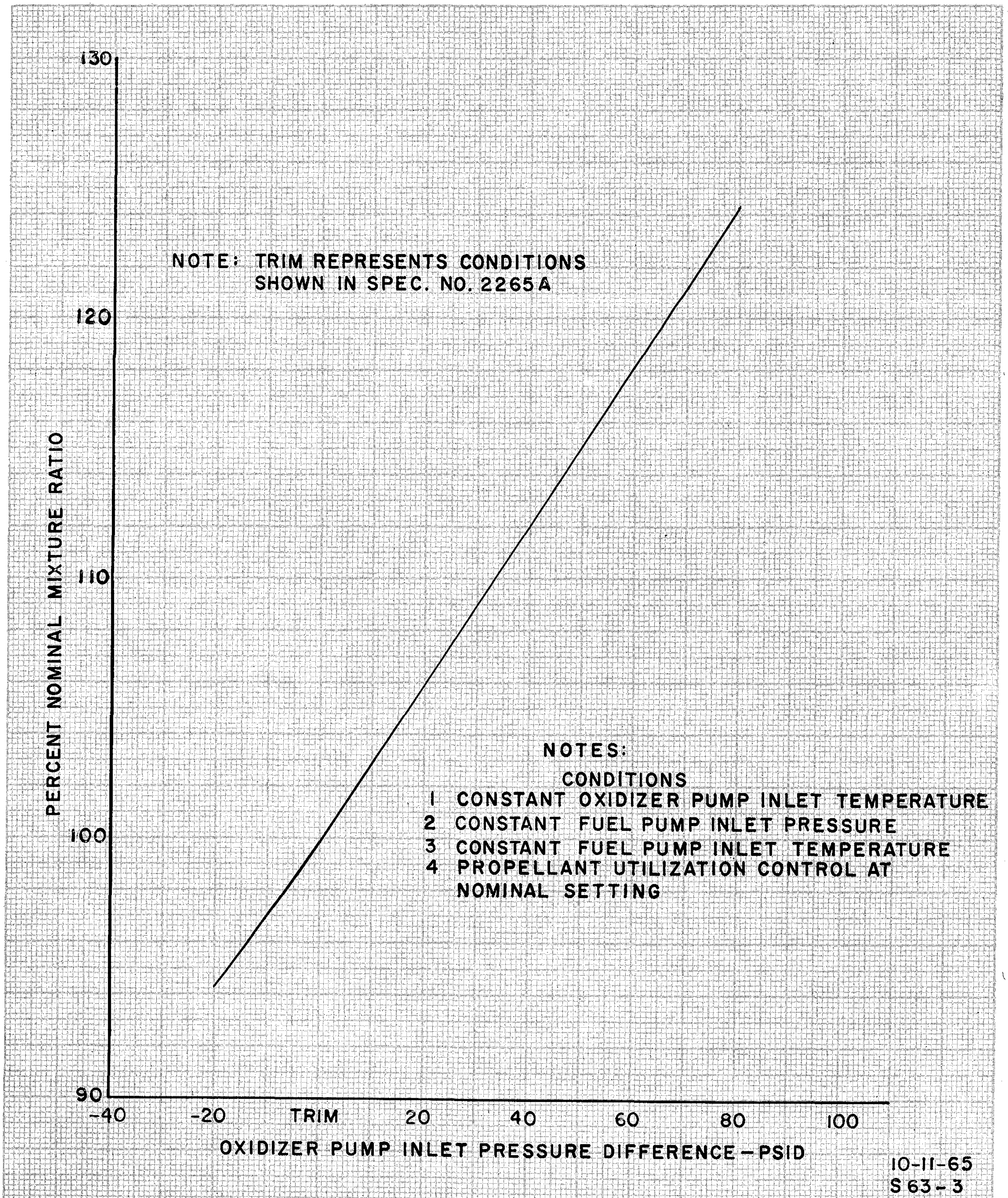
CURVE NO. INST. 35342

RL10A-3-1 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF MIXTURE RATIO ON THRUST AND SPECIFIC IMPULSE

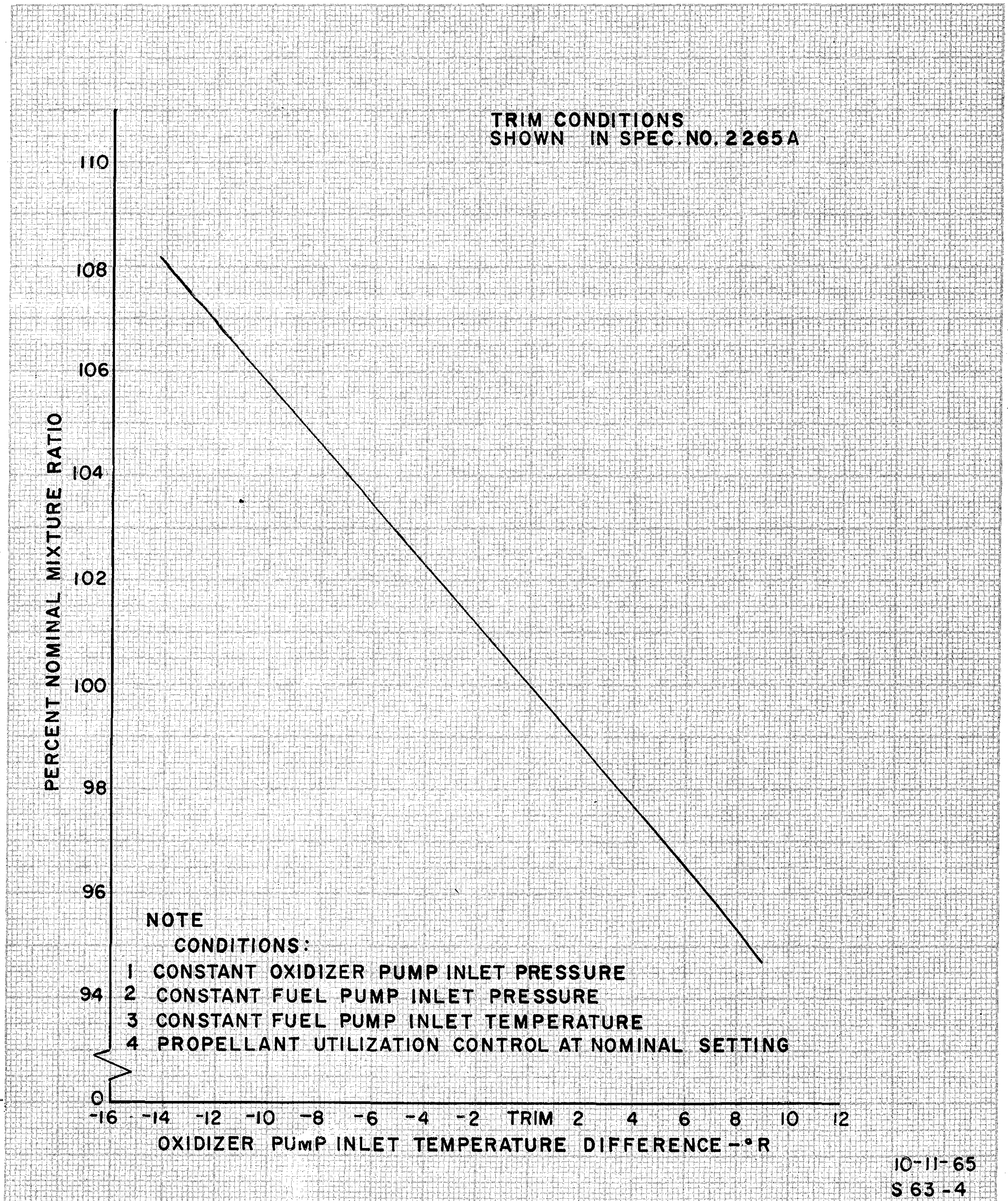


RL10-3-3 LIQUID ROCKET ENGINE

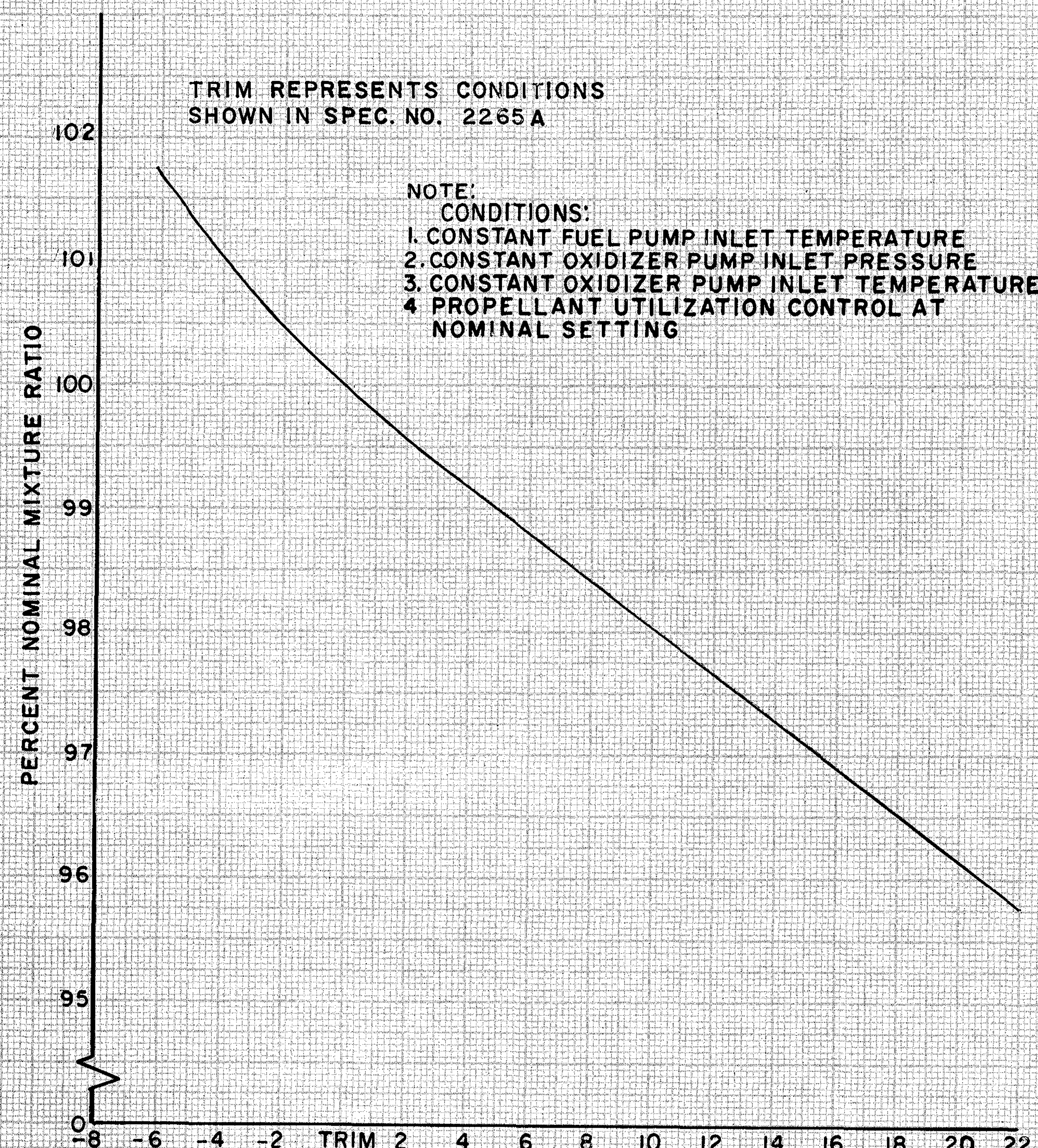
ESTIMATED EFFECT OF OXIDIZER PUMP INLET PRESSURE ON MIXTURE RATIO



RL10A-3-3 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF OXIDIZER PUMP INLET TEMPERATURE ON MIXTURE RATIO



RL10A-3-3 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF FUEL PUMP INLET PRESSURE ON MIXTURE RATIO

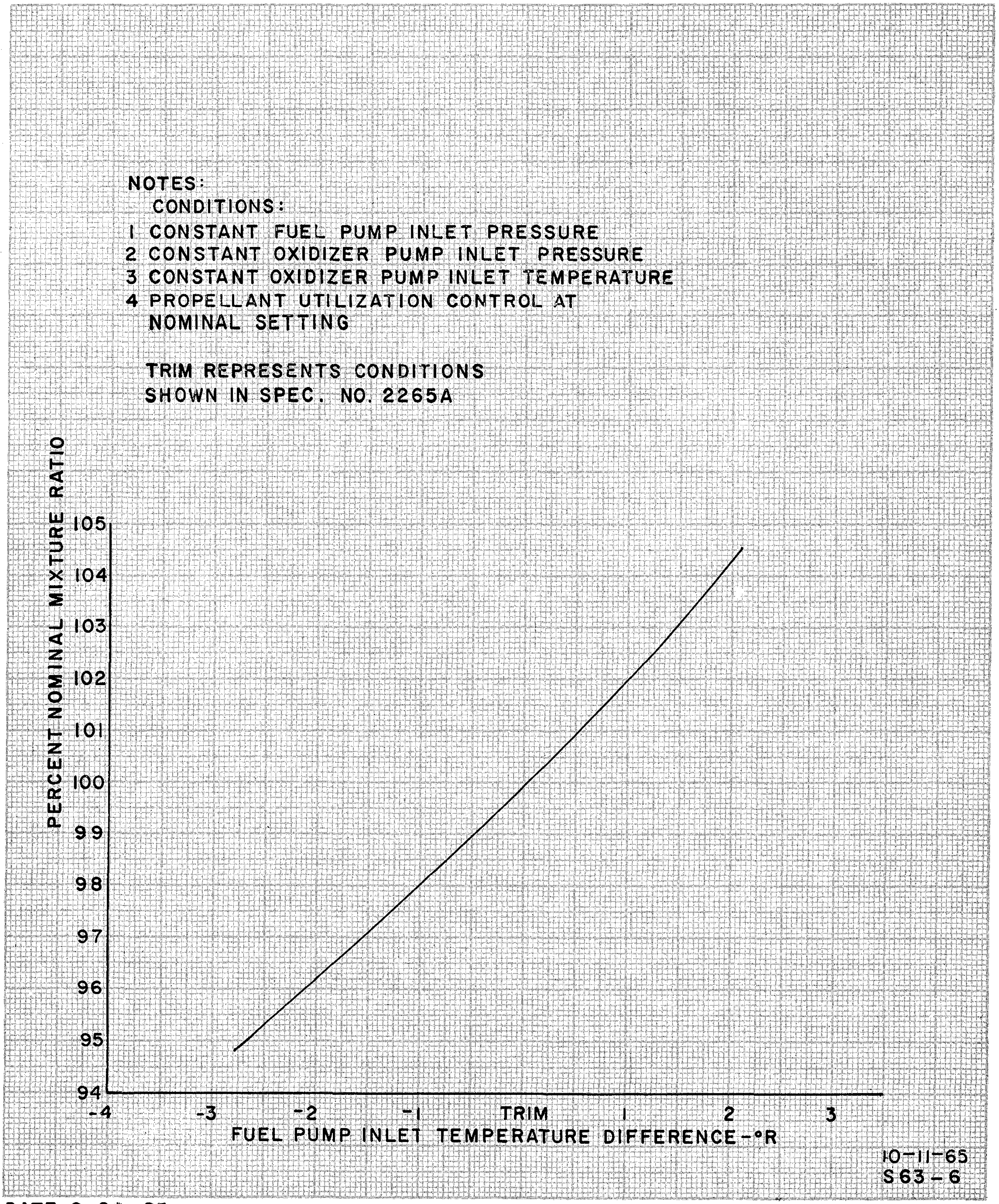


10-11-65
S 63-5

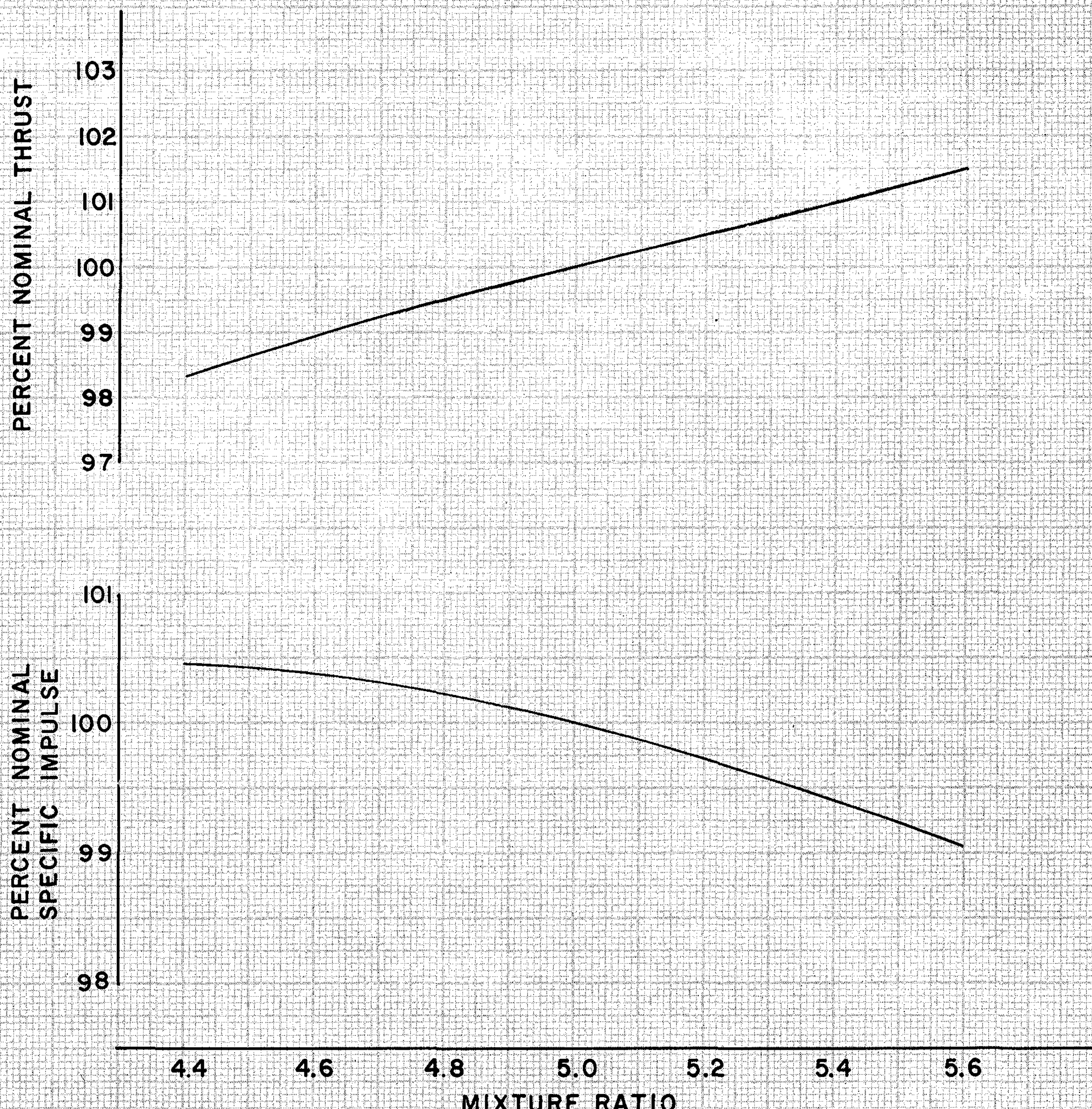
DATE 9-20-65
REV. 3-1-66

CURVE NO. INST. 35504

RL10A-3-3 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF FUEL PUMP INLET TEMPERATURE ON MIXTURE RATIO



RL10A-3-3 LIQUID ROCKET ENGINE
ESTIMATED EFFECT OF MIXTURE RATIO ON THRUST AND SPECIFIC IMPULSE



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MOUNTING SYSTEM

MOUNTING IN VEHICLE

The engine is attached to the vehicle by means of a gimbal mount assembly consisting of an aluminum pedestal, steel gimbal pins, a steel disk, and a forged aluminum conical engine mount. The steel pins and disk, which connect the pedestal to the conical mount, permit vehicle thrust vectoring of the engine gimbal of ±4 degrees about the engine geometric centerline in a square pattern while firing.

FLIGHT AND GROUND LOADS

Two lugs are provided on the thrust chamber fuel inlet manifold for attachment of the vehicle thrust vectoring actuators. These lugs are located on the engine pitch and yaw axes, ninety degrees apart. For the A-3 and A-3-1 models, the allowable axial load on each actuator attachment lug is 3050 pounds, which may be applied sinusoidally at a frequency not to exceed 10 cycles per second. For the A-3-3 engines, the maximum allowable load on each actuator attachment lug is 2640 pounds, which may be applied sinusoidally up to 10 cycles per second at an angle of $7^{\circ} \pm 1^{\circ}$ relative to the geometric thrust axis.

The flight maneuver loads are shown on Curves No. Inst. 31962, 35344, and 35345.

Maximum Allowable Flange Loads (RL10A-3)

	*Fuel Inlet	*Oxidizer Inlet	*Hydrogen Vent Collector Manifold	*Fuel Cooldown Valve Vents
Axial Load	110 lb	210 lb	150 lb	25 lb
Radial load (any direction)	210 lb	200 lb	70 lb	20 lb
Moment (any direction)	1800 in-lb	2200 in-lb	500 in-lb	300 in-lb
Torque	400 lb-in.	600 lb-in.	500 lb-in.	300 lb-in.

* These loads may be applied simultaneously.

Maximum Allowable Propellant Inlet Flange Loads (RL10-3-1)

	Fuel Inlet	Oxidizer Inlet
Axial load	110 lb	210 lb
Radial load (any direction)	210 lb	200 lb
Moment (any direction)	1800 in-lb	2200 in-lb
Torque	400 lb-in.	600 lb-in.

Maximum Allowable Propellant Inlet Flange Loads (RL10-3-3)

	Fuel Inlet	Oxidizer Inlet
Axial load	110 lb	210 lb
Radial load (any direction)	210 lb	200 lb
Moment (any direction)	1800 in-lb	2200 in-lb
Torque	400 lb-in.	600 lb-in.

