(NASA-CR-76993) LEM DESENT ENGINE STATUS (Bellcomm, Inc.) 18 p

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BELLCOMM, INC.

SUBJECT: LEM Descent Engine Status (U)
Case 330

DATE: February 9, 1966

FROM: R. R. Schreib, Jr.

MEMORANDUM FOR FILE

The attached material, prepared for Thomas M. Crawford, MAP, on January 28, summarizes the development status of the descent engine as derived from trip reports(1),(2) and other sources. It is of particular use in describing engine duty cycle history and engine performance estimates and requirements.

R. R. Schreib, Jr.

R. R. Schreib, Jr.

2031-RRS-sam

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(See next page)

[redacted]

FACILITY FORM
(ACCESSION NUMBER) (THRU)
(CATEGORY)

GROUP-4
Downgraded at 3 year intervals;
declassified after 12 years

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(1) "Trip Report - LEM Descent Engine 9th Quarterly Review, TRW/Systems, Redondo Beach, December 3, 1965 (U)", R. R. Schreib, December 14, 1965.

(2) "Trip Report - LEM Descent Engine, Eighth Quarterly Review, TRW/Systems, Redondo Beach, California, August 9, 1965", R. R. Schreib, Jr., September 11, 1965.

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LEM DESCENT ENGINE ITEMS

Duty Cycle: (See 3 figures and 2 tables attached)

- The December (1965) cycle is latest; specified by GAEC.
- There have been numerous although not drastic changes.
- Differences still remain between those being specified and those arising from simulations.

Performance: (See figure and summary of Engine Technical Requirements)

- Tests of Mod 29 injectors continue to give scattered performance results (falling between the TRW maximum estimate and their predicted curve in the figure).

- GAEC simulations (July 65) with a 32,500 lb LEM for a 803 sec descent indicated a propellant consumption of 17,230 lb for their "Required" Aug. 65 curve and 17,378 lb for TRW "Predicted" (Mod 29) curve. Specified usable capacity is 17,360.

- 30% total throat erosion had been predicted. This causes a 5% thrust increase in 400 sec and a performance dropoff of $\approx$ 4 sec.

- TRW says Barrier Cooling tests indicate: (See 14th Quarterly)

  - No net throat area change in 400 sec at full F with 95.8% C*

  - Stable at 93, 50 and 30% F

  - No change in C*

  - Compatible with 10 to 1 throttling

  (Configuration: 36 injection holes in face plate; 10% of fuel used in barrier).

Combustion:

- Bomb stability - demonstrated at 100, 50, and 10% thrust with four bomb locations.

- Some lightweight head ends show mid-range (30-50%F) roughness. (A fuel velocity/injector contour/performance problem.)

Throttling:

- More data needed to characterize Mixture Ratio changes during throttling. A characteristic "dip" in the MR vs F curve makes it more difficult to meet the spec.

- "Head end stops" for fixed high level thrust have led to mechanical and electrical changes in the actuator.

Altitude Starts:

- TRW has "demonstrated" altitude starts at 100, 90, 50, 30, and 16% F.
- These starts may be of questionable value because test stand (VETS) dead end "vacuum" is 1 to 2 psia. There is also some question of operational procedure (ex: use of purges).

Mechanical:

- Long duration runs are confirming ablator design (using previous duty cycle chambers).
- Needle-felt successful as a substitute for silica paper lightweight chamber insulation.
- Chamber design released December 17, 1965. Design margins and durability must be determined before final release.
- Lightweight head ends (injectors) being fabricated. All-steel pintle tip successfully solved erosion problem of copper tip.
- A Columbium nozzle extension has survived rough treatment in test. Fabrication and quality problems may come up.
- Propellant shut-off valve seals have been leaking.

Testing Facilities:

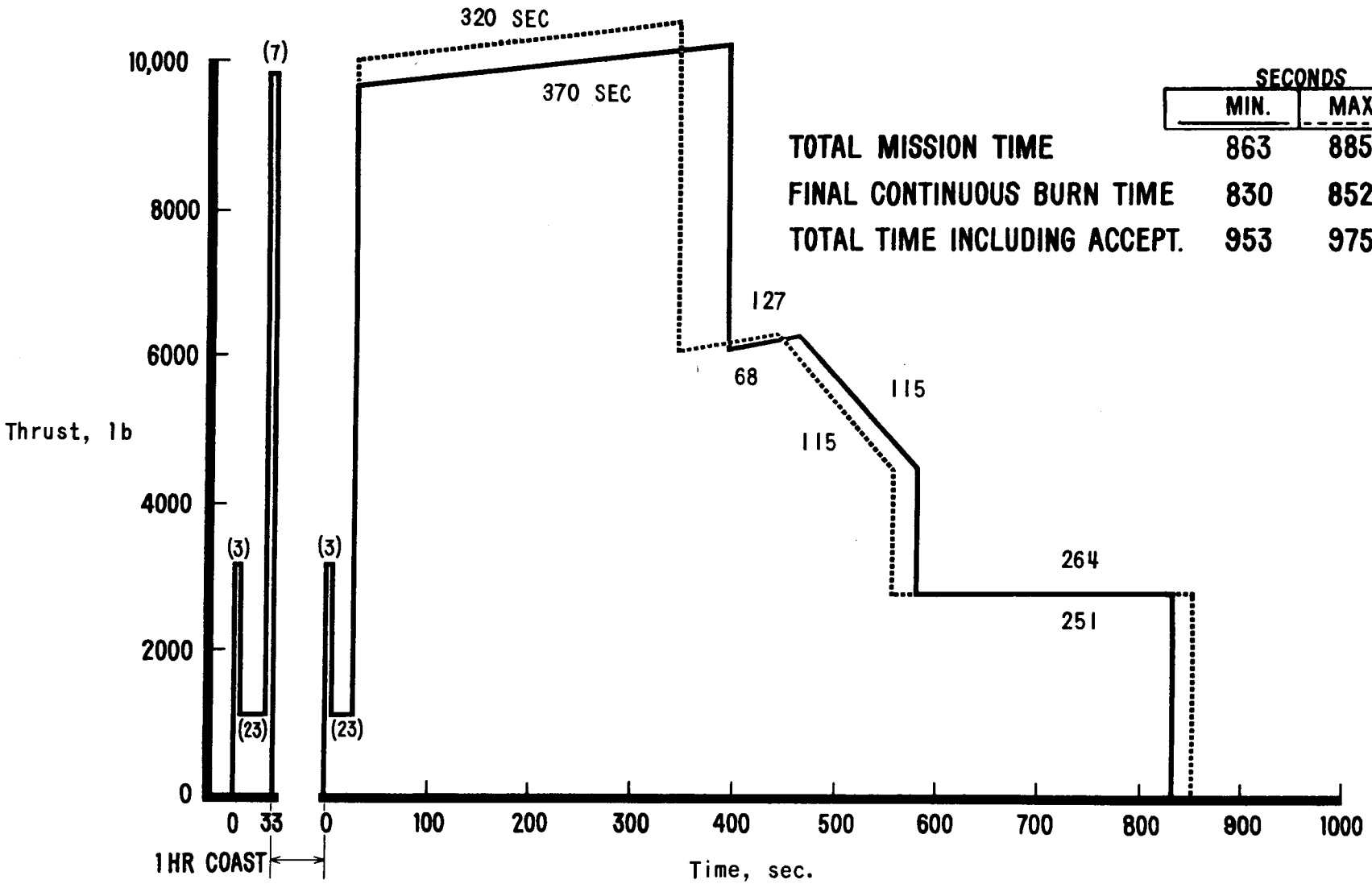
- AEDC producing little significant data.
- HATS facility modification for extended duration is on tight schedule.

Weight:

- December weight = 396 Spec = 390
- Weight study of 33 potential items totaling 17 lbs underway.

