TN-9 3-324

Bending Machine/Press for GEM Electromagnetic Calorimeter

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1.0 Introduction:

The absorber plates and signal electrode plates for both the barrel and end cap are both formed into the accordion shape with a common bending machine. A layout of this machine is shown in figure 1.0. This machine has moving dies which translate on low friction rollers as the part is bent. The machine must be driven by a large hydraulic press to generate the force necessary to form the shape prior to final forming and curing in the mold.

Prior to Bending, the absorber plates are pre-heated to soften the G10 to preclude tearing of the fabric at the corners. The signal electrode does not require pre-heating.

The plates are placed into the bending machine and the dies are aligned using a semi-automatic alignment system. The alignment prior to bending is critical to the shape of the final part. The clamping of the ends of the plate occurs automatically once load is applied. The part is then bent and removed from the machine on storage racks. They are then shipped to the location of the mold press for molding and curing.

2.1 Structure

The structure for the bending machine shall be configured as shown in figure 2.1. It consists of an array of solid rectangular steel beams, 2.5in x 5.0in on the bottom, and 12 inch Standard "I" beams on the top. This large steel strucute is necessary to keep maximum deflections below .001 inches. Three of the lower beams are extended out so as to allow the lower dies to be rolled far enough out to install the flat sheet prior to bending. Two of the upper and lower steel beams are extended towards the back of the bending machine to serve as the arms of the pivoting device, necessary to provide the projective angles. (See section 2.5). The Upper I beams pivot and move downward towards the stationary lower set of I beams through the use of a large press. (See section 3.0) The inner surfaces of the beams have a hardened tool steel palte, 0.20 inches thick, bonded to them. This is to provide a hardened way for the rollers, which would otherwise dig into the softer structural steel.

Fig 1.0 **BENDING MACHINE DIE CONFIGURATION**

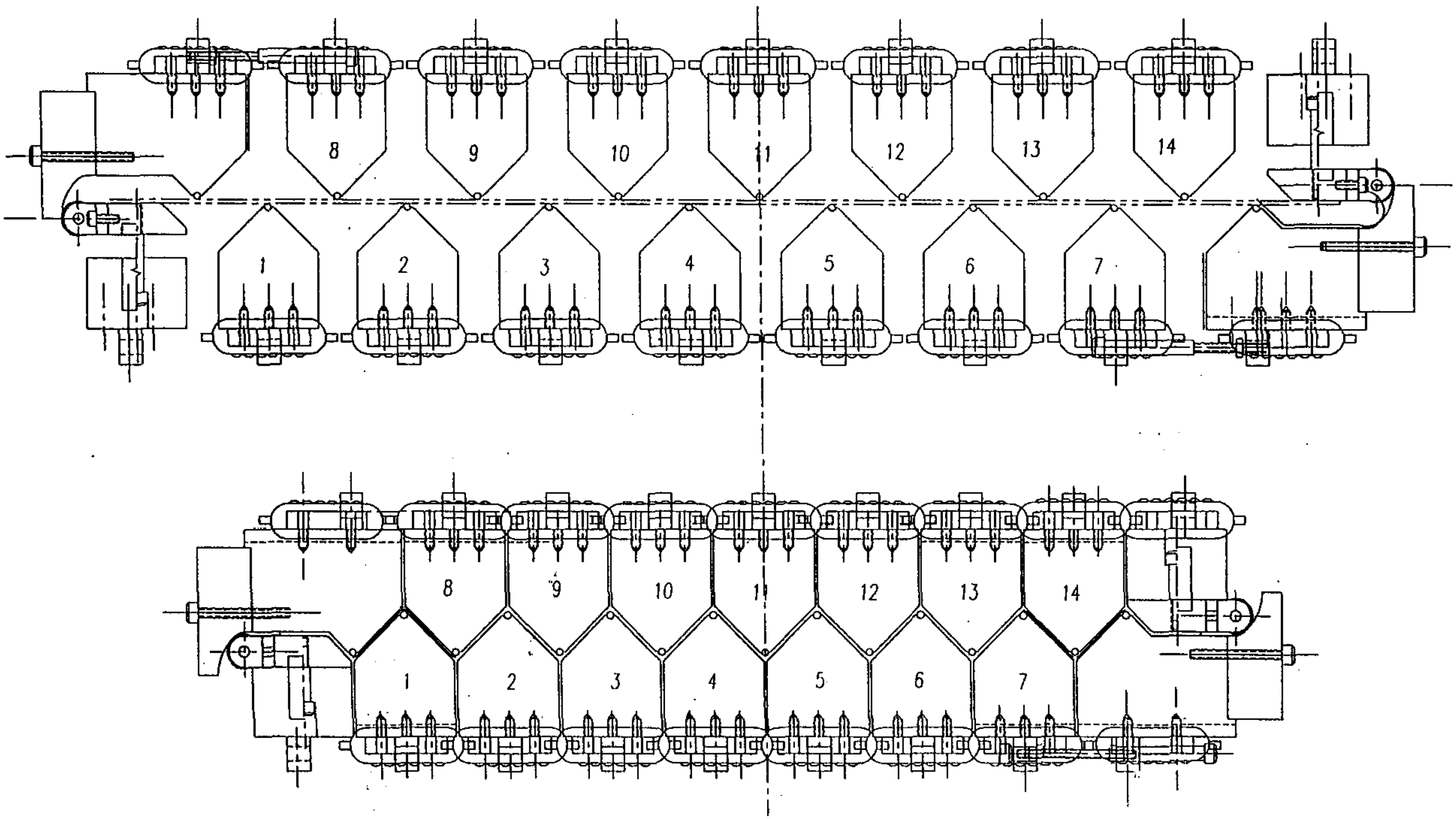
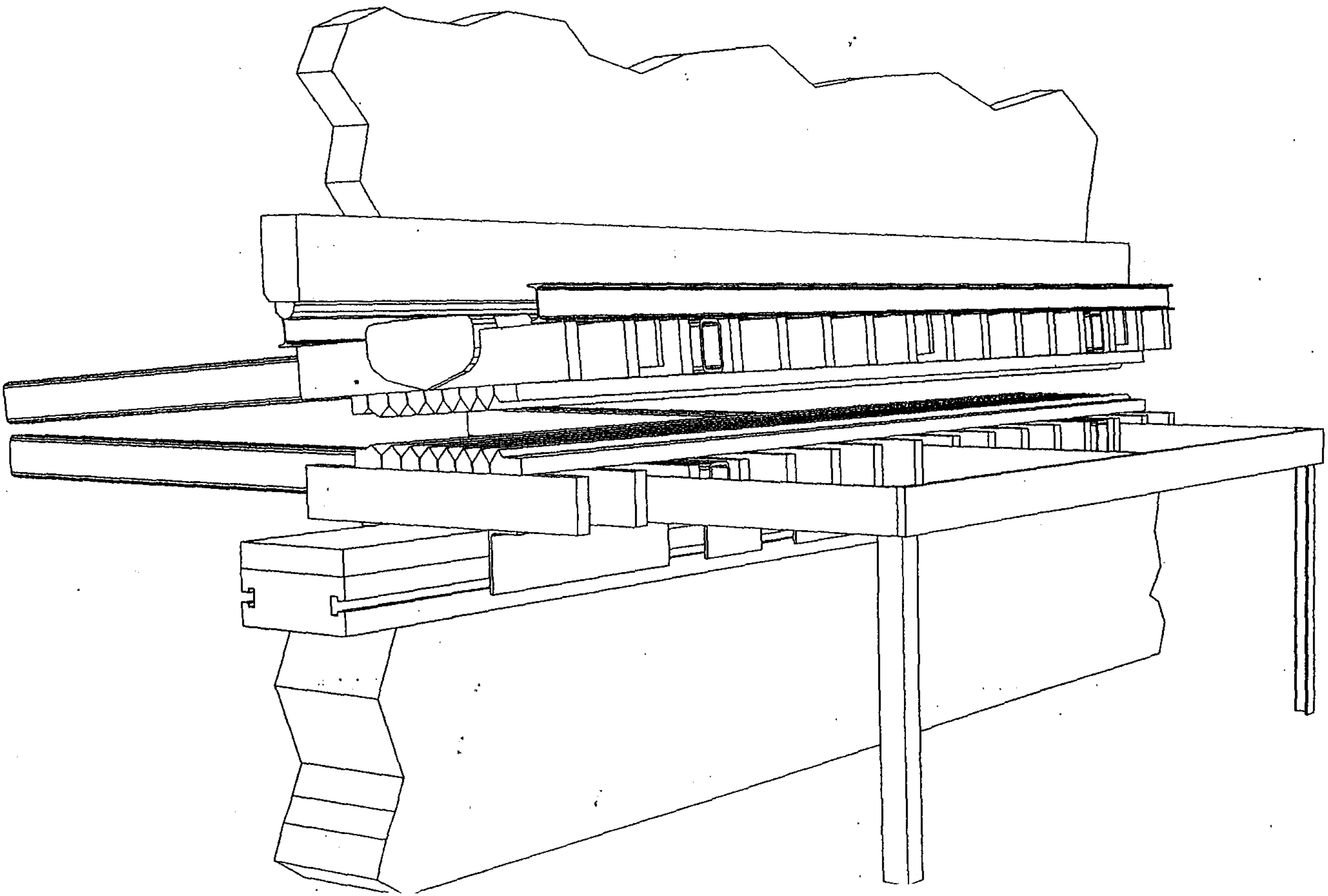


