ATLAS Internal Note
TILECAL-NO-035
16 November 1994

Support Girder Design for the Atlas Hadron Calorimeter

Norman F. Hill, Victor J. Guarino, Emil Petereit

High Energy Physics Division
Argonne National Laboratory, Argonne, Illinois 60439 USA

16 November 1994

Purpose of the Girder

The girder is the primary structural element of the Hadron Calorimeter. It provides the backbone of the Tile-Cal module and the basic construction reference for the assembly of the module. The girder also forms the outer radius support ring, when the individual modules are assembled into the barrel and extended barrel assemblies. The girder also serves as the primary flux return path for the solenoidal coil, and as a magnetic shield around the photomultiplier tubes and the electronics to prevent their being affected by stray fields created by the muon toroid. It should be noted that the amount of steel in the girder is dominated by the flux return requirement, and not by the structural requirement. The orientation of the individual components of the girder are demanded by the need to contain the PMT and electronics drawer which resides inside the box structure.

Girder Design

The original girder, as conceived for the baseline, is shown in Fig. 1. This design's cost was estimated in the U.S. at a cost of \$3.00 - \$3.50 per pound, which was considered far too expensive. This decision generated a complete review of the girder, with the objective of optimizing the design and thereby reducing the cost to an acceptable level. Several options were considered as illustrated in Figs. 2 through 4. The final configuration, that has been analyzed, is shown in Figs. 5a and 5b. This final design meets all of the original parameters with respect to flux containment, shielding, and space for the PMT/electronics drawer. The philosophy behind this design was to start with the premise that the girders primary purpose was structural support, and design the minimum girder that would satisfy that requirement. The steel required for flux containment, and the drawer space were then added to the basic design. This resulted in a significant cost savings over the original design.

Girder Structural Analysis

A complete structural analysis was then performed on the girder and those results are presented here.

The Atlas girder was analyzed in both the 12 and 3 o'clock positions, supported only at its ends. This is considered the worst case condition, and only occurs during handling. Hand calculations were used first, and did not include any stiffening effects from the module itself or the end plates which cover the ends. In the 12 o'clock position, the maximum stress found was 5,000 psi which occurred at the ends. In the 3 o'clock position the maximum stress was 14,000 psi. Most of this is shear stress from the torsion produced on the beam. An FEA model of the girder was then constructed, once again examining the girder in the 12 and 3 o'clock position. In the model, the end plate and front plates were included and the module was simulated by including 100 master plates. However, these master plates were only tied together along the front and back plates. In the 3 o'clock position, the maximum stress was 47,000 psi and occurred at the ends where the girder was supported (see Fig. 6). Away from this stress concentration, the stresses are reduced to approximately 26,000 psi. The front plate of the girder deflected .89" in the ϕ direction in this model. In this first model, the end plate did not close off the end of the girder. After adjusting the model to extend the end plate over the end of the girder, the deflection in the ϕ direction was reduced to .52" and the maximum stress was reduced to 16,000 psi (see Fig. 7).

In the 12 o'clock position the maximum stress was 18,000 psi, and the maximum deflection of the front plate was .189". Although the extra welded plates were not added to this model, they will contribute some additional stiffness to the girder. The bonding of the plates will also add stiffness to the system, but the calculation is extremely difficult with laminated structures.

Construction and Machining of the Girder

The girder is constructed using a standard square structural tube of 8" × 8" dimension. The heavy plates are then welded to the top and bottom of the tube, and an additional plate is welded to both sides of the tube to increase the cross section for magnetic flux containment.

After welding, the entire structure is stress relieved. The last step is to machine the necessary elements as shown on the drawings. The drawing references for these girders are shown in Appendices A (AT-210-1-1) and B (AT-210-1-2).

The barrel modules, and the extended barrel modules, are the same except for their length.

Material

The material specified for this construction is A-36 hot rolled steel, with the exception of the structural tube, which is specified as ASTM A-500 grade B. The mechanical properties and chemical composition of these two grades of steel are listed in the Tables below.

Mechanical Properties

Type	Tensile (ksi)	Yield (ksi)	% Elongation
A-36	58-80	36 min.	23
A-500 Gr B	58	46	23

Chemical Composition

Type	C	Mn	P	S	Si
A-36	.26	.60 -.80	.04	.05 max	------
A-500	.26	--------	.04	.05 max	

Welding

All welding should be performed by certified welders as specified in American Welding Society code Section D2.

Final Machining

Final machining should be performed only where necessary to meet dimensional requirements

Girder Function During Assembly

The girder's outer plate edge, provides the bearing surface that will be shimmed in assembly to maintain the required gap between modules. The machined angle surface at the outer radius will provide for the mounting of coupling plates, that will join modules and form a continuous circumferential structural ring in the final assembly.

Girder Cost

Budget estimates have been received from two vendors for the cost of producing the girders. These estimates vary widely but subsequent to the optimization of the design the cost has been reduced by at least a factor of two from the cost of the original design. These quotations are attached for reference (see Appendices C and D. The total cost of the girders for both the barrel and extended barrel is now estimated to be 1,779,065 CHF. This cost includes the outer radius filler plate and the tooling.

----

* Work supported by the U.S. Department of Energy, Division of High Energy Physics, Contract W-31-109-ENG-38.

