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Lubrication

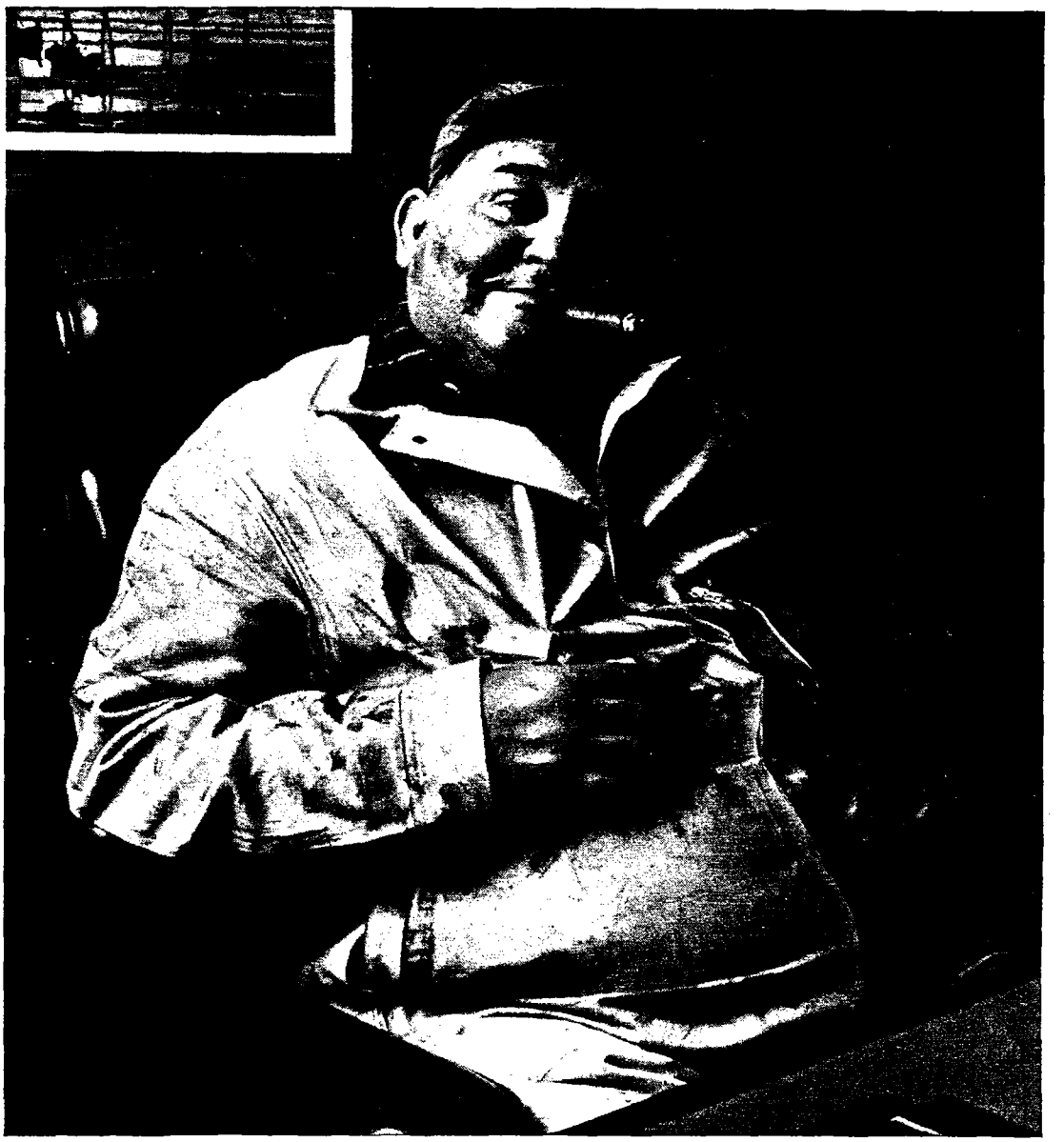
A Technical Publication Devoted to the Selection and Use of Lubricants



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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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PLASTICS INDUSTRY

MAN was endowed by nature with an innate curiosity and a certain degree of laziness. The combination of these attributes resulted in an insatiable desire to improve his way of living and status among his fellow beings. Progress was slow at the start. It took thousands of years for primitive man to effect the transition through stone and wood to copper but the tempo of progress increased rapidly with the advent of iron and steel. The acceptance of these products and other newer metal alloys as construction and manufacturing materials was a natural reflection of a desire to do better. The parade has not ended. Mankind is now embarking on a period in which plastics are replacing all the above materials, and others, in the fabrication of a countless number of products essential to all phases of our everyday living.

The rate of growth of plastics consumption since their conception and first use has not been spectacular. The first commercial plastic in the United States was developed by John Wesley Hyatt approximately one hundred years ago. It resulted from his search for a substitute for ivory. The basic ingredient was cellulose nitrate and it was only natural that the resulting product should be given the similar name "Celluloid."

The merits of plastics for diversified uses were evident from the start. Celluloid was used for billiard balls, dental denture plates, shirt collars and cuffs, shirt fronts and windowed side curtains for touring cars as the requirements developed. It is still used for printed cards, buttons, toilet articles, and spectacle frames, however its extreme flammability has greatly restricted new applications.

It was thirty years before the next major advance in plastics occurred. This was the introduction of shellac which is a natural resin obtained from the lac bug of India and South Asia. It was used originally as a plastic for the manufacture of phonograph records and is currently employed to a limited extent as a protective coating and electrical insulating material.

The most significant early development in plastics occurred in 1908. It was then that Dr. Leo H. Baekeland produced the first synthetic plastic using phenol-formaldehyde resin and named it Bakelite. The phenolic plastics had many outstanding characteristics which accounted for their wide acceptance.

The introduction of cold molded plastics immediately followed Dr. Baekeland's discovery. These were, and still are, a nondescript group of organic and/or inorganic materials. They derive their name from their ability to be molded without resorting to heating. The organic types contain asphalt, tar or synthetic resin as binders and any one of a number of finely divided inorganic materials as fillers. The inorganic type usually contain clay as a binder and

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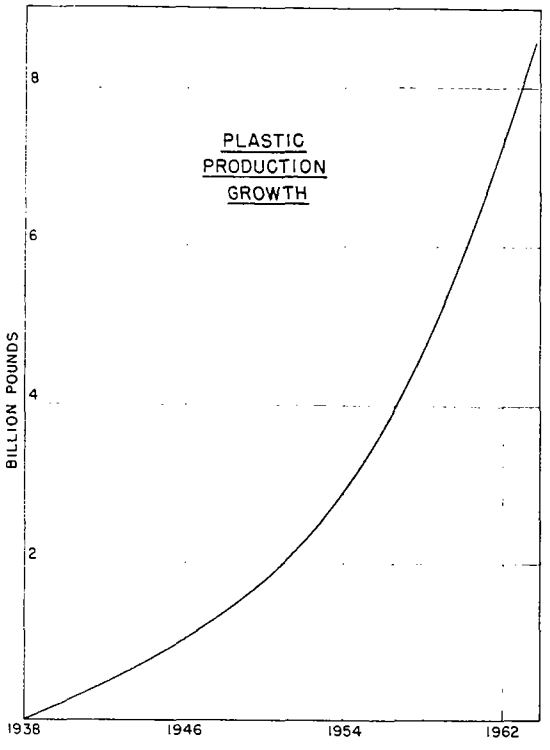


Figure 1 — Plastic production is increasing very rapidly.

asbestos or cement as a filler. These mixtures require fluidizing liquids to permit molding and which may be removed subsequently by baking.

Casein plastics were invented in 1919 and represent the last of the early era plastic developments. Their poor moisture resistance limited their usefulness.