Fig 2.1 BNL/GRUMMAN BENDING MACHINE/PRESS



This structure was designed to fit into either the Grumman Aerospace 1000 ton press to be used for producing the prototype, or the Shanghai, China press to be used for producing the full set of plates for GEM.

2.2 Rollers:

High load roller bearing cars, figure 2.2, are mounted to the underside of the dies at 17 equally spaced positions along each die. This spacing is 10.0 inches, and keeps deflection between the support beams below .001 inches. These roller cars are rated at 3860 kg force statically and 2660 kg force dynamically. The dies and roller cars move on hardened steel ways mounted to the steel beams as described in section 2.1.

2.3 Dies

The bending machine dies are the heart of the bending machine. A typical die is shown in figure 2.3, Each die is approximately 4000mm long, yet only 40mm to 90 mm wide, and 60mm tall. Each die is numerically milled to an angle and size which corresponds to the plate geometry at room temperature. (Reference document TN-903-323).

The following tolerances are used for all the dies:

Flatness/Parallelness	.05mm for the entire length
Angular Tolerance	+0.00/-0.50 degrees
Height	+/- 0.03 mm
All Other Dimensions	+/- 0.25mm

Note on the angualr tolerance, that no larger angle than that specified is allowed.. This is because it is better to overbend than to under bend since the part tends to spring back slightly upon removal.

The material was carefully chosen so that a sufficient hardness could be obtained without post heat treatment, which would distort such a high aspect ratio part. However, the material had to also be soft enough for free machining. After much research, the following material was selected:

