Fermilab

TM-909
2220.300

# A. EPOXIED LAMINATED SHEET STEEL CORES FOR LARGE CONVENTIONAL MAGNETS

# B. INSULATION OF LARGE COILS WITH A POLYESTER FILM/SYNTHETIC FILAMENT

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August 1979

## ABSTRACT

As a means of economizing the building of large picture frame magnets, especially where the long dimension in the X direction would require machining to provide adequate contact, the 70 ton Akhenaten and Beketaten were built with epoxy laminated steel sheet cores. A polyester film/synthetic filament with no potting of the coils was also used as an economy measure. They can be made and assembled into a finished magnet with a minimum of problems. Described below is a procedure for the handling of the sheet metal. The relative economic savings are presented.

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## INTRODUCTION

The laminated iron core consists of a 25 ton top and 25 ton bottom section and two side core pieces of 5 ton each. The side core pieces measuring each 32" high x 40" long x 30" wide were not laminated. A 25 ton section consists of five laminated pieces (three 8" thick, and two 6" thick) also two 2" thick end plates. They are 13'-4" long and 28" wide and are built up with low carbon 14 gauge steel sheets weighing about 95 lbs each. At the ends there is added to the 6" lamination the 2" steel plate to contain the magnetic force that tends to peel the laminations. See attached Fig. 1.

## EQUIPMENT AND MATERIALS

### 1. Lamination Bases

The laminating was done on 8" thick iron bases obtained from our scrap iron storage. On the bases were mounted blancher ground 1" steel plates, surveyed and leveled. There were three plates on each platform, separated by six inches where lifting straps could be placed for lifting and moving the finished laminations.

The steel posts were placed, one at the middle of the 28" end and the other two on the 13'-4" side about 14" from each end. The posts form a stacking fixture for positioning the steel sheets and the two posts placed 14" from the ends produce a smoother surface where the side pieces are in contact for magnet assembly. An irregularity in the long dimension edge is caused by the camber variation in the steel.

2. Lifting Bar

An aluminum hollow bar with vacuum cups and counterbalanced from an overhead gantry was used to lift and position the sheet steel.

3. Epoxy

A two system epoxy with a pot life of several hours was mixed and poured into a roller paint tray. The epoxy was specially formulated to be fluid enough to be easily applied with large handled paint rollers and have a 24 hour partial cure.

4. Steel Sheets

The steel sheets were a commercial low carbon steel unoiled with a length tolerance of 13'-4", -0", +1". Most sheets from the same batch or runs from the steel supplier were of the same length. The sheets were not resquared. The camber varied up to 1/2" causing some irregularity in the 13'-4" side surface. Cold rolled steel with flat surfaces from reliable vendors should be specified plus properly packaged sheets for handling.

## LAMINATION PROCEDURE

A three man team could easily assemble two 5 ton cores per day including removing the finished cores the next day. Using the vacuum lifting device the steel sheets were alternately positioned and applied with epoxy. The resulting epoxy was approximately 0.0005 to 0.001" thick.

After building up to our 8" thickness, side holding devices were positioned at the free sides to prevent sliding of the sheets. Another

8" slab of steel about the size of the sheet was laid on top to compress the epoxy. The sheets were clamped together at the edges where required. The next day, the core was a firm structural member that could easily be moved with slings and cranes. The first cores were then used as weights to compress the remaining laminations.

## MAGNET ASSEMBLY

Five bottom piece cores were easily assembled with slings and crane and compressed together between 2" thick x 13'-4" x 28" end plates to form a core 40" long by 13'-4" wide x 28" high. A top plate, 1/2" x 13'-4" x 40", was welded onto the 2" end plates to contain the lamination, plus a 3" x 1/4" x 40" bar was welded onto each 40" side. The 5 ton side pieces were placed on the bottom core and tack welded into position. The coils were then placed into the magnet.

For the top core the 2" thick end plates were welded onto another 1/2" plate to form a large 36" wide trough on the top of the magnet into which the laminated core pieces were lowered into with lifting lugs. Again, side bars were welded onto the sides.

## ECONOMICS

### Laminated Sheet Steel vs. Destressed Steel

Cost per 50 tons of steel for top and bottom of core:

A. Sheet Steel

| | | |
|---|---|---|
| 1. | Sheet steel cost at $405/ton | $20,250 |
| 2. | Manhours @ $20/hour | 2,400 |
| 3. | Epoxy cost | 340 |
| 4. | Fixture cost | 2,000 |
| | | $25,990 |

B. Destressed Steel

If Bekehaten had been made from destressed steel, it was estimated to cost as follows: With magnets that have a long surface (13'-4" in this case), it is difficult to obtain flat surfaced destressed steel, especially at the time of the construction, so additional machining is required. An extremely low price of 10% of normal machining costs was used in the estimate for facing this surface so the possible savings could be much higher.

