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Research Report No. 49.

Experimental Zinc Die Casting Equipment

(Preliminary Work on Project Zn-4)

By

J. O. Edwards

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April 25, 1949

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"Experimental Zinc Die Casting
Equipment.
(Preliminary Work on Project Zn-4)"

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Ottawa, Ontario.
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568 Booth Street,
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RESEARCH REPORT NO. 49.

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(Preliminary Work on Project Zn-4)

By

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INTRODUCTION:

The die casting machine had been operating as a cold chamber machine working with magnesium and aluminum alloys since its installation in the Physical Metallurgy Research Laboratories in 1946.

In view of the joint research project with the Hudson Bay Mining and Smelting Company Limited on the effect of high purity zinc on the properties of zinc base die castings, it was necessary to convert the die casting machine for use with zinc base alloys, and to gain some experience in operation before the research project commenced.

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In the course of this conversion and preliminary operation of the machine, and in subsequent work, a number of difficulties were experienced, both with the machine and with the dies. It was decided that these troubles and their solution should be placed on record.

DIE CASTING MACHINE:

The machine is manufactured by the Cleveland Automatic Machine Company, at present in Cincinnati, Ohio, and was previously known throughout the die casting industry as the "G and N" machine.

The characteristics of the machine are tabulated in Schedule 1, shown on Page 18 at the end of this report. It will be appreciated that the machine can be converted for use either with a hot or a cold chamber by substitution of the necessary parts at the shot end, adjustment of the automatic timing system and adjustment of the valves of the hydraulic system.

The machine is fitted with both 1,000 psi and 2,000 psi pumps, but so far has been operated only on the 1,000 psi pump.

A general view of the machine set up for zinc (hot chamber) is shown in Fig. 1, and the shot end for this set-up is shown in Fig. 2.

Machine Operation -

The principle of zinc die casting, although well known, will be briefly outlined here, and is shown diagramatically in Figure 3.

At the start of the shot, the plunger moves down into the gooseneck and, in doing so, seals off the metal inlet holes. This enables pressure to be developed, and the metal trapped in the gooseneck is forced into the die through narrow vents cut in the die blocks. As the die is filled, air trapped in the die escapes through the nozzle. Finally these vents are blocked with zinc, and the full pressure developed by the hydraulic system is transmitted through the plunger and liquid metal in the gooseneck to the metal freezing in the die cavity. Thus, the casting solidifies under pressure. The pressure on the plunger is then released and reversed so that the plunger travels towards the top of the gooseneck, the die is opened, and the casting is ejected. The liquid metal in the pot refills the gooseneck as soon as the plunger is clear of the inlet holes.

Metal Leakage Past the Plunger Ring -

The conversion of the machine from cold to hot chamber was satisfactorily accomplished, but on operating the machine it was found that there was considerable leakage of metal past the plunger ring. The plunger ring acts like a piston ring in an internal combustion engine and should give a tight joint and prevent

 metal leaking past the plunger. The machine was operated a

number of times in the hope that the ring would seal itself, but the leak became worse so that each time a stroke was made a jet of molten zinc shot from the top of the gooseneck. Consequently, the machine was shut down and the plunger and ring were examined. No apparent defects were observed, but it was noticed that the width of the ring slot in the plunger was only 0.001 in. greater than the width of the ring, and it was thought that the ring might not operate freely at casting temperature. It was also suspected that the ring may have become damaged or distorted in the long period of storage. A new ring was fitted which had about 0.004 in. clearance on the width but this was found to be no better than the original.

It was then suspected that the hydraulic system might not be in complete alignment with the gooseneck and plunger, and that this might be responsible for the poor seal between the plunger ring and the cylinder wall of the gooseneck. A number of shims were inserted under the gooseneck until it was perfectly level, and this caused considerable improvement, although a slight leakage still persisted.

<u>Metal Leakage in the Die and Nozzle</u> -

With these several improvements, it was found that the greater pressure developed in the molten metal resulted in leakage of metal past the faces of the die below the sprue. All adjustments of the platen of the die casting machine failed to stop this leakage, and examination of the die showed considerable roughness on the die block although the die inserts were in good condition. The die in use was the three-cavity test bar die illustrated in Fig. 4. It is probable that some drops of metal or flash had not been properly cleared from the working face of the die, particularly just below the sprue, when the machine was operating with magnesium. This would cause deformation and eventual damage of the die block which is relatively soft. Since no trouble was experienced using the same die for magnesium or aluminum, it is probable that the greater fluidity of the zinc alloys necessitates a more perfect fit of the various parts of the die. It was first thought that the surfaces of the die blocks would have to be reground and the inserts refitted. However, by putting a shim 0.004 in. thick beneath the sprue pin insert, a positive seal was obtained between the two sprue inserts in the cover and ejector half of the die, and the leak was stopped.

With the machine and die operating under these conditions, test bars of satisfactory appearance and structure were obtained, but, due to the increased pressure in the system through stopping the leaks at plunger and die, it was found that leakage developed between the gooseneck and the nozzle.

This leak was stopped by inserting a thin asbestos paper washer in the spherical seating between the gooseneck and the nozzle. Although this worked effectively, it was considered to be only a temporary expedient, and eventually the nozzle was ground into the seating with carborundum paste to make an effective seal.

Sticking of the Plunger in the Gooseneck -

The machine operated well for a short period, then the plunger stuck in the gooseneck. The metal temperature in the pot is controlled by a thermocouple which fits into a well in the cast iron pot. This works through a controller which actuates an on-off valve in the gas burner which maintains the temperature in the pot. During the operation of the machine, the thermocouple had gradually worked towards the top of the well until it was above the metal level, and consequently the metal temperature was considerably in excess of that shown on the instrument. Attack of steel or cast iron by molten zinc and its alloys increases very rapidly at temperatures in excess of 400°C, and it is thought that this factor, coupled with possible mechanical defects in the plunger, was responsible for the seizing of the plunger in the gooseneck. All attempts to free the plunger by heating, solution of the zinc in caustic soda, etc., failed, and the plunger had to be bored out, the gooseneck wall refinished, and an oversize plunger machined, polished and installed.

This new installation worked satisfactorily for a brief period, but it was noted that the bore of the cylinder in the gooseneck appeared to be slightly tapered so that the plunger was a

6 spaces left

tighter fit at the bottom of the stroke than at the top. Eventually, as the machine was used, the leakage past the plunger ring increased, and on each stroke the piston moved farther into the gooseneck until it eventually seized again.

New Gooseneck and Plunger -

In the meantime, a spare gooseneck and plunger had been acquired and these were fitted to the machine. This incorporated two new features, one being that instead of one plunger ring 1-1/4 in. wide, two rings about 1/2 in. wide were fitted. (It was learned subsequently that the latest models incorporate six stainless steel rings operating in three slots.) This arrangement proved to give a much better seal than the one wide ring. Also, a bar was forged into the plunger so that only a limited stroke was permitted. This prevents the end of the plunger from being forced into contact with the base of the gooseneck as plunger rings become worn and the plunger travel increases.