Moments of Inertia (Wet)(RL10A-3)

	Centaur Configuration	Saturn Configuration
Gimbal vertical axis	59.10 slug-ft^2	60.6 slug-ft^2
Gimbal horizontal axis	60.80 slug-ft^2	62.3 slug-ft^2
Axis formed by intersection of vertical and horizontal planes	9.70 slug-ft^2	10.1 slug-ft^2

Moments of Inertia (Wet) (RL10A-3-1)

Gimbal vertical axis	59.1 slug-ft^2
Gimbal horizontal axis	60.8 slug-ft^2
Axis formed by intersection of vertical and horizontal planes	9.7 slug-ft^2

Moments of Inertia (Wet) (RL10A-3-3)

Gimbal vertical axis	*
Gimbal horizontal axis	*
Axis formed by intersection of vertical and horizontal planes	*

* To be supplied

ENGINE PROTECTIVE COVERS

The protective covers protect the engine against damage during handling and provide moisture seals for all engine-vehicle interfaces, vents, and the thrust chamber.

The protective covers provide access to instrumentation, igniter, attachment lugs, and desiccant plugs. The thrust chamber tube covers are segmented, generally follow the engine outline, and are cushioned with sponge rubber. Desiccant plugs and protective covers are removable to allow vehicle connections.

GROUND HANDLING EQUIPMENT

Ground handling equipment provided with the engine consists of a handling and shipping frame, a handling and shipping plug, and an engine shipping container. The handling plug, as shown in Figure 3, consists of a cone shaped, rubber-cushioned, fiberglass nozzle plug which permits the engine to be transported short distances in the vertical position. The handling and shipping frame, Figure 4, attaches to the engine and in turn may be attached either to a transporting dolly, as shown in Figure 5, or to a shipping container, as shown in Figure 6, for transportation in a horizontal position.

USE OF HANDLING FRAME AND PLUG

Engine Shipping and Handling

For engine shipment and for handling the engine in a horizontal position, both the handling frame and handling plug are required.

Installation on the Vehicle and Shipment of the Vehicle

The following procedure must be followed for shipment of the engine with handling frame and handling plug installed:

1. Remove front ring and tube assembly from the handling frame.
2. Attach lift bar.
3. Lift engine in horizontal attitude.
4. Position and attach gimbal.
5. Support rear of engine by inserting a shaft through center bushing of handling plug and a pin through one of eight bushings in handling plug ring.
6. Remove remainder of handling frame.
7. Do not attach gimbal actuators.

The engine may be shipped, installed in the vehicle, using only the handling plug provided the maximum loads listed in Table I are not exceeded and the engine and handling plug are supported as described above.

Support of Vehicle

If desired, the handling frame can be left in place and used to support a portion of the vehicle structure.

1. The maximum allowable vertical loads with ±1640 lb axial load and 10,000 lb-in. torque on the gimbal are shown in Table II and Figure 1.

2. For the maximum allowable loads with no axial load or torque applied for the gimbal, see Table III and Figure 2.

Table I. Allowable Loads Using Handling Stand Only

(See Figure 1)

C	±1000 lb
D	±824 lb
E	±880 lb
F	±75 lb
R	±1640 lb
S	±968 lb
T	±10,000 lb
V	±912 lb

Table II. Allowable Loads Using Shipping Rig

(Gimbal Restrained)

(See Figure 1)

A	±75 lb
B	±250 lb
C	±1000 lb
D	±824 lb
E	±880 lb
F	±75 lb
R	±1640 lb
S	±968 lb
T	±10,000 lb-in.
V	±912 lb

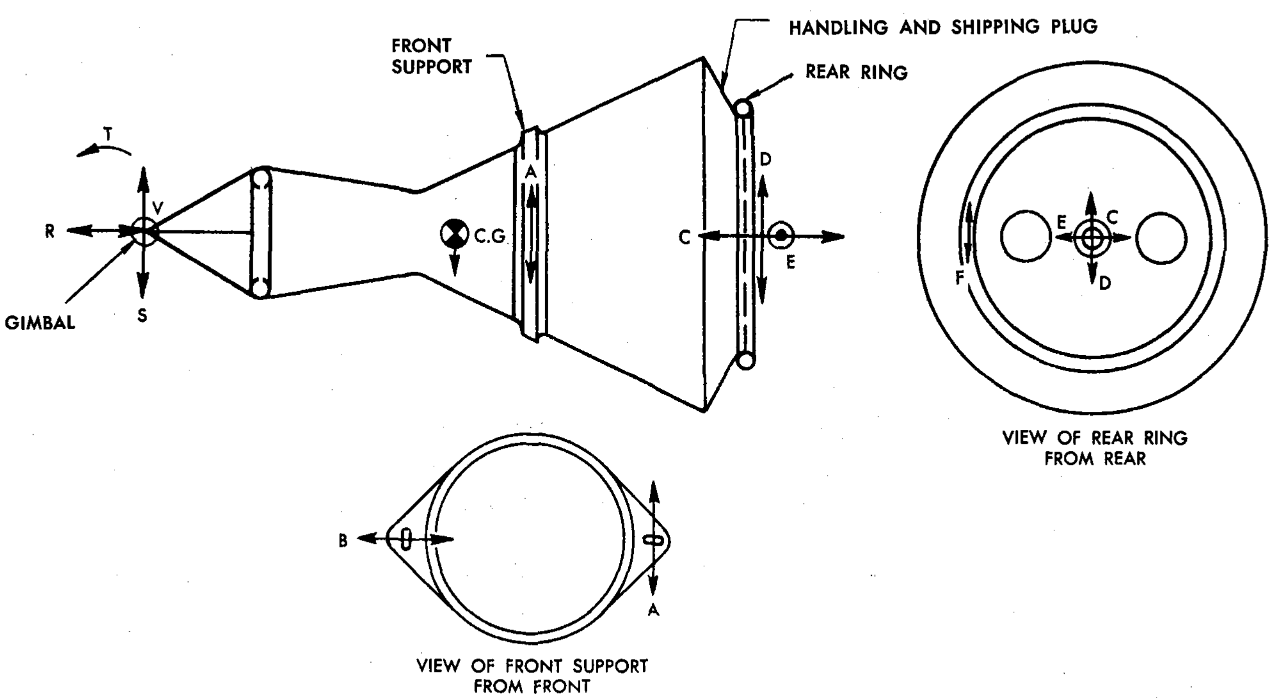


FIGURE 1
GIMBAL RESTRAINED

Table III. Allowable Loads Using Shipping Rig

(Gimbal Not Restrained)

(See Figure 2)

A	±4040 lb
B	±4040 lb
C	±2340 lb
D	±7350 lb
E	±1700 lb
F	±5080 lb

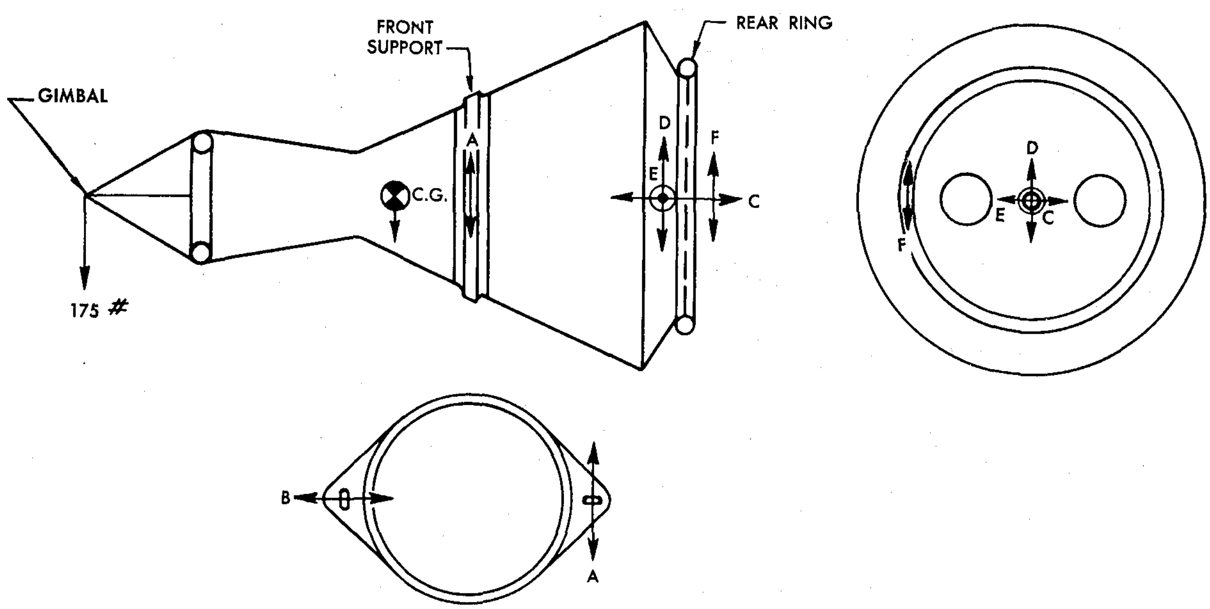


FIGURE 2
GIMBAL NOT RESTRAINED

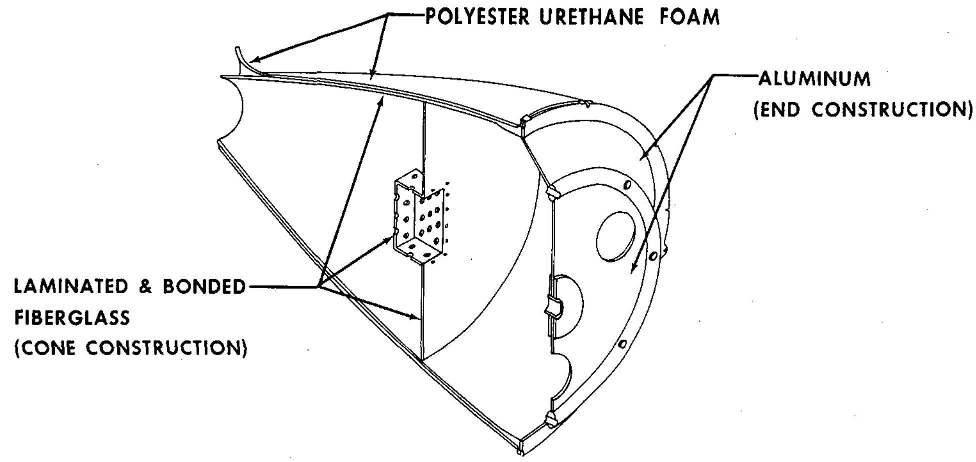


FIGURE 3
CUTAWAY OF HANDLING AND SHIPPING PLUG

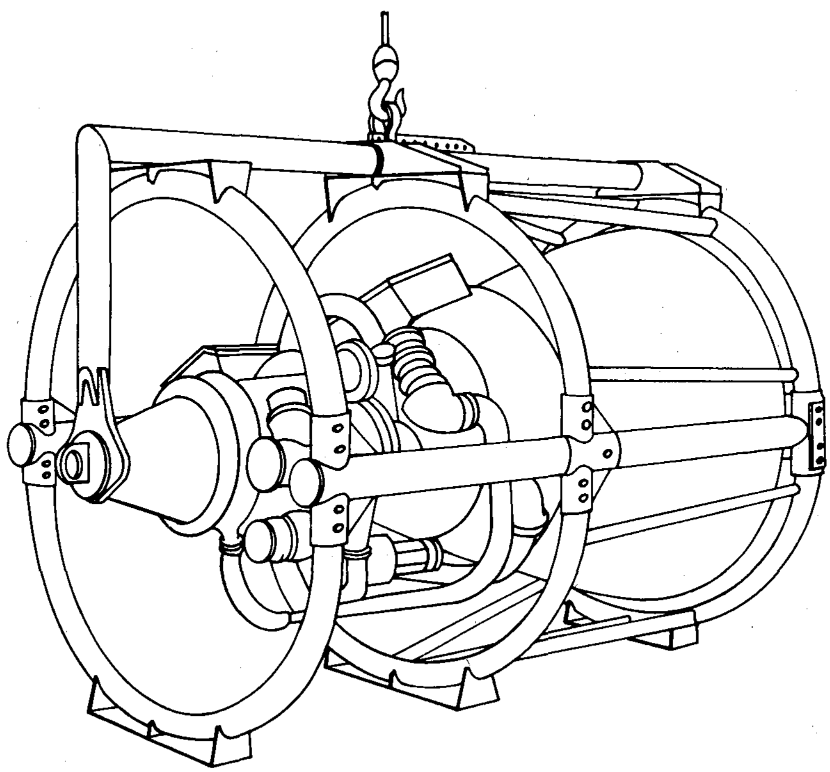


FIGURE 4
HANDLING AND SHIPPING FRAME

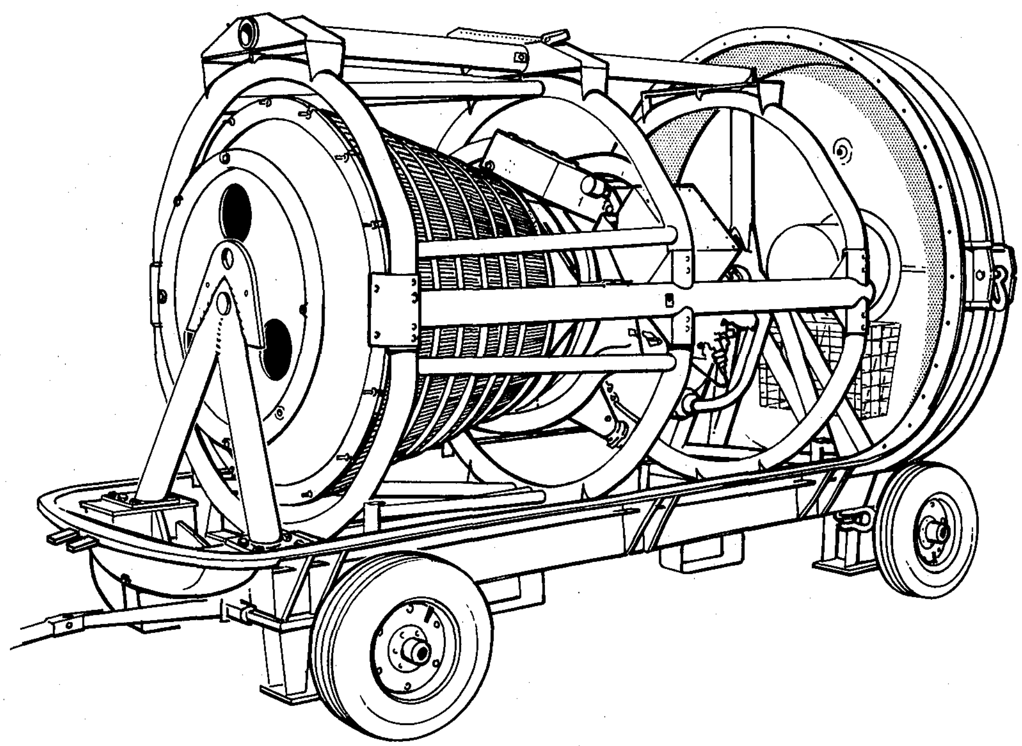


FIGURE 5
HANDLING PLUG, FRAME AND SHIPPING CONTAINER

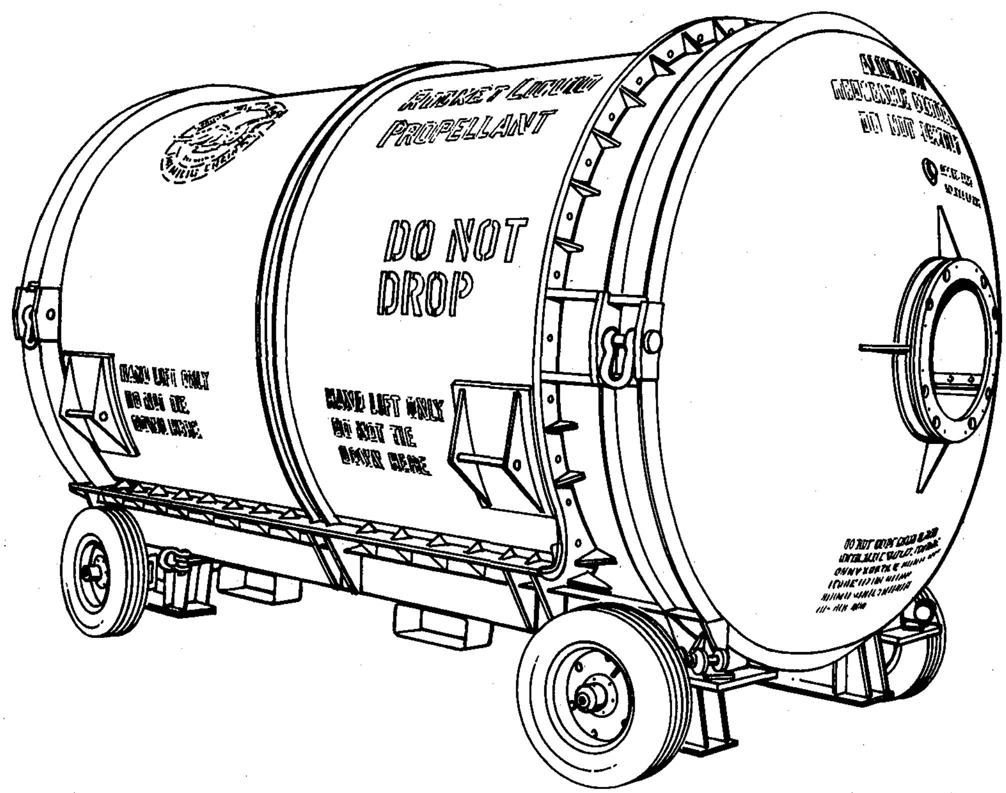
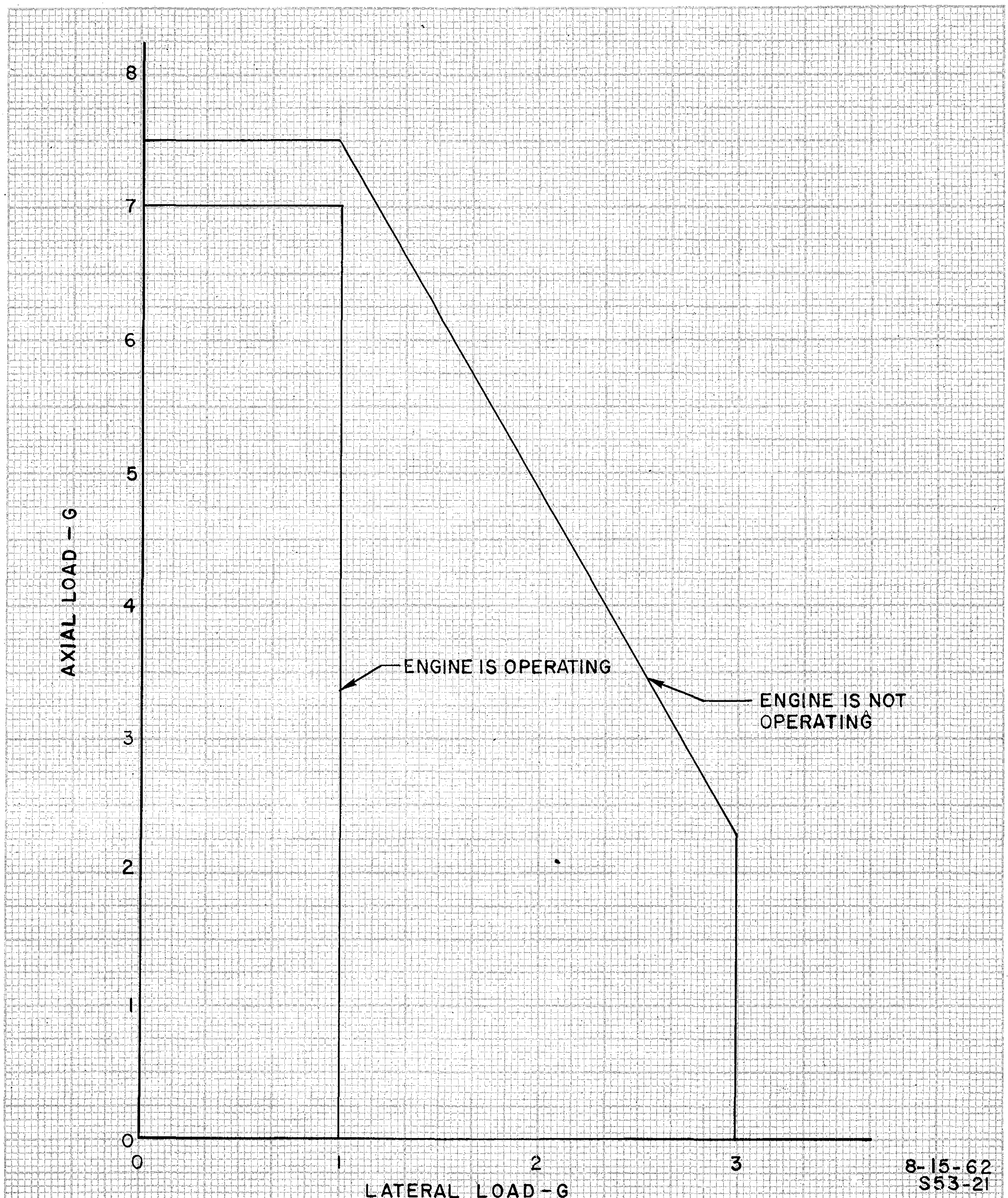
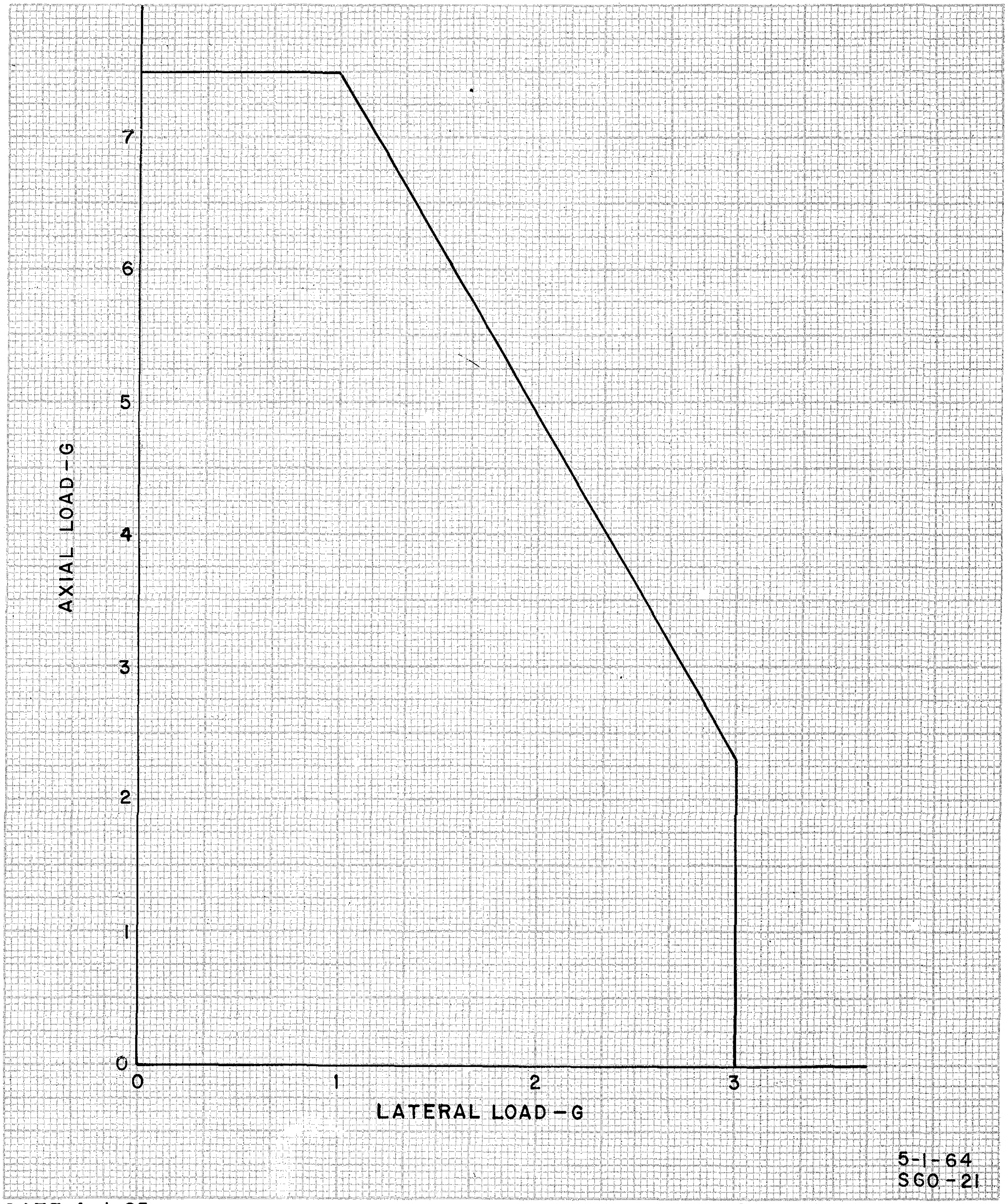