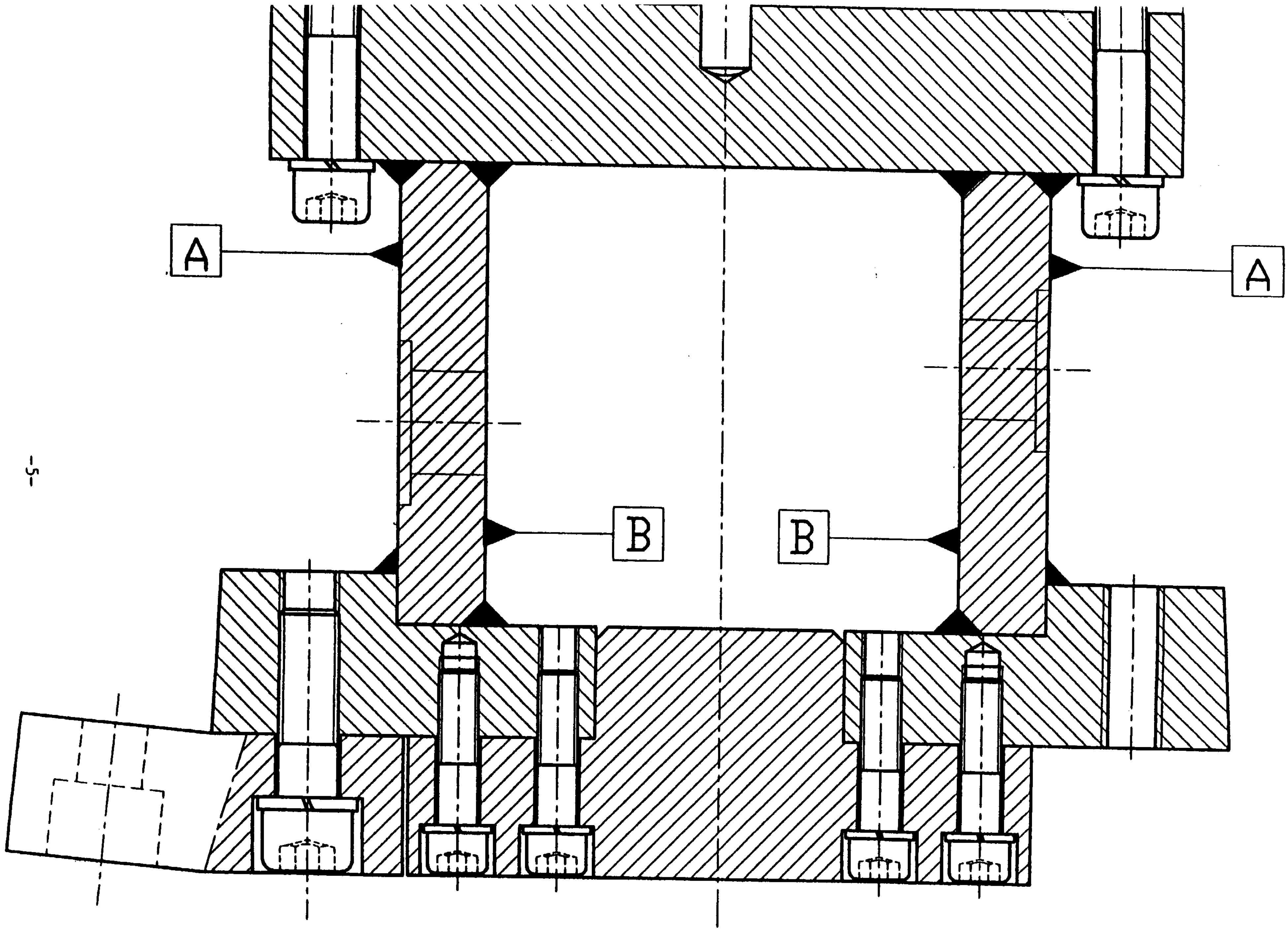


Figure 1 Original Design

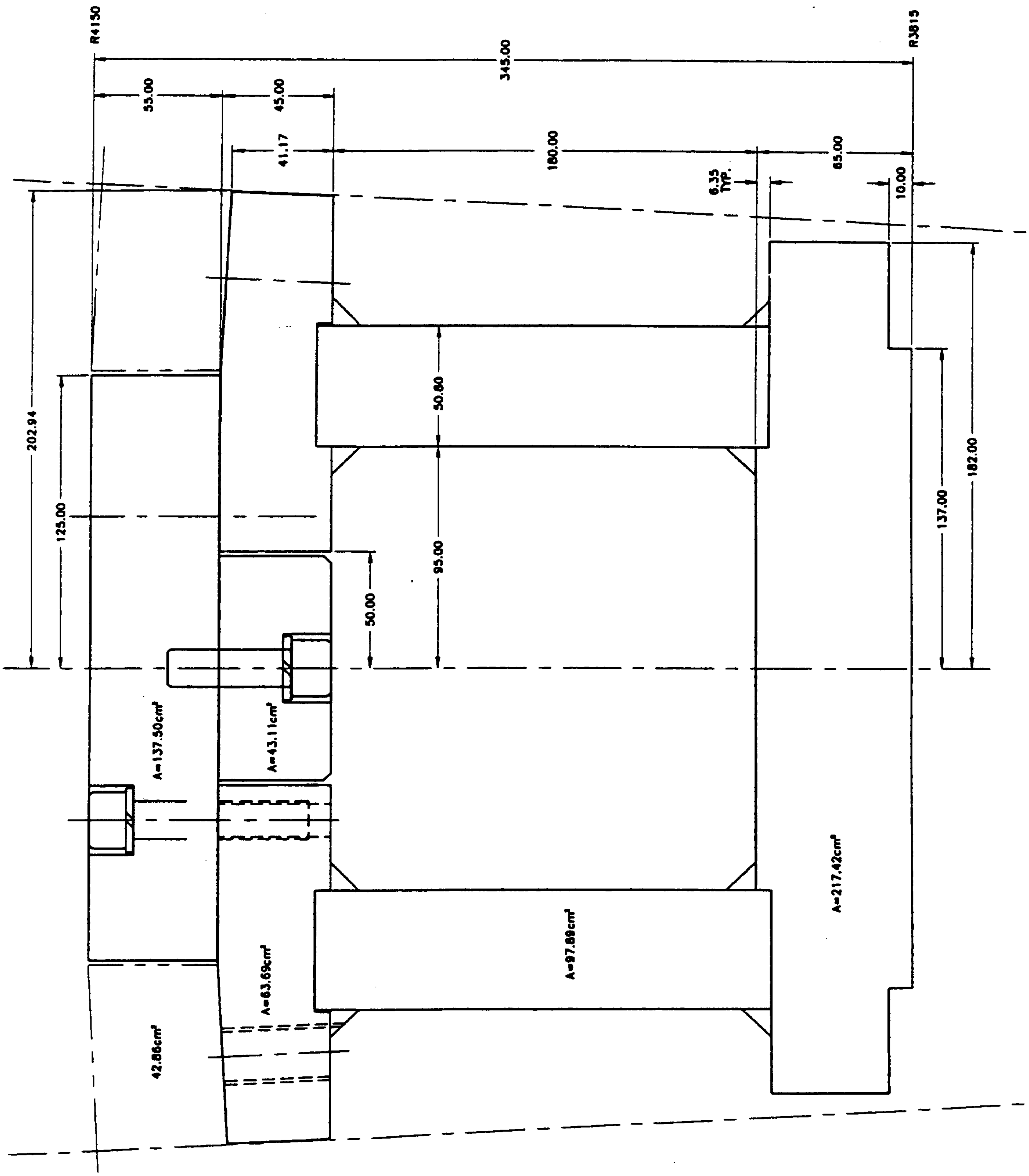


