BELOW-THE-HOOK LIFTING DEVICE
Engineering Note Cover Page

Lifting Device Numbers:

FNAL Site No.: 130 (if applicable) Div. Specific No.: ________ (if applicable) Asset No. ________ (if applicable)

ASME B30.20 Group: (check one)
- ✓ Group I Structural and Mechanical Lifting Devices
- ˇ Group II Vacuum Lifting Devices
- ˇ Group III Magnets, Close Proximity Operated
- ˇ Group IV Magnets, Remote Operated

Device Name or Description: T-block lifting hook (NuMI)

Device was: (check all applicable)
- ˇ Purchased from a Commercial Lifting Device Manufacturer
  mfg. name: ________________
- ✓ Designed and Built at Fermilab
- ˇ Designed by Fermilab and Built by a Vendor
  Assy drawing number: ________________
- ˇ Provided by a User or Other Laboratory
- ˇ Other. Describe: ________________

Engineering Note Prepared by: [signature] Date: 1/29/02

Engineering Note Reviewed by: [signature] Date: 1/29/02

Lifting Device Data:

Capacity: 20,000 Lbs

Fixture Weight: 165 Lbs

Service: ✓ normal ˇ heavy ˇ severe (refer to B30.20 for definitions)

Duty Cycle: ________ 8, 16 or 24 hour rating (applicable to groups III, and IV)

Inspections Frequency: ________________

Rated Load Test by FNAL (if applicable): Date: 5/6/2002 Load: 25,000 Lbs

ˇ Check if Load Test was by Vendor and attach the certificate.

Satisfactory Load Test Witnessed by: Andy Stefanik

Signature (of Load Test Witness): A. Stefanik

Notes or Special Information:

Test load held for 5 minutes.

Scale: Martin Decker Model # SU188-0250
Serial # 3580
USA-HW 494638

Measured 1 B-shielding block to test the scale.
Theoretical weight = 10,150 Lbs Measured weight = 10,200 Lbs

Fermilab
PPD/MD/Engineering Analysis Group

MSG-EAR-01-293
January 29, 2002

Stress Analysis of T-block Lifting Hook Modified for 10 Ton Load

Bob Wands

Introduction

The T-block lifting hook was originally designed for a load of 7.5 tons (15000 lb). Not long after the design was finalized, T-block weight has increased to 9.5 tons (19000 lbs). The T-block lifting hook has therefore been modified to handle the increased weight by welding 0.5 inch steel plates to the inside of the existing hooks. Stress analysis shows the modified hook to be adequate for lifting 10 tons.

Modifications

Fig. 1 shows the location of the additional 0.5 inch plates on the hook. Placing them on the inside of the existing hooks maintains the necessary clearances with the lifting bar on the T-block assembly.

