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Reactor Thrust During Boost in a High Altitude Trajectory

J. H. Moyer

November 12, 1962

Lawrence Livermore National Laboratory

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November 12, 196[redacted]

NAVAL APPLICATIONS MEMO NO. 12.

TO: Distribution

FROM: J. H. Moyer

SUBJECT: Reactor Thrust During Boost in a High Altitude Trajectory.

Reactor startup of a submarine based missile must be accomplished during boost, so that at burnout the reactor maximum wall temperature is at or near the design value. Because cooling air must be supplied during this period, there exists the possibility of obtaining some thrust to augment the booster.

To find how much reactor thrust might be available, a representative high altitude boost trajectory was selected. This is shown in Fig. 1 together with an estimated pressure recovery curve for the inlet. It has been assumed that by some appropriate means the flow rate passed by the inlet exactly matches that demanded by the reactor and nozzle. Hot day conditions are assumed.

The missile power plant was the Tory II-C reactor with its design point-optimized nozzle throat area of 750 in^2. Nozzle expansion is complete. The reactor maximum wall temperature was assumed to be constant at design (2500^oF) from time zero. Thus the thrust computed at any time is the maximum possible within the reactor design temperature limitation, and provides a guide to a desirable startup time.

Available thrust and reactor exit conditions (Fig. 2) were obtained with the digital codes Dash N and Nomac. The use of these steady state codes is justified for two reasons: (1) The assumption of constant Tw_{max} means that the only energy going into core heat capacity is that associated with changing the temperature distribution and bringing the

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structural components up in temperature, ~~and (2) The~~ short residence time of a parcel of air in the reactor permits the change in wall temperature distribution during this time to be neglected. The point in Fig. 2 at t = 46.2 sec was obtained from the performance maps of Tory II-C Memo 407, pp. 69-70. The other points represent specific Dash N problems.

The machine-computed values of $F_{j,net}$ and $C_{f,net}$ have been reduced by 7.3% to account for effects not analyzed in the code (see II-C Memo 407, p. 73). It is important to realize that the thrust values of Fig. 2 are those obtainable if the nozzle exhaust were unobstructed. This will not be the case if a tandem booster is used, and the thrust curves of Fig. 2 must be lowered accordingly.

CONCLUSIONS

1. For this particular boost trajectory, it is not useful from the thrust standpoint to bring the reactor to design wall temperature in less than 30 sec.

2. The total impulse available from the reactor from t = 30 sec. to t = 46.2 sec, without taking account of the exhaust angle necessary for a tandem booster, is about 140,000 lb_f-sec. A reasonable booster will need four or five million lb_f-sec. of impulse. Thus it appears that no significant reduction in booster weight or length can be achieved through this means.

3. The thrust coefficient of Fig. 2 is based upon the frontal area of a 57 in. diameter missile, and hence is directly comparable to that quoted in Tory II-C Memo 407 for the design condition. The latter value is $C_{f,net} = 0.174$. For the conditions of this study $C_{f,net}$ at 46 sec. is 36% higher than the 1000 ft. Mach 2.8 design value. One cannot draw conclusions about takeover without drag data for a particular missile, but it would seem likely that cruise stage flight might be possible at about this time.

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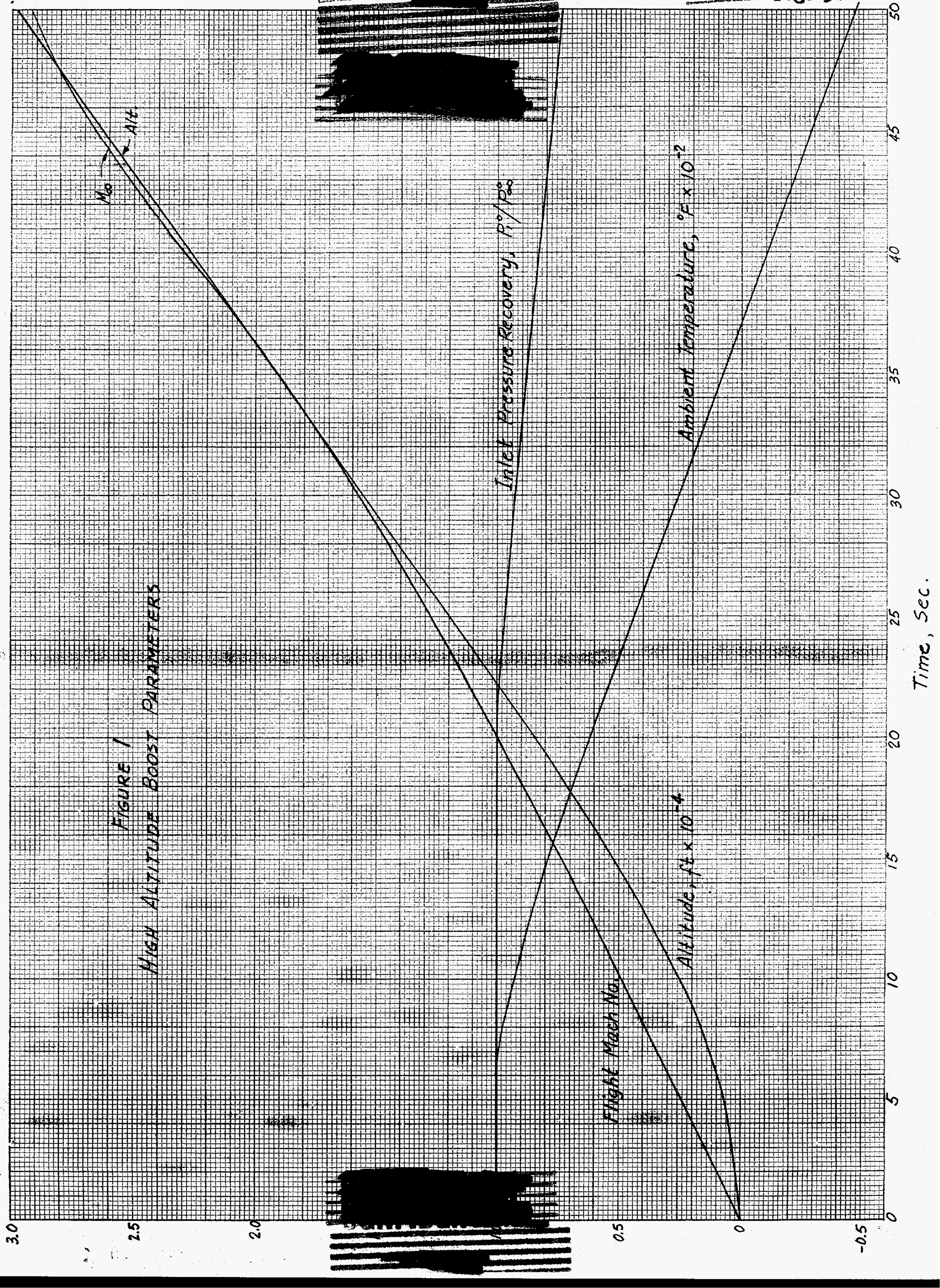

