This ATM contains material on the comparative analysis and design of the ALSEP Fuel Cask Thermal Shield. This report is submitted in accordance with MSC request generated during the System Preliminary Design Review of 12 July 1966.

Prepared by: J. L. McNaughton

Approved by: D. Courtois

Approved by: G. T. Burton

FILE

1.0 General

This technical memorandum presents the results of a comparative thermal analysis of the ALSEP Fuel Cask Thermal Shield. This analysis was undertaken to determine the optimum design approach necessary to integrate the fuel cask with the LEM vehicle consistent with overall NASA/GAEC/GE/ Bendix system requirements. The complete results of the Bendix Cask/ Shield/LEM Thermal Model will be presented in another ATM pending finalization of the current analysis.

1.1 Problem Statement

At the beginning of the Phase II portion of the ALSEP contract, a detailed analysis of the fuel cask/LEM/SLA envelope was undertaken to determine the specific requirements for a thermal heat shield to be located between the fuel cask and the LEM vehicle. During the late stages of the Phase I study and the early stages of the Phase II contract, several interface changes were made which directly increased the complexity of the final Phase II thermal shield design. These interface changes are denoted below:

1. Redesign of the G.E. fuel cask from finned type design to the present bomb type design, thereby increasing cask steady state interface temperatures from approximately 750°F to 950°-1000°F, due to reduction in the cask effective radiating area.

2. Incorporation of a 520 to 580°F ESM bond temperature limitation on the cask nose and flare ablative material on the redesigned cask.

3. Relocation of the fuel cask position from a position approximately 2 feet (cask centerline to -Z panel) from the right side of the Quad II ALSEP compartment, Pallet II, to a position less than 12 inches (from cask centerline to -Y LEM panel) from the left side of the ALSEP compartment, Pallet I, next to the -Y axis LEM landing gear strut.

4. Redefinition of the internal SLA optical surface properties from an emissivity of 0.9 to a value of 0.15, thereby increasing the cask/shield steady state temperatures while SLA is attached.

Together with the above mentioned changes affecting the cask interface, a number of cask/shield thermal design requirements were established in interface specifications between Bendix and NASA, GAEC, and GE. These requirements included:

1. 1550 watts maximum cask heat generation.

2. 100 BTU/ hr. maximum allowable heat input to LEM panels and LEM landing gear by direct radiation and conduction.

3. 270°F maximum LEM surface temperature.

4. 0 - 160°F LEM internal environment temperature range.

2.0 Concepts Studied

In order to determine the optimum shield design for the revised cask location, a detailed layout of the entire cask, SLA, LEM panels, LEM landing gear and ALSEP compartment envelope was made to select the position and orientation of the cask thermal shield. Figure 1 shows this layout and the position of the fuel cask and thermal shield. From the layout drawing, several specific design requirements and constraints for the position and orientation of the radiation heat shield were determined in order to minimize the thermal interaction between the high temperature cask barrel and surrounding surfaces. These requirements and constraints included:

1. A 180° thermal shield was required to protect the ALSEP compartment, the contracted LEM landing gear and LEM structure from the high temperature fuel cask.

2. Parabolic, elliptical and other oblate shaped shield designs evaluated, failed to provide sufficient radiation shielding for the LEM landing gear (contracted) and the LEM external structure due to the immediate proximity of the cask to the vehicle. Although this type of wide flared shield design reduced cask temperature gradients by increasing shield view factor to the surrounding environment, the wide flare introduced mechanical interferences with both the ALSEP line of deployment from the LEM bay and with the support strut of the -Y axis landing gear, reference Figure 1.

3. The maximum outer shield radius is limited to 7.23 inches in order to insure adequate clearance of the thermal shield and extended landing gear strut during lunar deployment when the cask is rotated downward.

