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MANGANESE STEEL--FABRICATION, MACHINING, AND HEAT TREATING

General Description

Austenitic manganese steel is more commonly called Hadfield manganese steel by the materials community after its inventor , Sir Robert Hadfield of Sheffield, England. It is an exceptionally tough nonmagnetic alloy in which the usual hardening transformation that occurs in low alloy steel has been suppressed by a combination of high manganese content and rapid cooling from a high temperature.

In the form of rolled shapes or castings, it serves many industrial requirements economically and is particularly useful for service that combines gouging, abrasion, and impact. In commercial production, its composition will usually vary within the range from 1.0%-1.4% carbon and 10%-14% manganese.

At MCSD, we call this material "SLL" which is the abbreviation for our "Supplemental Long Lyfe" trade-named materials. Parts made from "SLL" include flights, liners, special work handling fixtures, barrel head plates, and any other items exposed to shot blast cleaning action.

For optimum wear resistance, we normally specify that plate and bar stock meet the typical Hadfield composition requirements by U. S. Steel's Grade "B" alloy, or in the case of castings, by ASTM Specification A 128, Grade "A". Limited availability and higher cost of fully annealed "SLL" plate and bar stock dictate that we use this material in the "as-rolled" conditions for most of our applications.

Heat Treating

The heat treatment that gives austenitic manganese steel exceptional toughness consists of solution treating and water quenching. Wrought shapes are solution treated by heating to a temperature range of 1750°F to 1850°F (955°C to 1010°C). Castings are solution treated in a slightly higher range of 1800°F to 1950°F (980°C to 1065°C).

The speed of quenching is important, though difficult to accelerate beyond the rate fixed by heat absorption from the surface cooled by agitated water. It should be noted, however, that with sections less than 3/4" thick, it is possible to fast air cool without producing a serious loss in metal toughness.

Heat Treating (cont)

Reheating of manganese steel parts for any reason is much more serious than for ordinary structural steels. Instead of the usual softening and increase in ductility, the steel becomes embrittled if heated above 500°F (260°C) with the lower temperatures requiring longer time for impairments to develop.

As a general rule, austenitic manganese steel should never be reheated above 500°F (260°C) either by accident or plan unless the standard toughening treatment is to be applied afterward.

Cutting

A. Abrasive Sawing
Where good cut finish and fit-up are required in bar stock applications, we cut to length with our 20" diameter Stone Saw (Fig. 1). This saw is capable of cutting through 3" thick material with a 1/2" depth of cut limitation per pass. We also cut "SLL" wire screen with this same piece of equipment.

B. Shearing
Although we were successful in shearing "SLL" plate in thicknesses up to 1/4", shear blade life was reduced to the point where it became uneconomical to shear on a production basis.

C. Flame Cutting
We employ both multiple and single torch cutting procedures using acetylene, MAAP (Methyl Acetylene Propadine), or natural gas as a fuel gas. A four-torch cutting machine equipped with an electronic tracing device is used for multiple piece production. For single piece cutting, we use a track-mounted radiagraph which also can be used with a radius rod for cutting accurate circles.

When cutting heavily scaled or rusted plate, high gas flows and lower speeds should be used. Because of the lower speeds and unpredictable cut quality of typical "as-rolled" "SLL", flame cutting has recently been limited to thicknesses over 1 1/2".

Plasma Cutting

A recently installed, two torch Computer Numerical Control plasma cutting machine is now being used to straight line and shape cut "SLL" plate that is 1 1/2" or less in thickness. Cutting speeds are 8 to 10 times faster than any oxy-fuel cutting machine (Fig. 2). The cut surface quality is consistently excellent and because these particular plasma torches were made to cut under water, thermal distortion problems are kept to a minimum. Other important benefits of underwater cutting

Plasma Cutting (cont)

include elimination of ultra-violet radiation hazards and a dramatic reduction in arc noise and air pollution.

Plasma cutting of "SLL" is completely unaffected by any external or internal material conditions. This allows us to use the less expensive, more available "as-rolled SLL" wrought materials and maintain high quality.

In addition to cutting, this equipment is used to layout the parts with a center punch or powder marker.

Hole Making

We currently employ four different processes to make the various sizes and shapes of holes required in our "SLL" material. These are presented in order of improving dimensional tolerance as follows:

A. Plasma Cutting
The plasma machine previously described is also used to cut 3/8" diameter or greater abrasive drain holes in flight stock up to 1 1/2" thick. Though slightly irregular in shape, the quality of holes produced at such high speeds is considered to be very good for the intended function (Fig. 3, Fig. 4). We are also cutting the mounting holes in our "SLL" liner stock.

B. Metal Disintegrating
When irregular shaped holes or holes smaller than can be punched or drilled are required, we employ a type of electric discharge machine that uses hollow graphite electrodes shaped to the required hole configuration.

The machine is mainly used on flight stock and is called a "Cammann Metal Disintegrator" (Fig. 5). Though it was originally patterned after the well known "tap extractor", it more closely resembles a roughly controlled EDM machine. As in EDM machining, the work piece is submerged in a dielectric bath during machining with constant coolant flow through the electrodes to flush out burned material (Fig.6).