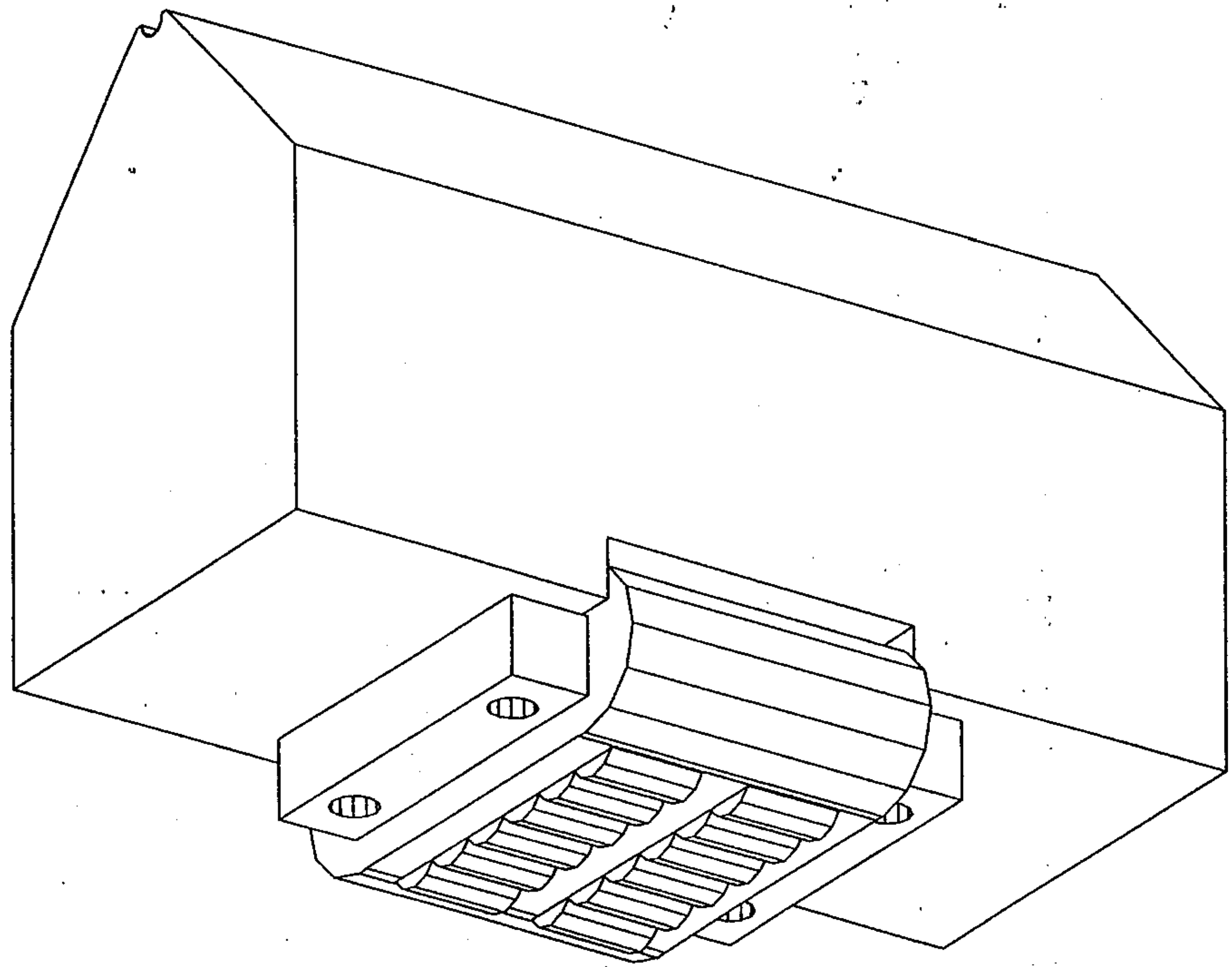
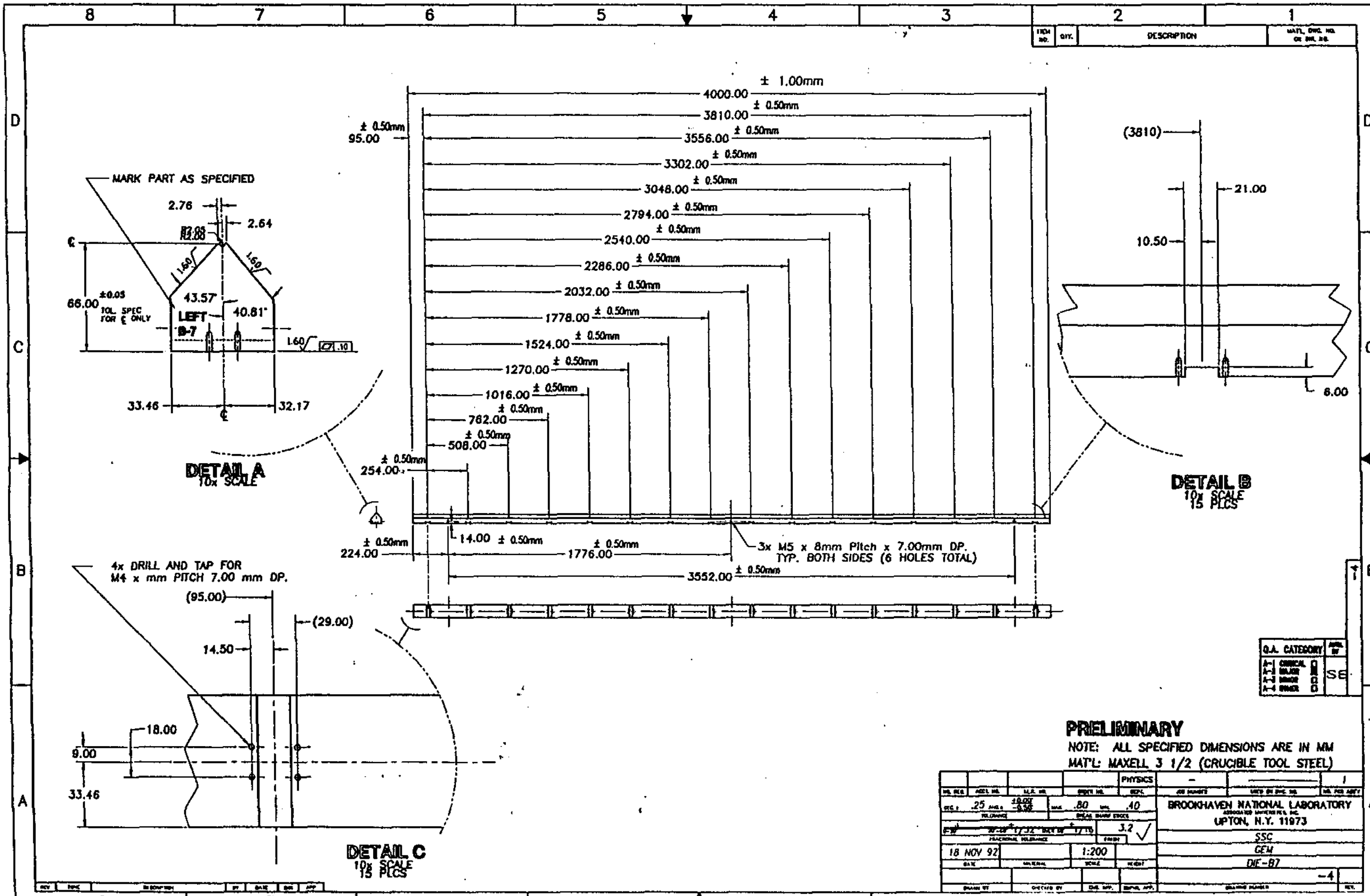