Consequently, when the original gooseneck and plunger were bored out and remade these features were incorporated. It was found easier to bore out the whole of the cylindrical insert in the gooseneck casting, and replace it with a new finished to size, than to try to bore out the plunger and reface the original insert while still in the gooseneck. The replacements were made from a good grade of cast iron of the meehanite type.

When the new gooseneck and plunger were put into operation, cast iron rings were fitted. These cracked after the first few shots and were replaced with a nickel-bearing alloy steel. These rings have been in continuous use for a long period and are now showing signs of wear, as indicated by an increased amount of metal leaking back past the rings.

Miscellaneous Troubles and Defects -

It was noted that, as time passed, the nozzle of the die casting machine was being increasingly eroded by the molten zinc. Eventually, a fine longitudinal crack developed through which metal was forced under pressure and the nozzle had to be replaced.

After operating for a period of approximately six months, the cast iron pot holding the molten zinc failed, partly by solution and partly by cracking. A new pot was installed and the single large central gas burner heating the pot was replaced by the small side burners, each having half the capacity of the original burner. It was thought that this would ensure a better heat distribution during melting and would minimize local overheating of the pot. The new arrangement works quite well, but due to the position of the thermocouple well, which is now directly over the top of one of the burners, the metal takes longer to melt than it did previously.

It was found that the hydraulic oil became quite hot during long runs, and subsequent examination showed that the water cooling system for the hydraulic oil was linked directly to the water cooling on the dies and platen. It was necessary therefore to ensure adequate cooling of the hydraulic oil, and to do this a number of additional water lines were installed which made the oil cooling more or less independent of the die cooling.

Apart from occasional replenishing of the nitrogen accumulator, and hydraulic oil, and routine maintenance such as greasing, cleaning and checking the tightness of various nuts and bolts, the machine itself has functioned without any trouble. It was noted that under some circumstances particularly when the machine had been operated, left standing for a period, and again operated, the plunger would make a shot with the die open. This was extremely hazardous to the operator of the machine. No satisfactory examination of this occurrence could be worked out from the electrical automatic timing system or from the hydraulic system, but it was thought that a slight leak in one of the many valves built into the machine was responsible. It was found that the procedure of opening and closing the die, once or twice before opening the valves to the shot end, prevented this phenomenon. Also, removal of the plunger until the machine was known to be operating successfully eliminated the hazard.

Occasionally, trouble was experienced with the temperature control instrument. Although only of a minor character, such troubles require immediate attention since accidental overheating of the zinc in the pot results in damage to the pot, the gooseneck and plunger, and to the alloy and coatings themselves. Furthermore, the overheated alloy, even when cooled to correct casting temperature, tends to give inferior castings.

During this development period, visits were paid to the Tool and Die Engineering Company, Cleveland, Ohio, and the Precision Castings Co. Inc., Fayetteville, N. Y. (see Memorandum No. V-193), also to the Schultz Die Casting Company of Canada Limited, Wallaceburg, Ontario (see Memorandum No. V-205). At each plant much was learned about the technique of die casting, the operation of machines, and the use of materials for dies, lubricants, etc.

DIE CASTING DIES:

Three-Cavity Test Bar Die -

This die is illustrated in Fig. 4 and is based on a design by Werley of the New Jersey Zinc Company. The die had been in operation with magnesium and aluminium alloys for a period, and on changing the sprue inserts for use with zinc, trouble was experienced due to metal leakage, as already outlined. Apart from this difficulty, which was quickly solved, the die has worked continually and successfully, only two other faults being detected.

The worst of these from a practical stand point is the design of the ejector system. As shown in Fig. 4, the ejector is a rack-and-pinion device, working on the centre of the ejector plate. There are no stable guides for this plate, and consequently when a torque is applied to the ejector pinion this torque is transmitted to the ejector plate, which rocks and causes binding of the ejector pins and return pins. Unfortunately, the ejector mechanism is built into the die in such a position that it cannot be easily adapted for satisfactory automatic ejection without considerable modification of machine and die. Because of this fault ejection has at all times been difficult, but actual sticking of the casting in the die has only rarely occurred.

The other fault concerns the 9 in. impact bar. Because of the length of this bar and the absence of any special facilities for accurate temperature control, it was found that the metal in the impact bar cavity cooled more rapidly at the top of the bar than at the bottom. This rapid cooling gave superior properties to the top 3 in. impact bar. Because of this feature, for certain work it was decided to reject the top portion of the impact bar, in case the high properties were not typical of industrial practice. In continuous operation, these differences were smoothed out somewhat, but to maintain perfectly uniform thermal conditions in the 9 in. impact bar required very close control of die temperature, water cooling, metal temperature, cycle time, etc.

Although the tensile bar is of the same length, the gauge length which is the only critical portion of the bar is only 2-1/2 in. long.

Castings from this die are photographed in Figs. 5 and 6. The centre bar is a waster bar designed to improve the heat distribution of the die.

Two Cavity Die -

This die was based on a design submitted by the Precision Castings Company Inc., Syracuse, N. Y., to ASTM Committee B-6. The die is illustrated in Figs. 7 and 8. Initially, half of the full hexagon gate was inserted, and sound castings were produced. The full hexagon gates gave less satisfactory results, and since neither of these gates was of conventional design it was decided to replace them with gates similar to those shown in Fig. 4.

The die was received from the die makers without vents. These were cut at the Bureau of Mines, as shown in Fig. 7. The overflow well at the top of the impact bar was also cut, in an attempt to clear porosity found in the bar. A large number of trials were made, with the depth of gates being progressively increased from 0.035 in. to 0.080 in. in an attempt to clear the porosity present in the impact bar. These efforts were not completely successful and it was eventually decided to suspend work on the two-cavity die, and return to the old three-cavity die, until more time was available for development work. In addition to these trials directly connected with gating and venting, a considerable amount of work on the working-in of the new die was also carried out. This entailed such factors as polishing out undercuts, relieving the ejector system, etc. Castings from this die are illustrated in Figs. 9 and 10.

<u>ASTM Test Shape Die</u> -

This die was developed by the Hoover Company in co-operation with ASTM Committee B-6 in an attempt to produce a casting which would incorporate all the difficult factors encountered in die castings. Such factors as thick bosses connected to thin members, large flat surfaces, deep cored holes, sharp angled corners, etc., are incorporated and the die is designed primarily for work with aluminium. A drawing of the die is shown in Fig. 11.

