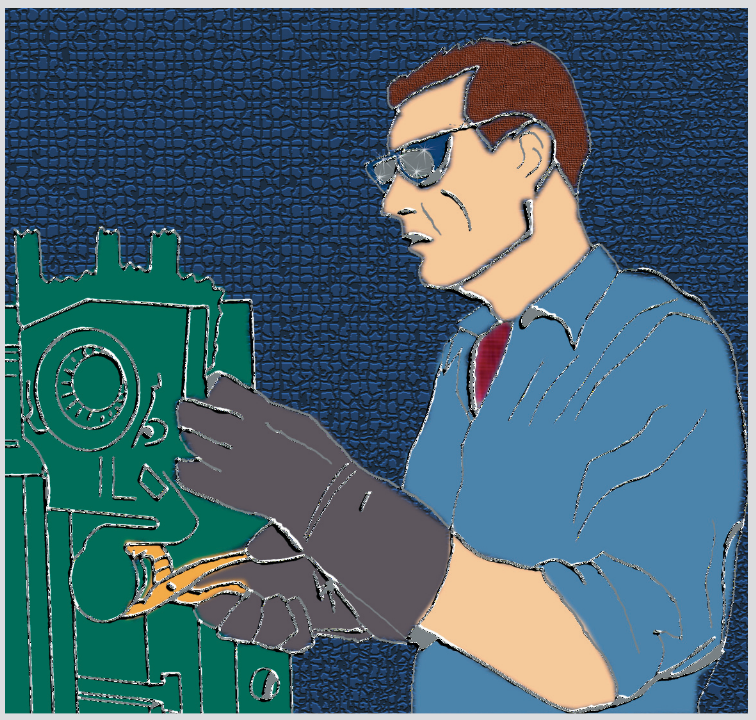
NORTH AMERICAN DIE CASTING ASSOCIATION

operating the die casting MACHINE



By:
Henry Bakemeyer

Publication #E-902

ENGINEERING CAREER DEVELOPMENT SERIES

The NADCA Education Program

The North American Die Casting Association's education program consists of a series of courses designed to help each individual develop his career within the die casting industry. The individual may prepare for advancement or broaden his understanding of subjects within his field of specialization through the NADCA courses.

Each course is supplemented with a thorough textbook. The textbook remains a useful reference long after the course is completed. Although each textbook is complete, the instructor may include information that is new since the printing of the textbook, that is unique to the student's plant, or that more fully explains the material. The student should make his own notes of such information.

TABLE OF CONTENTS

INTRODUCTION

Die casting is a complex process. The operator of a die casting machine is involved with molten metal, a very complex machine, expensive dies, extremely high pressures, critical temperature control, and a whole set of special safety considerations. Unlike a press operation - where the operator loads and unloads, and the press and die make the part - the die casting operator is called upon to manipulate, adjust, and otherwise control the above mentioned factors until “good” parts are being made. Additionally complicating the situation is the fact that some of these factors tend to “drift” out of adjustment during the running of the machine.

The die casting machine operator must be constantly alert to the condition of the castings he is making. He must be able to recognize defective conditions and be able to take corrective action. During this time he still must continue repetitive functions associated with the machine cycle. In addition, he must take care of the machine and die. This care includes housekeeping, lubrication, and the special activities associated with the molten metal.

These introductory comments are not intended to scare the potential operator. Instead, the intent is to emphasize the need for careful and complete training of all die casting machine operators. Enlightened management should provide such training, and the individual operator must be motivated to respond positively to training efforts.

Chapter 1
PROCESS DESCRIPTIONS

In die casting, molten metal is forced into steel dies. High pressures insure that the molten metal completely fills the empty space between the die halves in a fraction of a second. As the molten metal is held in the die, heat flows out of the metal and into the die, solidifying the metal. When solidification is complete, the die is opened and the solid die casting is removed. This solid casting is generally called the "shot”. The process of injecting the metal is also called the “shot”.

This process has many advantages over other manufacturing processes. The primary advantage is the ability to produce a net shape (or near net shape) component in one manufacturing step. The major disadvantage of the die casting process is internal porosity. This disadvantage has led to the development of process changes and improvements to the process we know as “Conventional High Pressure Die Casting”. “Conventional High Pressure Die Casting” has been modified by the addition of vacuum technology and very high cavity pressures in “Squeeze casting”. There also are new processes that cast the metal in a semi-solid state such as “Thixomoulding®” and SOD (Slurry on Demand) to name a few.

For the purposes of this text we will be focused on “Conventional High Pressure Die Casting”, both the Cold and Hot Chamber processes.

INJECTION MECHANISM

Two types of mechanisms are used for driving (or injecting) the molten metal into the die. The "cold chamber" mechanism is used for metals that melt at high temperatures, such as aluminum, magnesium, and brass. The "hot chamber" mechanism is used with metals such as zinc and lead, which melt at lower temperatures.

Fig. 1-1 illustrates the arrangement and operating sequence of the cold chamber mechanism. The cold chamber is a horizontal steel tube extending from a point outside the stationary platen, through the platen and through the stationary die. Molten metal is ladled through the shot hole into the cold chamber and the shot plunger pushes the metal into the die. The small portion of the metal that remains in the cold chamber and solidifies with the casting is called the biscuit.

Fig. 1-2 illustrates the hot chamber principle. The plunger and cylinder are submerged in the molten metal so that the cylinder is automatically refilled with molten metal after each cycle. Hot chamber machines are not normally used with aluminum, magnesium, or brass, because high tempera¬tures and chemical reactions cause rapid deterioration of the gooseneck.

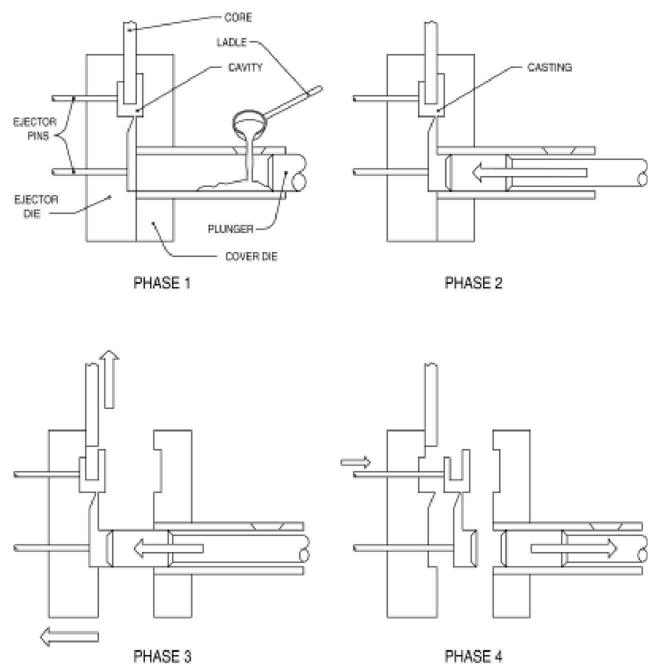


Fig. 1-1. Operating sequence of the cold chamber die casting process: 1) Die is closed and molten metal is ladled into the cold chamber. 2) Plunger pushes molten metal into die cavity. The metal is held under pressure until it solidifies. 3) Die opens and plunger advances to insure casting stays in ejector die. Cores, if any retract. 4) Ejector pin push casting out of the ejector die and plunger returns to ready to cast position.

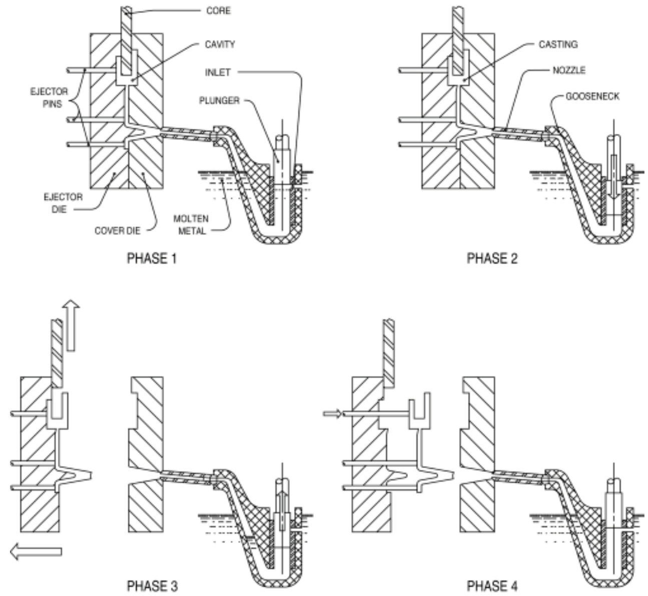


Fig. 1-2. Operating sequence of the hot chamber die casting process: 1) Die is closed and hot chamber (i.e.) Gooseneck) is filled with molten metal. 2) Plunger pushes molten metal through gooseneck and nozzle and into the die cavity. Metal is held under pressure until it solidifies. 3) Die opens and cores, if any retract. Casting stays in the ejector die half. Plunger returns pulling metal back through nozzle and gooseneck. 4) Ejector pins push casting out of the ejector die. As plunger uncovers filling hole, molten metal flows through inlet to refill gooseneck.

In this manual, careful distinction is made between the two processes whenever the operator's responsibilities are affected.

CLAMP MECHANISM

Because of the high pressures used to inject the molten metal into the die, many tons of force are required to hold the two die halves together. This holding force is accomplished with the tie bar-platen-toggle type machine construction shown diagrammatically in Fig. 1-3. The construction arrange¬ment not only achieves the required holding (clamping) force, but it also opens and closes the die rapidly. This speed helps achieve the high production rates of the die casting process.

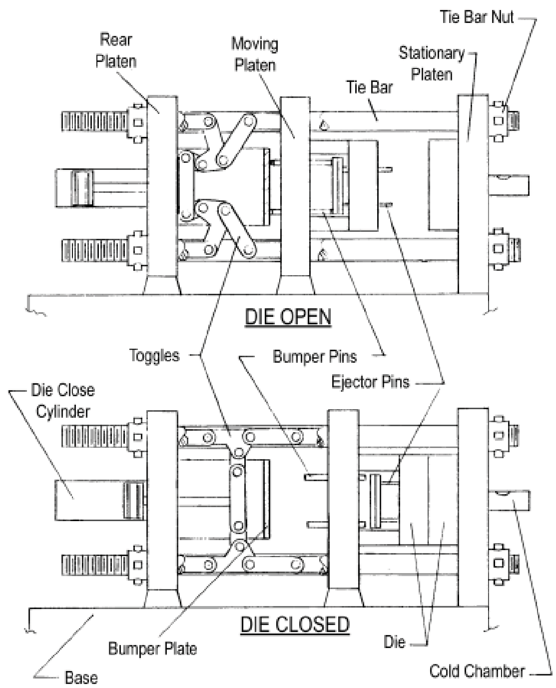


Fig. 1-3. Typical die casting machine construction. The hydraulic die closing cylinder straightens the toggle links to close the die. This arrangement achieves high die clamping forces and rapid die opening and closing action.

METAL HANDLING

A furnace to hold the molten metal is placed near the injection end of the machine. Metal is transferred (either mechanically or manually) from the holding furnace into the injection chamber of the die casting machine. The molten metal is usually carried in bull-ladles from the melting and alloying area to the holding furnace. A truck or overhead rail is used to transport the full ladle. Sometimes a heated trough known as a "launder" leads from the melting and alloying furnace to a series of holding furnaces.

TRIMMING

Behind the die casting machine-sometimes beside it, a press is set up with a die to trim the usable casting from the rest of the shot. Fig. 1-4 shows a complete shot as it appears when removed from the die. The molten metal enters the die through the sprue hole and then flows through the runners to the cavity. Overflow cavities are provided to control metal flow, air venting, and heat flow. The molten metal solidifies in all these die spaces. Only the actual casting (formed by the cavity) is usable. All parts of the shot, other than the casting, are trimmed from the casting and remelted and recycled.

Sometimes, the die casting machine operator is responsible for loading, cycling, and unloading the "trimming" press. At other times, he/she may be required to push the castings down a table or chute to the trimming machine. A second operator then is responsible for the trimming operation. The choice of method depends on the type of castings being made. The "trimmings" are disposed to a tub or conveyor for transportation to the "remelting" furnace, so that the material can be recycled.

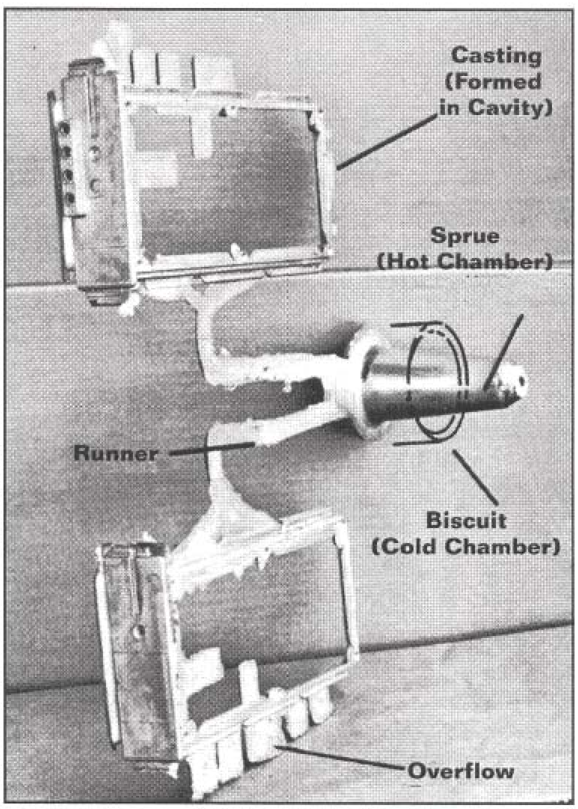


Fig. 1-4. A typical complete die cast shot as it comes from the die. Sprue (or biscuit), runners and overflows must be trimmed from the actual castings. After trimming, sprue, runners, and overflows are remelted and reprocessed.

Chapter 2
DIE CASTING DIES

The die uses the energy of the machine to form the desired part. It is impor¬tant for the machine operator to know the names of different parts of the die. Many die features have the same name as the part of the shot that they form. As shown in Fig. 1-4, these parts include biscuits, sprues, runners, gates, overflows and vents. The space in which the casting is formed usually called the die cavity.

A die casting die for an engine block is shown in Fig. 2-1. The die in the figure is out of the machine and open to show the cavity and other features that contain the molten metal.

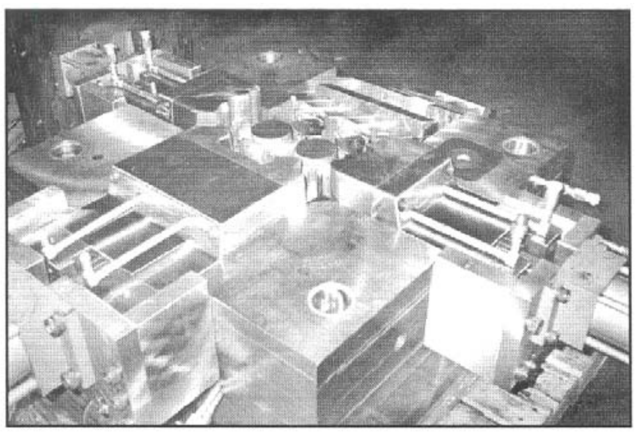


Fig. 2-1. A sophisticated die casting die showing the cavity areas and slides.

Fig. 2-2 shows a cutaway view of a typical hot-chamber die. Two large solid pieces of steel called "die blocks" form the frame of the die. These blocks hold all the other die parts and must be strong enough to resist the tremendous forces exerted by the machine. Grooves are provided around the edges for clamping the die to the machine platens. The cavity is the space between the die halves that is the size and shape of the part being manufactured. Often, the cavity is machined or sunk into an insert block of special steel. From the sprue or biscuit, metal travels via runners and through gates into the die cavities. The runner is progressively reduced in area to a thin slit-like opening where it joins the cavity. This narrow opening is called the gate.

The die is so constructed that the casting is held in the ejector half when the die opens. The casting is then pushed out with ejector pins that come through holes in the die, and are actuated by the ejector plates, powered by the machine. Guide pins extending from one die half enter holes in the other die half as the die closes to insure alignment between the two halves.

Some castings have complex shapes that cannot be formed by dies that open in only one direction. Dies for these parts have core slides, which move sideways as the die opens and closes. The slides are moved by cam pins or hydraulic cylinders and are locked in place by wedge surfaces when the die is closed.

Heat is removed from the metal by cooling channels drilled through the die. Heat is sometimes added by electric or gas heaters for warm-up or for making thin castings, which carry insufficient heat to maintain the die at the best operating temperature.

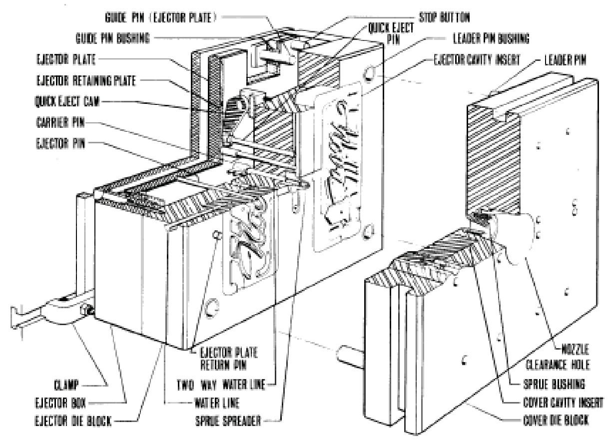


Fig. 2-2. The die casting die is constructed of many parts. The machine operator should be familiar with the name and function of each part of the die. This example shows a die for hot-chamber die casting of zinc.

DIE MAINTENANCE

The DCM operator also has responsibility to maintain the die good working order. This includes assuring that there are no practices undertaken that could shorten die life. The following list of practices should be followed to assure the die life is maximized:

1. Before injecting metal, make sure the die has been pre-heated to 350°F (175°C).

The die must be tough to absorb the thermal shock when hot metal is injected or cold water turned. Research has shown the die steel is tougher at elevated temperature. Figure 2-3 shows this phenomenon.

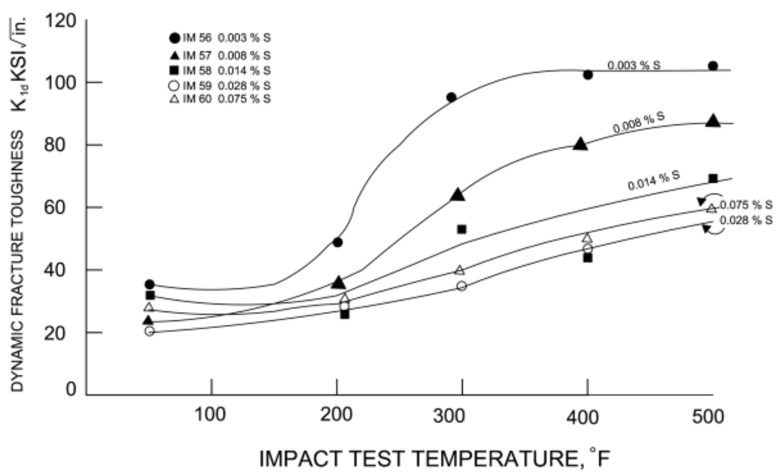


Fig. 2-3 Brittle to ductile transition curve for H-13 steel. Steel is much tougher when heated to 350°F

2. When the DCM is running, run consistent cycle times with each cycle element consistent.

Once the die is operating at a thermal equilibrium, temperature balance, it is important to maintain that condition This means the amount of heat going into the die equals the heat going out of the die. It also means that the expansion and contraction of the die surface is uniform each cycle, and the amount of stress going into the die each cycle is uniform. As productivity goes up, shorter cycle times, the amount of stress that goes into the die each cycle is reduced. This will yield longer die life before the onset of heat checking.

3. Minimize build-up on the cavity surfaces. This could be solder, carbon or waxes, usually a result of inappropriate die release application.

The application of die release is very important. Because the die spray is water based, it is used to control die temperature in regions that cannot be cooled with internal cooling. If not applied adequately, solder will occur. Soldering is the diffusion of aluminum into the die steel. Excessive die spray can result in a wax buildup on the die face that interferes with venting. These waxes could also burn up and form carbon that could become attached to the die and prevent obtaining a smooth casting surface.

Chapter 3
THE DIE CASTING MACHINE (DCM)

The die casting machine is the most important machine in the die casting plant. All activities in the plant focus on keeping the machine running, and producing acceptable castings. The die casting machine is a complex assembly of components that must work in concert with each other to produce the forces, generate high speeds, and withstand the high temperatures required to make a die casting. To be given the responsibility to run a die casting machine is similar to being given the keys to a finely tuned racing car, except the die cast machine may cost more.

In this chapter we will assemble a die cast machine from the ground up. We will identify all the components that make up the machine and define their function. Along the way we will show a number of illustrations to clarify and give you a good picture of the machine. The machine we assemble will be generic machine and will closely resemble the machine you are working on. At the conclusion of this lesson you will be able to identify the major machine components, explain their function and know the safety requirements related to running the machine.

STRUCTURAL COMPONENTS

Machine Base

The machine base is a steel fabrication that supports the major machine components. It is generally a rectangular box, but the shape may vary based on the machine size. On larger machines a separate pedestal supports the stationary platen. The base has several important functions. First, it serves as a platform for the heavy steel plates to rest on. On small machines the height of the machine base may be adjusted to place the work area of the machine at a convenient height for the operator. At large machines, a platform must be built for the operator.

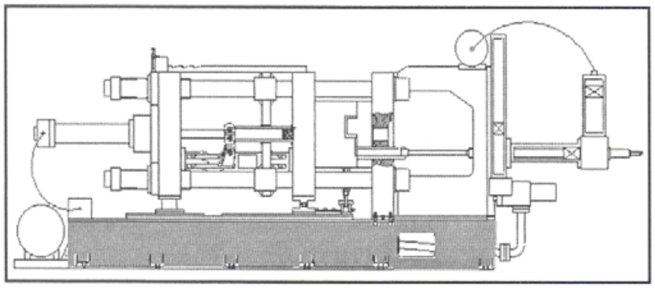


Fig. 3-1. This is a line diagram of a small die casting machine with the base extending the full length of the machine typically the reservoir would be located within the base at the rear of the machine. The base is shaded for clarity.

Many machine manufacturers enclose the rear portion of the machine base to form a steel tank. This tank becomes a reservoir for the hydraulic fluid that powers the machine. During operation the hydraulic fluid will heat. The normal operating temperature for water glycol hydraulic fluid is 100°F. For safe operation hydraulic fluid manufacturers recommend that the operating temperature of the fluid should not exceed 125°F. If the fluid gets too hot, it can lose its lubricity and fire resistance. Most machines have a thermometer is built into the reservoir to indicate the fluid temperature.

For the hydraulic fluid to operate efficiently it must also be kept clean. An effort must be made to keep the area of the reservoir clean and free of dirt and debris. The reservoir area should not be stacked with tools, castings and other materials.

The reservoir is specially built to be and oil tank. There is a "sight" glass on the side of the tank so it is easy to determine the level of fluid in the tank. Because of the high volume flow of hydraulic oil into and out of the tank, many tanks will be equipped with baffles and a breather. The purpose of the breather is to accommodate airflow in and out of the reservoir. You should make sure that the area around the breather is clear and airflow is not obstructed. Baffles are placed in the tank to prevent turbulence and foaming of the hydraulic oil.

The "rear" or "clamp end" of the machine is the end opposite the injection end. This is generally where the electrical utilities, motors, and pumps are located. The machine base must be strong enough to support the platens without sagging. The area around the base should be free of loose hoses and cords that could become trip-fall hazards.

Platens

The platens are the three large plates that support the machine loads. They rest on the machine base. They are known as the Stationary platen, Moving platen, and Adjustable or Rear platen. Their functions are fairly straightforward. The Stationary platen, located at the "shot" end of the machine, holds the stationary die half. The shot end is mounted on the other side. The Moving platen is located between the Stationary and Rear platens. The moving or ejector half of the die is mounted to the moving platen. The Rear platen is located at the rear of the machine. The Moving and Rear platens are generally resting on "shoes" that slide on replaceable wear plates. Both the Moving and Rear platens move every cycle. The Moving platen slides back and forth to open and close the die. The Rear platen slides a little as the tie bars stretch. The Rear platen is also known as the Adjustable platen due to its movement to accommodate die height adjustment.

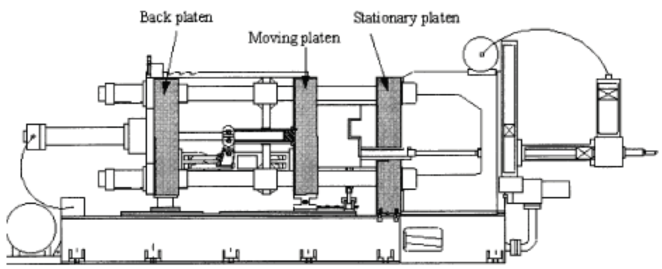


Fig. 3-2. Line diagram of a die casting machine with platens identified and shaded for clarity.

The platens must be kept clean, particularly the die mounting surfaces of the moving and stationary platens. These must be cleaned every set-up to assure that the die parting lines are kept parallel to the machine platens and to assure there is good heat transfer from the die to the platens.

The surfaces of the Stationary and Moving platens in the die space will have Tee slots or tapped holes for clamping the die. Care must be taken during set-up and operation to make sure these features are not damaged.

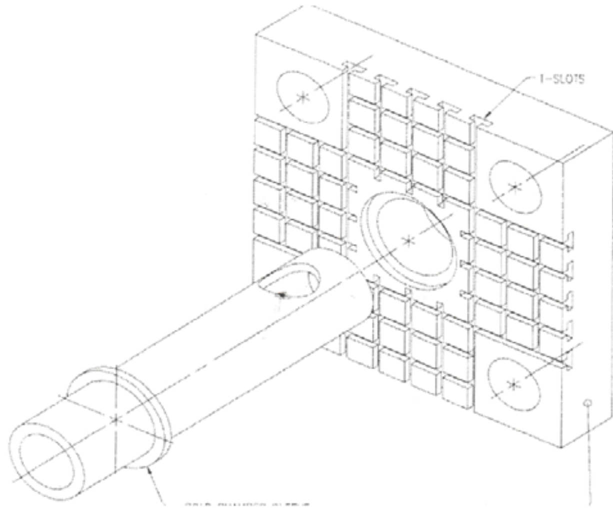


Fig.3-3 View of the stationary platen showing the Tee-slots and through hole for the cold chamber.

Fig. 3-4. View of a shot block.

The Stationary platen will have one or more holes machined through it. One hole is usually at the machine centerline and the other hole will be a position below the machine center. This will allow for two different die filling positions. Some machines will have a slot for an adapter that would allow multiple die filling positions. This is called a shot block or platen adapter.