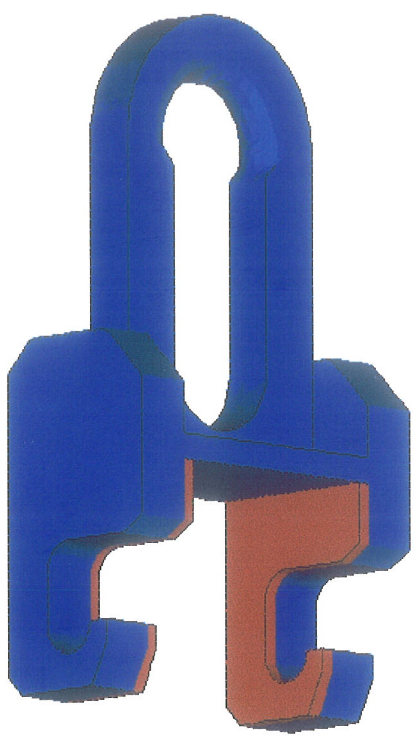

Figure 1. Location of Additional 0.5 inch Steel Plates

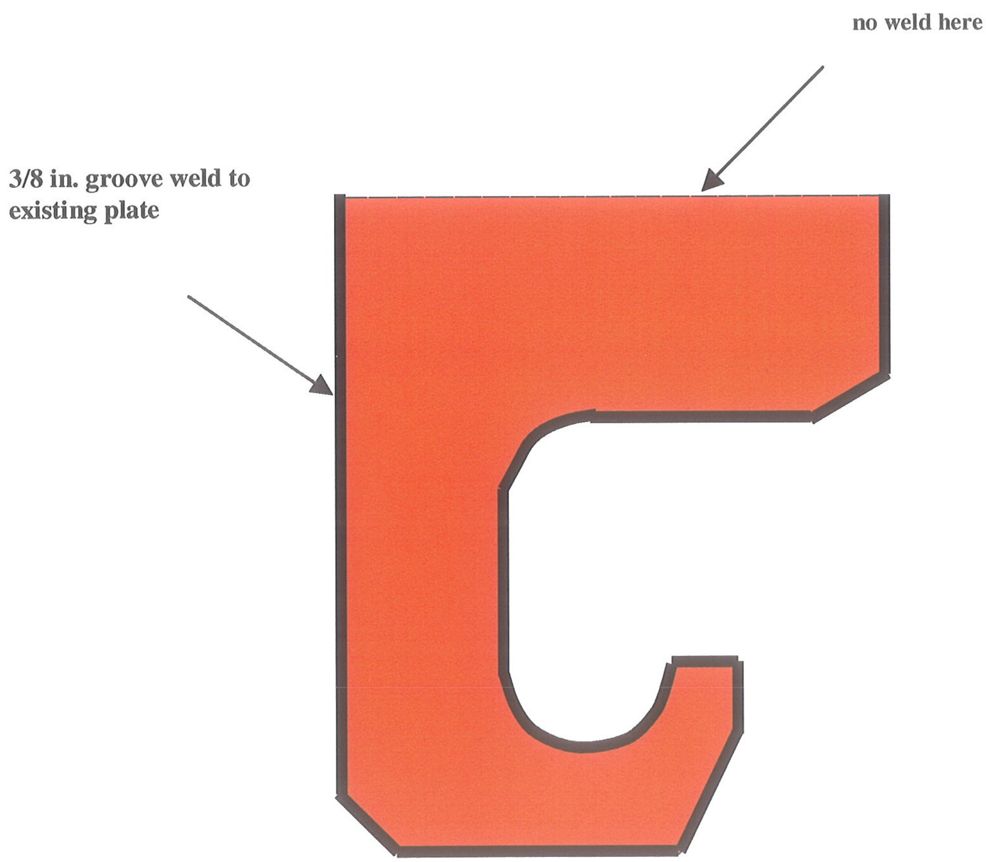

Figure 2. Weld between New Plate and Existing Plate

Fig. 2 shows the groove weld used to attach the new plates. Because of an existing weld on the assembly, the new plate is not welded along its upper boundary; all necessary strength is developed by the 3/8 inch groove weld, which has a total length of about 30 inches.

Analysis Approach

A finite element model of the lifting hook was created and subjected to the T-block load of 20000 lbs. Stresses across the hook regions were linearized into membrane and bending components, and compared to the allowable stresses. Welds were evaluated by determining their loads from the finite element nodal forces, and applying those forces to hand calculations of weld groups.

Materials and Safety Factors

The lifting hook is assumed to be made from A36 structural steel, with $S_y = 36$ ksi, and $S_u = 58$ ksi. A safety factor of 5 on ultimate strength is applied to both primary membrane and primary bending stresses. Therefore, the maximum allowable working stress is 58/5 = 11.6 ksi.

For welds, assuming $S_u = 70$ ksi, the maximum allowable working stress is 14 ksi.

It is unusually conservative to limit membrane and bending stresses to the same allowable stress, particularly in sections which don't admit the possibility of buckling, but the consequence of failure of this component is substantial, and the added safety is deemed worth the additional weight.

Figure 3. Finite Element Model

Results

Fig. 4 shows the stress intensities in the lifting hook. The maximum stress is a concentration in the hook, occurring at the tangent between the cylindrical and vertical hook surfaces.