Initial operation of the die revealed considerable trouble due to sticking of the aluminium casting in the mould. With zinc alloys, due to the self-lubricating property of the zinc and to its low melting point, a sticking casting can usually be freed by pulling or melting out. With aluminium, however, none of these methods was successful, and it was found to be quicker to dismantle the die and remove the casting. Thus, considerable time was required to ensure free ejection of the casting by polishing and grinding out undercuts, increasing the taper on core pins, etc. Work had just been started on the gates and vents, when the zinc project was undertaken. At this stage, the castings were of reasonably good surface finish but contained some porosity, and were in fact similar to commercial castings. Since the zinc castings were required for plating tests only, where surface finish is the main essential, no further development work was undertaken to remove the porosity at this stage.

An automatic ejection system was fitted to this die when it was certain that the ejector system was working freely, and this has functioned without trouble, ensuring a larger number of shots per hour with less work for the machine operator. Castings from the die are shown in Figs. 12 and 13.

<u>Lubrication</u> -

In general, "Die Slick No. 11" has been the basic lubricant used in the tests, and this is applied to the die and ejector pins, by means of a spray gun or a brush at suitable intervals. The lubricant works well, and retains its action over a long period, but tends to leave a resinous deposit on the die faces which must be periodically cleaned off.

An Aquadag-type lubricant had been used earlier for the die cavity, working with zinc or aluminium, and although this gave easy ejection, there was a tendency to stain or discolour the castings, and the material was abandoned.

Lustan 41, Caloria 150, and Caloria 675 were suggested as die lubricants by the Imperial Oil Company. Lustan 41 was not used since it contained graphite which, it was feared, would cause staining. Caloria 150 proved to be much too volatile and had little or no lubrication value for die temperatures about 200°C. Caloria 675 was a heavier grade, and although it had some lubricating properties, this material was again highly volatile so that the lubrication did not persist beyond one or two shots after the application. It may be remarked that neither of these Caloria materials left any residue and therefore might be suitable as carriers for graphite lubricants, if necessary.

ANCILLARY EQUIPMENT:

In addition to the die casting machine, other equipment was necessary in order to prepare the alloys.

Fisher Tilting Furnace, Type HNP -

This furnace, illustrated in Fig. 14, was installed in order to melt down the zinc sheets for the preparation of the die casting alloys. The furnace is of normal design and is fitted with a combination oil-gas burner. The furnace was gas-fired during the project, the flame being controlled by the usual gas/air proportioning valve and a hand-operated throttle on the air line.

All melting was carried out in a No. 400 Tercod crucible, the maximum operating capacity of the equipment being about 900 lb zinc. The tilting mechanism is hydraulically operated and enables very close control of the pouring rate to be obtained.

After melting and alloying, the metal was cast into ingots in the moulds shown in Fig. 14. The moulds were not filled so that the ingots were small enough to be easily handled.

Melting and alloying procedures are covered in Research Report No. 50, entitled "The Mechanical Properties of Zinc-base Die Casting Alloys of Very High Purity".

<u>Fisher Sulphur Dome Furnace</u> -

This is a normal fixed type, gas-fired crucible furnace fitted with a fume extractor hood and a cast iron pot cover to provide sulphur dioxide atmosphere when melting magnesium. This dome, together with the steel pot, was removed and a special Tercod bowl was used for melting zinc. This bowl had a capacity of about 300 lb zinc, ingots being cast using a hand ladle. This furnace, illustrated in Fig. 15, was used for melting aldehyde or mercury base zincs in order to avoid heavy contamination of the foundry with zinc fume or mercury vapour.

Hardeners for the ASTM Type XXV alloys were made in a small Tercod pot in a gas-fired crucible furnace.

CONCLUSIONS:

In conclusion, it may be said that in carrying out the research project on the effect of metal purity on the properties of zinc base die castings, considerable additional information and experience have been gained in the operation of die casting equipment.

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(An appended Schedule I, and Figs. 1 to 15, follow, on Pages 18 to 29.)

SCHEDULE 1

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GENERAL SPECIFICATIONS FOR

Cleveland-Made

High-Pressure Hydraulic Diecasting Machines for

	ALUMINUM, BRASS AND MAGNESIUM ALLOYS	LEAD, TIN AND ZINC ALLOYS
Size of Die Plates	36″ and 38″	36″ and 38″
Space between Bars	24″ x 24″ centers	24″ x 24″ centers
Die Opening	6″ to 12″	6″ to 12″
Max. Die Space	36″	36″
Min. Die Space	6″	6″
Die Closing Cylinder Dia	4½″	4½″
HP and Speed of Motor	10 HP—1200 R.P.M.	10 HP—1200 R.P.M.
Gals. per min. at 300 lbs	43	43
Plunger Oil Available at 1000 lbs. per sq. in	8 gals.	8 gals.
Tie Bar Diameter	4″	4″
Accumulator tank capacity	5000 cu. in.	5000 cu. in.
Oil reservoir capacity	65 gals.	65 gals.
Die and Rear Plates	5″ thick steel	5″ thick steel
Base Dimensions	48″ x 192″	48″ x 192″
Weight of machine	Approx. 19,000 lbs.	Approx. 19,000 lbs.
Shot Piston Diameter	6″	4″
Area	28″	12.566 sq. in.
Pressure	28,000 lbs.	12,500 lbs.
Stroke	11½″	7″
Effective stroke	9″	7″
Estimated Locking Pressure	800,000 lbs. plus	800,000 lbs. plus

ALUMINUM, BRASS AND MAGNESIUM MACHINE

Plunger Diameter		Pressure on Metal Lbs. per Sq. In. 1,000 Lb. Pump	Pressure on Metal Lbs. per Sq. In. 2,000 Lb. Pump	Cu. In. per Shot	Weight in Aluminum, Lbs.	Max. Area of Casting, Sq. In. 1,000 Lb. Pump	Max. Area of Casting, Sq. In. 2,000 Lb. Pump
1½	1.77	15,500	31,000	15.9	1.5	44	22
1⅝	2.07	14,000	28,000	18.6	1.8	50	25
1¾	2.41	11,500	23,000	21.7	2.1	60	30
1⅞	2.76	10,000	20,000	24.8	2.4	70	35
2	3.14	9,000	18,000	28.3	2.7	78	39
2⅛	3.55	8,000	16,000	31.9	3.0	86	43
2¼	3.98	7,000	14,000	35.8	3.4	98	49
2⅜	4.43	6,300	12,600	39.9	3.8	110	55
2½	4.91	5,600	11,200	44.2	4.2	121	61
2¾	5.94	4,600	9,200	53.5	5.1	145	73
3	7.07	4,000	8,000	63.6	6.0	175	88

LEAD, TIN AND ZINC MACHINE

Plunger Diam.	Pressure on Metal Lbs. per Sq. In.	Cu. In. per Shot	Weight in Zinc, Lbs.	Maximum Area of Casting Sq. In.
1¾	4,800	18	4.5	140
2	4,100	23½	5.9	160
2¼	3,100	30	7.5	220
2½	2,500	37	9.3	260
2¾	2,100	45	11.7	300
3	1,700	52½	13	320
3¼	1,500	62	15.5	350
3½	1,300	72	18	400

EXTRAS:

Complete furnace melting equipment can be furnished for all metals.
Electrical timing attachment for automatically timing the cycle of operation can be furnished at an extra price upon application.
A high pressure pump with 2,000 lbs. per sq. in. pressure can be furnished at an extra cost upon application.