The Stationary and moving platens may increase in temperature during operation. With hot chamber operation this may be enough to burn a person. The operator should be aware of this potential burn hazard. By its very nature, the Moving platen can become a strike hazard. Items attached to the Moving platen or items attached and projecting from the platens may be snag hazard. Care must be exercised around the Moving platen to make sure all guards are in place and properly mounted.

Tie Bars

Most machines have four tie bars. The tie bars are long, solid columns mounted through the four corners of the platens. They are used to orient and position the platens. The Moving platen actually slides along the tie bars. The size and strength of the tie bars determines the size of the machine. Every cycle the tie bars actually stretch to develop the force that is necessary to hold the die together against the force of injection. If the machine is improperly set-up or somehow a tie bar becomes excessively stretched, it is possible to break the tie bar.

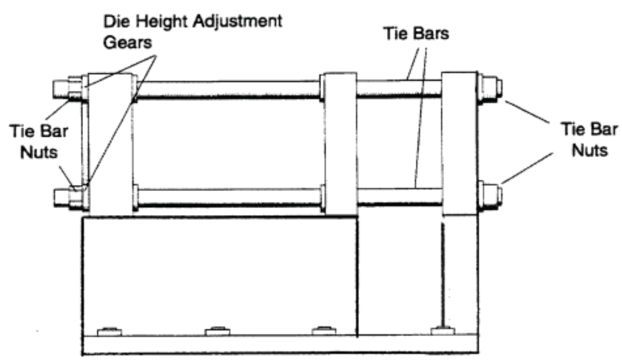


Fig.3-5. Schematic diagram of a generic die casting machine with the tie bars and tie bar nuts identified.

Toggle Linkage Mechanism

The Rear and Moving platens are connected to each other with the toggle linkage mechanism. The configuration of this mechanism differs among machine manufacturers. Some linkages apply force at the four corners of the platens; others apply force along vertical or horizontal lines inside the tie bars. It takes a great deal of force to stretch the tie bars and lock the machine. If this were to be accomplished with a hydraulic cylinder, the cylinder required would be very large and move very slowly because of the large amount of oil that would be needed. Some older machines in the 1940's did have very large cylinders. Die casting machine engineers developed the toggle linkage to overcome the deficiencies of using a large cylinder. The toggles act as levers and gain a mechanical advantage during die closing and locking. This allows the use of smaller closing cylinders that can operate at higher speeds.

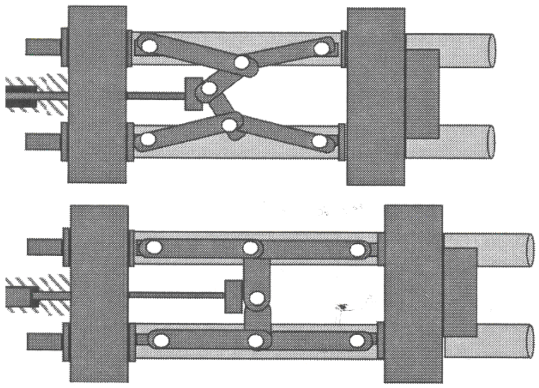


Fig. 3-6. Top figure shows toggle mechanism retracted, the machine/die would be open. The bottom figure shows the toggle mechanism extended, the machine/die would be closed.

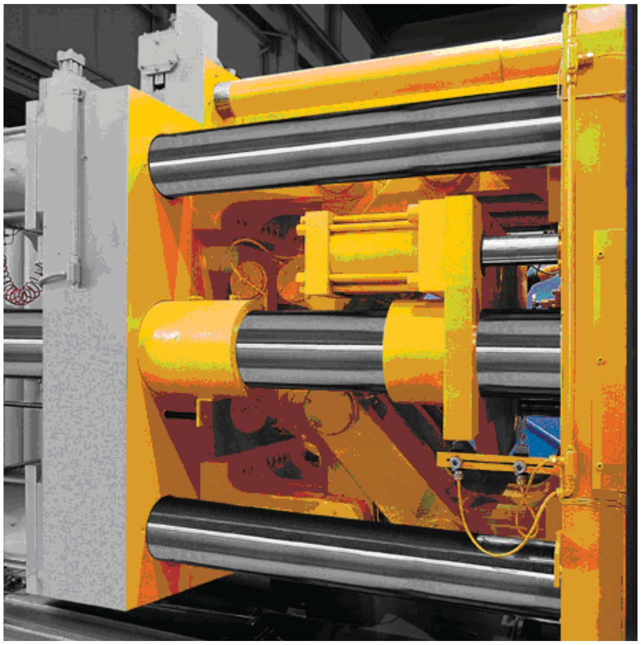


Fig. 3-7. The toggle mechanism of a modern die casting machine located between the Moving and rear platens.

The toggle linkage area contains many pinch points that can be hazardous when the machine is operating. Guards should always be in place when the machine is operating or being set-up. If the toggle linkage area needs maintenance, the machine must be locked out and in a zero energy state (ZES) to prevent injury.

ELECTRICAL SYSTEM

Motor and Control Panel

An electric motor(s) provides power for the machine. Generally, the motor is directly coupled to hydraulic pumps. Electrical power is converted into hydraulic power when the electric motor spins the hydraulic pumps. The pumps force oil into the hydraulic lines under pressure. The motor is located adjacent to the reservoir. Also located at the rear of the machine will be an electric power cabinet that encloses the motor starter and machine control logic. A disconnect switch is mounted on the outside of this panel along with the lockout tag. The motor(s) operate at high voltage, usually 440/480 volts. This area must be kept clean and dry in order to avoid an electric shock hazard. The couplings between the motor and pump must be guarded because these rotate at high speed and could cause injury if contacted.

Fig. 3-8. Lock-out tag in place on main disconnect switch located on the machine con¬trol panel.

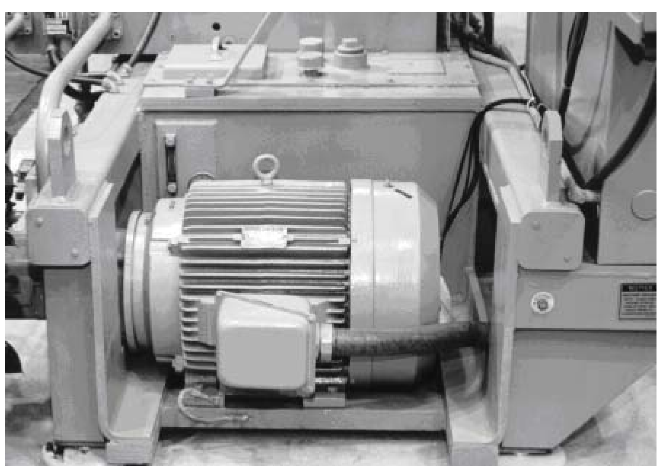


Fig. 3-9. Motor shown at rear of DCM.

Solenoids

Solenoids are used to shift valves to control the volume and direction of hydraulic fluid flow. A solenoid is an electromagnet that shifts a metal core. This is the same device that engages the car starter motor when you start your car. This core is attached to a valve spool to control and direct the oil flow. The solenoid/valves are relatively robust but should not be used as steps or otherwise abused.

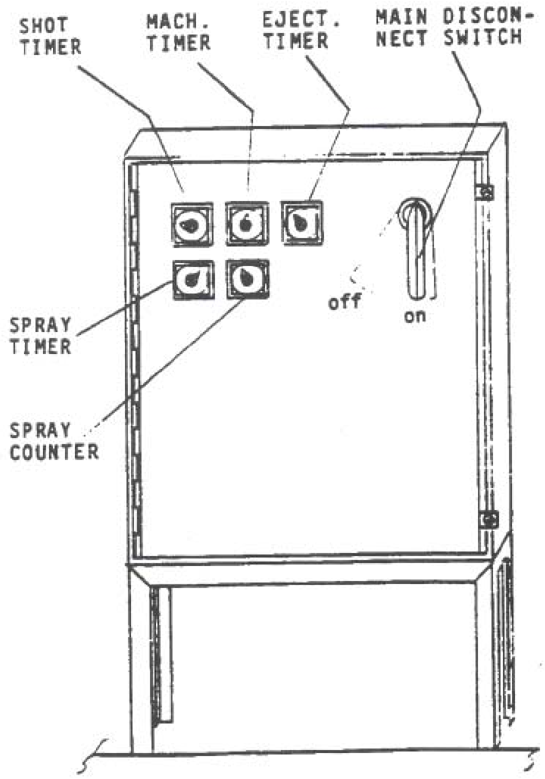


Fig. 3-10. Line diagram of an older style control panel for hot chamber die casting machine.

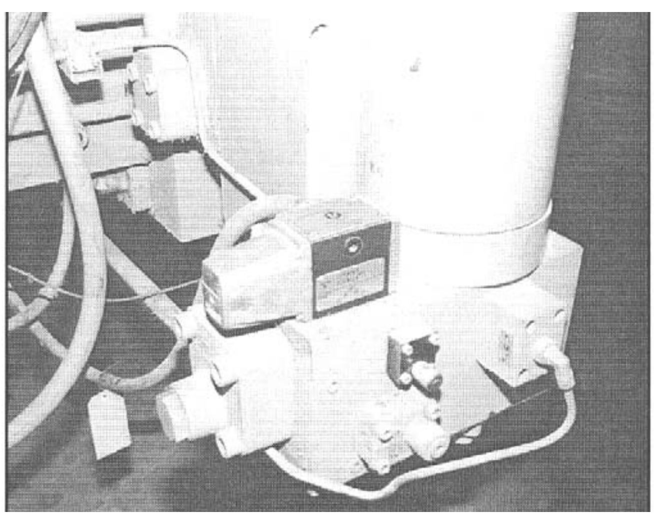


Fig. 3-11. Solenoid valve located all manifold at base of shot accumulator.

Limit Switches

Limit switches are the sensors, eyes and ears, of the electrical control system. They are located in many different places on the die casting machine. They are used to sense the position of doors, guards, cylinders and other moving components on the die casting machine. Their maintenance is essential to the safe operation of the machine. Limit switches must never be defeated or tied back. Broken connectors and exposed wiring at limit switches should be repaired immediately in order to assure safe operation of the machine. The trip rods or switch actuating mechanisms at the limit switch will cause pinch points.

The machine may also have other types of switches and sensors. Some of the limit switch functions may be accomplished with proximity switches. There may also be pressure switches that react to a given level of hydraulic pressure.

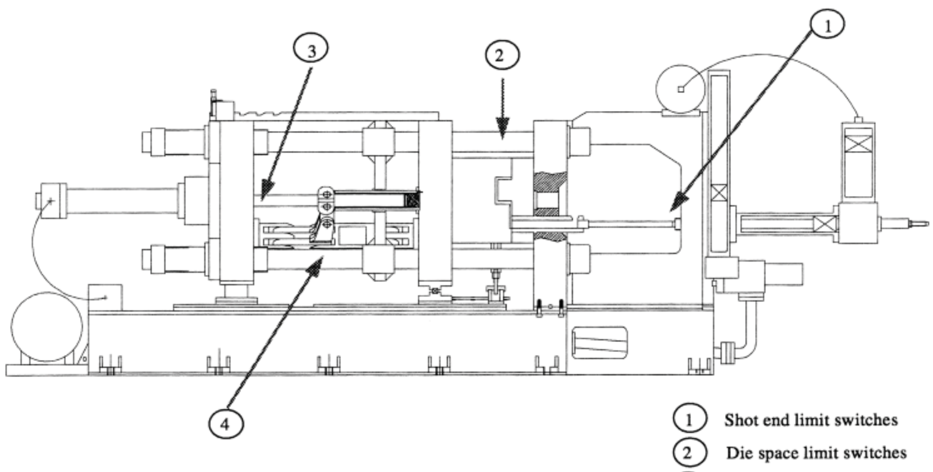


Fig. 3-13. Overall machine view, with arrows indicating key locations of limit switches.

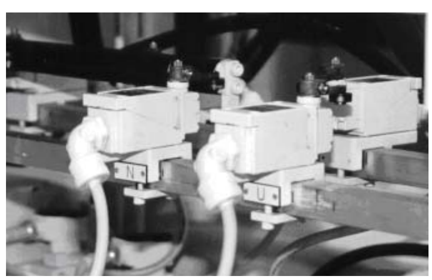


Fig. 3-12 Close-up of limit switches located behind the rear platen of the die casting machine.

HYDRAULIC SYSTEM

The die casting machine functions are operated by a hydraulic system. This means that a fluid, usually fire resistant oil, is used to power the cylinders that make the machine move. This hydraulic system operates at high pressures and high flow rates. For those reasons alone, we need to keep safety in mind.

Under unusual operating conditions the hydraulic fluid may be hot enough to cause burns. Leaks and spills should be repaired and cleaned up quickly. These not only waste costly oil but also can cause slippery surfaces that could result in injuries if someone slips and falls.

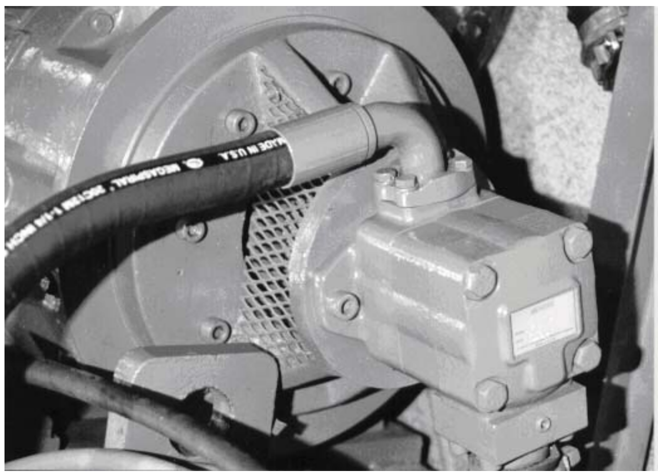


Fig. 3-14 Close-up of hydraulic pump mounted at the end of the motor shaft.

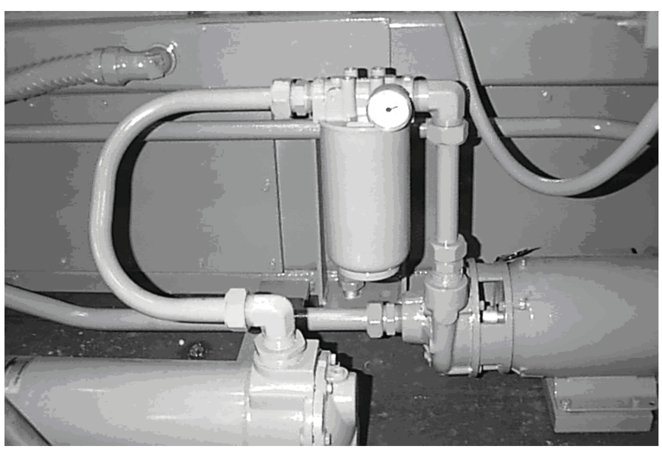


Fig. 3-15 View of filter at outlet of circulating pump used to pump hydraulic fluid through the heat exchanger.

Hydraulic Pumps

A die casting machine usually has a minimum of two hydraulic pumps. One pump is capable of providing oil at high pressures but in low volumes. A second pump would be capable of providing a high volume of oil at low pressures. For example, the pumping capabilities of a 400-ton machine may be 8 gallons per minute of 2000 PSI oil from the high pressure pump and 40 gallons per minute of 40 PSI oil from the low pressure pump. This type of pumping capability is used to solve the various demands of the die casting machine. The die close cylinder requires a large amount of oil to open and close the moving platen. Once the die faces close, only a small volume of high pressure oil is required to stretch the tie bars and lock the die. Just the act of closing requires the output of both pumps. (In cases where the output of both pumps is still too slow, an accumulator will be used to speed die closing.)

Filters

Filter(s} are required to keep the hydraulic fluid clean. The filter(s) are located at the outlet of the pumps to assure that clean oil is sent to the various valves and cylinders. The filters require routine maintenance to make sure they work properly. Most filters have a visual differential pressure gage on them that should be checked frequently to make sure that the oil is clean. Small dirt particles in the oil can cause valves to stick and fail because of the small clearances in the valves.

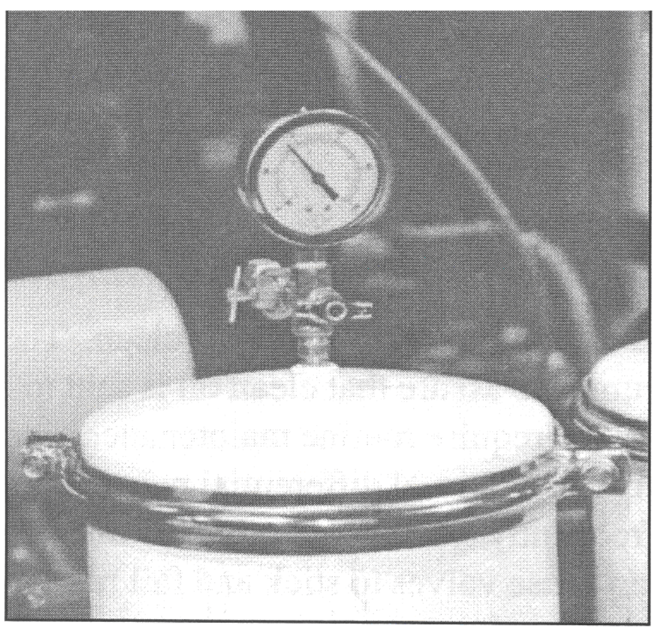


Fig. 3-16. Differential pressure gauge on top of a filter.

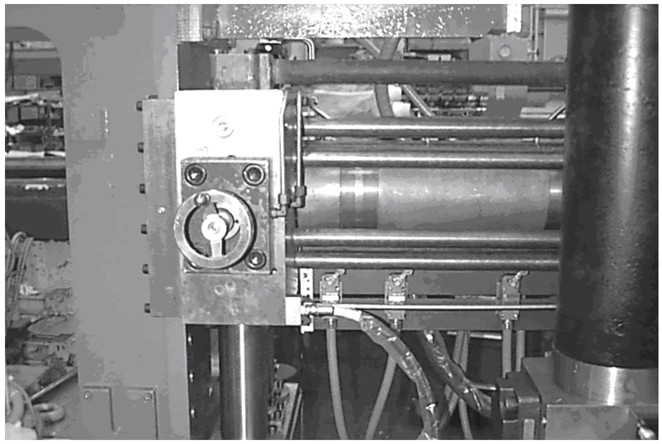


Fig. 3-17. Hand operated speed control valve for shot cylinder.

VALVES

Valves are used to control the amount and direction of oil flow. Solenoid operated valves are used to direct the flow to the head or rod side of a cylinder or they may direct oil to shift a large valve, such as the pilot operated (PO) check valve at the base of the accumulator.

Some of the valves may be manually operated. For example, the valves controlling the speeds of injection or die closing may be fitted with large hand wheels. These valves are used to control or shut off the oil flow.

On modern machines the speed control of machine functions is controlled by a series of valves mounted on a manifold. The manifold provides a centrally located source of hydraulic fluid for the speed control valves.

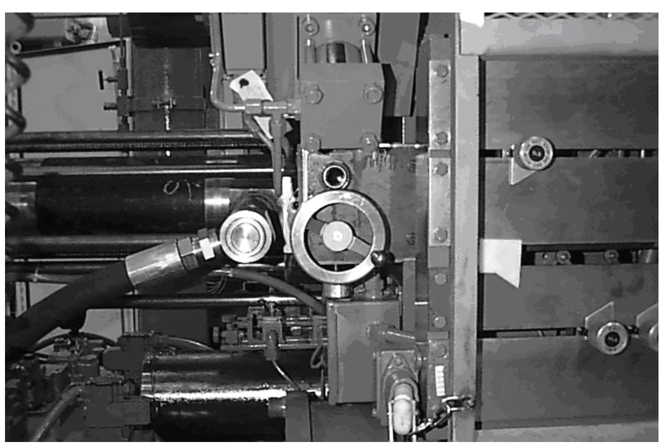


Fig. 3-18. Hand operated speed control valve for die close cylinder.

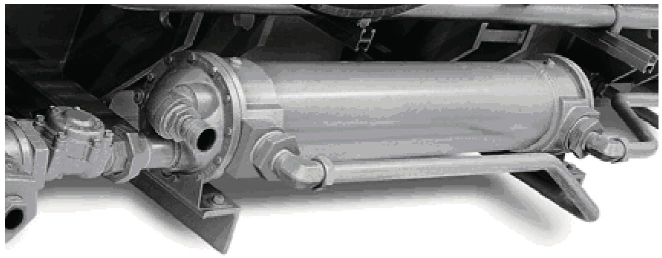


Fig. 3-19. Heat exchanger used to cool hydraulic oil in die casting machine

Heat Exchanger

Most machines will have a heat exchanger. This is a large tubular tank located adjacent to the reservoir. It operates similar to a boiler. Internally the heat exchanger will have a large number of pipes going through. Cooling water will circulate through these pipes. Hydraulic fluid will be let into one end of the heat exchanger; the fluid will flow over the water-cooled piping and give up heat to the water. The fluid will then flow out the exit. Factors affecting the efficiency of the heat exchanger are the same as those affecting die cooling. If the water lines fill up with lime (calcium), heat flow is reduced. If fluid flow is to slow, heat flow is reduced.

Leakage in the heat exchanger can be troublesome in two ways. First too much water can contaminate the hydraulic oil. Second the hydraulic fluid will contaminate the recirculating water. As an operator, you should be aware of the hydraulic fluid temperature. If the fluid gets to hot, check for flow of hydraulic fluid and coolant through the heat exchanger.

Cylinders

Hydraulic cylinders or actuators are used to open and dose the machine, to inject the metal into the die. They may also be used to operate the ejection system, move slides in and out of the die, actuate a safety ratchet and open and close a safety door at the die parting line. These cylinders may be liquid or air operated. Cylinders operate very simply; a fluid comes in one end and pushes an internal piston to the end of the cylinder. In order to accomplish work one end of a rod is connected to the piston and the other end of the rod is connected to whatever we want to move. Hydraulic cylinders can be very powerful. The force that a cylinder develops depends on its size and the pressure of the hydraulic fluid.

Die Close Cylinder

The die close cylinder is used to open and close the die. It is mounted on the rear platen, with the cylinder rod extending through the platen and connected to the center of the toggle linkage at the crosshead.

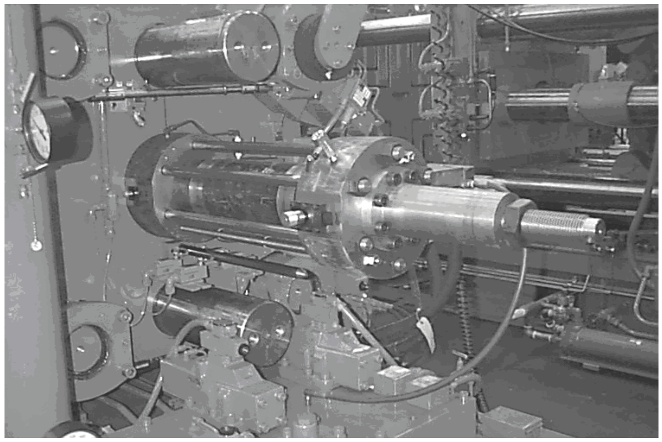


Fig. 3-20. Die close cylinder.

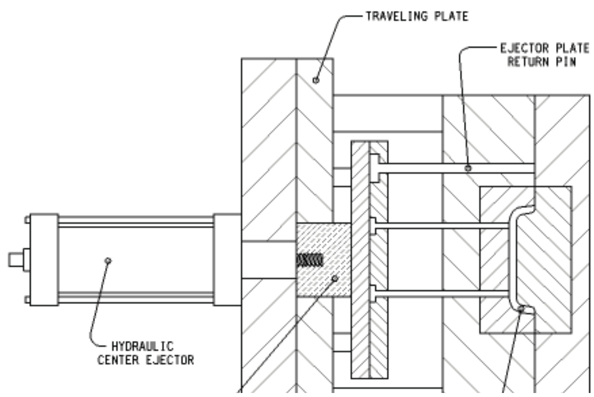


Fig. 3-21 shows an alternative ejection method. The ejection cylinder rod projects through the moving platen and either "bumps" or is coupled to the die ejector plate.

Ejection Cylinder

Some die casting machines have cylinders to actuate an ejection bump plate or a single cylinder used to actuate the die ejector plate. The ejector cylinders are mounted to Moving platen on the toggle linkage side. The other end of the cylinders is attached to the large hump plate that will actuate "bump pins" that operate between this large plate and the ejector plate in the die. The guards that cover the toggle area usually cover the area of the ejector bumper plate. You must be sure that the pinch points in these areas are protected.

Shot Cylinder

On a cold chamber machine the cylinder rod is connected to a plunger that is located in the cold chamber. The shot cylinder is mounted to a "C" frame that is mounted to the stationary platen.

Injection Components

The cold chamber components include the shot cylinder, plunger rod and tip, coupling and the cold chamber. Alignment of the chamber, tip and rod, and shot cylinder is critical to the efficient operation of the injection system. The shot cylinder rod extends from the shot cylinder and is connected to the plunger rod with a coupling. Care must be taken to avoid damage to the cylinder rod. It is a precision-machined component that extends through a packing gland that seals the high pressure oil into the shot cylinder. This should not be used as a step or tool rest. In some cases the position and velocity transducers for the shot cylinder are machined into the cylinder rod. The plunger tip is usually made from a beryllium copper alloy in order to achieve fast cooling of the biscuit or plug at the end of the cold chamber. Proper cooling and temperature control of the tip is necessary to prevent metal from bypassing the tip and spitting out of the chamber. This can be hazardous. Sticking tips can also be a problem and proper training is necessary before one attempts to remove a stuck plunger.

For efficient operation, care must be taken during set-up to assure that the shot cylinder and plunger are in proper alignment. This will assure a minimum of wear and operating problems.

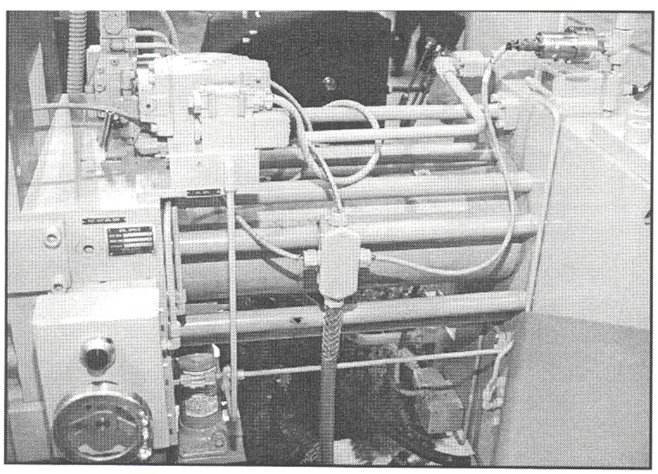


Fig. 3-22. Shot/injection cylinder, note speed control valve at the lower left of the photo.

