A VERSATILE STRUCTURE FOR GAS PAYLOADS

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ABSTRACT

This paper describes a structure, and some of its characteristics, which is to be used by the A&T Student Space Shuttle Program for carrying GAS experiments. The structure is sufficiently versatile that other GAS experimenters may be able to use it. The concept is easily capable of being extended to the 5 cu.ft. cannister.

DESCRIPTION OF STRUCTURE

The concept is simply that of a strong, square cross-section, central column to which experimental and accessory compartments are attached. The attachment may be by direct bolting or through vibration and/or thermal isolators, as needed.

It was felt that a hollow 4"x4", 1/2" wall thickness, 6061-T6 Aluminum column would be adequate. Because Aluminum tubes of these dimensions are not commercial stock items, it was fabricated in the following manner: Four 3/8" thick 6061-T6 Aluminum plates, two of which are 3.75" wide and the remaining two are 3" wide, were slid into a 4"x4",1/8" wall thickness, 6063-T5 Aluminum tube, and seam-welded at each end to the tube. (Chamfers were milled on the plates prior to welding to provide space for the weld material to enter and create a strong bond.) The ends of this composite column were milled to remove excess weld material, and to make its ends at right-angles to its sides. Details of the column are further elucidated in Figure 1. There is no reason for the choice of a different alloy for the outer tube other than that it was readily available.

The next step was to provide means for attaching the column to NASA's Standard Experiment Mounting Plate (NMP) [1], p.19, and [2], item (a), and to incorporate lateral supports [2], item (h). This was accomplishec by constructing two initially identical 19.75" diameter, 1/4" thick, 6061-T6 Aluminum plates, with 3"x3", 0.75" deep, stubs at their centers each fabricated as follows: A 1" thick 6061-T6 Aluminum plate was milled down to 0.25" thickness leaving the stub at the center. (The reason for this method of manufacture is that bolting or welding a stub onto a 0.25" plate could, it was felt, create strength problems.) The remaining 0.25" plate was held through four holes on a rotary table and the edge was milled to 19.75" diameter. Eight countersunk clearance holes, two per side, were drilled at each end of the column, corresponding holes were drilled and tapped in the stubs to accept Tridair KN420J inserts [3] , and the column was secured , using Unbrako 1960 series 1/4-20x3/4", alloy steel socket head cap screws [4] , to the stubs. One plate is intended for attachment to NMP, the other to carry lateral supports. We shall refer to these, respectively, as A&T's Top Plate (ATP) and A&T's Bottom Plate (ABP). This assembly is shown in Figure 2.

It was initially felt that the attachment of ATP to NMP should incorporate thermal isolators. For this purpose twelve Polypenco Nylon 101(6/6) [5] spacers, each as specified in Figure 3, were fabricated and inserted at twelve locations in ATP. Twelve Unbrako 1960 series 10-32x1.25" alloy steel socket head cap screws [4] are expected to be adequate to hold the complete structure and apparatus (total weight at most 100 lbs.) to NMP during flight. Details of the mounting of ATP to NMP are shown in Figure 3. This method of mounting creates an air space, and puts Nylon barriers in the heat conduction path between ATP and NMP. The efficacy of this device, as a thermal isolator, will be commented upon in the next section. However, the air gap remains necessary to prevent obstruction of the purge ports and grounding points on NMP. The four holes in ATP which were used to hold it down for machining purposes now serve to provide convenient access to NMP for a grounding strap, plumbing for possible venting of batteries, and permit purging.

The structure uses four lateral supports, each mounted on top of ABP with four Unbrako 1960 series 10-32x7/8" alloy steel socket head cap screws [4] . The locations of the lateral supports are shown in Figure 4. The details of a lateral support are shown in Figure 5. It consists of a threaded base through which a 1/2-13 galvanized steel threaded rod moves. The rod is provided with a lock nut. One end of the rod is squared to allow the use of a wrench to turn it; the other end is turned and press-fitted into the cone (part no. A2037) of a Timken tapered roller bearing. The cup (part no. A2126) of the bearing is mounted in a Polypenco Nylon 101(6/6) [5] bumper made according to [2], item (h). The operation is simply that of turning the threaded rods by a wrench through slots in ABP until the bumpers press against the GAS cannister walls as much as desired. The lock nuts are tightened to prevent the threaded rod from vibrating loose during launch.