Figure 2 Option 1

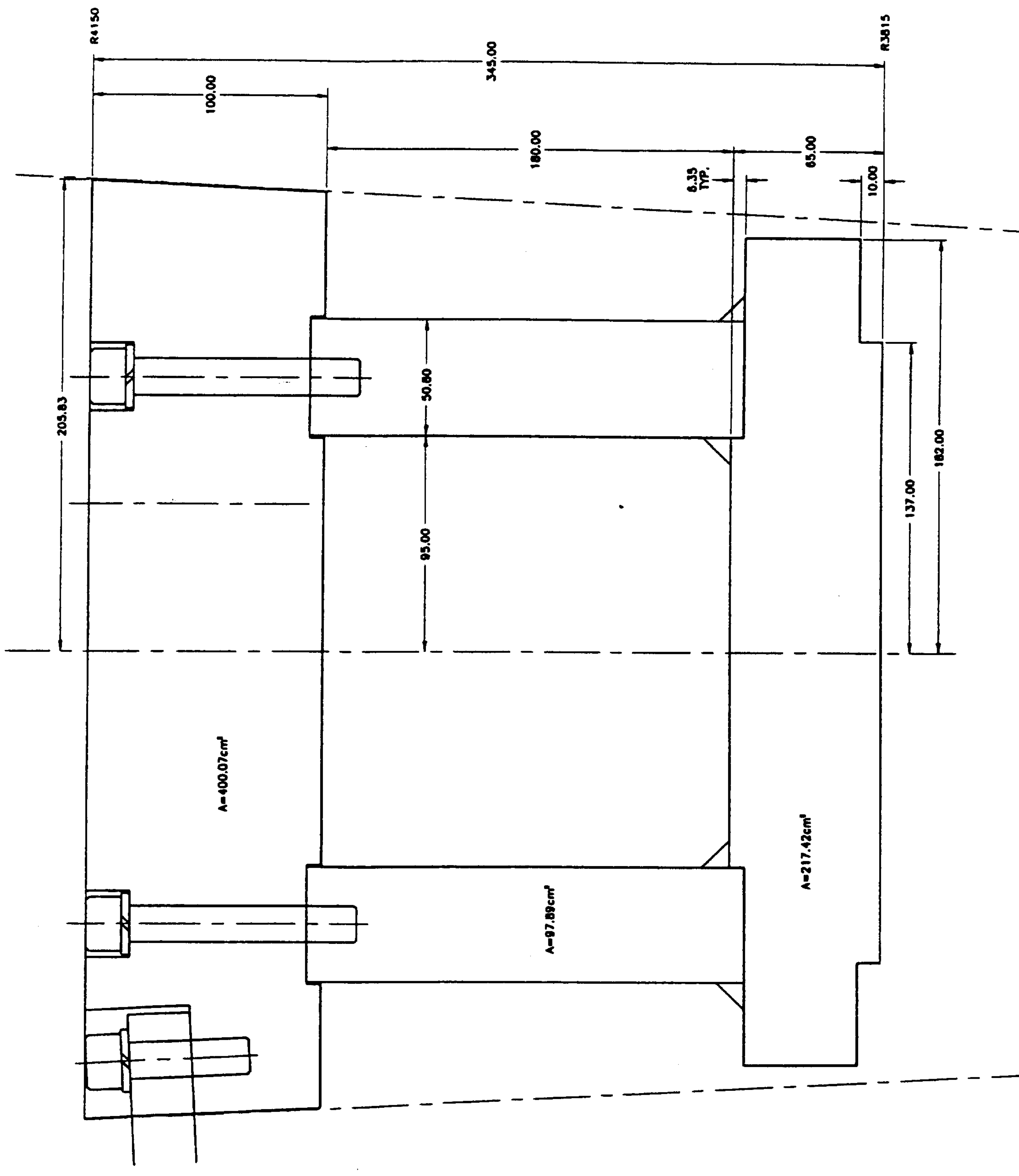


Figure 3 Option 2