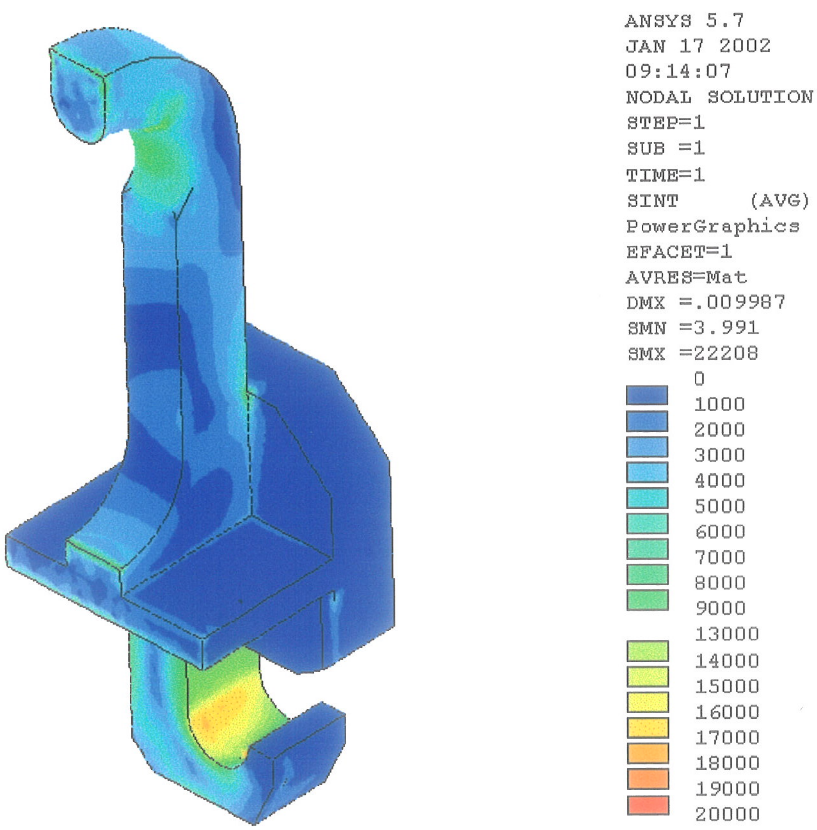

Figure 4. Stress Intensity in Lifting Hook

Fig. 5 shows a line A-B, which passes through the most highly stressed portion of the hook. The stress distribution is linearized by ANSYS, into primary membrane and bending stress intensity components, and graphed against the total stress in Fig. 6. Maximum linearized values are shown in Table I. The graph shows the stress concentration at point A. Peak stress (the difference between total stress and linearized stress) is 3.8 ksi.

Peak stresses are significant only for fatigue loading. The lifting hook will see at most a few hundred cycles during its service life; therefore, the peak stress can be ignored as a basis for design. The significant stresses are the primary membrane and bending stresses, and their sum.

The maximum membrane plus bending stress intensity is 11.48 ksi, which is below the allowable maximum stress of 11.6 ksi.

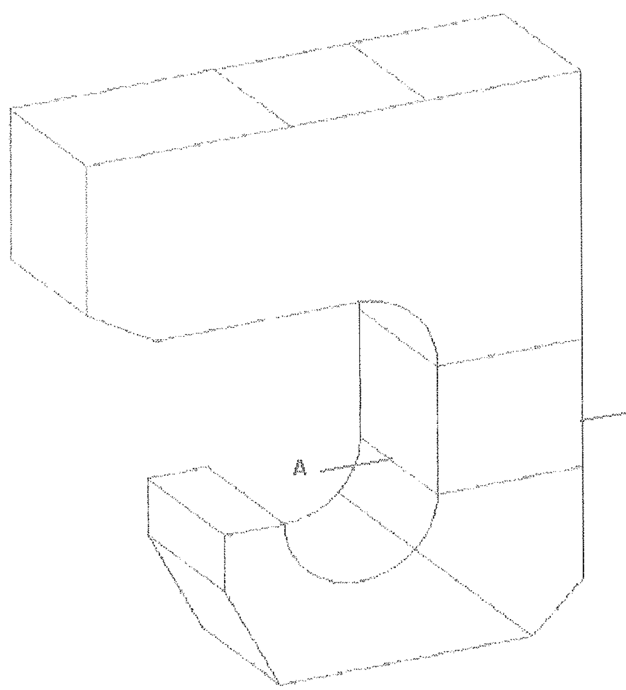

Figure 5. Section for Stress Evaluation

Figure 6. Stresses Along Line A-B (see Figure 5)