The structure described above can easily be used in the 5 cu. ft. cannister by constructing a longer central column, possibly increasing the thickness of the Top and Bottom Plates (in which case the stubs may be bolted), and possibly increasing the number of screws holding the Top Plate to NMP.

CHARACTERISTICS OF STRUCTURE

This section contains a brief presentation of some characteristics of the structure which are publishable at this time. The characteristics mentioned below are among those which are required to be considered by NASA-NHB 16700.7A [6] , the associated Gas Payload Safety Manual [7] , the GAS Experimenter Handbook [1] , and A&T's own requirements.

A) Structural:

The following format coincides with that in the Structures Hazards Checklist of the Safety Manual [7] , pp.165-169.

Structural Analyses

a. The presentation of a detailed stress analysis according to the requirements of Appendix A of [7] is beyond the scope of this paper. It suffices to say that our preliminary estimates have shown that all elements in the structure are capable of withstanding the flight loads with more than the margin of safety required.

It is of importance to obtain some insight into the vibration frequencies of the structure without any chambers attached to the column. The structure will be excited by the motion of NMP. If we regard the ATP and NMP assembly as a rigid body the column may be regarded as an elastic body which is clamped at its upper end and attached to an elastic support (i.e., ABP) at its lower end. Utilizing the general principle that stiffening a structure raises its vibration frequencies, we may obtain lower bounds to the frequencies of the column by regarding it as free at its lower end. In this manner, we find that all longitudinal vibration frequencies are greater than

1225 Hz

and all lateral vibration frequencies are greater than

333 Hz

These values are far in excess of the minimum value 35 Hz specified by Appendix A of [7]. We therefore conclude that the column is rigid with respect to any vibratory excitations transmitted by NMP. These excitations will be transmitted almost unaltered to ABP. It now becomes important to consider vibration frequencies of ABP. Because ABP is supported in a complicated manner, we must resort to the following technique for their determination: ABP is certainly far more stiff than a 19.75" diameter, 0.25" thick Aluminum plate which is clamped at its boundary, because of the 4"x4" region in ABP which is also clamped. The fundamental frequency of the former plate is

74 Hz

We conclude therefore that neither the column nor ABP will resonate.

b. With the exception of items (4) & (9), which are procedural requirements which will be followed in structural analyses, it will be easily seen that all other general practices listed have been followed.

Structural Materials

At the time of writing we have not convincingly demonstrated to ourselves that damaging stress corrosion cracking, hydrogen embrittlement, or galvanic corrosion will not occur. Nor have we checked that the materials have sufficient fracture toughness to be able to tolerate cracks of those sizes which may be expected. Studies of this sort will take place soon after we obtain documentation of reliable recommended practice such as NASA-MSFC-SPEC-522A.

Structural Supports

It will be seen that all requirements of this section have been met. These will also be taken into consideration in the design of supports for the chambers which are to be attached to the column.

B) <u>Thermal</u>:

It is of considerable interest to know how well the structure is thermally isolated from the cannister. For this purpose, we have done some calculations assuming that the structure and cannister inner wall are at constant temperature, and heat flows between them in the following modes:

i) Conduction through Nylon-Cap Screw Assembly
ii) Conduction through Air Gap between ATP and NMP
iii) Conduction through Lateral Supports
iv) Radiation from ATP and ABP to Cannister Inner Wall

If Q denotes the heat flow rate, TC denotes cannister inner wall temperature, and TS denotes structure temperature, the energy balance equation reads as below:

$$G_r (TS)^4 + G_c (TS) = Q + G_r (TC)^4 + G_c (TC)$$

where the G's are calculable heat conductances.