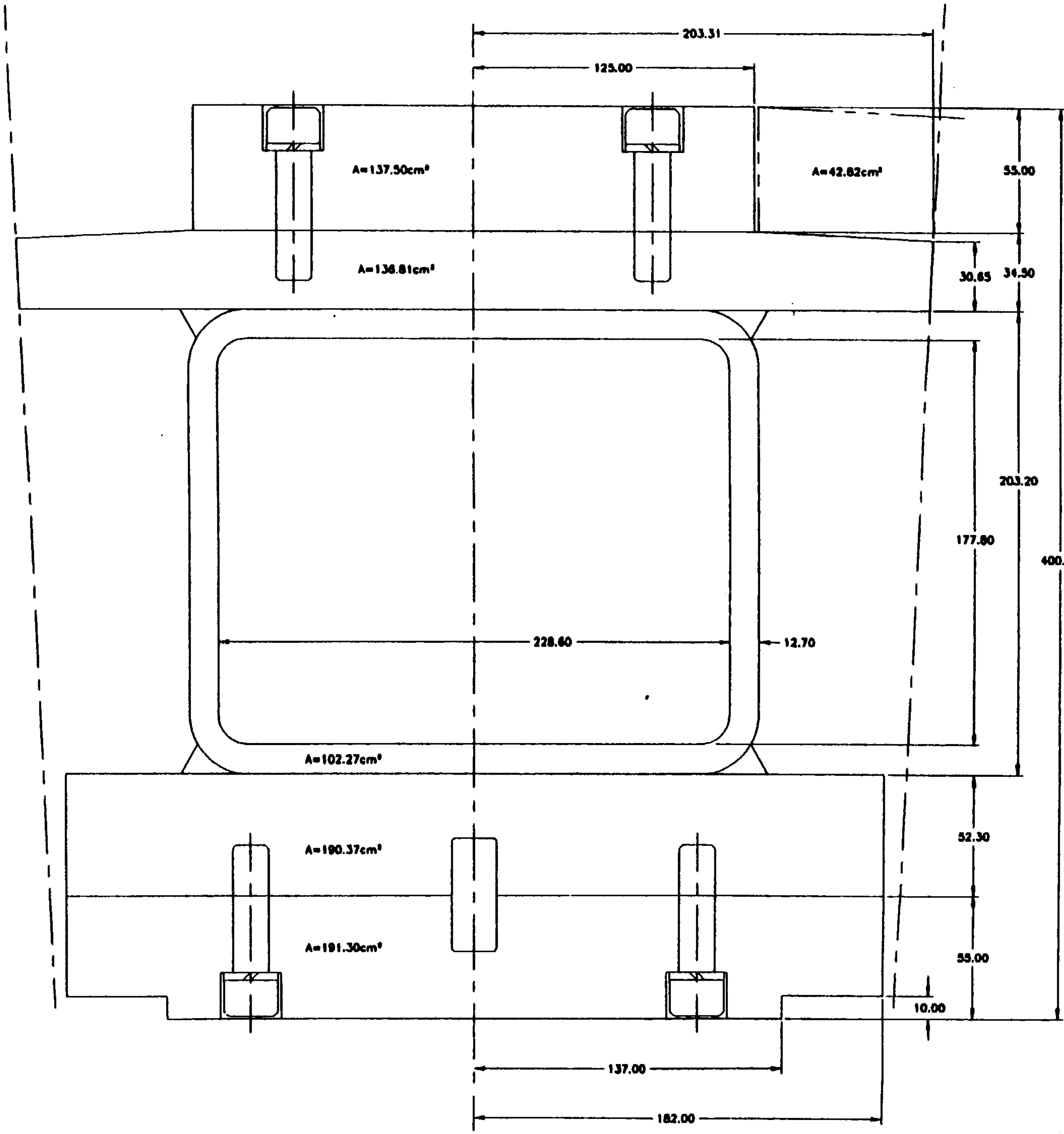


Figure 4

Option 3

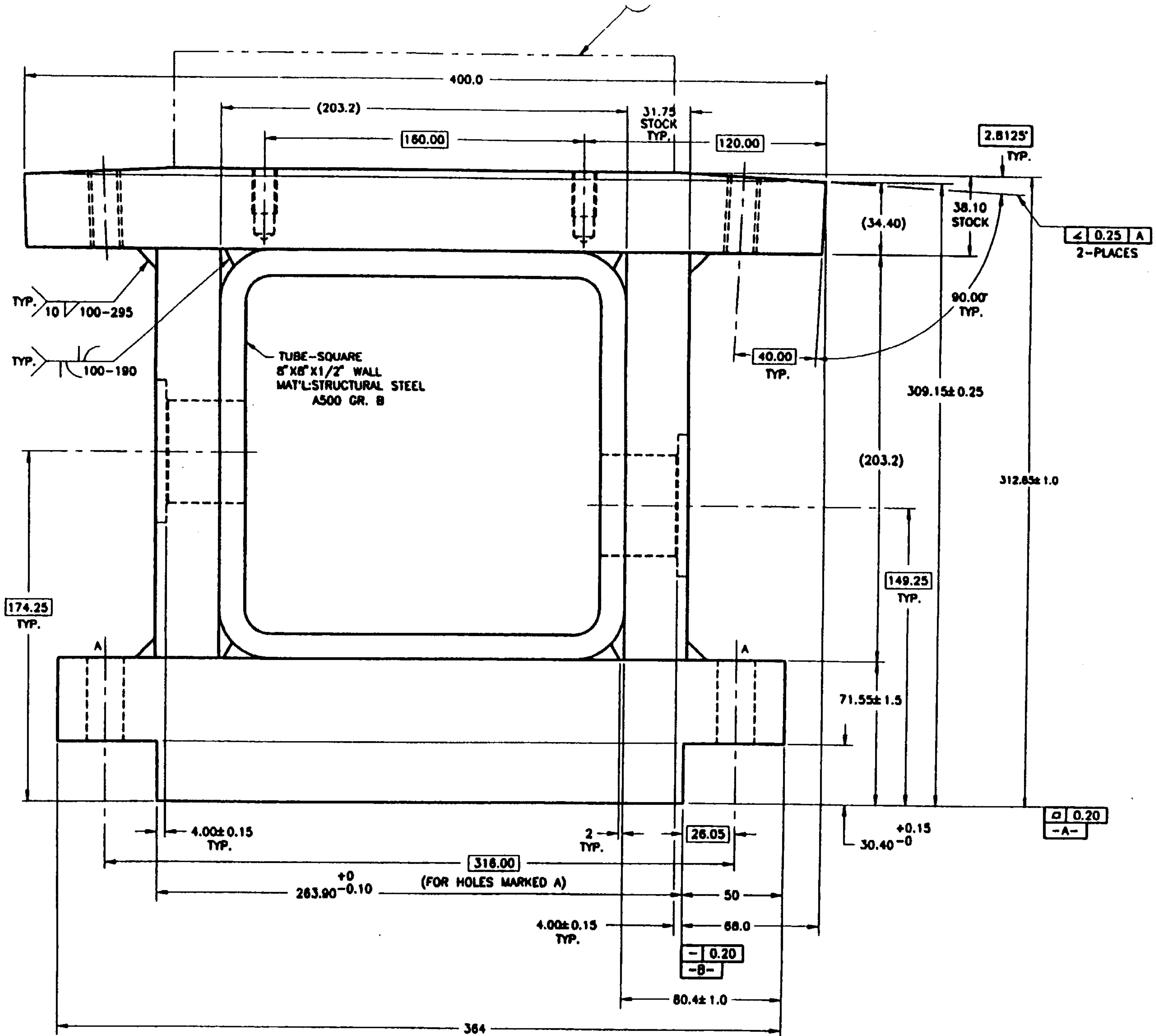