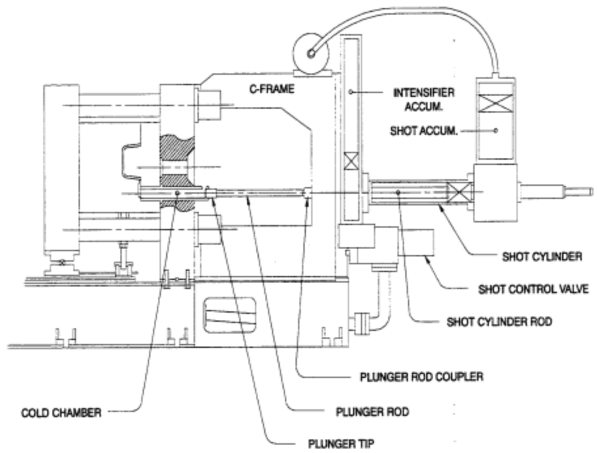


Fig. 3-23 injection components of a cold die casting chamber machine.

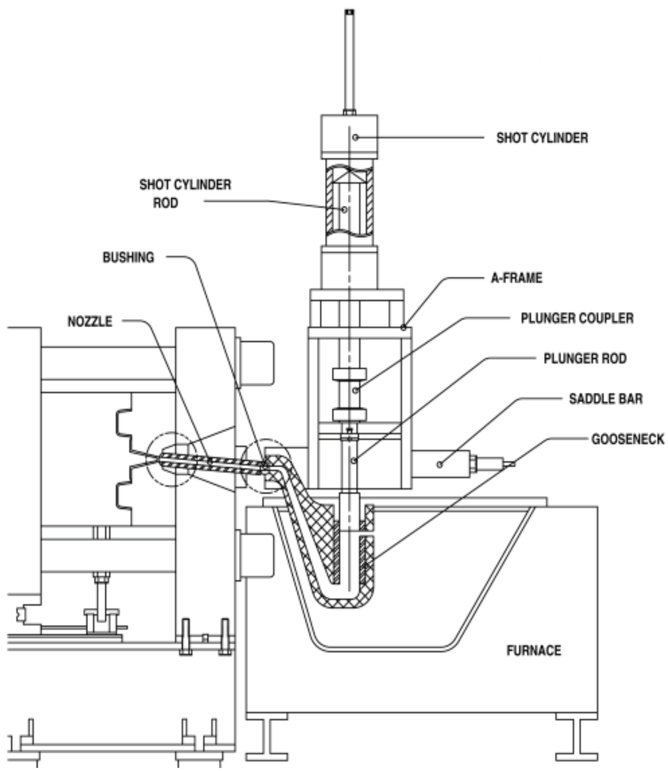


Fig. 3-24. Injection components of a hot chamber die casting machine.

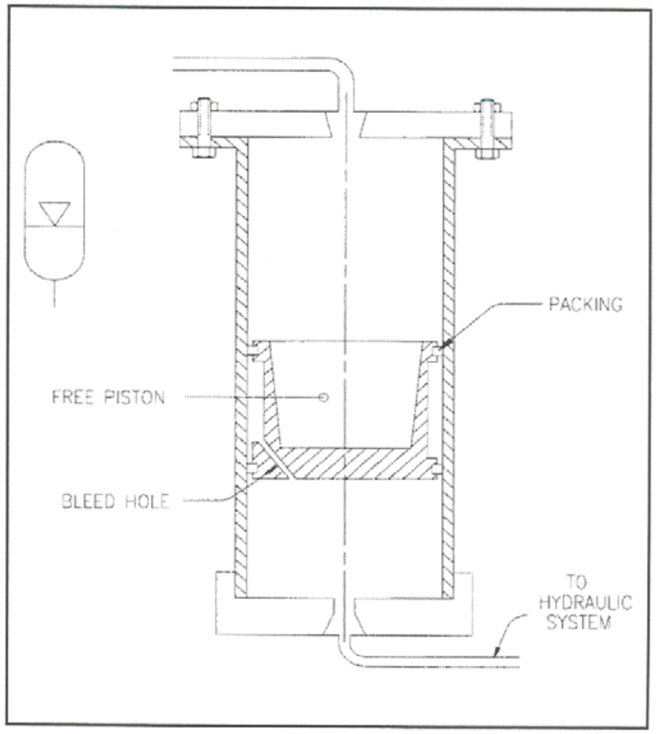


Fig. 3-25. Cross-section through a typical piston accumulator.

Accumulator

Most machines use piston type accumulators. The accumulator is simply a large steel vertically oriented cylinder. This cylinder is partially filled with hydraulic fluid above which is a column of high pressure nitrogen gas. The fluid and gas are separated with a piston. The accumulator is used when large volumes of hydraulic oil are required. This is during die opening or closing, and during injection.

For example, during the fast shot phase of injection, the valve at the base of the accumulator is opened and oil is supplied to the shot cylinder. Neither of the hydraulic pumps can supply the gallons per second of oil needed for cavity filling. Once the die cavity is filled, the accumulator's job is complete. During another portion of the casting cycle, the oil is pumped back into the accumulator, recharging it.

The accumulator stores a large amount of oil under high pressure. This could be potentially hazardous. When maintenance to the machine or die is required, activities that require the machine to be "locked out", the accumulator must be returned to a "zero energy state" or ZES. This will require relieving the pressure in the accumulator to eliminate the possibility that a hydraulic cylinder could move.

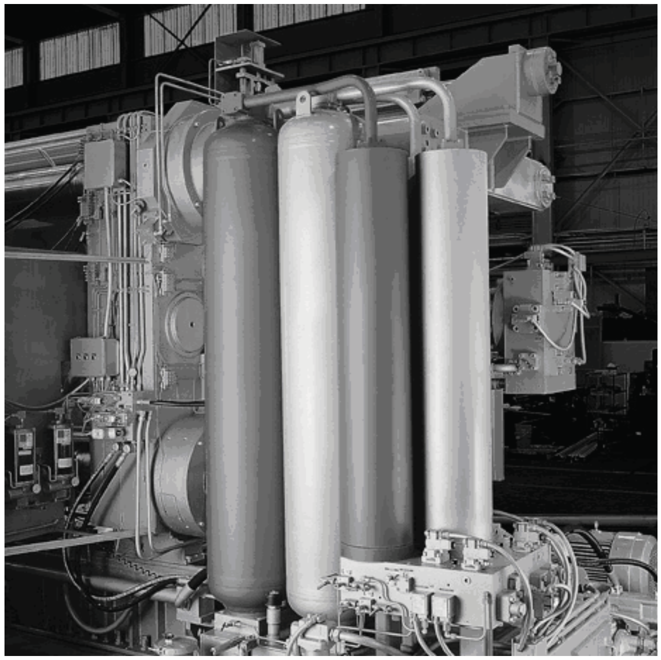


Fig. 3-26. Several accumulators located near the "rear" end of a large die casting machine.

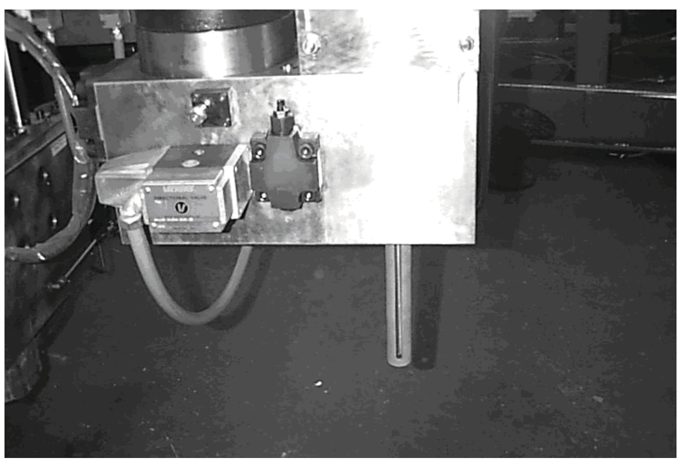


Fig. 3-27. View of manifold below the intensifier accumulator showing a solenoid and intensifier tail-rod

Intensifier

The intensifier is a hydraulic device that increases the hydraulic fluid pressure at the end of the injection stroke. The purpose of this high pressure is to dramatically increase the metal pressure in order to squeeze additional metal into the die cavity as the metal shrinks and to further compress trapped gases.

SAFETY COMPONENTS

The current safety standard for die casting machines shipped for use in North America is NADCA B152.1-2006. This standard details the safety devices required on the DCM, to make it acceptable for use in North America. This safety standard applies to new DCM's shipped after its implementation date and to existing installations within the implementation period allowed by the standard. This standard is available for no charge at the NADCA website "diecasting.org".

Die casting safety and DCM safe operation are extensive topics. Chapter 10 in this manual addresses die casting safety from a general point of view. The NADCA course EC908, Die Casting Machine Safety is recommended for anyone working with or in the DCM environment.

Chapter 4
MACHINE, CLOSING AND INJECTION

DCM closing and injection are two of the most important machine functions. This chapter will discuss the conditions that must be met before the machine will close the die and how the tie bars work to develop the force necessary to hold the machine closed against the force of injection. Then the conditions necessary for injection are discussed followed by an explanation of the injection sequence and shot profile.

CLOSING

Before the DCM will close, a number of conditions must be satisfied. The following list of conditions may not be complete for every particular circumstance. The actual list of conditions depends on the age and manufacturer of the particular DC machine that is being used. The DC machine operator must take responsibility to determine accurately if this list is complete or if additional conditions must be met. As each cycle is initiated, the machine logic will check limit switches and sensors to determine if the conditions for closing are satisfied.

Conditions at the DCM

1. *The moving platen must be in the fully open position. The die closing cylin¬der must be fully retracted. If this is not the case, the DC machine must be fully opened manually.*
2. *The hydraulic ejection cylinder(s) must be retracted.*
3. *The injection cylinder is fully retracted, in the ready to cast position.*
4. *Safety doors and barriers are in place preventing access to the die space.*
5. *Guards are in place over and around the toggle linkage.*
6. *The pawl is engaged in the safety ratchet if the machine is so equipped.*

Conditions at the DC Die

1. *For dies equipped with hydraulically actuated cores; cores mounted to the moving/ ejector die half must be "in" or in the ready to cast position, cores mounted to the stationary or cover die half must be "out" or withdrawn.*
2. *For dies equipped with hydraulic ejection coupled to the ejector plate, the ejector plate must be returned, in the ready to cast position.*
3. *For dies employing the use of "cast-in" inserts, the inserts must be loaded in the die.*

Once all the machine/die closure conditions have been satisfied, and upon receipt of the cycle start signal, the safety pawl is withdrawn and the machine can begin closing. The machine will close rapidly, but under low pressure. The speed of die closing can be controlled by opening or closing a throttle valve; or if cartridge valves are used, by programming the logic controller. A properly set machine will close using low pressure hydraulic oil. In case an obstruction is encountered, the machine will stop, not having enough power to overcome the obstruction and cause damage. The setting is only good to prevent damage to tooling and equipment and should not be considered a personnel safety device. A limit switch setting should determine the transition from low to high pressure. This should be 'within 0.030" of the die faces meeting. High pressure oil is used to close the die, stretch the tie bars and lock the die.

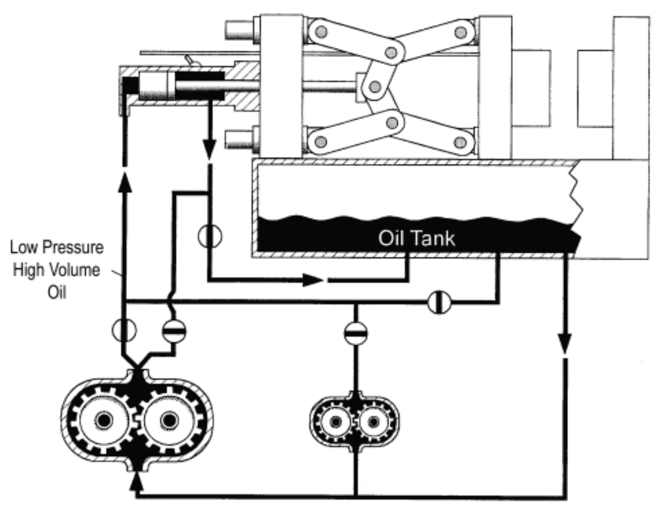


Fig. 4-1. Hydraulic schematic showing oil flow during the first stage of die closing. Oil flows from the high volume, low pressure pump into the head side of the die close cylinder.

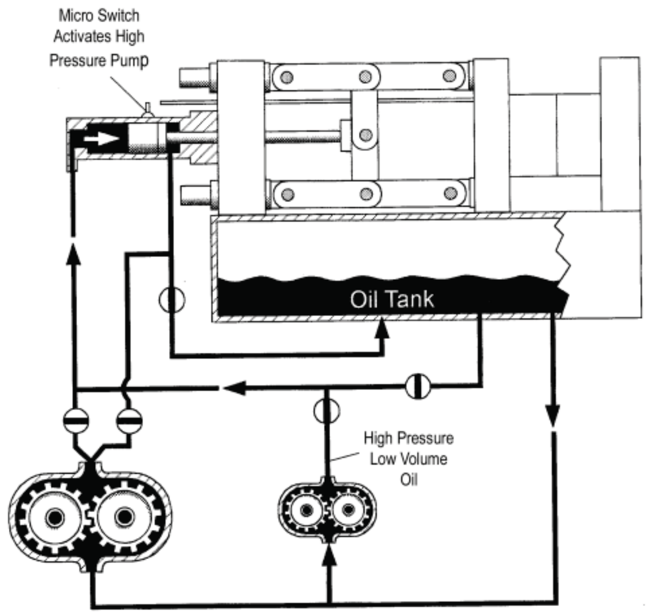


Fig. 4-2. Hydraulic schematic showing oil flow during the second stage of die closing. Oil flows from the low volume, high pressure pump into the head side of the die close cylinder.

If you review the hydraulic schematics in Figs. 4-1 and 4-2, for the two stages of die closing you will note the differences in oil volume and pressure requirements. During the first stage of die closing the cylinder has to move a long distance, whatever the die closing stroke is. During this stage the only resistance the cylinder must overcome is the static friction to get the platen moving and then a lesser dynamic friction to keep the platen moving.1-lost machines have enough low pressure pump capacity to supply this oil directly from the pump. At the second stage of die closing, the die faces are in contact, so the cylinder travel requirement will be relatively small, but it will take a great effort to stretch the tie bars to lock the machine. For the second stage of die close, the high pressure pump supplies a smaller volume of oil at very high pressure. Once the toggles are locked, a limit switch, activated by the crosshead, senses this condition.

Die locking and tie bar loading is one of the major die casting process variables. As the machine operator, you should be aware of this and observe the lock up sequence as frequently as possible. The tie bar loading, or amount of stretching, can vary from cycle to cycle. Usually these changes are not large or important, but when they are, you should be aware of them in order to take corrective action. The amount of tie bar stretching can be measured. By measuring the stretch of each tie bar every cycle and observing the readings you will know if a change has occurred. If this is not practical, other methods of monitoring the tie bar strain will have to be developed.

Measuring Die Locking

The amount of stretching can be measured. This is called "strain." Strain is a mechanical property of many materials. Strain is predictable and depends on the material used. Strain is defined as the amount of stretch (elongation or **ΔL**) divided by length (**L**) over which the stretch was measured.

$$\varepsilon = \frac{\Delta L}{L_o} \quad \text{or} \quad \Delta L = \varepsilon \bullet L_o \qquad \text{Eq. 4-1}$$

Where:

ε = strain
ΔL = change in length
L_o = original length

For example, if a tie bar stretches 0.008" over a distance of 8.0", the strain is:

$$\varepsilon = \frac{0.008\text{in.}}{8.0\text{in.}_o} = 0.001 \text{ in./ in.}$$

The strain is equal to one one-thousandth of an inch per inch. Or every inch of the tie bar stretches 0.001". A 10 foot long tie bar, 120 inches long, would stretch 0.120". Almost an 1/8 of an inch.

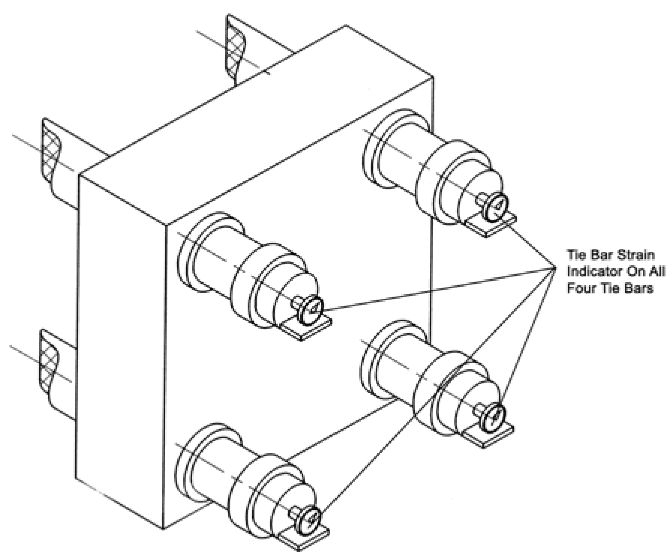


Fig. 4-3. Dial indicators mounted at the ends of the tie bars can be used to measure strain.

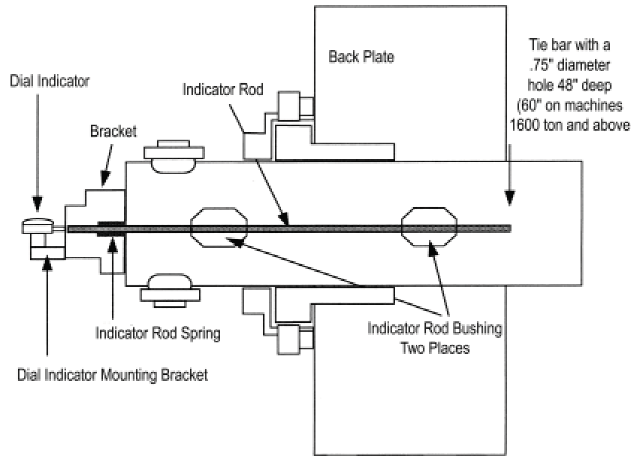


Fig. 4-4. Schematic diagram of a dial indicator mounted to a drilled tie bar.

The tie bar strain can be measured a number of ways. The simplest method is to drill the center of the of the tie bar to a specific depth and measure the elongation over the depth of the hole.

Another method is to use a temporary magnetic device with a dial indicator that clamps to the tie bar and measures the amount stretch between the magnets..

We can actually calculate the tie bar loads from measurements made at the machines. The formula for this calculation is as follows:

$$\mathbf{F_{tb} = \varepsilon \cdot A_{tb} \cdot E} \qquad \text{Eq. 4-2}$$

Where:

$\boldsymbol{\varepsilon}$ = Strain is the amount of stretching, in./in.

$\mathbf{A_{tb}}$ = cross-sectional area of the tie bar, in^2.

$$\mathbf{A_{tb} = \Pi \cdot \frac{D_{tb}^{\ 2}}{4}} \qquad \text{Eq. 4-3}$$

E = Modulus of elasticity of the steel, F. This is 30,000,000 lbs./in^2.

Calculate Force/Load

Remember, strain is the "unit elongation", the amount of stretching for each inch of measured length. If the dial indicator reads 0.004 inches, over a measured length of 8.0 inches, the strain (ε) is 0.0005 inches.

$$\varepsilon = \frac{\textit{Measurement}}{\textit{length}} = \frac{0.004\text{in.}}{8.0\text{in.}} = 0.0005\text{in./in.}$$

Example: A machine with 4 inch diameter tie bars has a measured strain of 0.0005 in./in. What is the load/force on the tie bar?

Answer: $\mathbf{F} = \boldsymbol{\varepsilon} \bullet \mathbf{A} \bullet \mathbf{E}$ $\quad \boldsymbol{\varepsilon} = 0.0005$ in./in.

$$\mathbf{A} = \Pi \bullet \frac{\mathbf{D}^2}{4} = 3.1416 \bullet \frac{(4\text{in.})^2}{4} = 12.57\text{in.}^2$$

$$\mathbf{F} = \boldsymbol{\varepsilon} \bullet \mathbf{A} \bullet \mathbf{E} = (0.0005 \text{ in./in.}) \bullet (12.57 \text{ in.}^2) \bullet (30{,}000{,}000 \text{ lbs./in}^2)$$

$$\mathbf{F} = 188{,}550 \text{ lbs. or } 94.3 \text{ tons}$$

This would be equivalent to a 400 Ton DCM, about 100 tons per tie bar.

Exercise: The 400 Ton DCM in the previous example has tie bars that are 12 feet long. Prior to start-up you noticed flash sticking to the leader pin on the top of the die opposite the operator. You removed the flash but were surprised to find it 0.015 inches thick. Could this damage the DCM or die? Explain.

Changes to Die Locking

As noted previously, die locking/tie bar strain is an important process variable and you as the operator should be continually aware of how the die lock is behaving. Under normal operating conditions the machine cycle will have a particular rhythm to it. The normal cycle will have various noises, such the sprayers, the shot and the hydraulic pumps and motors. You should be aware when changes to this normal cycle occur, be aware of the exceptions. In the case of die locking, is the machine slowing down and straining more to lock the die? Has the machine sped up and is it locking with less effort? Is the machine straining and twisting, or bending? Is the machine "popping" or jumping when it unlocks? Machine locking and unlocking should be fluid movement with a hesitation when the machine locks and stretches the tie bars.

The objective of the die is to maintain a consistent and uniform lock, straining the tie bars uniformly. If the die lock changes during production you should try to determine why the change occurred and correct the problem. There are several common causes for the die lock changing. They are:

- Temperature
- Flash
- Loose fittings

As the die heats up to operating temperature, it expands. This means the shut height dimension will get longer. As the die gets bigger, it will be more and more difficult for the machine to lock up. When this occurs, you will have to open the shut height and adjust for the larger die.

As with the die, during production the machine also warms up. It is possible that the tie bars could increase in temperature by 20-30°F. This will cause the tie bars to expand (get longer). If this happens the lock will get looser. The shut height will have to reduce to tighten the lock.

Flash stuck to the die faces will make the die thicker. This is similar to the die expanding due to heat, except it can be more of a problem. First, changes due to flash are usually greater than expansion. Second, the flash is not uniform and causes a load imbalance. Excessive flash has been responsible for a large number of broken tie bars.

As the machine locks, it squeezes the die faces together and pushes against the stationary and rear platens. The platens in turn push on the tie bar nuts. The tie bar nuts grip and stretch the tie bars. If the nuts are loose and can rotate on their thread, the die lock can change. Each nut will have a hold down device to prevent the nut from turning. You should make sure on a daily basis that the nuts are secure. This should be part of your start up machine inspection.

INJECTION

Before injection will occur a number of process and safety conditions must be satisfied.

- o The die must be locked.
- o The plunger must be retracted in the ready to cast position.
- o All safety doors and barriers must be in place.
- o Plunger tip has been lubed and is cooling properly.

The injection sequence begins when metal is poured into the cold chamber. The metal should be dipped/pumped from the holding furnace and transferred to the cold chamber as quickly as possible, to minimize heat loss and with as little turbulence as possible. Agitation at this time would only add to oxidation problems.

The alloy should be poured into the cold chamber quickly, but without agitation. It has been estimated that the heat lost during alloy transfer could be as much as 20-30°F per second. Then the shot is initiated. The wave formation, in the cold chamber, during slow shot is very important. A wave forms as the alloy is poured into the sleeve. The alloy quickly runs down to the parting line of the die and is reflected back to the pour hole. The ideal time to start the shot is when the wave arrives back at the shot hole and is reflected toward the biscuit block. An alternative is to pour slowly and try not to start a wave.

During injection a number of important process characteristics are executed, characteristics that have a great influence on the casting quality. These characteristics (or variables) are:

- o Slow velocity past pour hole
- o Critical slow shot velocity (CSS)
- o Slow/Fast transition point
- o Fast shot speed/fill time
- o Static pressure
- o Intensification start time, ramp time and pressure

Many machines have limited injection capability. For example, many hot chamber machines only have a fast shot without intensification. A few will have a slow and fast shot. Most cold chamber machines have a slow and fast shot capability with some capability for increasing hydraulic force at the end of cavity filling, called intensification or pre-fill. The example calculations that follow could be used to construct a theoretical shot velocity profile.

Pour Hole Velocity

For purpose of this discussion the pour hole velocity will be defined as the portion of the injection sequence when the plunger travels from its start position to past the pour hole. Plunger speed during this first step is very slow. The objective is to travel past the pour hole without splashing metal out of the pour hole and minimizing turbulence in the shot sleeve. Pour hole speeds are generally in the range of 3-7 inches per second (0.8-0.18 ms).

Critical Slow Shot Velocity (vcss)

The ideal slow shot speed is a speed that is slow enough to allow the air in the cold chamber to be pushed through the die and fast enough to prevent a significant amount of alloy to freeze and loose temperature in the cold chamber. For the case of non-vacuum die casting, this is called the "critical slow shot velocity" or $\mathbf{v}_{css}$. The $\mathbf{v}_{css}$ should be reached as soon as the plunger passes the pour hole. This speed is dependent on the sleeve diameter and the amount of metal poured into the sleeve on a percentage basis.

This speed can be calculated from the following formula:

$$\mathbf{v}_{css} = \mathbf{c}_{cc}\left[\frac{(100\% - \mathbf{f}_i)}{100\%}\right]\sqrt{\mathbf{d}_{pt}} \qquad \text{Eq.4-4}$$

Where:

$\mathbf{v}_{css}$ = critical slow shot velocity, in/sec (m/s)
$\mathbf{f}_i$ = volume fraction of shot sleeve initially filled with molten metal, %
$\mathbf{d}_{pt}$ = plunger diameter, in. (m)
$\mathbf{c}_{cc}$ = curve fitted constant, 22.8 in0.5 /sec., (0.579 m0.5/s)

The percent of initial shot sleeve filling, $\mathbf{f}_{i,}$ must be calculated. The percent of initial shot sleeve filling, $\mathbf{f}_i$, is determined from Eq. 4-5 and 4-6

$$\mathbf{f}_i = \left(\frac{\mathbf{V}}{\mathbf{A}_{pt} \bullet \mathbf{L}_s}\right) \bullet 100\% \qquad \text{Eq.4-5}$$

Where:

$\mathbf{V}$ = Volume of metal ladled into shot sleeve, in^3 (cm^3)
$\mathbf{L}_s$ = Length of the shot sleeve between the face of the plunger and the face of the ejector die, in. (cm)
$\mathbf{A}_{pt}$ = shot plunger area, in^2 (cm^2)

and

$$\mathbf{A}_{pt} = \Pi \bullet \frac{\mathbf{d}_{pt}^{\ 2}}{4} \qquad \text{Eq. 4-6}$$

Where:

$\mathbf{A}_{pt}$ = the area of the metal plunger, in2 (cm2)
Π = 3.14
$\mathbf{d}_{pt}$ = diameter of the plunger tip, in. (cm)

Exercise: Find the initial percent fill and the critical slow shot speed required to manage the air given the following parameters: (the solution can be found in the appendix).