Given the space available for battery storage, we expect to be able to provide a maximum value for Q of 2.4 watts. Assuming TC = -15 degrees Centigrade, the above equation can be solved for TS to give

TS = -14.8 degrees Centigrade

The above calculation is an important one showing that with 2.4 watts of power available for heating, there is practically no thermal isolation of the structure from the cannister. They are practically at the same temperature. We do not expect to be able to raise the power available for heating too much beyond 2.4 watts because of battery space unavailability. We may therefore question the necesssity for the Nylon spacers and use metal spacers instead. It is also apparent that any desired temperature control of experimental and accessory chambers must take place by insulation and heating of the chambers directly.

REFERENCES

1. GAS Experimenter Handbook, Sounding Rocket Division, NASA-GSFC.
2. Update to [1], Letter from Clarke Prouty, Technical Liason Officer, GAS Program, Special Payloads Division, NASA-GSFC.
3. Keenserts, Catalog No. 200-E, Tridair Industries.
4. Unbrako Socket Screws Catalog, Form 4080-15M-6/81 SPS, SPS Technologies.
5. Polypenco Nylon Catalog, The Polymer Corporation, 1975.
6. NASA-NHB 1700.7A, Safety Policy and Requirements for Payloads Using the Space Transportation System.
7. GAS Payloads Safety Manual, NASA-GSFC, Nov. 1983.

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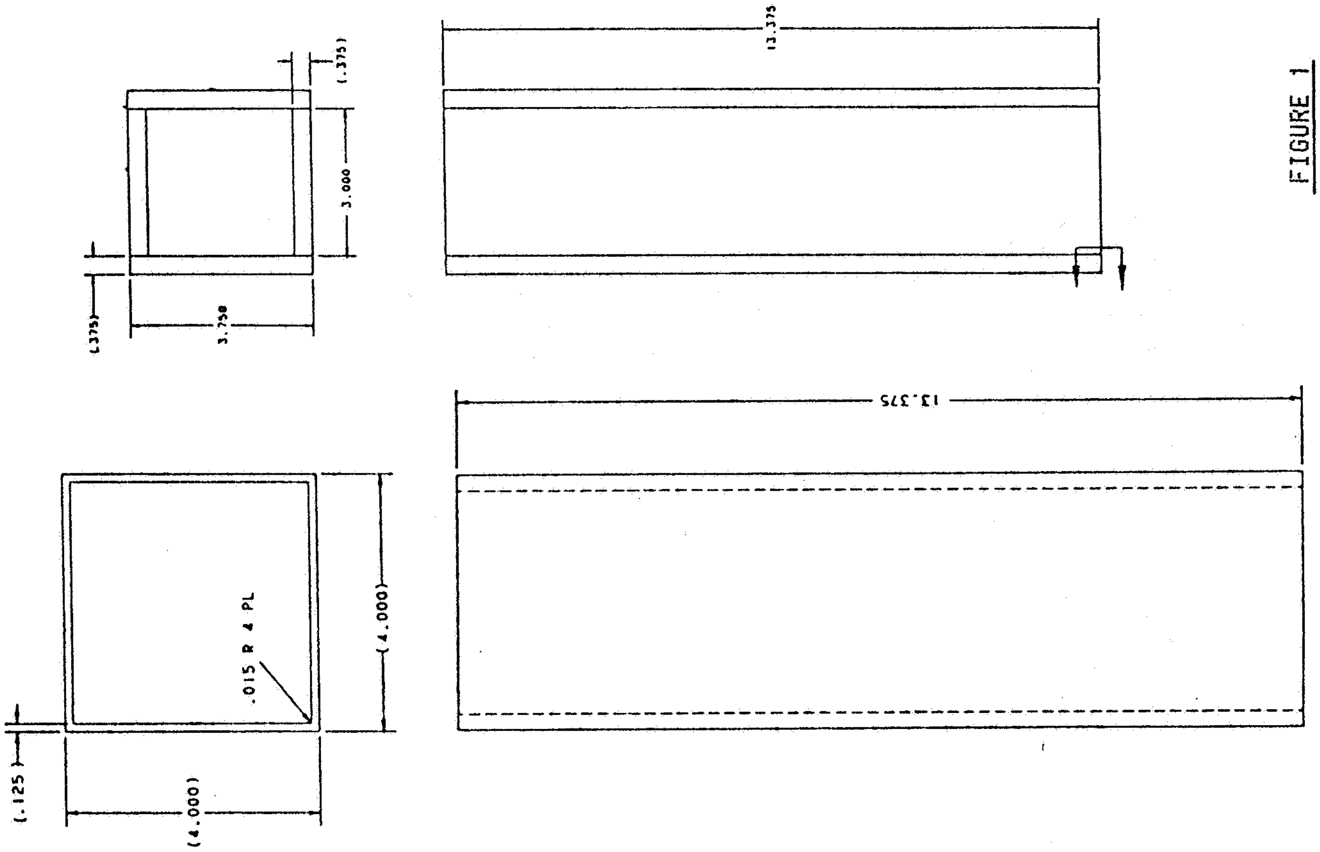

