LAB 3 COSMIC RAY TEST STAND ANALYSIS OF STEEL STACK SUPPORTS

D-ZERO ENGINEERING NOTE # 3823.113 EN-493

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Summary:

A cosmic ray test stand is being constructed at Lab 3. The stand consists of two stacks of steel plates one resting on top of the other. The top stack is composed of 6 plates of steel making an overall stack size of 34.5"x40"x99". The bottom stack also has 6 layers of plate making an overall size of approximately 49.5"x82"x99". The bottom stack is supported with three support legs. See drawing 3823.000-ME-900428 for the individual plate orientation. The minimum support leg size and necessary welds between plates are determined.

Analysis:

Support leg size determination:

The three support legs must support the entire weight of the steel stack. The support height gives a 6" clearance between the stack bottom and the floor. The width of the leg is approximately 3" wide to provide space for detectors under the stack. The top stack weight is approximately 40,000 lbs. The bottom stack weight is approximately 115,000 lbs. The total stack weight is approximately 155,000 lbs. The supports rest on high compressive strength steel plates and grout. Two 1.25" steel plates and 1" of grout is used for this purpose. The concrete under this is assumed to be a conservative 2000 psi compressive strength. Assuming all the weight of the stack rests on one support the minimum required area on the concrete is:

$$155,000 \text{ lbs}/2,000 \text{ psi} = 77.5 \text{ in}^2$$

Assuming 45 deg load cones through a thickness of 3.5" from each support and a maximum support leg width of 3" the minimum required length of the support is:

$$77.5 \text{ in}^2 / (3" + 3.5" + 3.5") - 7" = 0.75 \text{ inch}$$

This determines the support plate size to be a minimum of 0.75"x3" in area.

The minimum support plate size determined by compressive stresses in the support leg is determined by assuming a total load of 155,000 lbs, a maximum allowable conservative compressive stress for the support leg of 15,000 psi and a maximum width of 3". The support length is then determined by:

$$155,000 \text{ lbs}/15,000 \text{ psi}/3 \text{ inch} = 3.5 \text{ inches.}$$

In this situation the minimum support leg size is determined by the maximum allowable compressive stress in the plate. The support plate cross-sectional area should not be less than 3.5"x3".

Determination of weld locations on the bottom steel stack.

The bottom stack consists of two steel plates per layer for six layers. The

seam in the bottom layer is at 90 degrees from the seams in the top five layers. The top five layers have a seam offset of 3.75" between layers. The three support plates are orientated such that they support two opposing corners of the plates in the bottom layer. This forces the plate stack to have welds to ensure that the bottom plates do not shift in the stack.

Area of weld required to support the bottom two plates from the plates in the second layer:

The weight of the larger plate in the bottom layer is 11,000 lbs. Assuming a 1/4" wide weld bead, and maximum tensile strength of the weld to be 15,000 psi, the necessary linear length of weld required to support the plate is:

$$11,000/0.25"/15,000 \text{ psi} = 3 \text{ inches}$$

A minimum weld bead length of 3" would be enough to support the larger of the two plates. Drawing 900428 calls out for 3" long welds at 24" spacings between the first and second layers. Also welds are called for at the seams between plates in the same layer.

The welds as marked on the drawing are conservative for the purpose of supporting these plates.

Deflections and stresses on the bottom two layers caused by the weight of the stack:

Since the bottom two layers are welded to form one large plate, it is assumed that this joint layer supports the weight of the rest of the stack.