Plunger diameter - 3 in
Sleeve length - 20 in
Total shot volume - 65 in3

If vacuum is being used, the slow shot speed is set to allow enough time to draw a vacuum. This may be 1.5 - 2.0 seconds.

Many older machines do not have enough pump capacity to supply oil required to maintain the $\mathbf{v}_{css}$. You can calculate the pump requirements if you know your shot cylinder diameter.

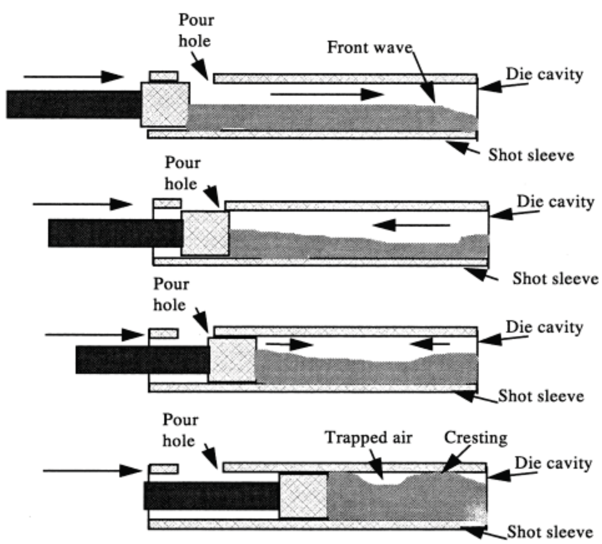


Fig. 4-5. Schematic diagram of wave formation in cold chamber during the slow shot.

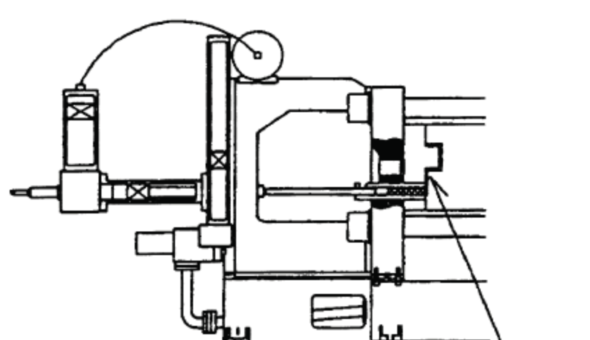


Fig. 4-6. Schematic diagram of shot end during fast shot

Once the cold chamber is filled with metal, you need to consider when the fast shot should start. When the metal arrives at the gate, you want it to have reached its desired gate velocity. You can calculate the ideal length of fast shot by determining the volume of metal required to fill the die cavity, and converting this volume to a cylinder having the same diameter as the plunger the cylinder height would be equal to the plunger stroke needed to fill the cavity.

Example: If the metal through the gate has a volume of 55 in3 and the cold chamber is 3.0 in. in diameter. What shot stroke length is required to fill the cavity?

$$\mathbf{V_{cyl}} = \mathbf{A_{cyl}} \bullet \mathbf{H_{cyl}} \qquad \text{Eq. 4-7}$$

Where:

$\mathbf{V_{cyl}}$ = volume of a cylinder, in3
$\mathbf{A_{cyl}}$ = area cylinder (cold chamber) in2.
$\mathbf{H_{cyl}}$ = height of cylinder containing the volume through the gate, in.

Rearranging and solving:

$$\mathbf{H_{cyl}} = \frac{\mathbf{V_{cyl}}}{\mathbf{A_{cyl}}} = \frac{55\text{in.}^3}{7.07\text{in.}^3} = 7.78\text{in.} \qquad \text{Eq. 4-8}$$

For this example, the minimum length of fast shot would be about 7.8 inches. It is not possible for the machine to instantly shift from slow to fast shot. This transition takes time. You should determine how much plunger travel takes place for this transition to take place. For most machines this can be 1-2 inches of travel. This transition length should be added to the previously calculated minimum fast shot length.

If your transition from slow to fast shot requires 2 inches travel, the minimum fast shot length would then be 9.8 inches (7.8 in. + 2 in. = 9.8 in.). This transition point is usually controlled by the fast shot limit switch or timer.

Fast Shot Velocity

The fast velocity/shot speed is one of the most important process variables. This speed will determine the gate velocity and the cavity fill time. When the die is engineered, a lot of effort goes into determining the best gating, both gate size and flow pattern. This is based on the best estimate of a maximum allowable time to fill the die cavity and achieving atomization of the metal during filling. The calculation of cavity fill time is based on the casting geometry (mostly wall thickness) and die and metal temperatures. When a cavity fill time is calculated, this is the best estimate of the maximum time available to make an acceptable casting. This is an estimate or starting point that is then refined by experience. Fast shot speed is very important, since only one speed will give the best initial combination of gate velocity and fill time. The relationship between gate velocity, fill time and fast shot speed is as follows:

The die casting machine pumps the metal at a given fill rate, it pumps "Q" cubic inches of metal in a second. In fact, the shot end of a machine is rated by its maximum pumping capacity or filling rate for a give plunger size. The pumping rate for a particular job is determined by multiplying the plunger area times the plunger speed, or

$$\mathbf{Q} = \mathbf{A_{pt}} \bullet \mathbf{V_{pt}} \qquad \text{Eq. 4-9}$$

Where:
Q = flow rate of metal into the cavity, in^3/sec.
$\mathbf{A_{pt}}$ = area of plunger tip, in^2.
$\mathbf{V_{pt}}$ = velocity of plunger, in./sec.

Example: Given a 3 inch diameter plunger traveling at a fast shot speed of 120 inches per second, what is its filling rate?

$$\mathbf{Q} = \frac{\mathbf{\Pi \bullet d^2}}{4} \bullet \mathbf{V} = \frac{3.1416 \bullet (3in.)^2}{4} \bullet 120in./sec. = 848in.^3/sec.$$

Once the filling rate or pumping capacity for a given plunger diameter and plunger speed is known, you can determine the gate velocity and fill time straight away.

The fill time is equal to the volume of the metal through the gate (casting and overflows) divided by the filling rate.

$$\mathbf{Q} = \frac{Vol}{\mathbf{t_f}} \qquad \text{Eq. 4-10}$$

In this example the casting and overflow volume was given as 55 cubic inches and flow rate at 848 in^3/sec. The fill time can be calculated as follows:

Rearranging Eq. 4-10 and solving:

$$t_f = \frac{Vol}{Q} = \frac{55in.^3}{848in.^3/sec.} = 0.0648 \text{ sec.}$$

t_f = 0.0648 seconds or 65 milliseconds

The gate velocity is equal to the filling rate divided by the gate area. If this example has a gate area of 0.75 square inches, the gate velocity of speed of metal through the gate is 1130 inches per second. This is determined as follows:

$$Q = A_g \bullet V_g \qquad \text{Eq. 4-11}$$

Rearranging Eq. 4-11 and solving:

$$V_g = \frac{Q}{A_g} = \frac{848in.^3/sec.}{0.75in.^2} = 1130.7in./sec.$$

The machine hydraulic pumps do not have enough capacity to supply oil to the shot cylinder to achieve the fast shot speeds that are necessary to inject the metal. For this reason, an accumulator is used. The accumulator is an energy storage device, it stores a volume of oil under very high nitrogen gas pressure. When the fast shot is required, the accumulator discharges pressurized oil into the shot cylinder.

Static Metal Pressure (P_m)

Static metal pressure is the pressure in the die cavity at the moment it is filled. In the simplest case it is related to the system hydraulic pressure, the area of the shot cylinder and the area of the plunger tip. The following formula defines this relationship:

$$P_m = P_{hyd} \bullet \frac{A_{sc}}{A_{pt}} \Rightarrow P_m = P_{hyd} \bullet \frac{\frac{\Pi d_{sc}^2}{4}}{\frac{\Pi d_{pt}^2}{4}} \Rightarrow P_m = P_{hyd} \bullet \frac{d_{sc}^2}{d_{pt}^2} \qquad \text{Eq. 4-12}$$

Where:

P_{hyd} = hydraulic pressure in the shot cylinder, lbs./in2 (kg/cm2)
d_{sc} = diameter of the shot cylinder, in. (mm)
d_{pt} = diameter of the shot cylinder, in. (mm)

Example: Given the following, what is the static metal pressure.

$\mathbf{P_{hyd}}$ = 1500 lbs./in2)
$\mathbf{d_{sc}}$ = 6.0 in.
$\mathbf{d_{pt}}$ = 3.0 in.

Substituting into Equation 4-11:

$$\mathbf{P_m} = \mathbf{P_{hyd}} \bullet \frac{\mathbf{d_{sc}}^2}{\mathbf{d_{pt}}^2} = 1500 \frac{\text{lbs.}}{\text{in.}^2} \bullet \frac{(6\text{in.})^2}{(3\text{in.})^2} = 6000 \text{ lbs./in.}^2$$

Static metal pressure is 6000 PSI, in this case 4 times the hydraulic pressure.

Intensification

Intensification refers to increasing or multiplying the hydraulic pressure in the shot cylinder. This intensified pressure is then multiplied at the biscuit, and used to generate a high cavity pressure to control both shrinkage porosity and the size of gas porosity.

Intensification is one of two ways to increase the output of the shot cylinder. Mathematically the out put of the shot cylinder is a force (**F**), defined as follows:

$$\mathbf{F} = \mathbf{P} \bullet \mathbf{A} \qquad \text{Eq. 4-13}$$

Where:

P is the hydraulic pressure in the shot cylinder in lbs./in^2 (kg./cm.^{2})
A is the area of the hydraulic piston in in.^{2} (cm.^{2})

The force (**F**) can be increase by increasing the hydraulic pressure (P) with an intensifier or increasing the area (**A**) as with the Lester Die Cast Machine's Prefill system.

Intensification occurs after the cavity has been filled. Today, many DCM's intensifiers are rated by how much they multiply the system pressure. A reasonable multiplier would be 3X. If applied to the previous example of static metal pressure, a 3:1 intensifier ratio would increase the 6000 PSI pressure in the cavity to 18,000 PSI.

A hydraulic intensifier is shown in the sketch of Fig 4-7. The force input at $\mathbf{F_1}$ is equal to the force output at $\mathbf{F_2}$.

$$\mathbf{F_1} = \mathbf{F_2} \qquad \text{with} \qquad \mathbf{F_1} = \mathbf{P_1} \bullet \mathbf{A_1} \qquad \text{and} \qquad \mathbf{F_2} = \mathbf{P_2} \bullet \mathbf{A_2}$$

Therefore:

$\mathbf{P_1 \cdot A_1 = P_2 \cdot A_2}$ and for $\mathbf{A_2} = \frac{\mathbf{A_1}}{3}$, $\mathbf{A_1}$ is 3X larger than $\mathbf{A_2}$

$\mathbf{P_1 \cdot A_1 = P_2 \cdot} \frac{\mathbf{A_1}}{3}$ Then $3\mathbf{P_1} = \mathbf{P_2}$

The multiplier ratio in this case would be 3:1.

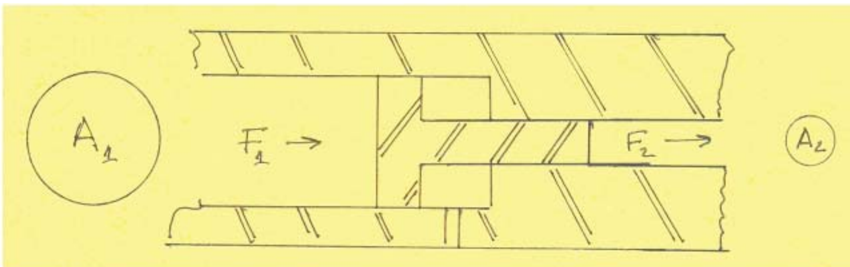


Fig. 4-7. Sketch of hydraulic intensifier. The ratio of A1 to A2 determines the intensifier multiplier.

The intensifier has three variables that must be controlled to optimize the effectiveness of the intensifier. They are:

- Initiation of intensification
- Maximum hydraulic pressure
- Rate of build-up to maximum pressure

On most machines, all are adjustable. They are controlled to achieve maximum pressure in the cavity without the die spitting or losing pressure. To see and control the intensifier you must have a shot monitoring system that displays the shot cylinder hydraulic pressure with respect to the shot plunger/rod.

Shot Profile

There must be some way of measuring the shot end speeds and pressures. A printout of these measurements is referred to as a shot profile. The shot profile records the pressures and speeds of the shot cylinder with respect to plunger position and/or elapsed time. Without measurement there is no way to know how the shot cylinder is actually performing.

As an operator, there are several things that you should be watching for during every shot. First, note the stopped position of the plunger at the end of the shot. If the plunger has not reached its normal end of stroke position this could be an indication of a thick biscuit or some other hazardous problem. Next, watch to see that the plunger moves smoothly, no stuttering or lurching. This could be an indication of lack of lubrication, metal build up, or inadequate cooling. Watch for metal bypassing the plunger tip. This could indicate the tip is worn out and needs replacement.

Fig. 4-8 is a typical shot profile. For the purposes of this course, only a brief description of the profile is provided, not a detailed analysis. Further evaluation of shot profiles is done in a course dealing with process control.

This shot profile shows the output of three transducers. Transducers are devices that convert a physical motion or pressure into an electrical signal. These electrical signals are then plotted or displayed on a screen to show a record of events during injection.

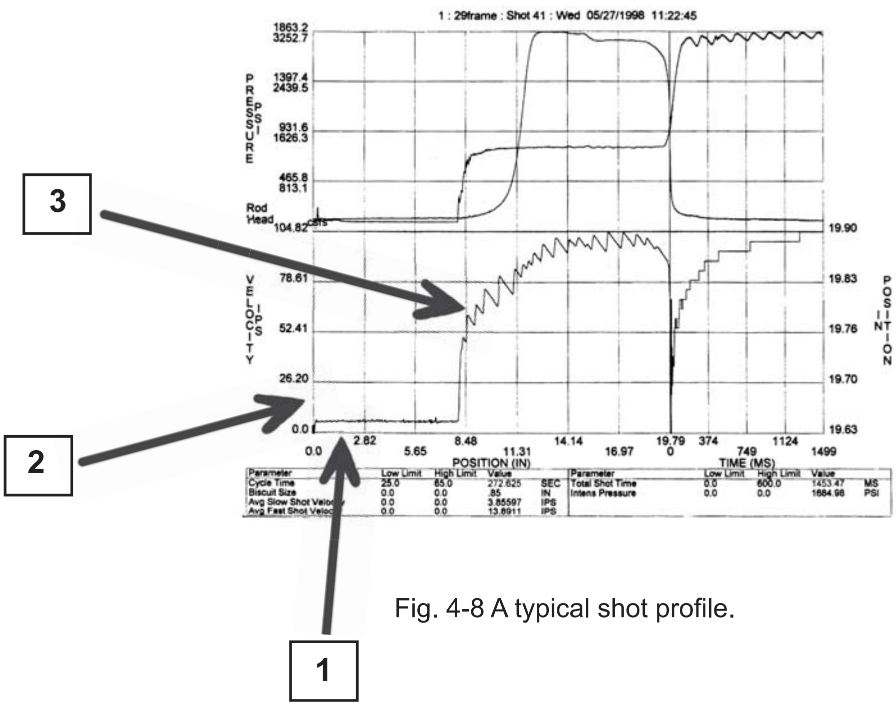


Fig. 4-8 A typical shot profile.

The horizontal axis, identified by (1), shows the plunger position during injection. After the cavity is filled, this axis shows time. The vertical axis on the left is the magnitude of plunger velocity. This is identified as (2). The trace identified as (3) is the plunger velocity trace. The plunger velocity trace starts in the lower left corner at 0,0, the origin. As the plunger starts to move, the trace jumps up to approximately 5 inches per second (ips) plunger speed. The slow shot and critical slow shot speeds for this trace. After approximately 7 inches of travel the velocity again jumps up in speed. This is not a sudden increase; it takes approximately 6 inches of plunger travel position (8 to 14 inches) to go from 5 ips to 100 ips. The plunger travels at this fast shot speed until it reaches 19.79 inches of travel and then the velocity drops to zero. This indicates the cavity is filled. After the cavity is filled, the horizontal scale switches to time, and starts from zero time, when the cavity was filled. The trace now shows the plunger's position verses time. The vertical axis on the right is scaled in inches to show the plunger's position. This scale starts at 19.63 inches, so it slightly overlaps the velocity curve end point of 19.79. This portion of the curve shows the affect of intensification. Once the cavity is filled, the metal begins to solidify and shrink, when the intensifier is turned on, it moves the plunger forward, forcing more metal into the cavity. This trace indicates the plunger has moved from 19.63 inches to 19.90inches.

The top two traces are pressure lines. Line 4 is the hydraulic oil pressure on the head side of the shot cylinder. The vertical scale on the left indicates the amount of hydraulic pressure. The large values (813.1-3252.7 PSI) apply the head side pressure line. The line identified as 5 is the rod side pressure of the shot cylinder. The lower values (465.8-1863.3 PSI) refer to the values of this line.

The head side pressure, line 4, jumps up to about 200 PSI at the start of plunger movement, and stays at that level during the slow shot travel. The pressure increases to 1400 PSI when the plunger moves to fast shot. During the fast shot, as the metal is forced through the gate, the pressure remains constant. Then as the cavity becomes filled and the plunger comes to a stop the pressure builds to the maximum value, about 3200 PSI.

The rod side pressure behaves somewhat differently. This trace was made on a machine that controls the flow of oil out of the shot cylinder as opposed to having the flow control on the oil line going into the cylinder. This is called a "meter out" flow control. During the shot, flow into the cylinder is unrestricted. A valve at the cylinder outlet is opened and further opened to control the oil flow. At the beginning of the shot, during the slow shot phase, this pressure is very low, about 100 PSI. As the plunger speeds up and then during the fast shot, this pressure is very high, about 1800 PSI. Then as the cavity fills up, and the plunger speed drops the zero, the pressure also drops to a minimum value.

Chapter 5
CONTROLS

Modern die casting machines (DCM) may differ widely in placement of the machine controls. In general, the basic machine functions are common with most differences occurring in machine accessories and ancillary equipment. This chapter will deal with the basic machine functions and safety related items and some specific cases of accessories and ancillary equipment. Accessories are defined as equipment that is optional and in addition to the basic machine functions. Examples of accessories are automated tie bar pulling systems or automated die locking systems. Examples of ancillary equipment are extractors, autoladles, robots, reciprocators and conveyors.

The machine controls can be segregated into several logical groups. First, there is a sequencer or logic system, the brains of the machine. The logic system may step the machine through a pre-programmed sequence, or may respond to inputs from the operation via a control panel or may respond to inputs from other devices, such as limit switches, pressure switches, or various transducers. This logic controller may be in the form of a programmable logic controller (PLC), a drum switch or a relay tree. This will depend on the machine's age and rebuild status. It is not uncommon to replace the machine controls with a modern PLC when rebuilding or remanufacturing a machine.

Another component of the machine controls system is input devices. These are components that send signals to the machine to report the status of various actuators. Examples are the limit switch activated by the crosshead, or the pressure switch that signals when the accumulator is fully recharged. Pushbuttons and selector switches are also devices that are used to interface with the machine controller. These are all considered to be "input" devices.

The last components of the machine control system are the "output" devices. The output devices control the motions of actuators or cylinders. An example of an output device is a solenoid. Solenoids shift valves directing hydraulic fluid flow.

Discussion of the machine controls will begin with an example of a simple zinc DCM, followed by an example of a modern aluminum DCM work cell.

ZINC DCM

Control functions accessed by the DCM operator are found in two locations, the operator control panel at the operator's work station, usually near the stationary platen, and the main electrical panel located near the motor and pumps.

Main Electrical Panel

All electric power enters the machine through this panel. A hypothetical panel is shown in Fig. 5-1, and the individual controls will now be discussed.

Main Disconnect Switch. 'When this switch is "off" no electric power will go to any part of the machine. [The only exception is the holding furnace for the metal that has it own controls.] The main disconnect switch can be locked in the "off" position with a padlock. Such "locking-out" is a safety precaution taken by individuals who must do repair work in dangerous areas in or around the machine. When the main disconnect switch is "on" electric power is turned onto the machine controls. Electric motors are not started, however, and the machine will not move.

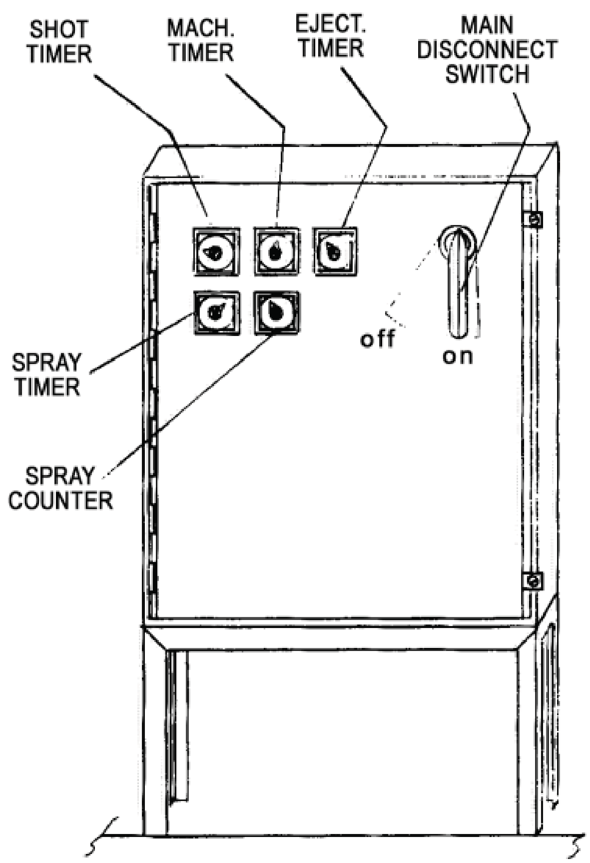


Fig. 5-1. Diagrammatic view of an older zinc DCM main electrical panel. All electric power to the DCM is distributed through this panel. The main disconnect switch can be locked in the "off" position with a padlock. These panels will vary in size and may have different controls depending on the machine manufacturer.

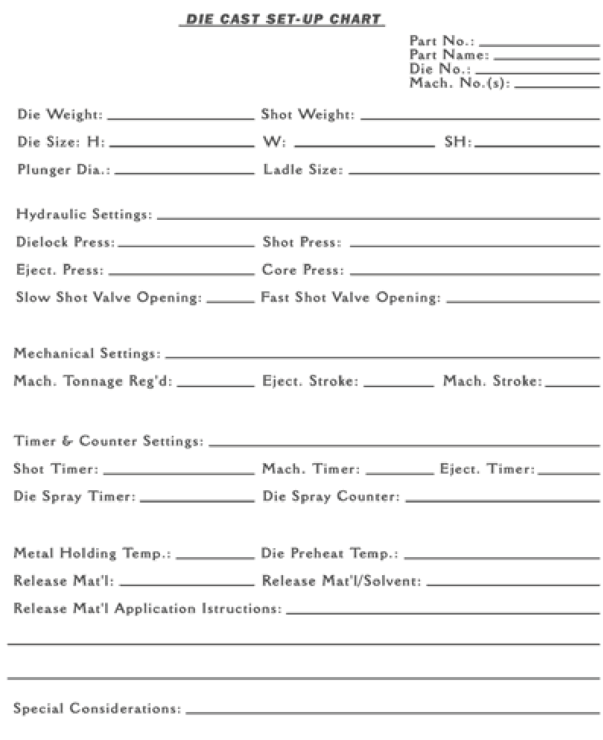
Shot Timer. This timer controls the length of time that pressure is maintained on the molten metal after it is driven into the die. The timer is started when the metal injection starts. When the timer "times-out;' the injection plunger is retracted-releasing the pressure on the metal in the die and repositioning the mechanism for the next shot.

Machine Timer. The machine timer sets the time for which the die remains closed after the shot is made. Some hot chamber machines do not use this timer. Instead, the retracting injection mechanism operates a limit switch to open the dies.

Ejection Timer. The ejection timer holds the machine open after the casting is ejected. It is used when extra time is required for die cooling and/or evaporation of die release materials.

Spray Timer. The spray timer determines the length of time that the automatic system will spray the dies with release material. Machines without automatic die. Spray systems will not have this timer.

Spray Counter. A spray counter is used when it is not desirable to spray the dies with release material at every machine cycle. Setting this counter at (I) will cause the spray system to operate at each cycle of the machine. Setting it at (2) will cause the die spray system to operate at alternate machine cycles. The higher the setting, the more times the machine will cycle between automatic spray application of the release material Each of the timers in use and the counter must be set for the particular die being run in the machine. These settings are normally given to the operator on a "set up chart:' An example of such a chart is shown in Fig. 5-2. (The other items on the chart will be discussed later.)


DIE CAST SET-UP CHART

Part No.: ________
Part Name: ________
Die No.: ________
Mach. No.(s): ________

Die Weight: ________ Shot Weight: ________
Die Size: H: ________ W: ________ SH: ________
Plunger Dia.: ________ Ladle Size: ________

Hydraulic Settings: ________
Dielock Press: ________ Shot Press: ________
Eject. Press: ________ Core Press: ________
Slow Shot Valve Opening: ________ Fast Shot Valve Opening: ________

Mechanical Settings: ________
Mach. Tonnage Req'd: ________ Eject. Stroke: ________ Mach. Stroke: ________

Timer & Counter Settings: ________
Shot Timer: ________ Mach. Timer: ________ Eject. Timer: ________
Die Spray Timer: ________ Die Spray Counter: ________

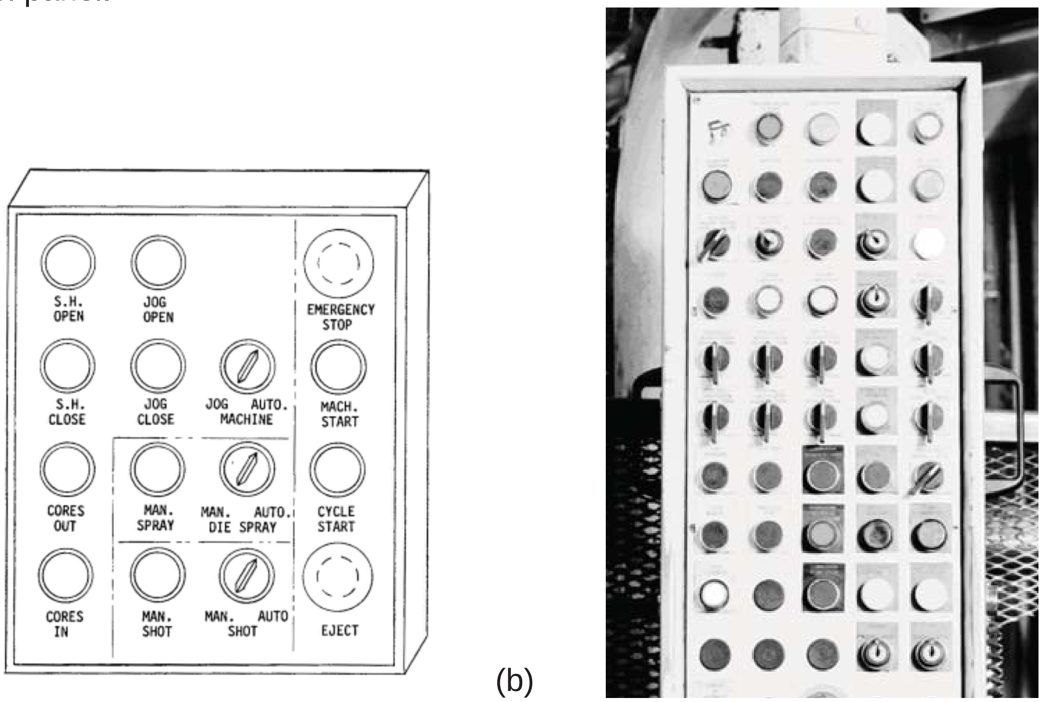
Metal Holding Temp.: ________ Die Preheat Temp.: ________
Release Mat'l: ________ Release Mat'l/Solvent: ________
Release Mat'l Application Istructions: ________

Special Considerations: ________

Fig. 5-2. The die casting set-up chart lists the machine controls; and shows how each must be set for proper operation of the specific die.