Cutting is done by a rapid series of low voltage (<30V) sparks produced when the electrode touches the work, using a magnet and spring combination inside the head to produce a vibrating type of movement. Each spark removes a small particle of metal directly under the electrode 3,600 times a minute.

A typical "SLL" flight part (1" thick X 6" wide X 60" long) that requires four 3/4" diameter plow bolt mounting holes at each end (Fig. 7) plus sixty 3/8" abrasive drain holes can be produced on this machine in approximately 1.5 hours. Our latest develop-

B. Metal Disintegrating (cont)
ment work using the CNC plasma cutting machine for drain holes has reduced this time to .7 hour.

C. Punching
Punching of "SLL" plate thickness through 1/2" thick is performed on a press used exclusively for this material. Tonnage requirements are 1 1/2 to 2 times that of mild steel and punch life is generally much shorter. If adequate press tonnage is unavailable, hot punching may be employed at reduced press requirements. Since some degree of embrittlement will result from heating, the part application must be given careful consideration.

The key to trouble-free punching of "SLL" is to allow for a greater amount of die clearance that would be used for mild steel. It has been determined that a clearance of 1/32" on a side must be used for punching 7/16" - 13/16" diameter holes. For punching larger holes, we increase this clearance to approximately 3/64" on a side.

D. Drilling
Where close hole tolerances are encountered in hole diameters ranging from 7/16" through 1 1/2", we route the parts to a radial drill. Drills smaller than 7/16" tend to break easily because of inadequate column strength.

Our choice of drill material lies with the AISI type T-15 grade tungsten high speed tool steel. For optimum tool life, we have developed a drill shape similar to that shown in this sketch. (Fig. 8)

Moderately heavy cuts and slow speeds on a rigid machine using a good grade of sulfur-bearing cutting oil are all required for successful drilling of a material that is frequently typed as unmachinable. Good cutting feeds and speeds were found to be about 1/10 and 1/20 respectively of those used for mild steel.

E. Tapping
Attempts made at mechanically tapping holes in this material have been unsuccessful. When threaded holes are required, we punch a hole, weld in a soft insert and then tap. If possible, we design around the fastening method.

Machining

As in drilling of "SLL", machining is difficult because the material work hardens rapidly ahead of the tool point. This factor demands careful attention in all machining operations and although details of practice and tool design differ, there are some basic principles which must be observed.

Machining (cont)

A. The machine should be rigid, in good condition, well maintained, and capable of machining without surface chatter.

B. Tools must be kept sharp at all times to ensure positive cutting.

C. As in drilling, slow speeds should be used. High speeds tend to create red hot chips and rapid tool breakdown.

D. Both high speed steel and sintered carbide tools can be used. Machining without a cutting fluid is possible with carbide tools. If a cutting fluid is used, it should be the sulphur bearing type.

E. Machining operations possible on "SLL" include turning, drilling, slotting, boring, and planing but milling is not normally recommended.

Forming

"SLL" can be cold formed by techniques similar to those used with austenitic stainless steels but with greater difficulty. Plates up to and including 1" thick may be angle bent or formed to moderate radii with the suggested minimum of two (2) times thickness of the plate. Bending should be performed "across-grain" and since springback is more severe than in mild steel, more allowance for this effect must be made.

For severe forming operations such as those required by T-line flights, fully annealed material should be the first choice. The second choice involved heating the material to 500°F (260°C) maximum and slowly forming preferably with a hydraulic press. Heating to this level for short times will not cause any appreciable loss in toughness but will reduce cracking problems and press power requirements.

Since there is a limitation on the amount of cold work possible on "SLL", it is sometimes necessary to run test samples to establish the forming limits of a given design.

Welding

The welding of "SLL" requires considerable care. Though it is very tough, it is sensitive to reheating and therefore should not be pre- or post-heated for any welding operation. Arc welding is entirely practical and many tons of austenitic manganese steel electrodes are used annually.

Experience and research have shown that the following procedures are helpful:

Welding (cont)

A. Welds in which both parts are "SLL" should be made with covered manganese steel electrodes meeting the requirements of AWS Specification A5.13 Classification, E FeMn-A.

B. Welds in which one part is "SLL" and the other part carbon or low alloy steel, should be made with covered austenitic stainless electrodes that meet the requirements of AWS Specification A5.4 Classification, E 309.

C. Never weld "SLL" with plain carbon or low alloy steel electrodes.

D. Oxyacetylene welding should be avoided since it is likely to cause severe embrittlement of the base metal.

E. The energy input per inch of weld should be kept to a minimum while still capable of producing a sound weld.

F. Temperatures adjacent to welds should never exceed 600°F one minute after bead is deposited.

G. Maintain a short arc, minimize puddling, and use "skip" welding in various locations to distribute heat more evenly. Allow time for cooling; the judicious use of water quenching is helpful in some applications.

H. Wherever possible, a work hardened surface should be removed before welding because of its greater susceptibility to embrittlement. Areas that cannot be easily indented with a center punch should be removed by grinding or air-carbon arcing before welding.

