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PRELIMINARY EVALUATION OF PRESSURE DROP AND TEMPERATURE RISE
IN EST PUMP SUCTION LINE

MASTER

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- REFERENCES: 1. TSD-FR-1, Revision 1
2. TSD-DC-1, Revision 1

I. INTRODUCTION

This report presents predicted pressure drop and temperature rise for the EST pump suction piping system.

The EST pump will be located on the test car at a considerable distance from the liquid hydrogen dewar. Therefore, pressure drop in the pump suction line will be greater than it was for the NRX tests. In addition, certain items of equipment which are located in the pump discharge piping for NRX tests will be relocated to the suction piping for the EST, thereby increasing the pressure loss between dewars and pump.

II. SUMMARY AND CONCLUSIONS

Pressure Drop

There will be a total pressure drop of 26.5 psi between dewar and test car plug, and 31.5 psi between dewars and EST pump inlet for a propellant flow rate of 75 lb/sec. Therefore, based on a dewar pressure of 98 psia, there will be a minimum pressure of 71.5 psia at the plug

and a minimum pressure of 66.5 psia at the pump inlet. Figure 1 (Pressure Drop vs. Flow Rate in EST Pump Suction Line) shows the variation in pressure drop with flow rate of liquid hydrogen. The upper line shows pressure drop from dewar to test plug and the lower line from dewar to EST pump inlet.

Temperature Rise

Propellant temperature rise will result from two causes, (1) frictional heat and (2) heat leak into the piping. Frictional heat generated at the highest flow rate contributes approximately 0.5°R temperature rise. Heat leak into the piping is dependent primarily upon the amount of pipe surface area exposed to ambient conditions and, therefore, it is practically constant regardless of propellant flow rate. Since the heat leak is constant, temperature rise in the propellant will be inversely proportional to the flow rate.

Temperature rise is estimated to be less than 1°R for flow rates in the range of 10 to 75 lb/sec. For these flow rates, the liquid hydrogen temperature at the EST pump inlet will be approximately 39°R which is 9° below the vaporization temperature at 66.5 psia. In terms of net positive suction pressure, the minimum will occur at the highest flow rate (75 lb/sec) and will be approximately 44.5 psi. Figure 2 (EST Pump Inlet Pressure and Net Positive Suction Pressure vs. Propellant Flow Rate)

shows the variation of pump inlet pressure and net positive suction pressure at the pump inlet with liquid hydrogen flow rate. Dash lines below 10 lb/sec flow rate indicate approximate shape of curves in this flow range.

The above conditions are consistent with the functional requirements described in TSD-FR-1, Revision 1.

Review and possible revision of these predictions will be in order after equipment selections have been made and final installation drawings and specifications are issued.

III. DISCUSSION

A. Requirements

The functional requirements for the EST pump suction line are given in TSD-FR-1, Revision 1, dated December 1, 1964. In summary, the line must include four (4) major components; flow element, filter, and two (2) valves, in addition to dewar piping and valves. Pressure drop from dewars to test car plug must not exceed 30 psi. Temperature rise must not exceed 3°R. The conceptual layout which has been made to meet these requirements is shown on isometric sketch SK-1.

B. Assumptions

1. Eight (8) inch, stainless steel, Schedule 10 pipe will be used.
2. Vacuum jacket insulation between dewar and test plug, and no insulation on the test car.
3. Both the ACV and the PSOV are assumed to have full eight (8) inch seats, and are treated as vacuum jacketed globe valves for pressure drop and heat leak calculations.

C. Methods of Calculation

1. Pressure drop for each component of the system has been calculated on the basis of velocity head loss.

a. Piping and Valves

For pipe, fittings and valves, the "Flow of Fluids" Technical Paper No. 410, by Crane Company, has been used to estimate losses as a number of velocity heads. It is noted that in eight (8) inch pipe, the friction factor is constant for flow rates above 5 lb/sec.

b. Flow Element

Flow element FE-4 is a venturi meter with a long recovery section which can normally be expected to have a pressure recovery of better than 85%. Therefore, net pressure loss has been estimated conservatively at 15% of the calculated pressure difference between inlet and pressure taps.

c. Filter

Pressure loss in the filter could be specified arbitrarily, since a unit may be designed to specification. However, in this case, an eight (8) inch vacuum jacketed in-line filter has been considered to be desirable for reasons of simplicity, minimum space requirement, minimum heat leak, etc. Data on pressure drop versus flow rate of liquid hydrogen were obtained for a commercially available filter with a five (5) micron density element.

2. Heat leak to the vacuum jacketed portion of the line has been estimated on the basis of commercially available piping. In view of the small total heat leak, the calculated temperature rise was somewhat insensitive to assumptions. Valves, filter and venturi were treated as pipe.

For EST piping on the test car, heat leak was calculated on the basis of bare pipe using an overall coefficient of 5 BTU/hr. sq.ft./°F. It is evident that any measurable temperature rise (more than 1°R) at flow rates down to 10 lb/sec. will not be due to heat leaks which are readily subject to calculation. Rather, it will be due to poor vacuum, excessive conduction through valve stems, or other miscellaneous stray leaks.

Fig 2

Fig. 1

EST. PUMP SUCTION
PIPING SYSTEM

SK-1 NOV. 20, 1964
TEST SYSTEMS DESIGN - N&F