Operator's Control Panel

The operator's control panel is located conveniently to the operator (assuming he is unloading the machine manually). Although this is basically the operator's control panel, several controls are used only for die set-up. Fig. 5-3 shows a hypothetical operator's control panel.



(a) (b)

Fig. 5-3 a and b. Operator control panels. These push button and selector switch controls are placed at the operator's workstation for convenient access during the normal operation of the machine and during die set-up.

Emergency Stop. The emergency stop (or stop) is the most important control. It is usually the largest button and is shaped like a mushroom. Also, it is usually red. Being large and distinctive in color, it is easy to find and hit in an emergency, to stop the machine. When the emergency stop button is hit, either the machine opens or stops where it is. Although, once the shot is made, the machine will not open until the machine timer "times out' (Note: The injection mechanism and sometimes the die close mechanism, is powered by stored energy in accumulators that still can be active when the motors are not running.) The emergency stop control is frequently set to lock in the off position. A reset must then be depressed to release the control button before the machine can be restarted.

Machine Start. The machine start control (usually a push button) starts the electric motors that power the machine. These motors then run continuously until they arc stopped. They should be run for 10 to 20 minutes before normal machine operation is started to bring the hydraulic fluid up to operating temperature. However, the motors should not be allowed to run through extended shutdown periods because of the unnecessary wear-and-tear on the hydraulic pumps, the electricity used, and the generation of waste heat in the hydraulic system. The waste heat must constantly be removed by the water-cooled heat exchanger, or damaging overheating, will result.

Cycle Start. If the machine is properly set-up, the hydraulic controls (described later) open, the safety doors close (operating their limit switches), and the machine, die spray, and shot switches are in the automatic settings, the cycle start push button will cause the machine to go through its automatic cycle. Several different types of operation are in common use and have resulted in as many machine sequence cycles. The operator should be aware of the most common since they all may exist in a single plant

The simplest instance is the fully automatic machine. Pushing the cycle start button causes the machine cycle to start, and:

1. Cores (if any) move into position (if hydraulic)
2. Die release material is sprayed in die.
3. Ejectors retract (if hydraulic)
4. Die closes
5. Metal is ladled (if cold chamber)
6. Shot is made,
7. Delay for solidification/cooling
8. Shot plunger returns (if hot chamber)
9. Die opens
10. Cores retract (if any)
11. Shot plunger returned (if cold chamber)
12. Casting ejected
13. Casting is removed
14. Cycle restart

The cycle will continue to repeat until an uncompleted safety interlock interrupts it or until the operator stops the cycle (usually by opening the operator's safety door).

WARNING, THE SAFETY DOORS MUST NOT BE OPENED WHEN SHOT IS BEING MADE OR WHEN SHOT PRESSURE IS ON METAL IN THE DIE.

If a machine is not equipped for mechanical casting removal, the machine will stop after the casting is ejected. The operator must then open the safety door and place his tongs between the die halves, grasp the casting with the tongs, and remove it from the die. He then closes the safety door, operating a safety limit switch that in turn restarts the machine cycle. (*The casting is disposed of in whatever manner is prescribed by the supervisor.*)

Some cold chamber machines do not have mechanical ladling devices. Such a machine will stop when the die is closed. The operator then ladles the metal into the cold chamber and restarts the machine cycle by pressing the cycle start or restart button.

Eject. The eject control is only used on machines having hydraulic ejection. If the machine is set up for automatic casting extraction, the eject button is operative only when the machine selector switch is in the jog position. If the machine is set up so that the operator must extract the casting, the eject control is operative when the dies are open. When depressed, this mushroom-headed button actuates a hydraulic cylinder connected to the ejector mechanism. The ejector pins push the casting out of the ejector die.

Die Spray & Manual Spray. During set-up and trouble shooting; it is desirable to have manual control of the die spray system that applies the release agent. When the die spray selector switch is in the auto position, the system sprays release material on the dies automatically every time the die closes. When in the manual position, the spray system only operates while the manual spray button is pushed.

Shot & Manual Shot. When the shot selector is in the auto position, the machine will make the shot automatically as soon as the die has closed (except with a hand-ladled cold chamber machine). However, when the selector is in the manual position, the machine cycle will stop when the die is closed. This arrangement allows the automatic cycle to be test run with no danger of shooting molten metal into a die that may not be properly closed. It is also possible to leave the machine closed without having metal in the die, as is sometimes necessary.

Machine. The machine selector switch lets the operator choose the automatic cycle providing normal operation, or the jog mode for setup and adjustment. In the jog position, the shot (injection) mechanism will not operate. All other machine movements can be controlled by their respective push buttons as described below.

Jog Open & Jog Close. With the machine selector switch set to the job position, the machine platen will move to the closed or open positions when the appropriate button is pushed. The platen will move only while the button is held in, producing short movements (jogs) that are necessary when setting dies. (Some machines have a special jog hydraulic circuit that requires a valve to be opened manually. The operator or set-up man should check with the supervisor when operating an unfamiliar machine.)

S.H. Open & S.H. Close. Shut height controls only appear on a machine with power-driven shut height adjustment mechanisms, which move the rear platen to open or close the die space. This adjustment allows the use of dies of different thickness. (*Note: The toggle mechanism must always be completely straight when the die is closed*). During operation, the die will expand slightly as it approaches operating temperature. This expansion will either slow down the die closing movement or stop the machine completely. It is then necessary to open the shut height slightly. When doing this the operator must watch the "flash" on the casting. If excessive flash develops on the shot following the S.H. adjustment, too much adjustment was made. Machines not having power driven shut height controls must be adjusted manually by rotation of the tie bar nuts at the rear platen.

Cores Out & Cores In. Core operating controls are provided on machines equipped for dies with hydraulic core pulls. The controls provide for moving such cores in or out for set-up, lubrication, or trouble shooting. The switches should function only when the machine selector switch is in the jog position.

Hydraulic Controls

A thorough study of hydraulic circuit functions is beyond the scope of this description of how to operate the die casting machine. However, certain of the hydraulic valves must be adjusted, opened, or closed by the operator or set-up man under certain conditions. These controls must be identified and the end results of their adjustment must be understood.

Slow Shot Control Valve. Most machines have some provision for advancing the injection (shot) plunger slowly for the first part of the stroke. This eliminates splashing" of the metal before the pouring or filling port is closed by the plunger. In hot chamber machines, this slow advance is sometimes continued until the metal fills the gooseneck and nozzle. Time is thus allowed for venting the air displaced from these components. Although some machines have no speed control on the slow shot, others have a valve in the hydraulic system that can be turned to adjust the speed.

Fast Shot Control Valve. The large shot hydraulic lines have several control valves. At least one of these has a hand-wheel that can be turned manually to close the line. The stored energy of the accumulator is thus prevented from accidentally activating the injection (shot) plunger. By partially closing this control valve, the shot speed can be reduced to any desired value.

Manual/Jog/Inch Control. Some machines have a special manual circuit so that during setup, the machine can be manually open and closed slowly. With such a circuit, the manual valve must be opened manually. The valve is usually located near the operator's control panel.

Deceleration Valves. On large, high speed machines where the natural toggle motion and the die close cylinder cushion will not overcome the machine's momentum, a deceleration valve is provided. Limit switches controlling these valves are operated by cams driven by the moving platen. The cams must be adjusted to suit the stroke being used.

Safety Limit Switches

There are several limit switches on the die casting machine. Most control the sequential steps in the machine cycle. Some perform functions directly associated with the personal safety of the operator. These safety limit switches must be checked out by the operator each time he starts the machine.

Die Lock L.S. The toggle mechanisms must be in the proper (straight) position before the shot is made. If the shot is made when the toggles are out of position, they will not hold against the force exerted on the metal. The die will open and the molten metal will spray out. A limit switch is therefore, fitted so that it will be actuated by the toggle crosshead when the toggle is fully erected. It is important that the limit switch closes at the very end of the crosshead travel.

Safety Door L.S. Each safety door (enclosing the die spaces) closes a limit switch when the door is properly closed. If one of these switches is open, the machine will not close. Sometimes, large machines have power-operated safety doors. These doors have a safety bar to detect any object (arm, hand, body, etc.) that may get caught as they close. When such an object is detected, the door and the machine instantly return to the open position and the machine cycle stops.

Casting Removed L.S. A limit switch, electric eye, infrared detector, proximity or vision device is used to detect the casting as it is being automatically removed from the die. Naturally, machines on which the operator removes the casting will not have such a device. If the removal of the casting is not detected, the machine cycle will stop. Usually, the detector must be adjusted differently for each die run in a particular machine.

A CASTING REMAINING BETWEEN THE DIE HALVES MAY PRESENT A SAFETY HAZARD TO THE OPERATOR.

Individual machines may have other limit switches that are adjustable. If so, the supervisor should be sure the operators are aware of their functions.

Stroke Adjustment

The machine stroke is set by turning the stroke adjustment screw at the back of the machine-dose cylinder. The location of the stroke adjustment is shown in Fig 3-22. Set screws or a jam nut are usually provided to lock the screw when the desired adjustment is achieved.

ALUMINUM DCM AND WORKCELL

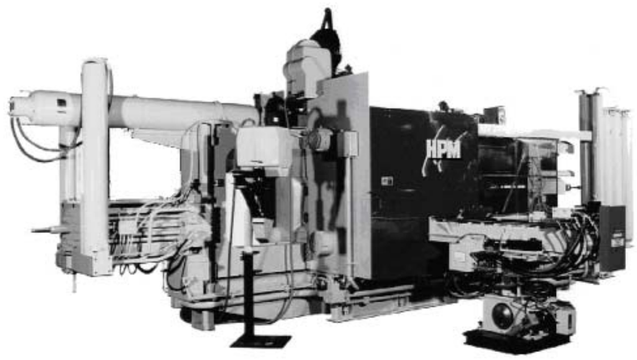


Fig. 5-4. A 1200-ton aluminum DCM in a workcell with a reciprocator, auto-ladle, and extractor robot.

The modern aluminum DCM is much more sophisticated than the machine of 30 years ago. This machine still provides the same functions; opening, closing, and injection of the earlier machine. However, these functions are provided in a more repeatable and reliable manner. Today's machines also have much more injection and locking capability than older machines.

Additionally, many of today's machines are provided in workcells with ancillary equipment. To keep the modern DCM’s ladles, reciprocators, and extractor/robots running requires knowledge beyond operation of the basic die casting machine. The operation of ancillary equipment is beyond the scope of this text.

The modern machine is controlled by a programmable logic controller (PLC), a computer. The PLC replaces the hardwired relay logic of older DCM's. The PLC provides greater reliability and versatility. Versatility means the machine operation sequence can be changed with programming as opposed to rewiring the machine. This programmable capability makes it possible to have an optimized program for every die.

Each piece of ancillary equipment will have its own control cabinet and operator panel. For a conveyor this could be as simple as a disconnect switch and on and off pushbuttons. For an extractor robot the control panel and operator station could be more sophisticated than the DCM controls. If the ancillary equipment has to operate in conjunction with the DCM cycle, it must be able to communicate with the DCM. To accomplish this they will be hardwired together.

Fig. 5-5. A data acquisition system for monitoring the shot profile can be useful piece of process control equipment.

In a custom die casting shop it is not unusual to run a DCM with ancillary equipment one-day and then run the machine manually the next day. This means there must be a way to tell the DCM whether the ancillary equipment is to be used. An on-off selector switch for each piece of ancillary equipment can be located at the control cabinet to accomplish this requirement.

Several examples of when the various pieces of ancillary equipment must interface with the die casting machine are as follows:

Autoladle. The autoladle receives an electrical signal from the DCM when the DCM is locked. This signal initiates pouring by the auto ladle.

DCM. When the auto ladle has completed pouring, it sends a signal to the DCM. This signal initiates the shot at the DCM.

Extractor. Once the DCM has fully opened, it sends a signal to the extractor. This signal initiates the extraction cycle.

Reciprocator. After the part has been completely removed, the extractor sends a signal to the reciprocator. This signal initiates the reciprocator cycle.

These are just a few examples of signals and communication that may be necessary for a DCM workcell to operate. With all the variations of equipment and DCM 's it is impossible to detail all the interface communication that would be necessary. Each workcell and system must be customized to the machinery and ancillary equipment that is available.

A sophisticated DCM may also be equipped with shot/process monitoring and data acquisition equipment. This equipment can be set-up to monitor the process variables discussed in Chapter 4. In addition to monitoring, many die casters are using this equipment to determine and establish the values of the process variables prior to monitoring them. Also, the maintenance department can use this equipment to diagnose machine problems.

REVIEW

Controls have been discussed by looking at two examples, a simple zinc OCM and an aluminum workcell. In is clear that the basic functions of all DCM's are the same. The machine opens and closes and metal is injected. The controls determine the machine sequence and how the actuators (cylinders) are energized to perform the machine functions. If the machine has accessories, such as a tie bar pulling mechanism or multiple stage injection, the controls become more numerous and sophisticated. Another control issue is ancillary equipment. Ancillary equipment must be interfaced with the OCM for safe and productive operation. Finally, control technology has changed in the last half of the twentieth century. Machines in the 1950's had a control cabinet full of relays; today the control cabinet contains a PLC.

Chapter 6
SETUP PROCEDURE

Actual setting of dies may or may not be part of the normal duties of the machine operator.

However, the operator should know how to set dies because:

1. he must be able to check the set-up,
2. he may be required to set dies on a day-rate basis, and
3. die setting is usually the next advancement set for a skilled operator

Die setup and teardown has gone through a revolution in thinking in the several past decades. In short, setup time is not productive and must be minimized. Dr. Shigeo Shingo an International consultant, had a great impact on manufacturing with his teachings in three concepts: Just in time (J IT), Single Minute Exchange of Dies (SMED), Zero Quality Control. Dr. Shigeo introduced the SMED concept.

SMED is an acronym for Single Minute Exchange of Dies. This means that the entire die change process, from last good part to first good part is completed in less than 10 minutes. This is the goal. Some die casters with both large and small dies have already achieved this goal.

Dr. Shigeo's approach to developing the SMED concept was to isolate and identify the setup time as two entities: internal setup time and external setup time. According to him, a simple approach to achieving a quick setup and changeover of dies can be done in the following steps:

- Separating internal and external as it is existing
- Converting internal to external setup
- Streamlining all aspects of the setup operation

EXAMPLE

This chapter uses the setup of a single cavity hot chamber die as an example. Each step of the setup is listed and explained. Thirty-three steps are required to set the die, teardown is not included in the example. At the conclusion of the example, the first step of SMED is exercised:

Separating internal and external as it is existing

Assuming there is no die in the machine, the following steps are to be followed:

1. **Deactivate Shot**. The shot mechanism is deactivated by closing both the slow shot control valve and the fast shot control valve. These valves must be closed because the stored energy in the accumulators provide enough power to actuate the shot system even when the main disconnect switch is locked out. Hot chamber machines must also have the shot plunger taken out of the gooseneck or physically blocked. (If there is no die in the machine, the plunger should already have been removed or blocked.)
2. **Open Machine**. The machine is opened by turning the Machine Selector Switch on the operator's control panel to Manual (jog/inch) and then pushing the open button until the machine platen is open. On some machines, a die close speed control valve will have to be closed and a manual valve opened. The main disconnect switch must then be locked out. Note: Before locking out the main disconnect switch, it may be convenient to make the measurements detailed in Step 8 and Fig. 6-5 to select bumper pins of the correct length.
3. **Clean Die Mounting Surfaces**. With the main disconnect switch locked out, clean, (scrape, if necessary) all dirt, grease, and die cast metal from the machine platens. Be sure T-slots are clean so clamp bolts can be placed wherever necessary. Any burrs from previous misuse must be filed flush. Select cold chamber per set-up chart and install through front platen.
4. **Clean Mounting Surfaces of Die**. Like the machine, the die surfaces must be free of grease, dirt, and die cast metals.
5. **Insert Eyebolts into Die**. Eyebolts should be of the shoulder type, and should be threaded into the die until the shoulder seats against the die as shown in Fig. 6-1.
6. **Install W.L. Pipes**. If the water line pipes are not in the die, it is usually most convenient to install them before the die is placed in the machine. Sometimes, water lines are placed in areas where pipes cannot be installed after the die is in the machine. Each water line inlet or outlet should be identified by letters and numbers stamped into the die beside the hole as show in Fig. 6-2. The letters W.L. identify the hole as a water line. The words IN and OUT show if the water is to enter (in) or leave (out) the die through that particular hole. The use of the number identification is described later. Special consideration must be given to two-way fittings to insure that the inner tube is not too long (stopping or reducing water flow) or too short (water flow failing to reach required cooling area).

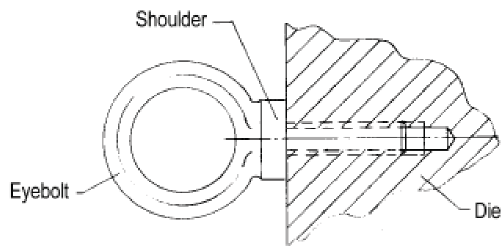


Fig 6-1. An eyebolt should always be screwed completely into the hole so the shoulder seats against the die face. This procedure makes full use of the bolt strength and prevents bending of the bolt.

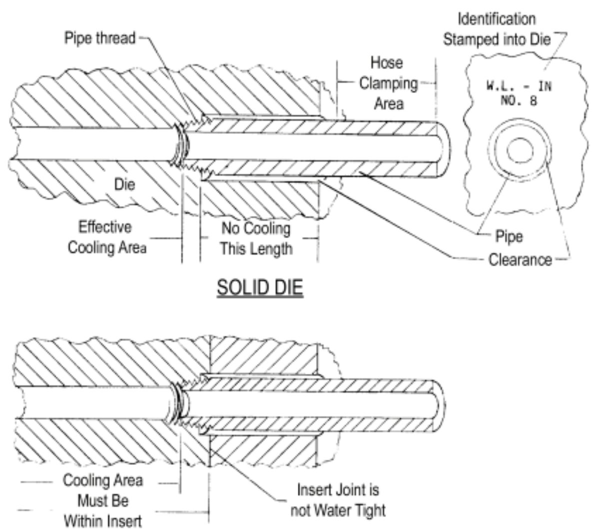


Fig. 6-2. Different types of water line connections are often required to achieve proper cooling of the die. When a die is set in a machine care must be exercised to insure correct installation of pipes and fittings. Also, the machine operator must be aware of the effective and the ineffective cooling zones of each waterline.

7. **Attach Crane or Chainfall**. When using chains between the crane hook and eyebolts, the spread of the chains should not exceed their length as shown in Fig. 6-3.

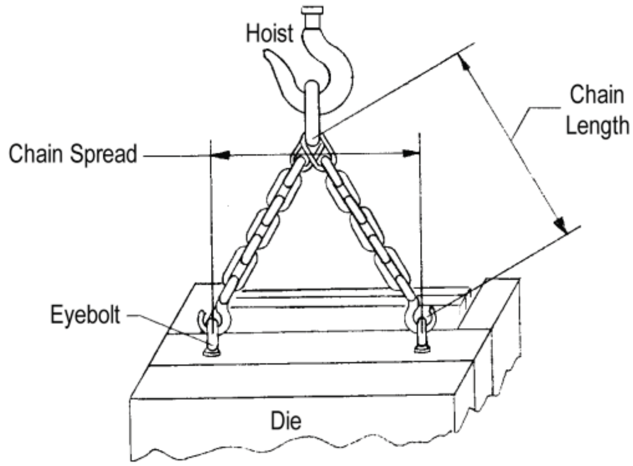


Fig. 6-3. When lifting dies, the spread of the chains should not exceed their length. When the spread is too great, excessive load is put on the chains and eyebolts)

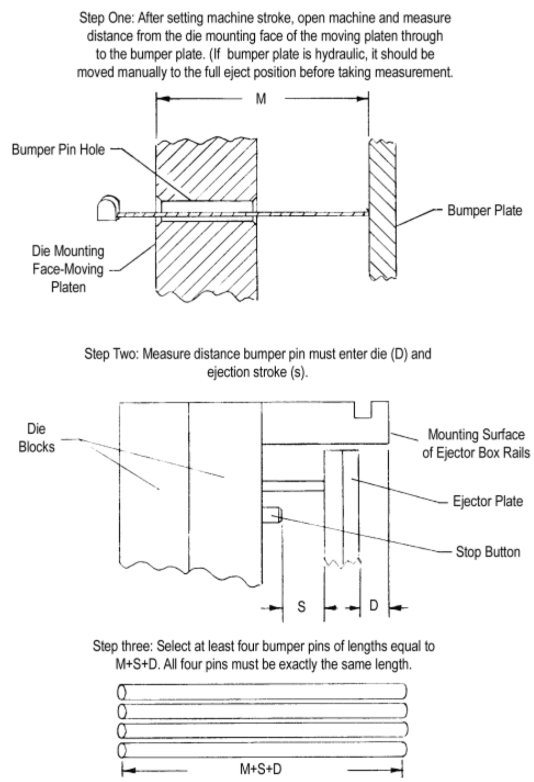


Fig. 6-4. Ejector bumper pins must be the correct length to suit the die and machine in u

8. **Install Positive Knock-out/Bumper Pins**. Bumper pins go through the ejector (or moving) platen to make contact with a stationary or hydraulically actuated bumper plate. These pins push forward the ejector plate in the die to eject the casting. Unless there is a plant standard, it is necessary to select the proper length of bumper pins as shown in Fig.6-4. (Note: Short pins will either not eject the casting or will require excessive machine stroke; excessively long pins may damage the die or clamps as the die ejector plate is forced against the rear of the die.) Once the correct pins are selected, the machine stroke must not be changed if the machine has a solid bumper plate. The selected pins are now placed through the ejector platen holes. BUMPER PINS MUST BE PLACED NEAR EXTREME CORNERS OF THE DIE EJECTOR PLATE AND MUST ALL BE THE SAME LENGTH.
9. **Place Die in Machines**. Raise the die, with the crane (to clear the bar), position over machine, and lower between platens.

   NEVER STAND UNDER DIE AT ANY TIME.

   Place the die in position against the stationary platen of the machine. When placing the die in a cold chamber machine, the shot sleeve extension must fit into the hole provided in the die. Care must be taken not to bump the shot sleeve with the die. If the die has a safety keyway, a safety key can be installed in a T-slot and then the die clamps can be installed and finger tightened. Dies for hot chamber machines must be set so the nozzle will be 1/4 to 1/2 inch higher at the die than at the gooseneck.
10. **Close Machine**. Unlock the main disconnect switch, start machine, and jog closed. Watch bumper pins to insure that they enter the die properly. Move die as necessary to properly align with bumper pins. If toggles do not completely straighten, jog the shut-height control to open or adjust the tie bar nuts at the rear (adjustable) platen to provide proper die space. If toggles straighten and machine has not gripped the die, jog the shut-height control (or adjust tie bar nuts) to close the machine until the moving platen contacts the die.
11. **Install Ejector Pinion**. Rack and pinion ejectors are not used with bumper pin ejection as described in Step 8 above. However, if an ejector pinion is to be used, it should be installed before the die is secured. Insert the pinion through the actuating device and into the die. If slight die alignment is necessary, jog the machine open until clamp pressure is off and realign die. Then jog machine closed to grip the die.
12. **Secure Die**. A clamp and clamp bolt must be installed in each T-slot that engages the die. Standard clamps and clamp slots in the die are recommended. Fig. 6-4 shows recommended and not recommended clamping arrangements. Tighten the bolts to the recommended torque for the size of bolt being used, being careful not to over tighten. Use of a standard wrench is recommended.

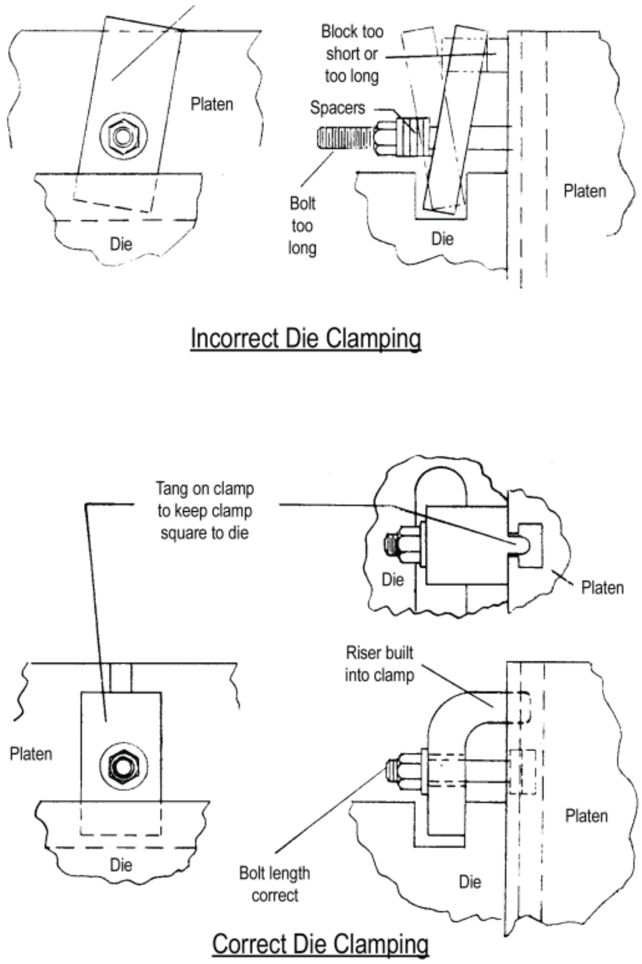


Fig. 6-5. Clamps and bolts must fit the die properly. Incorrect clamping may result in loosening and movement of the die

13. **Remove Crane**. Unhook chains, remove eyebolts, and move the crane out of machine area
14. **Check Die Closing**. Jog machine open and closed to check proper closing of die.