I. Immediate peening of hot beads will assist in reducing warpage and internal stress from contraction during cooling--but do not peen the last pass!

Peening

It is important, when fabricating large SLL weldments particularly cabinets, to peen the components prior to welding. The purpose of doing this is to reduce the distortion that results from the welding operation and to eliminate cabinet distortion which could result when the machine is in operation.

Jim Vaselin
9-21-81

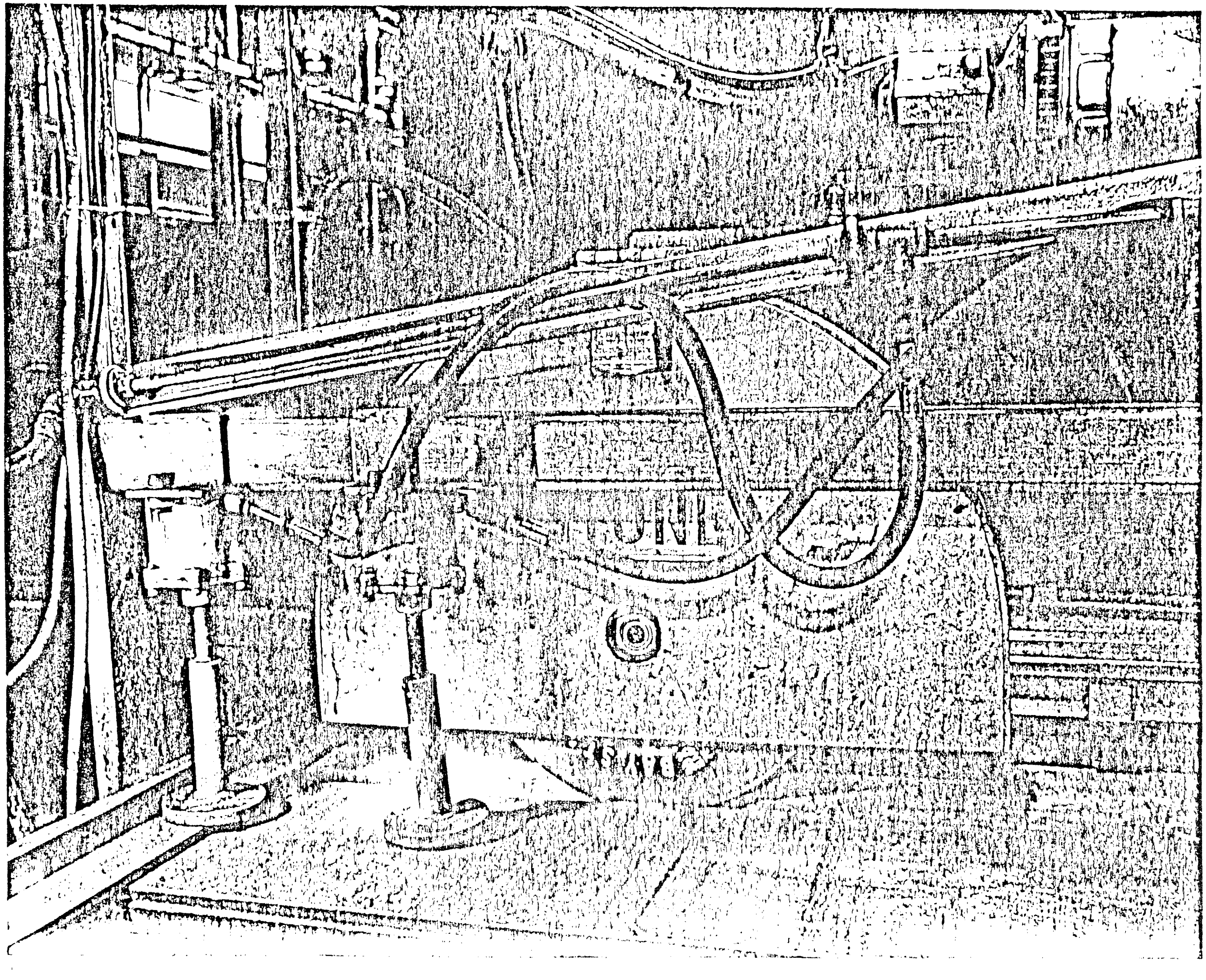


FIG. 1

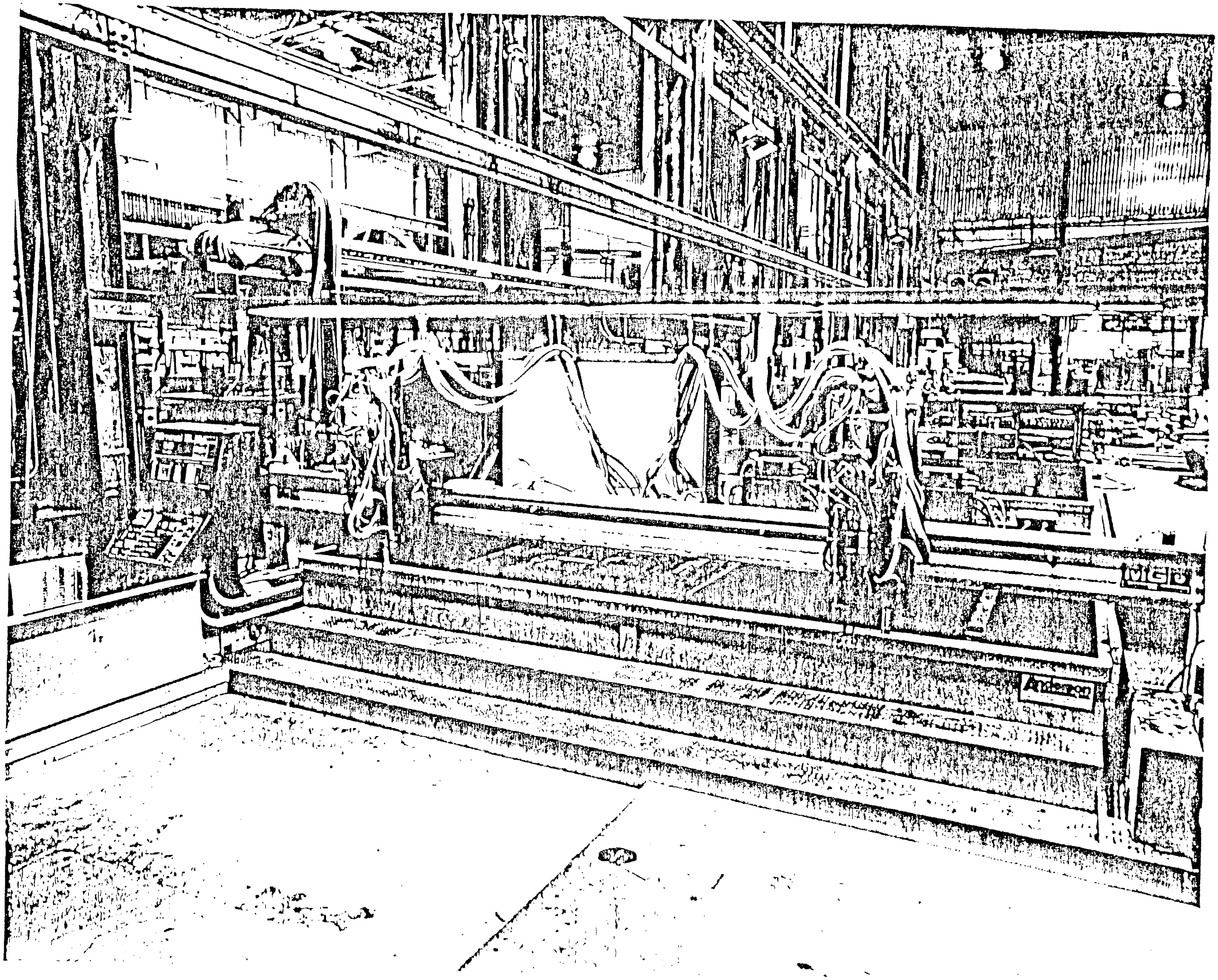
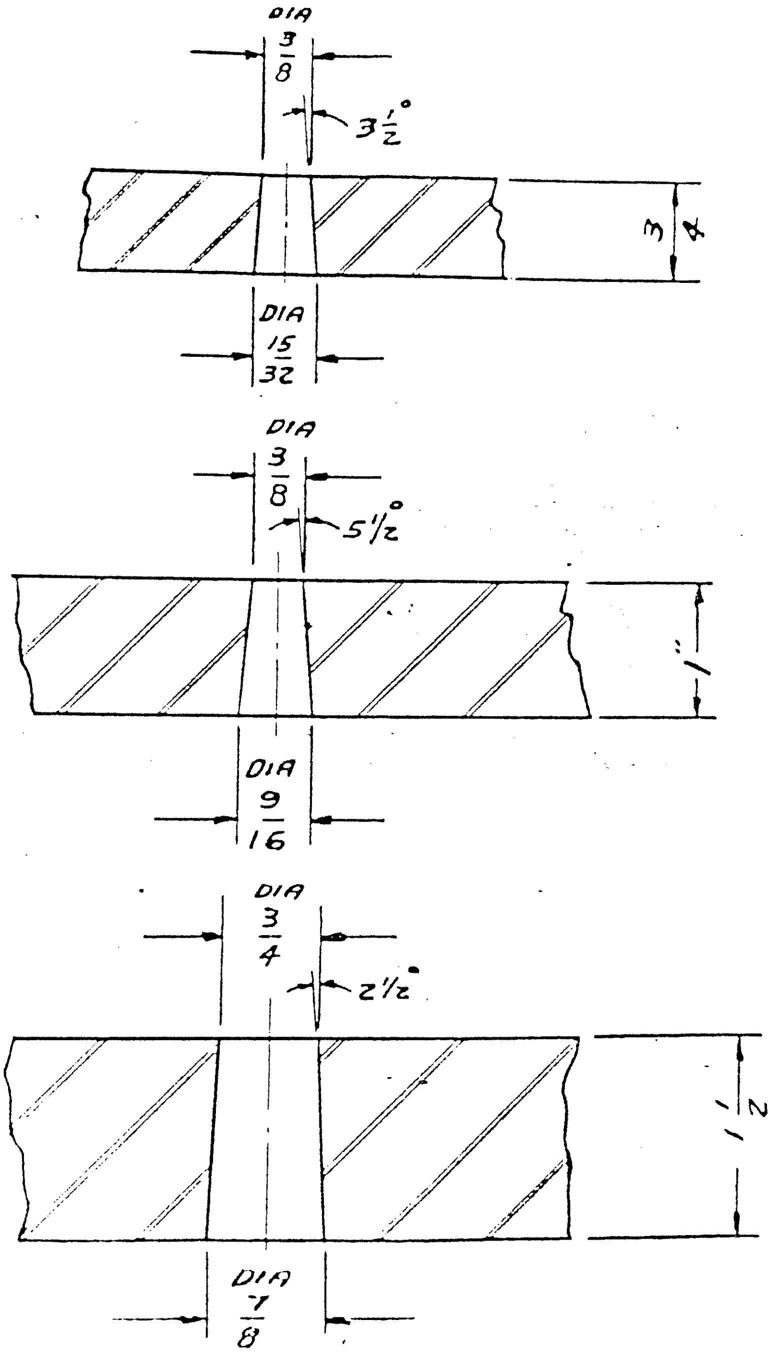