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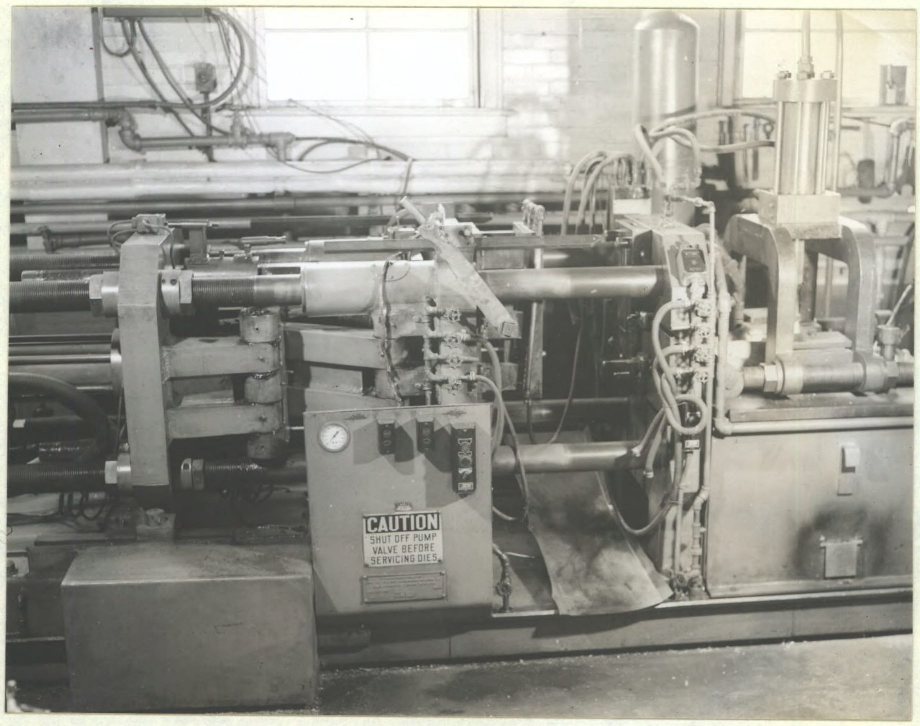
Fig. 1.



General view of zinc die casting machine, showing toggles, which operate the die; controls; die mounted on platens; and shot end.

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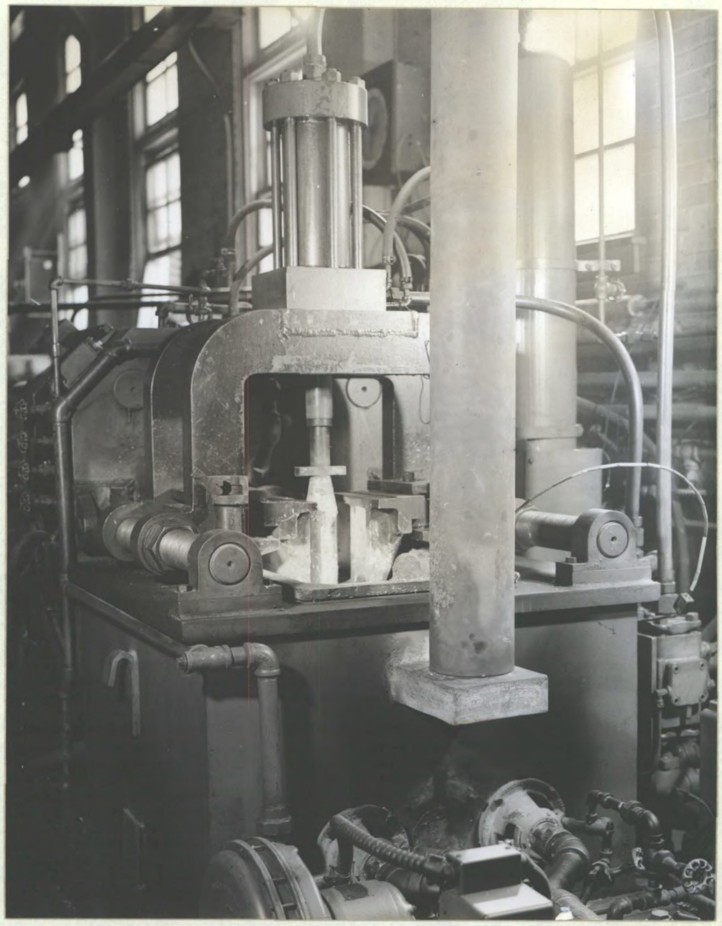
Fig. 2.



Showing shot end of zinc die casting machine including melting furnace, plunger, and hydraulic system