FIGURE 6
SHIPPING CONTAINER

RL10A-3 LIQUID ROCKET ENGINE
PERMISSIBLE MANEUVER LOADS



RL10A-3-1 LIQUID ROCKET ENGINE
PERMISSIBLE FLIGHT MANEUVER LOADS



RL10A-3-3 LIQUID ROCKET ENGINE
PERMISSIBLE FLIGHT MANEUVER LOADS

8-25-64
S63-31

DATE 4-1-65
REV 3-1-66

CURVE NO. INST. 35345

PROPELLANT FLOW AND CONTROL SYSTEM

INTRODUCTION

The propellant flow systems for the RL10A-3, RL10A-3-1 and RL10A-3-3 models are shown schematically on diagrams Inst. 30497, 30544, 35360, and 35361, respectively, at the end of this section.

Engine cooldown is initiated by two separate electrical signals that energize the fuel and oxidizer prestart solenoids on the RL10A-3 model and a single prestart solenoid, for both fuel and oxidizer, on the RL10A-3-1 and RL10A-3-3 models.

The prestart solenoid valve(s) remain open throughout the period the engine is operating. The helium signal resulting from the opening of the prestart solenoid valve(s) actuates the propellant inlet valves allowing the propellant to flow through the supply system, thus lowering the temperature of these parts to operating conditions.

During the prestart phase, liquid oxygen flows through the oxidizer pump, the propellant injector, and overboard through the thrust chamber. The fuel enters the fuel pump, passes through the first stage and enters the interstage connecting tube where a portion of the flow, controlled by the port area of the interstage cooldown valve, is diverted overboard. The remainder flows through the port area of the pump discharge cooldown valve.

Engine start is initiated by an electrical signal from the vehicle which energizes the start solenoid valve and routes helium pressure to both cooldown valves and to the main fuel shutoff valve. The relative valve timing is controlled by the orifices in the helium lines. On receipt of the helium pressure signal, the two cooldown valves close to the preset overboard bleed area required to prevent fuel pump stall during acceleration. Simultaneously with the start signal, the ignition system is energized by the vehicle for a minimum of 1.5 seconds. As the turbopump accelerates, fuel pump discharge pressure completely closes the bleed ports in the cooldown valves.

On the RL10A-3-1 and RL10A-3-3 models, the fuel pump discharge cooldown valve has no bleed port.

During these engine operations, thrust control is achieved by regulating the amount of fuel that is bypassed around the turbine, and consequently, the amount of propellant flow entering the injector. This is accomplished by sensing and responding to the combustion chamber pressure which is proportional to thrust.

The shutdown signal consists of a simultaneous removal of the electrical supply to the start and prestart solenoid valve(s). This removes the helium pressure signal from all propellant valves by venting all helium controlled valve actuators overboard, thereby permitting the valves to return to their normal position. The pump interstage and pump discharge cooldown valves open to full overboard area venting the fuel system lines overboard. Fuel system overpressurization is precluded through the use of fuel boosted cooldown valves: this rapid opening feature ensures that system fuel pressure has decayed prior to the closing of the slower acting main fuel shutoff valve. The oxidizer inlet shutoff valve, fuel inlet shutoff valve, and main fuel shutoff valve close, stopping the propellant supply to the engine and providing a rapid cessation of burning in the combustion chamber.

Engine component operating sequence for the RL10A-3, RL10A-3-1 and RL10A-3-3 models are depicted on Inst. Nos. 31419, 35356, and 35357, respectively.

DESCRIPTION

FUEL PUMP

The fuel pump is a two-stage centrifugal pump with back-shrouded impellers, volute collectors, and tangential diffusers. The first-stage impeller consists of 50 degree swept vanes for the RL10A-3 and RL10A-3-1 models and 22 1/2 degree swept vanes for the RL10A-3-3 model. The second stage impeller is a radial vane type. The two stages are mounted back-to-back to minimize thrust unbalance. The first stage of the pump is preceded by a three-bladed axial flow inducer operating at the same speed as the main impellers. The RL10A-3 and RL10A-3-1 fuel pumps are designed to operate at approximately 30,000 rpm with a minimum net positive suction pressure of 8 psi. The RL10A-3-3 fuel pump is designed to operate with a minimum net positive suction pressure of 4 psi. The RL10A-3 and RL10A-3-1 fuel pumps are designed to provide a weight flow of 5.88 pounds per second with a head rise of 30,000 feet of hydrogen. The RL10A-3-3 pump design weight flow is 5.63 pounds per second with a head rise of 31,630 feet of hydrogen.

The net thrust loads are minimized and controlled by selection of pump impeller and turbine rotor disk areas. The net axial thrust of the fuel pump and turbine shaft assembly is transmitted to the turbodrive housing through a non-lubricated ball thrust bearing, cooled by hydrogen bled from the inlet of the second stage fuel pump impeller. Each pump stage incorporates a diffusing volute collector and conical diffuser. The inducer, impellers, and pump body are made of aluminum while the pump drive shaft and bearings are stainless steel.

Fuel pump cooldown time during the prestart period is a function of inlet supply pressure and temperature, as shown on the following curves:

RL10A-3	Inst. Nos. 31563 and 31564
RL10A-3-1	Inst. Nos. 35350 and 35352
RL10A-3-3	Inst. No. 35351

OXIDIZER PUMP

The oxidizer pump is a single-stage fully shrouded, centrifugal pump driven through a reduction gear from the fuel pump drive shaft. The RL10A-3 and RL10A-3-1 oxidizer pumps are designed to operate at approximately 12,000 rpm with a minimum net positive suction pressure of 15 psi. The RL10A-3-3 oxidizer pump is designed to operate with a minimum net positive suction pressure of 8 psi. The RL10A-3 and RL10A-3-1 oxidizer pumps are designed to deliver a head rise of 900 feet of oxygen and a weight flow of 29.4 pounds per second. The RL10A-3-3 design weight flow is 28.2 pounds per second with a head rise of 1,091 feet of oxygen. The shrouded, axial flow inducer has a labyrinth seal on the outside diameter to minimize recirculation. Loads on the ball thrust bearing are minimized by the double shroud design. Pumping vanes on both impeller shrouds reduce the pressure at the labyrinth seal and the carbon face shaft seal.

Three vented compartments, separated by carbon ring seals, prevent leakage of the oxidizer into the fuel side of the turbopump system. The center compartment is pressurized with gaseous helium for ground test. The impeller and inducer are made of stainless steel while the housings are machined aluminum.

Oxidizer pump cooldown time during the prestart is a function of inlet supply pressure, as shown on the following curves:

RL10A-3	Inst. No. 35392
RL10A-3-1	Inst. No. 35354
RL10A-3-3	Inst. No. 35355

TURBINE

The RL10A-3 and RL10A-3-1 propellant pumps are driven by a two-stage, partial admission, impulse turbine attached directly to the fuel pump drive shaft. Both sets of turbine blades, the single hub, and the disk are integral, being machined from an aluminum alloy forging. At rated speed the turbine produces approximately 620 horsepower. The shrouds are also aluminum and are attached by dip brazing.

The RL10A-3-3 propellant pumps are driven by a full admission, pressure compounded, two-stage turbine. This turbine produces approximately 644 horsepower.

PROPELLANT CONTROL VALVES

The fuel flow of RL10 engines is controlled by the fuel pump inlet shutoff valve, the fuel pump cooldown valves, the thrust control, and the main fuel shutoff valve. On the RL10A-3S model, the tank pressurization check valve permits hydrogen gas to be bled from the engine for vehicle tank pressurization. Oxidizer flow is controlled by the oxidizer pump inlet shutoff valve, the mixture ratio and propellant utilization valve, and the igniter oxidizer supply valve. Except for the mixture ratio and propellant utilization valve, igniter oxidizer supply valve, and the thrust control, all of the propellant control valves are actuated by helium gas pressure, controlled by the prestart and start valves. These valves are solenoid-actuated in response to electrical signals from the vehicle. Electrical requirements and schematics are shown in Section 6.

Propellant Pump Inlet Shutoff Valves

It is the function of the propellant pump inlet shutoff valves to prevent leakage of propellants into the engine during periods when the engine is not running. These valves are ball-type, normally closed, helium actuated, and are mounted directly on the propellant pumps. Propellant leakage is kept to a minimum by the use of spring-loaded, resilient plastic, seals. Actuating helium leakage is minimized by the use of bellows-type actuators.

Fuel Pump Cooldown and Bleed Valves

The fuel pump cooldown and bleed valves are sleeve type valves which, during non-operation of the engine, are spring loaded open to vent the fuel system overboard. During the prestart cycle, the pump interstage and discharge cooldown valves are in the open position allowing fuel to flow and cool the pump to operating temperature. Upon receipt of the start signal, helium pressure actuates both cooldown valves to a partially closed position on the RL10A-3 model (on the RL10A-3-1 and RL10A-3-3 models, the fuel pump discharge cooldown valve has no partially closed (bleed) position). Fuel pump discharge pressure, as it increases, completely closes both valves. Removal of the helium pressure signal at shutdown allows both cooldown valves to vent overboard.

Main Fuel Shutoff Valve

The fuel shutoff valve is a normally-closed, bullet-type valve with a bellows actuator. This valve starts and stops the flow of fuel to the propellant injector. It is opened by helium pressure from the start solenoid valve. Removal of the helium pressure at shutdown allows a positive closure of the valve consistent with the fuel system pressure decay, thus preventing a high pressure surge in the fuel system.

Tank Pressurization Check Valve

A tank pressurization check valve is provided on the RL10A-3S model. It is a spring loaded, pressure operated, poppet-type valve. The valve permits hydrogen gas to be bled from the fuel injector manifold for vehicle tank pressurization and prevents back flow of fuel from the vehicle tank into the engine during periods when the engine is not operating. This valve is an optional piece of equipment which can be furnished to provide, within limits, the particular flow and pressure required for the installation. The minimum quantity of hydrogen that can be provided is 0.075 pounds per second at a discharge pressure of 280 psia.

Thrust Control

The thrust control is a servo-actuated proportional control which senses combustion chamber pressure. Two separate, but interacting, sections make up the control: the thrust control bellows section and the thrust control valve section.

The forces on the thrust control carriage, which positions the servo lever, consists of combustion chamber pressure acting through the reference bellows, the reference spring load and the feedback spring load. Servo pressure is supplied from upstream of the venturi through a fixed orifice. An increase in thrust chamber pressure moves the bellows carriage against the springs lifting the shear orifice valve lever arm which opens the shear orifice and thus increases the body case pressure. The overboard vent orifice maintains a constant case differential pressure. As the servo chamber pressure decreases, the net force on the bypass valve changes and the bypass valve piston moves to increase the bypass area. As the bypass area increases, the quantity of fuel bypassing the turbine increases, thus reducing the power produced by the turbine, lowering pump speed and discharge pressure and decreasing propellant flow; thereby reducing chamber pressure to the desired value. The bypass valve travel is transmitted to the bellows carriage through the feedback spring, thus balancing the forces on the carriage and returning the servo lever to its normal position.

During the start transient, pressure build-up in the reference bellows lags behind the body pressure due to the accumulator effect of the bias volume. This lag, properly timed, minimizes thrust overshoot without affecting steady state performance.

A decrease in the chamber pressure allows the bellows carriage to move and closes the servo valve orifice. Servo chamber pressure then increases and the resulting force differential moves the bypass valve piston to decrease the bypass area. As less fuel is bypassed, turbine flow and power increases, pump speed and discharge pressure increase, thereby increasing pressure to the preset value.

The chamber pressure which the thrust control must maintain is set during the engine acceptance test by adjusting the ground thrust adjustment on the control. This adjustment preloads the reference spring and determines the chamber pressure to which the valve will regulate.

Oxidizer Flow Control and Propellant Utilization Valve

The oxidizer flow control and propellant utilization valve on the RL10A-3 and RL10A-3-1 models has three variable area orifices which perform three functions. Orifice "A" (refer to Inst. Nos. 30497, 30544, and 35360 respectively) bypasses oxidizer flow during the prestart phase and the early part of the start cycle. Orifice area is regulated as a function of oxidizer pump inlet pressure during the cooldown flow and the proper mixture ratio for ignition. Orifice "B" is in parallel with Orifice "A" and is spring loaded closed. It opens during engine acceleration as a function of oxidizer pump pressure rise, providing a controlled oxidizer flow and mixture ratio during the engine acceleration. During engine operation, Orifice "C" can be varied by rotation of the adjustment shaft to vary operating mixture ratio in accordance with the vehicle requirements. The valve incorporates provisions to mount a drive motor which is controlled by the vehicle propellant utilization system. The adjustment shaft drive pad incorporates stops which control the area of Orifice "C". These stops are set during acceptance test of the engine to indicate the permissible variation of operating mixture ratio. The RL10A-3-3 valve configuration and operation is essentially identical except that Orifice "A" is fixed. Refer to Inst. No. 35361.

Igniter Oxidizer Supply Valve

On the RL10 models, a combustible mixture at the igniter is assured by the introduction of gaseous oxygen through drilled passages in the igniter plug housing to mix with the gaseous cooling hydrogen already flowing around the igniter. This gaseous oxygen flow is controlled by the igniter oxidizer supply valve. The valve is actuated by the difference between oxidizer pump inlet pressure and oxidizer injector pressure. The valve is open to furnish gaseous oxygen to the igniter during start and is closed during the acceleration when injector pressure becomes higher than pump inlet pressure.

THRUST CHAMBER

The high pressure fuel from the fuel pump passes through the tubular walls of the thrust chamber, cooling the tubes by absorption of heat prior to being expanded in the turbine. The required nozzle contour is obtained through the use of alternate full length and half length double-tapered and single-tapered thin wall stainless steel tubes. The tubes, together with the inlet and discharge manifolds and necessary stiffening bands, are furnace-brazed into a single lightweight assembly.

PROPELLANT INJECTOR

The RL10 propellant injector is a concentric jet type with a central liquid oxygen stream at each injection point surrounded by an annular stream of hydrogen gas. This design atomizes and promotes mixing of the fuel and oxidizer to provide the correct conditions for ignition and efficient combustion.

The oxidizer and fuel orifices are supplied from two separate chambers formed by the assembly of three mutually supported conical plates. Liquid oxidizer is supplied to the forward chamber through a central manifold, and gaseous fuel is supplied to the rear chamber by an external manifold. Machined tubes projecting from the center plate form the oxidizer orifices and extend through holes in the rear plate, thus forming annular fuel orifices. The rear plate is formed of porous welded steel mesh to provide transpiration cooling of the injector face.

The propellant injector contains 216 elements arranged in equally spaced concentric circles. Each element consists of a liquid oxygen nozzle and a concentric fuel annulus. The concentric jet design brings the fuel and oxidizer into immediate contact when they leave the injector rear face. This tends to shorten the required mixing time, minimizes combustion instability, and improves combustion efficiency and, consequently, the engine specific impulse.

Pressure taps are provided to sense combustion chamber pressure for the flight instrumentation kit and the thrust control. These taps are located on the propellant injector fuel manifold and sense injector face static pressure.

Prelaunch Cooldown Check Valve

The RL10A-3C, RL10A-3-1, and RL10A-3-3 models are fitted with a check valve for introduction of cold helium or hydrogen into the turbopump prior to vehicle launch. This partially cools the turbopump before vehicle launch.

In the open position, the valve allows liquid helium or hydrogen from a test stand or vehicle supply at 15-40 psig to flow into the first stage fuel pump and fuel pump shaft seal cavity. The helium or hydrogen is then discharged overboard through the gearbox relief vent and fuel bleed-cooldown valves. When the helium or hydrogen supply is removed, the check valve is closed by spring force, augmented by fuel pump discharge pressure as the engine accelerates.

HYDROGEN VENT COLLECTOR MANIFOLD

Pratt & Whitney Aircraft provides on the RL10A-3S model, as additional equipment, a hydrogen vent collector manifold. This manifold collects hydrogen from all engine vents and transfers it to a vehicle interface.

INSTALLATION REQUIREMENTS

FUEL

Liquid hydrogen: Preliminary Specification MIL-P-27201

OXIDIZER

Liquid oxygen: Specification MIL-0-25508A

HELIUM

Helium: Specification Bureau of Mines Type A

Gaseous helium at a pressure of 470 ±30 psi and a temperature of 300°R to 600°R is required for pneumatic valve actuation.

OXIDIZER PUMP INLET PRESSURE

Liquid oxygen must be delivered to the oxidizer pump inlet as specified in the following curves:

RL10A-3	Inst. No. 30505
RL10A-3-1	Inst. No. 35346
RL10A-3-3	Inst. No. 35347

FUEL PUMP INLET PRESSURE

Liquid hydrogen must be delivered at the fuel pump inlet as specified in the following curves:

RL10A-3	Inst. No. 30506
RL10A-3-1	Inst. No. 35348
RL10A-3-3	Inst. No. 35349

PROPELLANT PUMP INLET FLOW PATH

RL10 engine performance is predicted on uniform pressure distribution at the propellant pump inlets. The vehicle propellant supply system immediately preceding the pump inlet shutoff valves should be straight for at least 4.53 inches for fuel inlet and 5.18 inches for oxidizer inlet.

PROPELLANT FLOW RATE (NOMINAL)

	RL10A-3	RL10A-3-1	RL10A-3-3
Fuel pump design flow rate	5.88 lb/sec	5.88 lb/sec	5.63 lb/sec
Oxidizer pump design flow rate	29.4 lb/sec	29.4 lb/sec	28.2 lb/sec

VENTAGE OF FLUID AT CONTROL POINTS (DISPOSED OVERBOARD)

RL10A-3

	During Engine Operation	When Engine is Not Operating
Hydrogen	25.0 lb/min*	0.02 lb/min
Oxygen	3.2 lb/min	0.05 lb/min
Helium	0.044 lb during shutdown transient	4×10^{-4} lb/min
Helium	0.001 lb/min during steady state operation	

* Hydrogen leakage does not include vehicle tank pressurization flow.