WARNING: WATCH CORE SLIDES FOR PROPER ENGAGEMENT.

The faces of the die halves should make contact slightly before the machine-closing cylinder reaches the end of its stroke. Adjust shut height if necessary. Leave machine closed and shut off power (use emergency stop button).

15. **Set Machine Stroke**. The machine stroke should be as short as possible. Unnecessary machine stroke slows the cycle. However, die opening must be large enough for easy casting removal. The stroke is adjusted by turning a threaded rod projecting from the outer end of the die closing cylinder, as seen at the center-right in Fig. 3-22.

16. **Set Ejector**. If mechanical die ejectors are used, the hydraulic or mechanical ejector mechanism must be connected. Side hydraulic units require adjustment, installation of the drive gear, and replacement of the gear cover. Mechanical systems require the hookup of some type of linkage. The varieties of these mechanisms exceed the scope of this book. If installation is not obvious, the set-up man should get detailed instructions from his supervisor. Once the ejector is connected, the machine should he restarted and the operation of the ejector checked. Adjustments should be made until correct operation is achieved. The die is left in open position and the machine is again shut off.
17. **Install Nozzle**. Hot-chamber machines have a nozzle between the gooseneck and the die. The nozzle is held in place and the gooseneck adjusted until the nozzle is held loosely. The gooseneck is adjusted by turning a pinion in the gooseneck supporting frame (also called the A-frame). While slowly rotating the nozzle to insure proper seating, the A-frame is tightened against it. The A-frame clamping nuts are then HAND TIGHTENED.
18. **Heat Nozzle**. Set nozzle torches to apply a lazy, low flame over the nozzle and allow heating for about 20 minutes. The torch arrangement (shown in Fig. 6-6) must heat the nozzle uniformly. Hot spots must be avoided.

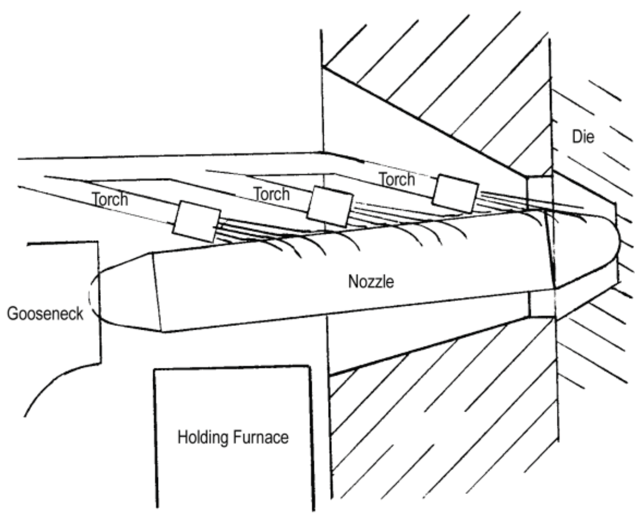


Fig. 6-6. Nozzle heating torches must be set to give all even ge1ltle flame that wraps around the nozzle. Spots of hot flame can damage the nozzle and should be avoided.

19. **Connect Water Lines**. One or more water manifolds on or near the machines supply die cooling water. Each manifold has a series of outlets, and each outlet has a control valve. A hose must be connected from a manifold valve to each die water line inlet. Valve number 1 must be connected to die water line number 1. Valve 2 connects to water line 2 and so on. This valve number to water line number sequence must be strictly adhered to so that lines leading to overheated and overcooled die areas can be readily identified for adjustment of the water flow rates to achieve optimum casting conditions. A hose must also be connected between each die water line outlet and the drain.

    The same numbering sequence must be followed on the drain. As each water line is connected, it is turned on, check for leaks, and the flow into the drain is checked. If water is not flowing into the drain, the line is plugged and must be opened. After each line has been checked, the water flow is turned off.

20. **Set Safety Ratchet**. A safety ratchet mechanism prevents the moving platen from closing when the safety door is open. Check the operation of this safety device and adjust as necessary.

21. **Set Deceleration Valve**. The cams actuating the deceleration valve limit switch are held in place with set screws. The appropriate set screw is loosened and the earn adjusted so that the roller on the decelerating valve limit switch is completely on the appropriate cam with the platen in the die open and the die closed positions. The set screws must then be tightened.

22. **Lubricate Die**. Start the machine. Ejector pins, guide pins, and core slides must be lubricated. Ejector pins will be extended out of die if mechanically operated. If hydraulic, they must he moved out for lubrication by the eject push-button. Jog the die closed and lubricate the mechanism inside the ejector box. Lubricate exposed parts of core slides. Pump grease into all grease fittings on the die.

23. **Install Die Heating**. Gas torches or other types of heaters are placed around the die for preheating. The die halves should he in contact to help both heat uniformly unless a heater designed to fit between the die faces is in use. Both die halves should have the same number of heating units. Equal heating is important because the die expands as it is heated. If both halves are not expanded equally, they will not close properly, and incomplete closure may cause a serious safety hazard if metal is injected.
    Expansion will also cause the die to tighten in the machine, stretching the tie bars and, perhaps, bending the platens. To guard against excessive tightening, the machine should be jogged open to move the toggle crosshead about 1/2 inches. This slight movement will not open the die, but will loosen the toggle sufficiently to prevent locking as the die expansion generates force. The die should be allowed to heat to operating temperature before making the first casting.

24. **Install Release Spray**. Die release material is usually contained in a tank that is pressurized with compressed air. This tank must be filled and the pressure adjusted. Machines not equipped with automatic spray systems to apply the release material have a hand spray gun or wand. The spray gun must be connected to the pressure tank and checked for proper operation. If there is an automatic system, the spray heads must be attached to the machine and adjusted to apply the release material evenly over the die surfaces. The machine should be opened as necessary, but should be closed again as described in Step 23.
25. **Close Safety Doors**. Check safety doors, and the limit switches they operate, to insure proper operation. The operator's door must move freely and easily. After checking, turn off the machine and lock the main disconnect switch.
26. **Tighten Nozzle**. The nozzle should have expanded sufficiently from heating to tighten the A-frame clamp nuts. If not, they must be tightened with a wrench. If excessive expansion has occurred, the springs between the clamp nuts and the A-frame will be fully compressed. If the springs are compressed, check the nozzle temperature. If it is turning color from the heat, turn down the torches. If cooling does not free the springs, the clamp nuts must be loosened. Excessive pressure can bend the nozzle, destroy the seal at the die and/or gooseneck, bend the die, or stretch the die clamps.
27. **Replace Shot Plunger**. Install new rings on the plunger (if hot chamber) and fit plunger into gooseneck. The plunger rings should be turned so that the split gaps are not in line with each other. Plunger must first be placed on edge of furnace until it is preheated sufficiently to dry off ALL moisture. Any moisture carried on an object placed in molten metal will instantly turn to steam with explosive results. Such reactions splash molten metal over a wide area. Once the plunger is installed, the safety shields are replaced on the furnace an A frame. The plunger is inserted manually into the gooseneck. The shot cylinder must never be used to start the plunger into the gooseneck.
28. **Set All Timers and Metal Temperatures**. The holding furnace must be filled, and the metal temperature control set at the desired temperature, The recommended time settings and metal temperature should be specified on the set-up chart as shown in Fig. 5-2.
29. **Check Hydraulic System**. Check accumulator levels and hydraulic pressures. Adjust pressures and have accumulators charged as necessary.
30. **Check Machine Lube System**. Check the machine lubricator to be sure it is full. Check the lines for any flattened or kinked areas. Check that all machine wear points (tie bar bushings, toggle pins, etc...) are being adequately supplied with lubricant.
31. **Turn Off Die Heating Torches**. When die is sufficiently preheated, the die heating torches can be turned down to low flame or sometimes turned off completely. Removal of torches from the machine is not recommended as they are required during temporary shut downs.

32. **Check Lock- Up Sequence**. Start machine and jog open and close. Check the proper tie bar strain (rear platen should move about 1/32 in.) and core slide operation. Make any final shut -height or stroke adjustments. Leave machine OPEN.
33. **Make Shot**. Open slow shot control valve, open fast shot control about halfway, open die close valve and close jog valve, if used. Open water valve to heat exchanger.

CLEAR PERSONNEL FROM AREAS IN SIGHT OF INJECTION END OF MACHINE.

Place "Shot" selector switch to “Man” Place “machine” selector switch to ”Auto”, Place “Die Spray” selector switch to “Man” and spray release material on dies.

Close operator safety door. When machine has properly closed, and all personnel are clear, make the shot by pushing the "Man. Shot" button. Check nozzle for metal leaks at gooseneck and die. Turn on cooling water to plunger tip if cold-chamber, and to sprue bushing and spreader if hot -chamber. Make several shots, checking for proper die closing, excessive flash and ejection problems. If cold chamber, check for excessive plunger flash. The die and machine are now ready for normal operation. The individuals responsible for set-up should study the operating and maintenance procedure manuals supplied by the machine manufacturers. Each make and size of machine may have unique equipment that requires special consideration.

The following is a condensed list of the 33 setup steps. How can this setup sequence be improved using SMED techniques.

1. Deactivate shot
2. Open DCM
3. Clean die mounting surface
4. Clean mounting surfaces of die
5. Insert eyebolts into die
6. Install cooling line pipes
7. Attach crane or chain fall
8. Install bumper pins
9. Place die in DCM
10. Close DCM
11. Install ejector pinion
12. Secure die
13. Remove crane
14. Check die closing
15. Set DCM stock
16. Set ejector
17. Install nozzle
18. Heat nozzle
19. Connect cooling lines
20. Set safety ratchet
21. Set deceleration
22. Lubricate die
23. Install die heating
24. Install release spray
25. Close safety doors
26. Tighten nozzle
27. Replace shot plunger
28. Set all timers and metal temperatures
29. Check Hydraulic lines
30. Check machine lube system
31. Turn off die heating torches
32. Check lock-up sequence
33. Make shot

Step one of SMED is to sort these activities into external and internal activities. The following items have been sorted as external activities:

5. **Insert eyebolts into die**. Eyebolts will be installed into each die half permanently, they could be tack welded to make sure they do not get lost and also prevent rotation.
6. **Install cooling pipe in die**. All cooling pipes are installed into the die as it comes from die Repair, the only time cooling pipes are removed is for repair and maintenance.
18. **Heat nozzle**. Nozzle can be pre-heated just as the die is pre-heated off-line.
20. **Set safety ratchet**. Operation of the safety ratchet can be observed as an external activity. Adjustment is not necessary.
22. **Lubricate die**. Die lubricated as part of die maintenance.
23. **Install die heating**. Die is pre-heated at the die pre-heat station and will be set hot.
27. **Replace shot plunger**. Plunger does not have to be removed for the setup as long as it is physically blocked and cannot move or drift.
29. **Check hydraulic lines**. Hydraulic lines are checked as part of a preventative maintenance program.
30. **Check machine lube system**. The machine lube system is checked as part of a preventative maintenance program.
31. **Turnoff die heating torches**. Die is pre-heated at the die pre-heat station and will be set hot.

Chapter 7
START UP & SHUT DOWN PROCEDURES

START UP

SHIFT “WALK-AROUND” INSPECTIONS

When starting the machine at the beginning of the shift or after any shut-down period, certain things must be done in a particular sequence. Otherwise, there is a definite chance of personal injury or damage to the equipment. The items in this procedure are inspections designed to find trouble before it develops into serious proportions. These inspections are to be made once each shift, plus each time the machine is started after a shut-down period.

1. Check machine for water and hydraulic fluid leaks. Loose hoses must be tightened. If leaks are found, inform the supervisor.
2. Check all safety switches and all other controls for proper operation.
3. Check accumulator levels, hydraulic fluid level in reservoir, and hydraulic pressures. Check for excessive or unusual noise from hydraulic pumps.
4. Check that the water valve to the heat exchanger is open. Check that the hydraulic fluid temperature does not exceed 120°F or the fluid manufacturer’s maximum temperature recommendation.
5. Check settings of all timers, counters, temperatures, water valves, selector switches, and hydraulic valves to be sure they conform to the set-up chart values.
6. Check machine lubrication system.
7. Check for excessive drift of the shot plunger when at bottom of stroke if hot-chamber. Drift is a downward movement of the plunger after the shot, caused by metal leaking past the rings. If drift is excessive, consult supervisor on changing rings, plunger or gooseneck. If cold-chamber, check for excessive flash around the piston tip.
8. Check locking tonnage. All tie bar nuts should be tight before making any casting.

START-UP PROCEDURE

When starting to operate the machine after any shut-down period, the operator should first make the start-up inspections listed above. He/She should then:

1. Turn machine on, and if recommend by the DCM manufacturer, cycle the pumps on-off quickly six to eight times. This procedure extends hydraulic pump life by lubricating the rotor at low speeds, and is especially important if the machine has been shut down for a long period.
2. Skim dross from holding furnace. Rest the perforated skimmer at the edge of the furnace to let metal drip out of the dross back into the melt. Deposit dross in molds. Aluminum die casting metal may form sludge. Existence of sludge is checked by inserting a rod to within a few inches of the furnace bottom. If a sandy, semi-liquid, solid condition is felt, as the rod is moved back and forth, sludge has developed. Once sludge develops in aluminum, the condition cannot be corrected in the holding furnace; the metal must be removed and returned for refining. To minimize sludging, aluminum should be maintained at a temperature above 1130°F. To minimize the formation of aluminum oxide on the furnace walls, the aluminum should be maintained at a temperature less than 1220°F.
3. Check the temperature of the metal in the holding furnace and the pyrometer setting. Metal must be at the temperature specified on the set-up chart before making castings.
4. Some cold-chamber machines have automatic ladles. The mechanism must be checked out to be sure that all controls are properly set and functioning. It is important that exactly the correct amount of metal is ladled into the cold chamber. The ladle mechanism and the pouring trough leading to the cold chamber must be properly aligned to prevent molten metal spills during pouring. Spillage of molten metal can cause fires when the metal falls on flammable material such as grease or oil on the floor or the machine.
5. The die must be cleaned of any flash, excessive grease, dirt, rags, and other foreign materials. Lubricate all moving parts of the die (i.e., ejector pins, guide pins, core slides, cam surfaces and core locks). Care must be taken to lubricate all moving parts inside the ejector box. Some wear points inside the ejector box are not always easy to see. Get an inspection lamp, if necessary.
6. Jog the die close button and watch for any misalignment. Special care must be taken when the die includes core slides. If core slides are hydraulically actuated, they should be jogged in and out separately during the inspection.
7. Open the shot valves as noted on the set-up chart. It is desirable for safety reasons to open the shot valve partially so that the speed of the first shot is reduced. Some dies must be completely filled with metal on the first shot or parts of the casting will stick in the die. For such dies, the high speed shot valve should be completely opened. If the set-up chart does not tell how the shot valve is to be set, the operator should check with his supervisor.

8. Turn on the cooling water to the shot plunger tip (if cold chamber) or to the sprue spreader (if hot chamber).
9. CLEAR PERSONNEL FROM SHOT END OF MACHINE.

   Any machine that has been shut down presents a safety hazard when making the first shot of a series. If the die was changed, there may have been an improper set-up of the metal injection mechanism. Thermal expansions and contractions could have loosened joints resulting in leakage of the molten metal. Also, there is a chance that the die is not completely sealed and molten metal will shoot out between the die halves.

   No person should be in line with potential flying molten metal should any failure occur.
10. Spray die surfaces with release material and check spray pattern if automatic. Lubricate plunger tip if machine is cold chamber.
11. Make shot and check for proper plunger movement. Check for metal leakage at nozzle joints, between die halves, and around plunger. Any metal leakage must be corrected.
12. Open the shot valves (if previously restricted) and operate the machine at its normal cycle sequence.

WARM-UP PROCEDURE

While making the first several shots, the heat transferred from the molten metal to the machine and die will cause dimensional changes that must be compensated for. The operator must be alert to these changes and make appropriate adjustments.

1. The cooling water flow to the shot plunger tip of a cold chamber machine may be inadequate, causing the tip to expand with the heat. When the tip expands, it will stick in the cold chamber. Such sticking will slow down the shot plunger movement, which in turn will have bad effects on the casting. In severe conditions, the plunger may seize in the sleeve and stop completely. The operator must keep the cooling water flow adjusted so that the plunger operates smoothly and freely.
2. Hot metal flowing through the nozzle of a hot chamber adds heat to the nozzle. This extra heat reduces the external heat requirements. Overheating can result in excessive pressure against the die and gooseneck, damage to the seals at gooseneck and die, and even bending of the nozzle. There may also be excessive erosion of the nozzle from the metal flowing through. The operator must keep the nozzle-heating torches properly adjusted.
3. The sprue junction on hot-chamber machines requires close operator con¬trol as shown in Fig. 7-1, the metal in the sprue must solidify. If the sprue does not solidify, the metal will "run" when the die opens. This "run" may freeze on the die face and interfere with the next closing of the die; it may freeze in a runner or cavity creating a discontinuity in the next casting; or it may splash as the die opens creating a safety hazard.

   When the metal solidifies inside the nozzle, the sprue sticks as the die opens and may bend the shot or break off and plug the sprue hole. The operator must carefully balance the nozzle heating and sprue cooling to prevent these conditions and insure trouble-free operation of the machine.
4. Release material should be applied heavily for the first few shots. The release material will protect the die and assist ejection.
5. The sprue or biscuit areas of the die are the first to warm up. The operator must inspect these parts of the shot as he removes it, and turn on cooling water to the sprue or biscuit area of the die as required. The water line to open may be found on the water line chart. As shown in Fig. 7-2, this chart shows where each numbered water line is in the die relative to the cavities. The operator must take special note of exactly where the effective cooling areas are for each water line. Fig. 6-2 shows how water lines are constructed to achieve effective, as well as non-effective, cooling areas. Blistering, surface porosity, or waves on the casting indicate excessive die temperatures.

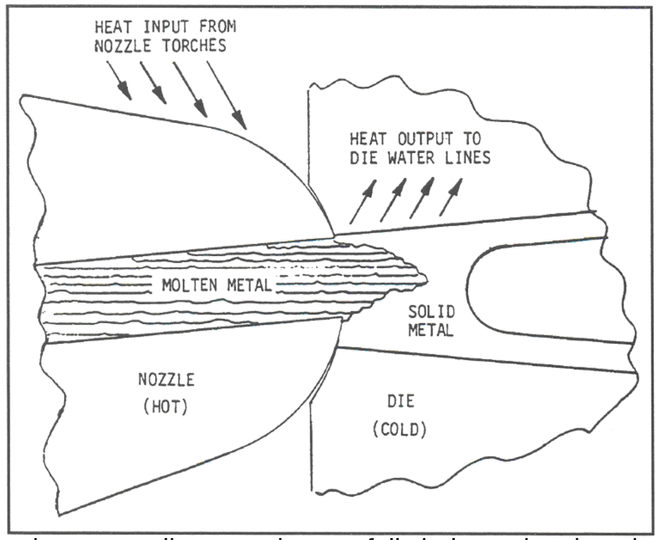


Fig. 7-1. Nozzle heating and sprue cooling must be carefully balanced on hot chamber machines. Otherwise, sprues may stick in the nozzle, or liquid metal may run out of the sprue hole when the die opens.

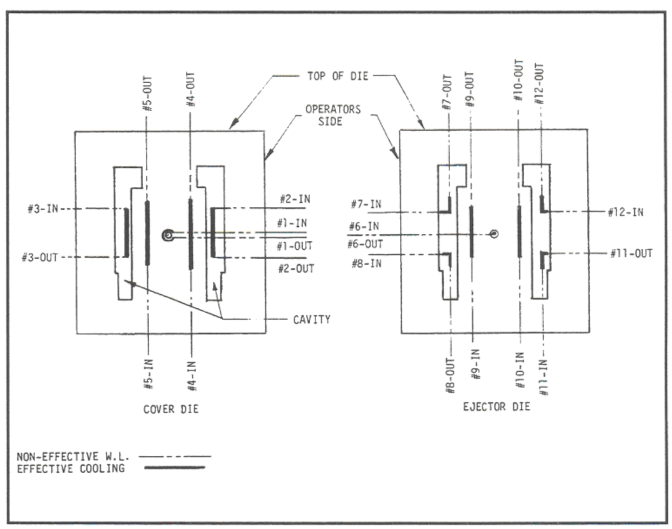


Fig. 7-2. The water line chart shows the operator where the effective water line cooling areas are. He can then adjust the appropriate water line valve on the machine to control the quality of the castings produced.

6. As the die continues to warm up, different areas will reach operating temperature at different times. The surface condition of the casting changes as the die operating temperature is reached. (Note: This change in surface appearance must be demonstrated to a new operator.) As each area reaches operating temperature, the operator must adjust the appropriate die heating torches and cooling water flows. Also, as the die approaches operating temperature, the operator should reduce the amount of release material applied. During normal operation, the amount of release material used should be reduced to the very least possible amount.

7. Temperature stabilization of the die can also affect the size thickness of the die. If excessive flash develops or if the machine starts to "lock-up" slowly, the shut-height must be adjusted. Once the die stabilizes and is making good castings, the warm-up is complete. Only rarely are usable castings made during the warm-up period. Normal practice is to dispose of these castings to the remelt conveyor or tub.

Shut down Procedures

Any time the normal operating cycle of a die casting machine is interrupted, the many conditions that had stabilized during the normal operation begin to change. The longer the shut-down period, the more things become affected. Generally, shut-down periods can be described as cycle interruptions (up to ten minutes); temporary shut-down (up to two hours); or extended shut-downs (indefinite period). Each type of shut-down requires a different action by the machine operator.

CYCLE INTERRUPTION

Short interruptions to the normal cycle occur when castings stick in the die and must be removed manually, solder build up in the die must be removed, excessive flashing requires tie bar adjustments, or when the die needs cleaning or extra lubrication. During these periods, the cooling water to the die must be turned off. If the cooling water continues to flow through the die, the die will cool down quickly. As a result, several scrap castings will be produced when normal cycling is resumed.

When the cooling water is no longer needed, it should be turned off at the main control valve. Settings of the individual water line valves should not be changed. For short-term cycle interruptions, it is preferable to turn off the cooling water flow two or three shots before the shut-down. When such a procedure is possible, it builds up a heat reserve in the die that will maintain the temperature during the shut-down.

TEMPORARY SHUT-DOWN

When shutting down the machine for less than two hours, the operator should:

1. Shut off die cooling water to die by turning off the main water valve. Do not change adjustment of individual water line valves.
2. Visually inspect machine for water leaks, hydraulic fluid leaks, and lubrication failures. Any equipment defects should be reported.
3. Stop motors by depressing pump off or emergency stop buttons. Turn main disconnect switch to off position. Close the accumulator shut-off valve if it is not automatic.
4. Be sure die is clean. Remove any flash or other material from die.
5. Install and/or turn on die heating torches.
6. Increase heat to nozzle if machine is hot-chamber type.

EXTENDED SHUT-DOWN

When shutting down the machine for an extended period, the operator should execute the following procedures:

1. Shut off die cooling water. Close all individual water line valves. (When the machine is restarted, these water valves will have to be opened individually during the warm-up period.)
2. Inspect the machine for water leaks, oil leaks, lubrication problems, etc., and report any item requiring repair.
3. Inspect the last casting for any die maintenance-related defects such as flashing, ejector pins or cores, drags, solder, broken cores, etc. Any such defects should be reported to the operator's supervisor.
4. Clean flash and other material from die faces and oil die faces, including cavities, after the die cools to near room temperature to prevent rusting. When cleaning flash and other accumulations from the top of the die, care should be exercised to avoid pushing the material into the ejector mechanism or into water line holes.
5. Be sure die is open and shut off pump motors, turn main disconnect switch to off. Close the accumulator shut-off valve, if it is not automatic.
6. If the machine is the hot-chamber type, close the die, remove shot plunger from gooseneck and maintain heat to nozzle. (If the die is to be removed from the machine, turn nozzle heat off.)
7. Clean machine and machine area. Remove excess grease and oil, die release material, rags, paper, flash, and scrap castings. Hose down floor and scrape floor, if necessary, to remove stubborn material. Return all tools and other loose items to their storage areas.

Chapter 8
NORMAL OPERATIONS

Normal operation will occupy the bulk of the operator's time and effort. His responsibility is to maintain continuous and uniform cycling of the machine and to perform the prescribed handling functions to the casting. Several basic operational sequences are used. The most common sequences are described in previous sections (see Chapter 5 - Controls Section, Cycle Start subsection).

Although any rule has exceptions, the operator must handle each casting. When the die casting machine is fully automatic, the operator usually operates the trim press. Otherwise he will remove each casting from the die casting machine, quench it in a water bath, and send it onto the trim operation. Sometimes the operator hand ladles the metal into cold-chamber machines. While performing these more-or-less mechanical duties, the operator must be alert to all the items discussed in the previous sections. The operator must make minor adjustments to the machine controls as required.

Two specific areas of responsibility are added, once normal operation begins. These responsibilities are: (l) care of the molten alloy, and (2) casting quality.

METAL CARE

The metal in the holding furnace is very carefully mixed or alloyed. The amount of each element in the metal is precisely controlled. It is of the utmost importance that no foreign material gets into this metal because even tiny amounts of some elements have a very bad effect on quality. The following procedures should be followed to maintain this metal quality (the references to a ladle apply to the cold-chamber process):

1. Avoid any unnecessary turbulence or disturbance of the metal.
2. Ladle so as to break the surface of the metal as little as possible.
3. When ladling, use backward motion to skim metal dross with the ladle lip, followed by a forward motion to dip metal from the skimmed area (see Fig 8-1).
4. Do not coat ladles or furnace pouring troughs with grease or oil.
5. Avoid broken streams when pouring. Pour from minimum heights.
6. Skim metal periodically, but not excessively.
7. Do not add wet or oily scrap to the holding furnace.
8. Do not burn paper, trash, or oil on the metal.
9. Keep all scrap and trimmings as clean as possible.
10. Avoid excessive temperature changes.
11. Keep all iron tools and ladles that contact molten aluminum properly coated to prevent iron from entering the aluminum.

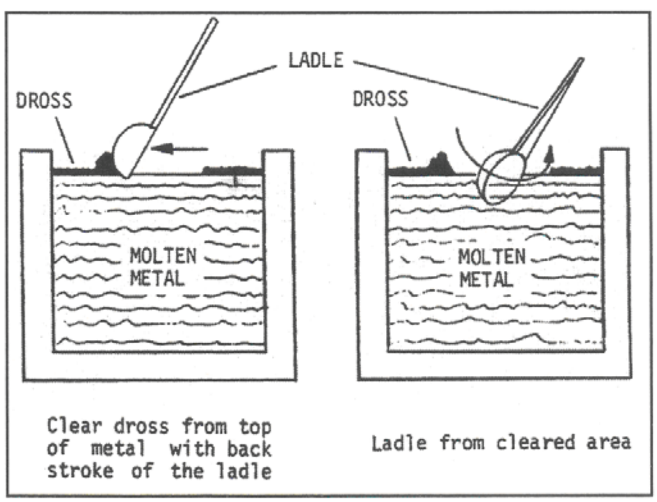


Fig. 8-1. Care must be taken to insure that dross is not ladled into the cold chamber

Chemical or metallurgical changes may take place in some alloys, the aluminum alloys in particular, if they get too hot or too cold. Even if such changes do not occur, the temperature is very important to the casting process. Therefore, the operator must maintain the specified metal temperature in the holding furnace. He must be alert when metal is added to his holding furnace. If additions change the temperature, he should inform his supervisor.