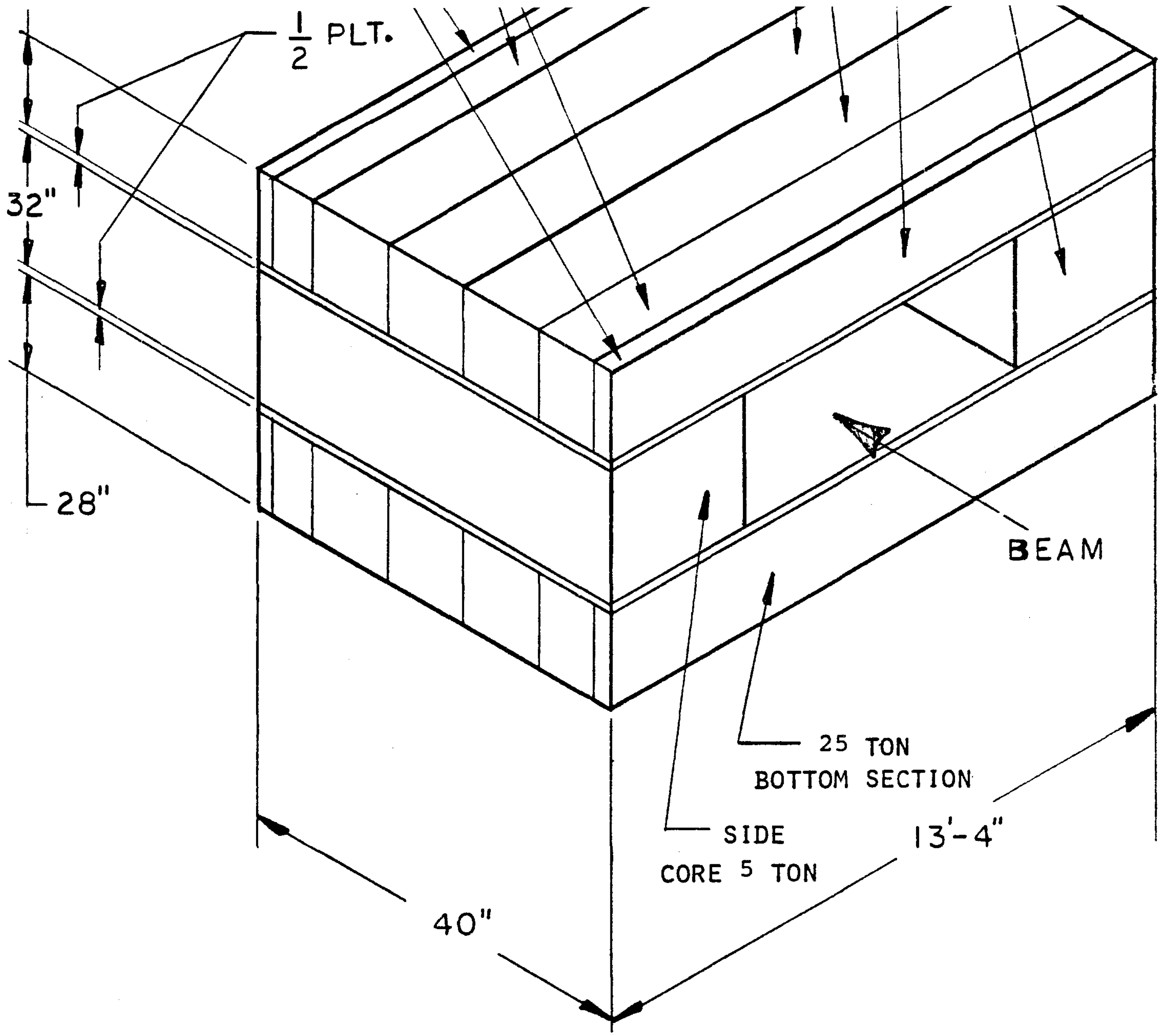
| | | |
|---|---|---|
| 1. | Material 50 tons at $200/tons | $10,000 |
| 2. | Flame cutting at railhead $26/ton | 1,300 |
| 3. | Transportation 50¢/100 wt (two ways) | 1,000 |
| 4. | Riggers 1/2 day | 500 |
| 5. | Machining edges ($165/sq ft x 86 sq ft) | 14,190 |
| 6. | Estimate of machining the 13'-4" ft x 28" irregular sides to reduce air gaps 10% of $165/ft$^2$ x 620 sq ft. | 10,230 |
| | | $37,220 |

It was elected to proceed with the laminated steel because of the predictable cost while the unknown machining of the destressed steel could have increased the price to provide more than the $11,000 savings.

POLYESTER FILM/SYNTHETIC FILAMENT REINFORCED INSULATED SYSTEM

The eight copper coils (each 7000 lb) made from 1.25" x 0.83" conductor were insulated with a 3M insulating tape product 1312 which requires no potting. It is a polyester film/synthetic filament reinforced. The tape which is 8 mil thick was half lapped on the conductor for a 0.016" thick insulation to provide a 0.032" thickness between conductors. The coil was half lapped twice for a 0.032" thick overwrap.