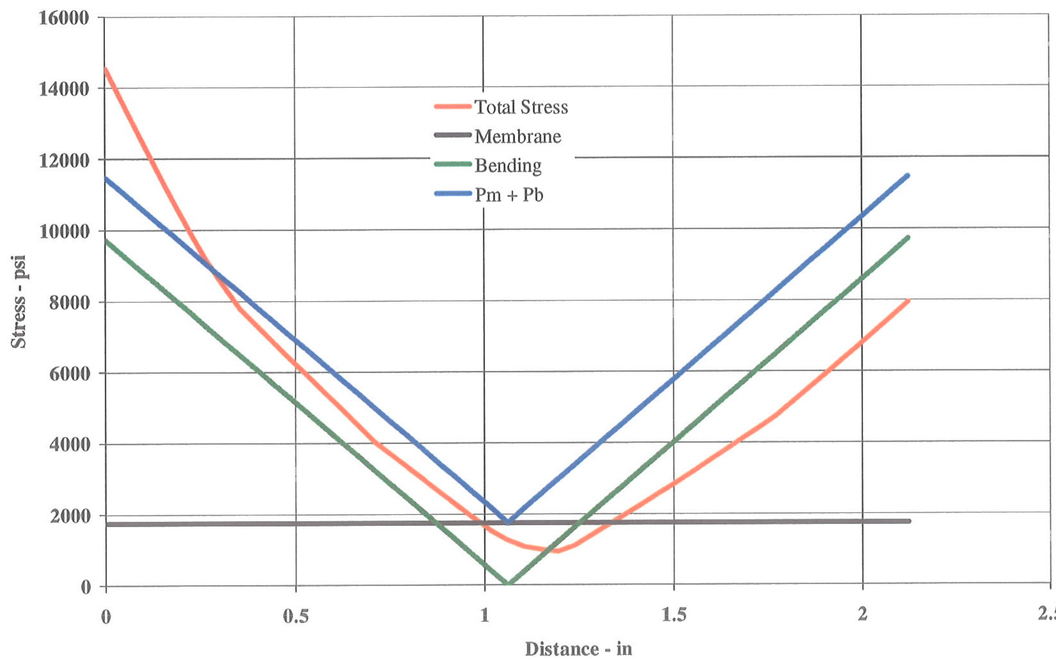

Table I. Linearized Stresses Across Line A-B

Section Line	Pm Primary Membrane (psi)	Pb Primary Bending (psi)	Pm + Pb (psi)
A-B	1763	9720	11480

Weld Analysis

Weld between Plates and Crane Hook

The piece which engages the crane hook is attached to the two lower hooks with ½ in fillet welds. A 1 in thick plate is also welded to this assembly. The weld is shown schematically in Fig. 6.

The section properties of the weld are shown in Table II, assuming a weld leg of 0.707x0.5 in = 0.353 in. The moment applied to this weld group is equal to the weight carried by one hook (10000 lbs) times the offset of the weight from the weld plane (1.125 in). Therefore,

Total moment = 11250 in-lbs
Maximum distance to outer fiber from centroid = c = 4.57 in
Moment of inertia of weld group = 58.32 in^4
Bending stress on weld = Mc/I = 881 psi

The weld is also under a shear force of 10000 lbs. Therefore,

Total area for shear = 10.07 in^2
Shear stress on weld = 10000/10.07 = 993 psi

In both cases, the calculated stresses are well below the allowable stress for both weld metal and base metal in the joint.