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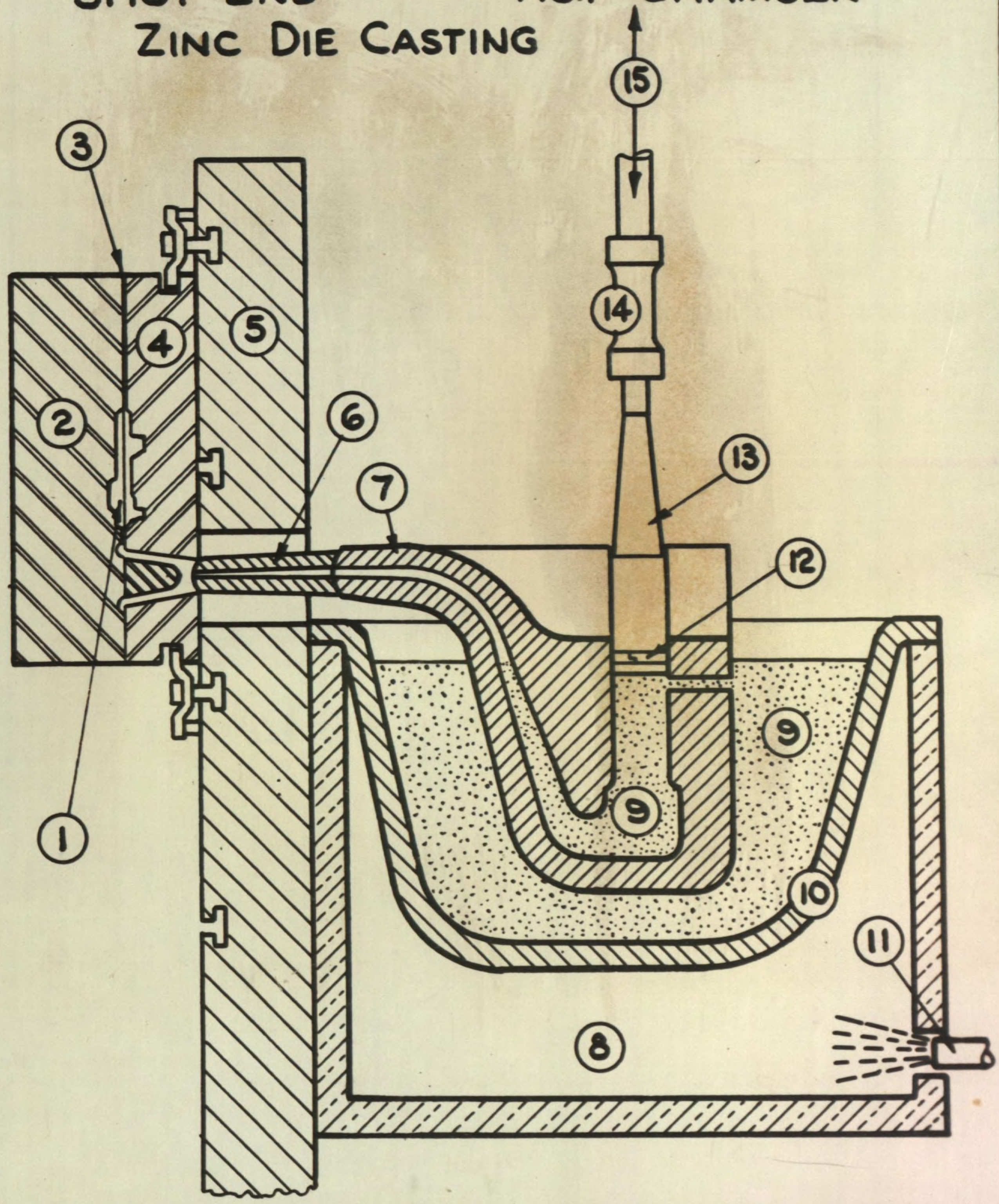
FIGURE 3

SHOT END HOT CHAMBER ZINC DIE CASTING



1. DIE CAVITY
2. EJECTOR HALF OF DIE.
3. VENTS.
4. COVER HALF OF DIE.
5. STATIONARY PLATEN.
6. NOZZLE.
7. GOOSENECK.
8. MELTING FURNACE.
9. ZINC.
10. CAST IRON POT.
11. BURNER.
12. PLUNGER RING.
13. PLUNGER.
14. FLEXIBLE LINKAGE.
15. HYDRAULIC SYSTEM.

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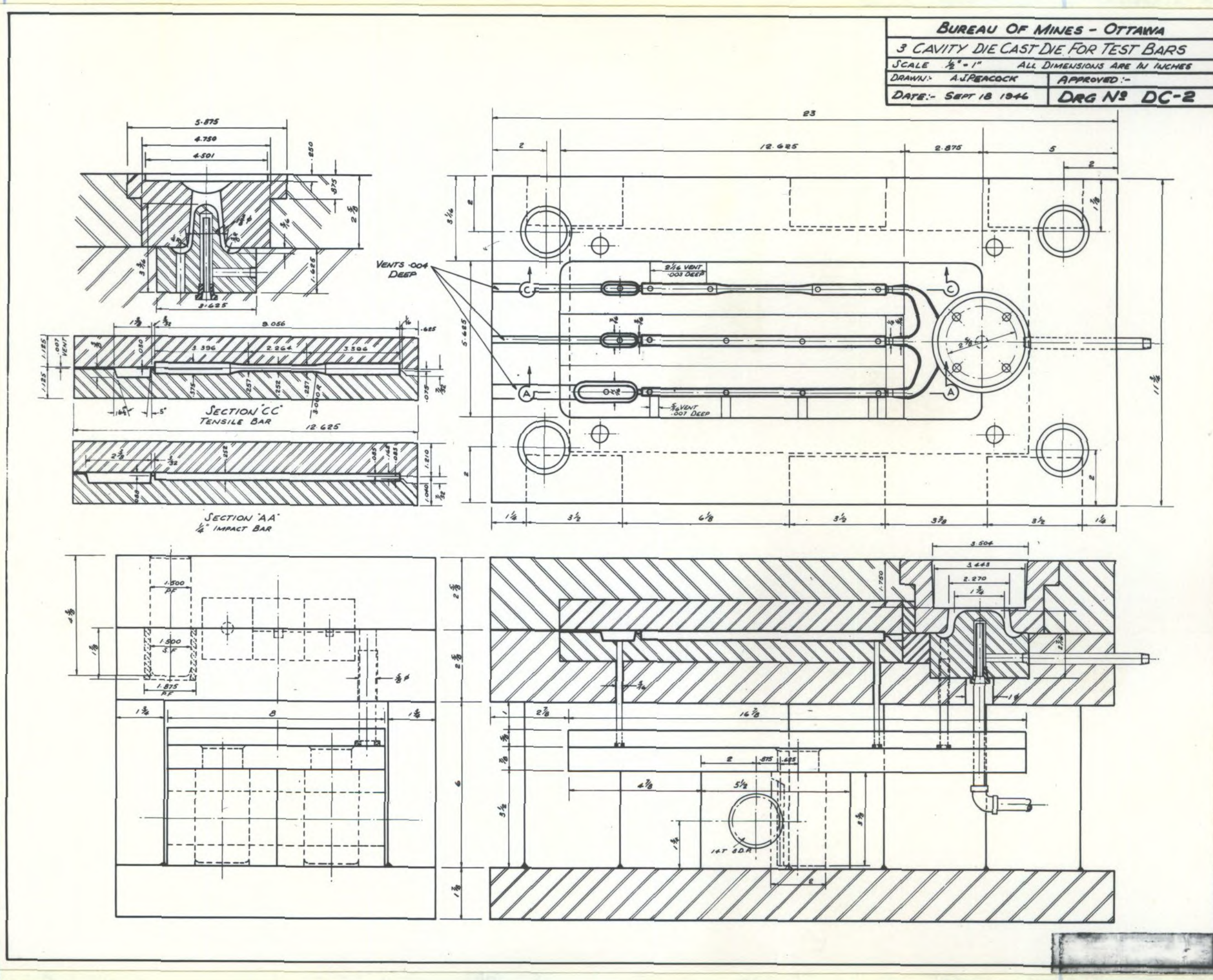
Fig. 4.



Drawing of three-cavity test bar die.