The growth of plastics during the fifty years following conception was slow. Only five major developments occurred in this period. It should be noted that four of these were based on the use of naturally occurring materials and only one on synthetics. This growth rate was not peculiar to plastics. It characterized most of our industrial advances in that period. Any early lethargic tendencies have been completely eliminated during the past ten years. All phases of the plastic industry are currently "hopping" since the rate of plastic consumption is increasing at a faster rate than that of any other major commercial material. The growth rate shown in Figure 1 is expected to continue for several years. This is due to the industry's transition from producing "buttons" to much larger industrial and structural units.

The rapidly expanding uses for plastics can be attributed to the availability of a very large number of newly synthesized materials each having different chemical and physical properties. It is this variation in properties that permits the selection of optimum plastic materials for specific applications. These can be further modified by the addition of fillers. It would be futile to attempt to list all the basic materials or the products made from or treated with plastics, however polyethylene, styrene and polyvinyl chloride account for over half of the plastic material currently being processed. The application spectrum for plastics is indicated by the wide variety of tests by which they are evaluated. In addition to the basic impact and tensile strength tests, plastics are subjected to other specific mechanical, electrical, optical, thermal and chemical tests. Only a few of these tests are applicable to any other single industrial material.

In order to better appreciate the different basic procedures for forming plastic products it should be recognized that there are two entirely different classes of plastics, i.e., "thermoplastic" and "thermosetting." These may be defined as follows:

Thermoplastic: Those materials which undergo only a physical change during processing. These materials may be considered analogous to ice. They will liquify under the application of heat and pressure and re-solidify on cooling. Included in this group are the cellulose derivatives, casein, polyethylene, fluorocarbons, polystyrene, acrylics, nylon and the vinyls.

Thermosetting: Those materials which become rigid as a result of a chemical reaction which occurs when they are subjected to heat and pressure. After completion of the reaction, they are insensitive to further heat application. The ureas, polyesters, alkyds, melamines and phenolics are typical of this classification.

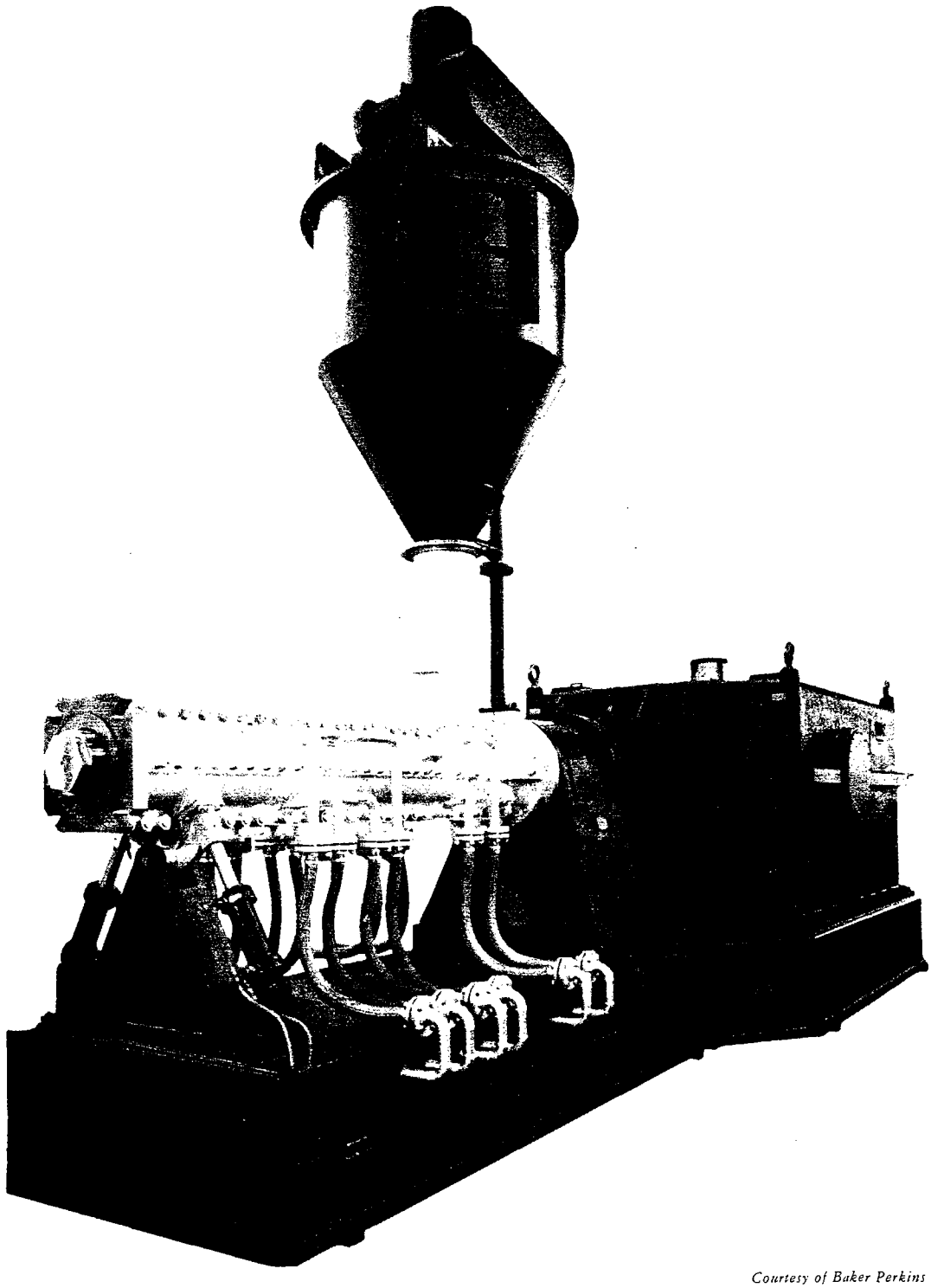
If one can overlook the many critical details pertaining to the selection and uniformity of raw materials, equipment design and temperature control, the production of plastic articles becomes a relatively simple operation. The raw material is charged to the equipment, plasticized by heating, forced into mold cavities or through dies and finally cooled. This applies to compression, injection and blow molding and to a lesser extent to extrusion which are the principle procedures used in the manufacture of plastic articles. It must be recognized that the differences in the properties of plastics and the size and design of the finished product are responsible for the many variations in operating conditions and equipment.

Figure 2 illustrates a type of equipment used in blending plastics, incorporating pigments and otherwise preparing feed stock for pelletizing or molding.

The developments in materials, techniques and equipment in the plastic industry were a natural growth born of a desire to improve older equipment and methods, increase production and economy, produce more serviceable products and take advantage of the beneficial characteristics of the many

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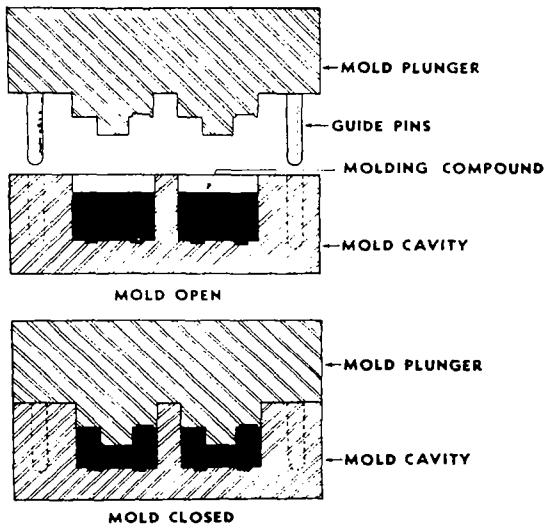


Courtesy of Baker Perkins Inc.

Figure 2 — A "Ko-Kneader" with power feeder which uses an interrupted rotating and reciprocating flight screw to compound plastics and disperse pigments prior to pelletizing or molding.