FIGURE 1

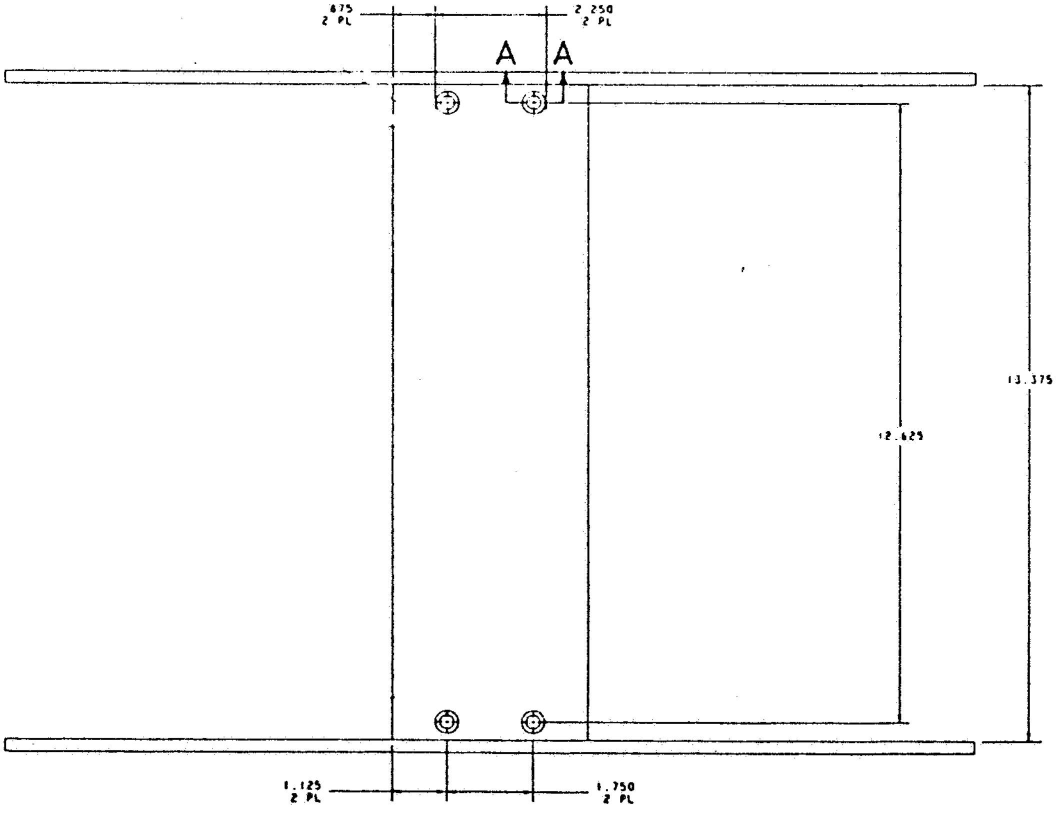

FIGURE 2

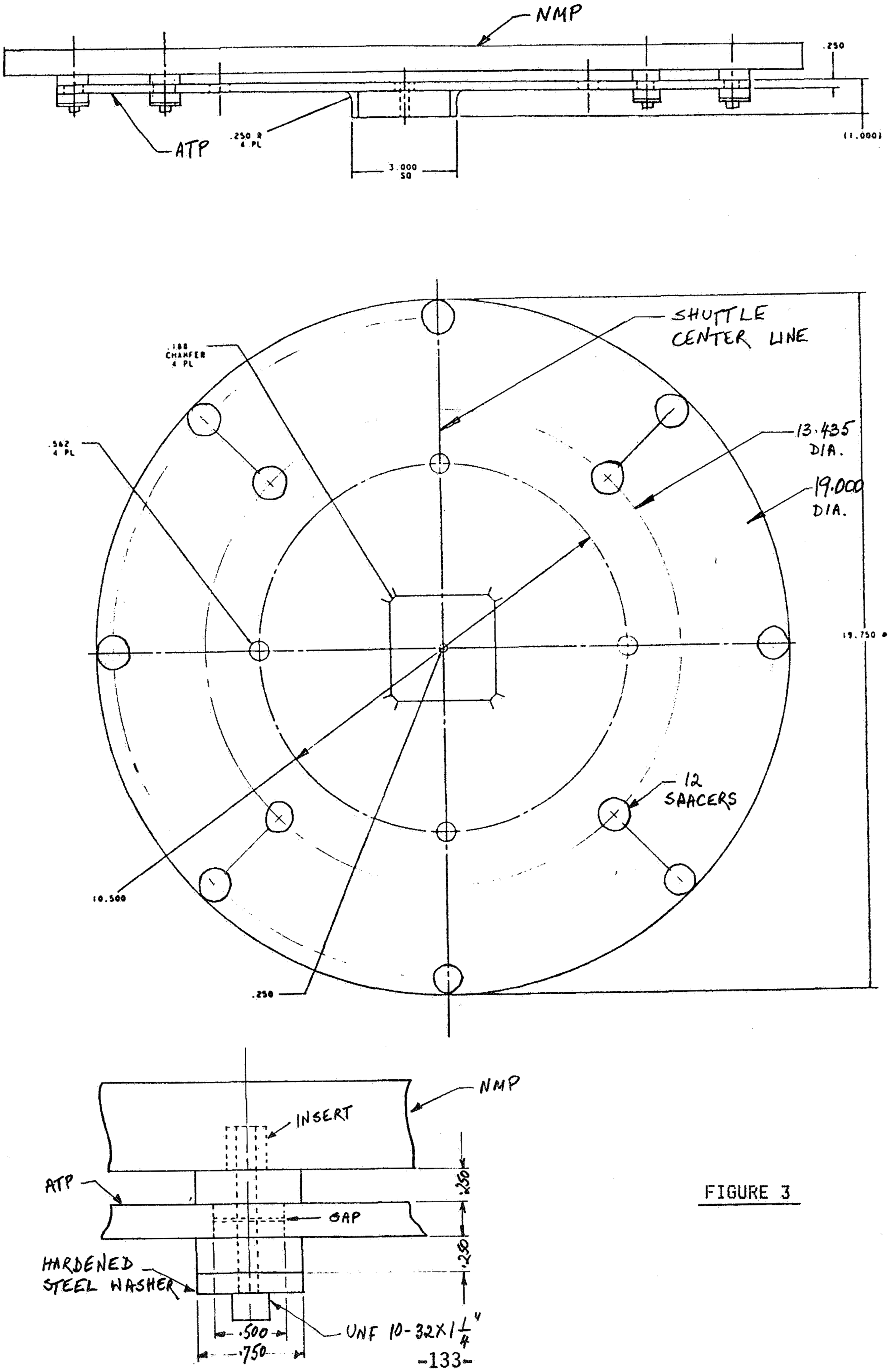
NMP
.250
ATP
.250 R
4 PL
3.000
SQ
(1.000)
SHUTTLE
CENTER LINE
.188
CHAMFER
4 PL
.562
4 PL
13.435
DIA.
19.000
DIA.
19.750
12
SPACERS
10.500
.250
NMP
INSERT
ATP
.250
GAP
.250
HARDENED
STEEL WASHER
.500
.750
UNF 10-32X1 $\frac{1}{4}$"