A possible difficulty with this type of insulation system is that there is a less rigid structural system, but this could be an advantage for large coils when the thermal expansion forces tend to crack potted coils. The 1312 tape is currently used successfully for other magnets at the laboratory. For large coils an egg crating system with G-10 could make a more protective system from foreign materials that are more adept to get into the large area required for assemblying large coils. Cost wise we estimated a savings of $20,000 when comparing this system with potted coils. This is based on comparing our costs with an estimated cost of $3.00/lb for potted coils. Another advantage is the elimination of one manufacturing step, that is the potting of the coils.



$\frac{1}{2}$ PLT.
32"
28"
BEAM
25 TON
BOTTOM SECTION
SIDE
CORE 5 TON
13'-4"
40"


FIGURE 1

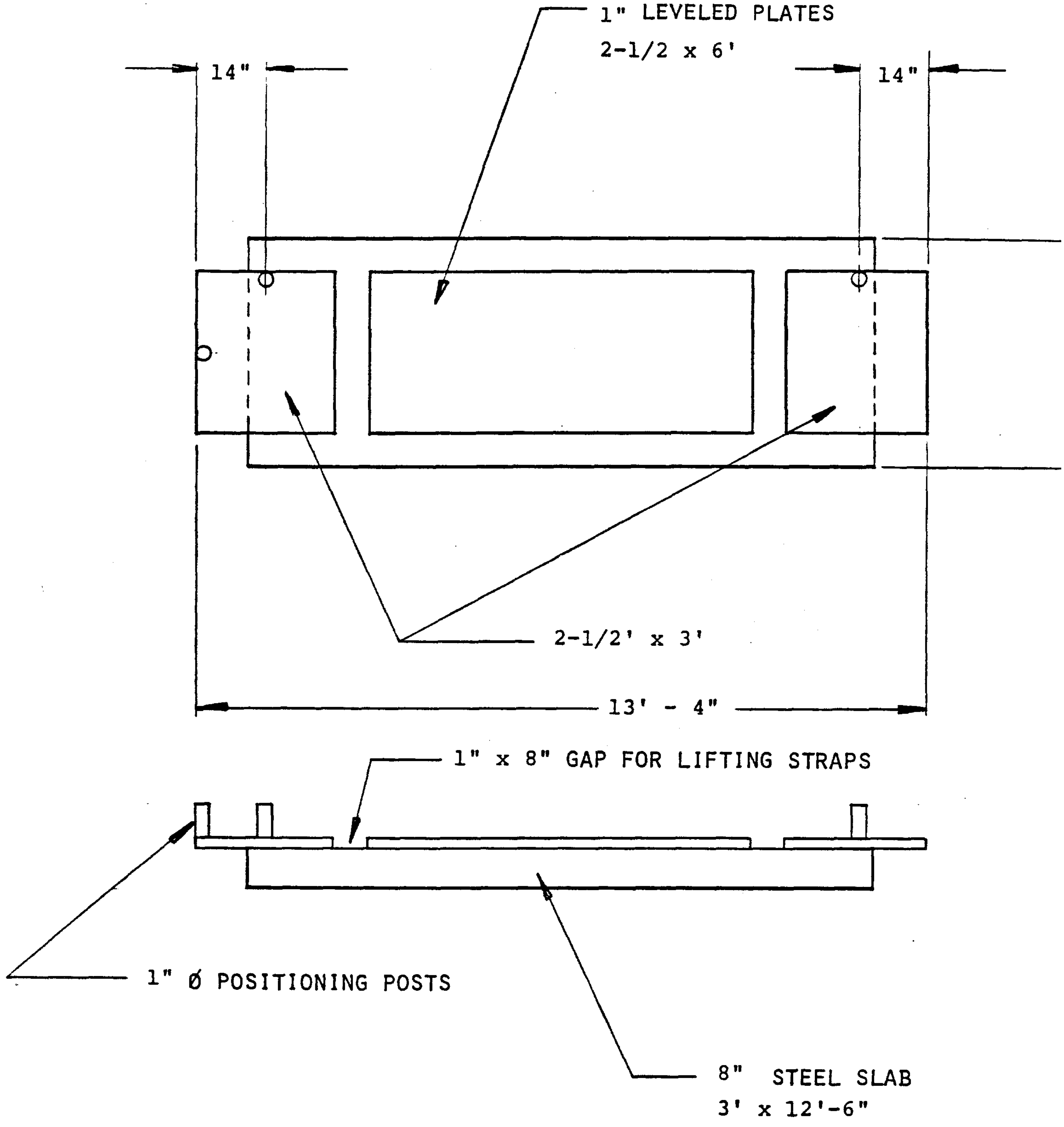

1" LEVELED PLATES
2-1/2 x 6'
14"
14"
2-1/2' x 3'
13' - 4"
1" x 8" GAP FOR LIFTING STRAPS
1" Ø POSITIONING POSTS
8" STEEL SLAB
3' x 12'-6"

FIGURE 2