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Courtesy of HPM Division, Koehring Company

Figure 3 — Schematic of a simple compression mold.

newly developed raw materials. The progress attained can be compared to that achieved by the automotive industry during the past sixty years. These developments have resulted in the introduction of many variations in the basic equipment used in the different procedures for forming plastic pieces. The following account will be restricted to the four basic molding processes together with the extrusion and calendering methods of processing plastics.

MOLDING PROCESSES

The word "molding" encompasses four specific processes in the plastic industry: "compression," "transfer," "injection" and "blow" molding. In these operations a controlled amount of plastic material is placed or forced into a mold before or after "plastication" (plasticized) by heating, cooled, and then removed in essentially final form. All molds contain one or more cavities conforming to the dimensions of the piece being produced, but vary widely in respect to both size and simplicity. These two latter factors are mainly responsible for selection of the specific molding process used.

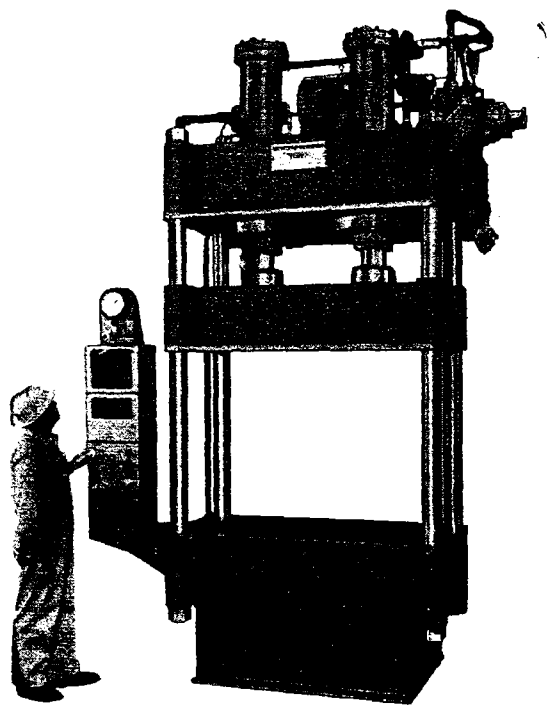
It is within the cavities of the molds that the shapeless plastic powders or pellets are transformed into the many intricate, smooth and shiny objects which are now so important in everyday life. The plastic product will be an exact duplicate of the mold cavity in every detail, even to the surface finish, consequently the mold must be dimensionally and mechanically perfect, and made of materials which will withstand the high temperatures and pressures to which it will be subjected. It must also resist dimensional change due to the abrasive action of fillers used in some molding compositions. Molds are usually made from tough, high quality alloy steel in order to comply with above requirements and are frequently chrome plated to insure against rusting, corrosion and wear. Should the particular plastic tend to stick to the mold, use of a mold release or parting compound will be required. Considerable care in selection and application may be necessitated if damage to the finished articles is to be avoided.

Molds are always divided into at least two parts; one part has the outside shape of the article to be made while the other part has the inside shape of a hollow article or is a simple plunger. Some operations employ multiple cavity molds which permit the simultaneous molding of a number of pieces which increases production and lowers costs.

The trend toward the molding of much larger and more intricate plastic articles has required much consideration of mold design in respect to factors such as heating, cooling and shrinkage. The importance of mold design, construction and operation in the plastic industry cannot be overemphasized.

Compression Molding

Compression molding is primarily used for the fabrication of large plastic articles of simple design from thermosetting plastics. Thermoplastics can be used in compression molding, however they are seldom used since they necessitate alternate heating and cooling of the molds which seriously

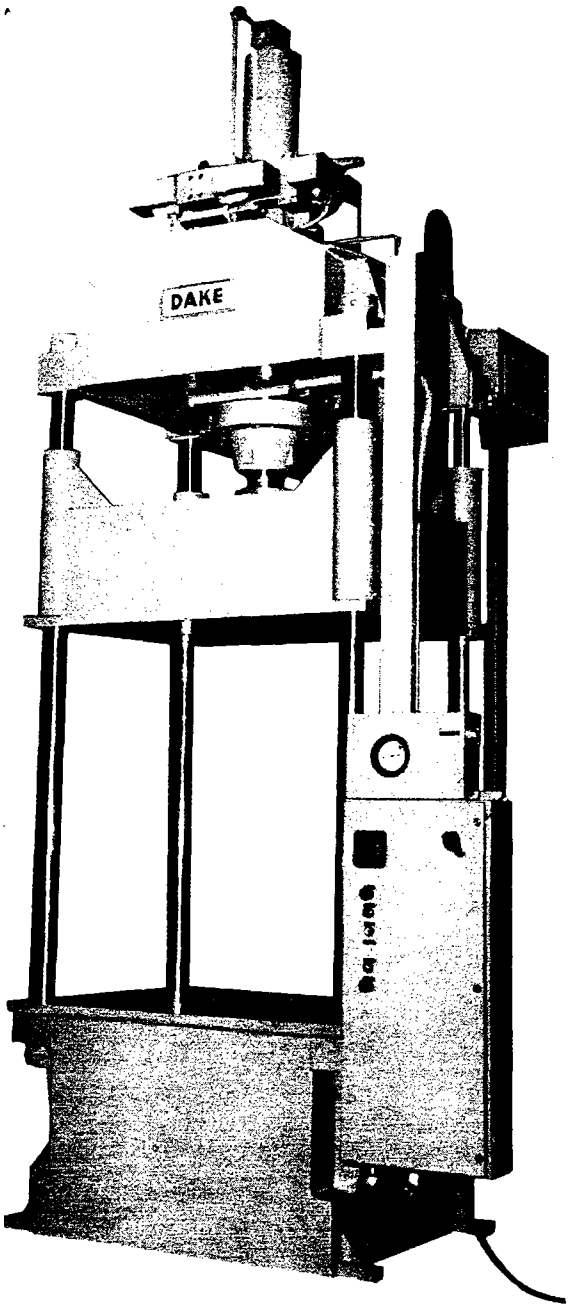


Courtesy of Nordberg Manufacturing Company

Figure 4 — A 100 ton, double ram fiberglas molding press equipped with adjustable automatic cycle controllers.

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Courtesy of Dake Corporation

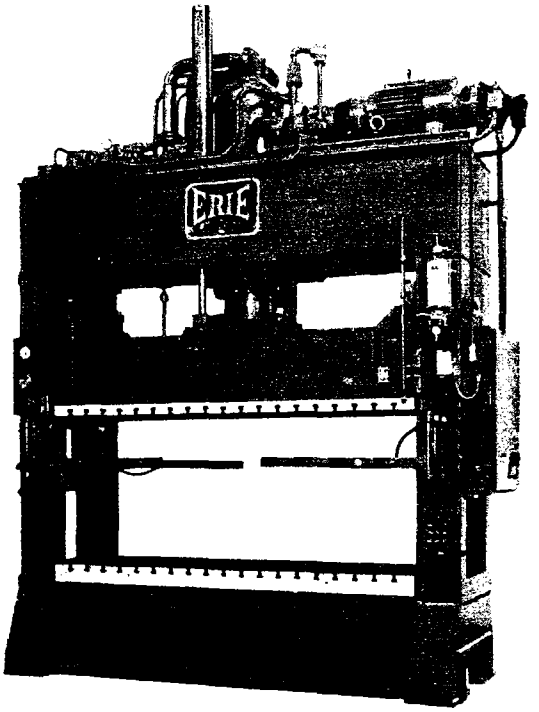
Figure 5 — A 100 ton, single ram fiberglas molding press equipped with automatic controls.

retards production. In fact the compression molding of thermoplastics is restricted to those articles that are too large to produce by other methods.

The equipment required for compression molding is simpler but much more rugged than that used in other plastic forming operations. The primary requirement is a hydraulic press that is capable of exerting the required pressure for closing the mold sections which are located between the press platens. This pressure will average 2 tons per square inch of plastic surface. The size of the presses in this service have increased proportionately to the size of the molded pieces. Presses capable of exerting several thousand tons of clamping pressure are currently in use.