Fig 2.2 **DIE ROLLER ASSEMBLY**

Fig 2.3 **TYPICAL BENDING MACHINE DIE**



Material	Supplier	Composition	Properties
Maxel 3 1/2	Crucible	AISI 4150 derivative	Free machining tool steel alloy supplied with a hardness of 30 Rockwell "C".

The die tips are insulated with a high strength non-metallic rod to prevent heat loss into the steel die and also provide the necessary radii on each bend. A simple thermal model was developed to analyze the effect of this insulating rod, as shown in figure 2.3a. The results of this analysis are shown in figure 2.3b The part will cool quickly once the sides come in contact with the steel dies.

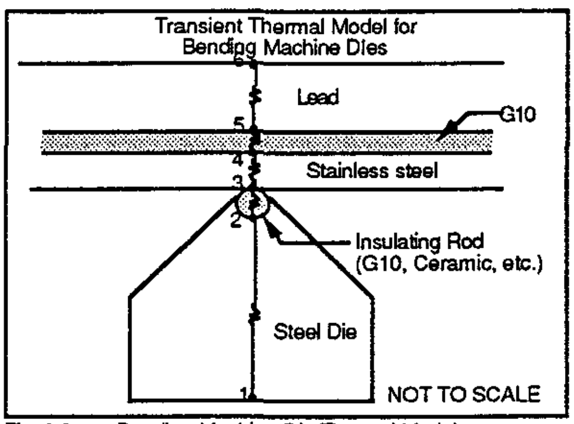


Fig 2.3a Bending Machine Die Thermal Model

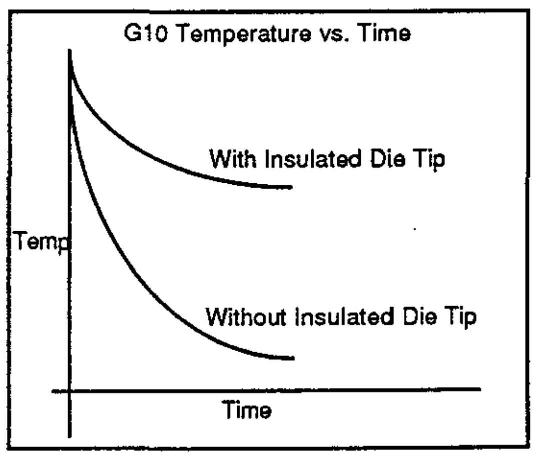


Fig 2.3b Thermal Transient of Absorber Plate

2.4 Alignment System:

The alignment system was designed to allow quick insertion and bending of the plates. Each die has a set of precision ground stop blocks mounted on their undersides. Each block has a set of shoulder bolts which, when adjusted, cuase the dies to stop in a pre-determined postion. See figure 2.4. This position can be initially determined with measurements or a template ("comb"). Once pre-aligned, and the adjustment bolts adjusted and locked into position with a set screw, the dies will automatically stop in the correct position when pulled apart, which can be done manually by hand or automatically with a counterweight.

The plate is then placed into the machine, with the need to only align one edge against a stop (To locate the massless gap on the accordion plates, or electrode locations for the Signal electrode plates).

2.5 Pivoting Mechanism:

The pivoting mechanism is shown in figure ~~2.5~~ 4.1. This is simply an extension of two upper and two lower support beams, towards the back of the machine. The location of the pivot represents the interaction point within the detector. This assures the correct projectivity for the bending of the plates.

For the barrel, the pivot point is constant, whereas for the end cap, it must be relocated for the varying towers.

2.6 End Clamps:

The end clamps act also as dies, as shown in figure 2.6. One of the Center dies is fixed. In order for the plate to pull together as it is being bent, the ends must be clamped to the end dies. This design causes a clamping force on the ends of the plate using springs, a shoulder bolt, and a cam to guide the end die/clamp in the proper trajectory. Once fully closed, the clamping occurs directly between the upper and lower end dies, and the springs are no longer exerting the force. The cam continues to guide the end dies to their final position. This is a fully automatic system without need for clamping by the bending machine operator.