Deflections and stresses due to the self weight of the bottom layer:

The self weight of the bottom joint layer is

$$2 \times 8.25" \times 83" \times 99" \times 0.284 \text{ lb/in}^3 = 38,500 \text{ lbs}$$

The joint layer is assumed to be simply supported at both ends by 12" wide support legs. The span between edges is assumed to be 84". The moment of inertia is then assumed to be:

$$I = 12 \text{ in} \times 16.5 \text{ in}^3 / 12 = 4492 \text{ in}^4$$

$$\delta = 5Wl^3 / 384EI = 5 \times 38,500 \text{ lb} \times 84''^3 / 384 \times 30 \times 10^6 \text{ psi} \times 4492 \text{ in}^4 = 0.002''$$

$$\sigma = -Wl/8Z = -38,500 \text{ lb} \times 84'' / 8 \times 4492 \text{ in}^4 / 4.125'' = -371 \text{ psi}$$

Deflections and stresses due to the remaining weight of the bottom stack:

The remaining weight of the bottom of the stack is:

$$4 \times 8.25" \times 83" \times 99" \times 0.284 \text{ lb/in}^3 = 77,000 \text{ lbs}$$

The weight is assumed to be uniformly loaded on the bottom layer.

$$\delta = 5Wl^3/384EI = 5 \times 77,000 \text{ lbs} \times 84''^3 / 384 \times 30 \times 10^6 \text{ psi} \times 4492 \text{ in}^4 = 0.004''$$

$$\sigma = -Wl/8Z = -77,000 \text{ lbs} \times 84'' / 8 \times 4492 \text{ in}^4 / 4.125'' = -742 \text{ psi}$$

Deflections and stresses due to the weight of the top stack:

The top stack is assumed to rest on two rails, one along each 99" long side, which rests on the bottom stack. The top stack puts a load of 20,000 lbs on each rail. The rails are positioned approximately 20" from each side of the bottom stack.

$$\delta = Wa/24EI \times (3l^2 - 4a^2) \\ = 20,000 \text{ lbs} \times 20'' / 24 \times 30 \times 10^6 \text{ psi} \times 4492 \text{ in}^4 \times (3 \times 84''^2 - 4 \times 20''^2) = 0.002''$$

$$\sigma = -Wa/Z = -20,000 \text{ lbs} \times 20'' / 4492 \text{ in}^4 / 4.125'' = -368 \text{ psi}$$

Total stack deflections and stress at the bottom layer:

$$\delta_{\text{total}} = 0.008''$$

$$\sigma_{\text{total}} = -1481 \text{ psi}$$

Conclusions:

The 155,000 lb steel stack assembly planned for the cosmic ray stand at Lab 3 is thought to have the bottom two layers of the stack welded and supported by three legs. The legs are thought to be 12" long x 3" wide and 6" tall. The legs are assumed to be supported by at least 3.5" thick high compressive strength material such as steel plate and grout. Two legs are at each end of the 99" long length and the third leg is on the opposing side of the stack at the bottom plate seam. This sufficiently exceeds the size requirements of the support leg. The bottom two layers are thought to be welded together by a 1/4" wide weld 3" long at 24" intervals around the stack. Welds are also thought to be at the plate seams in the bottom and second layers. This sufficiently exceeds the weld requirements to support the stack.

FLOOR PLAN
SCALE: 1/2" = 1'-0"

SECTION A-A
SCALE: 3/4" = 1'-0"

SECTION B-B
SCALE: 3/4" = 1'-0"

REV.	DATE	DESCRIPTION OF REV.	BY
1	10/1/80	ISSUED FOR CONSTRUCTION	J. J. J.

PARTS LIST			
QTY	DESCRIPTION	U.S. G.S.	DATE
1	YAC TEST CONTROL	2. 10/1/80	10/1/80
1	DESK	2. 10/1/80	10/1/80
1	UNIT HTB	2. 10/1/80	10/1/80
1	RACK #1	2. 10/1/80	10/1/80
1	RACK #2	2. 10/1/80	10/1/80
1	RACK #3	2. 10/1/80	10/1/80
1	RACK #4	2. 10/1/80	10/1/80
1	RACK #5	2. 10/1/80	10/1/80

✓ **APPROVED**

FERM: NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

**DO DETECTOR UPGRADE
COSMIC RAY TEST STAND AT LAB 3
NORTH ANNEX LAYOUT PROPOSAL**

NO. 3823.000-ME-900428

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