Figure 5a

Final U.S. Version

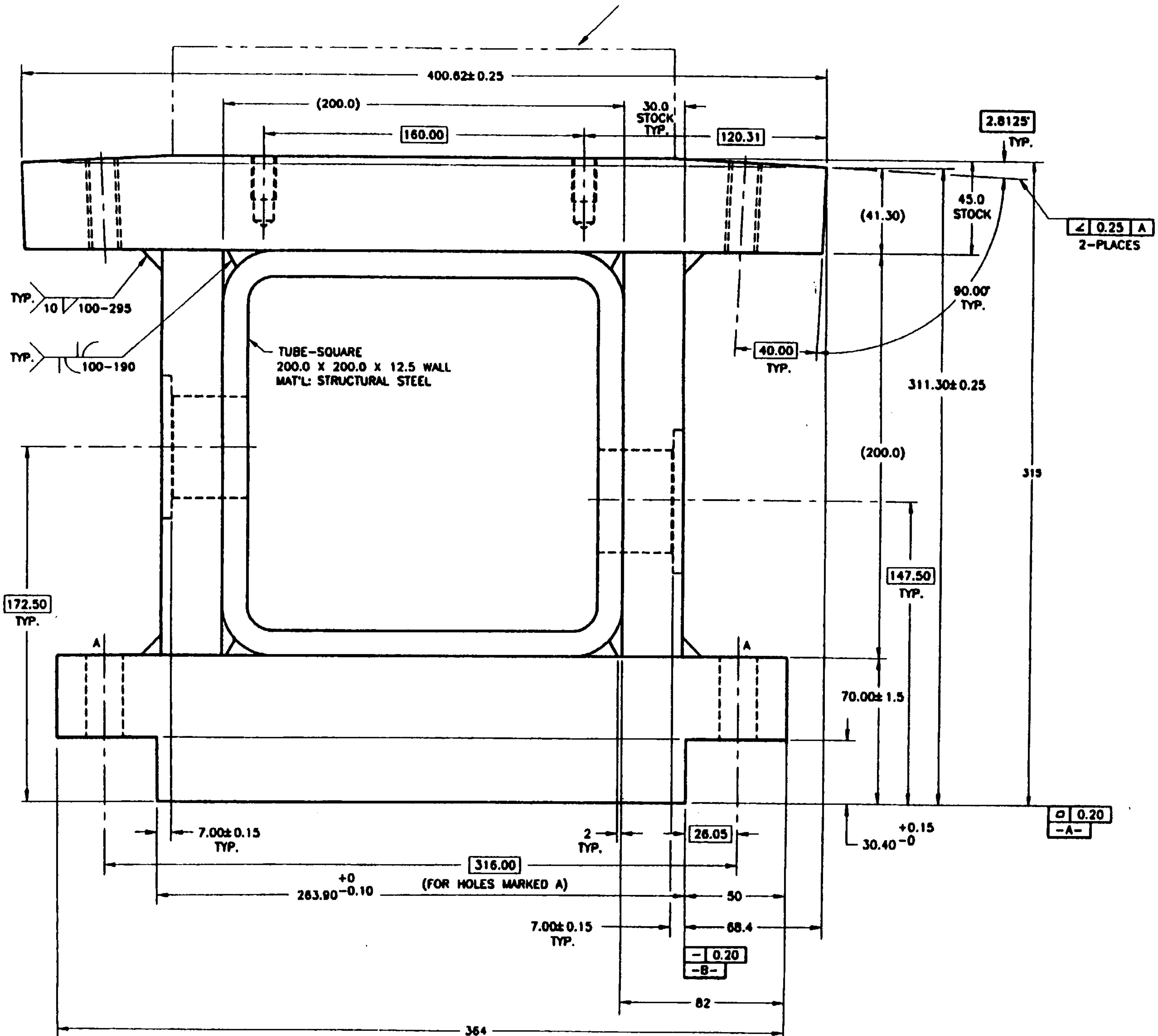