Fig 2.4 **BENDING MACHINE DIE ALIGNMENT SCHEME**

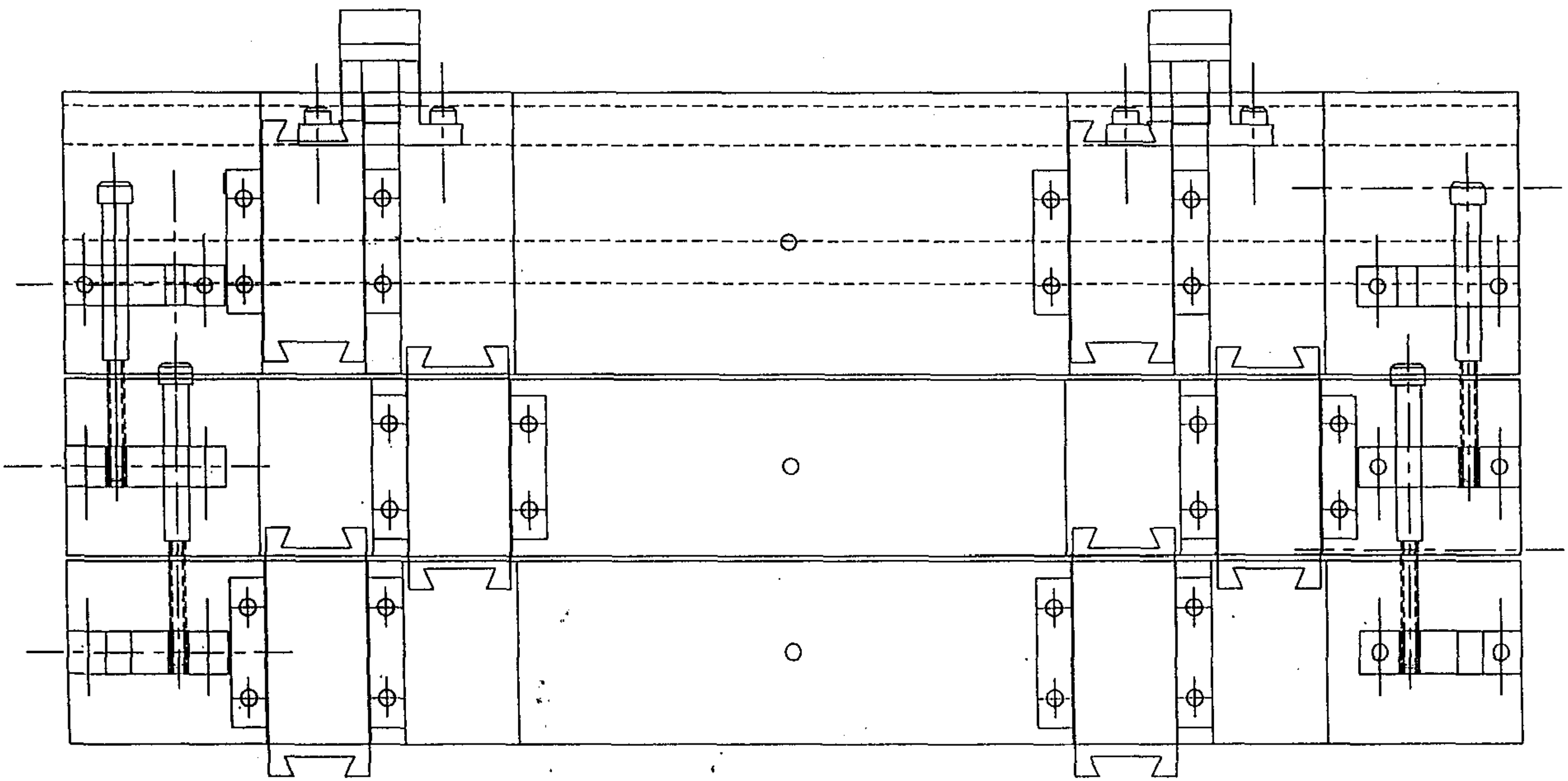
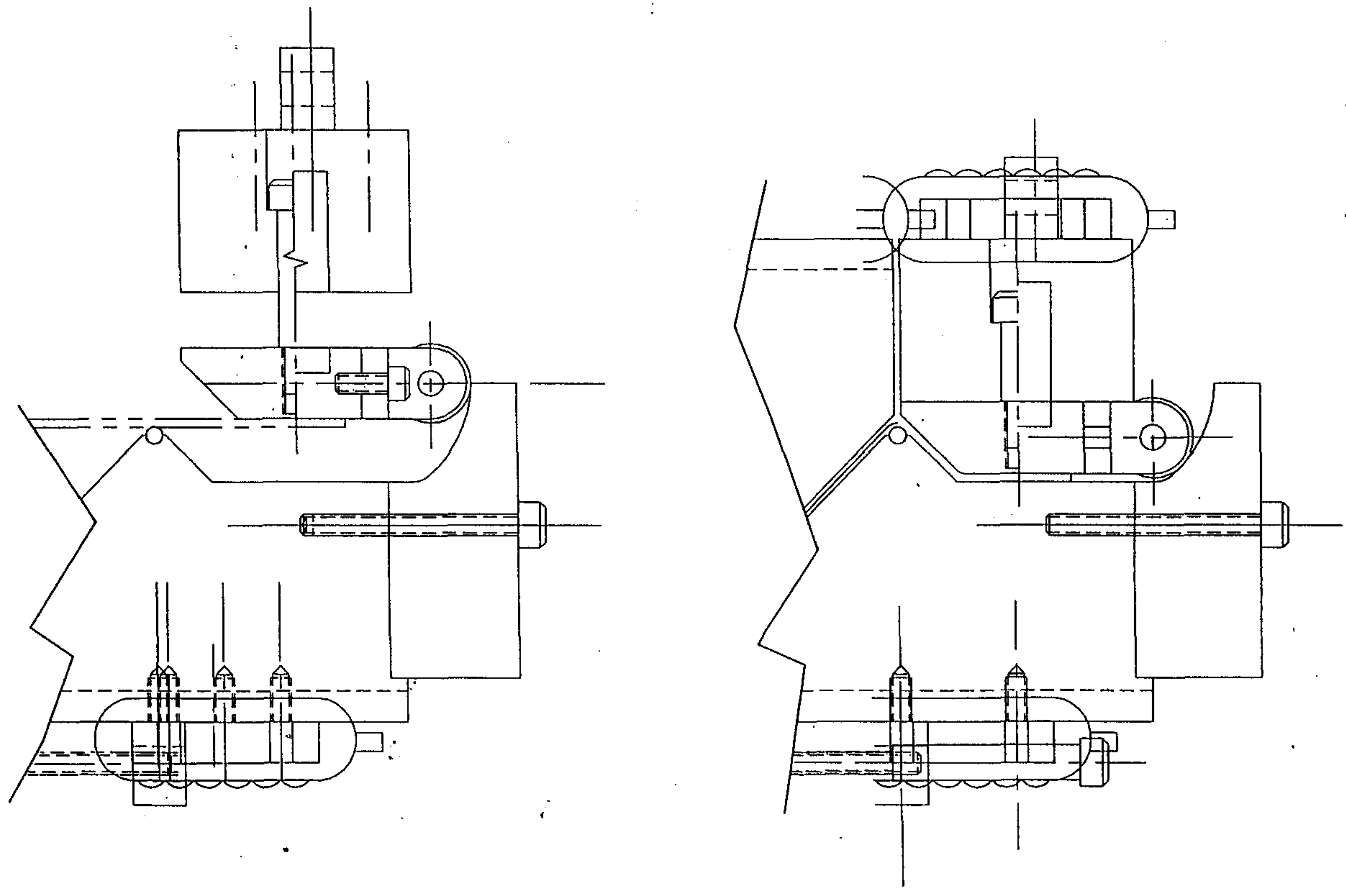


