Ernest Orlando Lawrence Berkeley National Laboratory - University of California

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Author: Russell Wells		Date 1/20/98	

PROGRAM-PROJECT-JOB

STAR Project

TITLE

SMT Lifting Beam

REV. A	**1/15/97**	Increased load test weight from 4000 to 4800 lbs. and increased rating to 2400 lbs. Made STAR Note 300 a Controlled STAR Note.

Jay Marx 2/5/98

Jay Marx, Project Director

Bill Edwards 2/10/98

Bill Edwards, Deputy Project Director

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Author Rusell Wells	Department Mechanical Engineering		Date 1/20/97	STAR WBS # 4.2.10	

Program
Solenoidal Tracker at RHIC

Sub program
Time Projection Chamber - Assembly and Test

Title
SMT Lifting Beam

Rev A: 1/15/98 Increased load test weight from 4000 to 4800 lbs. and increased rating to 2400 lbs. Made STAR Note 300 a Controlled STAR Note.

Person in Charge: Russell Wells Date 2/6/98
Russell Wells

Reviewed by: Frederick Angliss Date 2/4/98
Frederick Angliss

Introduction

A spreader lifting beam is needed for hoisting the STAR TPC Sector Mounting Tool (SMT) into position. The SMT with outer sector weighs 1027 lbs. and is 82 inches in length. The spreader consists of a simple 6061-T651 aluminum bar with holes at either end to accept small, 4.75 ton, shackles and a series of 9 holes placed symmetrically around the bars mid-span sized to accept a large shackle. The large shackle allows a direct connection to the B77A room 105 crane hook.

Rev A: To accomondate sector removal with the TPC in the magnet a 940 counter weight and assorted hardware has been added bringing the total weight of the assembly to 2100 lb.

Calculations

Beam dimensions of height, h, thickness, b, and length, l, (between load points) are given below.

$$b := 1.0 \cdot in \qquad h := 6 \cdot in \qquad l := 81.76 \cdot in$$

The spreader will be designed for a lifting capacity, P, of 2000 lbs. The material selected is 6061-T6 aluminum. The load from the SMT will be transferred to the beam via the two end points at a span of 81.8 inches. The beam in turn transmits the load to the crane hook via one or more of the lifting points near mid-span. The nine centrally located holes provide a means of balancing the load (leveling the beam).

$$P := 2400 \cdot lbf \qquad E := 10 \cdot 10^6 \cdot \frac{lbf}{in^2} \qquad \rho := .1 \cdot \frac{lbf}{in^3}$$

The spreader can be treated as a simply supported beam with a central point load. The maximum stress in the beam is due to bending.

Area moment of inertia $I := \frac{b \cdot h^3}{12}$ $I = 18 \circ in^4$

Bending moment $M := \frac{P \cdot l}{4}$ $M = 4.906 \cdot 10^4 \circ in \cdot lbf$

Distance to the extreme fiber $c := \frac{h}{2}$

Bending stress $\sigma := \frac{M \cdot c}{I}$ $\sigma = 8.176 \cdot 10^3 \circ \frac{lbf}{in^2}$ $\sigma = 5.637 \cdot 10^7 \circ Pa$

Maximum deflection $\delta := \frac{P \cdot l^3}{48 \cdot E \cdot I}$ $\delta = 0.152 \cdot in$ $\delta = 3.856 \cdot 10^{-3} \cdot m$

Safety Factor , on ultimate strength of 6061-T6

$\sigma_{ult} := 42000 \cdot \frac{lbf}{in^2}$ $SF := \frac{\sigma_{ult}}{\sigma}$ $SF = 5.137$ OK, SF> 5

Shear tear out, where a is the distance from edge of hole to edge of plate, where dH is the hole diameter and the distance from center to edge is 2.5 and 1.5 inches for the large and small holes, respectively.

Large hole to edge $d_H := 1.44$ $a := 2.50 \cdot in - \frac{d_H}{2} \cdot in$

$\tau := \frac{P}{2 \cdot a \cdot b}$ $\tau = 674.157 \cdot \frac{lbf}{in^2}$

Small hole to edge $d_H := 0.94$ $a := 1.50 \cdot in - \frac{d_H}{2} \cdot in$

$\tau := \frac{P}{2 \cdot a \cdot b}$ $\tau = 1.165 \cdot 10^3 \cdot \frac{lbf}{in^2}$

Bearing failure, where d is the diameter of the lifting shackle pin.