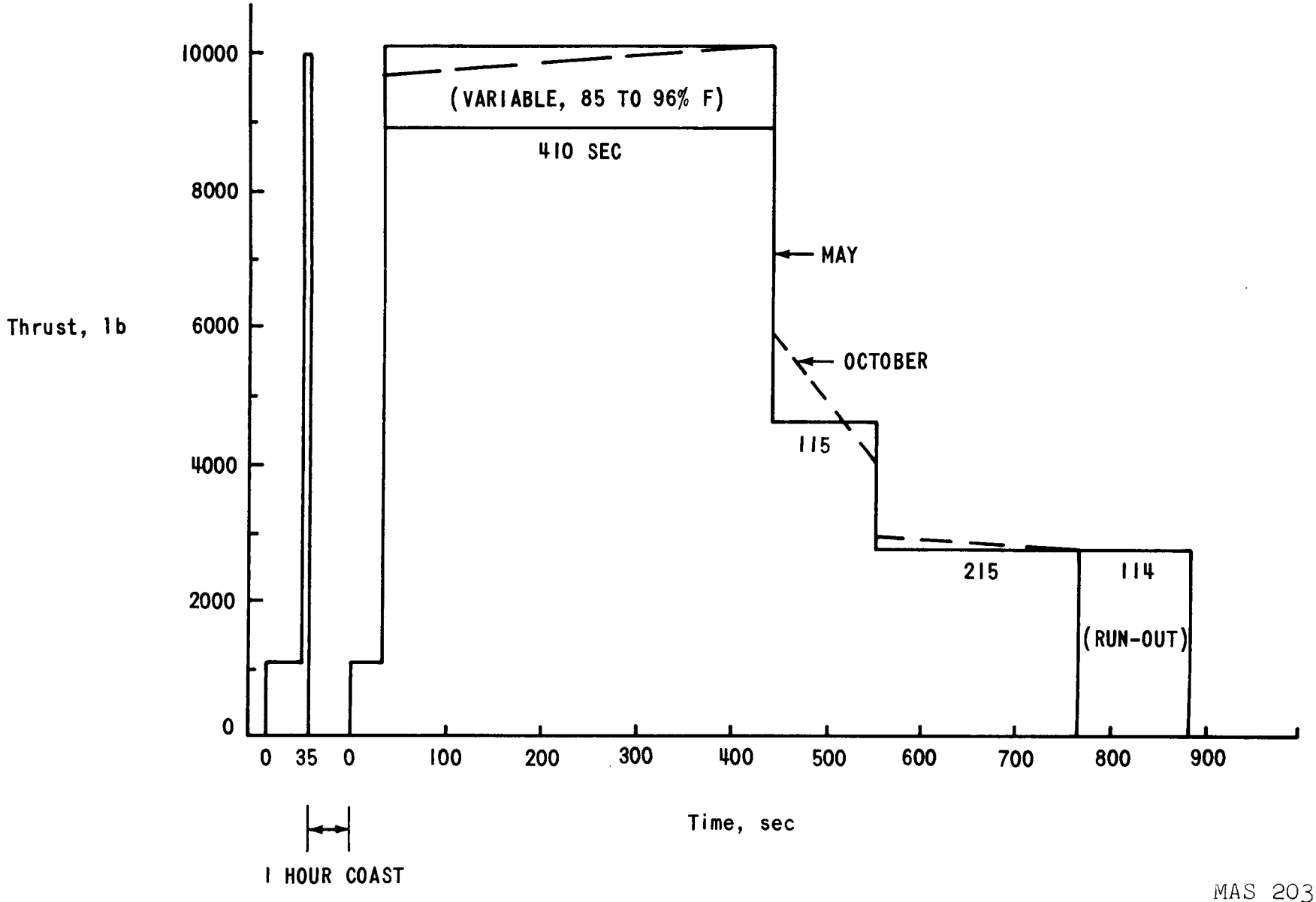
Schedule: See attached comparative schedule.

DECEMBER DUTY CYCLE



	SECONDS MIN.	SECONDS MAX.
TOTAL MISSION TIME	863	885
FINAL CONTINUOUS BURN TIME	830	852