The basic principle of compression molding is relatively simple. One or more heated molds like that illustrated in Figure 3, are charged with a predetermined amount of plastic, closed, and then subjected to a high clamping pressure. Typical hydraulic presses are shown in Figures 4, 5 and 6. The temperature must be sufficiently high to liquify the plastic so that it will flow and conform to the shape of the mold cavity. The plastic is maintained at a controlled temperature and pressure until the chemical reaction has proceeded to a point where the plastic article has acquired the desired physical properties. The mold is then opened and the piece removed. The reaction temperature, pressure and time required all vary for different plastics and the volume of the article being formed.

A steady improvement in the equipment used for compression molding has permitted a transition



Courtesy of Erie Foundry Company

Figure 6 — A 200 ton, single ram fiberglas trimming press with speed of 1000 inches per minute through a 38 inch stroke. Note automatic Trabon lubricating equipment on right column.

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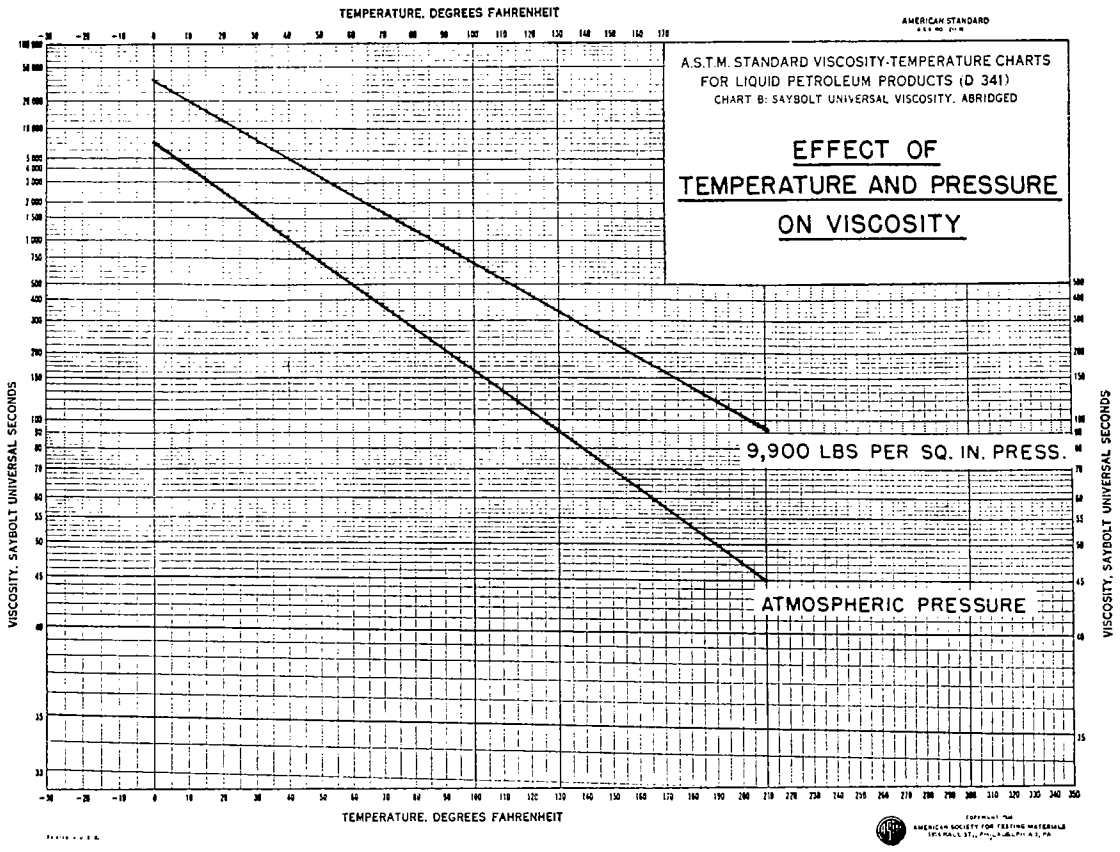


Figure 7 — Both temperature and pressure change the viscosity of any petroleum oil.

from hand operation through semi-automatic to fully-automatic molding. Presses which formerly required manual handling at each stage of the process now operate unattended.

Press Lubrication

The automation of the newer hydraulic presses has had little effect on their lubrication requirements. The hydraulic system, the most vital part of these units, is most carefully designed since it is essential that the press be able to operate continuously over long periods without distress. Shutdowns due to malfunctioning can result in high maintenance costs and expensive downtime.

With a properly designed system, the primary consideration of the operator is the choice of the hydraulic oil. Manufacturer's recommendations should be followed whenever possible. Viscosity is the most important single property of an hydraulic oil that relates to service performance of the system, and oils having Saybolt Universal viscosities at 100° F. between 150 and 700 seconds are normally used. A specific viscosity within this range is selected depending on the temperature and pressure to which it will be subjected. Since the viscosity of a petroleum oil varies with both temperature and pressure as shown in Figure 7, both of these factors must be taken into consideration in the selection of an oil for use in compression molding presses. The following undesirable results can be caused by using an oil of incorrect viscosity.

Viscosity Too High

1. Increased internal friction with increased flow resistance through pumps, valves, and piping.
2. Increased operating temperature.
3. Sluggish operation.
4. Increased pressure drop throughout the system.

Viscosity Too Low

1. Excessive internal and external leakage.
2. Increased pump slippage, reduced pump efficiency and increased oil temperature.
3. Increased rate of wear of moving parts.
4. Loss of pressure.
5. Loss of precision control.

Viscosity alone will not guarantee trouble-free operation over prolonged periods. There are other

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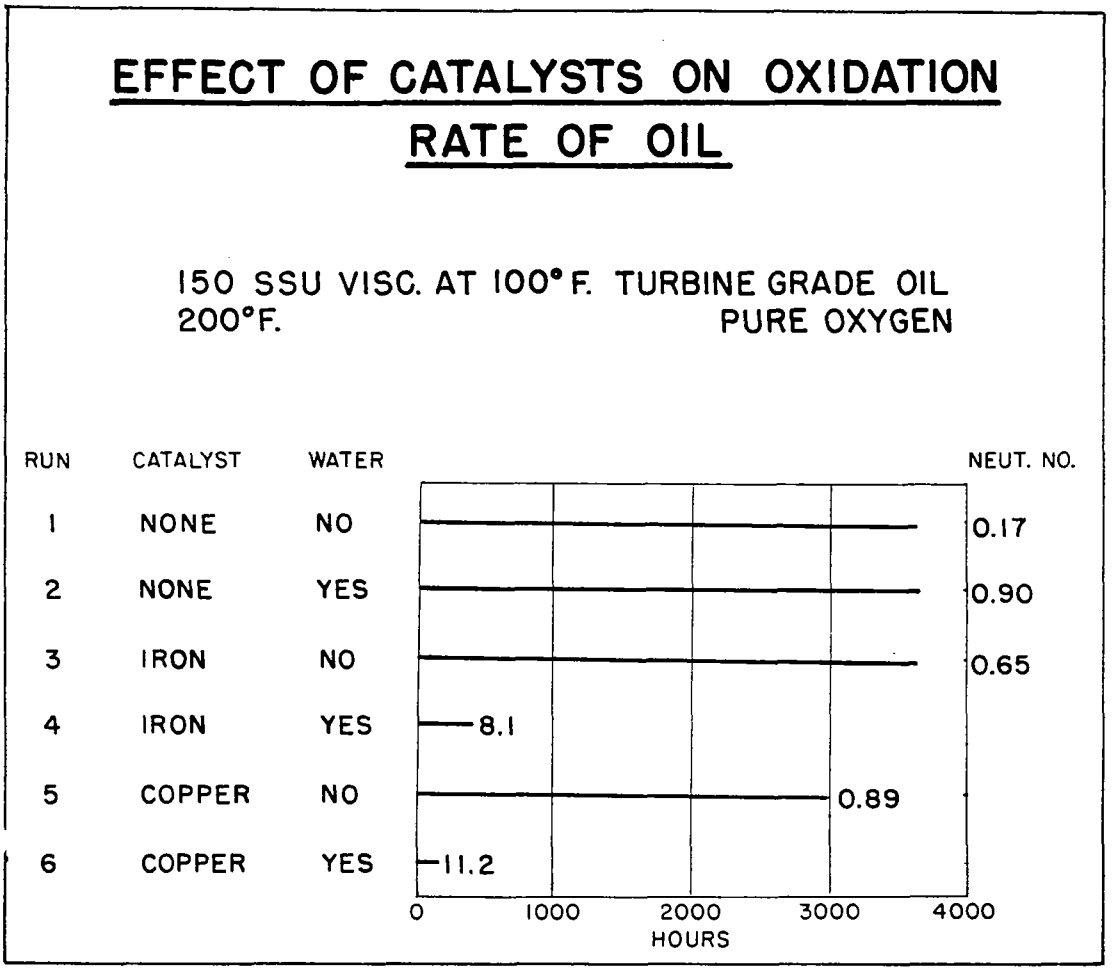