Large shackle $d := 1.37 \cdot in$

$\sigma_b := \frac{P}{d \cdot b}$ $\sigma_b = 1.752 \cdot 10^3 \cdot \frac{lbf}{in^2}$

Small shackles $d := .88 \cdot in$

$\sigma_b := \frac{\frac{P}{2}}{d \cdot b}$ $\sigma_b = 1.752 \cdot 10^3 \cdot \frac{lbf}{in^2}$

Weight of spreader beam, $Wt := b \cdot h \cdot l \cdot \rho$ $Wt = 49.056 \cdot lbf$

Elastic Stability

An approximation of the elastic stability of the lifting beam can be made by application of the formula for a straight uniform beam of narrow rectangular section under a center load applied at a point a distance of "a" below (negative value) the centroid of the section. The ends of the beam are simply supported but restrained from twisting. In the case of the lifting beam the end load tends to hold the beam vertical and resist twisting to some degree. From Roark and Young 6th Ed. Table 34 No. 12.

Large hole to edge $d_H := 1.44$ $\quad a := \left(2.50 \cdot in - \frac{d_H}{2} \cdot in\right) - 3.0 \cdot in$

Poisson's ratio $\quad \nu := .34$

Shear Modulus $\quad G := \frac{E}{2 \cdot (1 + \nu)}$

Buckling Load:

$$P_b := \frac{2.82 \cdot b^3 \cdot h \cdot \sqrt{\left(1 - 0.63 \cdot \frac{b}{h}\right) \cdot E \cdot G}}{l^2} \cdot \left[1 - \frac{1.74 \cdot a}{l} \cdot \sqrt{\frac{E}{G \cdot \left(1 - .63 \cdot \frac{b}{h}\right)}}\right]$$

$P_b = 1.528 \cdot 10^4 \cdot lbf$

Nominal safety factor on buckling ;

$SF_b := \frac{P_b}{P}$

$SF_b = 6.369$ $\quad$ OK

Side loads

If the load is not directly beneath the crane hook a transverse, or side, load is imposed on the lifting beam. If the transverse load is great enough to substantially bend the beam out of plane twisting occurs and the beam can fail. To prevent bending due to an off vertical lift and/or play between the shackle and beam, aluminum channel has been bolted to either side of the main bar. The channels are sized to resist the side loads generated by up to a 15 degree misalignment. To allow for free movement of the top shackle, the flanges of the channel at the top of the beam have been milled down. The calculation of the area moment of inertia reflects this detail.

Approximate flange thickness (tapered) $t_f := .250 \cdot in$

Web thickness $t_w := .314 \cdot in$

Width of channel web $h_i := h - 2 \cdot t_f$

Height of channel flange, milled flange $b_f := 2 \cdot in$ $b_{fm} := .53 \cdot in$

Transverse thickness of assembly at web $b_w := b + t_w$

Transverse thickness at assem. at milled flange $b_{wm} := b + 2 \cdot b_{fm}$

Transverse thickness of assembly at flange $b_o := b + 2 \cdot b_f$

Area moment of inertia for bending in the transverse direction

$$I_{xeq} := \frac{h_i \cdot b_w^3}{12} + \frac{t_f \cdot b_o^3}{12} + \frac{t_f \cdot b_{wm}^3}{12}$$

$$I_{xeq} = 3.826 \cdot in^4$$

Assuming the load is within 15 degrees of vertical, the side load is:

Transverse load $P_x := P \cdot \sin\left(\frac{\pi}{12}\right)$ $P_x = 621.166 \cdot lbf$