TOTAL TIME INCLUDING ACCEPT.	953	975

MAY AND OCTOBER DUTY CYCLES



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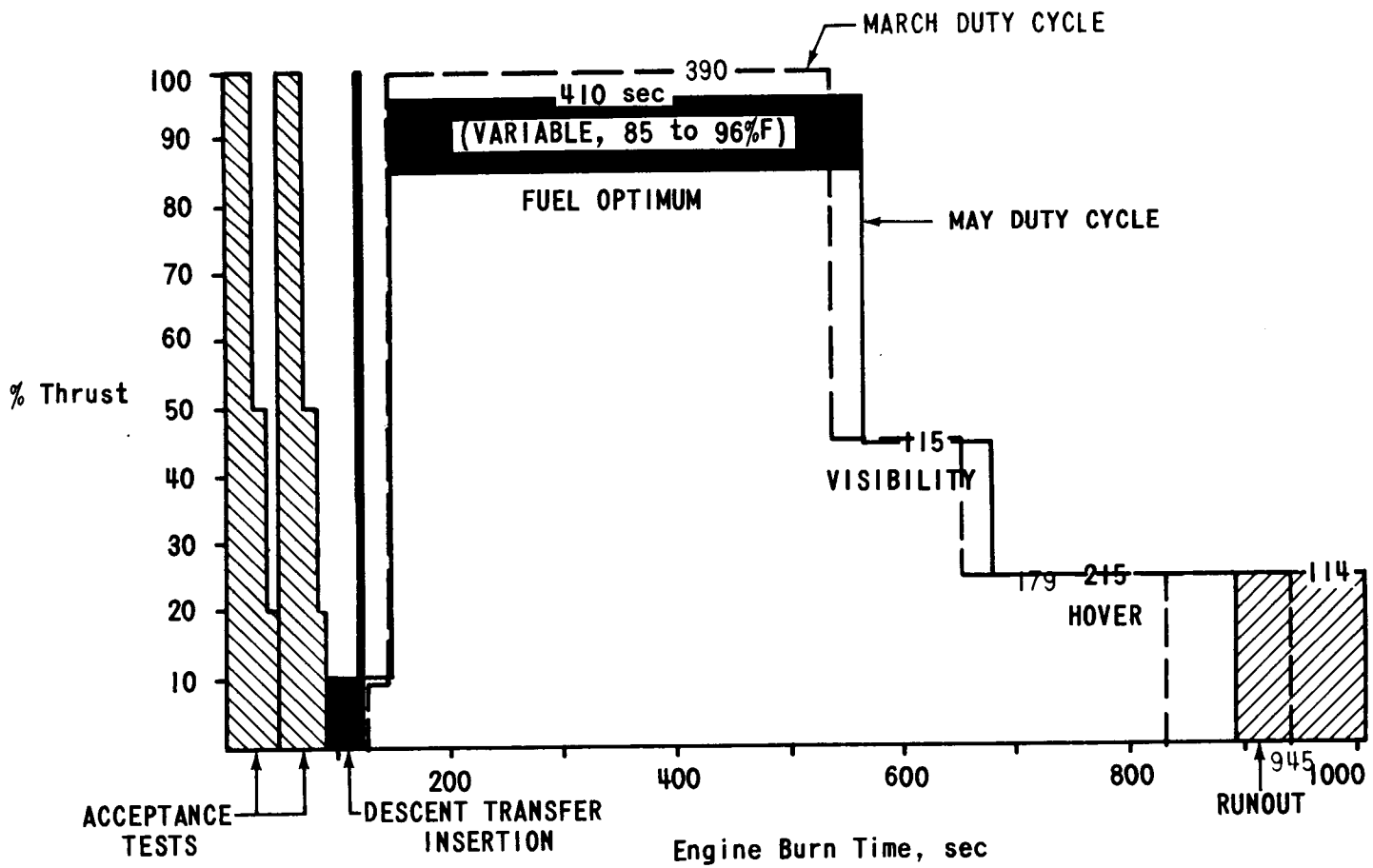
MARCH AND MAY DUTY CYCLES