In addition, a series of parametric design curves were derived to determine an optimum inner shield insulation radius consistant with the vehicle interface and heat leak requirements. The effect of shield variables as facing materials, weight, view factor to SLA, view factor to the fuel cask, and view factors to the LEM structure were evaluated versus shield length/diameter ratio, L/D. Figures 2 and 3 show the results obtained from this analysis. Figure 2 presents parametric data of the thermal shield weight for stainless steel shield facings, titanium facings and a combination of titanium and aluminum facings for the inner and outer shield insulation structure. Thin metallic facings of .010 inch thickness selected for the shield structure due to the high temperatures involved with the cask interface. Inner shield temperatures are predicted to approach approximately 600°F. Figure 3 presents the parametric results completed to evaluate thermal shield geometric view factors to the surrounding cask/LEM environment. These results were necessary in order to evaluate at what shield radius the reradiation from the shield to the cask was minimizing and radiation from the shield to the environment was maximizing. From this information, it was determined that the optimum shield radius lies between 5 and 6 inches beyond which there is an excessive penalty in shield weight with marginal improvement in cask/shield performance. Also, above this radius range interferences problems were introduced with the surrounding vehicle envelope. Furthermore, as the size of the shield increases above these radius values, the localized heat flux to the LEM panel directly behind the shield rises significantly as the view factor from the back of the radiation shield to the LEM approaches unity.

Based on this information, the shield was designed with an inner radius of 5 1/2 inches directly behind the cask, increasing circumferentially to a maximum radius of 7 1/4 inches. Figure 4 presents the present design for reference purposes.

3.0 Summary

This technical memorandum discussed the comparative analysis which was made in order to select the optimum design for the fuel cask thermal shield. In order to accomplish this comparative analysis, design requirements were established from the vehicle thermal protection requirements, launch accessibility requirements, interface envelope requirements and astronaut protection and deployment requirements. Design considerations that determined the position, orientation and size of the shield have been presented together with the parametric analysis completed in support of the final shield design.