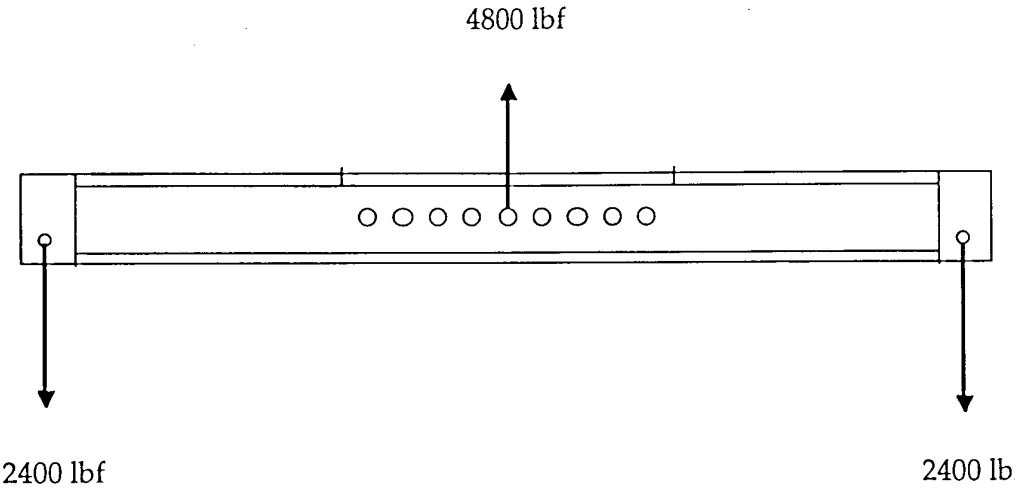
Horizontal deflection $\delta_x := \frac{P_x \cdot l^3}{48 \cdot E \cdot I_{xeq}}$ $\delta_x = 0.185 \cdot in$

Bending Stress $\sigma_x := \frac{P_x \cdot \frac{l}{4} \cdot \frac{b_o}{2}}{I_{xeq}}$ $\sigma_x = 8.296 \cdot 10^3 \cdot \frac{lbf}{in^2}$

Safety Factor $SF := \frac{\sigma_{ult}}{\sigma_x}$ $SF = 5.063$ OK

Proof Load Test.

The lifting (spreader) beam load test consists of anchoring the beam to a weight of at least 5000 lbs. via the lifting points at either end and applying a 4800 vertical force at the center lift point or attaching two weights of 2400 lb each to either end.



Remarks:

Test Performed by: Dwight A.P.S. Date: 1/21/98

Test Witnessed by: Jan Ulf Date: 1-21-98

PE #_____

UP-GRADE OF SPR-009-77A

Oakland * Santa Clara * Sacramento

Testing Engineers, Incorporated

NDT DEPARTMENT

2811 Adeline Street * Oakland, CA 94623 * 510-835-3142

LABORATORY NO. Y0636 DATE 06/25/97
CLIENT U.C. LAWRENCE BERKELEY LAB
ADDRESS No. 1 Cyclotron Road
Berkeley, CA 94720
JOB LOCATION NDT Lab - Oakland
CLIENT P.O. NO.
JOB NO.
ITEM DESC. STRONG BACK
PLAN OR DRAWING NO.
EXAMINATION: PARTIAL SEE BELOW 100%

LIQUID PENETRANT INSPECTION REPORT

NDE Standard ASTM E165

Acceptance Standard No Cracks

Procedure No. SPP-PT-400 (Rev. 3)

Stage of Fab.: In Process ☐ Final ☒

Type of Work: New ☒ Repair ☐

Heat Treatment: Before Inspection ☒ After Inspection ☐

Surface Condition: Machined

Material: Type Aluminum Temp. Ambient

Other NDT Required: Yes ☐ No ☒

Type:

PENETRANT Visible ☒ Fluorescent ☐
Solvent Removable ☒
Post-Emulsified ☐
Water Washable ☐

Mfgr. Magnaflux Corp NO. SKL-SP

Batch No. 92K08K Dwell Time 20 min

CLEANER
Mfgr. Magnaflux Corp. NO. SKC-NF

Batch No. 95M13K

EMULSIFIER
Mfgr. N/A NO.

