TID/SNA -- 2189

AEROJET NUCLEAR SYSTEMS COMPANY
SACRAMENTO, CALIFORNIA

1 November 1971
WWM:rja:N8620:036M

TO: W. J. Houghton

FROM: W. W. Madsen

SUBJECT: Recirculation of Flow to the Tank

COPIES TO: A. D. Cornell, D. Buden, W. E. Stephens

REFERENCE: (a) Memo N8610:069M, W. J. Houghton to W. E. Stephens,
dated 5 October 1971, subject: Dissemination of
Tail-Off Penalty Derivation

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MASTER

After reviewing Reference (a), I feel that the 6000-lb payload advantage is extremely optimistic. The system that was used was much too idealized and did not take into account for extra piping and plumbing necessary in order to do the job. For instance, in order to hold the chamber temperature at 4250°R we would have to very rapidly shut off the flow to the engine and shunt the remaining flow to the tank. This flow would amount to approximately 40 lb/sec that would have to be returned to the tank. This flow has an added disadvantage in that if we use a valve to drop the pressure to match tank pressure, the fluid will be two-phase as it enters the tank. It is therefore not feasible to use the cooldown lines for this return flow since the two-phase flow would then be bubbling through the liquid hydrogen at the bottom of the tank near the point at which the pump flow is delivered.

I did some preliminary analysis both with a 24-lb tank and a 30-lb tank to determine the line size required in order to handle the 40 lb/sec return flow. This analysis indicates that approximately a 3-1/2-inch inside diameter line would handle the flow, assuming that no heat was being transferred to the fluid, and make it just sonic as it entered the tank. The line would have to be made such that entropy and energy increases are kept at a minimum. A small amount of heat input could vaporize more of the liquid than assumed in the above analysis and thus a much larger line would be required. This line should also be a separate system in that it has to enter the tank from the top in order to alleviate the bubble problem that we should have if we used the cooldown lines.

A thought was also expressed that we might use the tank pressurization line for this system. However, it is not only too small, but since it would leave an open path back to the engine system, we would have to use a quadpack arrangement for the valves, thereby requiring more valves and thus more weight. All of this extra line weight and associated valves should therefore be accounted for and it would deduct from the 6000-lb payload advantage.

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<i>J. W. Madsen</i>	11/1/71

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Another decrease in the 6000-lb payload advantage would have to be taken since it is felt that if we scram the reactor at the throttle point with the new \$6.00 drums, the power drop would be so rapid that the flow rate could not be shut down quick enough in order to maintain 4250°R in the chamber. Therefore, a dip in chamber temperature would occur and this should also be taken into account, since it will deduct from the aforesaid 6000-lb payload.

This system, in order to be used immediately upon departure from the throttle point, would also require a control system that would move valves both open and closed very rapidly.

We could alleviate the two-phase flow or the bubble problem in the liquid hydrogen if, on the return line, we ran some length of it into the liquid hydrogen at the bottom of the tank and could therefore cool it, removing approximately 1500 Btu/sec at the full flow return of 40 lb/sec. It would allow us then to throttle the flow down to tank pressure and this flow would then be a liquid. This, however, would require a considerable amount of piping and would probably make the cooldown line not function as effectively for the cooldown system.

I feel that the system is required on this engine, not so much as a payload saving but just to make the system work. We need a recirculating system to keep the pumps out of stall for both the startup and the shutdown. In the shutdown its real use should be at the point where we were required to switch from two pumps to one pump because of the stall problem. We could therefore, with this new system, postpone the switching to one pump until we had to go into pulses. This would allow us to run closer to engine limits because we would no longer have to worry about the switching point and component limitations there. It would also give us a savings in payload over the present system since chamber temperatures could be held higher during the shutdown. This recirculation system should be sold to the Customer based upon its requirements in order to make the engine not only work but work safely. It also looks like it will give us an increase in payload but this should be only a secondary advantage that would aid its chances for adoption and not be the main reason for its use.

W. W. Madsen
Performance Analysis &
Hybrid Computer Section

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cc: D. Buden, C.L. Bowen, J.A. Beyer, A. D. Cornell*, J. L. Dooling*, R. Dryden,
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CAD Files*

* w/o enclosure

December 28, 1971
N8620:051L

Mr. R. F. Dickson, Manager, Program Management
NERVA Nuclear Subsystem
Westinghouse Astronuclear Laboratory
P.O. Box 10364
Pittsburgh, Pennsylvania 15236

Attention: E. Hemmerle/P. Blake

Subject: Transmittal of Start-Up CAM, Revision 0

Reference: (a) DEM 52978, Revision A, NSS Equations for Flight
CAM Start-Up Model (U), dated 10-22-71

Dear Mr. Dickson:

Enclosure (1) is a set of equations for the Start-Up CAM, Revision 0.
Included is a list of the variables and a steady state solution
of these equations from the Hybrid Computer at ANSC. The nuclear
subsystem equations are taken from Reference (a).

It is being sent to you for your review and acknowledgement. As soon
as the title page is returned, the report will be issued and distributed.

Yours very truly,

AEROJET NUCLEAR SYSTEMS COMPANY

G. F. Mader, Manager
Program Controls Department
NERVA Rocket Operations

Enclosure (1) Start-Up CAM, Revision 0

cc: M. M. Carness, SNSO-C Res. at Sacto
C. L. Carvile, SNSO-C

If enclosure No. 1 is withdrawn (or
not a part of the correspondence)
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