CASTING QUALITY

The operator must check each casting for obvious defects. Defective castings must be disposed of. In addition, he must occasionally make a thorough inspection of one or two shots. Minor variations in appearance from previous inspections indicate changes or "drifting" of the process (i.e., die temperature, metal temperature, nozzle temperature, shot speed). When these changes are detected, the operator must make compensating adjustments to the machine settings. Some of the most common casting defects and the techniques for their elimination are described in Chapter 9. The reader should observe that because of interrelationships, many suggested corrections apply to more than one defect. For this reason, the procedures for making corrections to machine conditions (for example die temperature) are not repeated in the discussion of each defect. Refer to Chapter 7 - Start-Up, and Warm-Up sections for details of such adjustments.

Chapter 9
ELIMINATING CASTING DEFECTS

The conditions described in this chapter are common to the die casting process, and usually represent defective products that must be scrapped. It is impossible to illustrate all the defects that may be encountered, and it is equally unrealistic to describe accurately the exact corrective measures. The following illustrations show the new operator the general conditions he/she should watch for, and the suggested corrective measures provide a pattern for the operator to follow when he/she encounters a problem. Defects will be discussed as surface defects, defects that are visible; internal defects, defects that cannot be seen; and dimensional defects.

A major problem die casters have is that a particular defect may have different root causes or different defects have the same root cause. For example, we cannot say that all cracks are due to uneven ejection. Cracks could be due to shrinkage, or a cold die, or some other cause. On the other hand a casting may exhibit poor fill and chill and flow marks, all possibly due to a cold die.

Cold flow	Laps
Cold shut	Flow lines
Flow marks	Swirls
Cold	Knit lines
Chill	Blisters
Severe chill	Cracks
Non-fill	Mis-run
Poor-fill	Solder

This is by no means a complete list. The list may vary by shift, by plant by state or by country. Within a given plant, the list should be simplified, with everyone understanding the terminology for a particular defect.

SURFACE DEFECTS

Soldering. This condition, illustrated in Fig. 9-1, is the result of soldering of aluminum in the die casting alloy fusing with iron from the surface of the die cavity. Upon ejection, the casting tears away, leaving a layer that has bonded to the die. When soldering occurs, it may create additional problems such as cracking or bending of the casting, out of tolerance dimensions, depressed ejector pin marks in the casting and/or porosity within the casting.

Soldering may be caused by excessive metal temperature; incorrect die temperature (too hot or too cold), insufficient die release material, incorrect alloy, or too little draft. If the condition is severe or when other methods fail to remove the solder, it must be cleaned from the die. Caustic solutions provided for this purpose may be used, or the material may be polished out the die. It is recommended that a die maker, or other person with special training, polish the die cavity. If the polishing is not done properly, a rough die surface may be created that will increase the soldering condition. Care must also be exercised when increasing the amount of die release material applied to the soldering area. Excessive amounts of this material may create other defects such as porosity, chill, or blisters.

The purpose of die release is to provide a protective barrier between the aluminum and die steel. If the die release is ineffective, or casting conditions are such that the die release cannot wet the surface, conditions for soldering will be present.

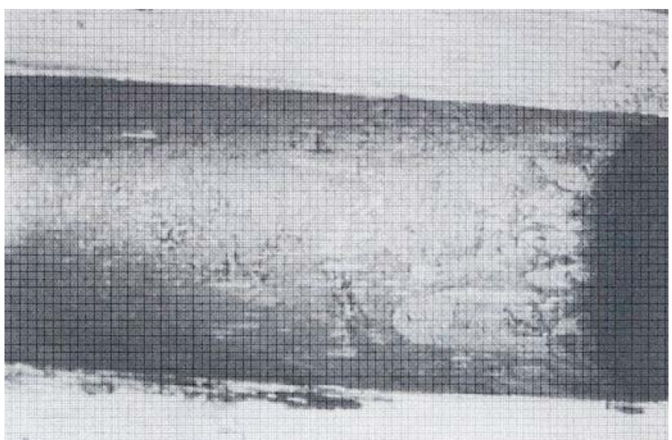


Fig. 9-1. Soldering is the adhesion of the die cast metal to the die. Additional die release material, lower metal temperature, or a change in die temperature will usually reduce soldering.

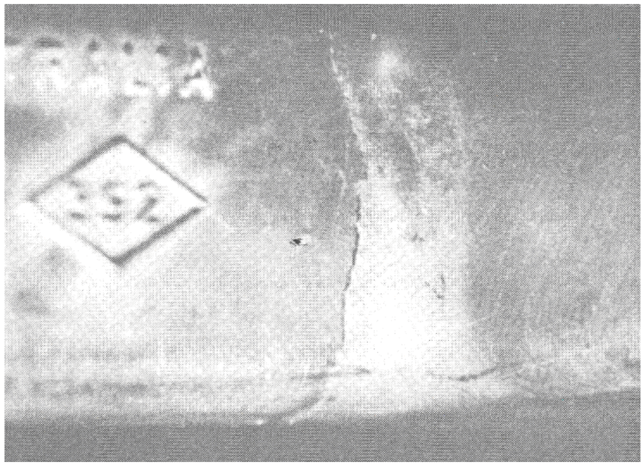


Fig. 9-2. Excessive die temperature may cause the casting to crack when it is ejected. Causes in addition to ejection are shrinkage and internal stresses

When adjustments to the above conditions do not eliminate the soldering condition, the operator should inform his supervisor. It is possible for the problem to be caused by the metal alloy being cast or it may result from the die construction.

Cracks. Castings may crack as shown in Fig.9-2, from internal stress or from abnormal pressure during ejection. The first cause, internal stress, is created by excessive metal or die temperatures. If the condition persists after several temperature adjustments have been made, it may be necessary to increase the shot or machine timer settings. The timers should be adjusted only after everything else has failed, and the operator's supervisor should be notified.

Cracks from abnormal ejection pressure may, indirectly, be the result of soldering. The operator should carefully inspect the casting for signs of soldering. If soldering exists, the appropriate corrective measure should be taken. Insufficient draft or a rough cavity finish in the die can also cause abnormal ejection pressure. Additional die release material may help, but will not correct, this situation. In severe instances, die repair may be necessary so the operator should notify his/her supervisor.

Cracks can also be the result of shrinkage. As metal solidifies it takes up less volume. Normally, high metal pressures are used at the end of cavity filling to force more metal into the cavity to make up for this shrinkage. This shrinkage occurs at a location that freezes last. If this is at the surface a crack or sink will appear. Cooling this local area will move the shrinkage from the surface.

Blisters. Blisters are gas porosity that has been trapped near the casting's surface. The trapped gas pressure is greater than the strength of the castings skin, causing the surface to rise. To eliminate the blister, the source of gas must be eliminated. Sometimes the short term solution of strengthening the skin by cooling the die is employed. This hides the blister.

Lack of Fill. As shown in Fig. 9-3 and Fig. 9-4, this condition has three basic causes. They are inadequate metal in the gooseneck or cold chamber, low temperatures, or improper shot control settings. The metal level in the holding furnace of a hot chamber machine must be maintained above the gooseneck inlet ports. For cold chamber machines, the correct size ladle must be used and care must be taken to insure that the ladle is full for each shot. When an automatic ladle is being used, it must be properly adjusted to ladle exactly the correct amount of metal into the cold chamber.

Secondly, cold metal, cold die, or both may cause this defect. The temperatures should be checked and adjusted as necessary.

Third, lack of fill may be the result of slow shot speed. The shot control hydraulic valves should be opened the proper amount. As with all other machine malfunctions, if the shot is still slow and the valves are properly adjusted, the operator should notify his supervisor.

Lack of fill is also commonly known as poor fill and non-fill.

The next group of defects is categorized as flow defects. This means they are a result of the metal flow in the die cavity. The following list is a number of factors that affect flow defects. Following the list is an explanation of each of the factors and then a discussion of who is responsible for this factor and how it may be controlled.

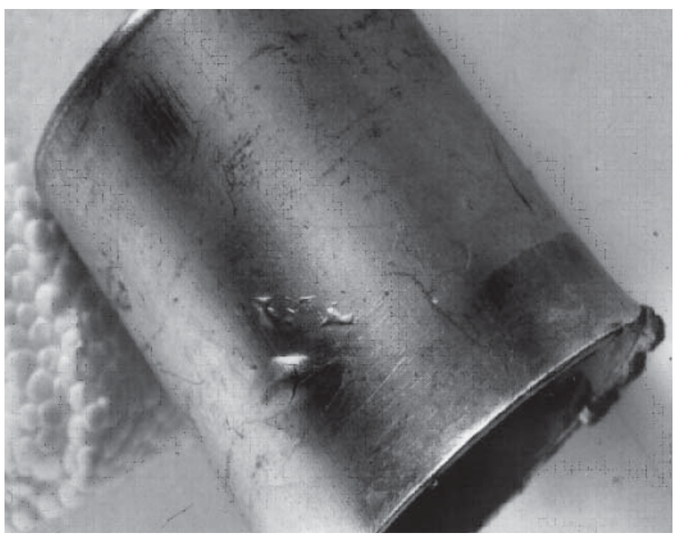


Fig. 9-3.Insufficient metal, cold metal, or a cold die can cause incomplete fill. The thin biscuit indicates an insufficient amount of metal was ladled into the cold chamber.

Fig. 9-4. Lack of fill may be caused by slow shot speeds (long cavity fill times), which allows the metal to solidify before the cavity fills. However, when there is flash on the casting, insufficient metal is more likely the cause.

FACTORS AFFECTING FLOW DEFECTS

Fill time

Wall thickness

Die temperature

Alloy temperature

Flow distance

Gate velocity

Alloy type

Venting

Cold Shut. Seen in Figs. 9-5 and 9-6, cold shuts, like lack of fill, is caused by cold metal, slow shot, or low die temperatures. If air vents and/or overflow are clogged with flash, they may also contribute to the problem. All these factors must be checked and corrected as necessary.

Severe Chill. Illustrated in Fig. 9-7, severe chill is similar to cold shut, but it will cover a large surface of the casting instead of being a single line. Excessive release material, as well as cold metal, slow shot, low die temperature, or clogged air vents, may be the cause. Severe chill usually appears when shots are made into a cold die, but will rarely occur during normal operation.

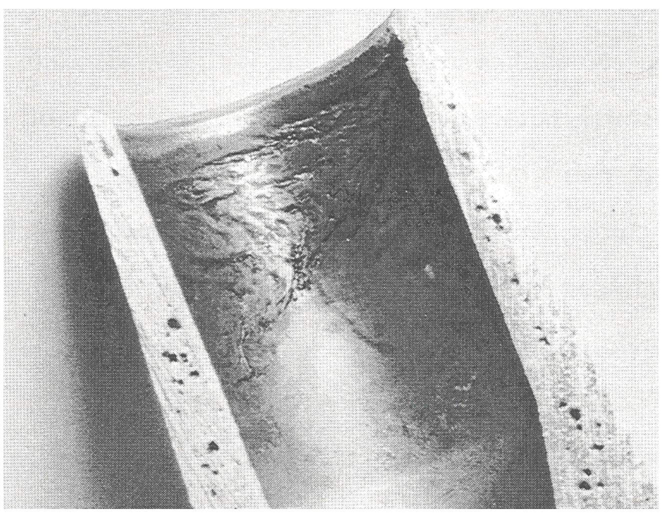


Fig. 9-5. Cold shut may be caused by cold metal or a slow shot. The metal has insufficient heat to fuse properly as it flows together.

Fig. 9-6. Cold shut may be caused by cold metal or a slow shot. The metal has insufficient heat to fuse properly as it flows together.

Chill. This defect has the same appearance and is caused by the same conditions as severe chill, but is less noticeable. Slight or faint chill lines on the surface may not be cause for rejection of certain types of castings. Castings used for ornamental parts will usually require a chill-free surface. Low die temperature, low metal temperature, slow shot speed, or excessive die release material are all causes of chill.

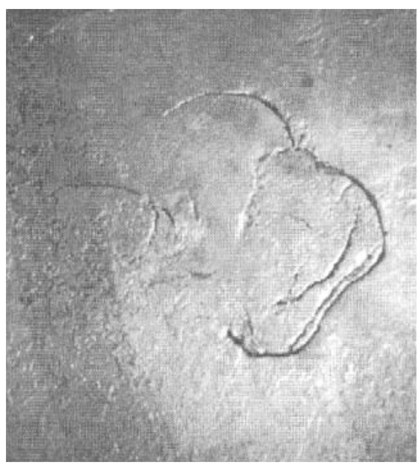


Fig: 9-7 Severe chill is usually the result of a cold die. Die cooling water flow in the area should be reduced until the chill disappears.

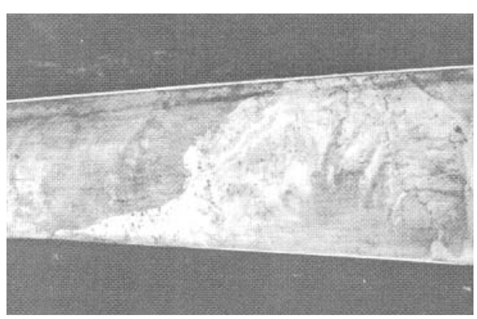


Fig. 9-8. Flow lines are similar to cold shut and chill. However, entrained release materials display the flow pattern of the metal while the die was filling.

Flow Lines. As seen by the example in Fig. 9-8, flow line defects are similar to chill and cold shut. Flow lines can usually be reduced or eliminated by increasing the die temperature, metal temperature, or both. Like chill, the defect may be corrected by higher shot speed or less die release material.

Heat Marks. Have the appearance of surface pits as shown in Fig. 9-9 and Fig. 9-10, and are caused by excessive die temperature or excessive metal temperature. Depressed areas in the casting and sharp inside corners are the most susceptible to this defect. Sometimes die temperature "balance" can be adjusted to eliminate heat marks. For example, the flow of cooling water to the area affected maybe increased, and decreased to the other die half in the same area.

Clogged vents or excessive die release may cause large volumes of gas to become entrapped in the die. Such gases will increase the size of heat marks and may cause the pits to become rounded and smooth on the inside.

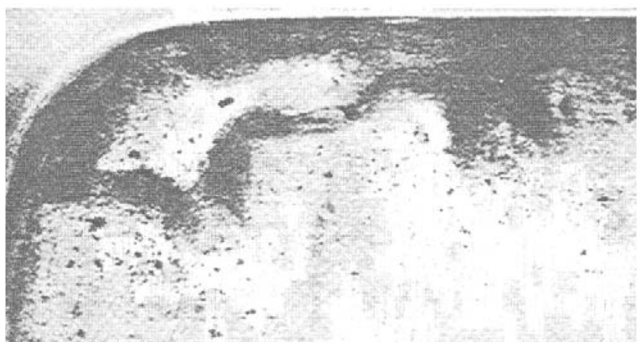


Fig. 9-9. Heat marks are actually shrinkage pits in the surface of the casting. Light colored areas surround each pit.

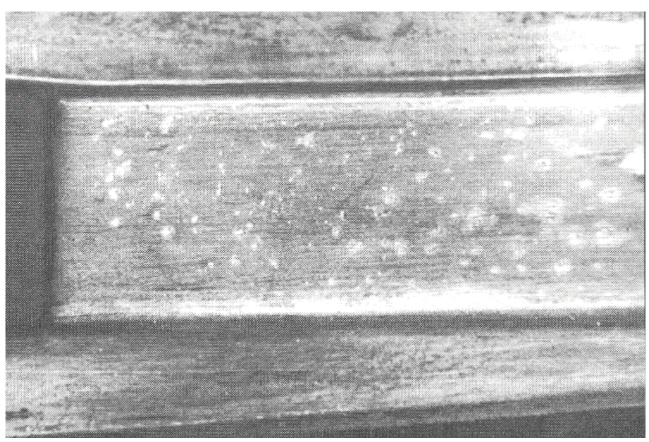


Fig. 9-10. Heat marks usually occur in depressed areas on the casting. Depressed areas are formed into the casting by raised areas in the die, and such parts of the die tend to mil hot.

Scale. Build-up of die release materials (or their oxides) on the die results in an irregular, rough surface on the casting as shown in Fig. 9-11. The material must be removed with a caustic solution or by polishing the die. The same care is needed as described for soldering. After cleaning the die, the amount of release material applied for each shot must be reduced. Sometimes, it may be desirable to change the type of release material and/or the dilution ration of the material.

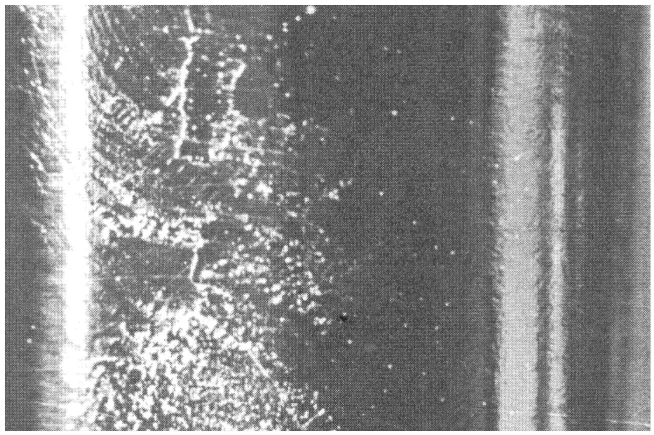


Fig. 9-11. Scale is caused by excessive die release material. The build-up of oxides must be cleaned or polished from the die.

Swirls and Discoloration. May be identified by stains on the surface of the casting and are caused by excessive die release material or the wrong type of release material. The die release spray heads should be checked for proper adjustment, to insure that an even thin film of re]ease material is deposited on the die before each shot. If the wrong material is being used, the spray system must be emptied and refilled with the correct material.

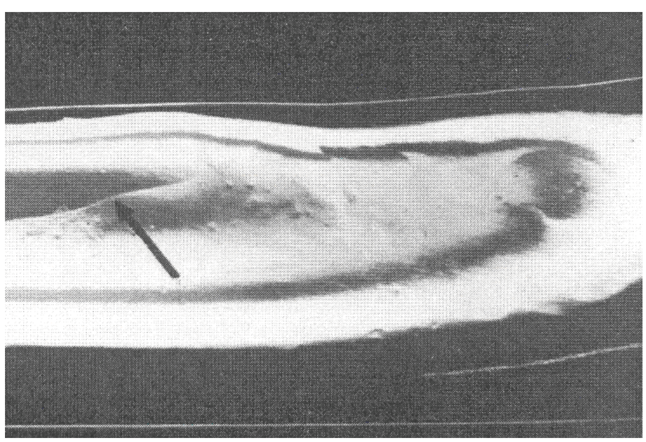


Fig.9-12. As with lakes, waves are caused by a hot die. Changes in the application of release material can sometimes reduce both waves and lakes.

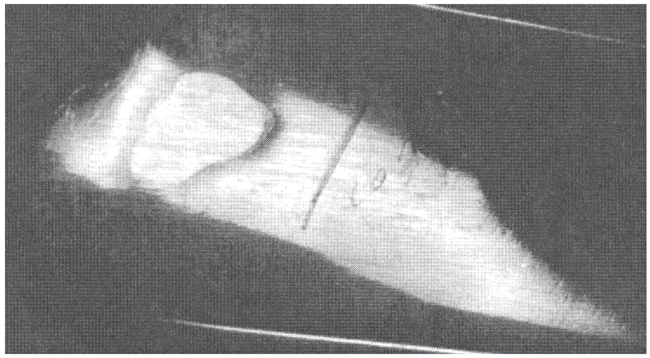


Fig. 9-13. Lakes are often apparent only after buffing the surface. Lakes are usually the result of excessive die temperature.

Wave or Lake. Irregular lines or slight steps on otherwise smooth casting surfaces, as shown in Fig. 9-12 and Fig. 9-13 are usually caused by excessive die temperature in the area of the defect. Increasing the flow of die cooling water or increasing the water dilution of the die release material will reduce such defects.

Blisters. Bubble-like bumps on the casting surface, as shown in Fig. 9-14, are caused by air or other gases trapped inside the casting. Slower shot speed, clean vents, reduced die temperature, or less die release material will usually eliminate blisters. If these measures do not work, the operator should notify his/her supervisor.

Broken Part. A portion of the casting may stick in the die during ejection and the rest of the casting break away and eject normally. An example is shown in Fig.9-. The cause is the same condition as described for cracks: excessive metal or die temperature, insufficient die release material, or soldering.

Bent Part Castings may bend instead of breaking when part of the casting sticks in the die. This is a different result from the same conditions that cause a broken part.

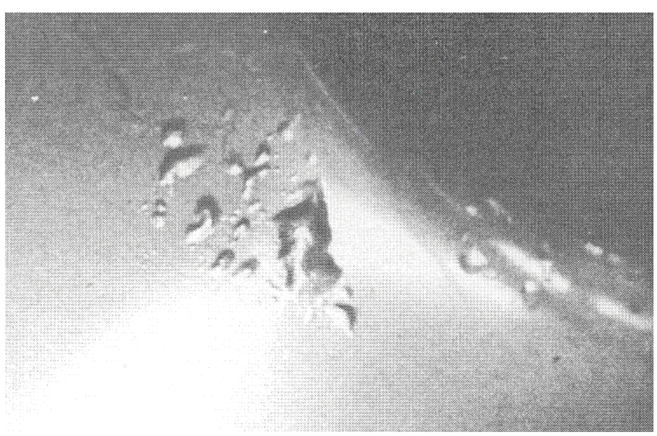


Fig. 9-14. Gases entrapped in the casting cause blisters. Reducing the amount of release material will often reduce blisters. Sometimes reducing the die temperature will also eliminate blisters.

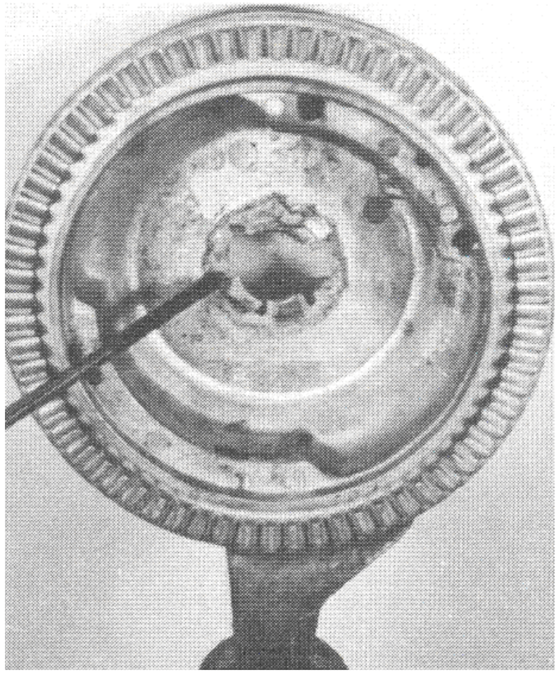


Fig. 9-15. When the casting breaks, part of it may remain in the die; a skilled die maker must remove pieces of casting stuck in the die sometimes.

Sink Marks. Shallow, smooth depressions on the casting's surface are called sink marks. Such marks usually appear on the casting surface opposite any heavy section such as a rib or boss, and are caused by uneven shrinkage of the casting. Reduced die temperature in the area of the sink mark, reduced metal temperature, and sometimes increasing the temperature of the other die half will minimize these defects. Sometimes, increased injection (shot) pressure coupled with higher die temperatures between the defect and the gate will help reduce sink marks.

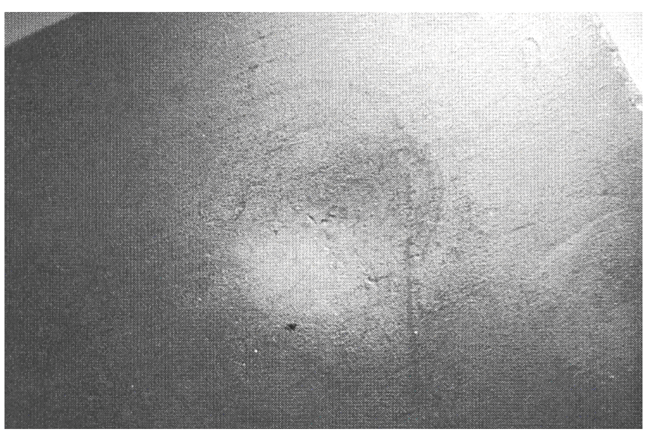


Fig. 9-16. The sink is a smooth depression.

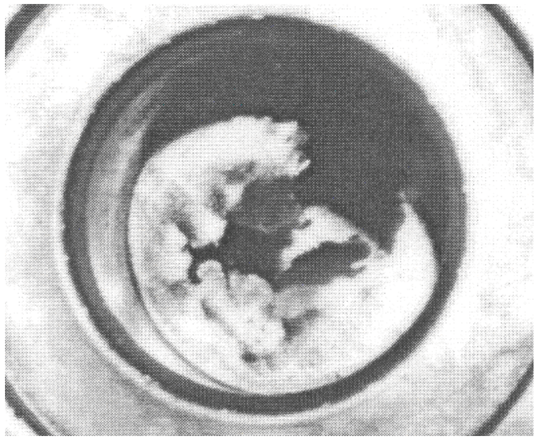


Fig. 9-17 Excessive flash indicates that an extra thick casting is being made and is a potential safety hazard from die spitting.

Excessive Flash. Excessive flash results from material such as flash sticking to the die faces and holding the die open, excessive injection pressure or speed, or insufficient clamping force. The first problem is corrected by cleaning the die faces. Flash that has become embedded into the die face must be scraped off. Corrections to injection speed and pressure must be made by adjusting the appropriate hydraulic valves. Adjusting the tie bar nuts increases the clamping force. Very slight adjustments to these nuts are usually all that is required. Flash indicates that an extra thick casting is being made. Extra thickness causes extra heat input to the die, and may result in additional problems. Fig. 9-17 illustrates various cases of excessive flash.

Mechanical Defects. The operator should be aware of all moving and fragile parts of the die cavity, which are subject to wear, breakage, or other failures that could cause defective castings. Small cores or thin blades of the die forming deep narrow holes or slots in the casting can be easily broken or bent. Ejector pins and moving cores can wear, break, or not seat properly. In any of these situations, the die will not make the part to the correct shape. The operator may have little control over mechanical failures of this type. However, he/she must be on the lockout for them, and inform his supervisor of any malfunction.