Fig 2.6 **BENDING MACHINE END CLAMPING ASSEMBLY**



3.0 Bending Machine Press:

The bending apparatus shall be driven by a 400 ton or larger press or press brake.. The press brake to be used for producing the prototype is shown in figure 3.0. The press will be hydraulically operated with a controllable rate of rise and decent.

4.0 Pre-Heating Oven

Prior to bending, both the barrel and end cap plates must be pre-heated in an oven, as shown in fig 4.0, to 85°C (185°F). The part must quickly be transferred to the bending machine. Results of a thermal analysis shown in figure 4.0a indicate that an insulating blanket may be required during the transfer from oven to molding to prevent rapid cooling.

The pre-heating oven is electrically heated providing approximately 8000 Watts of heat to the flat lay-up. There are 2 inches of insulation below the aluminum plate and on the top and sides of the oven enclosure, which is .063 in thick aluminum skins which sandwich the insulation.

4.1 Handling Scheme:

The transfer of plates from oven, to bending, to molding, to final inspection shall be handled using a series of tables with air tables or rollers as shown in figure 4.1.

The storage racks for the flat sheets and for the bent sheets shall be a series of shelves which support the plates to preclude bending. There will also be sheet of flexible plastic mesh between each plate to avoid damage between surfaces.

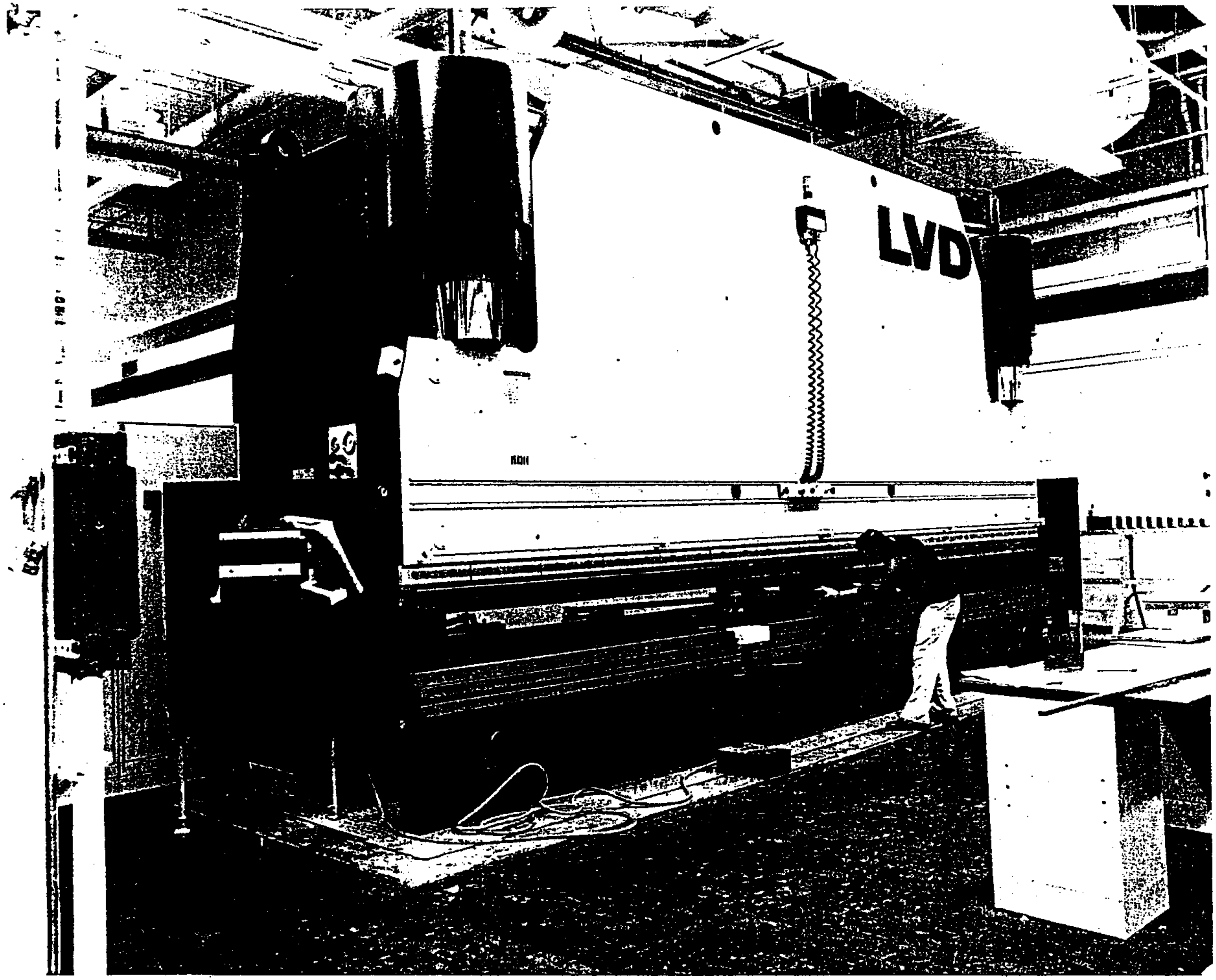


Fig. 3.0: Bending Machine Press

Fig 4.0 Pre-Heating Oven

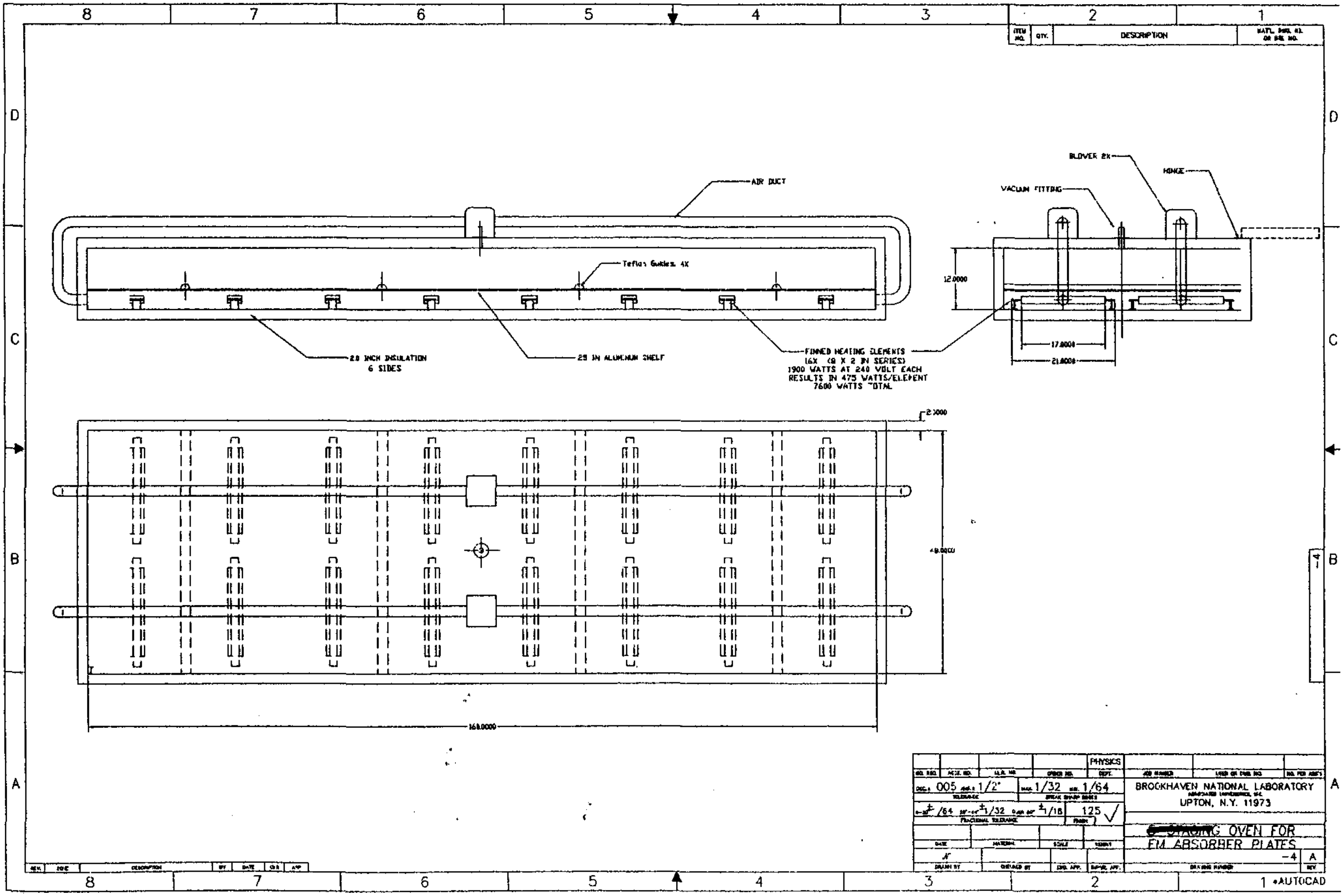
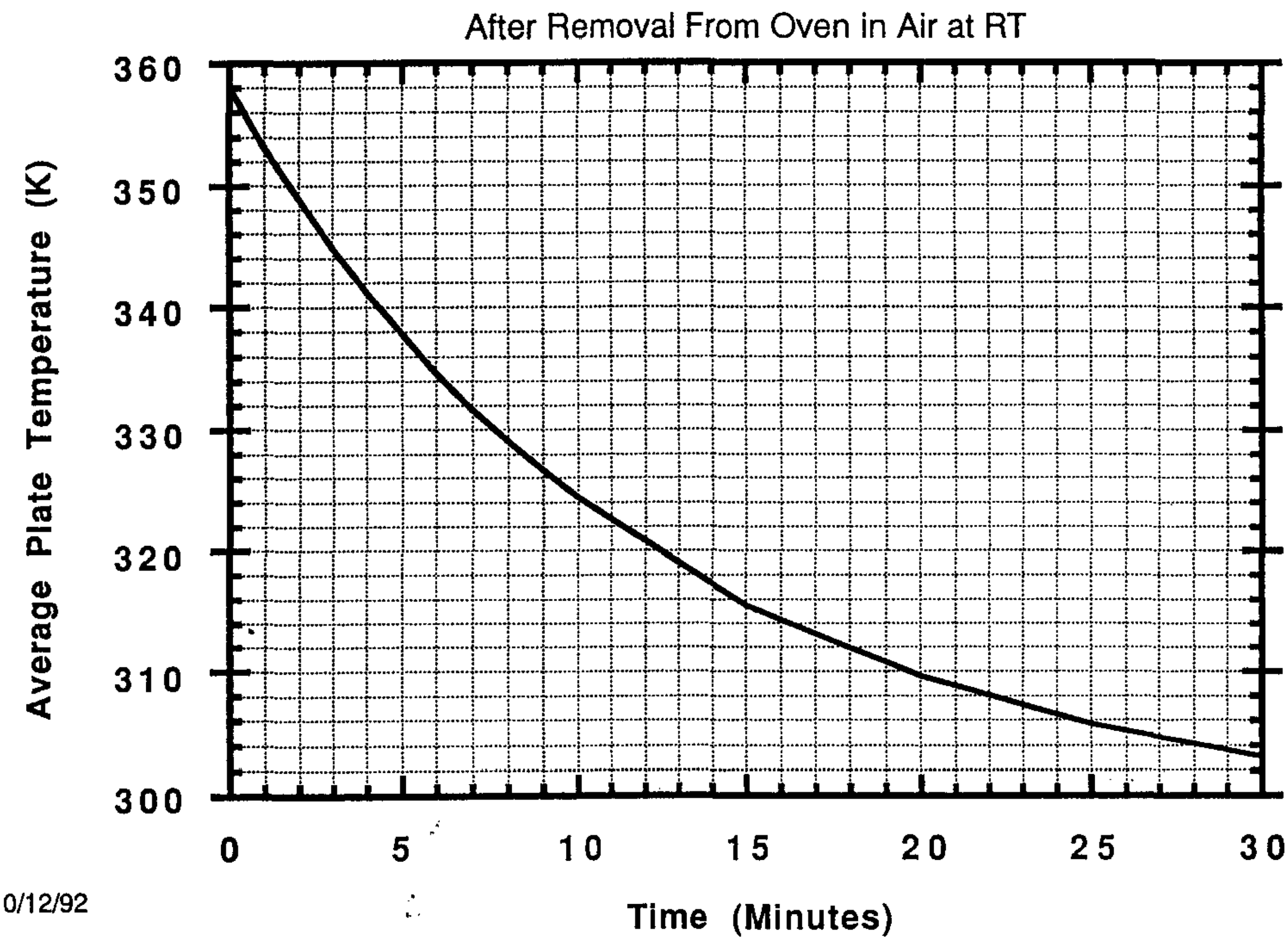


