

FR-2336

July 28, 1944.

NRL Report No. M-2336

NAVY DEPARTMENT

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Report on the
Thermit Process for Production
of
Steel for Castings

Number of Pages: Text - 12 Plates - 20 Tables - 3

Authorization: BuShips ltr. QP/Castings (692-334) of 22 February
1944, Project Order EP/1R.

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ABSTRACT

Tests have been made to determine the adaptability of the thermit process for making steel for emergency castings whenever regular steel melting facilities are not available. Sound, clean castings which meet Navy requirements for Class "B" steel can be produced without conventional melting equipment by using "Forging Thermit," which can be procured from the Metal and Thermit Corporation. The reaction is carried out in a standard thermit reaction vessel and the steel is tapped into ladles and transferred to molds which can be made of green sand. Neither fuel nor a source of electrical power is needed and most of the equipment can be improvised. A field trial was conducted which proved that very little foundry equipment is necessary to produce satisfactory castings by this method.

INTRODUCTION

Authorization

1. This work was authorized by Bureau of Ships letter QP/Castings (692-334) of 22 February 1944.

Statement of Problem

2. The object of this investigation was to develop a method for using "Forging Thermit" to produce steel for making emergency castings.

Known Facts Bearing on the Problem

3. The ability of finely divided, metallic aluminum to reduce metals from their oxides by exothermic reaction was discovered about 1897 by Dr. Hans Goldschmidt of Germany (1). The reduction is accomplished without the use of externally applied heat except to initiate the reaction. The Goldschmidt or Thermit Process, as it is now called, has been widely applied in the reduction of metals from ores and as a means for welding steel and iron. Patents for the thermit process and its applications in the United States have been under the control of the Metal and Thermit Corporation of New York City since 1918.
4. The British journal, "Engineering," of 22 July 1938, contains a description of the process developed by Thermoloy's, Ltd., for producing steel for castings and ingots by the thermit reaction (2). The manufacture of a small heat of 18 percent chromium, 8 percent nickel stainless steel is described, with references to "secret powders" and "special reagents". Among the advantages cited in favor of this so-called "Thermoloy's Process" for steel making are low initial investment for equipment, reportedly superior quality of steel produced by this method, and high temperature with resultant high fluidity, and speed of melting of a given quantity of metal.
5. In the welding application of the thermit process, the reaction for making the molten steel is carried out in a conical crucible made by lining a sheet steel shell with a magnesia-tar refractory. The materials and equipment used are shown in Plates 1 through 4. The tap hole at the bottom of the reaction crucible is formed by a magnesia-refractory sleeve which is closed by the insertion of a nail-shaped steel tapping pin. This tapping pin is covered with two disks of asbestos sheet, a steel disk and finally by a one-half inch thick layer of crushed alumina refractory as shown in Plate 3. The prepared thermit mixture is then charged into the crucible. The mixture (supplied by the Metal and Thermit Corporation in packages) is composed of iron oxides and aluminum in the amounts required by the equation listed below, and ferro-manganese to bring the manganese and carbon contents of the product to the required levels. "Forging Thermit" developed for use in thermit welding contains 15 percent of small steel punchings, which serve to reduce the temperature of the molten steel by dilution and to increase the weight of molten metal obtained from the reaction. The charge is ignited with a red-hot rod touched to match heads embedded in a special "Ignition Powder" supplied by the Metal and Thermit Corporation.

6. Molds for the thermit welds are made by ramming sand around a wax pattern and then heating with a torch to melt out the wax and pre-heat the parts to be joined. A large basin to catch the slag is molded in the sand above the weld. A downgate leads from the slag basin into the mold cavity and the reaction crucible is suspended so as to pour directly into the runner cup of this downgate. The crucible is tapped by driving the tapping pin upward through the refractory plugging material. The superheated steel then melts the tapping pin and drains from the crucible and the asbestos and refractory rise to the tap and join with the slag. On tapping, clean metal runs from the crucible first, filling the mold cavity, and the slag which follows collects in the slag basin above. The superheated steel fuses the parts to be joined into a satisfactory weld. Plate 5 shows schematically a typical welding arrangement.

Theoretical Considerations

7. The fundamental reaction in the thermit process is the reduction of iron oxide by aluminum according to the equation:



Once initiated by the application of intense heat (approximately 2100°F. at a localized point) to a mixture of fine particles of aluminum and iron oxide, the reaction proceeds exothermally throughout the mixture. The temperature of the reaction products is estimated to be 5000°F. Because of the chilling effect of the crucible in which the reaction is carried out, this temperature is reduced to approximately 4200°F. Due to the difference in specific gravity, the lack of mutual solubility, and the low viscosity of the metal, there is a rapid separation of the products into a bottom layer of molten iron and a supernatant layer of molten alumina (slag).

Narrative of Original Work Done at This Laboratory

8. The thermit process as described above for melting metal for welding, was used as a starting point for the development of foundry methods for making castings. The original work done to date is as follows:

a. A study was made to determine if steel could be tapped directly from the reaction vessel into molds made of standard foundry sand mixtures.

1. Green sand molds were used because in emergencies time and facilities would not be available for other methods.

2. Various increasing amounts of punchings were added to the reaction vessel to reduce progressively the temperature of the molten metal so that sand molds would be able to withstand the intense heat and erosive action of direct tapping.

b. Methods were developed for slag separation and temperature control in which a double ladle transfer proved more satisfactory than direct tapping.

c. The chemical composition and mechanical properties of thermit steel poured in sand molds were determined for representative heats.

d. The lining materials of the reaction vessel and its shape were altered to make them more suitable for emergency use.

e. A simplified method for igniting the thermit mixture was developed.

Preparation of Materials

9. The materials for this investigation are shown in Plates 1 and 2 and were used essentially as received from the Metal and Thermit Corporation and in accordance with their directions for melting and tapping.

Description of Experiments

10. Castability - To determine the castability of the thermit steel, typical castings were poured, using standard foundry green sand molds. Photographs of some of these castings are shown in Plates 6 and 7. These tests proved the steel to have highly satisfactory casting qualities and excellent fluidity because of its high temperature. Most of these castings were poured at 3400-3500°F., the steel being cooled to this temperature in transfer ladles as described later.

11. Mold Requirements - The requirements for the mold to be used in pouring castings with thermit steel are especially severe because of the high temperature involved. It was found experimentally that an air-dried sand mold, of the type used for ordinary steel castings at the Naval Research Laboratory, is entirely satisfactory. Such a mold can be poured immediately after ramming when the double transfer system is used, if moisture in the sand mix is kept low. The Metal and Thermit Corporation supplies a special fine-grained molding sand (used with a water content of about eight percent) for making thermit welds but this sand requires oven drying and is therefore less desirable than regular foundry molding sand. Any foundry sand with a moisture content not exceeding 3-1/2 percent is safe for use with steel made by the thermit process.

12. Pouring Temperature Control - Since "Forging Thermit" as tapped from the reaction crucible has a temperature of approximately 4200°F., it is much too hot for direct tapping into ordinary sand molds. Steel at this temperature was found to be very erosive and to produce castings having poor surfaces with much adhering sand. It was found by experiment that pouring temperatures of 3400-3500°F. would produce satisfactory castings in molds made from the standard Naval Research Laboratory synthetic sand for steel. Therefore, it was necessary to reduce the temperature of the steel to this level before pouring it into the mold.

13. The temperature of the steel as it emerged from the reaction crucible was found to be reduced to approximately 3800°F., when 35 percent of punchings was added to the forging thermit (making a total of 50 percent punchings in the mixture). Temperature measurements were made with a disappearing filament type optical pyrometer. The chemical composition of the heat of steel (M-1) resulting from this amount of punchings is shown in Table 1. Although the mechanical properties of this heat are satisfactory (Table 2), it may eventually prove undesirable to have such a high aluminum content in the steel.