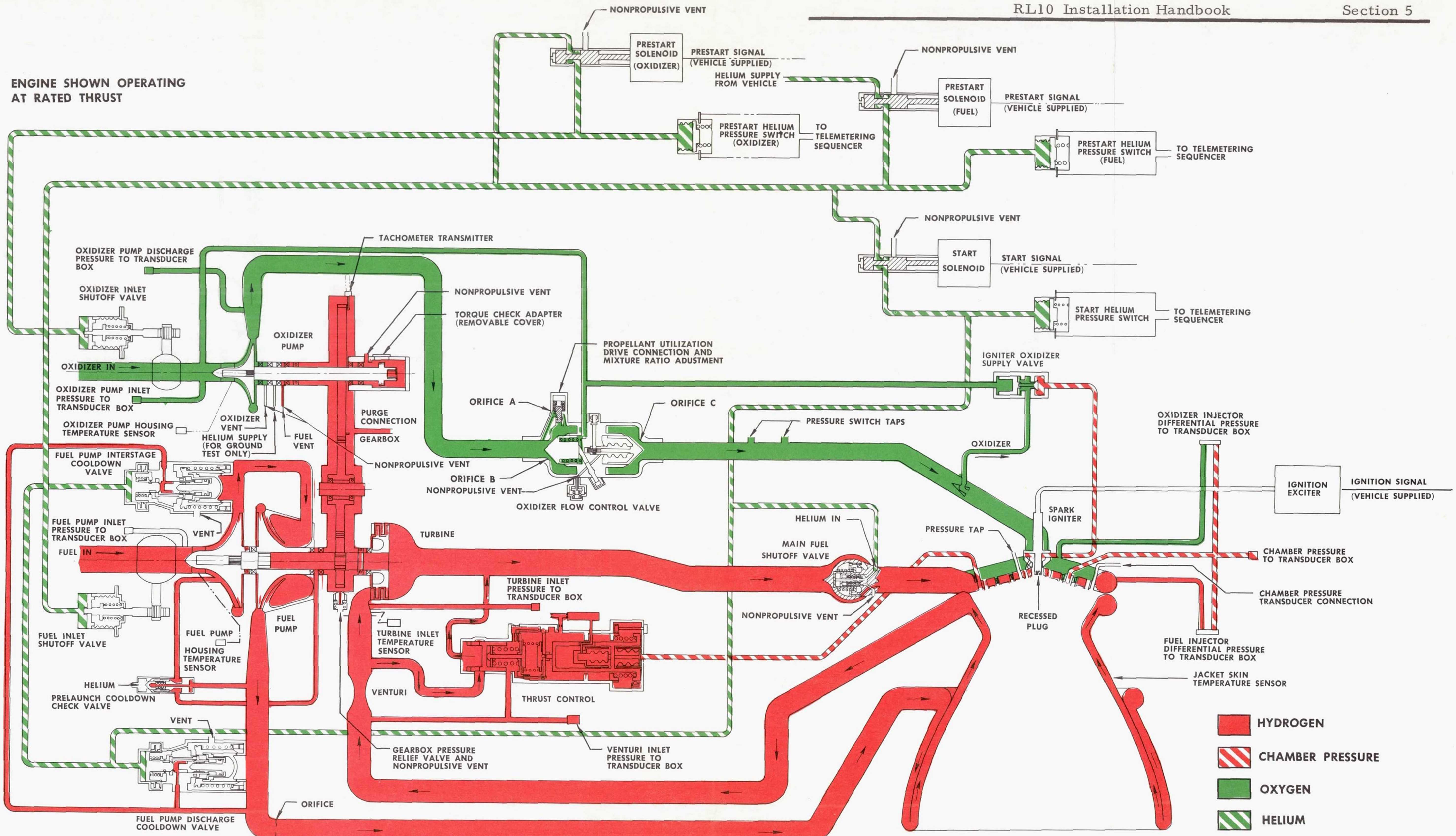
RL10A-3-1

	During Engine Operation	When Engine is Not Operating
Hydrogen	9.0 lb/min	0.02 lb/min
Oxygen	2.7 lb/min	0.05 lb/min
Helium	0.044 lb during shutdown transient	4×10^{-4} lb/min
Helium	0.00075 lb/min during steady state operation	

VENTAGE OF FLUID AT CONTROL POINTS (DISPOSED OVERBOARD)

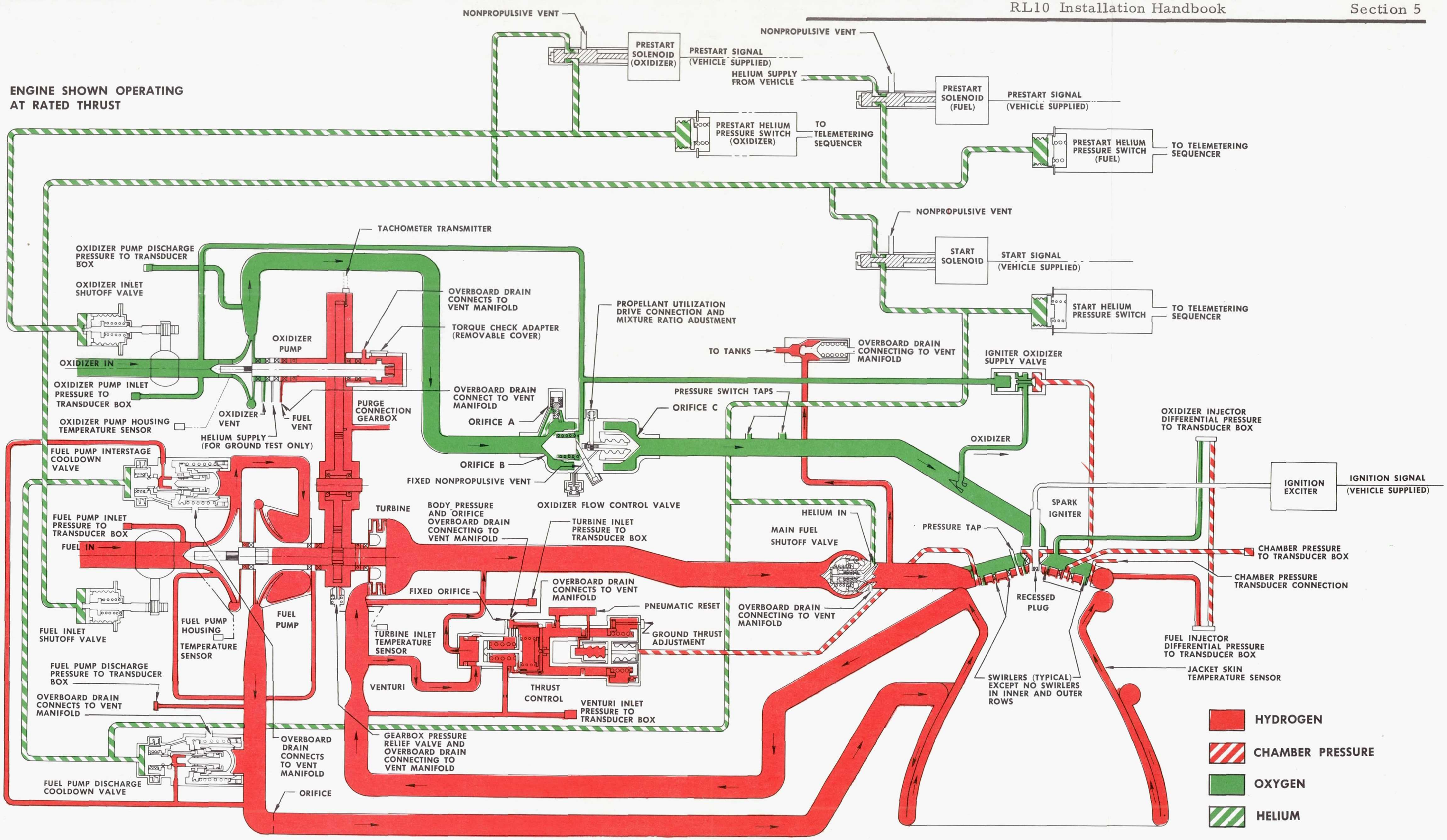
RL10A-3-3

	During Engine Operation	When Engine is Not Operating
Hydrogen	9.0 lb/min	0.02 lb/min
Oxygen	2.7 lb/min	0.05 lb/min
Helium	0.044 lb disposed overboard during each shutdown transient	4×10^{-4} lb/min
Helium	0.00075 lb/min during steady state operation	