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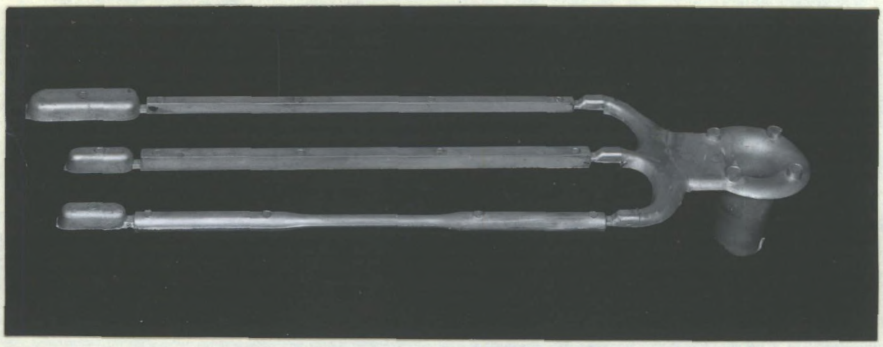
Fig. 5.



Test bar casting from three-cavity die, showing ejector surface.

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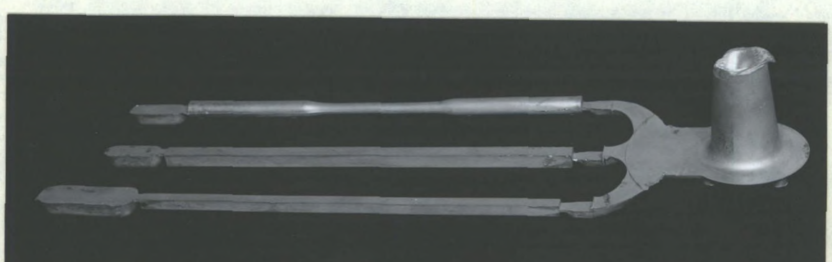
Fig. 6.



Test bar casting from three-cavity die, showing cover surface.

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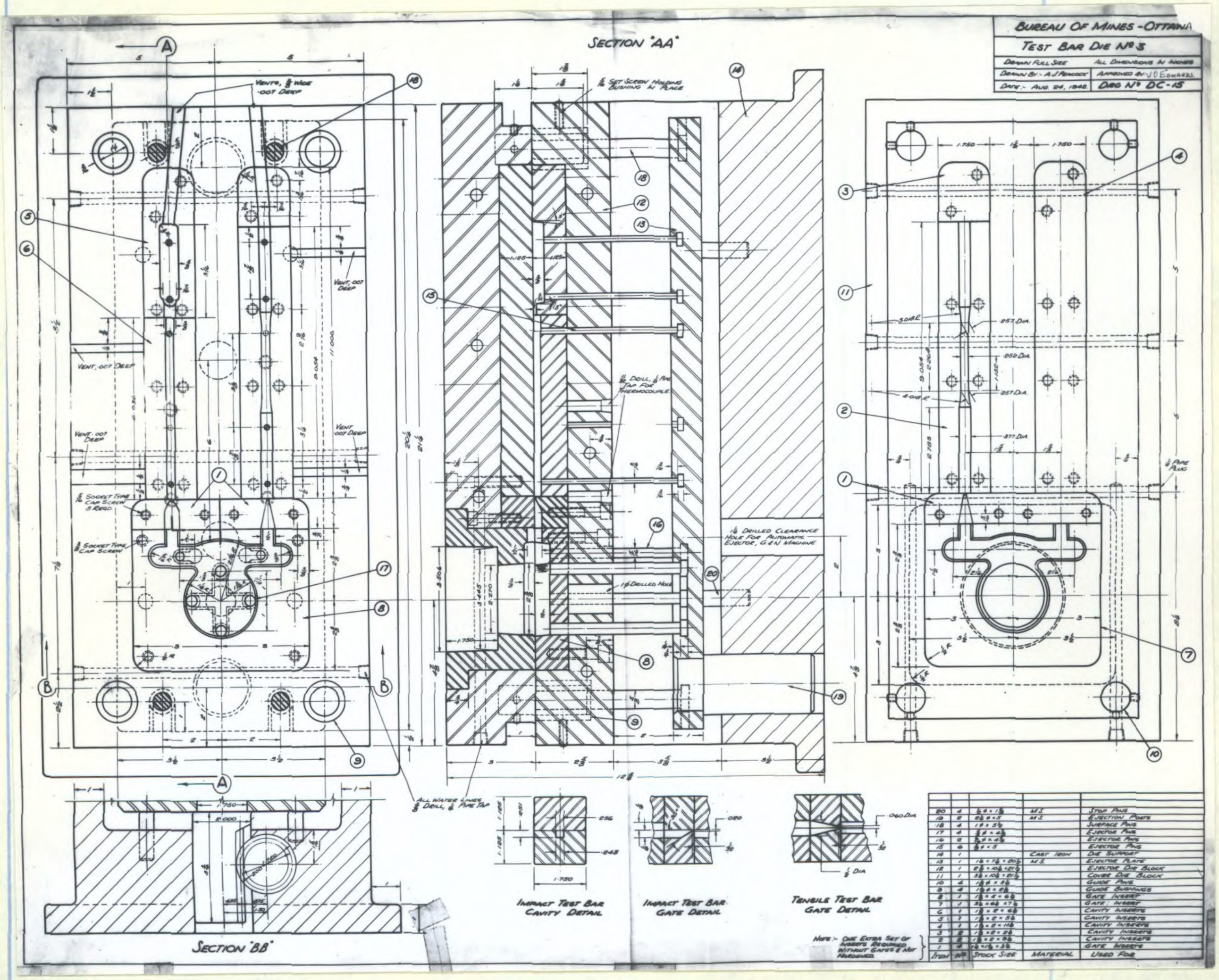
Fig. 7.



Drawing of two-cavity test bar die.