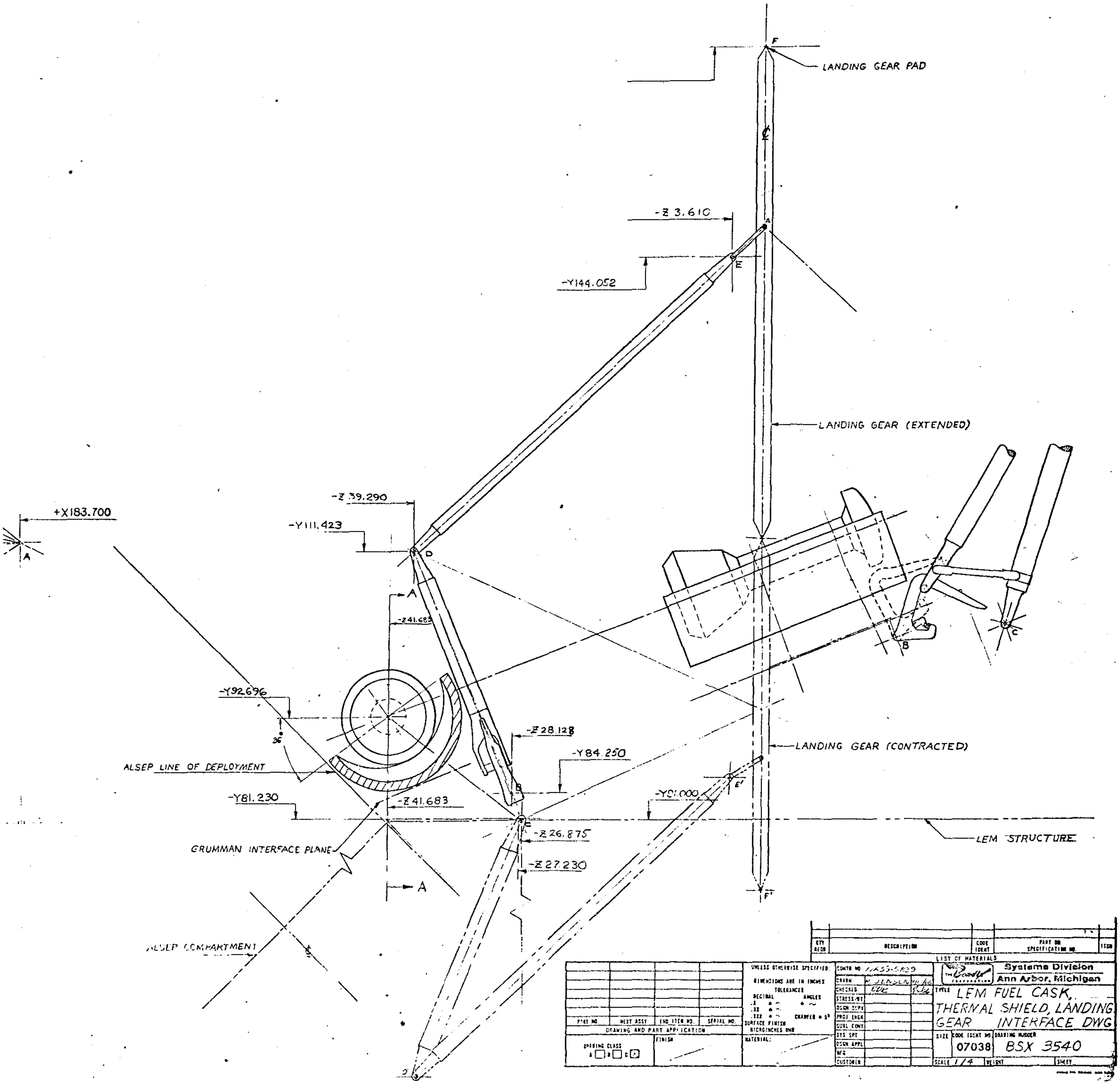