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DUTY CYCLE FROM MSC/MIT SIMULATIONS

Phase	Thrust Level	Time, sec Min	Time, sec Max
Fuel Opt.	92.5% +3% -0% (Fixed throttle)*	324	414
Visibility	60%	28	145
	60% to 10%**	144	198
Hover	10%	26	(fuel depletion)

*Reproducibility of initial setting and of the final [+5% max] thrust level is greater than the GAEC values of ±35 and ±100 lbF specified to TRW.

**Throttling during the latter portion of the visibility is a nonlinear decrease with time.

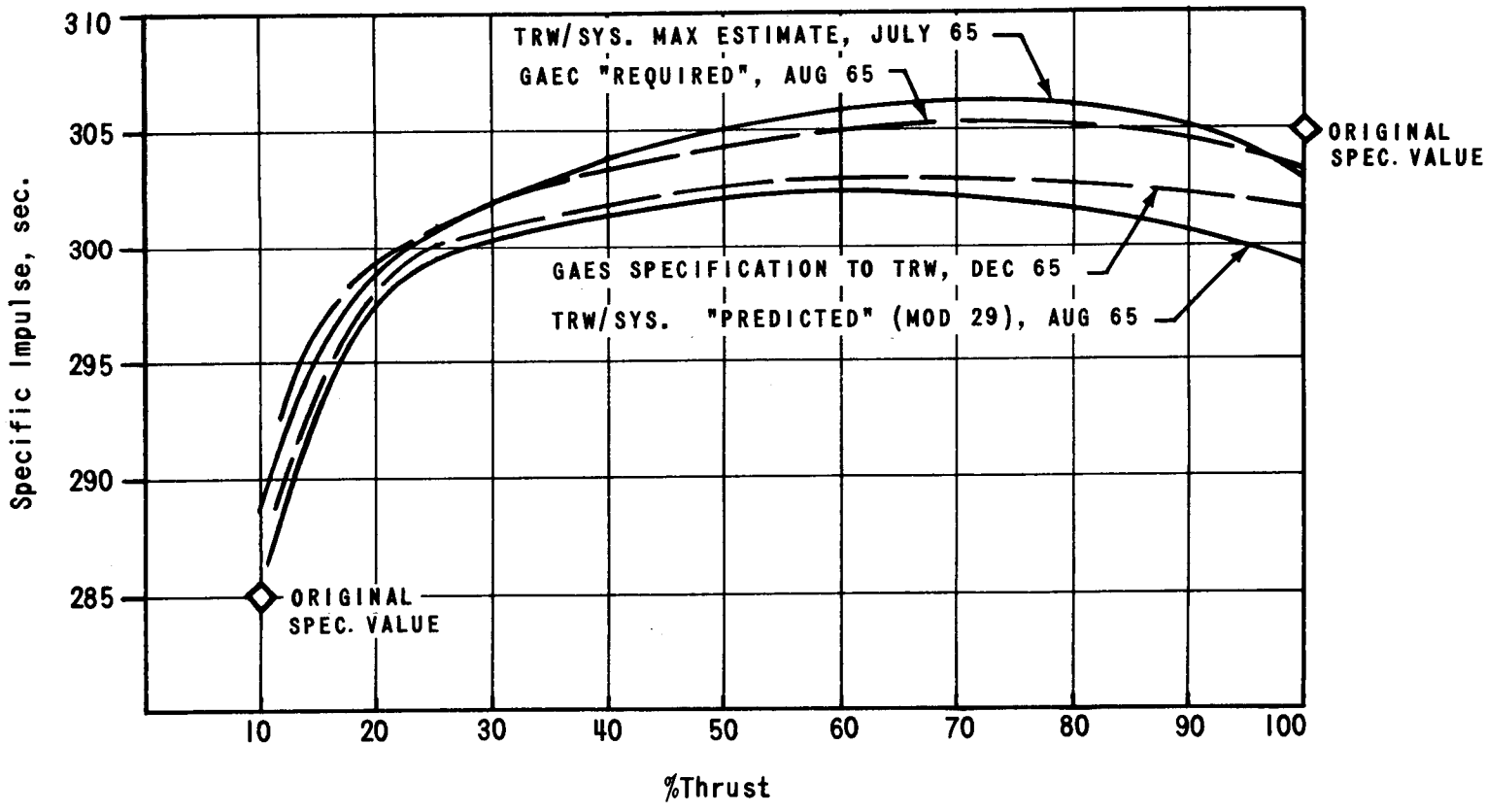
DUTY CYCLE FROM DRM II

Phase	Thrust Level	Time, sec
I (Fuel Opt.)	94.5 - 94.0% (9992 - 9875 lbF)	428
II (Visibility)	48.7 - 51.3% (5117 - 5392 lbF)	105
IIIa (700-100 ft alt.) (Hover)	28.8 - 27.4% (3028 - 2882 lbF)	80
IIIb (100 ft to TD)	26.2 - 25.8% (2743 - 2706 lbF)	27.6*

*"Nominal" final descent to touchdown

[redacted]

DESCENT ENGINE PERFORMANCE CURVES



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SUMMARY OF ENGINE TECHNICAL REQUIREMENTS*

SPECIFIC IMPULSE

THRUST (LBS)	I_{SP} (LB-SEC/LB) 3σ MIN.
9710 +3% -0% (FIXED THROTTLE)	302 (≡305 non-eroded)
5250	302.7
2625	300.3
1050	285

THRUST UNIFORMITY

INITIAL THRUST REPRODUCIBILITY (EXCL. INSTRUMENTATION)	±35 LBS
MAX. THRUST RISE DURING FIXED THROTTLE PORTION OF FIRING	+5%
AT END OF FIXED THROTTLE PORTION OF FIRING	±100 LBS (AROUND A SPECIFIED THRUST TIME CURVE)

PROPELLANT MIXTURE RATIO

9710 +3% -0% THRUST & 70°F	1.6 ±.014

WEIGHT (LBS) 390 MAX.