FIG. 2

FIG. 3



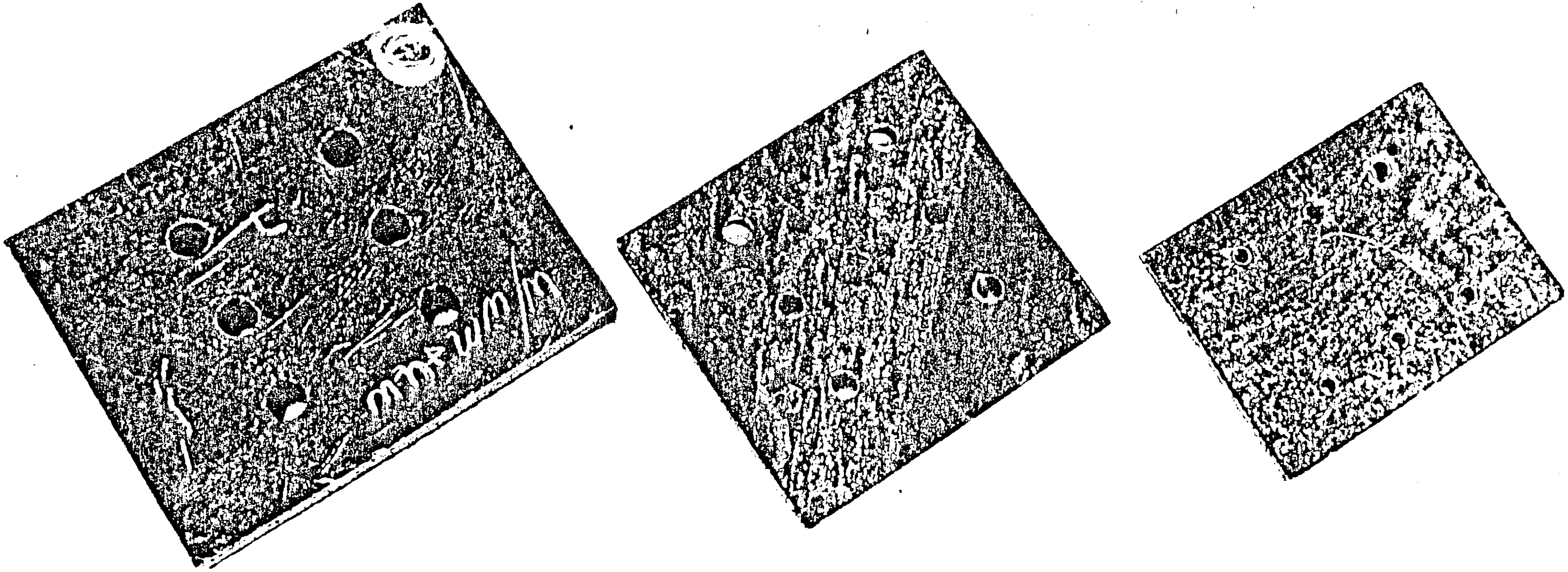


FIG. 4