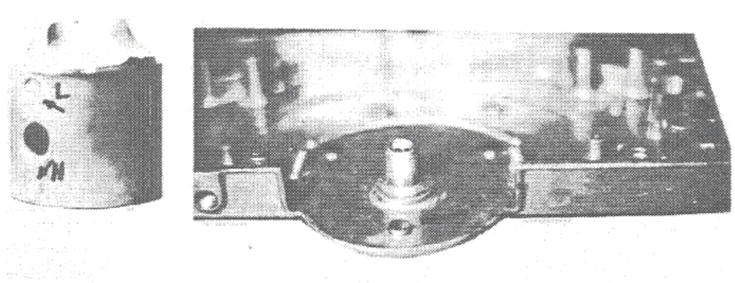


Fig. 9-18. The operator must watch for mechanical defects such as high or low marks from ejector pins. Low marks may be associated with solder or bending.

Fig. 9 -18 shows high and low ejector pin marks. Ejector pins may push into the casting when solder and/or a rough cavity surface results in the casting sticking in the cavity. High casting temperature at time of ejection can also let the pins push into the part. Increased flow of cooling water or more liberal application of release material will sometimes reduce low ejector pin marks

INTERNAL DEFECTS

Internal defects are detrimental to the die casting because they result in reduced mechanical properties of the casting, loss of pressure tightness in the casting, and poor machineability.

Porosity. Large holes in the casting, as shown in Figs. 9-19 through 9-23, are called porosity. Porosity has two root causes either trapped gases or shrinkage. Low die temperatures (particularly in the runner and gate areas), low shot pressure, clogged vents, or excessive released material can contribute to porosity. Porosity is also often related to lack of fill, cold shut. heat marks, and blisters. When such a relationship exists, the correction for the related defect will often improve or eliminate the porosity.

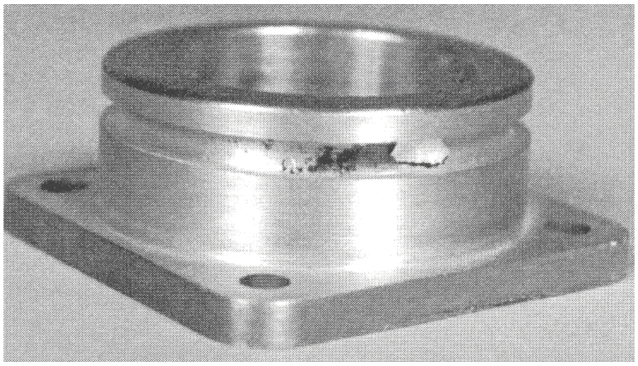


Fig. 9-19. Internal porosity is sometimes exposed when castings are machined. The operator should check all the process variables frequently as insurance against "hidden" defects.

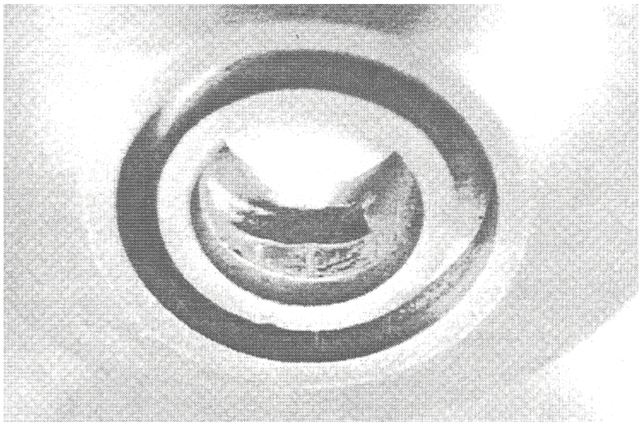


Fig. 9-20. Porosity frequently forms at small cores. The machine operator should check inside holes and deep recessed areas of the casting for porosity.

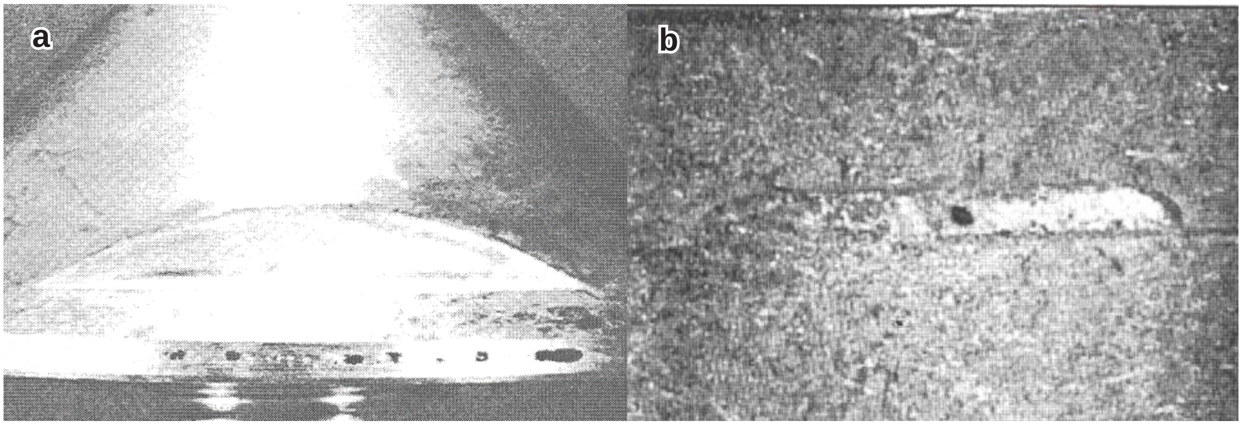


Fig. 9-21a & b. Porosity sometimes forms where the gate connects to the casting. These areas should be checked frequently immediately after trimming.

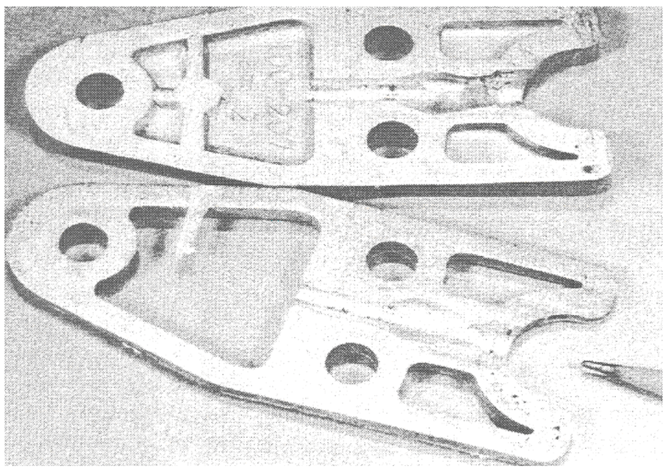


Fig. 9-22. The casting in this photograph has been cut in two to show the large internal hole. As illustrated by the pencil, the defect is in the path of a secondary drilling operation.

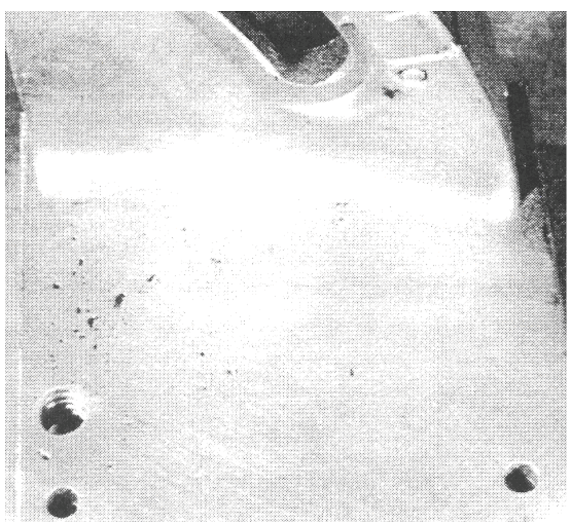


Fig. 9-23. The porosity shown on this part is related to cold shut. Cold metal or a cold die is the cause of such defects

GAS POROSITY

Trapped gas porosity has a distinctive appearance, it is round and smooth and looks like bubbles. Trapped gas for gas porosity can come from many sources. If you are trying to solve a gas porosity problem you have to look at all sources of gas generation.

The common gas sources are:

1. Air mixed with the alloy in the cold chamber.
2. Air trapped in the die cavity because the vents are blocked.
3. Gas from excessive die lube left in the die.
4. Gas from plunger lube left in the cold chamber.
5. Steam from water leaking into the die cavity due to cooling line leaks, or leaks from cracked die cavities.
6. Gas from hydraulic fluid leaking into the cavities from leaking cylinders or connections

OTHER SOURCES

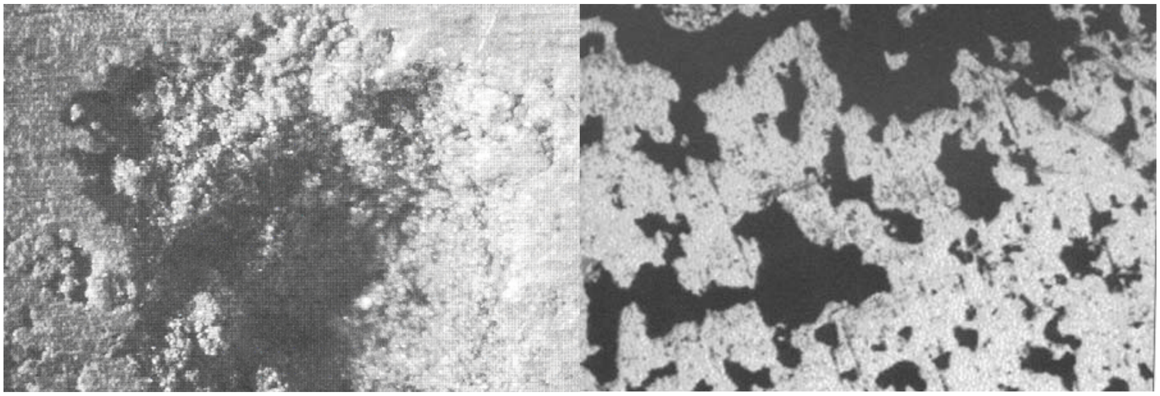
If the die cavity has cracks in it, if could be possible that this crack might allow fluid from the cooling line to leak into the die cavity. Water or oil in the cavity, when hit by alloy will form gas. There are several solutions to this type of problem. One is to abandon the cooling line by turning the coolant off. If cooling is critical and must be used the alternatives are to fix the leaking crack or to use a local cooling system that pulls the coolant through the die as opposed to pushing it through.

Sometimes the source for leakage into the cavity is not easily identified. All fluid sources need to be checked. Hydraulic cylinders can leak, and if they are above of the die cavities, hydraulic fluid can run into the cavities. Sources of leakage at the cylinder can be the seals at the rod or hose connections. Care must be taken when pre-heating the die to make sure the seals at the cylinder are not burned up.

Hydrogen gas is always discussed as a source for porosity. In die casting this is not a great source for porosity because of the minimal solubility of hydrogen is die casting alloys. At temperatures less that 1250"F (677°C) hydrogen solubility is very low. With other casting processes that require higher alloy temperatures, hydrogen gas porosity is a more significant problem.

SHRINK POROSITY

Shrink porosity or shrinkage is porosity that occurs if the alloy solidifies without pressure on it. As the alloy cools, it also contracts. That is, it takes up less volume. Pure aluminum shrinks 6.6% by volume. If you start with 100 cubic inches of liquid aluminum, and it freezes, similar to alloy freezing in an ingot mold, the frozen aluminum will only occupy 93.4 cubic inches. Aluminum die casting alloys shrink from 3.8 to 6.5%, zinc alloys around 3-4%, and copper alloys around 4-5%.



Figs. 9-24. The two figures show various view and magnifications of shrink porosity. Shrinkage voids are characterized by a rough or crystalline nature.

INCLUSIONS

ALUMINUM OXIDE, Al_2O_3

The vast majority of inclusions are non-metallic aluminum oxide, Al_2O_3 , Aluminum is a powerful reducing agent (oxidizing), and consequently oxidizes easily. This is one of the reasons for build-up inside furnaces. The oxides of aluminum are polymophic, that means that in certain environments the properties of the alumina crystals change drastically. When aluminum oxide first forms it is the soft gamma type with a specific gravity of approximately 2.8. This is very similar to the alloy from which it is formed. As this material is heated above 1500°F, it is transformed into a much denser and harder variety called alpha Al_2O_3. This is commonly called corundum and is rated right next to diamond on the hardness scale.

Aluminum oxide finds its way into the alloy bath during the wall cleaning process. It is in the spudding or cleaning of the sidewall or even wall contact with the furnace tools during routine fluxing that this build-up of corundum is broken up and dislodged. It becomes mixed with flux, parent alloy from the bath, air, and flue gasses. The resulting particles may vary widely in size and density. Some does sink to the bottom, but most is skimmed off as dross. An appreciable fraction, however, may have a density similar to the metal in the bath and will remain suspended in the melt ultimately finding its way into the dip well, and into the castings.

The color of Al_2O_3, as it appears in castings is a dull gray to black. The gradations in color from dull gray to dull black are undoubtedly related to the variations in the intense heat, which transformed gamma to alpha Al_2O_3 and the time frame in which it was formed. The size and shape of the individual corundum particles may vary widely.

Shotted Alloy. Shotted alloy is alloy that has solidified into small spheres or globules prior to or during injection. These small balls are incased in oxide and as such do not assimilate with the parent alloy. Because they are not homogenous with the alloy they can result in excessive tool wear, provide a leak path, or become the initiation site for a fracture.

Shotting is usually caused by splashing the alloy against the cold surface inside the cold chamber, and is aided if the alloy is to cold. If the melt contains fine corundum particles the formation of shotted alloy is enhanced.

OXIDE FILMS AND DROSS INCLUSIONS

Inclusions of oxide films and dross are a major cause for leakers and excessive tool wear. This is generally gamma aluminum oxide, the soft variety. The source of these thin films is the cold chamber, the runner or in the die from splashes of alloy ahead of the main alloy stream. The splashes and jets are usually a result of poor gale and runner design or by improper speed control of the plunger.

The real problem of the oxide films is that they prevent divergent alloy streams knitting together properly as the cavity fills. This will result in the formation of discontinuities such as laminations, orange peels, or cold shuts. If these films envelope air or vaporized die lube blisters or excessive internal porosity result.

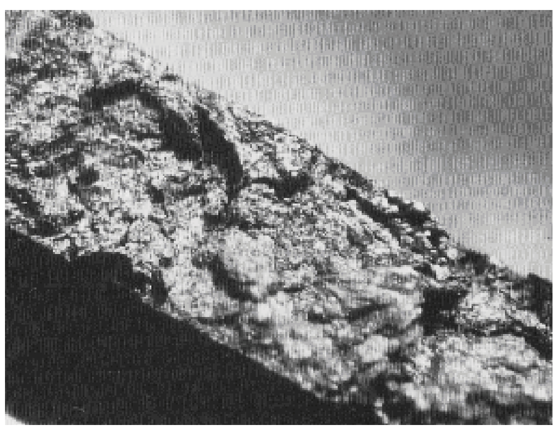


Fig 9-25. The problem with oxide films is that they prevent divergent alloy streams knitting together properly as the cavity fills.

Fig 9-26. Shotted alloy trapped within gas porosity.

SILICON CARBIDE REFRACTORIES

Silicon carbide refractories can find their way into castings if furnace-clean¬ing practices are not maintained. SiC, silicon carbide is as damaging as corundum because of its hardness. It is encountered infrequently compared to corundum and may be distinguished by it very black, glass-like coloring. Their source can be chips from carbide crucibles or from grinding wheels used to remove soldering from the die surfaces.

FLUX

Flux inclusions are not usually recognized during a cursory visual inspection. A simple test to determine whether or not castings contain flux inclusions is to simply submerge the casting in city water overnight. If flux inclusions are present, they will grow crystals on the casting surface since flux is composed of salt. The corrosive products, which developed, appear as light mottling on all surfaces of the casting.

Flux inclusions can be identified by a gray crystalline appearance, similar to rock salt. Flux inclusions are often associated with shrink voids, dross or hard spot inclusions. Flux inclusions will cause problems when coatings such as anodizing or alodining are applied, preventing adhesion. Shelf life of finished components with flux inclusions will be short; storing parts in a humid atmosphere will result in discoloration.

SLUDGE

Sludge is another inclusion considered to be a hard spot. Sludge is composed of complex inter-metallic compounds of Al-Si-Fe-Mn-Cr having melting points above the liquidus temperature of the alloy from which they are formed. Sludge is quite hard, and in a casting will surely damage cutter tooling. Under high magnification the extremely fine primary crystals and their pentagonal shape are easily recognized as sludge.

The components necessary to form sludge are always present in alumi¬num die casting. The tendency to form sludge can be minimized by purchasing alloy that is low in the sludge forming ingredients as the first step. The next step is to maintain good furnace temperature control.

You can check for sludging by raking the bottom of the furnace. Sludge is a silvery sandy material at the bottom of the furnace. It is best just to skim the material off the furnace bottom and discard it.

Since sludging depletes the iron in the bath, if the iron is not replaced, soldering can be expected with jobs that normally do not experience soldering problems. Also, reduced iron in the casting can result in hot cracking at die opening and ejection.

Each plant, each type of alloy being cast, each general type of casting, and each die will have its own set of operating characteristics. The operator must know how each process variable influences the quality from the particular die he/she is running. The defects listed above will help the operator evaluate his particular situation. The supervisor should always be informed when the operator observes a situation that he/she does not understand or that his machine adjustments do not correct.

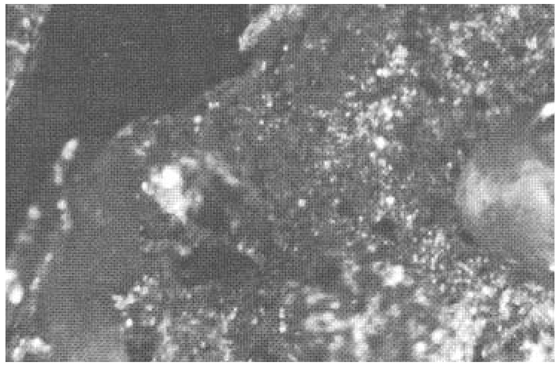


Fig. 9-27. Flux inclusions cause problems with coatings and adhesives identified by a gray crystalline appearance.

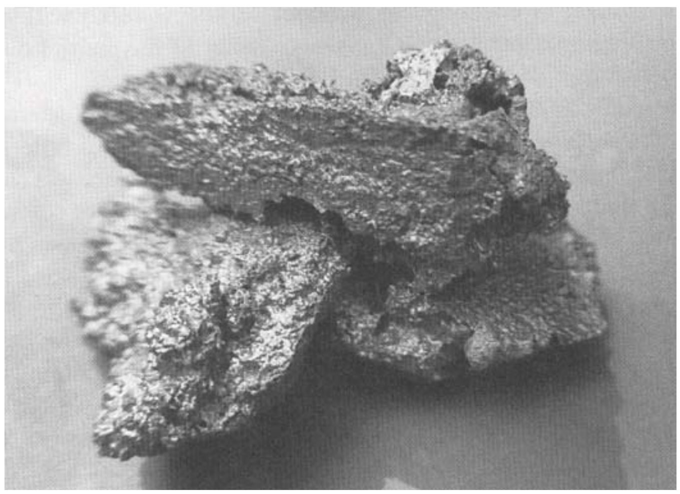


Fig. 9-28. Sludge is formed at the bottom of the furnaces due to temperature variation. Sludge is hard and will damage cutter tooling.

NOTES:

Chapter 10
SAFETY

The die casting plant has many unique situations that must be recognized and controlled to insure the physical safety of workers. Safety considerations have been stressed throughout the preceding sections. However, safety is so important to the individual involved that this special section is included to reinforce the operator's awareness of the problems and necessary procedures. In this section, safety devices and procedures are discussed for each of the major hazards.

MOLTEN METAL HANDLING

Splashes, burns from hot equipment, explosions, and toxic fumes are major hazards when handling molten metal. The following safety procedures should be followed:

1. Wear safety shoes of the molders type in which metal shields are included to prevent injury from falling heavy objects. They also stop molten metal from burning through the shoe should metal be spilled.
2. Wear gloves, hand leathers, asbestos pads, leggings and spats.
3. Wear arm coverings.
4. Wear safety goggles that provide side eye protection. Complete face shields are preferable.
5. Wear respirators during fluxing operations.
6. To prevent explosions, always preheat, until dry, all items to be immersed in molten metal (e.g., shot plungers, stirring paddles, skimming sieves, ingots, etc.).
7. Check all handling equipment before using; and never exceed rated loading.
8. Have all ventilation equipment turned on. Report any defective equipment.

DIE CASTING MACHINE OPERATION

Unexpected machine dosing, die spitting, molten metal splashing, and fire from leaking hydraulic fluid are the major hazards associated with the die casting machine. The following procedures are related to these problems:

1. Wear safety shoes of the molders type.
2. Wear gloves and arm coverings.
3. Wear goggles with side eye protection.
4. Be sure all machine safety shields are properly installed.
5. Be sure all machine safety controls and interlocks are working.
6. Be sure die is locking properly. Adjust tie bars to eliminate spitting from between the dies.
7. Do not stand in line with die parting line.
8. Use tongs or hook to remove casting from die.
9. Close shot valves and block die open when working between die halves. Remove shot plunger if machine is hot-chamber type.
10. Report or repair any hydraulic leak immediately.
11. Do not use flammable fluids such as kerosene as die release material.

DIE SETTING

When changing a die casting machine set-up, the proximity of molten metals and the high temperatures of the die and machine add to the normal hazards of manipulating heavy items. When setting die casting dies:

1. Wear protective clothing described above.
2. Be sure machine is properly deactivated (shot valves closed, shot plunger removed from hot-chamber, electrical panel locked off, etc.).
3. Use proper size eye bolts and seat the bolt shoulders properly against the die surface.
4. Use proper size chains. Avoid excessive spread of chains (see Fig. 6-3).
5. When two or more people are working together, special care must be taken to be sure everyone is clear of the machine when operating the controls.
6. Be sure that all safety devices function properly when die setting is complete.
7. Clear all personnel from area before making first shot on a newly-set die.

HANDLING CASTINGS

When handling die castings, several precautions must be taken:

1. If the casting has not completely solidified when the die opens, the liquid portion may blow or pop. This explosive action spits molten metal from between the partially-opened dies. The operator should stay clear of the die parting line until the die has opened about 2 inches. Once a blow is observed, the operator should adjust the machine controls to avoid a recurrence.
2. Castings are hot when first removed from the die. Sometimes the castings are still hot enough to cause serious burns even after quenching. Gloves and other protective clothing should be worn at all times to prevent burns.
3. Untrimmed castings have flash that is sharp. This flash can easily cut through light clothing. Gloves and protective clothing should be worn to prevent cuts from flash.
4. When disposing castings to containers or conveyors, be sure that no one is in the way. If the casting strikes another person, that person could be cut, bruised, or burned. It should be noted that careful ha/Idling avoids damage to the casting as well as improving the safety condition.

HOUSEKEEPING

A die casting machine presents several housekeeping problems. Lubricating oil and grease build up, water often runs or sprays over the machine and floor, and molten metal spills accumulate. When these materials are not constantly removed, they quickly become slippery and, therefore, hazardous. To eliminate these and other hazards, the operator should do the following every day:

1. Return all loose equipment to its storage area.
2. Wipe excessive grease and oil from machine.
3. Clean floor. Scrape hardened materials to insure removal.
4. Remove flash and other foreign material from inside of safety doors and from die area.
5. Check floor for slippery areas and clean as required.

FIRE

Because of the combination of molten metal, gas torches, hydraulic fluids, and lubricating greases and oils, there is a potential fire hazard in a die casting department. Good housekeeping and equipment maintenance are the best fire safety measures. All accumulation of oil, grease, or oily films must be removed periodically. All hydraulic leaks must be reported immediately.

Eliminating accumulations of flammable materials coupled with good metal handling and die heating procedures, greatly reduces the potential fire hazard.

Most serious industrial accidents are the result of someone having not observed an established safety rule. Operating the die casting machine can be a highly rewarding occupation; and if the operator learns and uses the safety procedures, there is little chance of injury.

APPENDIX

SOLUTIONS TO EXERCISES

Exercise: Find the initial percent fill and the critical slow shot speed required to manage the air given the following parameters: (the solution can be found in the appendix).

Plunger diameter - 3 in
Sleeve length - 20 in
Total shot volume - 65 in3

$$\mathbf{A_{pt}} = \mathbf{\Pi} \bullet \frac{\mathbf{d_{pt}}^{2}}{4} = 3.14 \bullet \frac{3^2}{4} = 7.065\text{in.} \qquad \text{Eq. 4-6}$$

Where:

$\mathbf{A_{pt}}$ = the area of the metal plunger, in2 (cm2)
$\mathbf{\Pi}$ = 3.14
$\mathbf{d_{pt}}$ = diameter of the plunger tip, in. (cm)

$$\mathbf{f_i} = \left(\frac{\mathbf{V}}{\mathbf{A_{pt}} \bullet \mathbf{L_s}}\right) \bullet 100\% = \left(\frac{65\text{in}^2}{7.065\text{in.} \bullet 20\text{in.}}\right) \bullet 100\% = 46\% \qquad \text{Eq.4-5}$$

Where:

$\mathbf{V}$ = Volume of metal ladled into shot sleeve, in3 (cm3)
$\mathbf{L_s}$ = Length of the shot sleeve between the face of the plunger and the face of the ejector die, in. (cm)
$\mathbf{A_{pt}}$ = shot plunger area, in2 (cm2)

REFERANCES

1. Safety in Pressure Die Casting, Fourth Edition, 1970, Zinc Alloy Die Casters Association, 34 Berkeley Square, London, England
2. Die Casting Industry Safety Manual, American Die Casting Institute, Inc., 366 Madison Ave., New York, N.Y. 10017
3. H. K. Barton, Die Casting Die Design, The Machinery Publishing Co. Ltd., National House, West Street, Brighton 1, England
4. E. T. Lees, Quality Control in Die Casting, Die Casting Engineer, Jan-Feb. 1971, p. 26.
5. P. Thukkaram, Refresher Course on Die Casting. Lecture No.6, Zinc Alloy Die Casting Society, Safdarjung Enclave, New Delhi-16, India
6. E. Oberg and F. D. Jones, Machinery's Handbook, The Industrial Press, 200 Madison Ave., New York, N.Y. 10016 .
7. S. D. Sanders, W. D. Kaiser, & P. D. Frost, Metalographic Analysis of Zinc Die Castings, Transactions. The Society of Die Casting Engineers, Inc. 1970, Paper 53.

NADCA
NORTH AMERICAN DIE CASTING ASSOCIATION

3250 N. Arlington Heights Rd., Ste. 101
Arlington Heights, IL 60004
P: 847.279.0001 F: 847.279.0002
www.diecasting.org