DOWNGRADED AT 3 YEAR INTERVALS;
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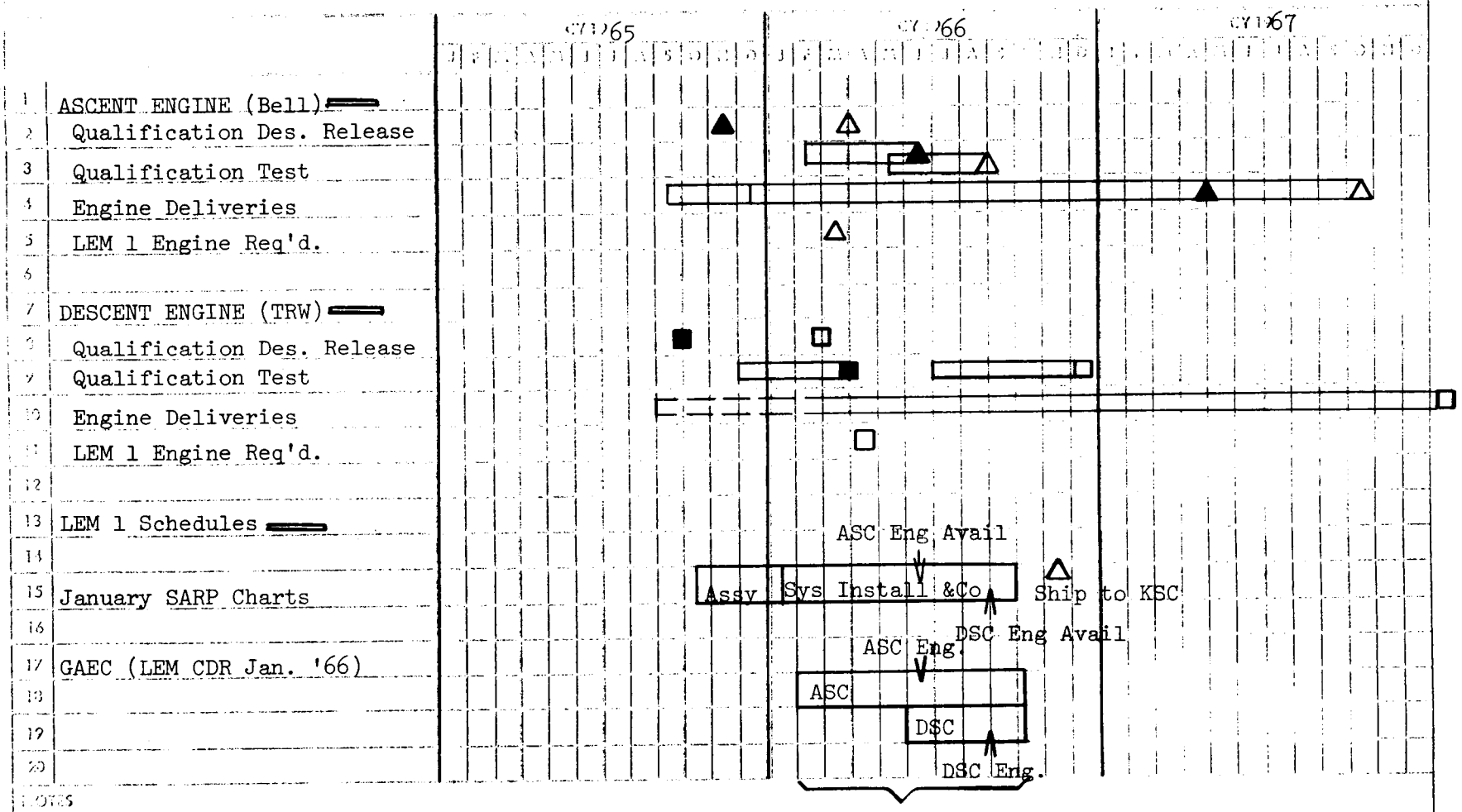
*Assumed to be GAEC specification to TRW

COMPARATIVE LEM ENGINE SCHEDULES



NOTES

Solid symbols are February 1965 schedule dates.
Open symbols are December 1965 schedule dates.

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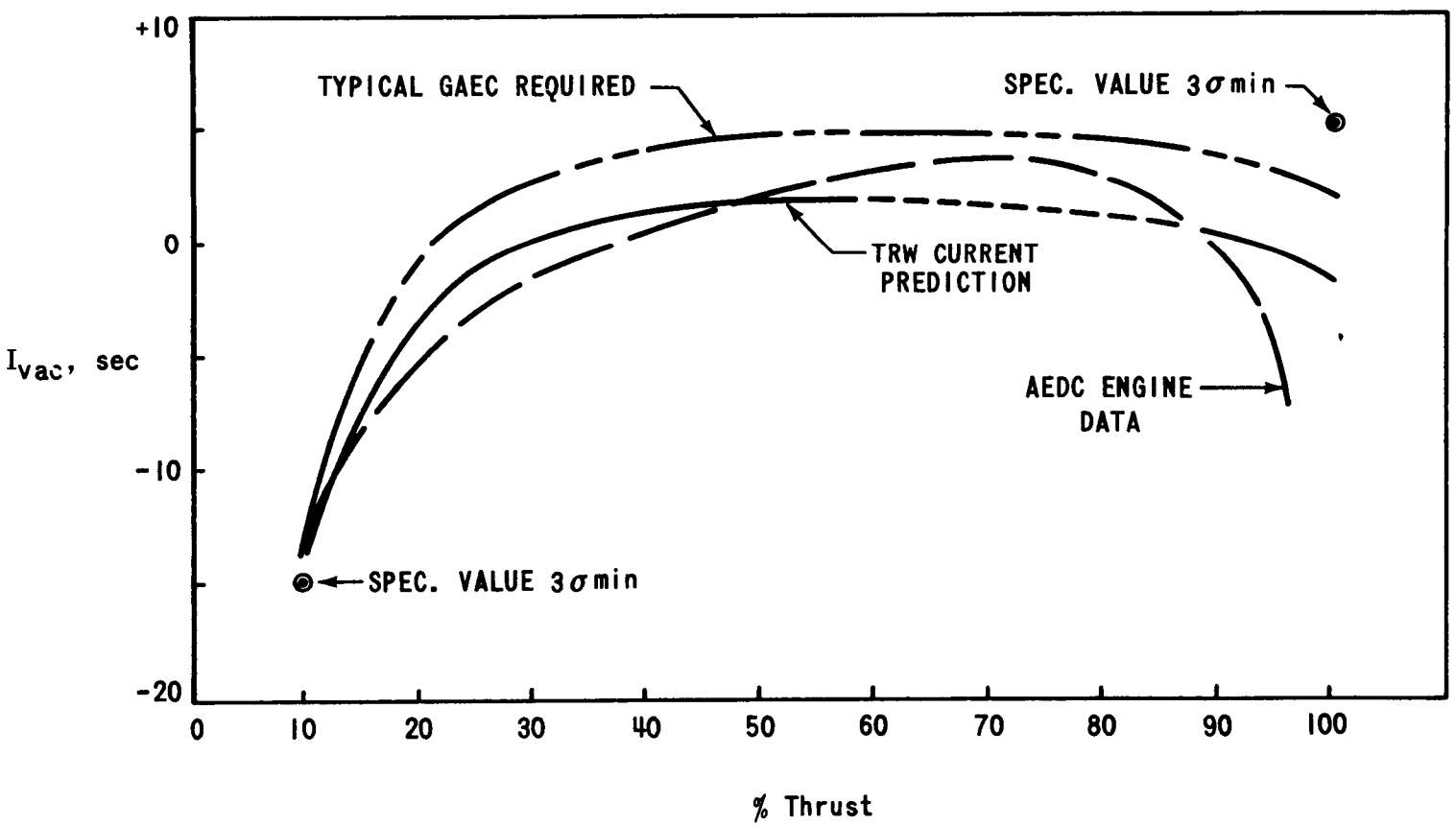
LEM DESCENT ENGINE PERFORMANCE