14. Temperature control and slag separation are both obtained by a double transfer system in which the steel and some of the slag are tapped into a ladle. The slag is raked off and the steel is then poured into a second ladle. When both ladles are used without preheating, the temperature of the steel following this double transfer, is reduced to approximately 3400°F. This temperature permits ample time for handling; moreover, thin sections can be cast and sound, clean castings are produced. This method possesses an advantage over the method of adding extra punchings to the thermit mixture for cooling in that it does not change the composition of steel so as to cause an excessively high aluminum content. This double transfer system also permits the pouring of more than one casting from a given heat of thermit steel and allows better control over the rate of pouring which is considered important in making quality steel castings.

15. Slag Separation - The problem of slag separation is considerably more acute in handling thermit steel than steel melted by ordinary processes since the thermit reaction produces two volumes of alumina slag for each volume of steel. Because of the differences in specific gravity, the slag and steel separate rapidly in the reaction crucible. When the crucible is tapped, practically all of the steel drains out before the slag begins to emerge. In thermit welding the slag is kept from the mold by the design of the slag basin. However, since direct tapping from the reaction crucible into the mold does not seem to be practical because of the destructive effect of the highly superheated steel upon ordinary foundry molds, with poor surface condition of the resultant casting, other means of slag control are required.

16. The method of double transfer which provides suitable temperature and slag control is a relatively simple process. The receiving crucible is held in a double-handled shank and is suspended over a pit dug in the sand of the foundry floor; the ends of the shanks are supported on blocks. The ladle, which has capacity approximately 50 percent greater than that required for the metal to be tapped, is tipped at such an angle that it will hold the steel (which comes out first) but will allow the greater part of the slag to overflow into the pit. The reaction crucible (suspended from the overhead crane) and handling accessories are shown in Plate 4. During tapping it is possible to observe the point at which the molten steel has completely drained from the crucible and the slag begins to emerge; if the reaction vessel is supported by an overhead crane, it can be moved at the proper time, so that most of the slag drains into the pit instead of the receiving ladle. When the reaction crucible is empty, or removed, most of the slag is skimmed from the steel in the receiving ladle, with a hoe-shaped skimmer. The remainder of the slag is skimmed when the steel is transferred to the pouring ladle. A small amount of clean, dry silica sand may be used to thicken the slag and facilitate skimming. The various operations for a typical thermit heat are shown in Plates 8 through 16.

17. Reaction Crucible Development - It was believed that a crucible with a round bottom would be more satisfactory than the standard conical crucible, due to the larger mass of metal at the tapping hole in the event that it was desired to hold the metal in the reaction crucible or if difficulties were encountered in tapping the steel. Such a crucible was supplied by the Metal and Thermit Corporation and was found to be satisfactory and superior to the conical type.

18. Lining Materials for Reaction Crucibles and Transfer Ladles - The magnesia-tar refractory supplied by the Metal and Thermit Corporation for lining reaction crucibles and ladles was found to be very satisfactory. The mixture is used in essentially the same manner as any other foundry lining refractory and is baked for several hours at approximately 700°F. to drive off the volatile constituents of the tar. During this baking, the crucible which has been properly lined with refractory is filled with sand to prevent excessive oxidation of the carbon in the lining. A sheet of paper is used as a separator between the refractory and the sand. Such oxidation makes the lining crumbly and soft.

19. An alternative emergency lining material was developed at the Naval Research Laboratory of the following compositions:

#80 silica sand	80 percent
Silica flour	15 percent
Bentonite	5 percent

This mixture is rammed in the conventional manner and baked at least four hours at 400°F. This lining is satisfactory in its resistance to the action

of the hot slag and metal in the reaction crucible, and possesses the important advantage of a simpler baking treatment than the magnesiatar lining although it is probably not as durable. There is some silicon pick-up from this lining but this is not considered objectionable since the thermit steel would otherwise have a lower silicon content than that which is generally considered desirable in steel for casting purposes. Heats made in reaction crucibles with silica linings showed silicon contents ranging from 0.60 to 1.60 percent. The second heat from a crucible lined with silica sand shows larger pick-up of silicon than the first.

20. Ignition of Thermit Mixture - The method of ignition recommended by the Metal & Thermit Corporation consists of placing about a teaspoonful of their special ignition powder in a small cavity formed in the top layer of the thermit in the reaction crucible, embedding three matches in the ignition powder so that only their heads protrude, and then touching a red-hot rod to the match heads. Although the method is quite effective finding a place to heat the ignition rod might be inconvenient under field conditions, so an alternative method of igniting the thermit was developed. In this connection, it should be stated that the ignition powder burns very rapidly and that the reaction quickly proceeds to the main charge of thermit so it is important as a safety precaution that the operator keep his hands far removed from the ignition powder when starting the reaction.

21. A flare, such as that of a match, is required to start the combustion of the ignition powder. A dynamite fuse may be used to supply this flare. The "fireworks fuse" which is used in certain items of naval ordnance also proved to be satisfactory as a method for starting the thermit ignition powder. This "fireworks fuse" operates best when a simple knot is tied in one end and the knot covered with the ignition powder; the other end of the fuse is lighted with a match. This provides a convenient and safe method of initiating the thermit reaction. Magnesium metal ribbon was tested for this purpose but was not satisfactory. An improvised fuse may be made with a piece of paper leading down to matches embedded in the ignition powder. This paper is ignited with a match and the flame travels down to the match heads whose flare initiates combustion of the ignition powder. This method should be used with care as the rapidity of reaction and the short "paper fuse" might cause the operator to be burned.

Discussion

22. From the preceding experiments several observations were made.

23. Air-dried molds are entirely satisfactory when the water content of the sand mixture does not exceed about 3-1/2 percent. The round bottom reaction crucible is more desirable although the conical reaction crucible is satisfactory. Ignition of the reaction mixture is easily accomplished

by the use of a fuse to fire the ignition powder, although the normal technique of using the red-hot rod and matches is the simplest method if there is a fire available to heat the rod. Slag handling and temperature control are most readily achieved by the use of the double transfer ladle system in which the reaction crucible is tapped into a receiving ladle which is placed to catch the steel and allow the slag to overflow into a pit. The steel is then transferred from the receiving ladle to a pouring ladle, being further skimmed of slag during the transfer. This procedure has other advantages in that it permits the pouring of more than one mold from a single heat of thermit. The use of a pouring ladle also provides control of the pouring procedure and pouring may be discontinued in the event of a run-out or other mishap. Also it has been found desirable to be able to regulate pouring speed manually as better castings are produced.

24. At present "Forging Thermit" is packed in 25-pound heavy paper bags. For emergency use it will probably be necessary to pack it in hermetically sealed containers of some suitable size. The Metal and Thermit Corporation recommends that the contents of a single container not be used in part as the mixture is carefully compounded to equilibrium proportions, and will not react properly under other proportions. Accordingly splitting the contents of standard containers is considered undesirable since segregation of the constituents of a bag may develop in shipping.

25. It is also important that "Forging Thermit" be used until such time as a more satisfactory casting mixture is obtainable. "Incendiary Thermit" has definitely been proved unsatisfactory for this purpose.

Field Trial

26. The thermit process was proved applicable to the production of molten steel for the pouring of emergency castings by actual field trial using limited equipment and supplies. Table 3 shows a list of the minimum equipment required for the production of castings under field conditions. This list was developed on the basis of field trials in which castings were poured using the listed equipment. Plate 17 shows a field arrangement for making a thermit heat, Plate 18 shows the mold made in an improvised board flask and Plates 19 and 20 show the broken casting which was used as the pattern and the replacement casting produced. This casting was made in two hours and forty-five minutes using three men. In this time, the flask was made from boards; the sand mixed by hand, the mold rammed manually and the steel melted and poured. The mixing of the sand with the binders and water consumed the largest portion of the time. No electrical or mechanical source of power was needed and only ordinary carpenter's and molder's hand tools were employed.