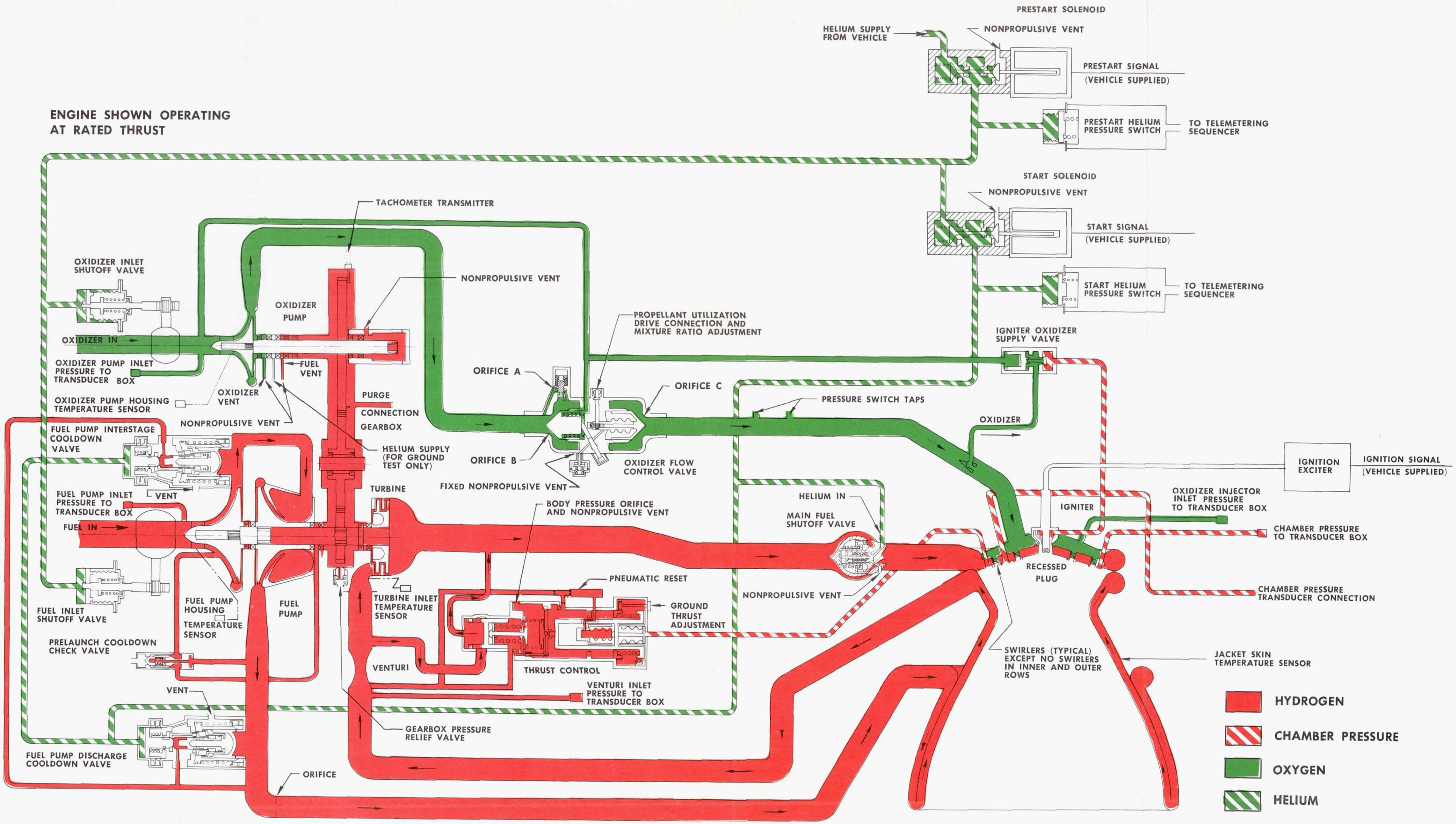
RL10A-3C
PROPELLANT FLOW SCHEMATIC

INST. 30497
DATE 9-1-61
REV. 3-1-66



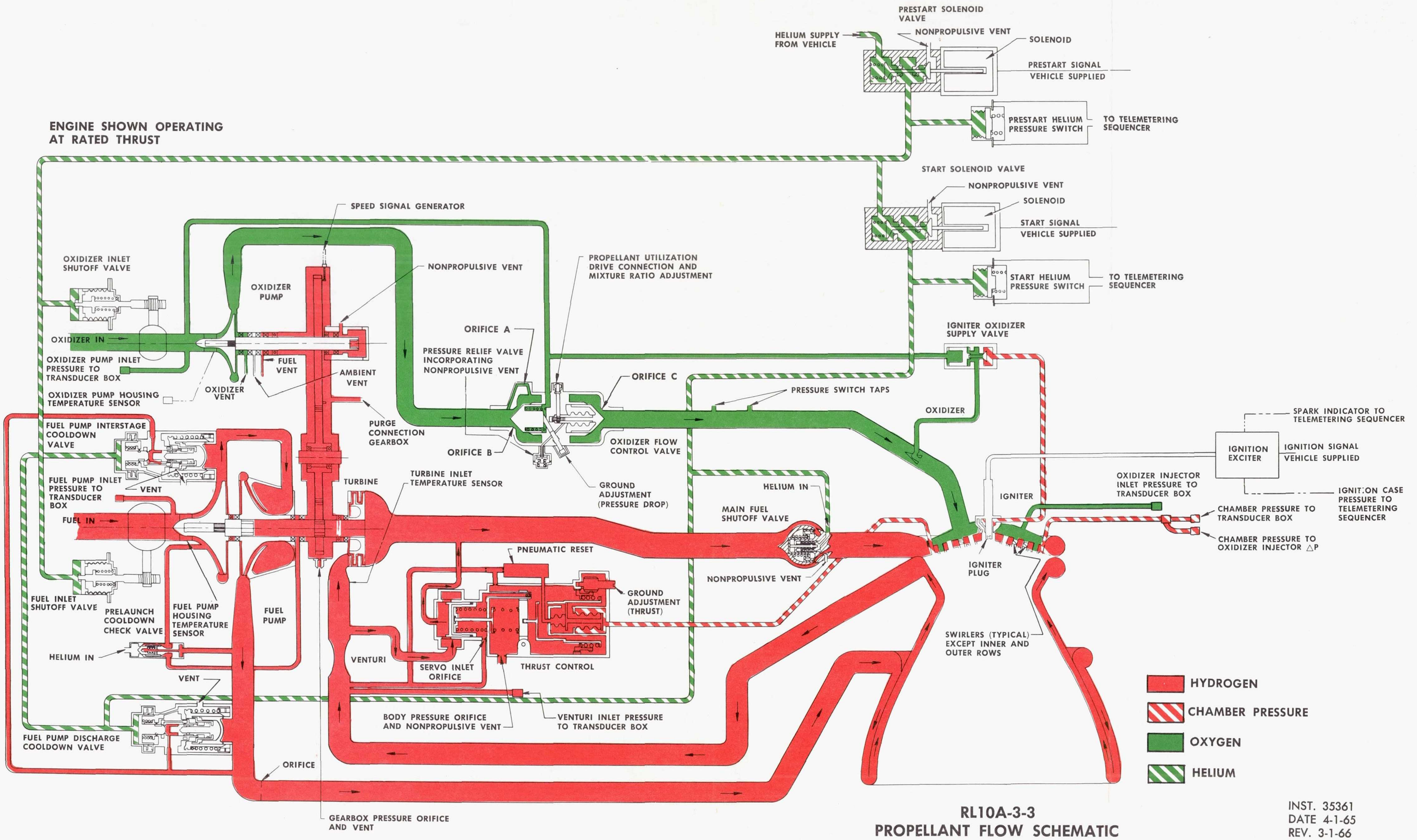
RL10A-3 S
PROPELLANT FLOW SCHEMATIC

INST. 30544
DATE 9-30-65
REV. 3-1-66



RL10A-3-1
PROPELLANT FLOW SCHEMATIC

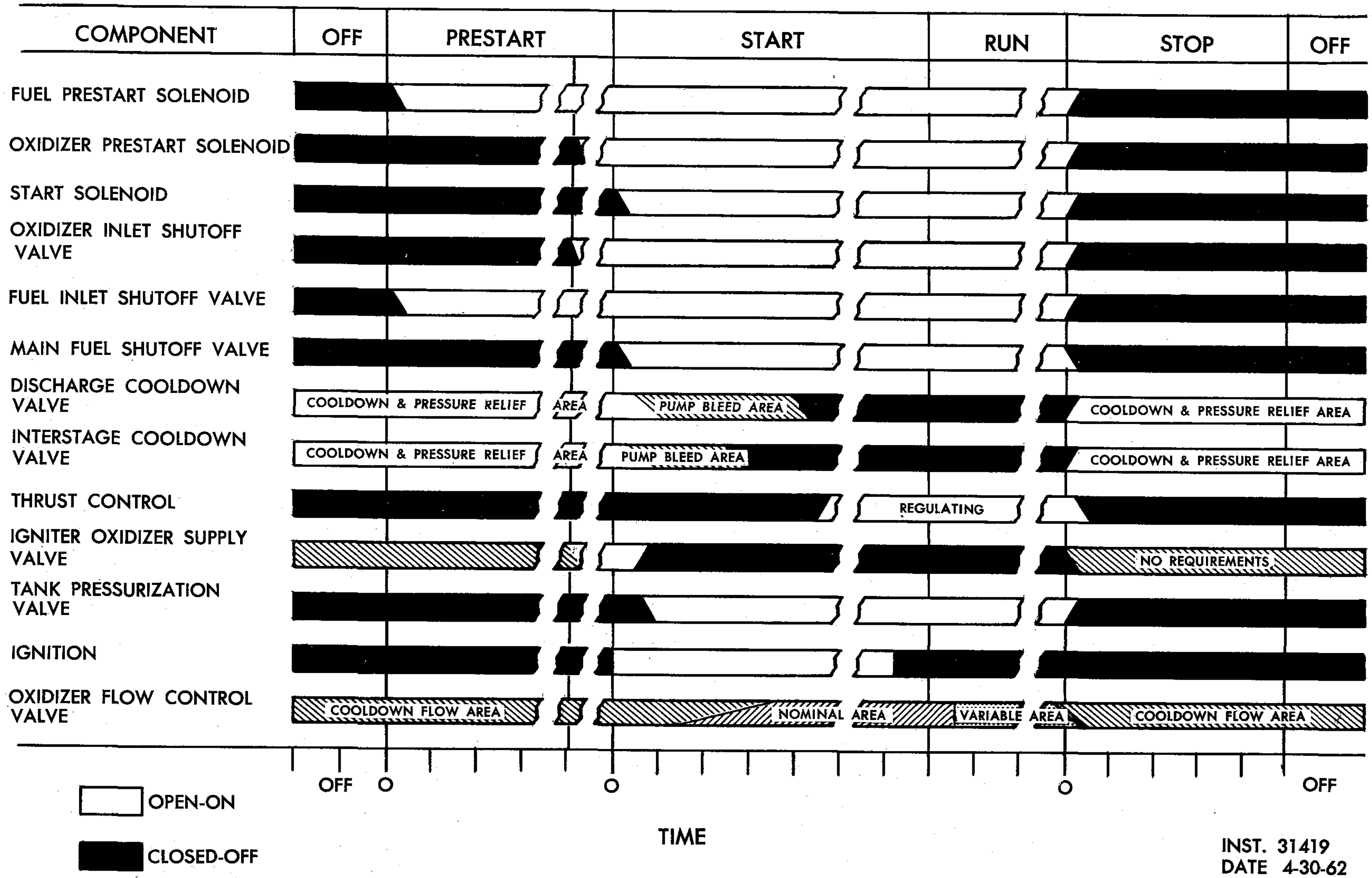
INST. 35360
DATE 4-1-65
REV. 3-1-66



RL10A-3-3
PROPELLANT FLOW SCHEMATIC

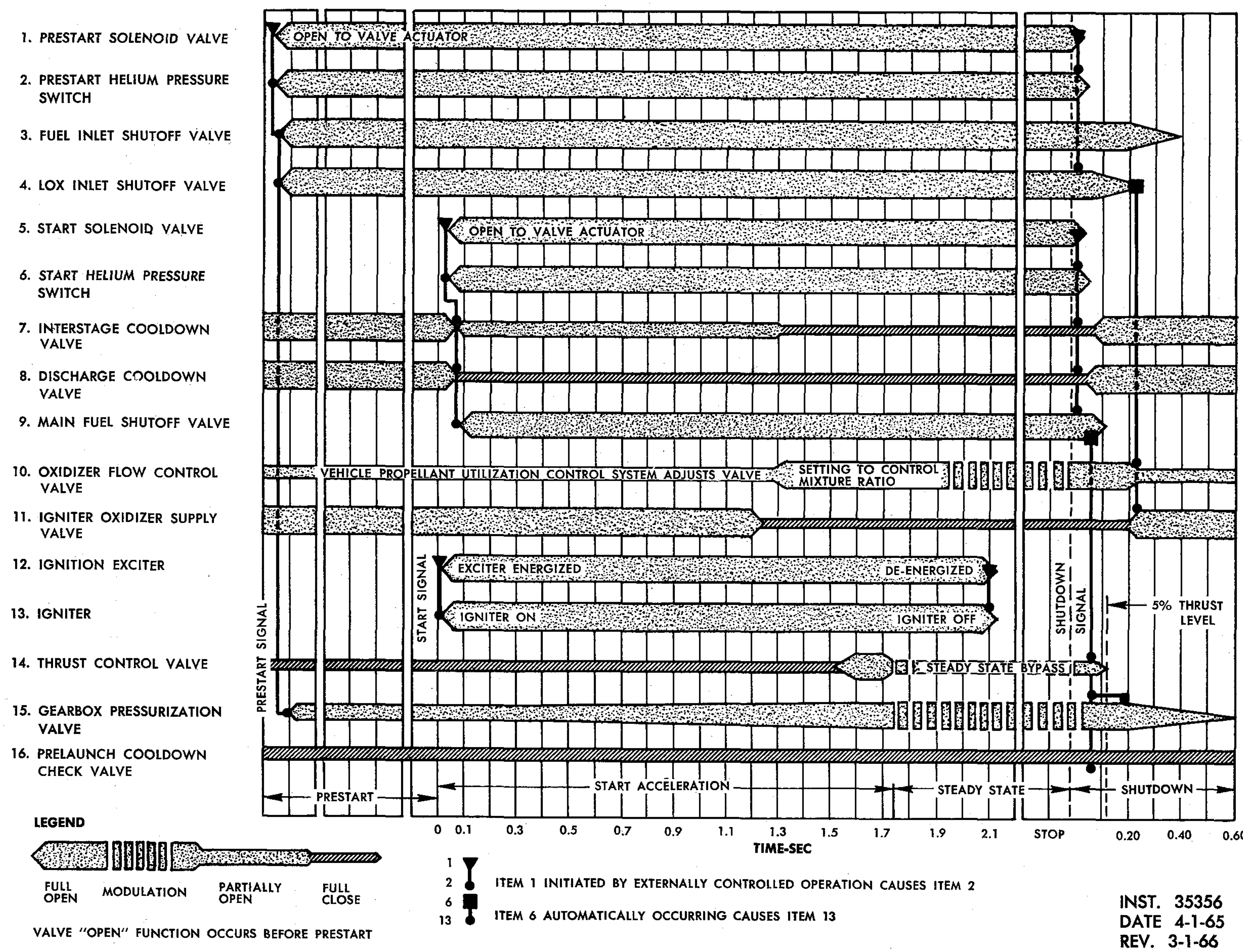
INST. 35361
DATE 4-1-65
REV. 3-1-66

RL10A-3 ENGINE COMPONENT OPERATING SEQUENCE



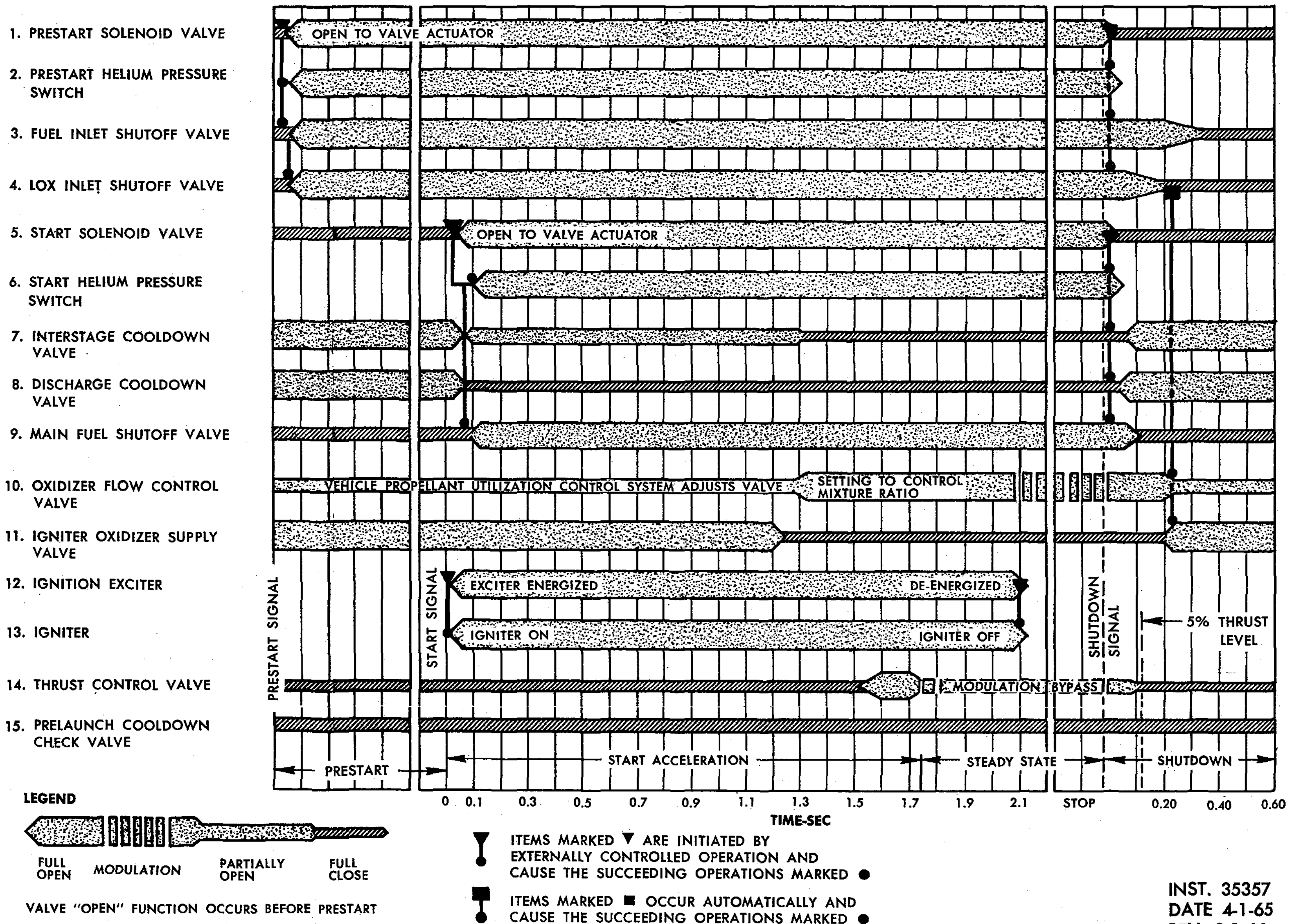
INST. 31419
DATE 4-30-62
REV. 3-1-66

RL10A-3-1 ENGINE COMPONENT OPERATING SEQUENCE



INST. 35356
DATE 4-1-65
REV. 3-1-66

RL10A-3-3 ENGINE COMPONENT OPERATING SEQUENCE

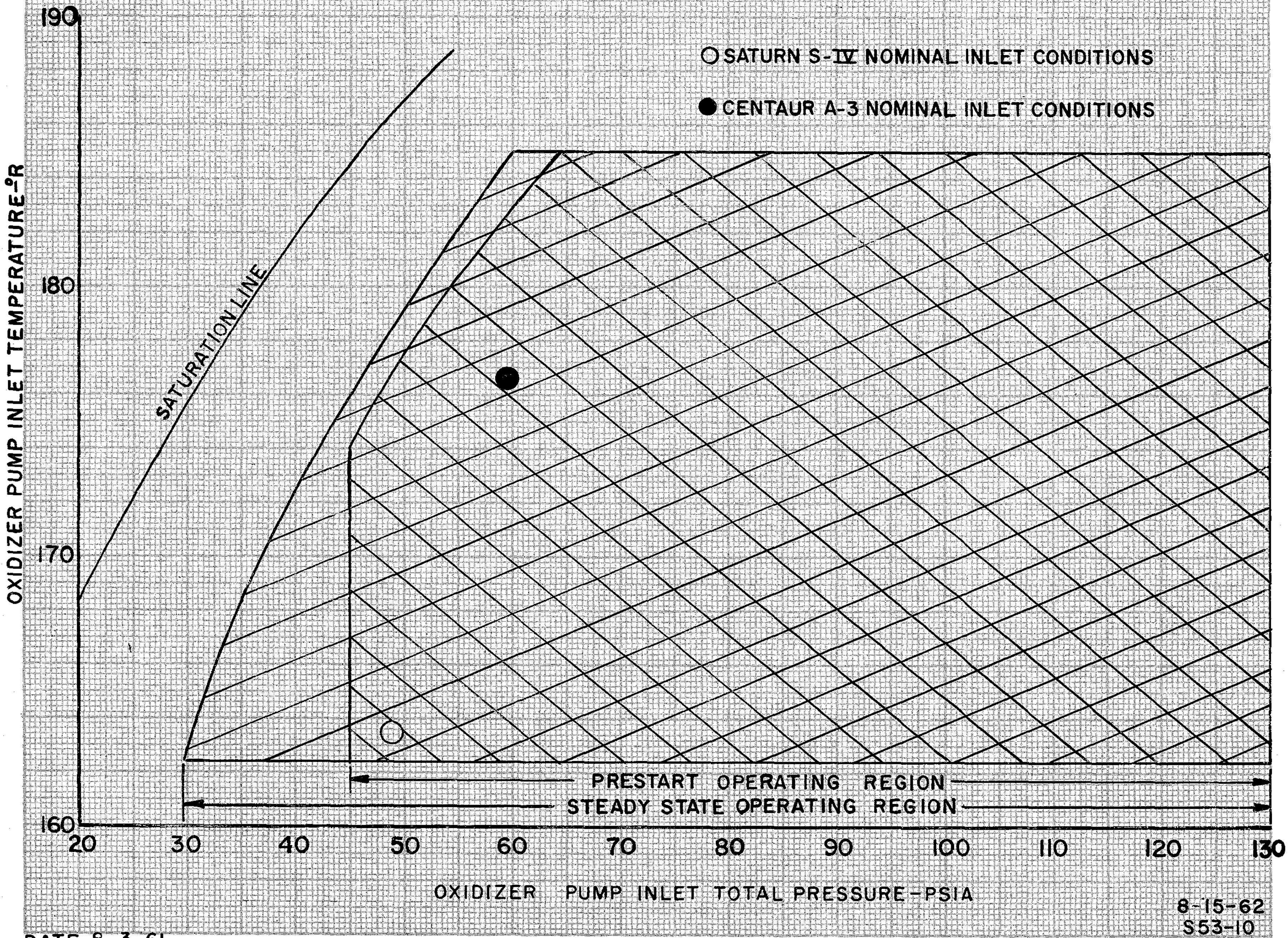


INST. 35357
DATE 4-1-65
REV. 3-1-66

Pratt & Whitney Aircraft

DIVISION OF UNITED AIRCRAFT CORPORATION

RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED LIQUID OXYGEN CONDITIONS REQUIRED AT OXIDIZER PUMP INLET

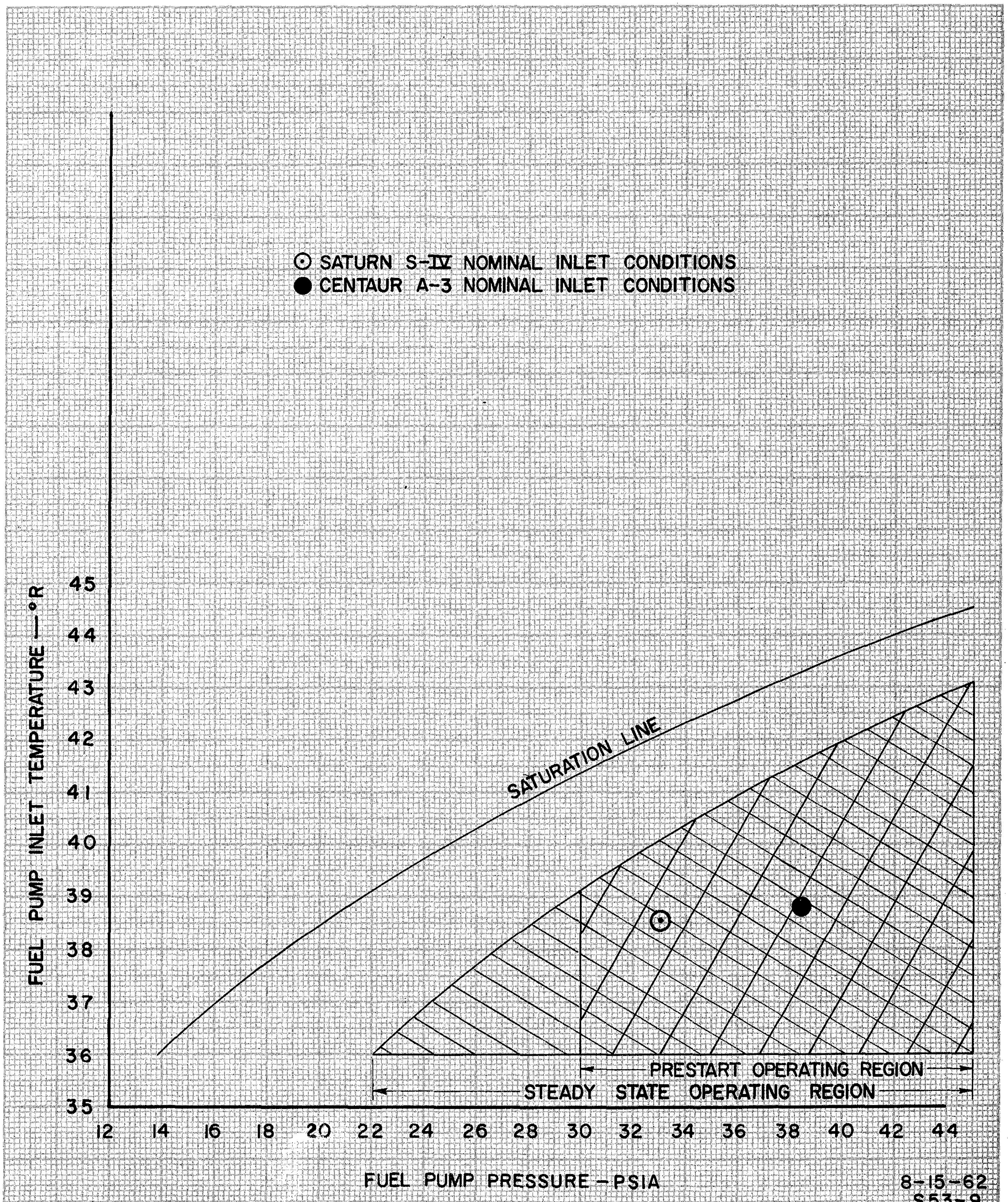


DATE 8-3-61
REV. 3-1-66

CURVE NO. INST. 30505

RL10A-3 LIQUID ROCKET ENGINE

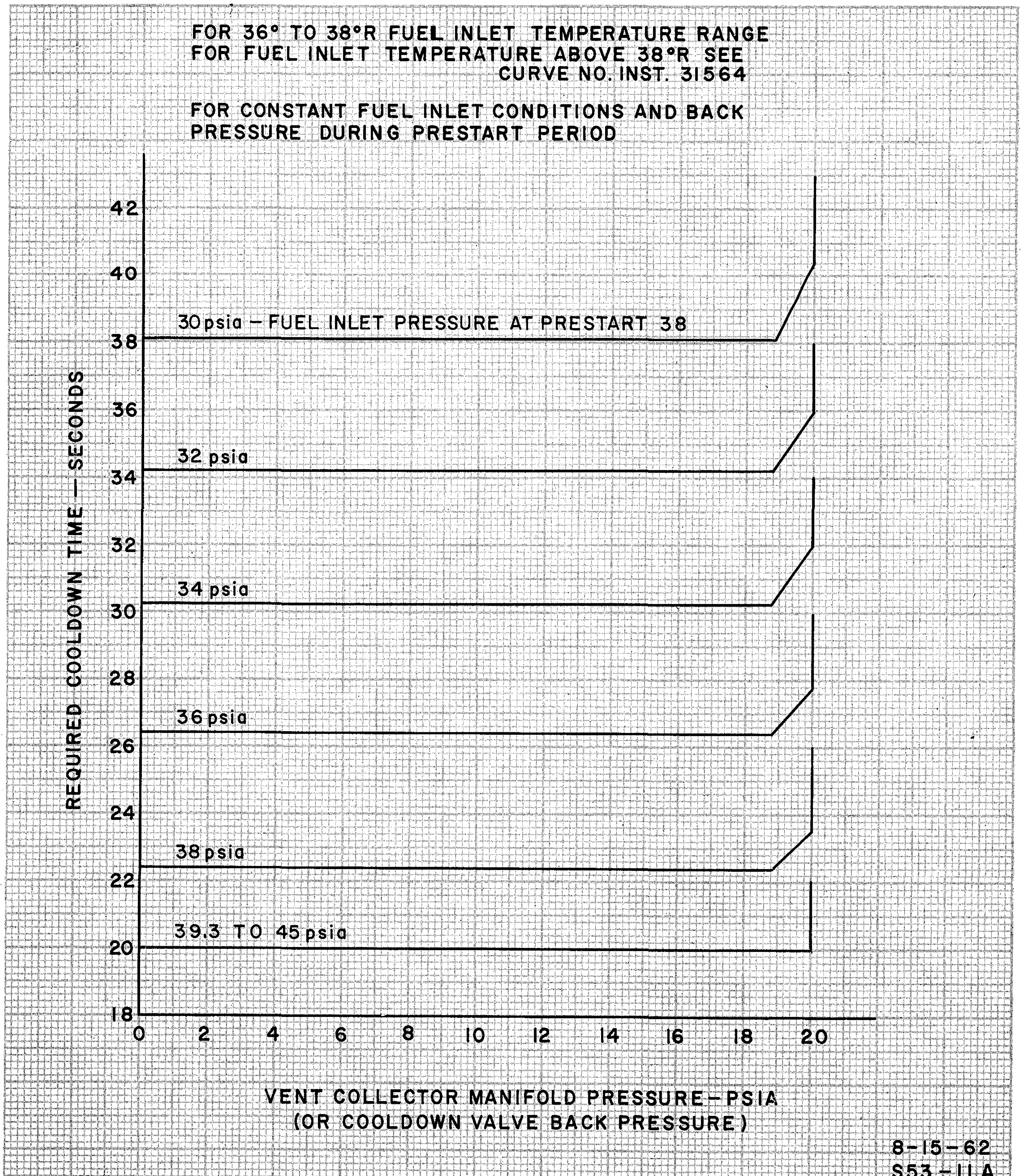
ESTIMATED LIQUID HYDROGEN CONDITIONS REQUIRED AT FUEL PUMP INLET



DATE 8-3-61
REV. 4-1-65

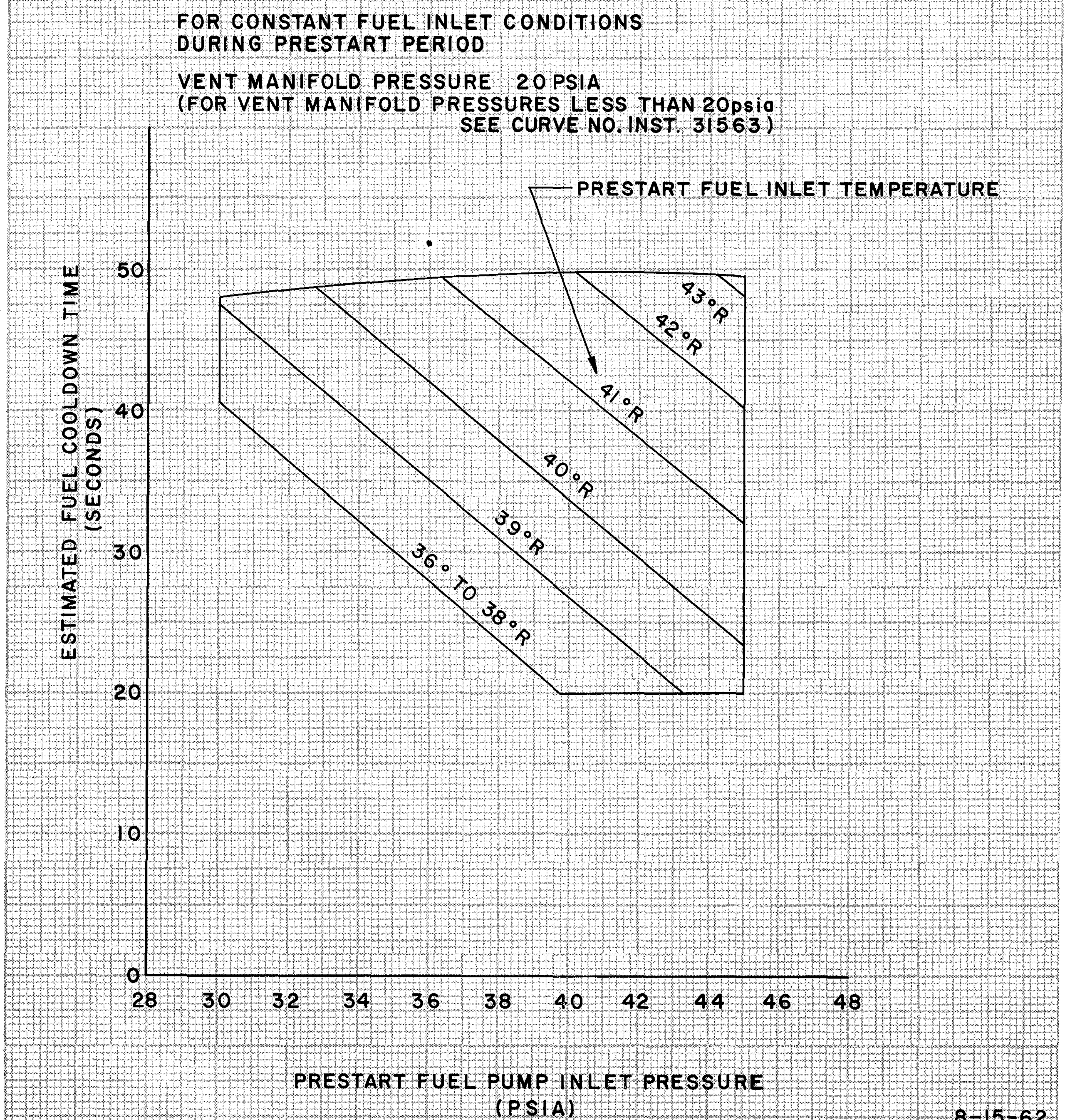
CURVE NO. INST. 30506

RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED MINIMUM COOLDOWN TIME VS VENT COLLECTOR MANIFOLD PRESSURE (OR COOLDOWN VALVE BACK PRESSURE)