Pg 8A Made in Sept '65

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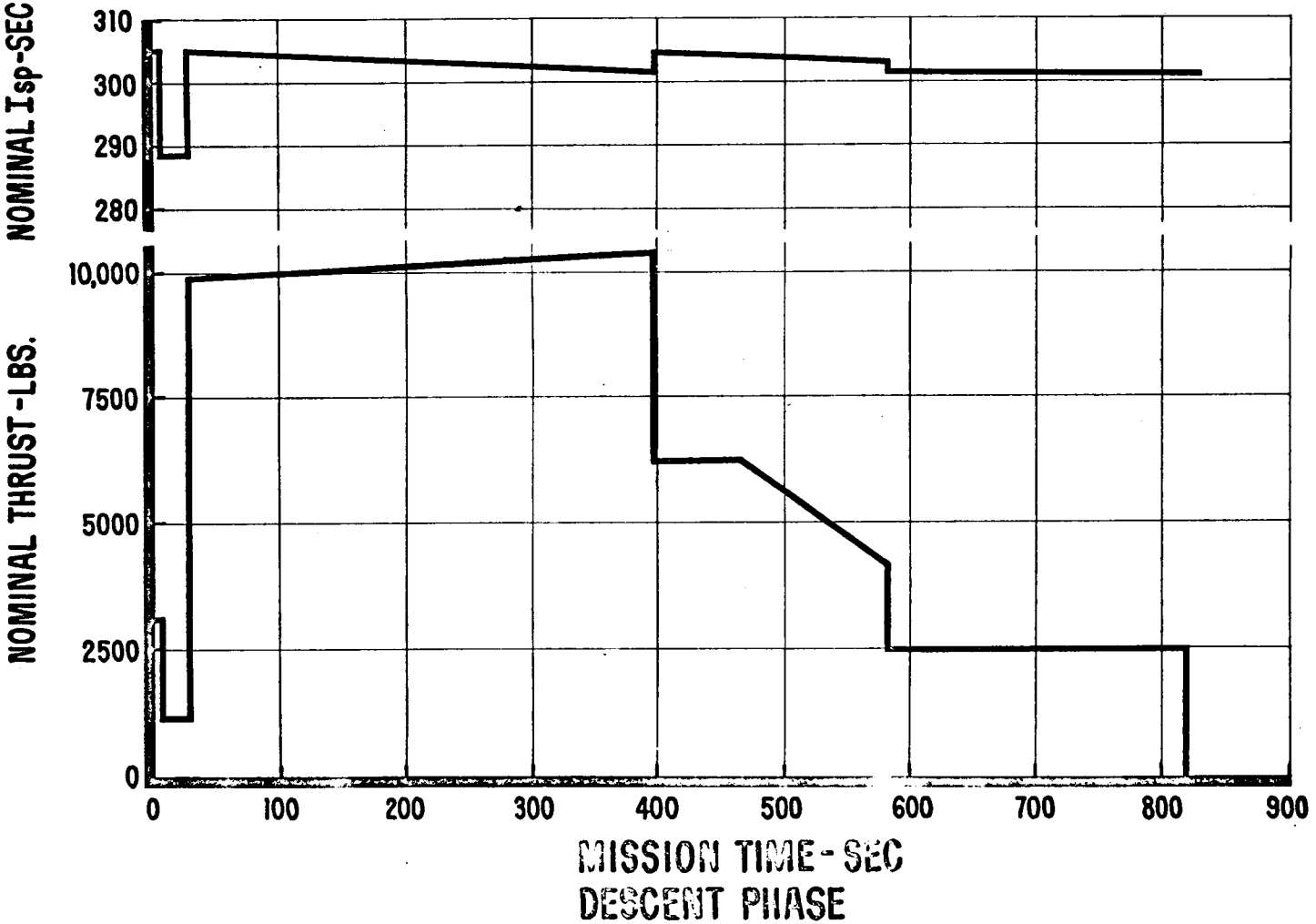
PREDICTED ENGINE PERFORMANCE