27. The limitations of the process are few. Thermit welds involving the making of more than 1000-pounds of steel have been made in a wide range of chemical compositions including 18 percent chromium, 8 percent nickel stainless steel. Steel castings of weights up to 1000-pounds can surely be made if the personnel and handling equipment are available. In the making of large castings weighing several hundred pounds, the problem would be essentially those of mechanical manipulation and protection of operating personnel from the high temperatures. For making the large castings, when mechanical handling equipment is inadequate, it would probably be good practice to use a crucible charge containing a relatively high percentage of punchings added to the forging thermit and to tap this mixture directly into a mold equipped with a slag basin. (Mechanical handling equipment, crane, etc. would be necessary for manipulation after the casting was made).

Data Obtained

28. Most of the heats made were sampled for chemical analysis and the results are summarized in Table 1. The aluminum content (determined as acid-soluble metallic aluminum) was found to be proportional to the amount of steel punchings added to the reaction mixture. Much more data will be needed to definitely establish the trend, particularly for aluminum recovery. A typical chemical composition for a heat of thermit steel to which 15 percent punchings has been added is:

Carbon	- 0.22 percent	Aluminum	- 1.00 percent
Manganese	- 0.80 "	Sulfur	- 0.060 " max.
Silicon	- 0.20 to 0.60 percent	Phosphorus	- 0.040 " max.

The aluminum content is considered to be excessively high and the silicon to be too low for steel for castings. However, Table 2, shows that the thermit steel test specimens meet tensile test requirements of Navy Specifications 49S1 for Navy Class "B" steel for castings.

Conclusions

29. Facts Established:

a. "Forging Thermit" can be used for melting steel for pouring castings or ingots.

b. The amount of auxiliary equipment is small and can be largely improvised. No source of electrical or mechanical power is necessary.

c. The temperature of the metal produced can be adjusted from 4200°F., the estimated tapping temperature of straight forging thermit metal, to 3400-3500°F. (suitable for regular foundry use in green sand molds) by the addition

of extra steel punchings or by a double ladling system. The use of transfer ladles is preferred and is no problem as ladle equipment will be available at emergency bases where other metals are melted by conventional means.

d. Castings poured from thermit made steel pass Navy Class "B" steel specifications.

e. Foundry silica sand can be used for emergency lining of ladles and reaction crucibles. The lining should preferably be used only once. When used only once it will be fully as satisfactory as the magnesia-tar recommended by the Metal and Thermit Corporation. The only reason for not reusing silica sand linings is danger of silicon pick-up by the metal in subsequent heats.

30. Opinions.

a. "Incendiary Thermit" should never be used for making steel for castings.

b. Unit bags of thermit mixtures should not be split and used in part.

c. It is desirable to test a newly rammed reaction vessel after baking with a small trial charge, to be sure that it is properly lined and that no moisture remains in the lining or is present in the materials. Special care should be taken to ensure the absence of all moisture which might come into contact with the molten steel; otherwise an explosive reaction might occur.

Recommendations

31. It is recommended that all emergency units be provided with facilities for making steel by the thermit reaction.

32. It is also recommended that further research on the use of thermit for foundry application be authorized for the following reasons:

a. Relatively little work has been done to improve the thermit process as a means for melting metal for the past several years and none specifically designed to improve the process for foundry use.

b. It is conceivable that one reason for this lack of interest is the low cost of finished castings compared to the cost of thermit welding. Thus it seems desirable that the development work be done largely by a naval activity in cooperation with the Metal and Thermit Corporation.

c. The thermit process could be developed for making irons and many alloy steels as well as stainless steels, and a similar process could be developed for melting non-ferrous metals.

d. Thermit reaction vessels could be charged and maintained in foundries to add heat to cold ladles of metal to prevent "skulling" and to facilitate "shanking" operations.

e. Metal could be tapped from melting furnaces colder if heat could be added by pouring thermit steel into the ladle from a reaction vessel. This would preserve furnace linings which erode badly when high superheating temperatures are employed. Much research would be necessary to determine the possibilities of such a technique, and its effect upon the metallurgy of the molten steel.

f. More favorable slag conditions, higher metal yield, lower metal temperatures, and chemical compositions more favorable for casting purposes may be possible by variations in the thermit mixtures.

g. The effect of graded additions of metal punchings for purposes of temperature control and increasing metal yield should be more fully studied, as should the possibilities for direct tapping.

h. Methods for making alloy steels should be developed by reduction of the alloy oxides, by direct melting of ferroalloys in the reaction vessels, or by ferroalloy additions to the ladle while tapping.

i. Comprehensive metallographic studies should be made to determine the relative cleanliness of steels made by thermit and by ordinary melting processes.

BIBLIOGRAPHY

1. Welding Handbook, American Welding Society, 1942, pp. 524-555.
2. Anonymous, "The Thermoloy Process for the Manufacture of Steel Castings", *Engineering*, July 22, 1938, pp. 110-111, Vol. 146, No. 3784.

TABLE 1

Chemical Compositions of Heats

Heat No.	Charge		Chemical Composition						
	Forging Thermit	Lbs. Punchings	C	Mn	Si	Al	S	P	
M-1	75	25 (33%)	.22	.79	.10	1.36	-	-	
M-2	200	-	.79	.82	1.21	.27	-	-	
M-3	80	-	.22	1.03	.32	.44	-	-	
M-4	125	-	.22	.93	.41	.18	-	-	
M-5 through M-12				No chemical					
M-13	25	3-3/4 (15%)	.24	.76	.61	.83	-	-	
M-16	15	-	.19	.51	.69	.18	.061	.031	
M-17	15	-	.21	.84	1.63	1.20	.047	.031	
M-18	175	25 (15%)	.24	.82	.13	1.10	.050	.027	
M-19	225	34 (15%)	.26	.80	.17	0.02	-	-	
M-20 and M-21				No chemical					
M-22	225	30 (13.4%)	.21	.68	.60	.54	.046	.036	

NOTE:

- M-1 Steel received in a clay-graphite crucible after holding for one-half minute in the reaction crucible, after completion of reaction.
- M-2 Steel received in clay-graphite crucible. The extremely hot steel picked up carbon from the receiving crucible.
- M-3 Steel received in magnesia-tar lined crucible.
- M-4 Steel received in periclase-monoclase lined teapot ladle.
- M-13 Steel tapped directly from reaction crucible into mold.
- M-16 Heat made in reaction crucible with new silica lining.
- M-17 Heat made in same reaction crucible used for M-16.
- M-18 through
- M-19 Magnesia-tar lined reaction crucible and handling ladles.
- M-22 Magnesia-tar lined reaction crucible and handling ladles.

TABLE 2

Tensile Tests of Thermit Steel (Test Coupons)

Heat No.	Notes	Yield Strength PSI	Ult. Tensile Strength-PSI	Elong. Percent in 2"	Redn. of Area Percent	Heat Treatment
M-1	no additions	no indications	67,150	26.8	46.6	1700°F., 2 hrs., AC
M-1	Ti. and Al. added for deoxidization	"	"	66,150	25.3	45.5 1200°F., 2 hrs., AC
M-18	No additions	"	"	68,750	15.8	15.3 As cast
M-18	"	"	40,100	71,700	30.5	43.9 1700°F., 2 hrs., AC; 1200°F., 2 hrs., AC

Chemical Composition

Heat No.	C	Mn	Si	Al
M-1	.22	.79	.10	1.36
M-18	.24	.82	.13	1.10

TABLE 3

Essential Materials for Emergency Thermit Steel Castings

Rigging for supporting reaction crucible:

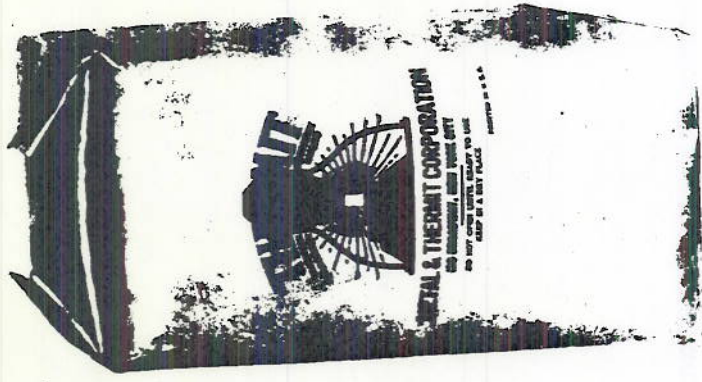
Timbers for tripod
Wire rope for lashing timbers
Chain hoist
Sling with hooks for hanging crucible

Melting and handling equipment:

Thermit reaction crucibles; appropriate sizes
Ladles for receiving and pouring - with shanks
Ignition powder
Thermit mixture and steel punchings
Ferroalloys
Tapping pin, plugging materials and thimble
Fuse and matches

Molding, etcetera:

Boards for flask
Carpenter's hammer
 nails
 saw
 hatchet
Wire with wirecutters
Reinforcing rods
Shovels
Molders' hand tools
Rammers
Riddles
Bentonite) Volume measuring cups for these materials -
Silica sand) standardized as to volume -
Mogul) weight relationship
Crowbars
Charcoal
Sheet steel
Cold chisel