FIGURE 3

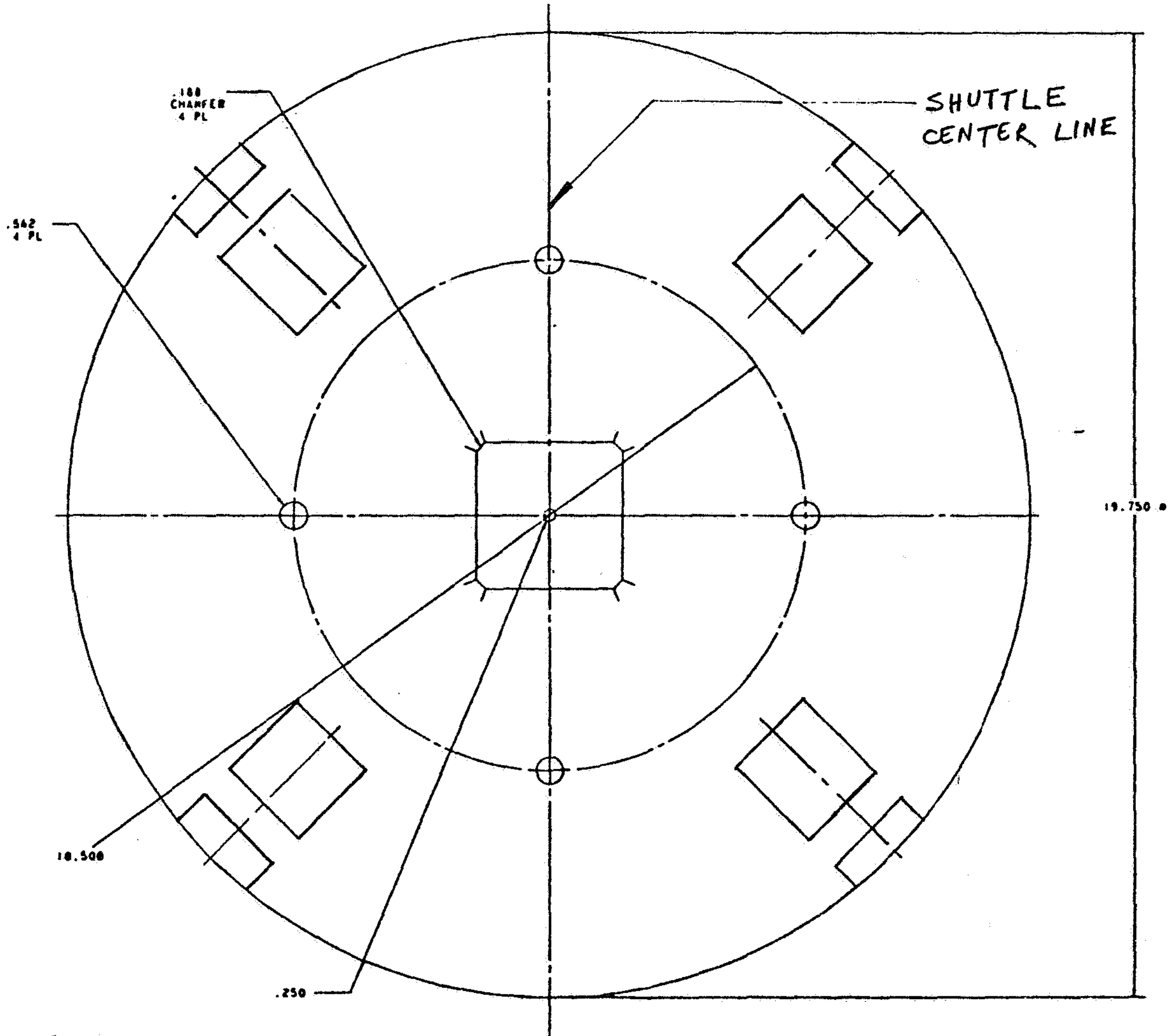