Figure 5b Final European Version

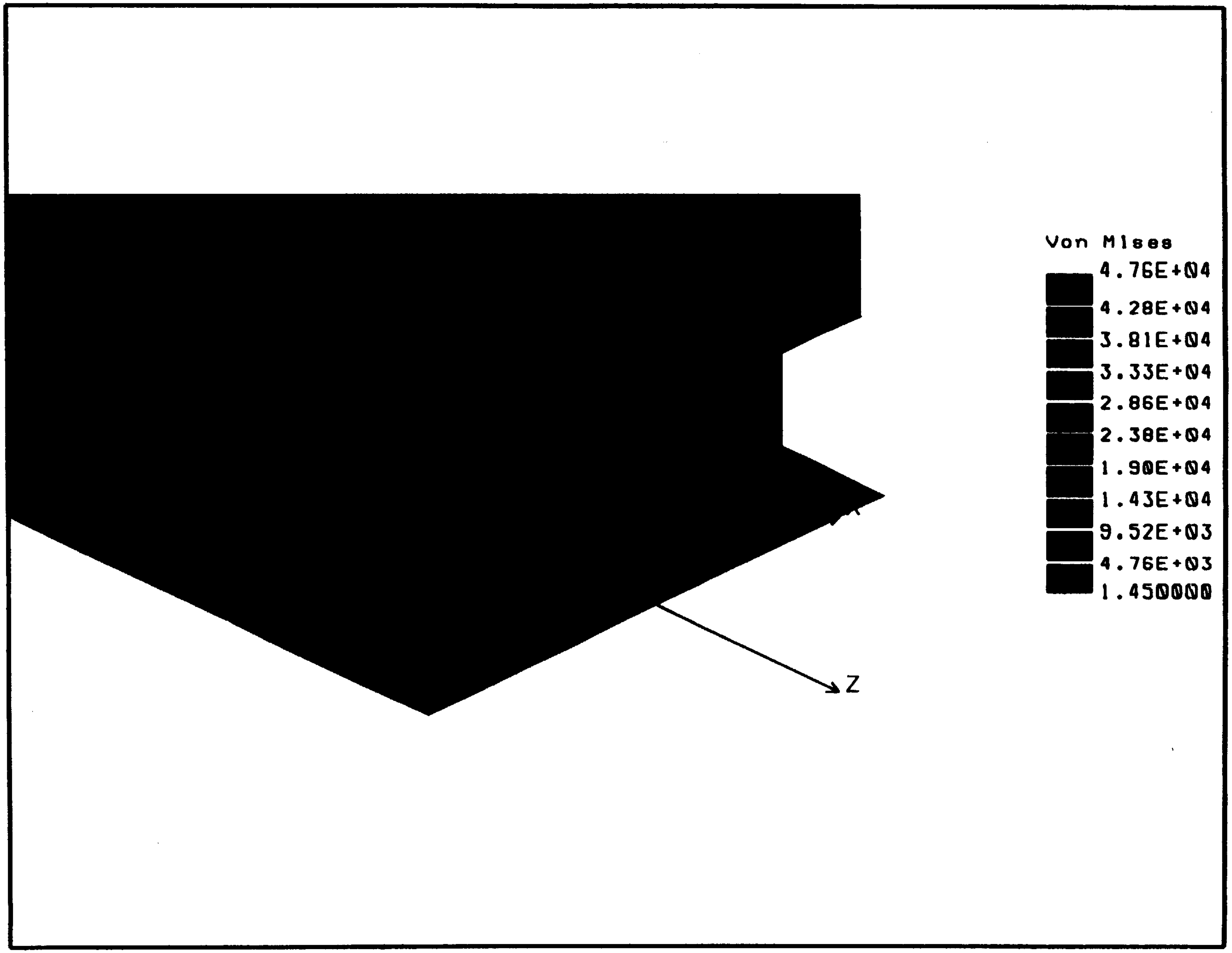


Figure 6 Open Ended Girder