Figure 8 — Water, iron and copper are all strong oil oxidation catalysts.

properties that require consideration. The four most significant of these are discussed as follows.

Oxidation resistance

All oils deteriorate to a greater or lesser extent when exposed to temperatures and pressures existing in hydraulic systems. They react with oxygen to form acidic materials which can be corrosive to the metals in the system. Progressive oxidation results in oil-insoluble sludges which will increase corrosion, plug lines and valves and thus cause the system to become inoperative. Oxidation is promoted by increased temperatures, the greatly increased amount of air absorbed at high pressures, and the presence of catalytic metals, sludge or moisture in the oil.

Oil oxidation is minimized by careful selection of base stocks, the methods and degree of refining used and the incorporation of oxidation inhibitors. The effects of water and two common metallic catalysts on the oxidation of an oil are shown in Figure 8.

Rust Prevention

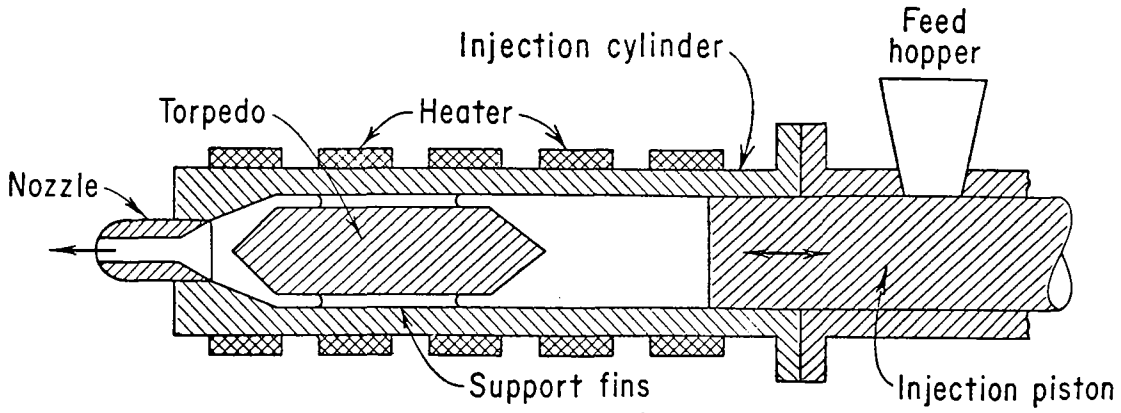
Hydraulic systems, like other equipment made of ferrous metals, can be adversely affected by rust more than by any other factor. This dictates the use of carefully refined oils containing rust preventing inhibitors.

Foam Resistance

Foaming in hydraulic systems may give rise to serious operating problems and is caused by ingress of air into the system. This can result from a low oil level or leaks in the pump suction lines. These defects should be corrected immediately. Oils will absorb approximately ten per cent of air by volume at low and much more at high pressures. As long as the air is in solution, no foaming will result. When the pressure is released the air comes out of solution and may cause foaming in the system. Oils having low foaming characteristics will minimize foam difficulties.

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Courtesy of Modern Plastics Encyclopedia, McGraw-Hill Inc.

Figure 9 — Conventional injection cylinder with torpedo.

Water Separation

The water separating characteristics of an oil are important. Water can enter a hydraulic system by either condensation or contamination. The oil must exhibit good water separation properties in order to prevent the formation of emulsions which may promote wear, oxidation, and the circulation of rust, dirt and grit that adversely affect the functioning of valves.

The No. 2 NLGI grade of a good ball and roller bearing grease is normally used for lubricating the hydraulic pump bearings and grease lubricated motor bearings. If the latter are designed for oil lubrication, a rust and oxidation inhibited hydraulic oil with a viscosity of about 300 SUS at 100° F. is recommended.

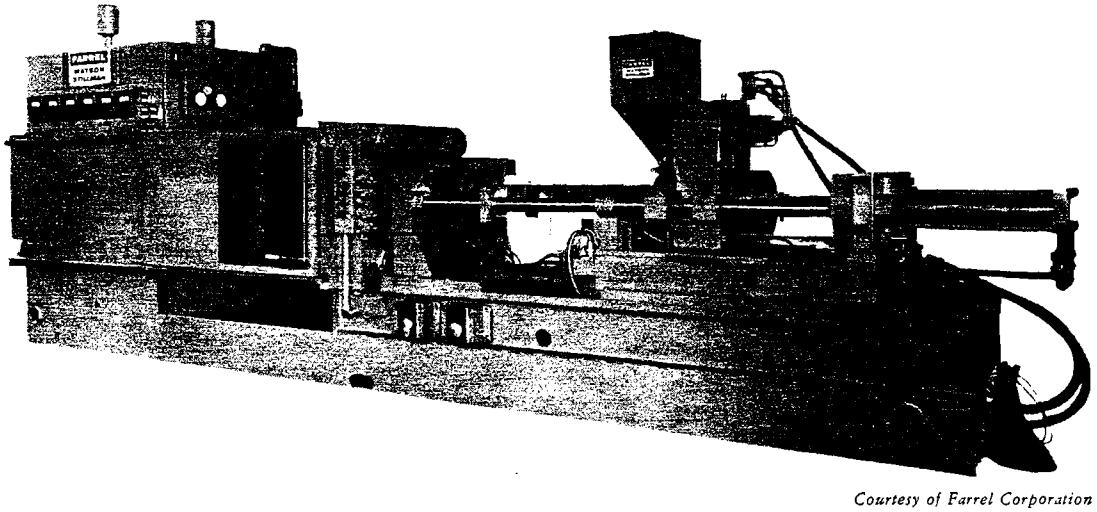
Transfer Molding

Transfer molding may be considered the same as compression molding in respect to equipment and type of plastics used. The main difference between these two procedures is in the manner in which the molds are loaded. In compression molding dry powder or pellets are charged to the molds. In transfer molding the charge is preplasticized outside the mold, then forced into it for curing. The principal advantage of transfer molding is its adaptability for making more complicated parts than possible by compression molding.

Lubrication considerations are the same as those discussed under compression molding.