Batch No. Dwell Time

DEVELOPER Dry ☐ Wet ☐ Non-Aqueous ☒

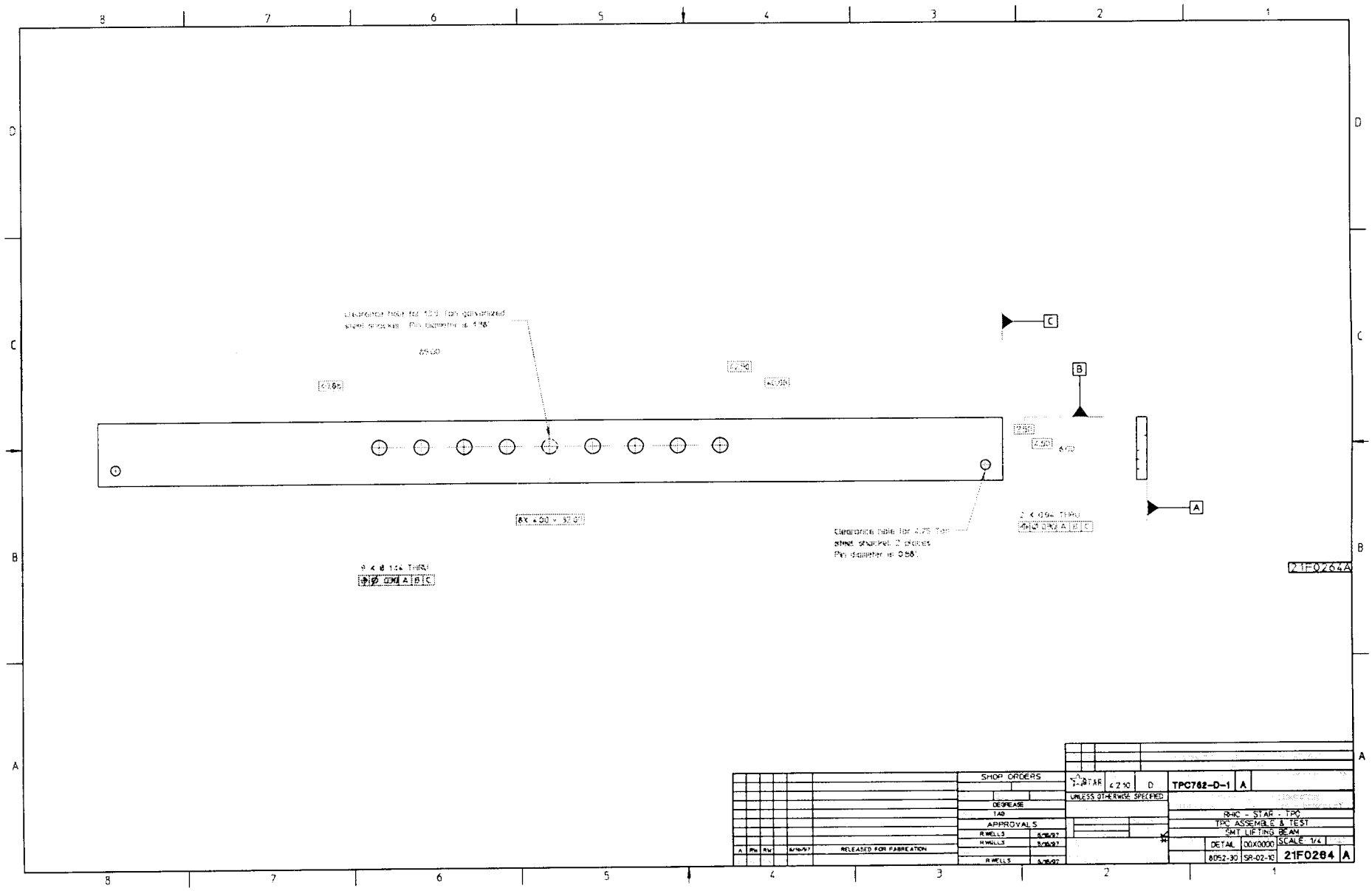
Mfgr. Magnaflux Corp. NO. SKD-S2

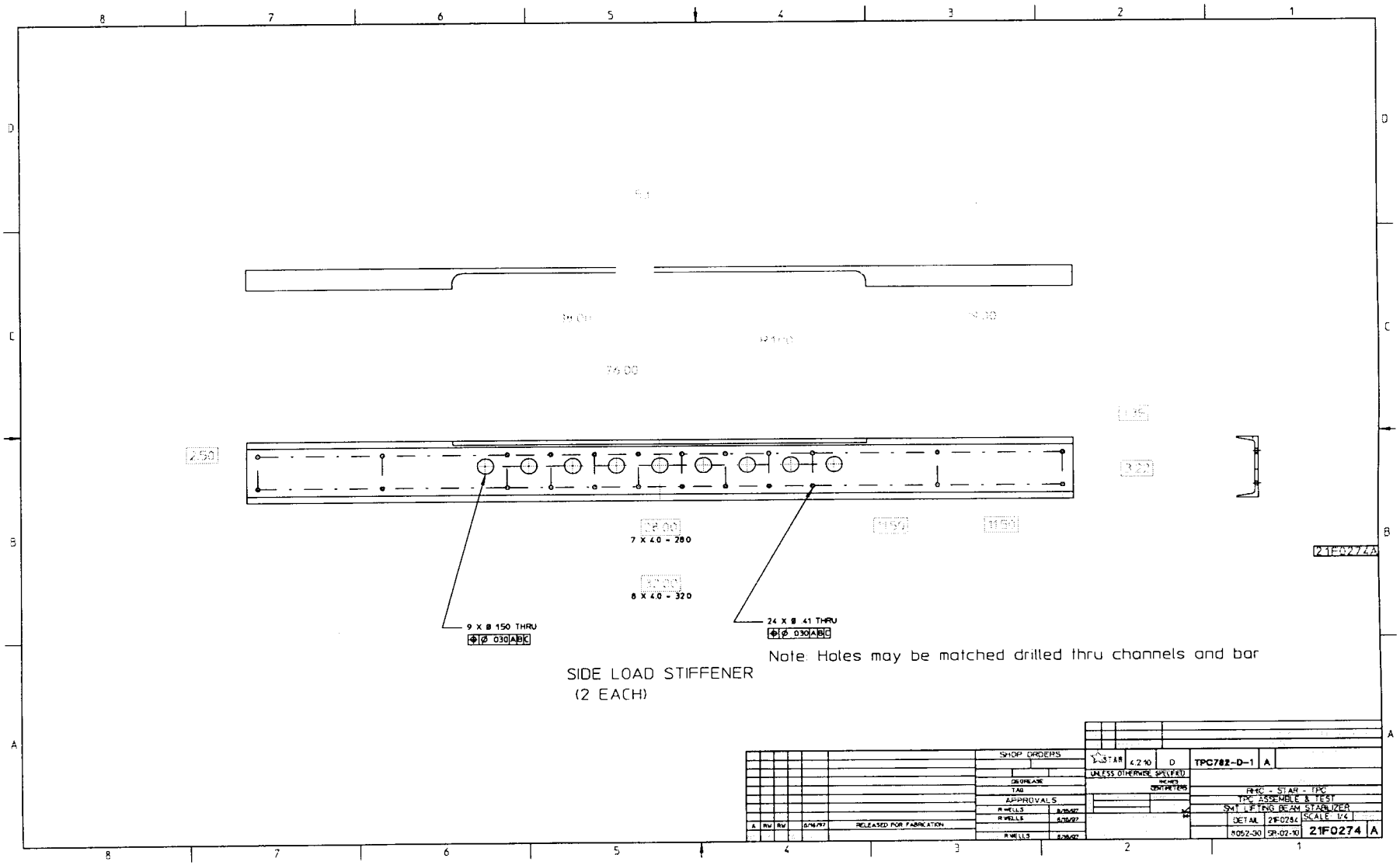
Batch No. 96C01K Dwell Time 10 min

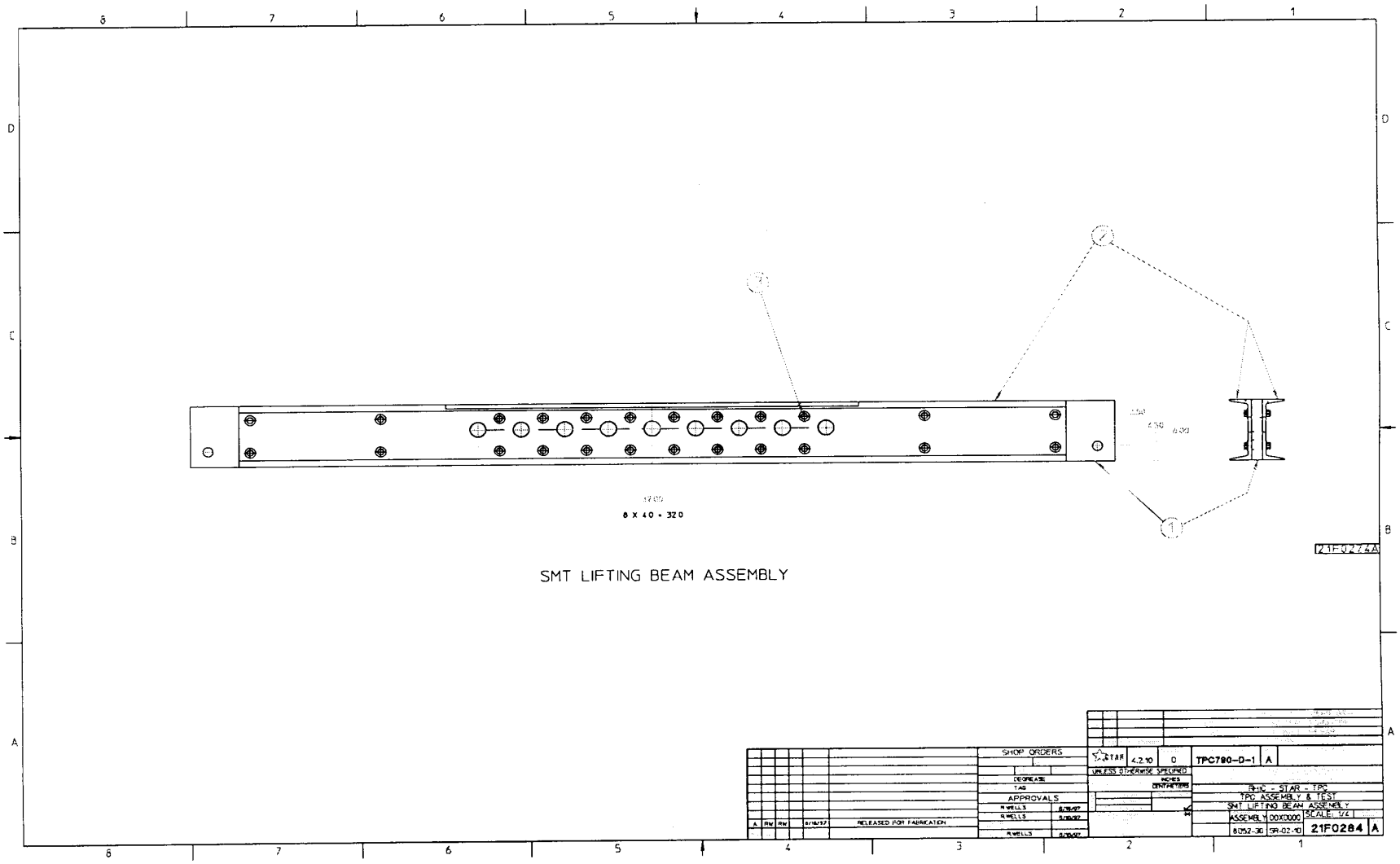
PC # or SN #		ACC	REJ	REMARKS
STRONG BACK		1	0	Performed liquid penetrant inspection on
Marked: 21F0284A (1 Total)				three (3) designated holes, specifically the 1" diameter holes at each end and the 1-1/2" diameter