FIG 5

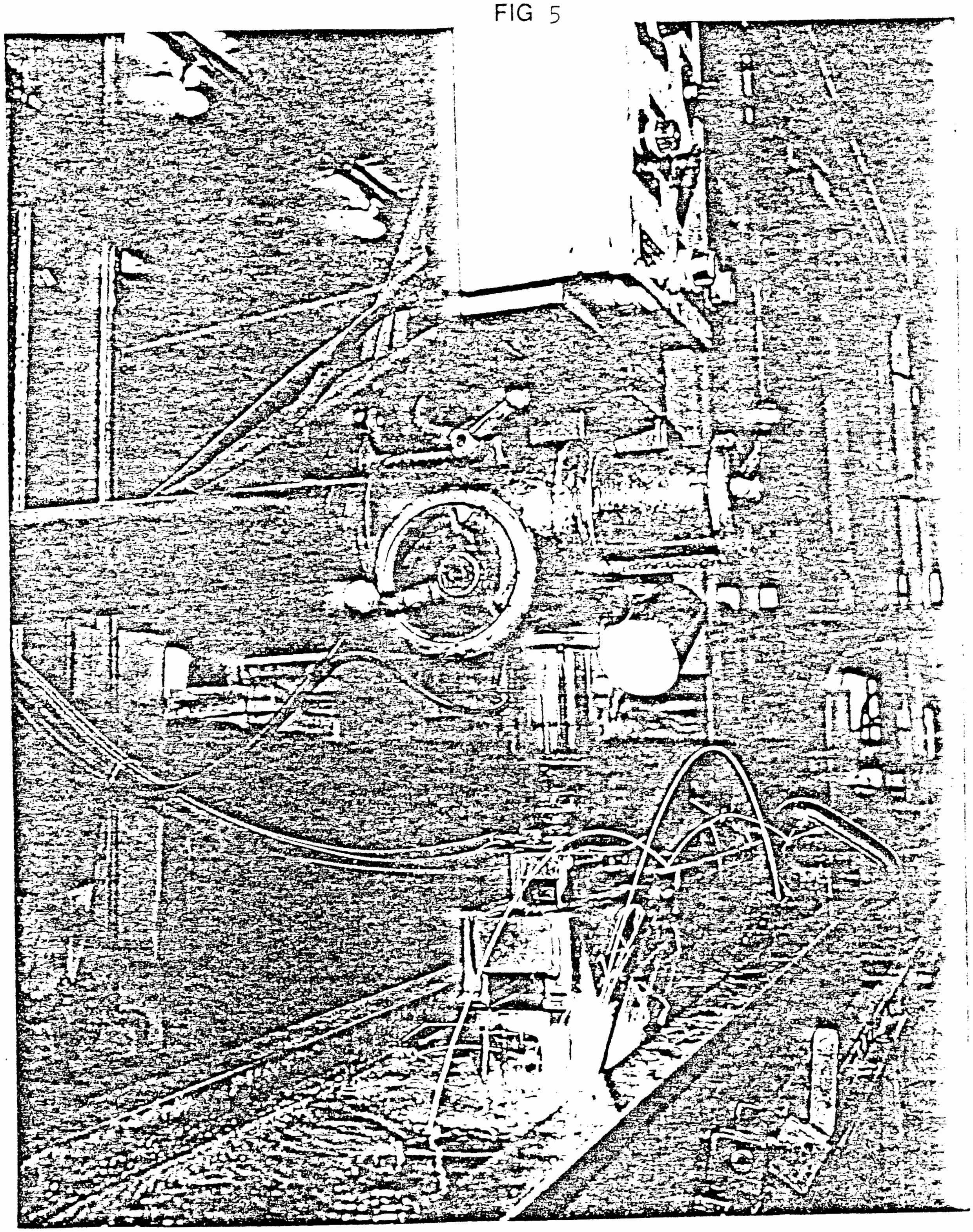


FIG. 6