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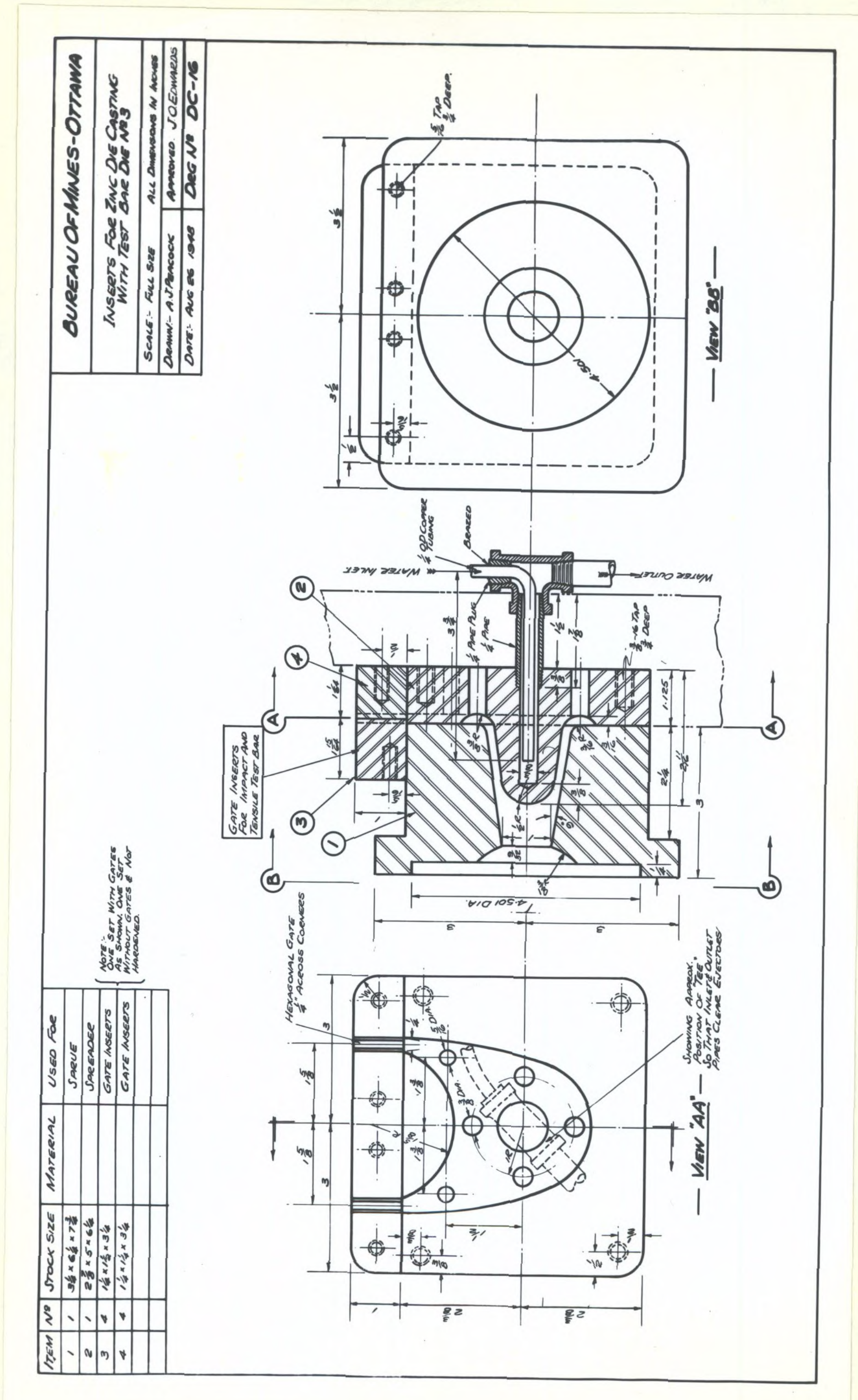
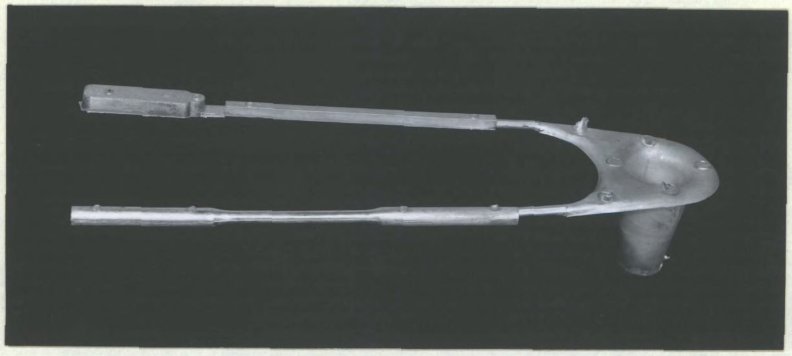
Fig. 8.



Drawing showing details of sprue and gate inserts for two-cavity test bar die.

<u>Fig. 9.</u>



Test bar casting from twp-cavity die, showing ejector surface.

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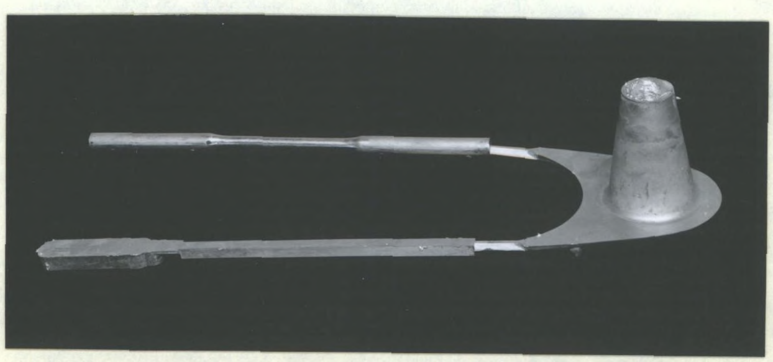
<u>Fig. 10.</u>



Test bar casting from two-cavity die, showing cover surface.