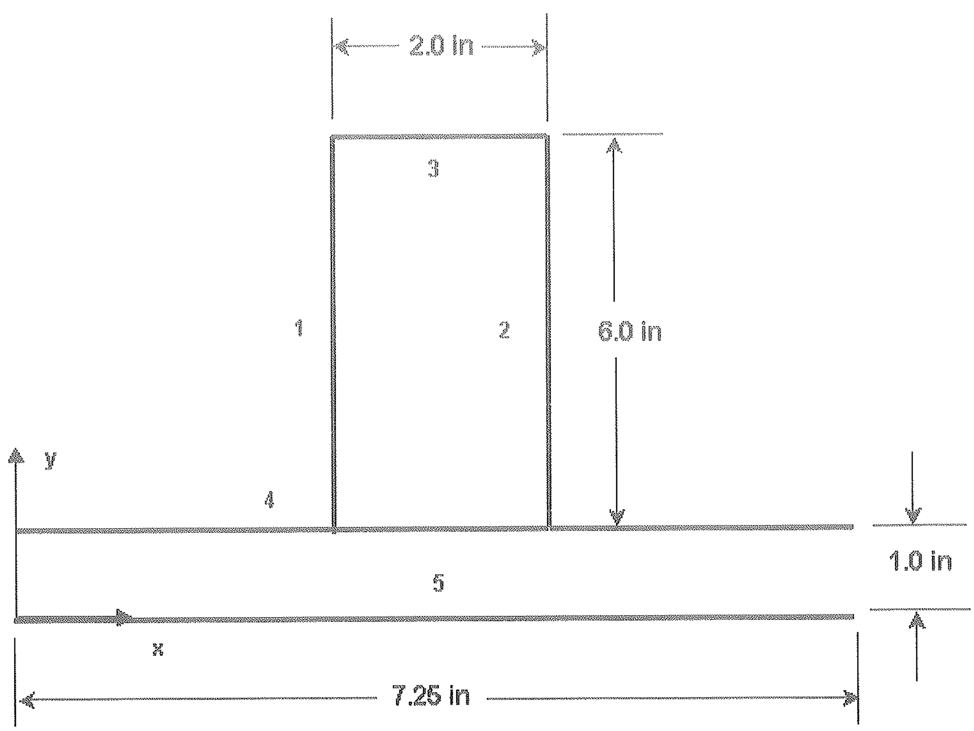

Figure 7. Weld Geometry

Table II. Weld Centroid and Moment of Inertia

Line	Length	Area	Ixx	y-Centroid	A*y	R	A*R²
1	6.00	2.12	6.36	4.00	8.48	1.57	5.23
2	6.00	2.12	6.36	4.00	8.48	1.57	5.23
3	2.00	1.06	0.00	7.00	4.95	4.57	14.77
4	7.25	2.56	0.00	1.00	2.56	-1.43	5.24
5	7.25	2.56	0.00	0.00	0.00	-2.43	15.13
Totals		10.07	12.73		24.48		45.60
Total I = 12.73 + 45.60 = 58.32 in^4							

Weld between Existing Hook Plates and ½ in Hook Plates

The weld between the existing hook plates and the additional ½ in plates is a 3/8 in groove weld, with a total length of about 30 inches. From the FEA, the total vertical force transmitted through the weld on one of the plates is 1887 lbs. For a stress area of 0.375 in^2/in, the nominal weld stress is 1887/(30*0.375) = 168 psi.

The preceding calculation assumes that the load is evenly distributed along the weld. Fig. 8 shows the nodal forces, which indicate that the forces are concentrated along the 1.125 and 0.50 inch long portions of weld indicated.

The total force on the 1.125 and 0.5 inch lengths of weld are 320 and 211 lbs, respectively. The corresponding stresses are 760 and 1020 psi, well below the allowable for the weld and base metals.