FORGING
THERMIT

PLUGGING MATERIAL



IGNITION
POWDER

NOTE



THIMBLE
FOR RE-
ACTION
CRUCIBLE

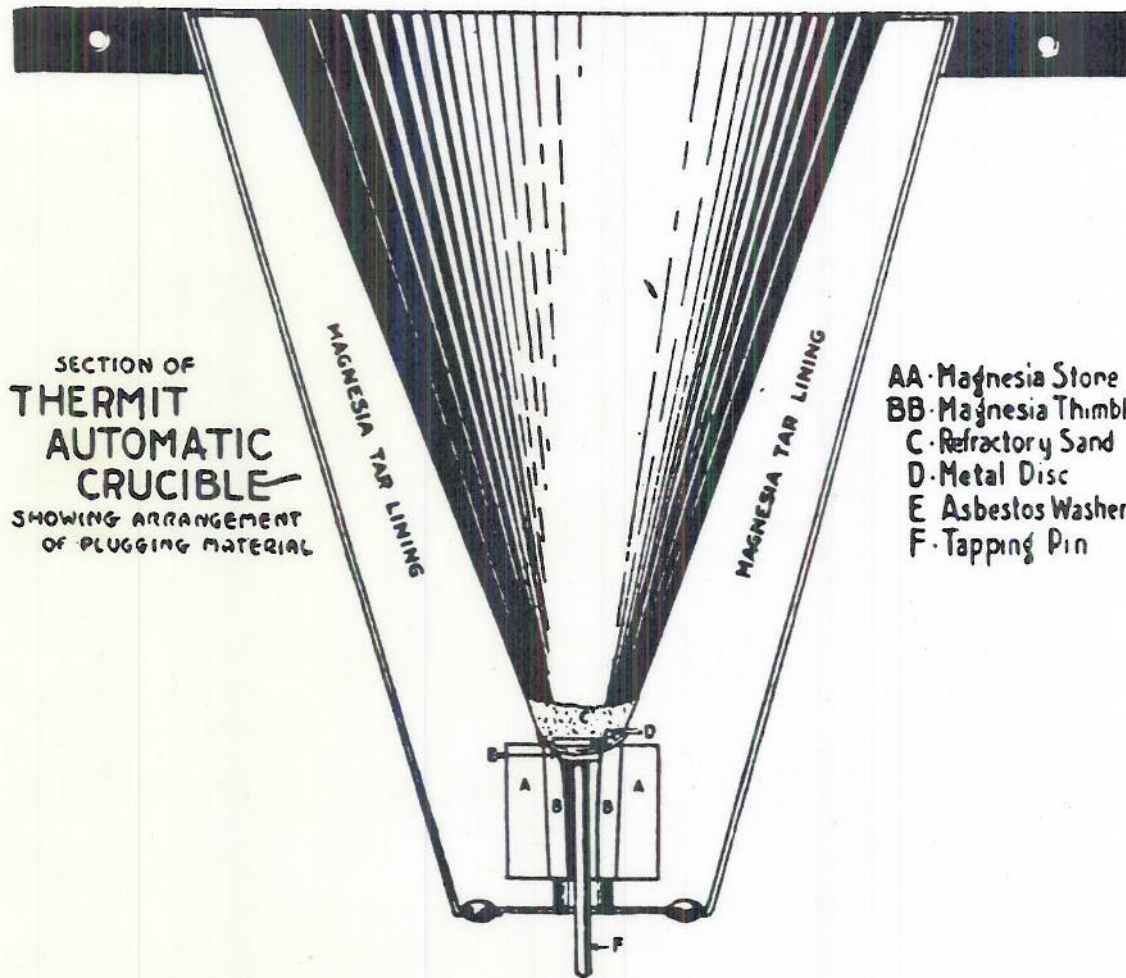


TAPPING
PIN

MATERIALS USED IN MAKING THERMIT STEEL CASTINGS

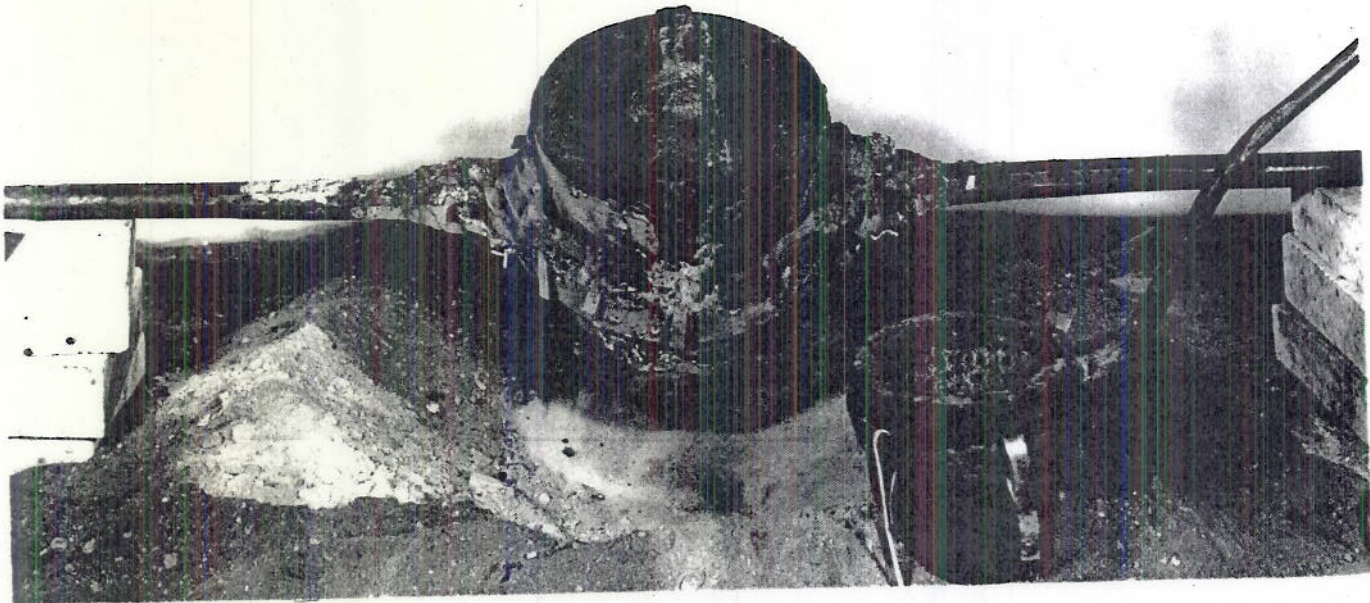


EQUIPMENT USED IN MAKING THERMIT STEEL CASTINGS

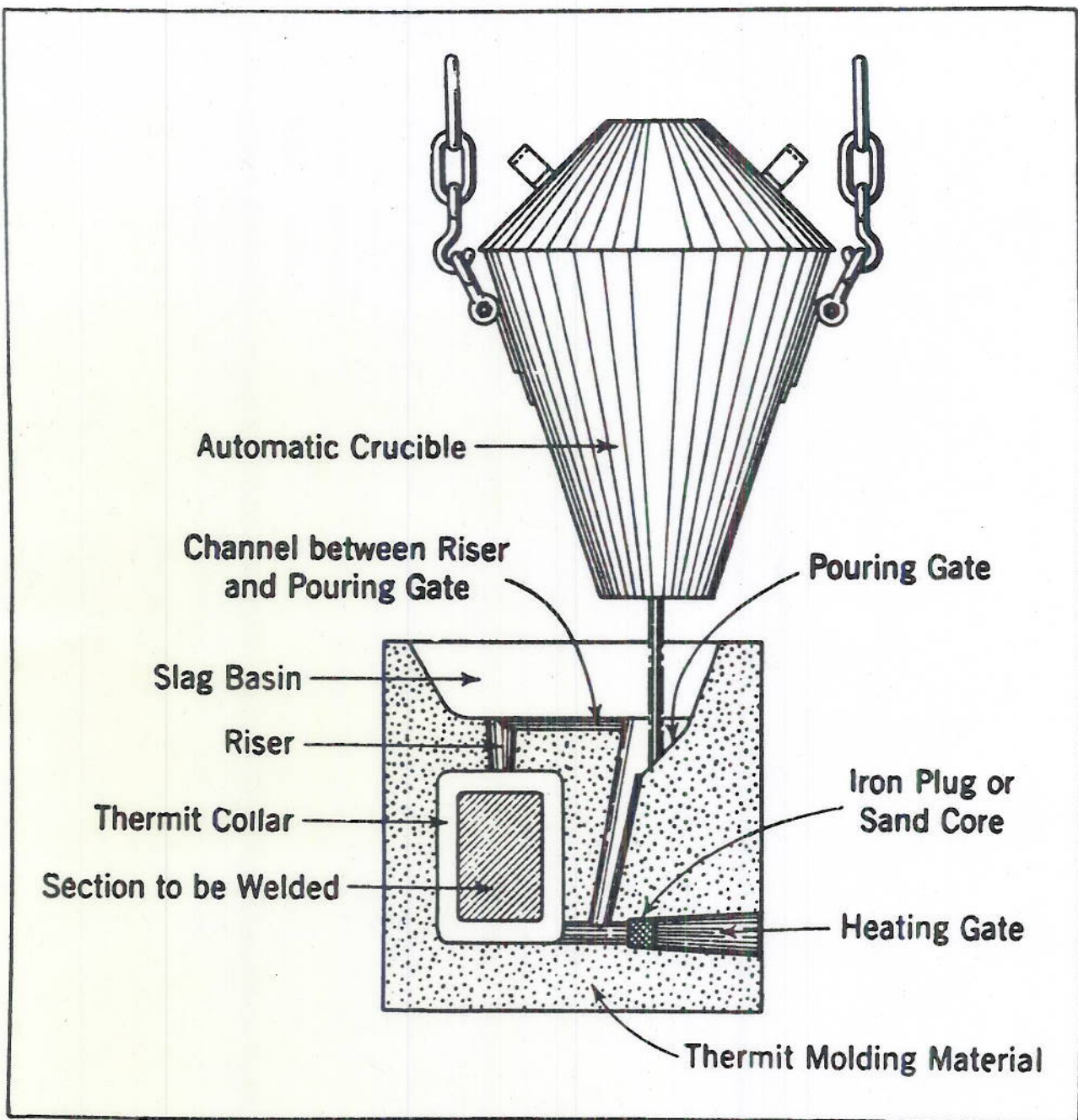


SECTION OF
**THERMIT
 AUTOMATIC
 CRUCIBLE**
 SHOWING ARRANGEMENT
 OF PLUGGING MATERIAL

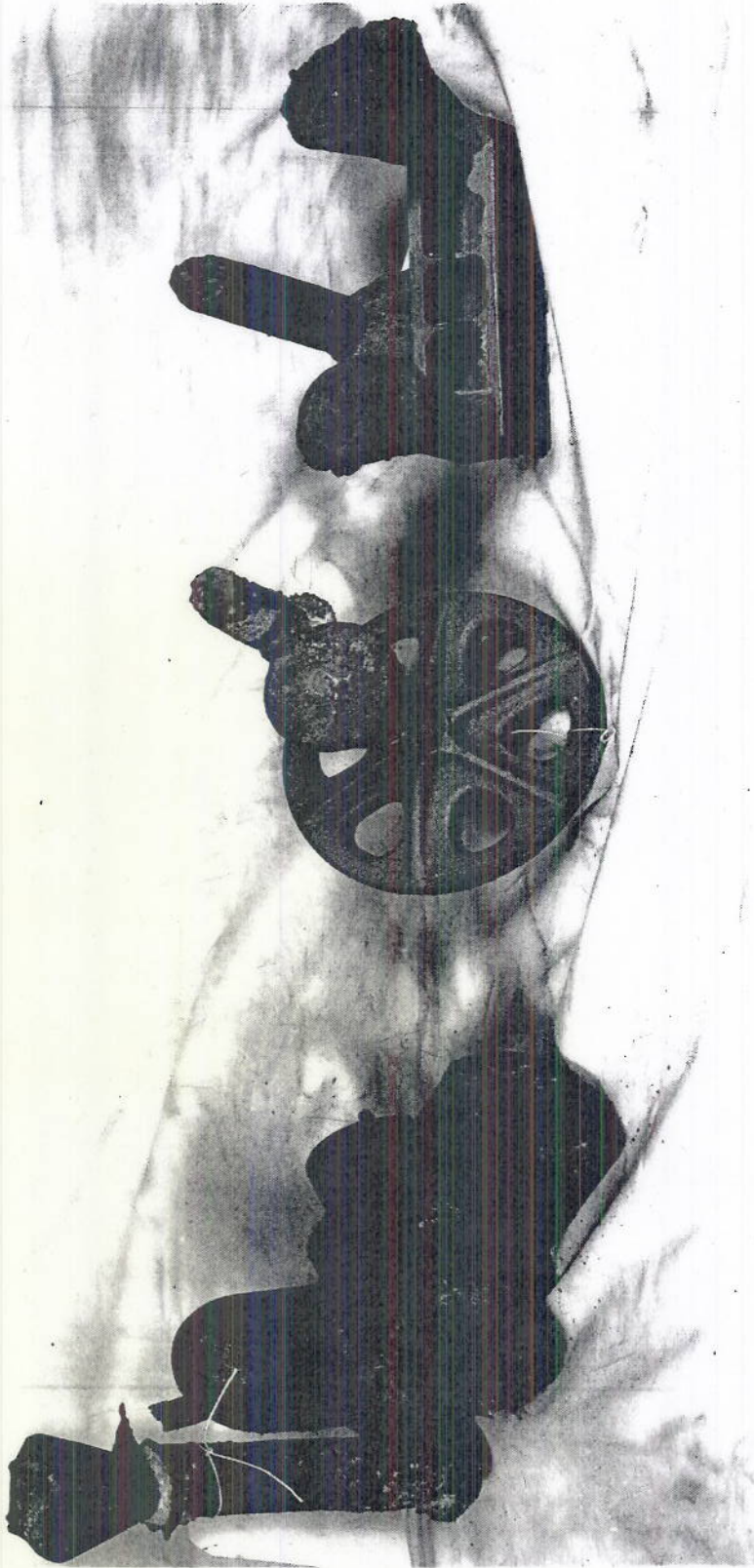
- AA · Magnesia Stone
- BB · Magnesia Thimble
- C · Refractory Sand
- D · Metal Disc
- E · Asbestos Washers
- F · Tapping Pin