Injection Molding

Injection molding consists of forcing a hot preplasticized feed stock through a nozzle and into closed molds where it is cooled and then removed. Injection molding is used exclusively on thermoplastic feed stocks, and is comparable to the transfer molding of thermosetting plastics. The main dif-

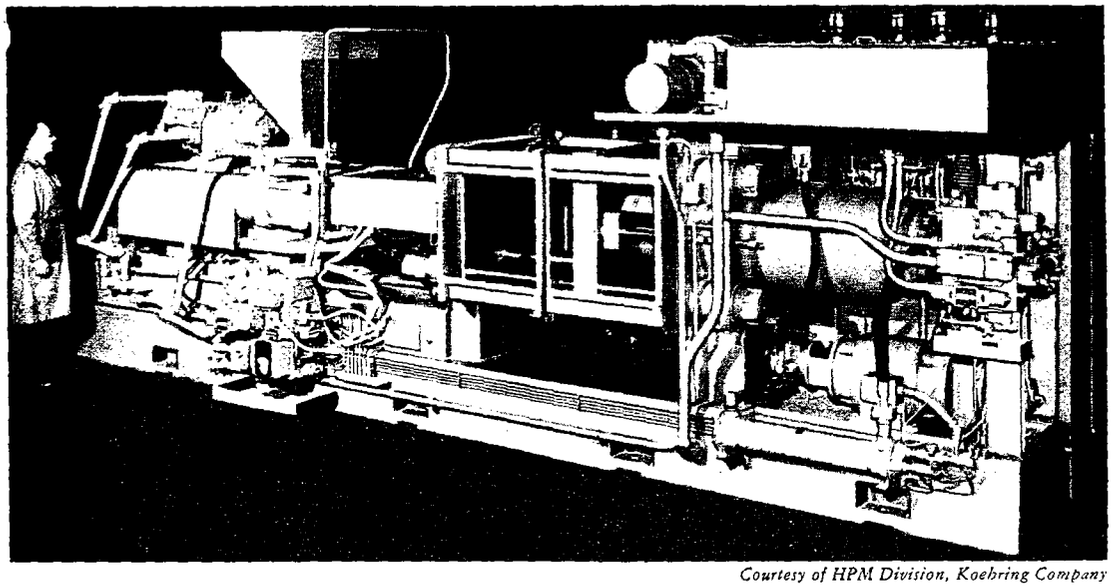


Courtesy of Farrel Corporation

Figure 10 — In-line screw plasticizer injection molding machine.

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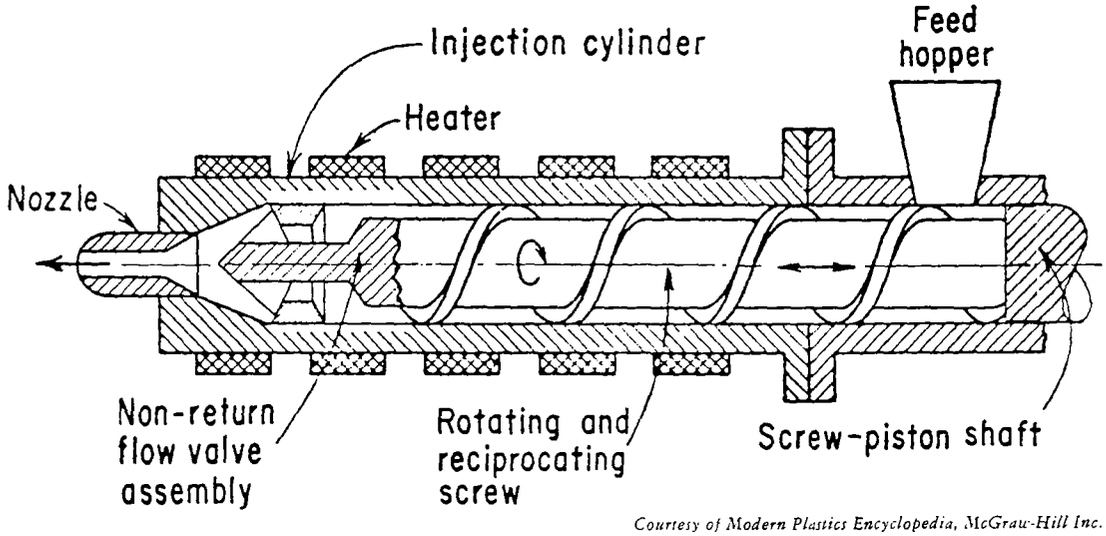
Courtesy of HPM Division, Koehring Company

Figure 11 — Rear view of single stage screw plastics injection molding machine.

ference is that the injection molds are cooled instead of heated to hasten solidification and removal of the finished articles.

The basic operations of injection molding consist of feeding the granulated plastic charge stock from a hopper into a heated plasticizing cylinder where it is liquefied and then forcing it through a nozzle into the molds. A schematic cross section of the equipment is illustrated in Figure 9. Photographs of commercial units are shown in Figures 10 and 11.

The wide range of properties of the vastly increased number of available plastics, the greater complexity of molded articles, and the demand for increased production have dictated many modifications in the design of injection equipment. These changes have been directed toward larger units, more rapid and efficient plastication, closer temperature control and cycle automation. One of the more critical factors in this procedure is the plastication of the feed stock. Plastics have low heat conductivities and consequently injection cylinders must be designed to continually move the cooler

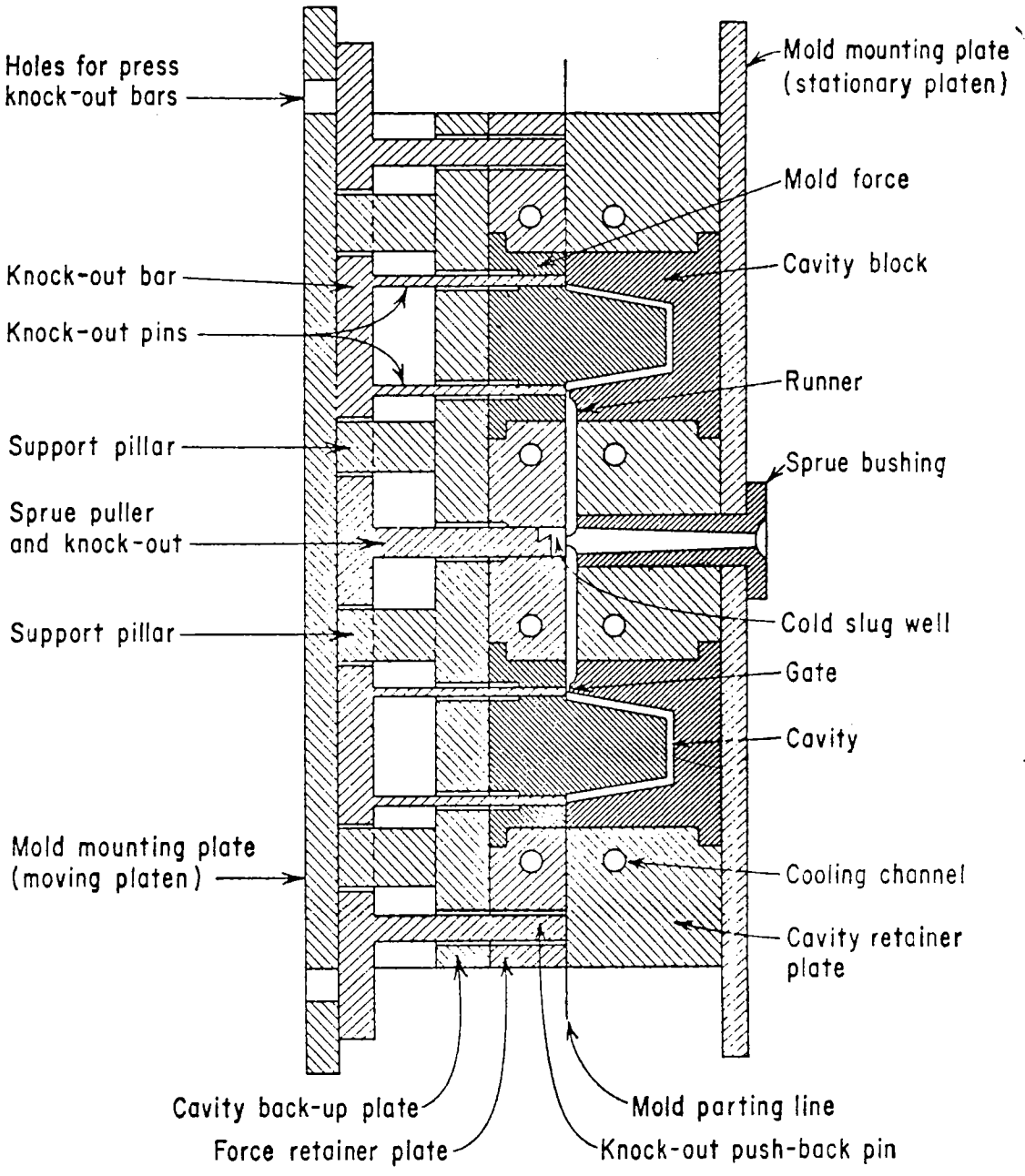


Courtesy of Modern Plastics Encyclopedia, McGraw-Hill Inc.