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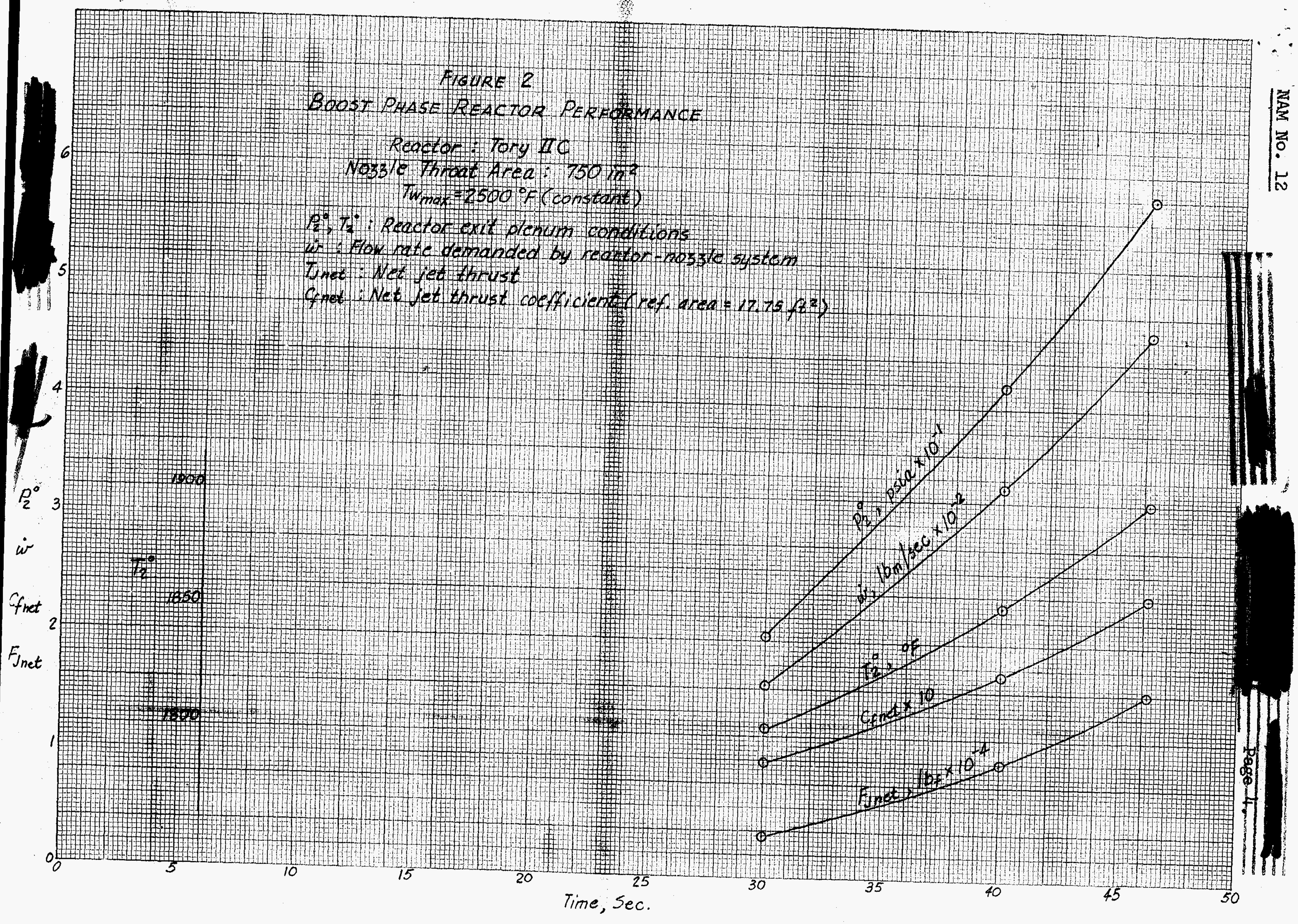

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NAVAL APPLICATIONS MEMO NO. 12.

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