hole at the very center. The inspection was performed on the I.D. surface of these holes and on the plate material surrounding them. No rejectable indications were detected.

TEST WITNESSED BY:

Technician John W. Lowe Level: II
Asst. Tech. Level:
Certification Expiration Date: 5/98
Report Reviewed by: Peter K. Palko, NDT Supervisor


21F0264A
SHOP ORDERS
DEGREASE
TAB
APPROVALS
R.WELLS
RELEASED FOR FABRICATION
UNLESS OTHERWISE SPECIFIED
TPC762-D-1
A
RHIC - STAR - TPC
TPC ASSEMBLE & TEST
SMT LIFTING BEAM
DETAIL
00X0000
SCALE 1/4
21F0284
A



7 X 4.0 = 280
8 X 4.0 = 320
9 X Ø 150 THRU
24 X Ø .41 THRU
Note: Holes may be matched drilled thru channels and bar
SIDE LOAD STIFFENER
(2 EACH)
21F0274A
SHOP ORDERS
APPROVALS
RELEASED FOR FABRICATION
UNLESS OTHERWISE SPECIFIED
TPC782-D-1
RHIC - STAR - TPC
TPC ASSEMBLE & TEST
SMT LIFTING BEAM STABILIZER
DETAIL 21F0284
SCALE 1/4
21F0274

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