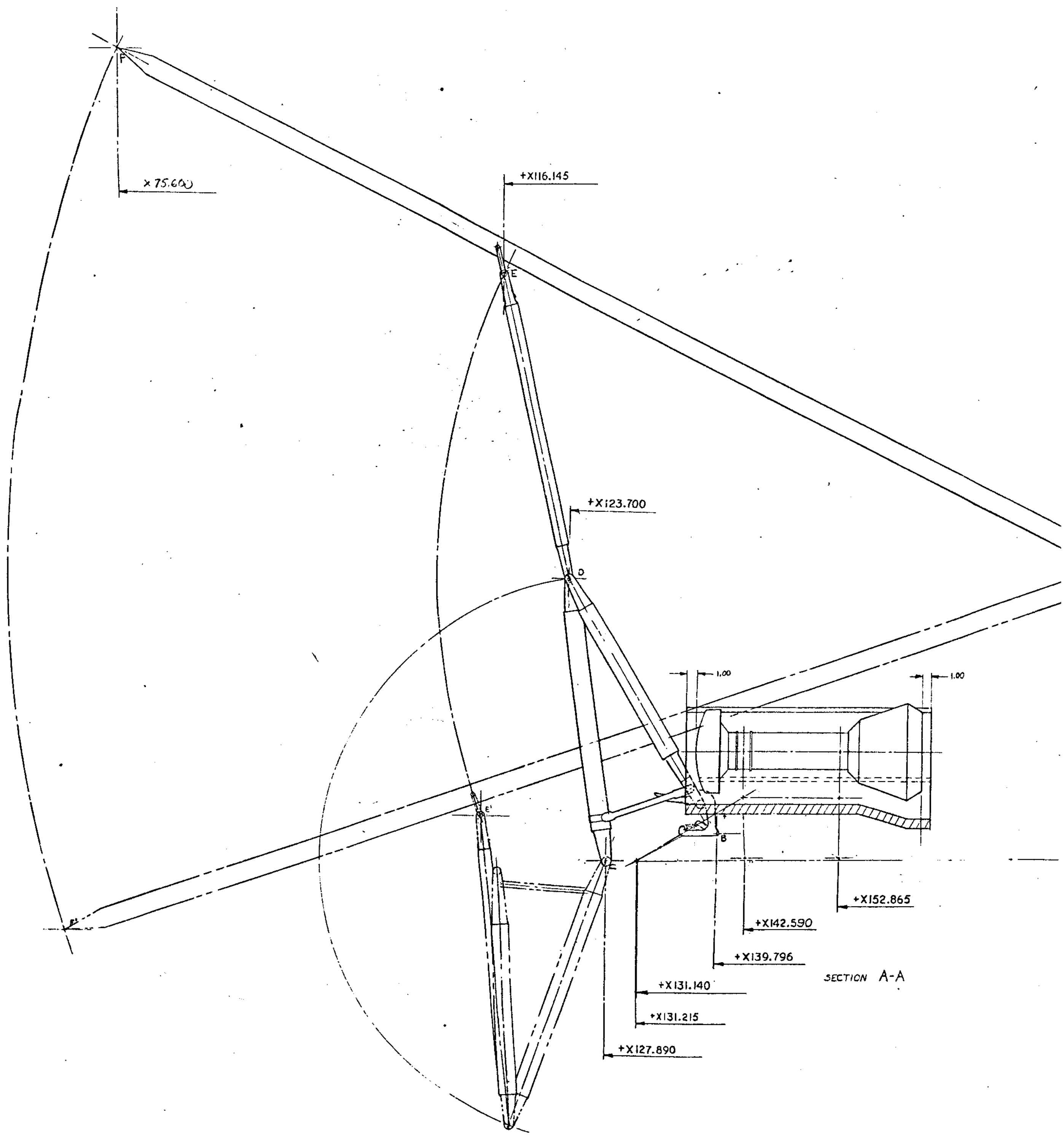