RL10A-3 LIQUID ROCKET ENGINE

ESTIMATED MINIMUM FUEL COOLDOWN TIME VS PRESTART FUEL INLET CONDITIONS

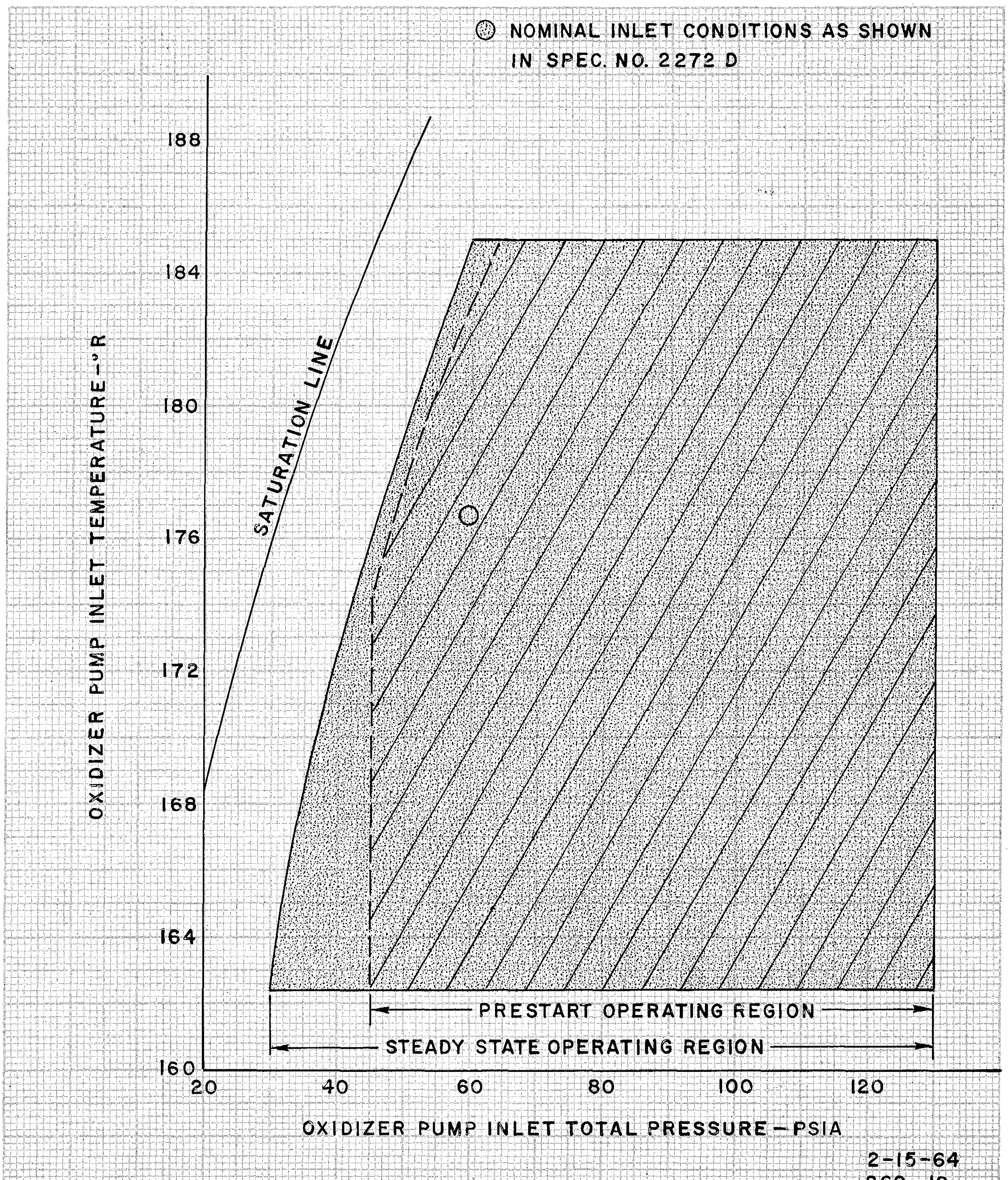


8-15-62
S53-11

DATE 4-15-63
REV 4-1-65

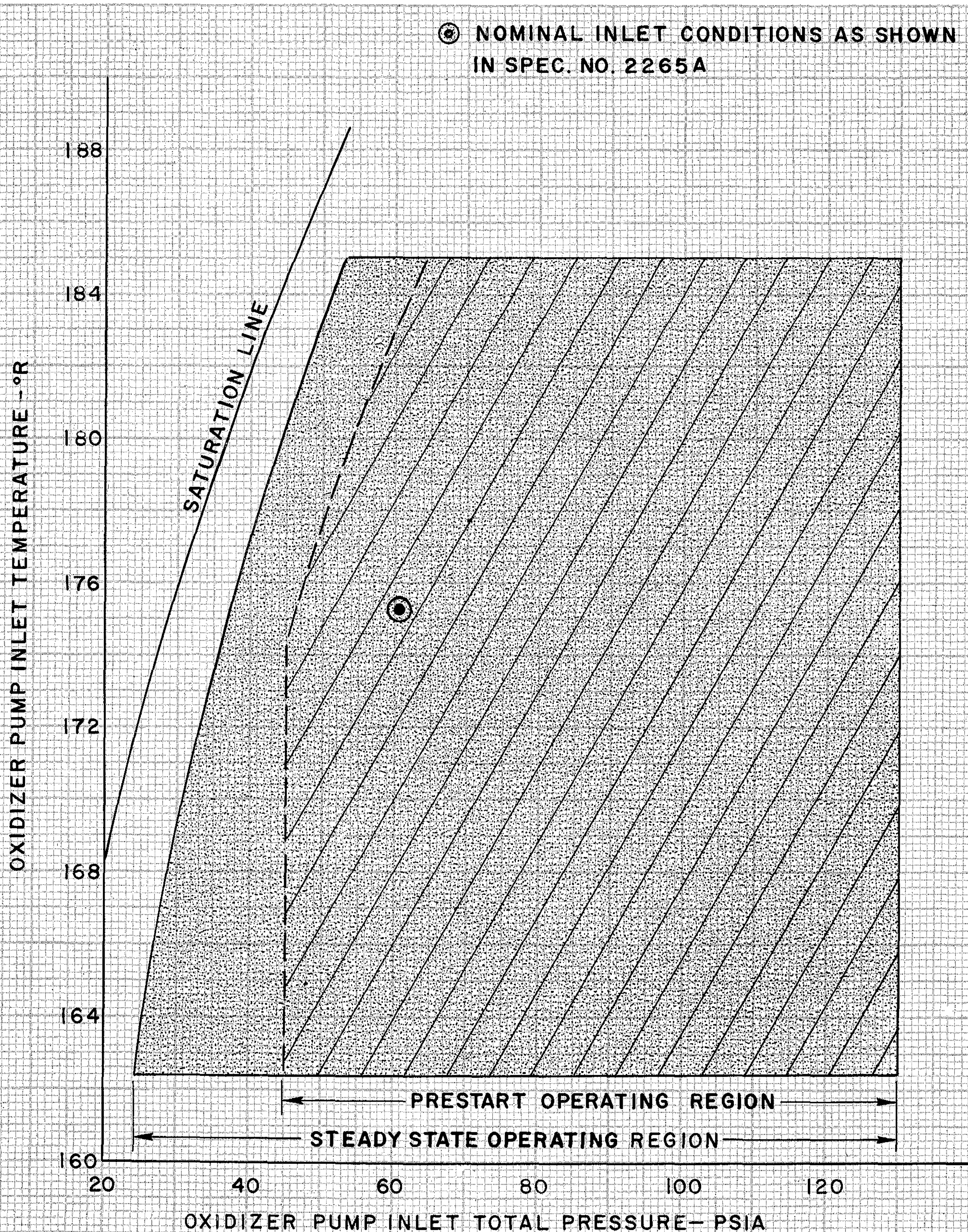
CURVE NO. INST. 31564

RL10A-3-1 LIQUID ROCKET ENGINE
ESTIMATED LIQUID OXYGEN CONDITIONS REQUIRED AT OXIDIZER PUMP INLET



RL10A-3-3 LIQUID ROCKET ENGINE

ESTIMATED LIQUID OXYGEN CONDITIONS REQUIRED AT OXIDIZER PUMP INLET



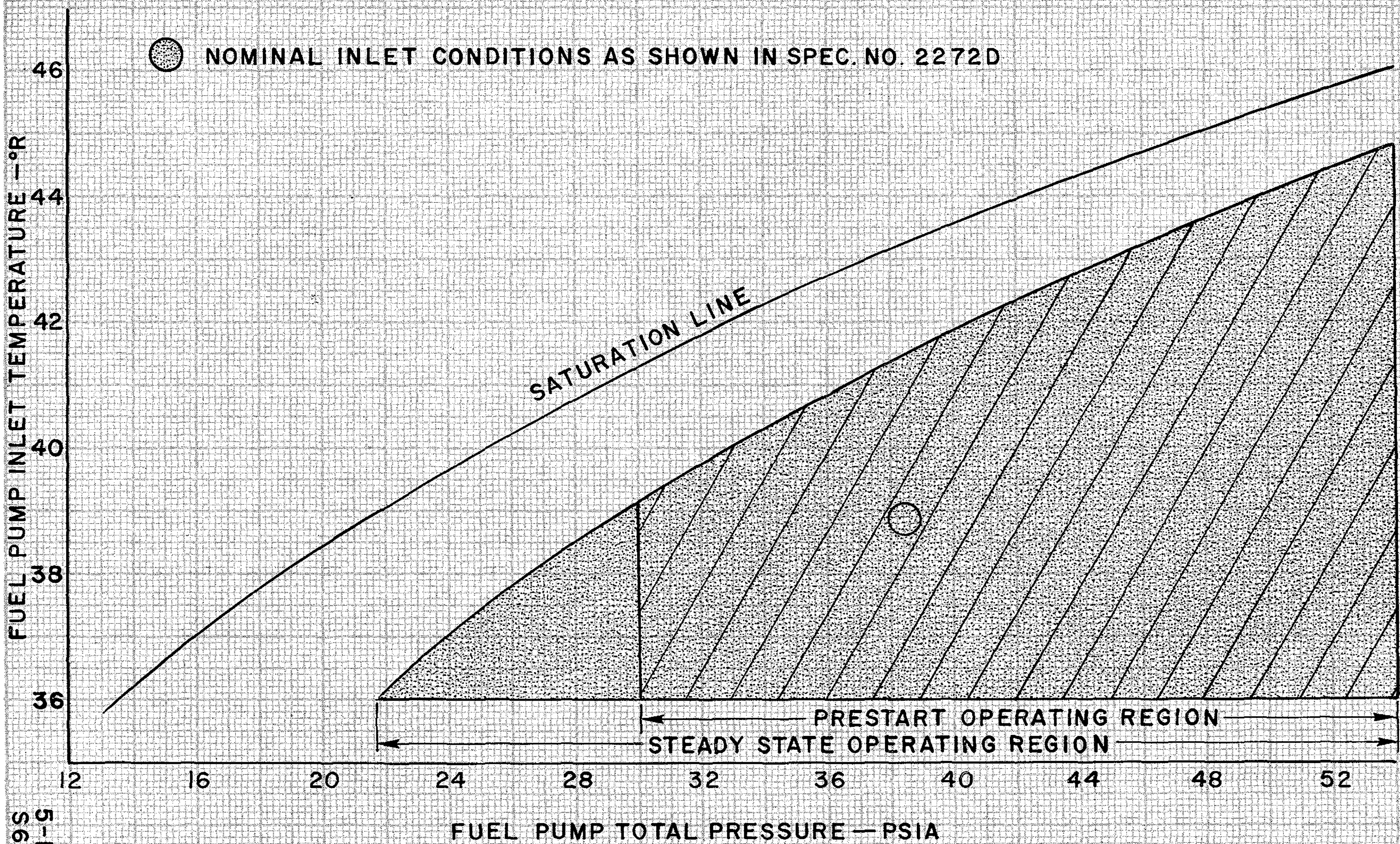
10-11-65
S63-10

DATE 4-1-65
REV. 3-1-66

CURVE NO. INST. 35347

Pratt & Whitney Aircraft
DIVISION OF UNITED AIRCRAFT CORPORATION

RL10A-3-1 LIQUID ROCKET ENGINE
ESTIMATED LIQUID HYDROGEN CONDITIONS REQUIRED AT FUEL PUMP INLET



DATE 4-1-65

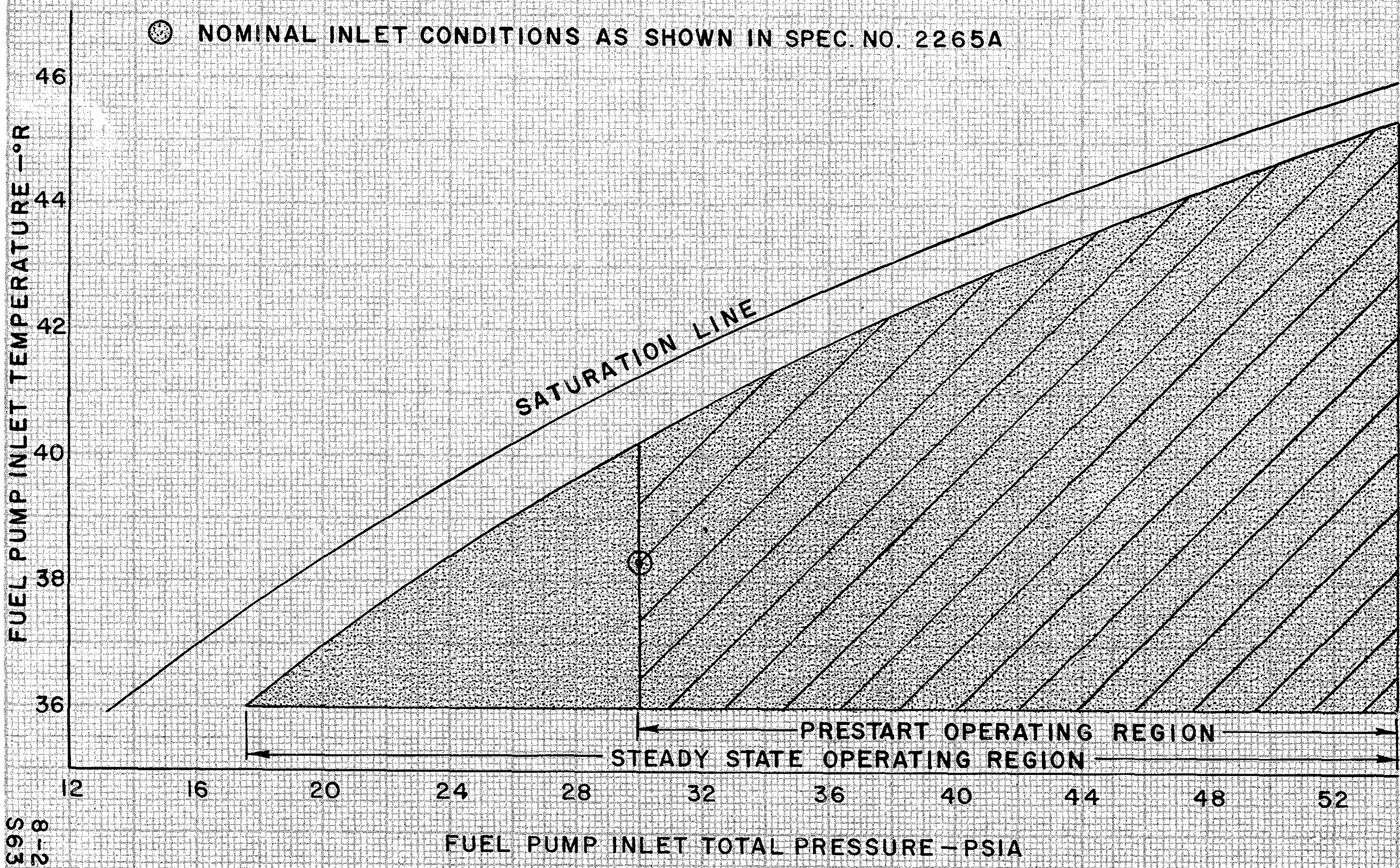
CURVE NO. INST. 35348

5-1-64
S60-9

RL10
Inst. Handbook
Section 5

Pratt & Whitney Aircraft DIVISION OF UNITED AIRCRAFT CORPORATION

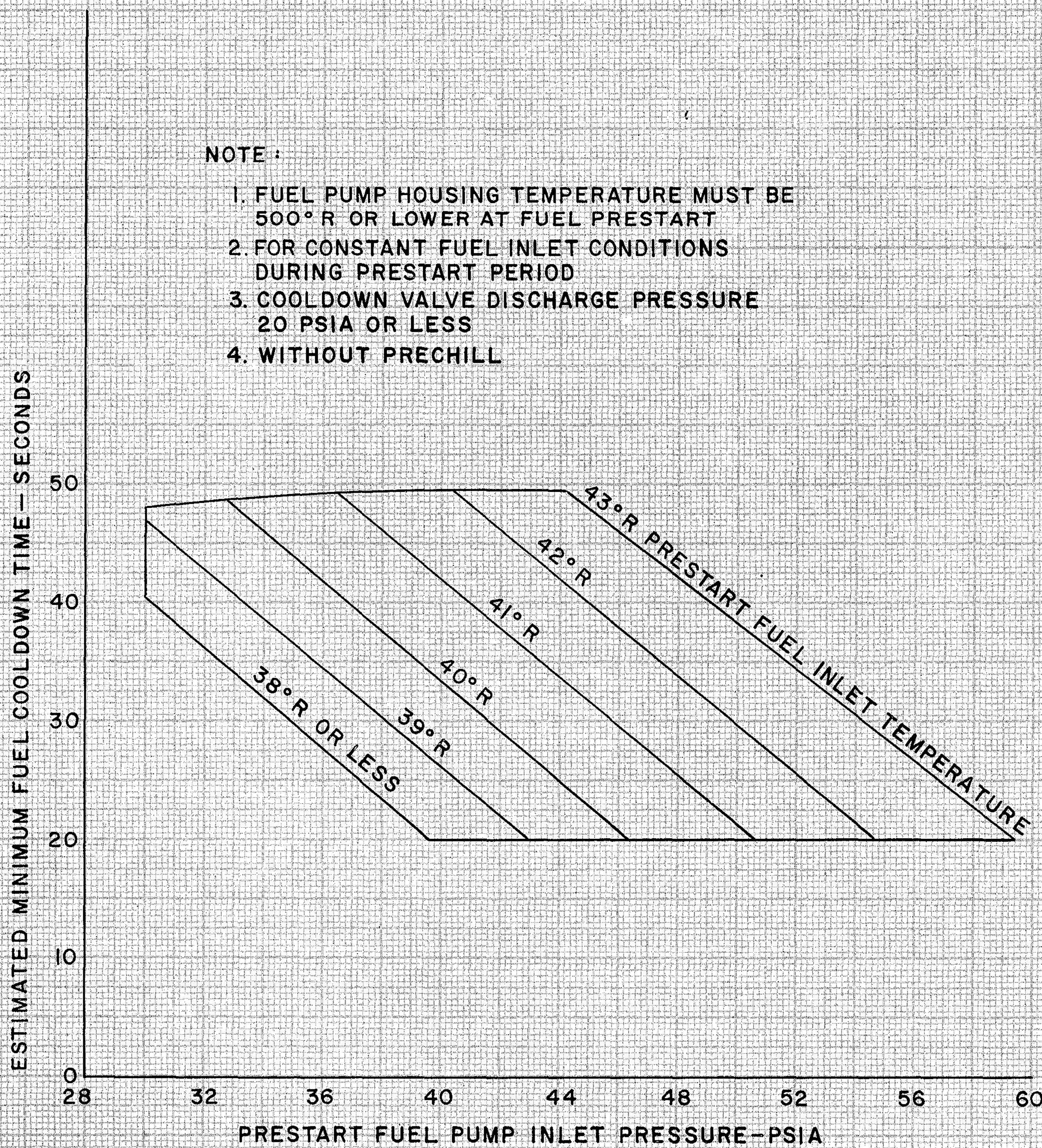
RL10A-3-3 LIQUID ROCKET ENGINE
ESTIMATED LIQUID HYDROGEN CONDITIONS REQUIRED AT FUEL PUMP INLET



CURVE NO. INST. 35349
8-25-65
S63-9

DATE 4-1-65
REV. 3-1-66

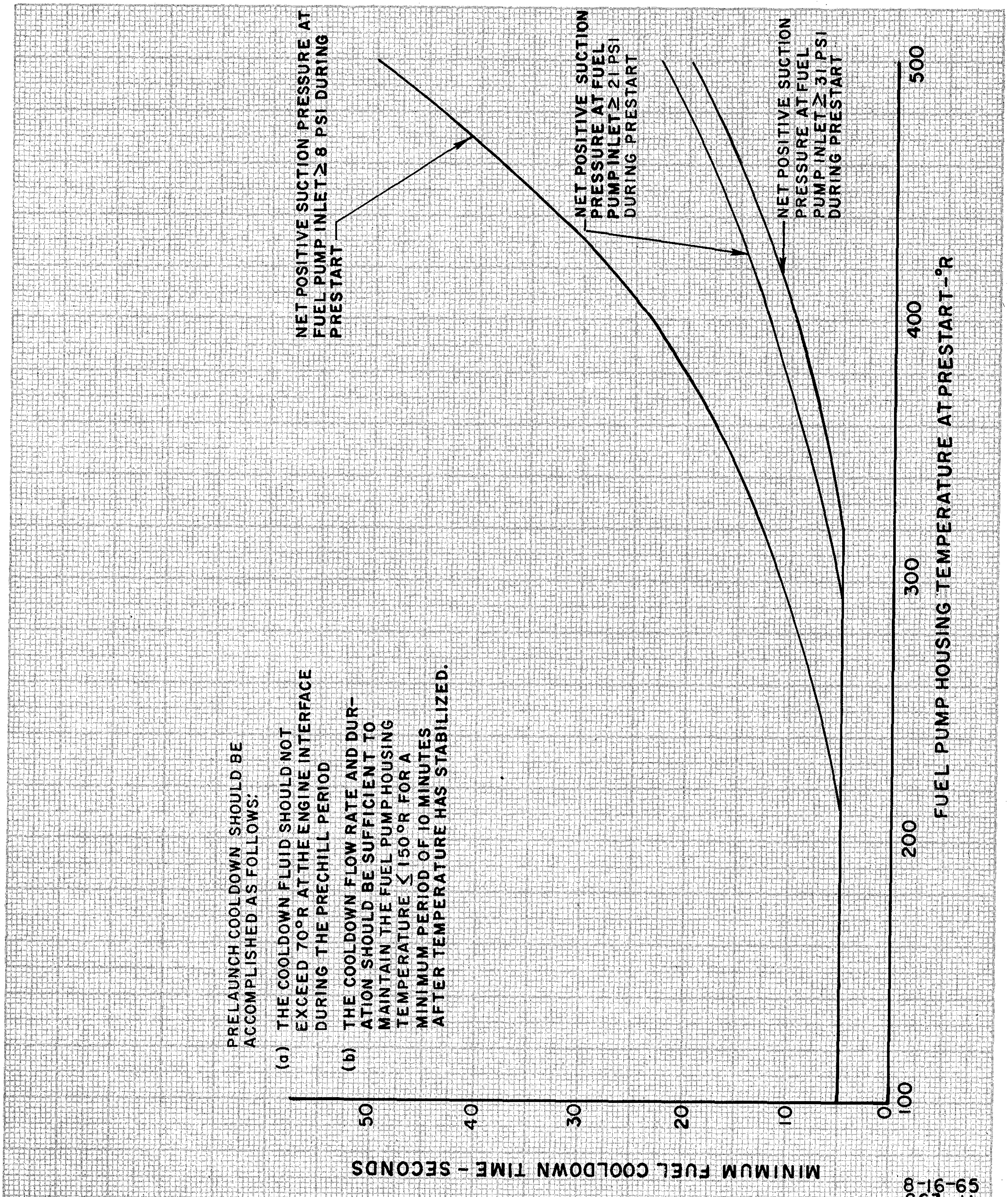
RL10A-3-1 LIQUID ROCKET ENGINE
MINIMUM FUEL COOLDOWN TIME VS PRESTART FUEL INLET CONDITIONS
(COOLDOWN VALVE DISCHARGE PRESSURE 20 PSIA OR LESS)