EQUIPMENT ARRANGED FOR MAKING SMALL CASTINGS



ARRANGEMENT FOR MAKING THERMITE WELD



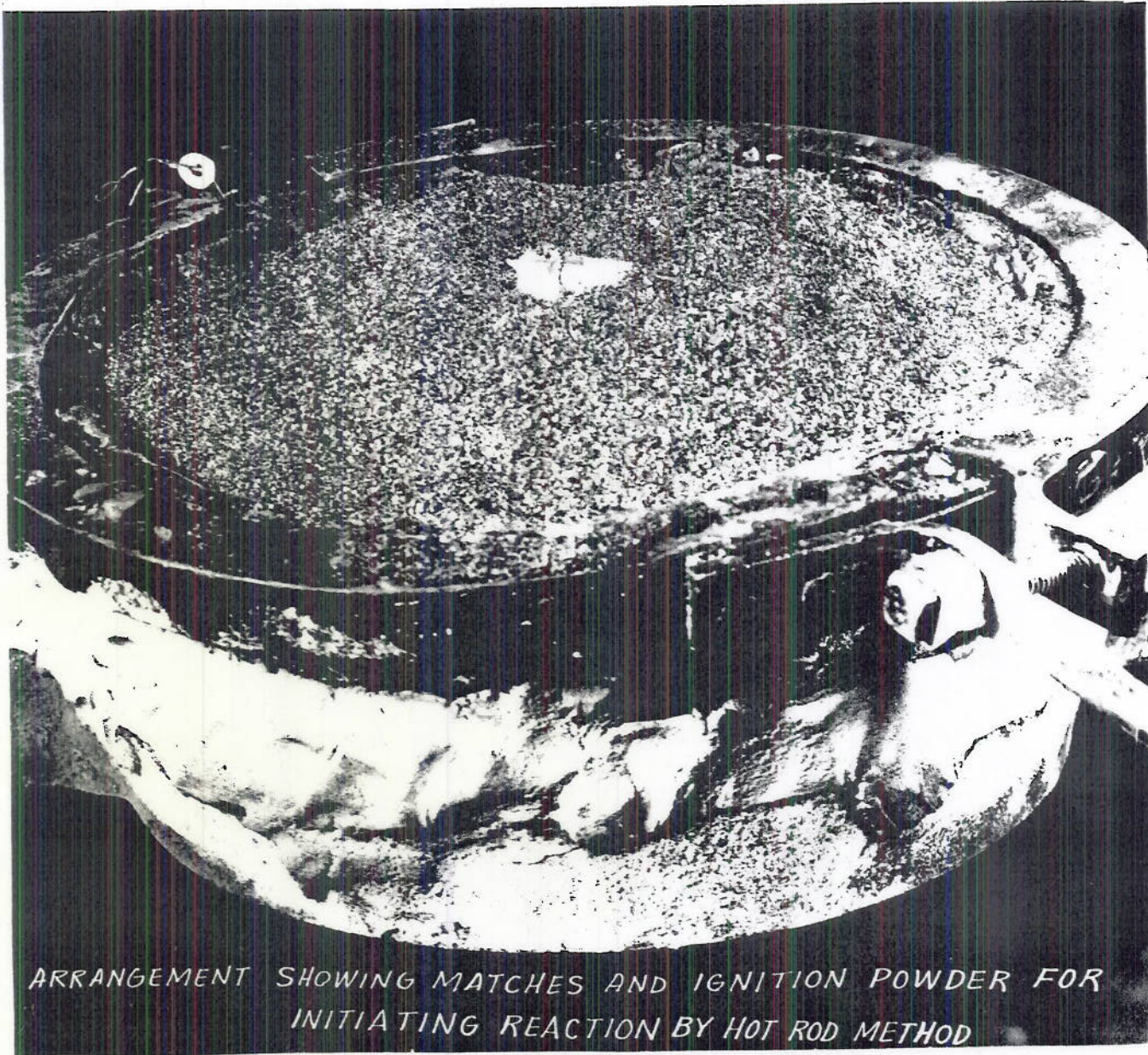
TYPICAL CASTINGS POURED WITH THERMIT STEEL



CASTING Poured WITH THERMIT STEEL



CHARGING STEEL PUNCHINGS AND THERMIT TO
#8N (ROUND BOTTOM) CRUCIBLE



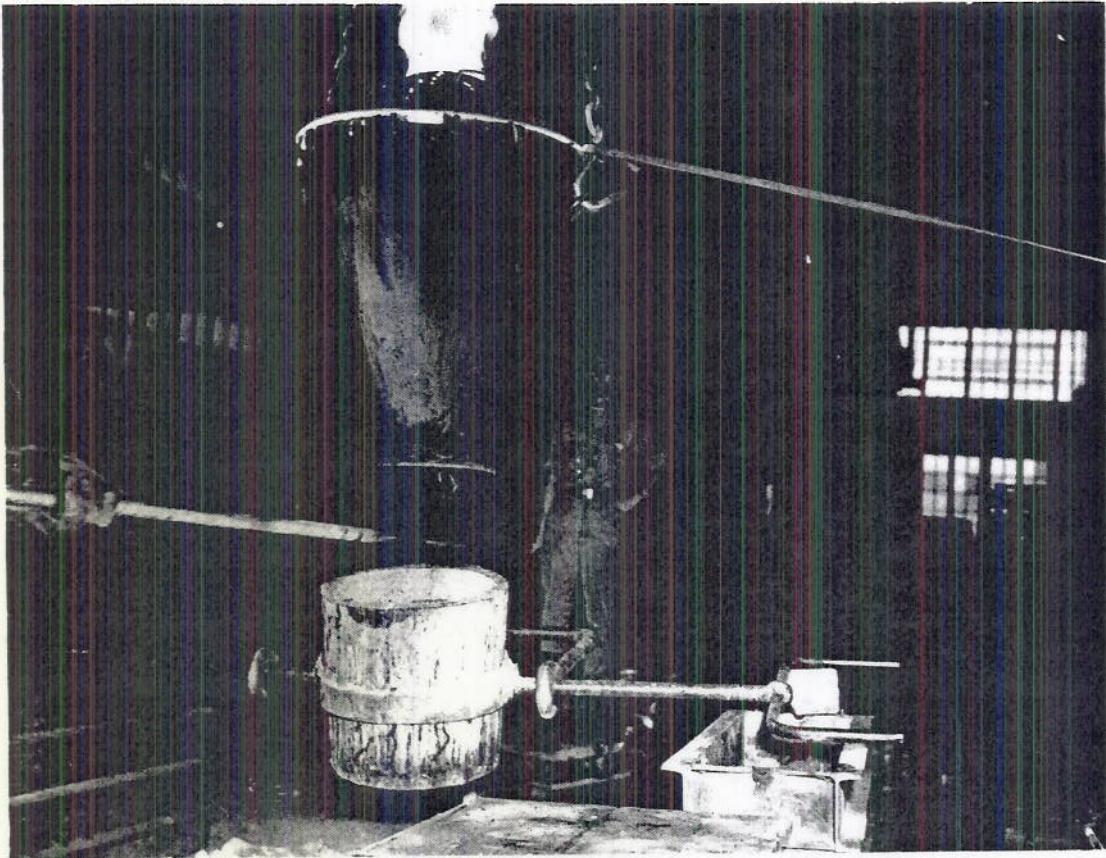
*ARRANGEMENT SHOWING MATCHES AND IGNITION POWDER FOR
INITIATING REACTION BY HOT ROD METHOD*