LANDING GEAR PAD
-Z 3.610
-Y144.052
LANDING GEAR (EXTENDED)
-Z 39.290
+X183.700
-Y111.423
-Y92.696
ALSEP LINE OF DEPLOYMENT
-Z 28.128
-Y84.250
-Y81.230
-Z 41.683
GRUMMAN INTERFACE PLANE
-Z 26.875
-Z 27.230
LANDING GEAR (CONTRACTED)
LEM STRUCTURE
ALSEP COMPARTMENT
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL
ANGLES
SURFACE FINISH
MICROINCHES RMS
MATERIAL:
LIST OF MATERIALS
CONTR NO NAS5-5829
DRAWN
CHECKED
Systems Division
Ann Arbor, Michigan
LEM FUEL CASK, THERMAL SHIELD, LANDING GEAR INTERFACE DWG
CODE IDENT NO. 07038
DRAWING NUMBER BSX 3540
SCALE 1/4

FIGURE 1


F
x 75.600
+X116.145
E
+X123.700
D
1.00
1.00
E'
B
F'
+X152.865
+X142.590
+X139.796
+X131.140
+X131.215
+X127.890
SECTION A-A

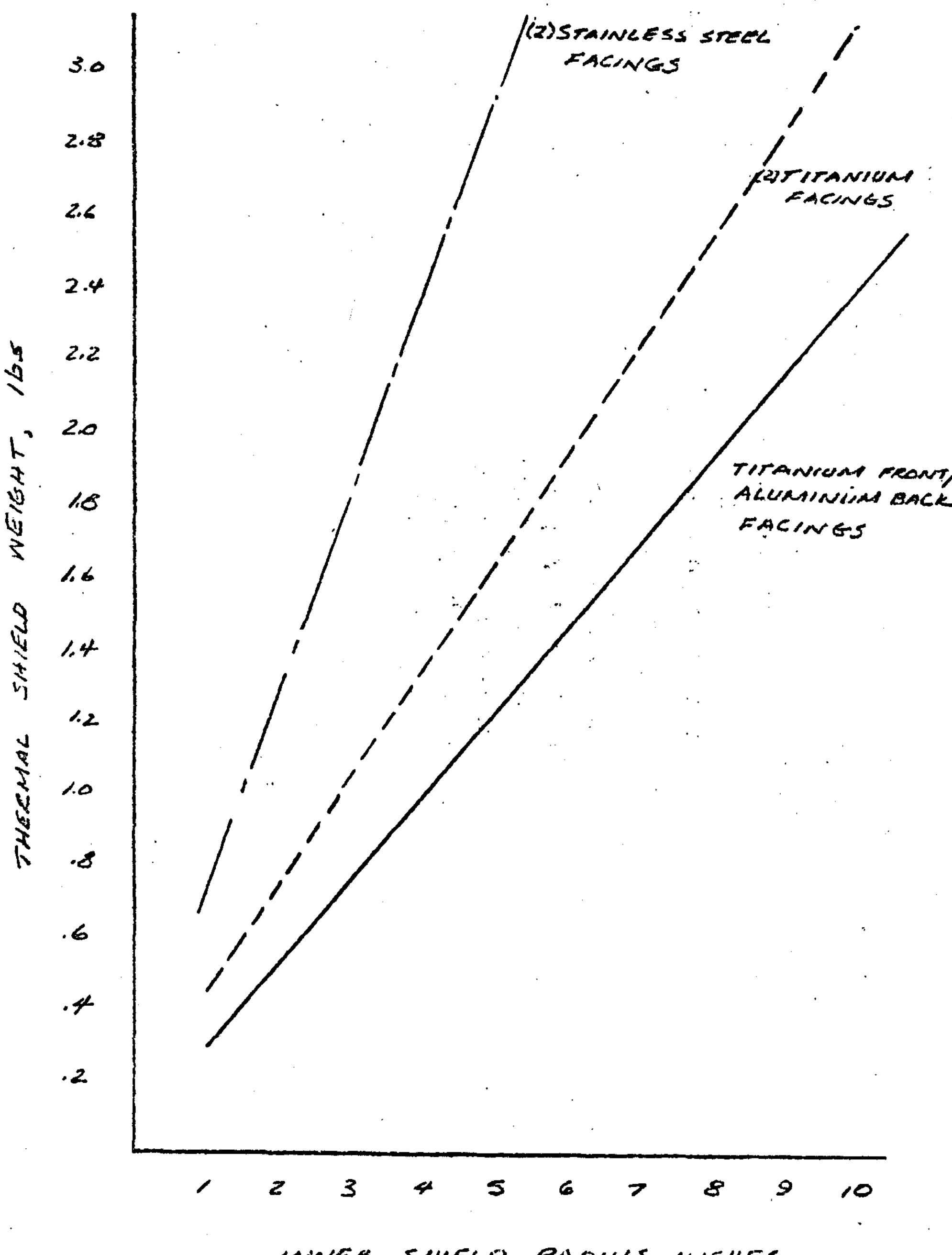


FIGURE 2

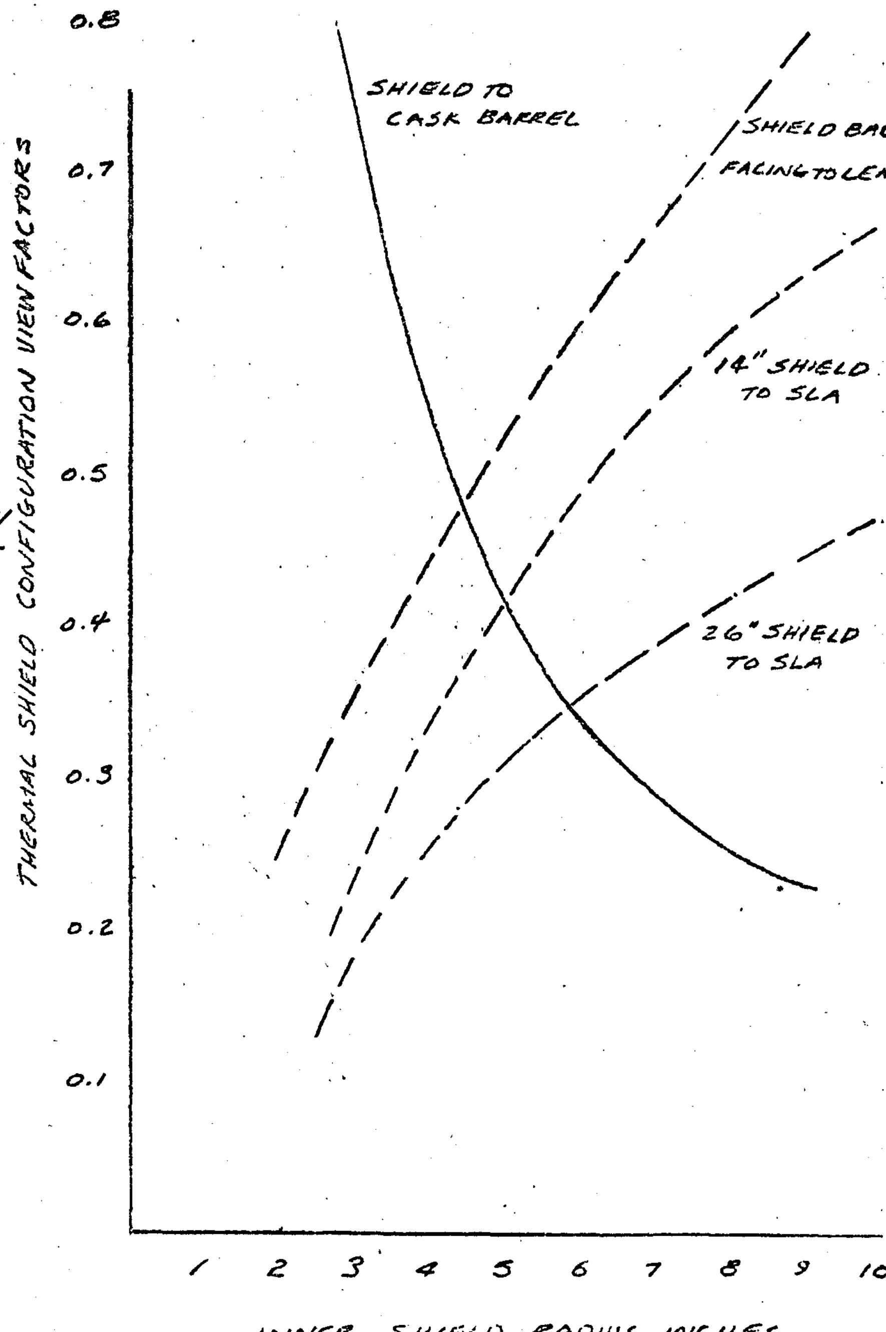


FIGURE 3

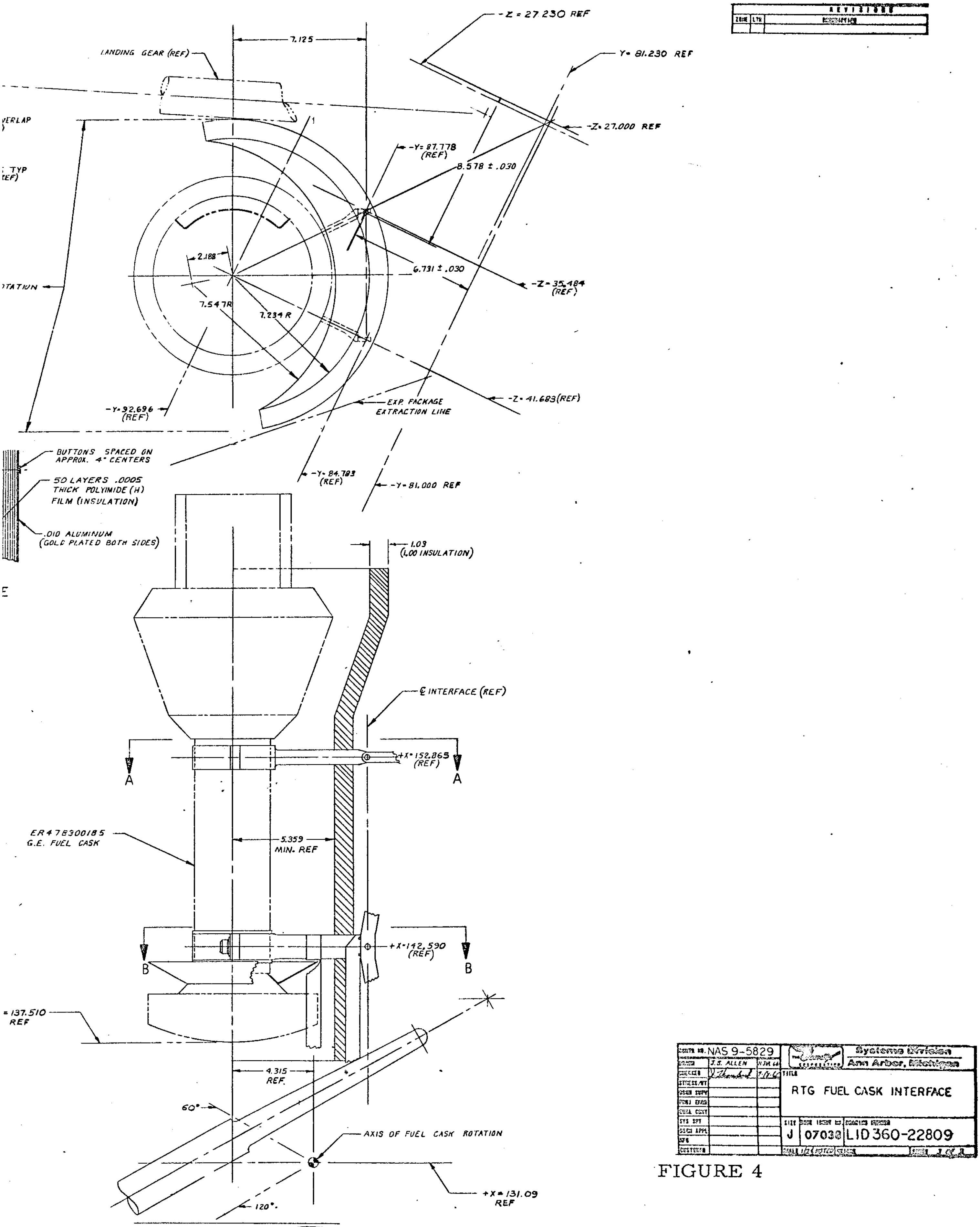

-Z = 27.230 REF
Y = 81.230 REF
7.125
LANDING GEAR (REF)
-Z = 27.000 REF
-Y = 87.778 (REF)
8.578 ± .030
2.188
6.731 ± .030
-Z = 35.484 (REF)
7.547R
7.234 R
-Z = 41.683 (REF)
-Y = 92.696 (REF)
EXP. PACKAGE EXTRACTION LINE
BUTTONS SPACED ON APPROX. 4" CENTERS
50 LAYERS .0005 THICK POLYIMIDE (H) FILM (INSULATION)
.010 ALUMINUM (GOLD PLATED BOTH SIDES)
-Y = 84.783 (REF)
-Y = 81.000 REF
1.03 (1.00 INSULATION)
℄ INTERFACE (REF)
+X = 152.865 (REF)
A
A
ER478300185 G.E. FUEL CASK
5.359 MIN. REF
+X = 142.590 (REF)
B
B
= 137.510 REF
4.315 REF.
60°
AXIS OF FUEL CASK ROTATION
120°
+X = 131.09 REF
REVISIONS
CONT. NO. NAS 9-5829
J.S. ALLEN
Systems Division
Ann Arbor, Michigan
RTG FUEL CASK INTERFACE
J
07030
LID 360-22809

FIGURE 4