5-1-64
S60-11

RL10A-3-3 LIQUID ROCKET ENGINE

ESTIMATED FUEL COOLDOWN REQUIREMENTS

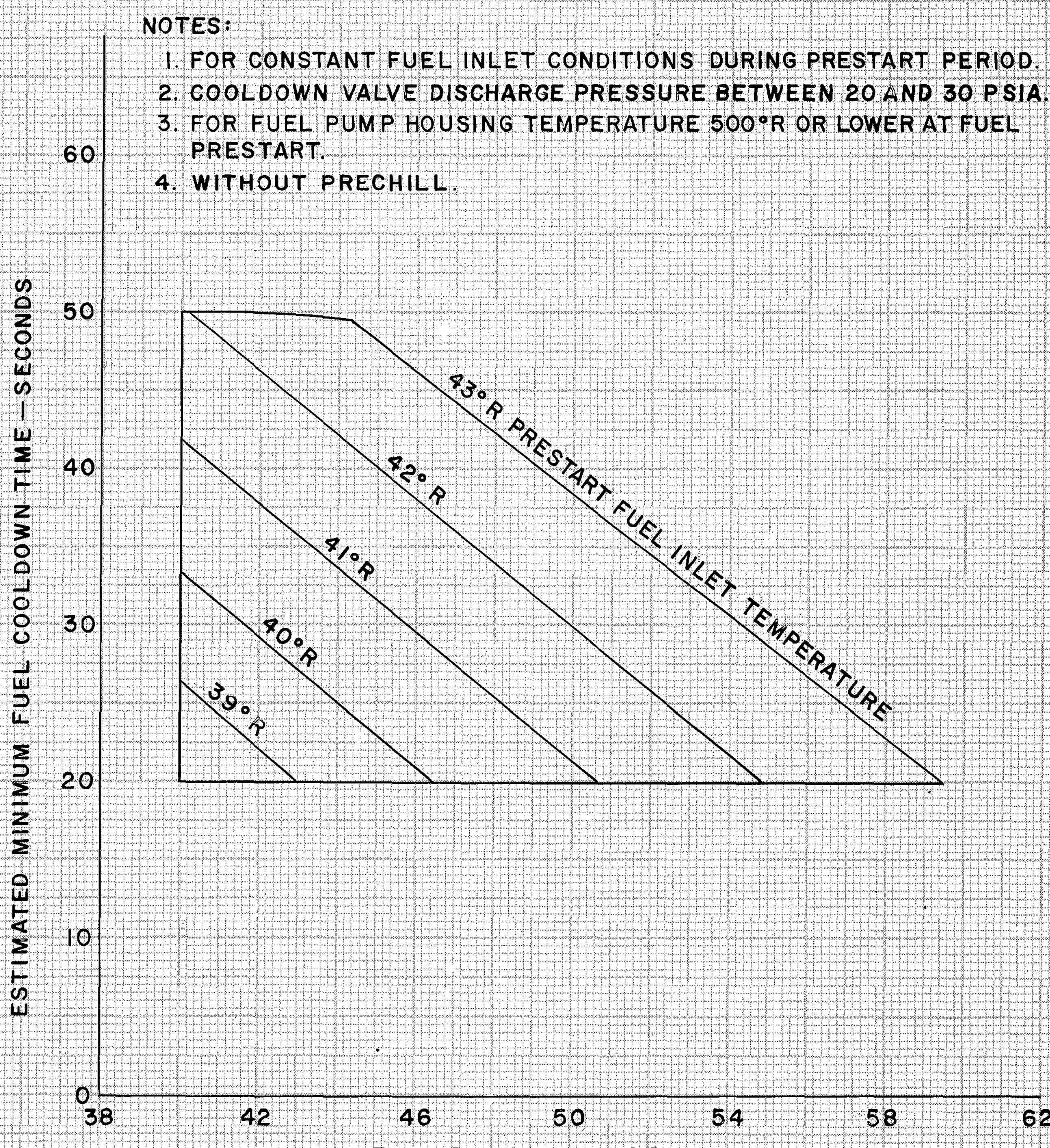


8-16-65
S63-11
CURVE NO. INST. 35351

DATE 4-1-65
REV. 3-1-66

RL10A-3-1 LIQUID ROCKET ENGINE
MINIMUM FUEL COOLDOWN TIME VS PRESTART FUEL INLET CONDITIONS

(COOLDOWN VALVE DISCHARGE PRESSURE BETWEEN 20 AND 30 PSIA)



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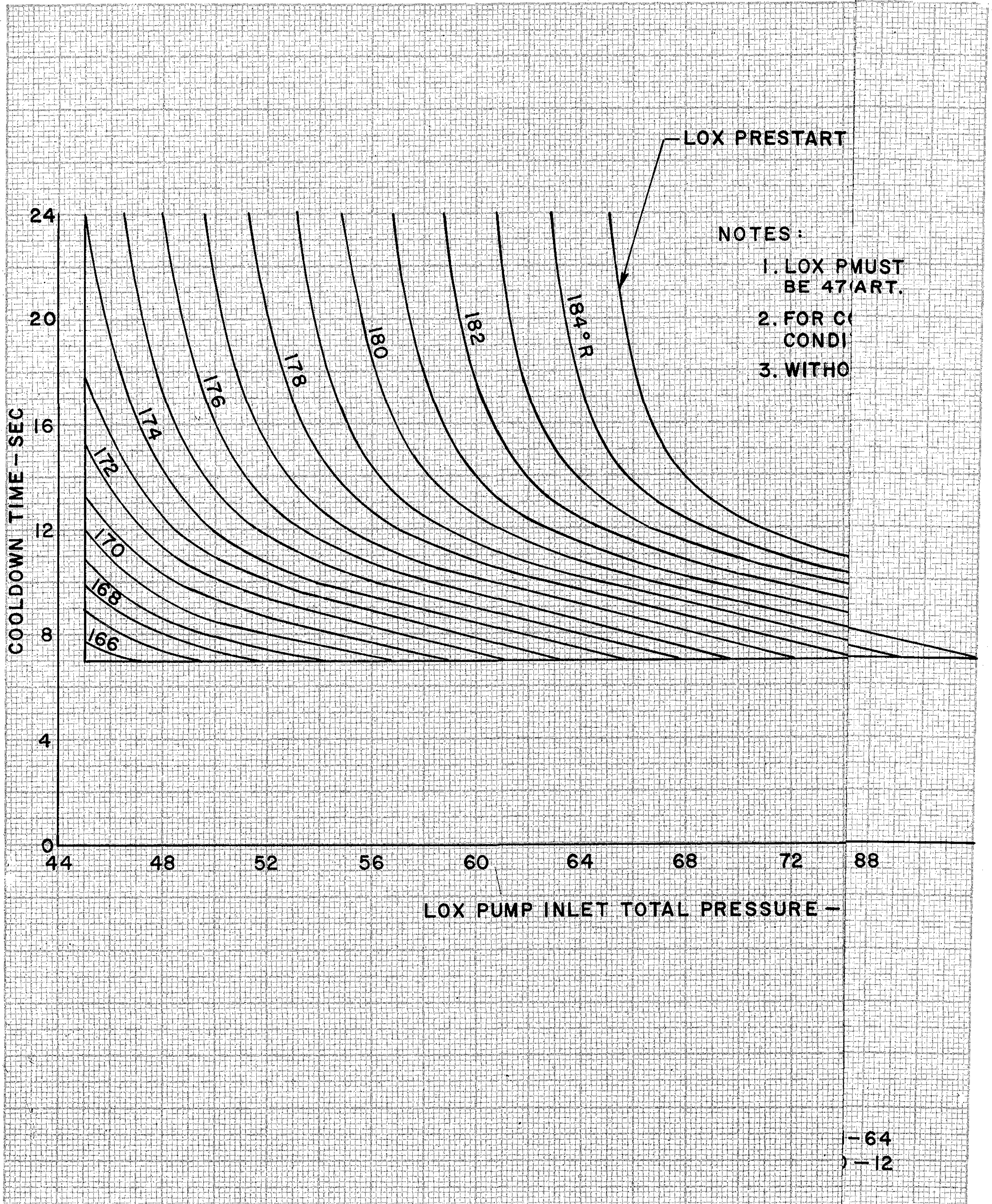
S60-11A

RL10A-3-1 LIQUID ROCKET EN

ESTIMATED MINIMUM COOLDOWN T
VS
OXIDIZER PUMP INLET CONDITIO



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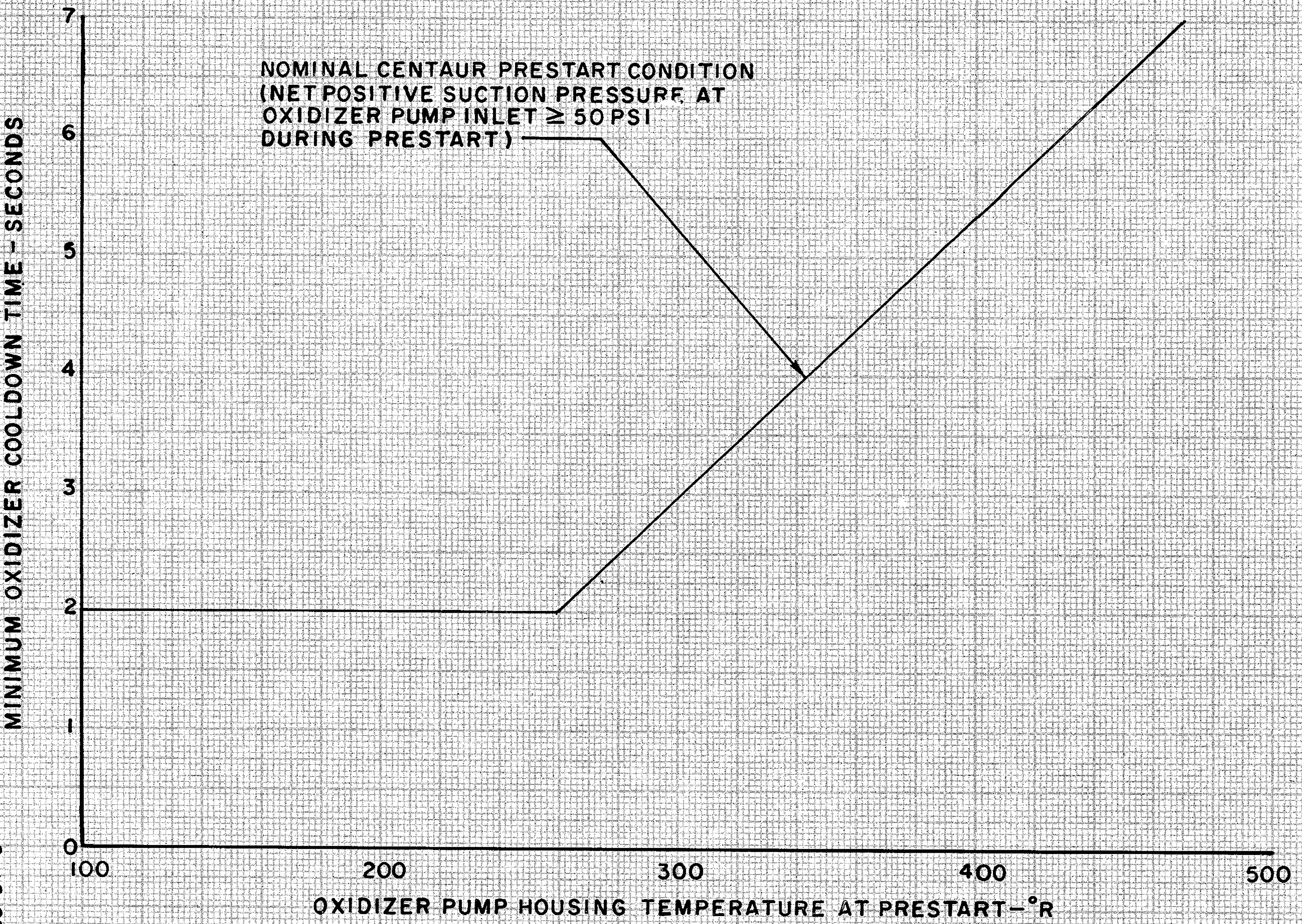
RL10A-3-3 LIQUID ROCKET ENGINE

ESTIMATED OXIDIZER COOLDOWN REQUIREMENTS

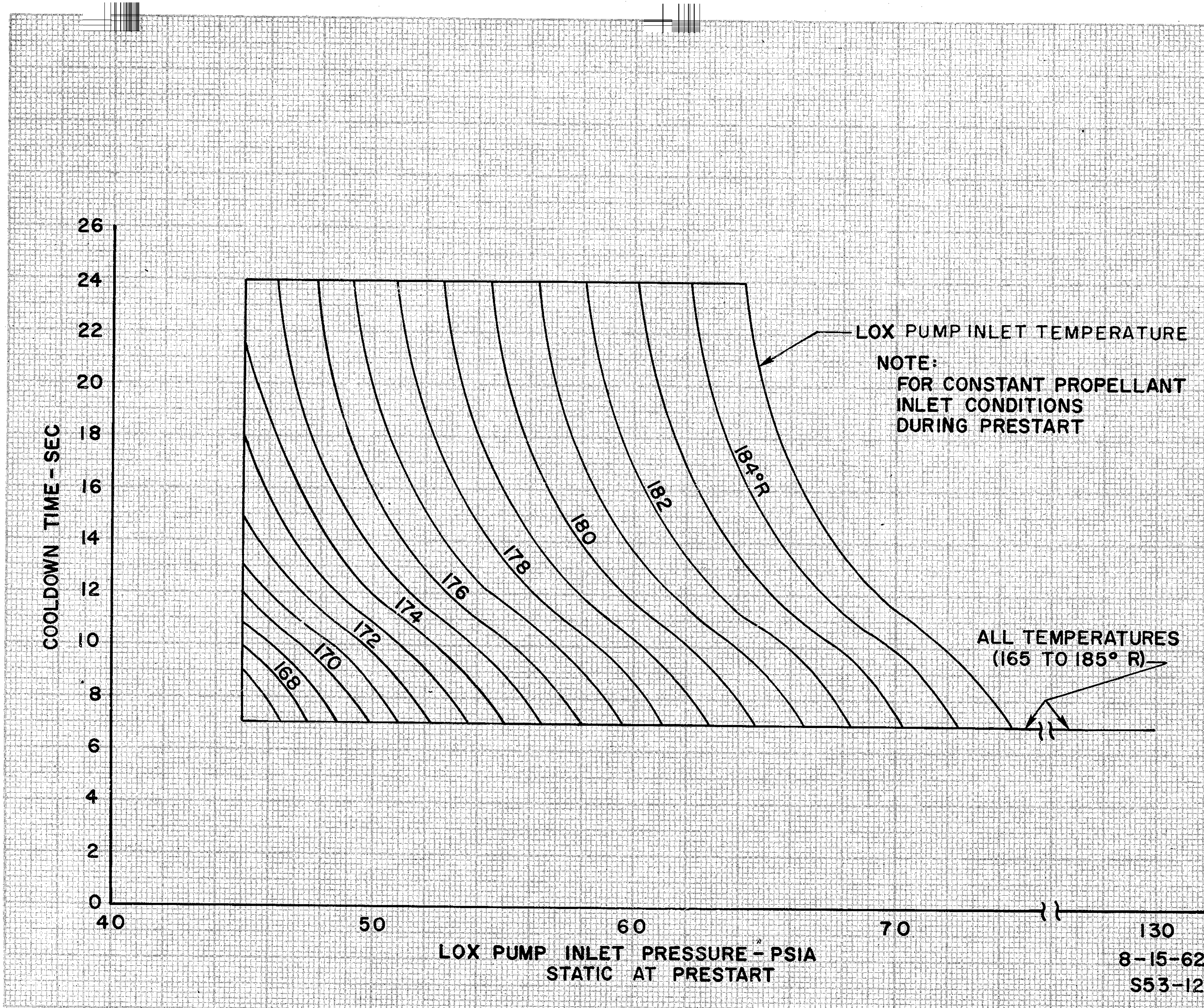


DATE 4-1-65
REV. 3-1-66

CURVE NO. INST. 35355
8-16-65
S63-12

Pratt & Whitney Aircraft
DIVISION OF UNITED AIRCRAFT CORPORATION

RL10A-3 LIQUID ROCKET ENGINE
ESTIMATED MINIMUM COOLDOWN TIME VS. PUMP INLET CONDITIONS



DATE 4-1-65
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CURVE NO. INST. 35392

ELECTRICAL SYSTEM

ELECTRICAL REQUIREMENTS

The RL10 engine requires 28 volts dc electrical power for propellant valve control and engine ignition. Steady state voltage shall be 20 to 30 volts dc. Connectors are shown on the following drawings:

RL10A-3	Inst. 30498
RL10A-3-1	Inst. 35362
RL10A-3-3	Inst. 35363

Specific power requirements are as follows:

Ignition System - 2.5 amp at 28 volt dc for a minimum of 1.5 seconds during each engine starting cycle. For ground test operation, see Service Manual.

Prestart and Start Solenoid Valves - 2.0 amp at 28 volt dc for each valve.

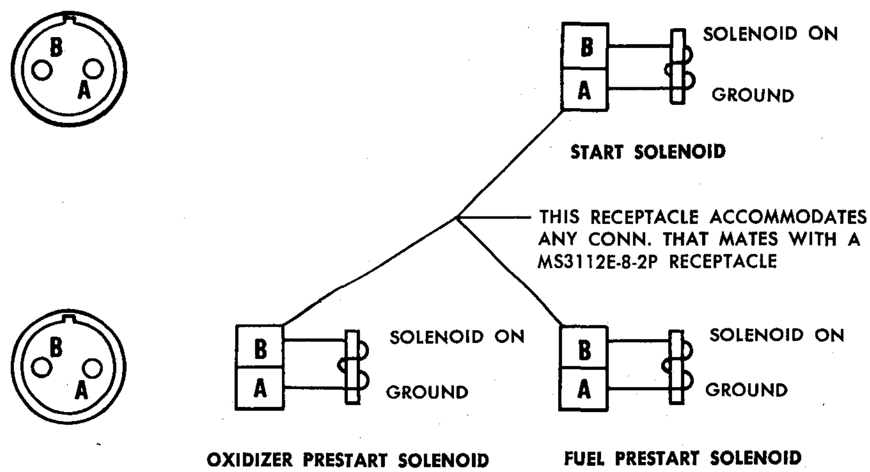
IGNITION SYSTEM

The ignition system consists of a sparkigniter, an exciter assembly, and a rigid, radio-shielded, high-tension lead. At the beginning of the start cycle, which follows the prestart (cool-down) cycle, the vehicle supplies power to the exciter assembly for approximately 2.0 seconds. The exact length of time is governed by vehicle programming and is independent of the actual time required for combustion to begin in the thrust chamber. The exciter releases a capacitance discharge to a high voltage spark-igniter that is installed in the propellant injector of the engine. The exciter furnishes a minimum of 20 sparks per second at a nominal stored energy level of 0.5 joule per spark.

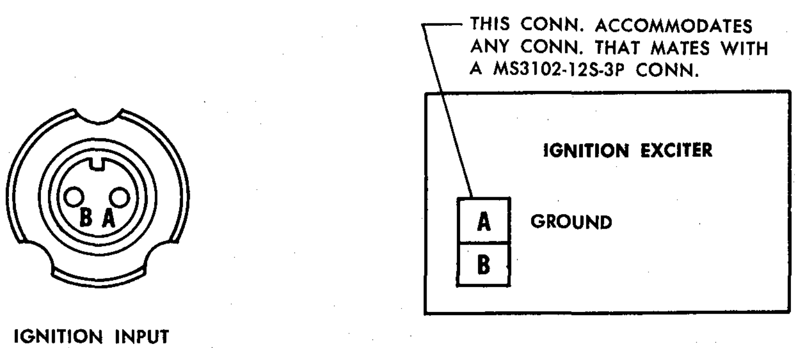
The exciter assembly and high-tension lead are hermetically sealed and internally pressurized to 20 to 30 psia to prevent electrical breakdown when operating under vacuum conditions.

Epoxy coating is applied to the external surfaces and joints of the system to minimize the possibility of internal pressure loss.

Fuel and oxidizer are fed into an annulus surrounding the spark-igniter. The annulus serves as a mixing chamber as the fluids flow toward the sparkigniter tip. The sparkigniter is recessed in the injector face to form a chamber that tends to keep the combustible mixture concentrated near the spark.