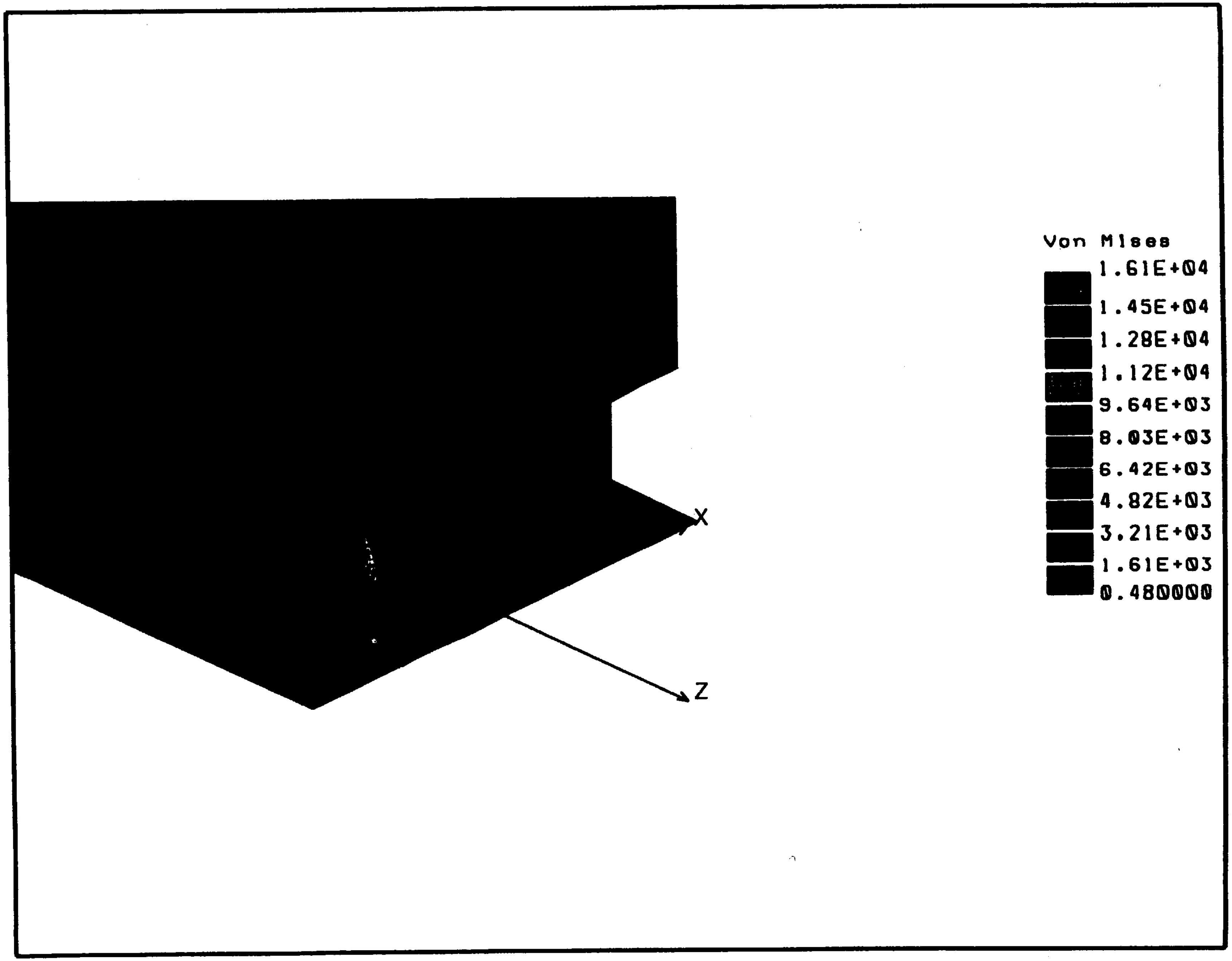
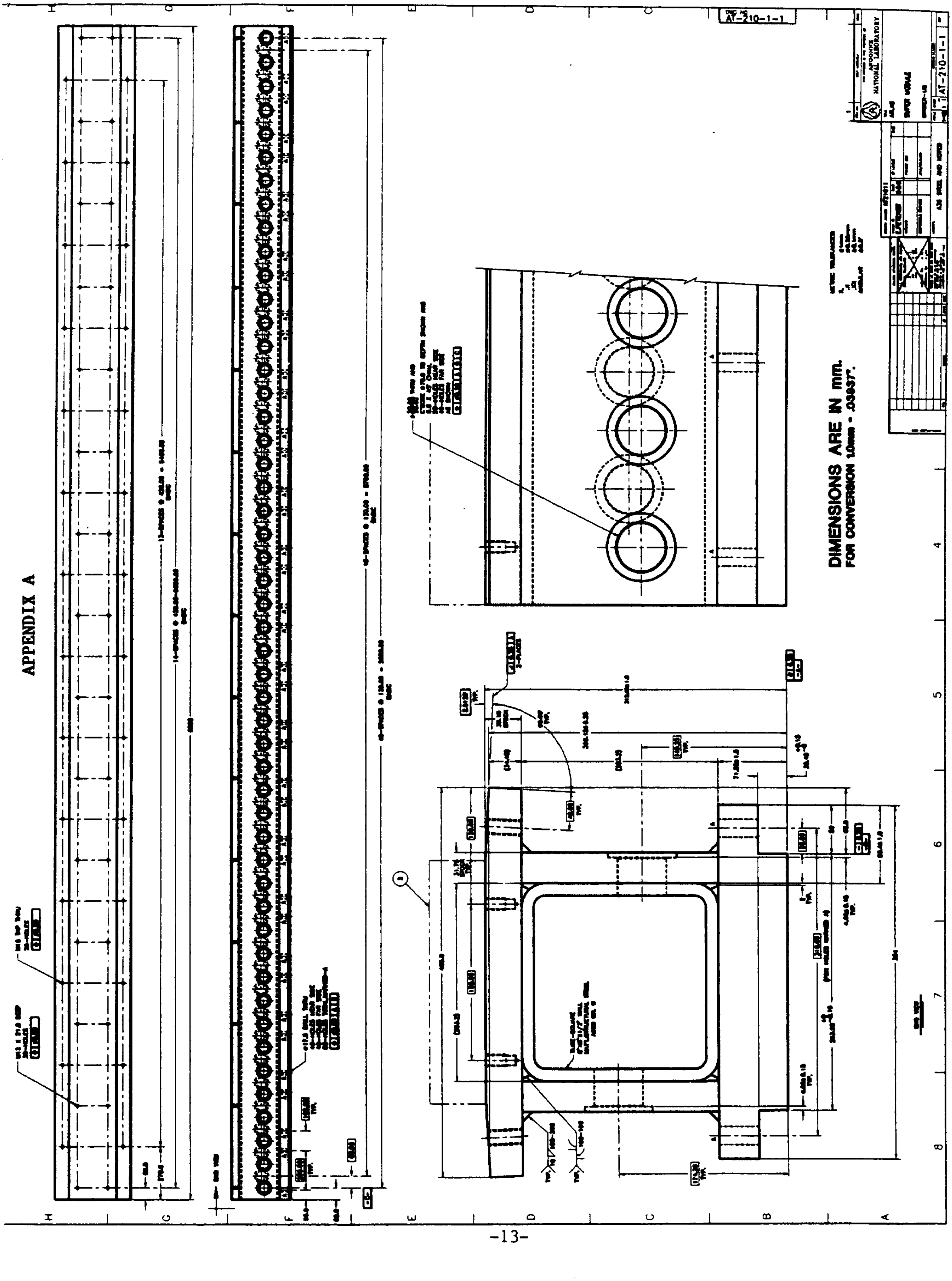