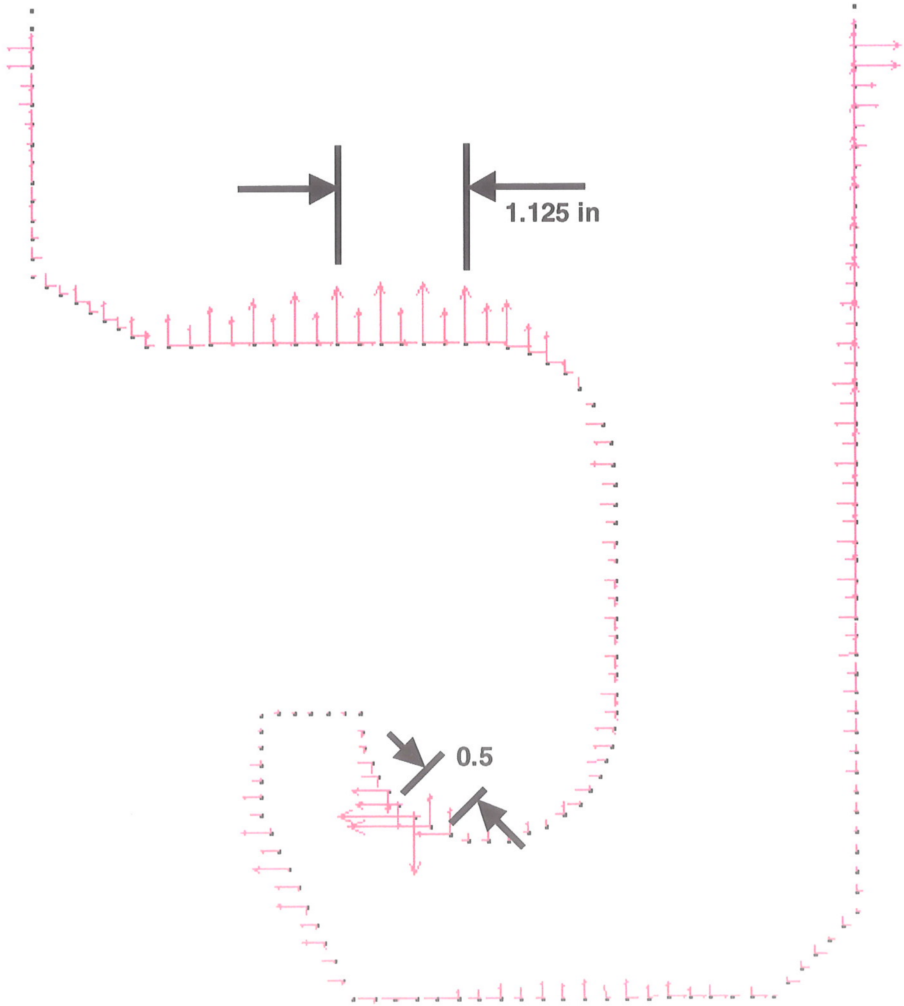

Figure 8. Nodal Force Distribution on Weld Between Original and Existing Plates

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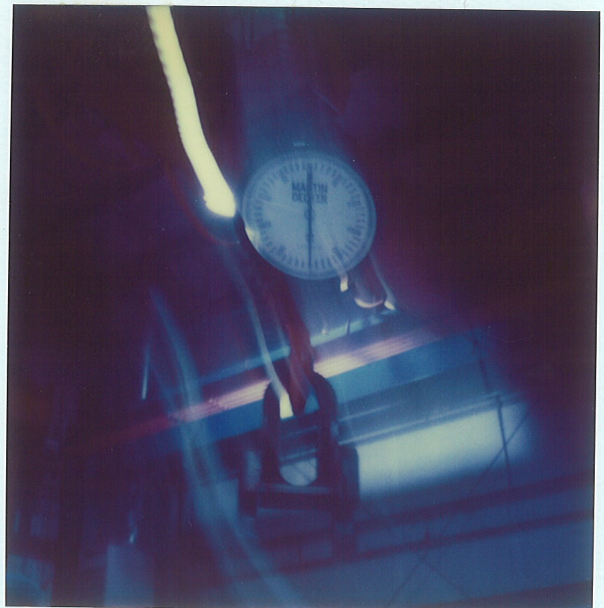
ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT	NAME	DATE	REVISION DATE
Lifting fixture #130 Load Test	Andy Stefanik	7/25/01	



Lifting fixture load test, Fixture #130, Scale reads 0 (zero) at no load. 7/25/01

Lifting fixture #130 load Test. 18,500 Lbs. July 25, 2001