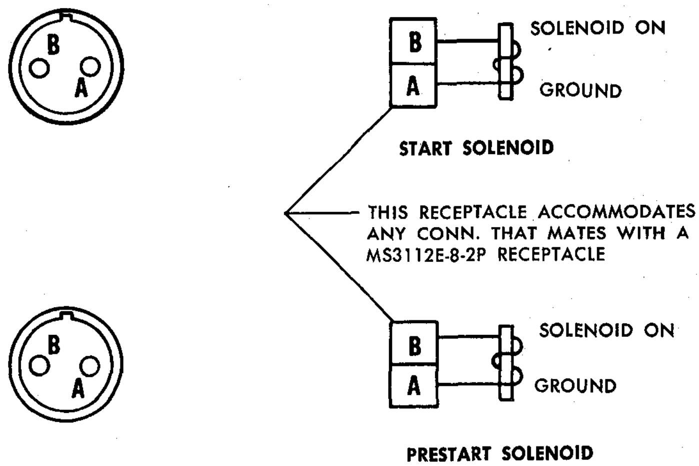


RL10A-3
PRESTART AND START SOLENOID CONNECTORS

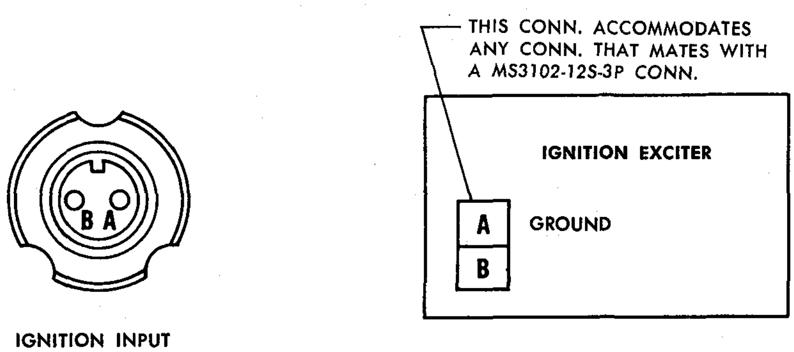


RL10A-3
IGNITION SYSTEM

INST. 30498
DATE 4-1-65
REV. 3-1-66

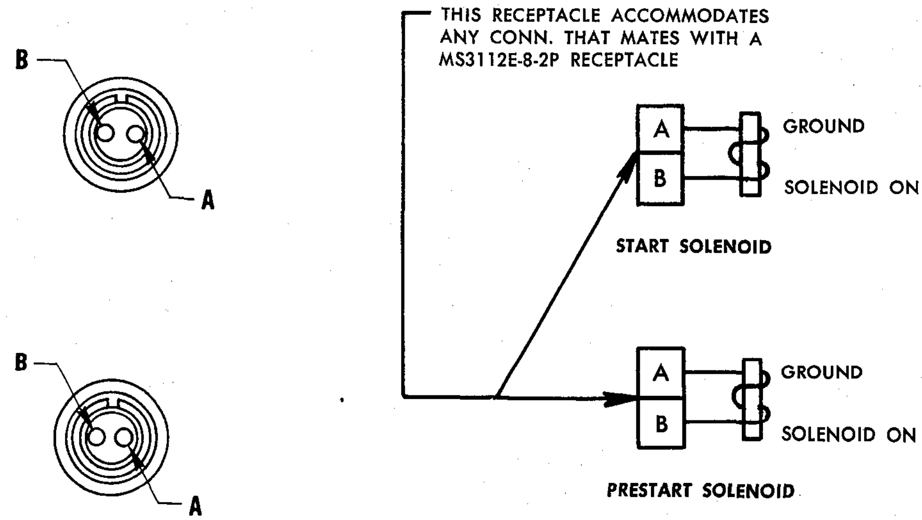


RL10A-3-1
PRESTART AND START SOLENOID CONNECTORS

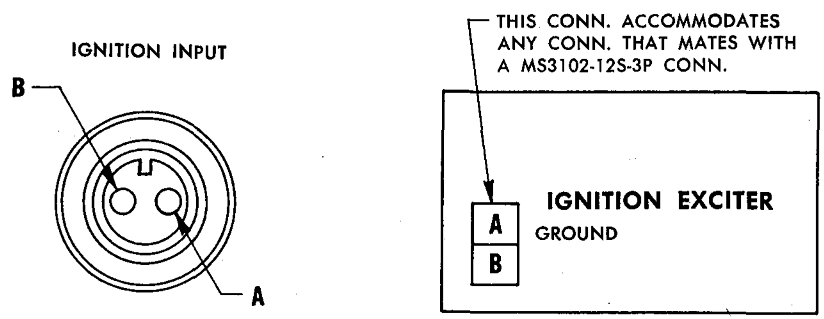


RL10A-3-1
IGNITION SYSTEM

INST. 35362
DATE 4-1-65



RL10A-3-3
PRESTART AND START SOLENOID CONNECTORS



RL10A-3-3
IGNITION SYSTEM

INST. 35363
DATE 4-1-65

INSTRUMENTATION

The RL10 engine is supplied with a flight instrumentation kit which provides for indication of rocket engine operation and malfunction. This kit includes temperature sensors, a speed signal generator, pressure taps, pressure switches, and enclosures for mounting and protecting vehicle-supplied instrumentation components.

If additional instrumentation provisions are required, such items must be furnished and installed by Pratt & Whitney Aircraft.

Instrumentation wiring schematics are shown on the following diagrams:

RL10A-3	Inst. 30535
RL10A-3-1	Inst. 35365
RL10A-3-3	Inst. 35366

FLIGHT TEMPERATURE SENSORS

The temperature sensors provided on the RL10 engine are the resistance type and are designed specifically for each location.

SPEED SIGNAL GENERATOR

The speed pickup is located on the oxidizer pump housing and is of the reluctance type sensing the passing of five steel pins on the oxidizer pump shaft gear. Each passing of a pin past the sensor produces a wave shape of one cycle duration, which is not sinusoidal. Dead time between cycles is a function of engine speed. Voltage output is approximately linear with speed.

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FLIGHT INSTRUMENTATION PROVISIONS

Engine Connections	Operating Range	Applicable Engine Model		
		RL10A-3	RL10A-3-1	RL10A-3-3
Fuel pump				
Inlet pressure	0 to 275 psia	X	X	X
Discharge pressure	0 to 1200 psia	X	-	-
Housing temperature	35 to 570°R	X	X	X
Oxidizer pump				
Inlet pressure	0 to 150 psia	X	X	X
Discharge pressure	0 to 750 psia	X	-	-
Housing temperature	140 to 570°R	X	X	X
Rotational speed	0 to 14,000 rpm	X	X	X
Turbine				
Inlet pressure	0 to 800 psia	X	-	-
Inlet temperature	35 to 700°R	X	X	X
Venturi				
Inlet pressure	0 to 850 psia	X	X	X
Injector				
Oxidizer injector differential pressure	0 to 115 psid	X	X	X
Fuel injector differential pressure	0 to 90 psid	X	-	-
Combustion chamber				
Pressure	0 to 340 psia	X	X	-
	0 to 460 psia	-	-	X
Outer skin temperature	100 to 670°R	X	X	-
Fuel prestart helium pressure switch *				
Oxidizer prestart helium pressure switch *				
Start helium pressure switch				
Ignition indicator				
Exciter box pressure indicator				

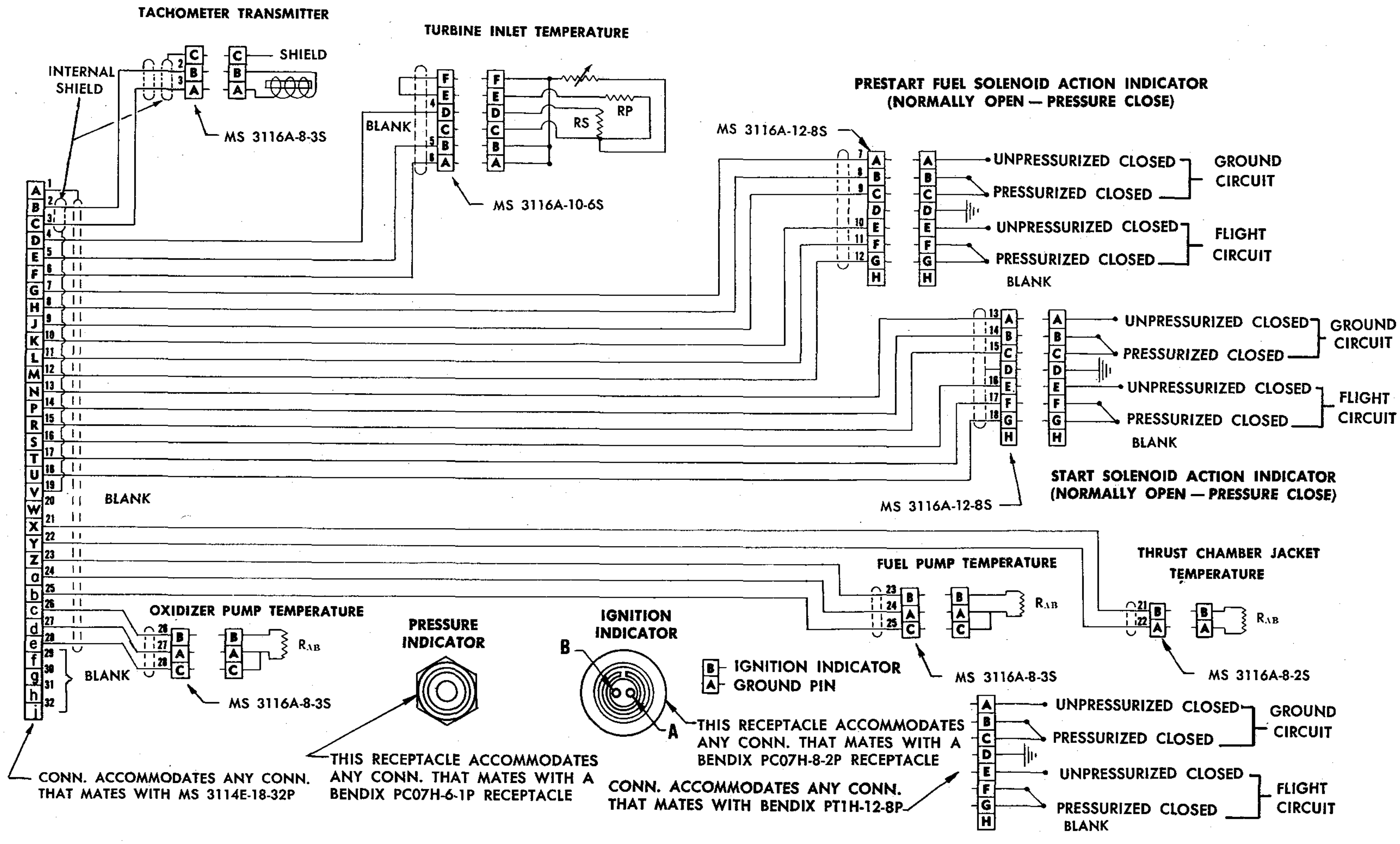
* A single prestart solenoid valve controls helium pressure on the RL10A-3-1 and RL10A-3-3 models.

Provisions are also made on the RL10A-3 model for:

> The attachment of two vehicle-supplied pressure switches on the oxidizer line downstream of the mixture ratio and propellant utilization valve.

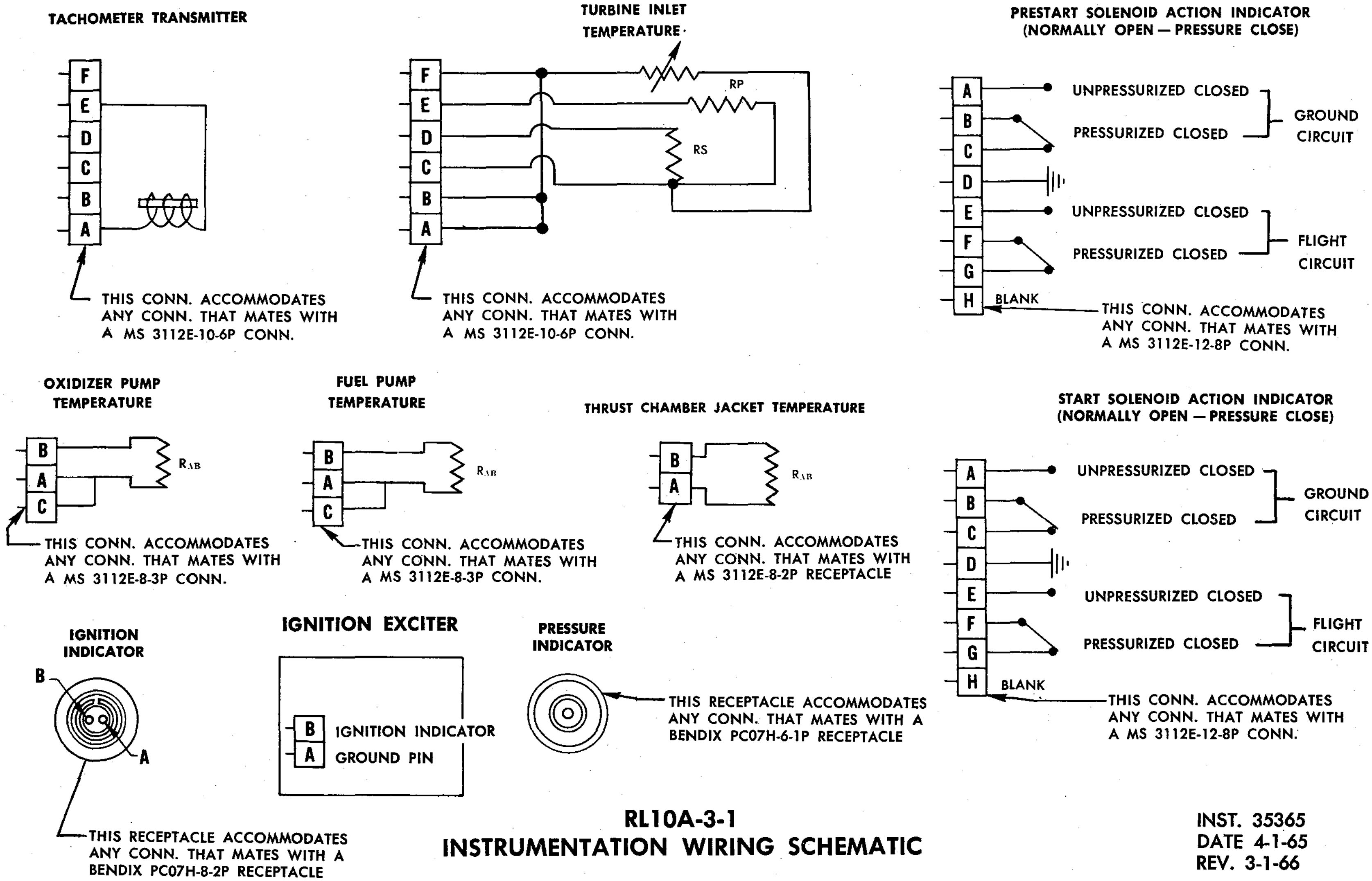
All models contain provisions for the attachment of vehicle-supplied gimbal angle indicators.

Recommended Vehicle Connections	Operating Range
Fuel Pump Inlet Temperature	37 to 45°R
Oxidizer Pump Inlet Temperature	160 to 200°R

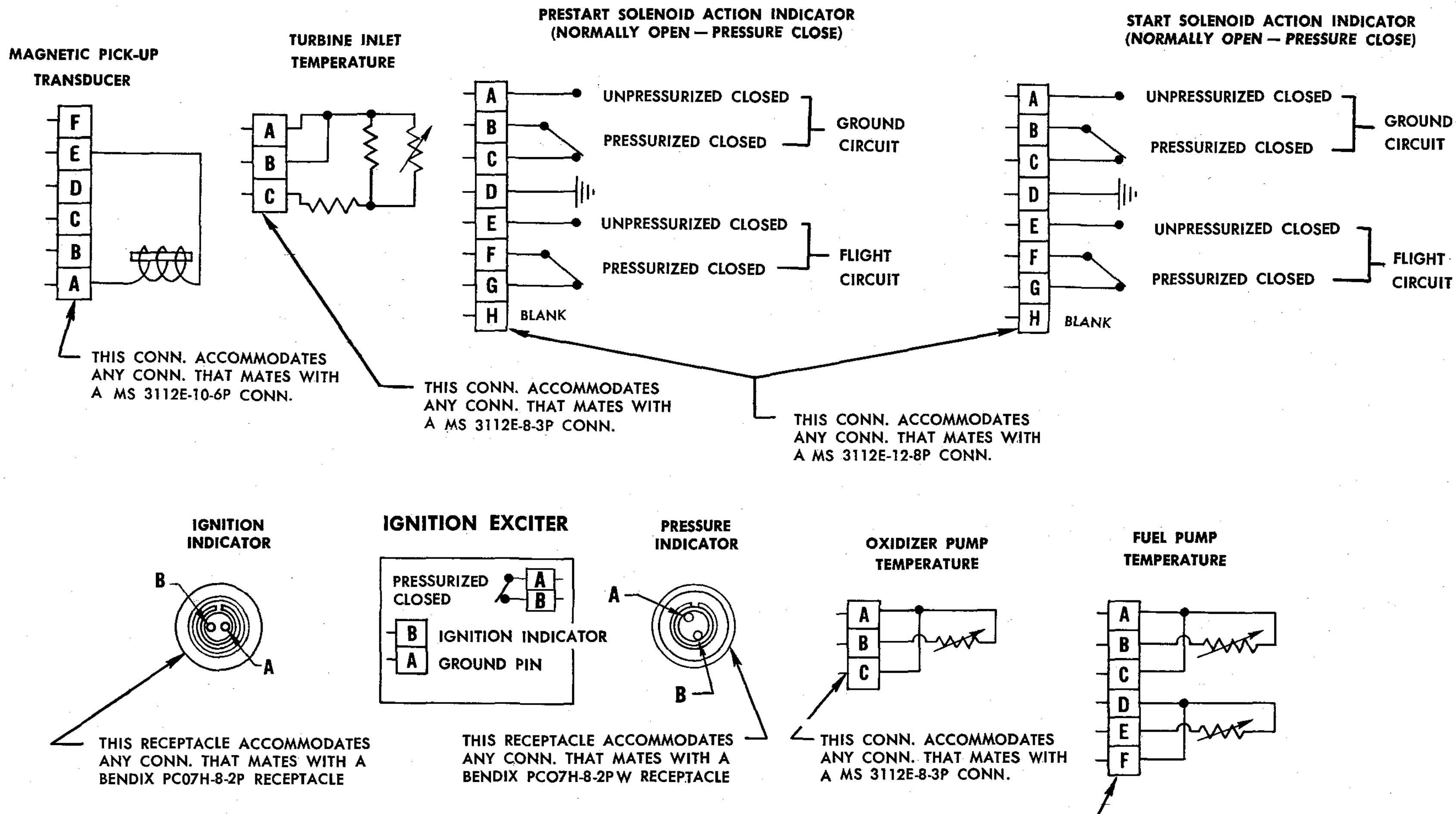


RL10A-3C AND -3S
INSTRUMENTATION WIRING SCHEMATIC

INST 30535
DATE 8-15-61
REV. 4-1-65



RL10A-3-1
INSTRUMENTATION WIRING SCHEMATIC



THIS CONN. ACCOMMODATES ANY CONN. THAT MATES WITH A MS 3112E-10-6P CONN.

RL10A-3-3
INSTRUMENTATION WIRING SCHEMATIC

INST. 35366
DATE 4-1-65
REV. 3-1-66

ACCESSORIES

Accessory Drive

The accessory drive pad is located on the aft end of the oxidizer pump shaft. Details of the pad and drive spline are shown on the Engine Installation Drawing.

Accessory Drive Characteristics	RL10A-3
Drive pad type	AND 20000, Type X-A (Dimensional only)
Speed, Nominal	11,400 rpm
Max Continuous Torque	20 lb-in.
Max Static Torque	20 lb-in.
Direction of Rotation	Counterclockwise
Temperature at pad face and drive spline	Approximately 80°R
Designed Accessory Load (1 g)	12 lb
Designed Overhung Moment (1 g)	33 lb-in.

The engine accessory drive will not accept leakage from the vehicle-supplied accessory of material which will:

(a) be solid at or above 40°R
(b) enter the interface cavity at a flow rate sufficient to raise the interface cavity pressure to 18 psia (at vacuum ambient), or
(c) otherwise introduce a hazardous condition

Accessory Drive Characteristics	RL10A-3-1
Drive Pad Type	AND 20000, Type X-A (Dimensional only)
Speed, Nominal	11,340 rpm
Max Continuous Torque	20 lb-in.
Max Static Torque	20 lb-in.
Direction of Rotation	Counterclockwise
Temperature at Pad Face and Drive Spline	Approximately 80°R
Designed Accessory Load (1 g)	20 lb
Designed Overhung Moment (1 g)	90 in-lbs

The engine accessory drive will not accept leakage from the vehicle-supplied accessory of material which will:

(a) be solid at or above 40°R

(b) enter the interface cavity at a flow rate sufficient to raise the interface cavity pressure to 18 psia (at vacuum ambient), or

(c) otherwise introduce a hazardous condition

Accessory Drive Characteristics	RL10A-3-3
Drive Pad Type	AND 20000, Type X-A (Dimensional only)
Speed, Nominal	12,000 rpm
Acceleration, Maximum	38,000 rpm/sec.
Max Continuous Torque	20 lb-in.
Max Static Torque	20 lb-in.
Direction of Rotation	Counterclockwise
Temperature at Pad Face and Drive Spline	Approximately 80°R
Designed Accessory Load (1 g)	20 lb
Designed Overhung Moment (1 g)	90 in-lbs

The engine accessory drive will not accept leakage from the vehicle-supplied accessory of material which will:

(a) be solid at or above 40°R

(b) enter the interface cavity at a flow rate sufficient to raise the interface cavity pressure to 18 psia (at vacuum ambient)