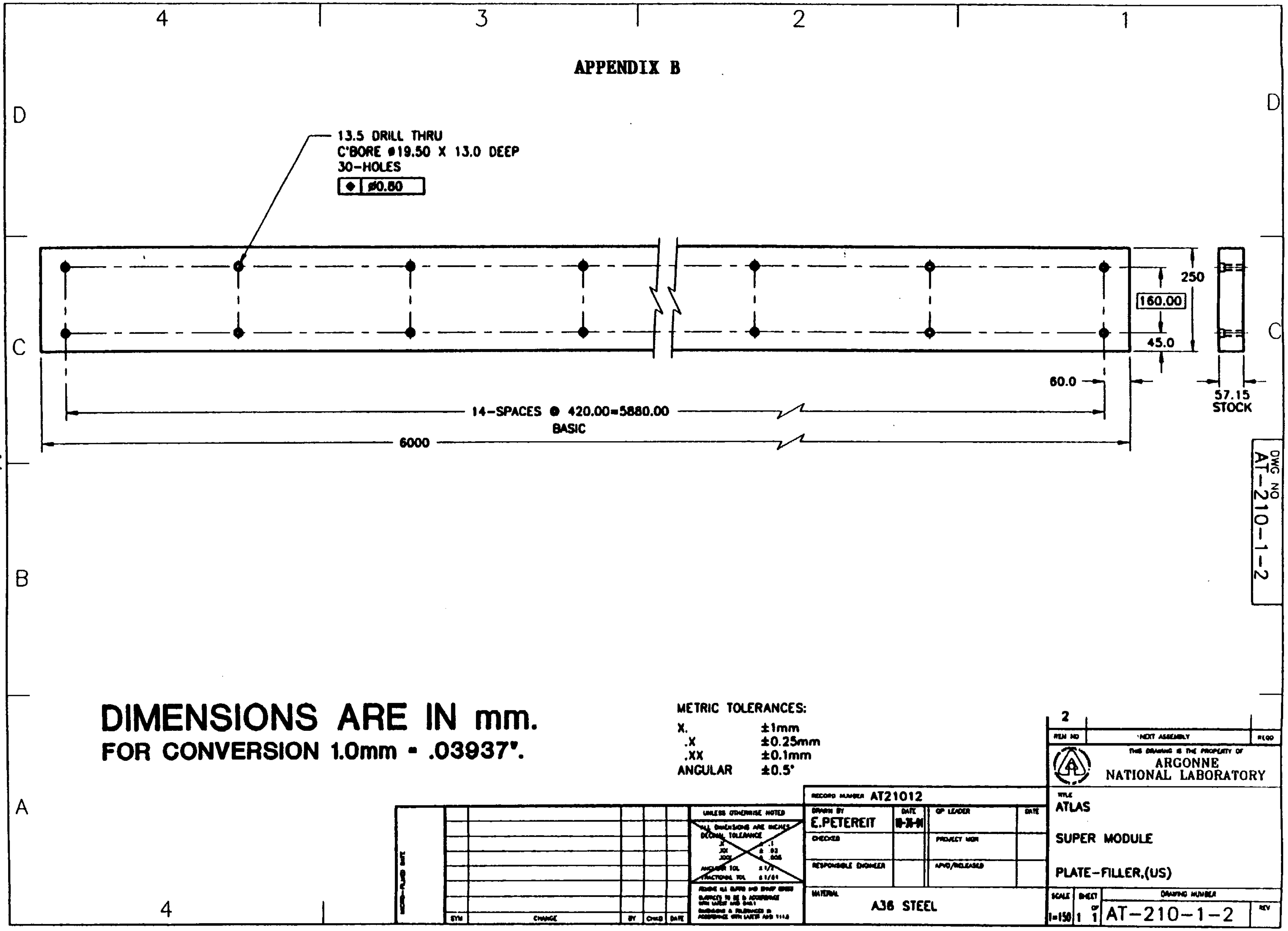
Figure 7 Closed with End Plate

APPENDIX A



AT-210-1-1
ARGONNE NATIONAL LABORATORY
DIMENSIONS ARE IN mm.
FOR CONVERSION 1.0mm = .03937"

APPENDIX B


13.5 DRILL THRU
C'BORE ⌀19.50 X 13.0 DEEP
30-HOLES
⌀0.80
250
160.00
45.0
60.0
57.15
STOCK
14-SPACES @ 420.00=5880.00
BASIC
6000
DWG NO
AT-210-1-2
DIMENSIONS ARE IN mm.
FOR CONVERSION 1.0mm = .03937".
METRIC TOLERANCES:
X. ±1mm
.X ±0.25mm
.XX ±0.1mm
ANGULAR ±0.5°
ARGONNE NATIONAL LABORATORY
RECORD NUMBER AT21012
DRAWN BY E.PETEREIT
ATLAS
SUPER MODULE
PLATE-FILLER,(US)
MATERIAL A36 STEEL
AT-210-1-2