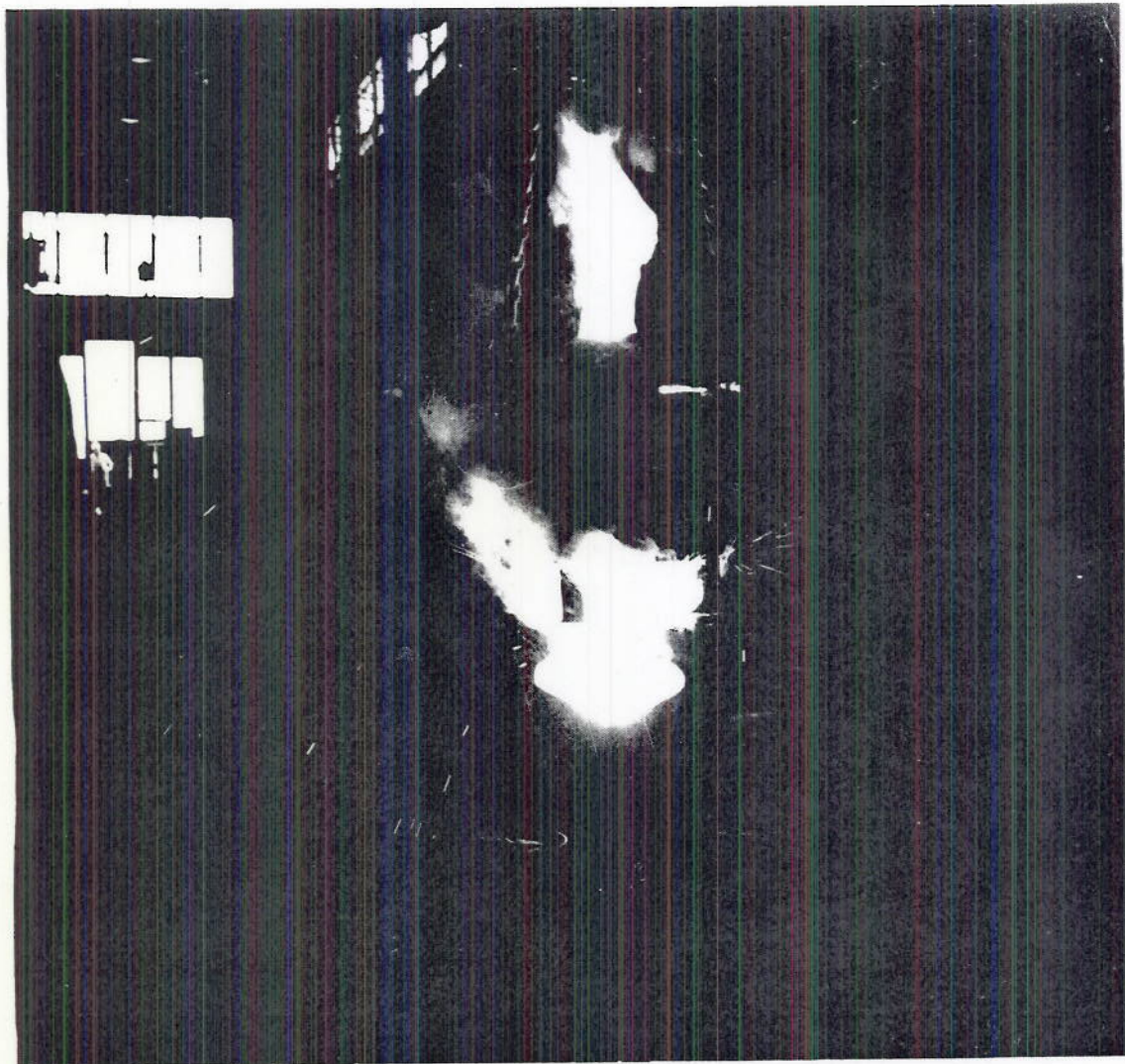
BEGINNING OF THERMIT REACTION



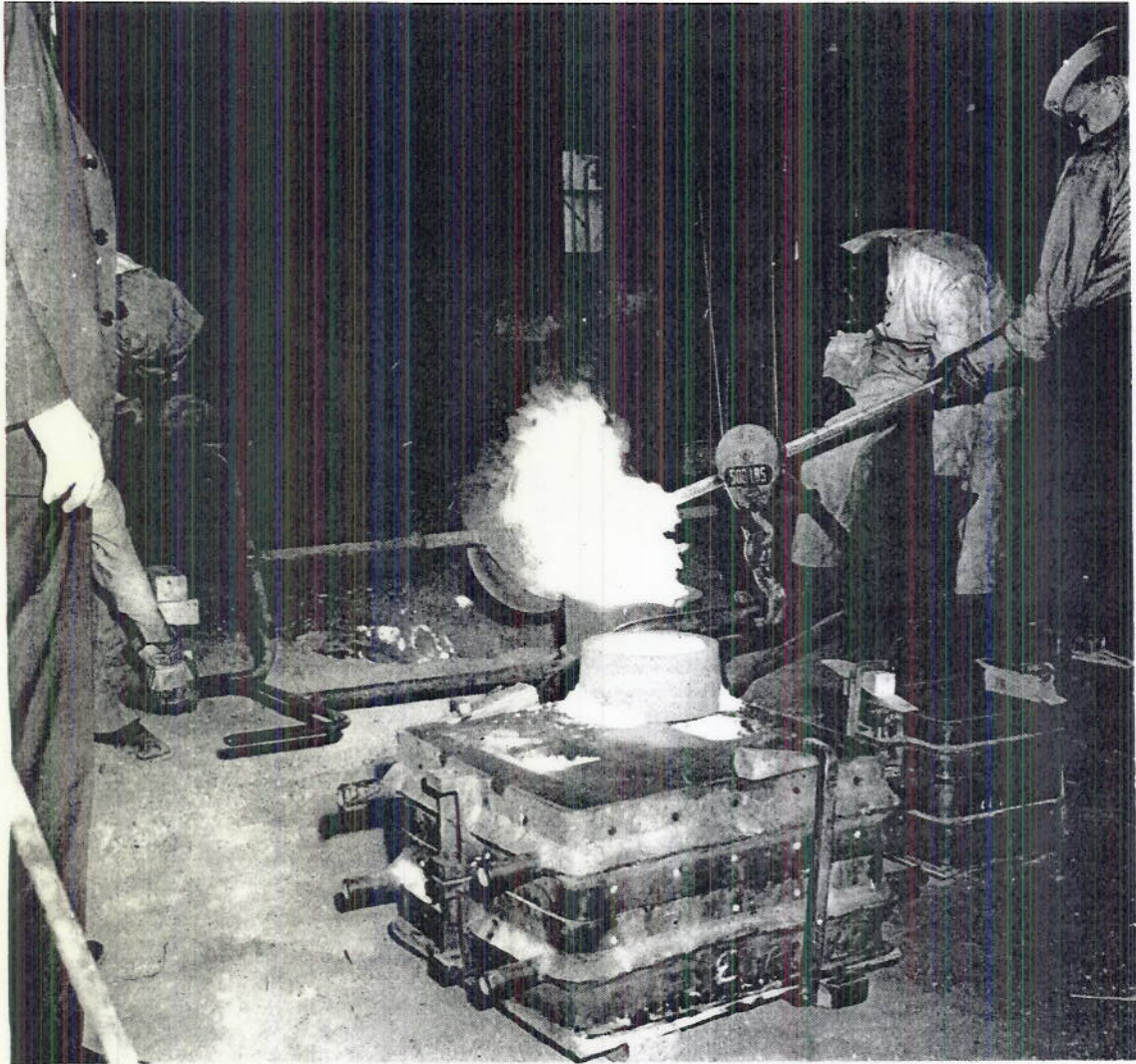
THERMIT REACTION APPROACHING COMPLETION



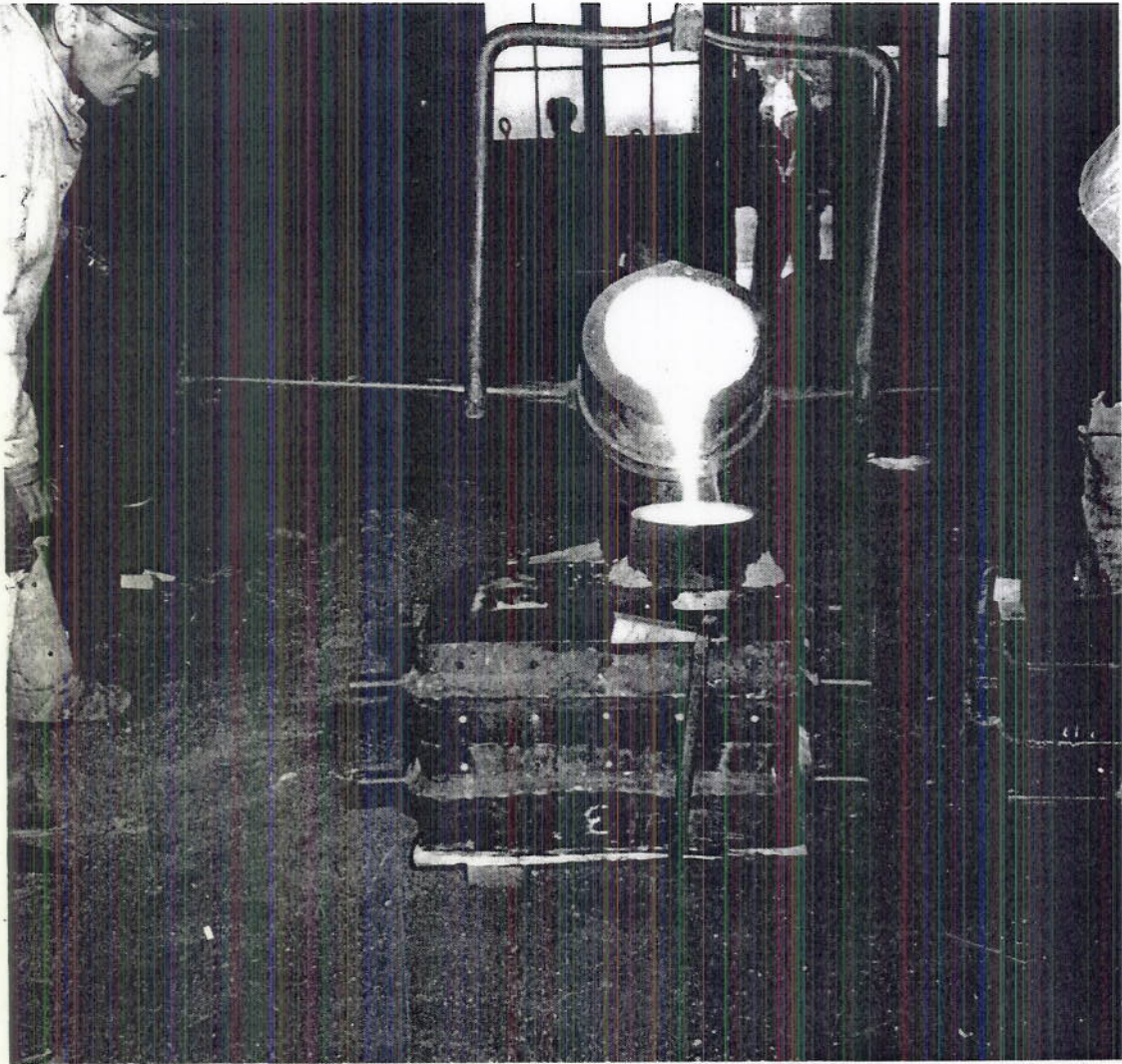
TAPPING THE THERMIT STEEL STEEL HEAT



STEEL FLOWING FROM THE REACTION CRUCIBLE



TRANSFERRING THE STEEL FROM THE
RECEIVING LADLE TO THE POURING LADLE