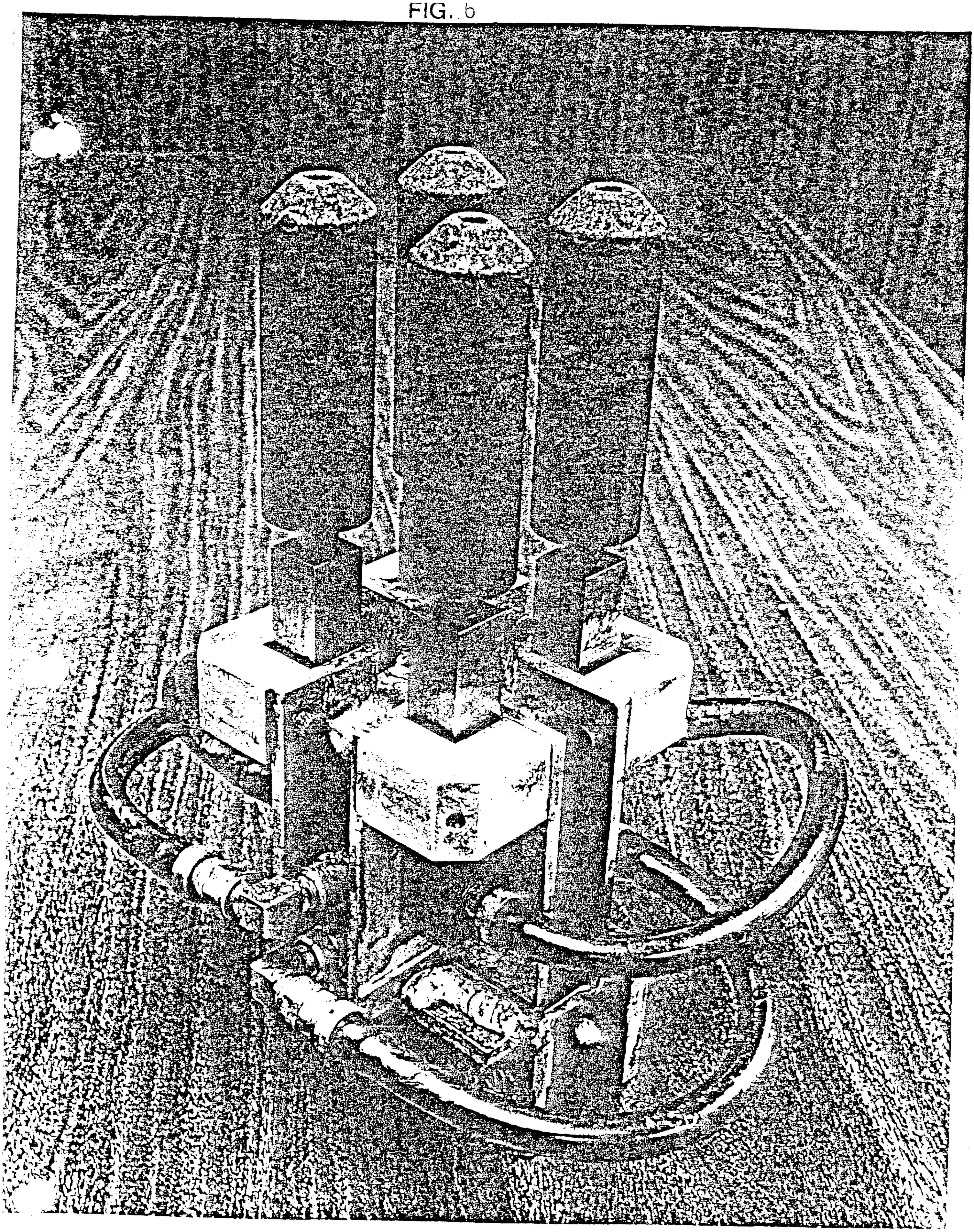
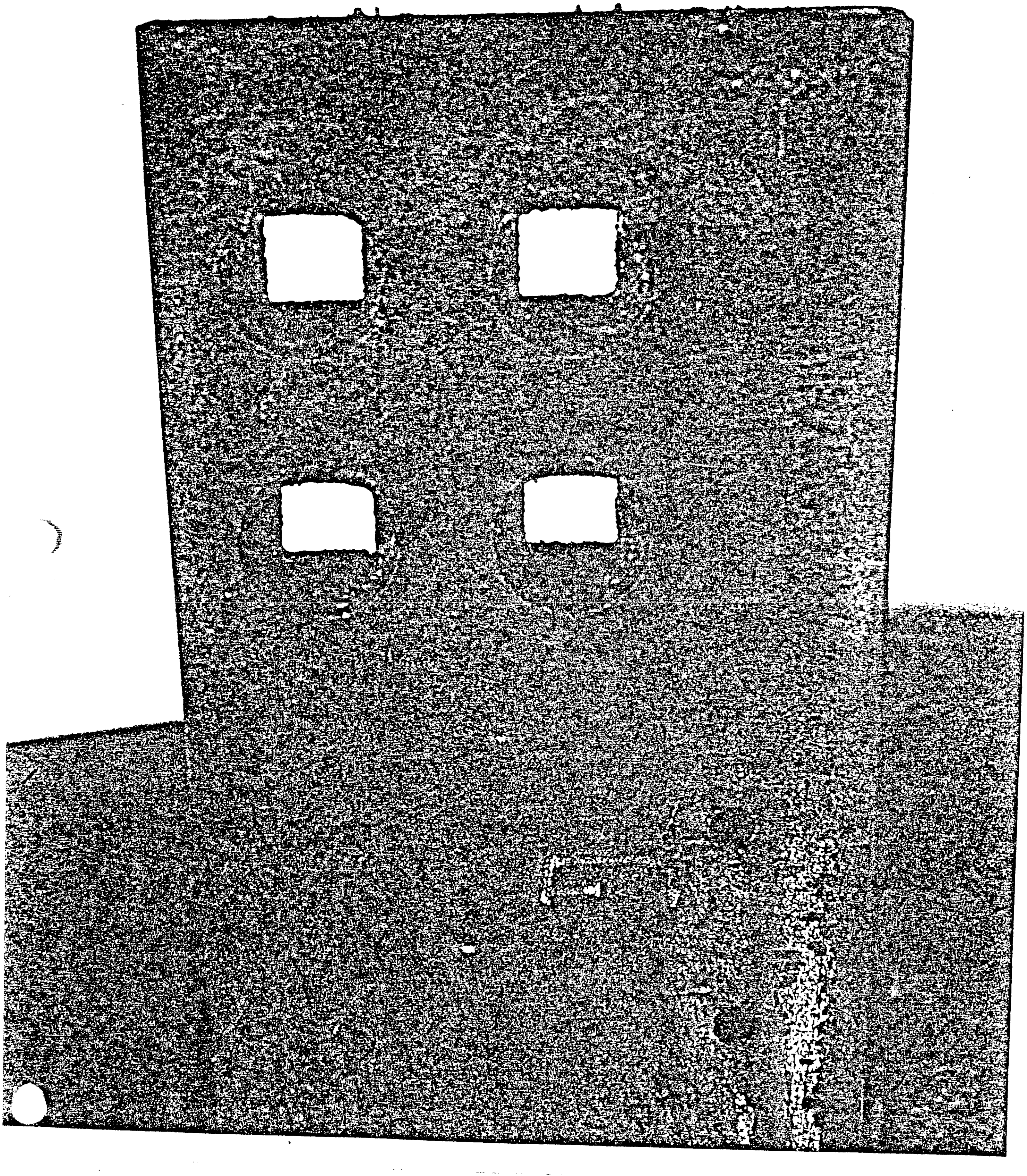