FIGURE 4

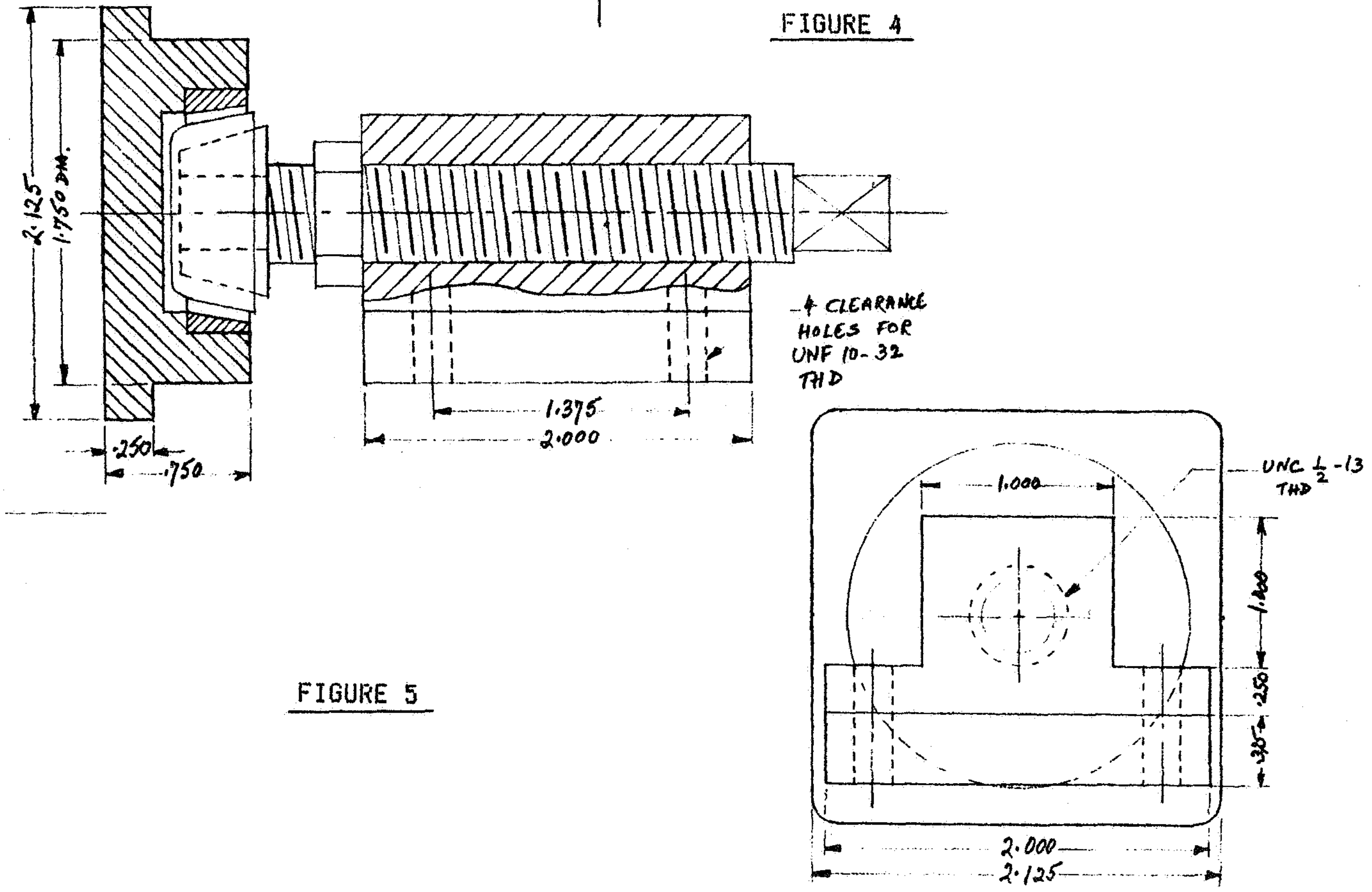

FIGURE 5