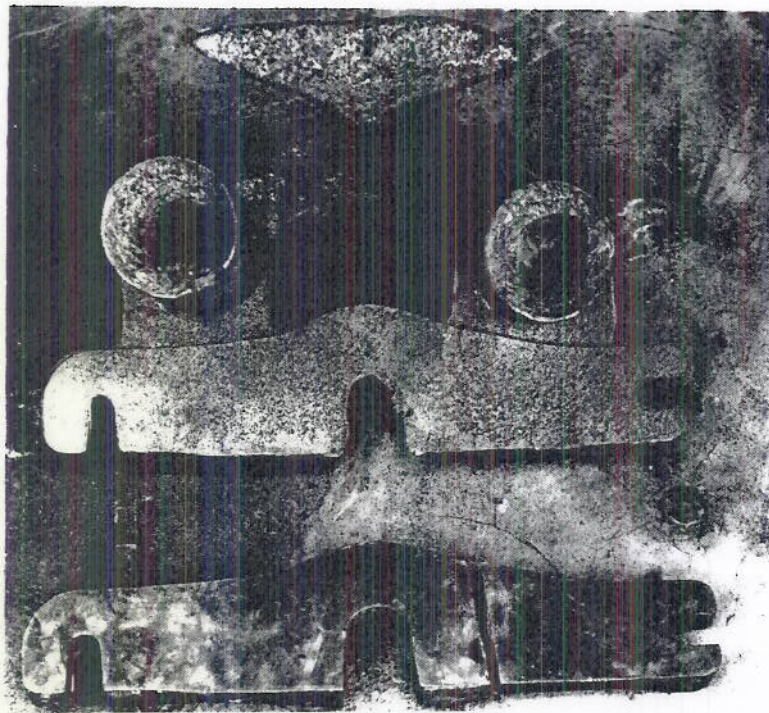
POURING THE CASTING



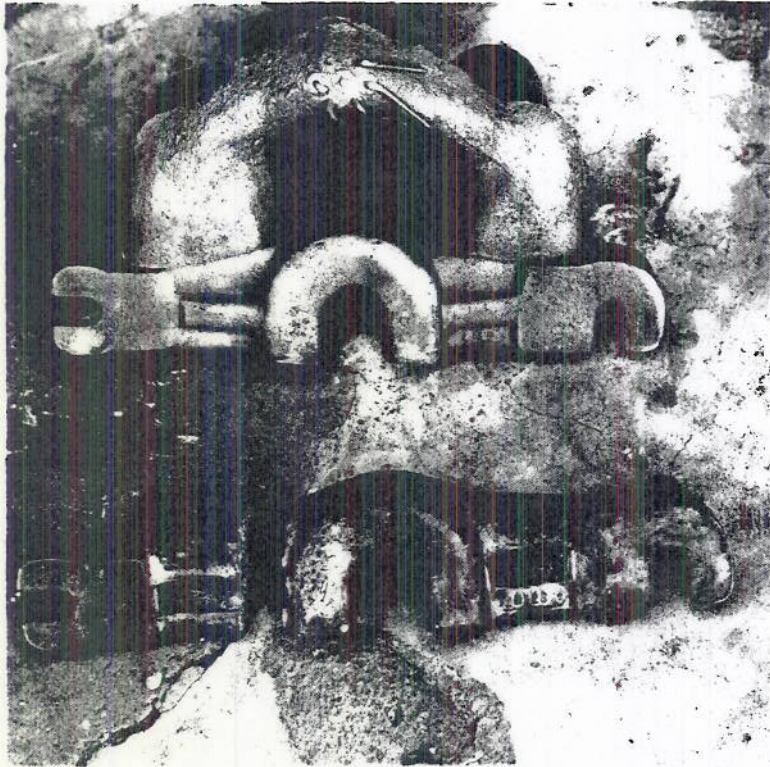
EMERGENCY RIGGING FOR MAKING A THERMIT STEEL HEAT



CASTING POURED INTO EMERGENCY MOLD



COPE VIEW OF CASTING MADE
AND OF BROKEN PART USED FOR PATTERN



DRAG VIEW OF CASTING MADE
AND OF BROKEN PART USED FOR PATTERN