Figure 12 — Schematic cross-section of rotating and reciprocating extruder screw which plasticates material and deposits it in front of itself within the cylinder while moving backwards (to right) to accommodate it. During injection, the screw moves forward (to left) into the position shown.

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Courtesy of Modern Plastics Encyclopedia, McGraw-Hill Inc.

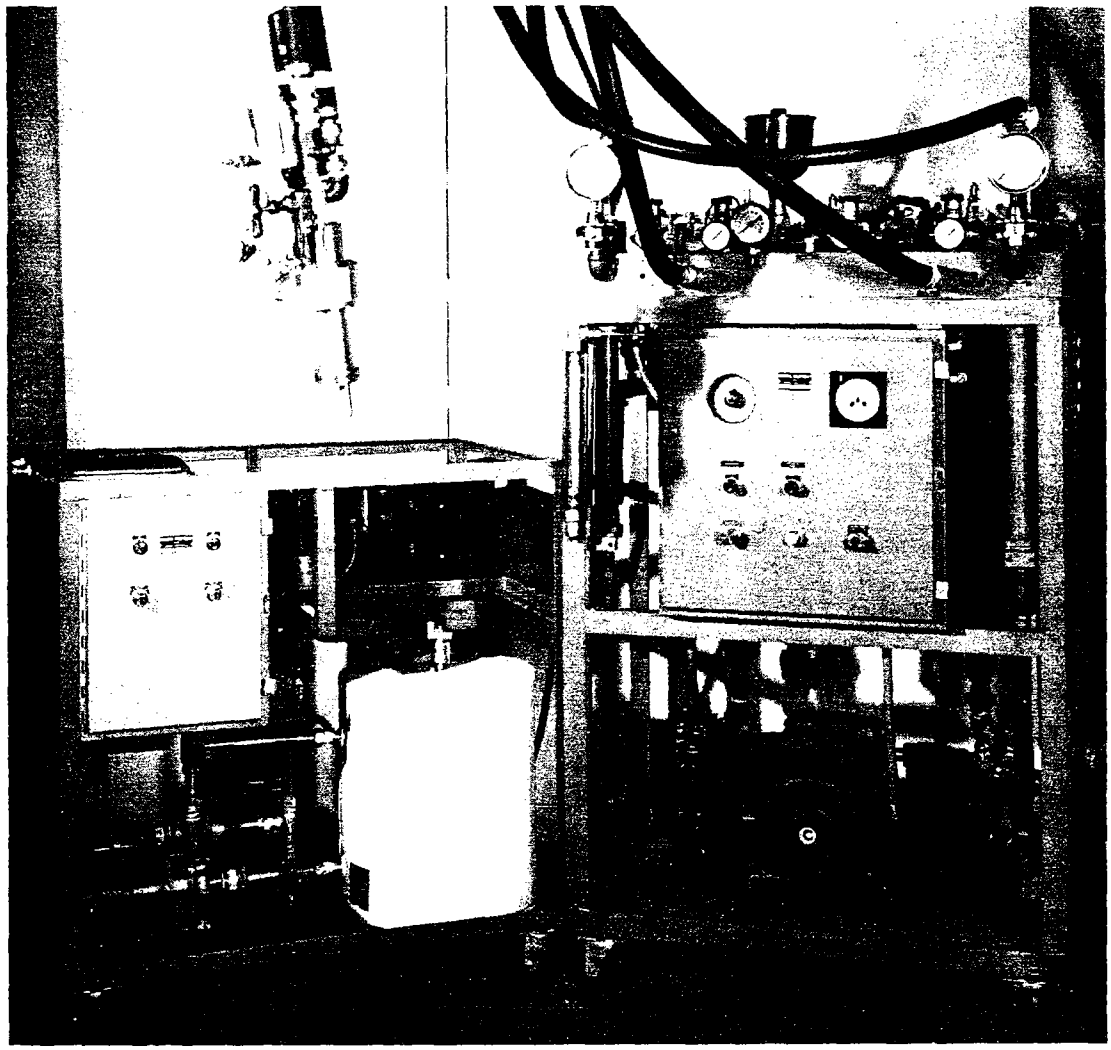
Figure 13 — Schematic cross-section of two-cavity injection mold.

plastic into contact with the heated surfaces in order to insure a uniform temperature. This is accomplished by the torpedo shown in Figure 9. In order to increase the rate of heat transfer to the melt and obtain a more uniform temperature, the torpedo has been replaced by rotating-reciprocating screws in some of the newer injection cylinders. The operation of one of these units is indicated schematically in Figure 12. The desired rapid attainment of a uniform melt temperature is important since it affects the machine's productive capacity.

The viscosity of a plastic varies inversely with temperature: the rate of change varies for each type of material. This requires careful consideration in the selection of optimum temperatures for processing different plastics. Close temperature control is necessary to insure a uniform melt consistency

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Courtesy of Admiral Equipment Corporation

Figure 14 — Mixing-injection equipment for rigid urethane foam.

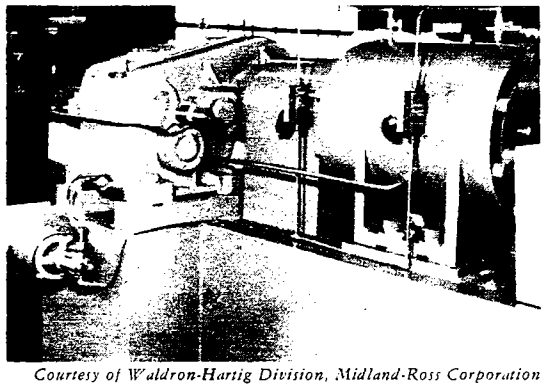
just ahead of the nozzle in order to insure uniform operation. Plastics are also non-Newtonian, consequently their viscosities vary with the rate of shearing to which they are subjected within the cylinder. This is not too significant since the shearing is relatively constant within any single piece of equipment. It is a factor however that requires consideration when contemplating the use of units having basically different designs that produce different rates of shearing. The importance of close temperature control for the melt cannot be overemphasized since it controls melt viscosity, injection pressure, timing, mold cooling and uniformity of the finished products.

The importance of temperature in injection molding extends beyond the plasticizing step. It requires attention until the molded articles are finally ejected from the molds. As a consequence injection molds contain channels for the circulation of cooling media for the removal of heat furnished by the melt. After the thermoplastic melt is injected into the mold, it must be cooled until it has sufficient stability to be ejected without distortion. Maximum production efficiency requires uniform and optimum temperatures in both the cylinder and molds. The units are normally operated at as low a temperature as practical since this permits maximum production.