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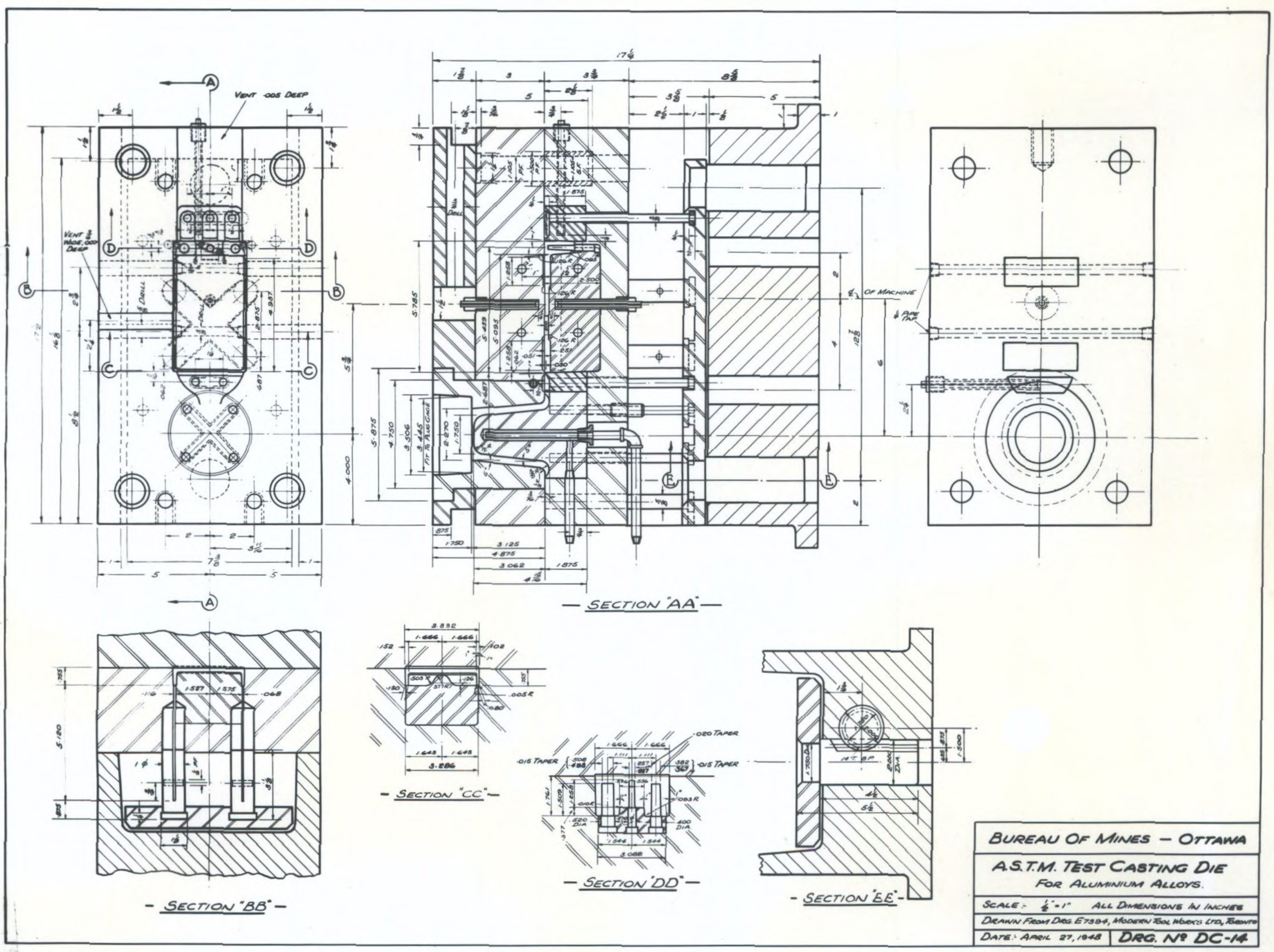
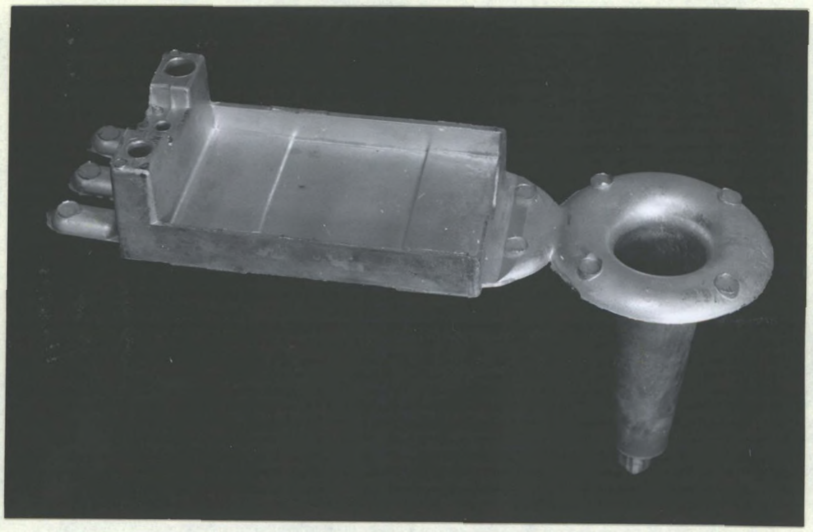
Fig. 11.



Drawing of ASTM test casting die.

Fig. 12.



ASTM test casting, showing ejector surface.

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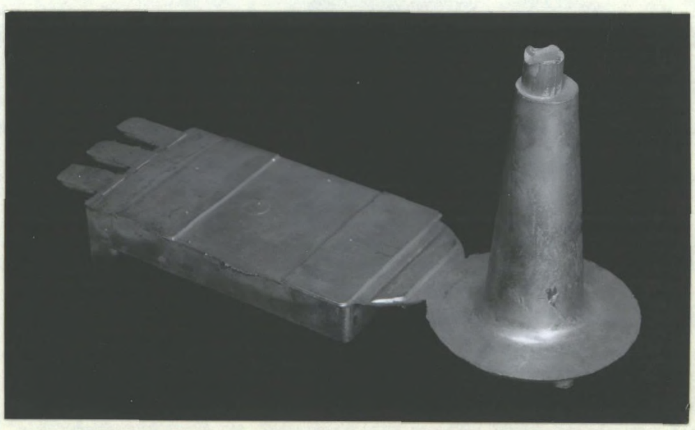
Fig. 13.



ASTM test casting, showing cover surface.

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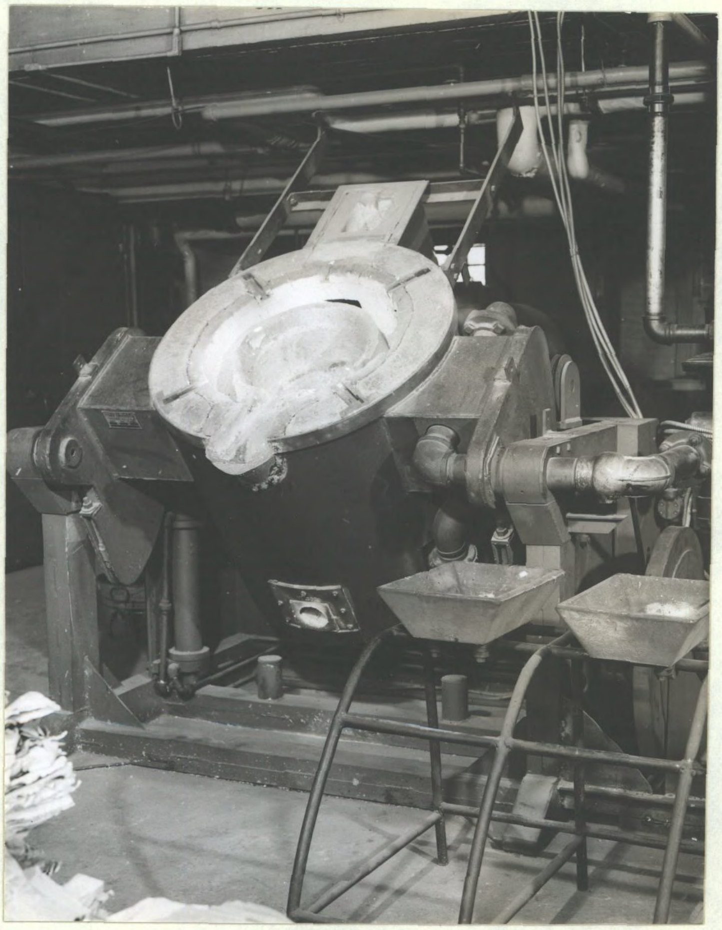
Fig. 14.



Fisher Tilting Furnace
Note ingot moulds on knock out stand.

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Fig. 15.

Fisher "Sulphur Dome" Furnace.

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