FIG. 7



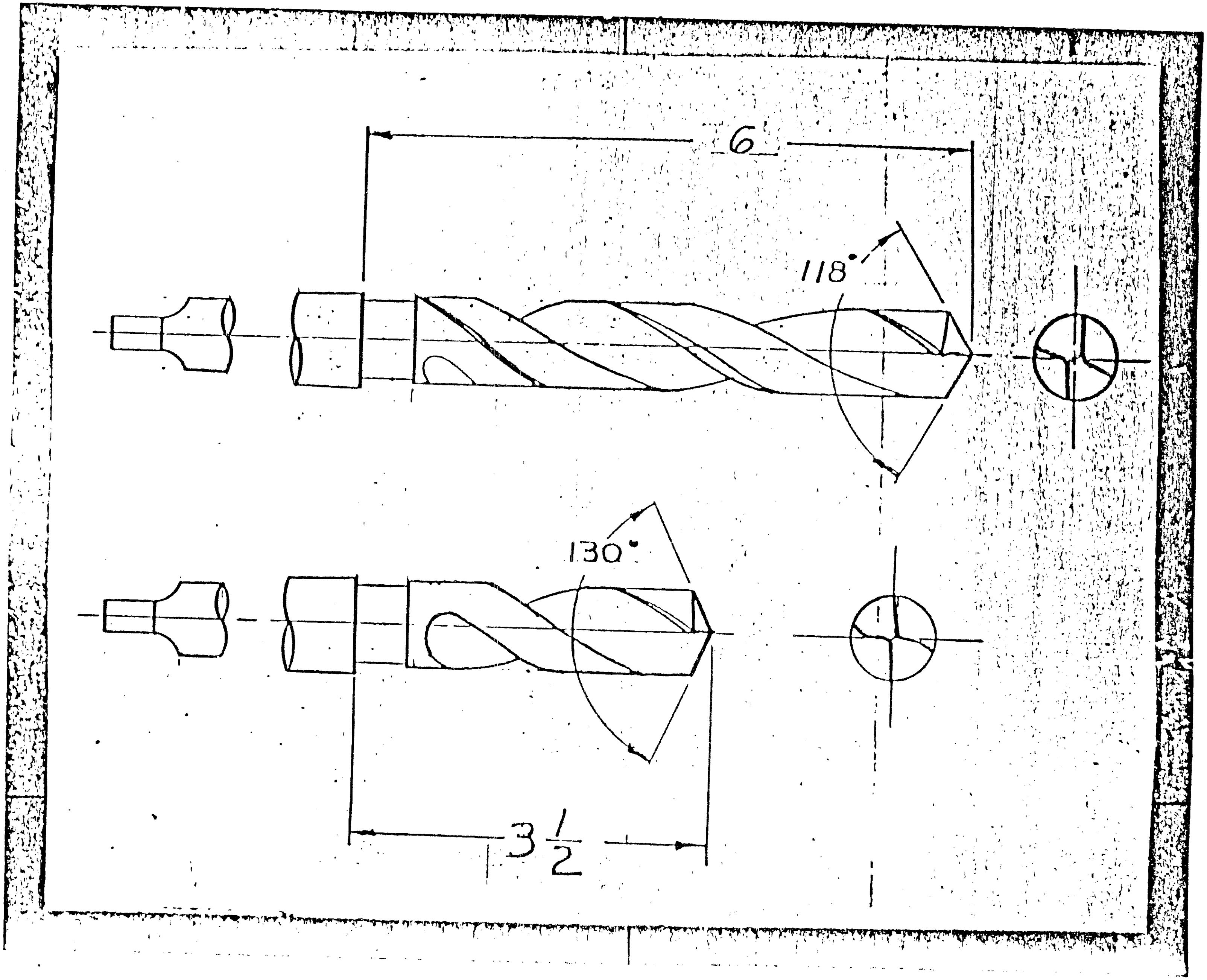


FIG. 8