30% TOTAL EROSION



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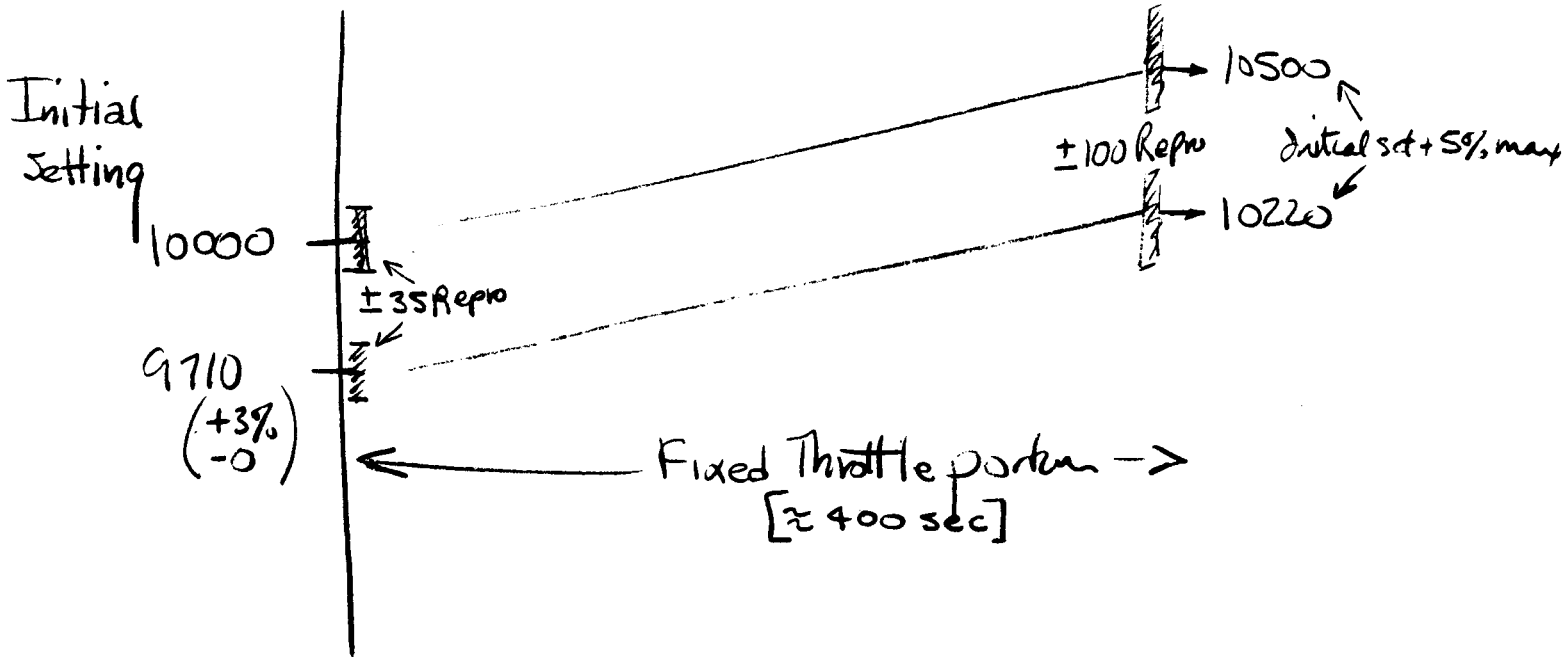
Pg 94

From 7th DSC Quarterly R

pg. 9B

From 9th DSC Quarterly Tech Rpmts. Table 5

Descent Engine Thrust Requirements.



(Note: LEM Gross Wt. [to be] known to ± 0.5%)