Fig 4.0a **Absorber Plate Cooldown Characteristics**



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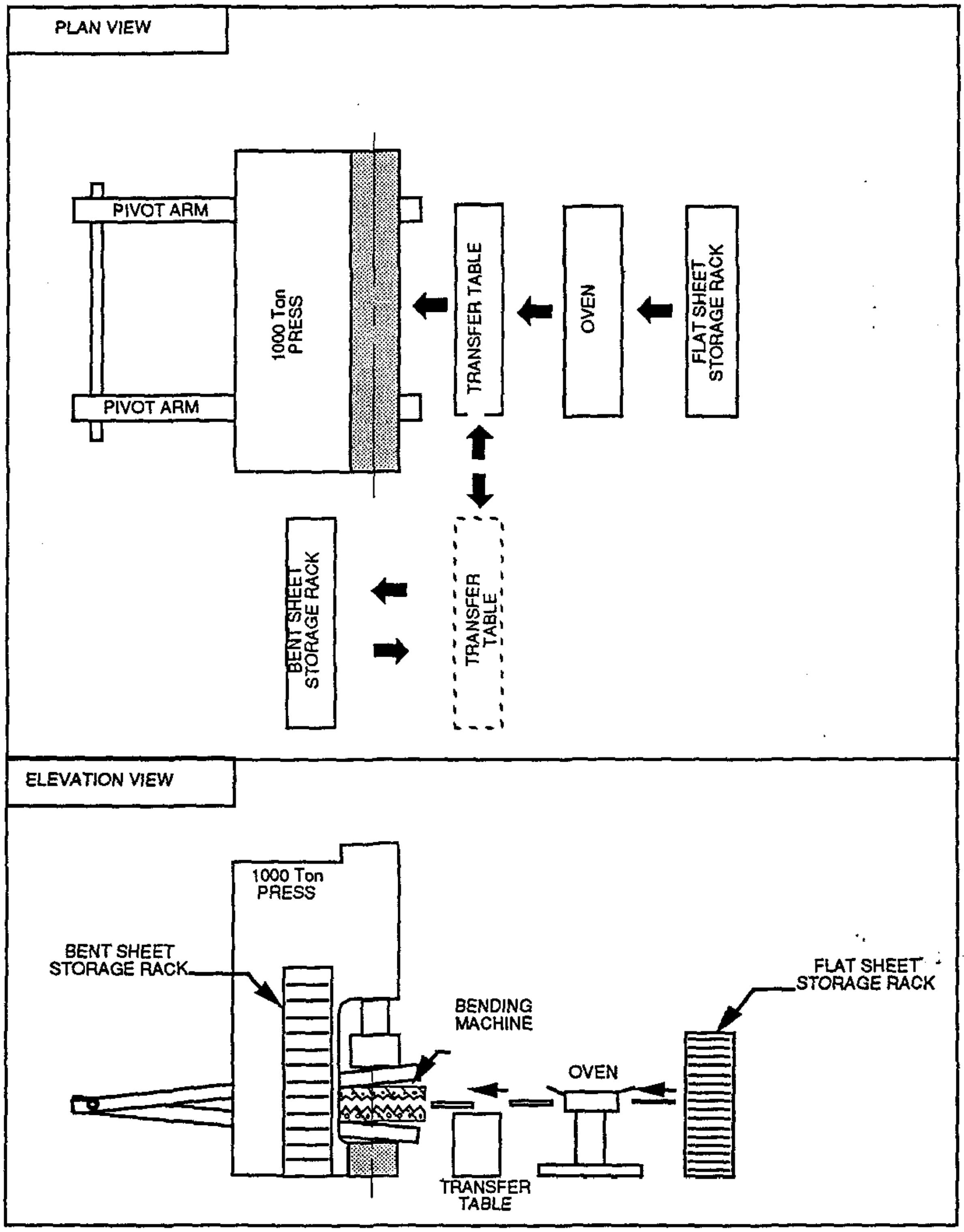

Fig. 4.1 Bending, Transfer & Storage Handling Scheme