Injection molding is considerably more automatic than compression molding and the cycle is much shorter. Molds usually provide for automatic ejection of the finished parts and are therefore somewhat more complex. Multiple cavity molds are also used whenever possible to effect operating econo-

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Courtesy of Waldron-Hartig Division, Midland-Ross Corporation
Figure 15 — Hartig 4½ inch extruder. Note two Manzel Lube-Line Alert devices used to either signal cessation of lubricant flow or to automatically shut down the machine.

mies. Figure 13 is a schematic cross section of a two cavity injection mold with automatic ejection.

Somewhat related to injection molding is the modern method of insulating and reinforcing hollow spaces in truck-trailer bodies, aircraft and small boats by using equipment like that shown in Figure 14 which mixes the ingredients of urethane foam, then pumps the mixture into the cavities where it quickly fills, expands and hardens in the cavity "mold" to make a light-weight but rigid foam.

Press Lubrication

There are several varieties of injection machines in current use but they are similar to the extent that each is comprised of two separate units: (1) a clamping unit which supports, opens, and closes the mold and maintains it in a closed position under clamping pressure; (2) an injection unit which converts the plastic from solid particles to a liquid mass, then injects it into the closed mold. The proper sequence of operation for the two units requires auxiliary equipment such as power units, timing controls and temperature controls. Injection machines normally have self-contained oil hydraulic systems for supplying power to both the clamping and injection units. The hydraulic power is developed through pumps driven by electric motors. The selection of a hydraulic oil for these units must take into consideration the same factors as previously discussed under COMPRESSION MOLDING.

Most machines used for injection molding employ a series of toggles to actuate the molds and hold them under pressure until the desired cooling is obtained. The bearings are subjected to unusually severe operating conditions which necessitates the use of an extreme pressure oil for lubrication. Many equipment designs provide automatic systems for lubricant application as illustrated in Figures 6 and 15. If the design calls for grease lubrication, an extreme pressure product of NLGI No. 2 consistency should be applied.

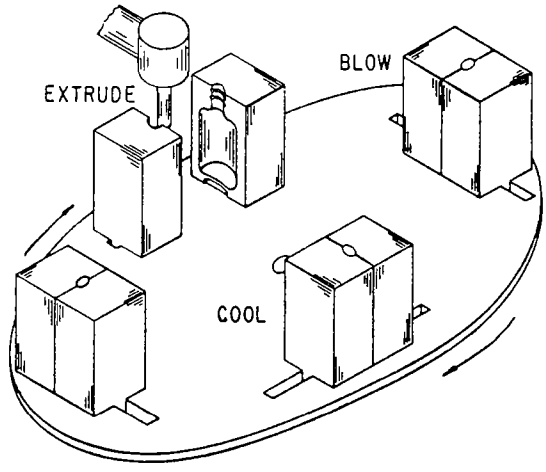
In those units employing rotating screws or spreaders to facilitate plastication, consideration must be given to the lubrication of the gear train and motor. Manufacturers' recommendations should be followed whenever possible. Enclosed gears are normally sump-lubricated with a mild extreme pressure oil having a Saybolt Universal viscosity at 210° F. of approximately 150 seconds. Lower viscosity oils can be used satisfactorily if this is preferable from the standpoint of simplified general plant lubrication.

Blow Molding

Blow molding is used for the production of hollow plastic articles. The procedure is not new since it was used in the days when celluloid was popular for the production of baby rattles and hollow balls. Its use has increased very rapidly in recent years with the introduction of new plastics suitable for larger and more marketable products. At the present time it is used extensively for toys as well as containers for numerous household products. Some of the plastic containers have capacities as large as five gallons. Current development work is pointed toward the production of even larger pieces, such as automotive body parts.

The basic principle of blow molding consists of first forming a hollow tube (or "parison") by injection or extrusion, heating and inflating it inside a mold by air pressure, cooling and finally ejecting. Thus it is strikingly similar to the method used to make glass bottles and jars.[1] There are many variations in the equipment used to perform this cycle of operation. The selection of any particular one is a matter of economics based on equipment costs and the volume of parts to be produced. Figure 16

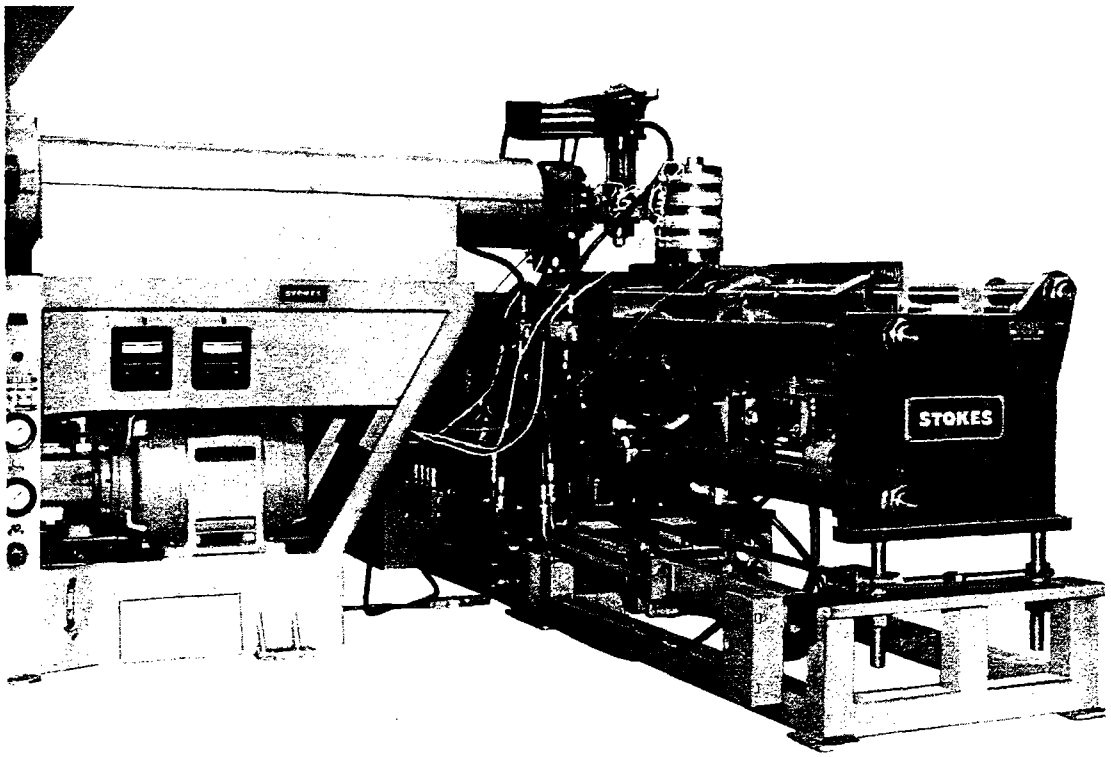
[1] Magazine Lubrication, Sept. '62, "Blown Glass."



Courtesy of Modern Plastics Encyclopedia, McGraw-Hill Inc.
Figure 16 — Schematic diagram of a rotary blow molding cycle, beginning with the extrusion of a parison.

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Courtesy of F. J. Stokes Company

Figure 17 — Stokes 3½ inch reciprocating-screw extruder (at left) feeding parisons to a blow molder.

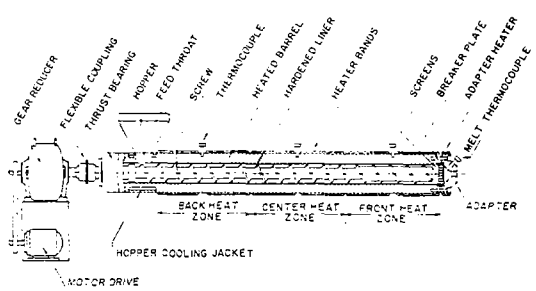
schematically illustrates a high speed rotary type arrangement for blow molding. In this case the parisons are produced at a fixed point where they are picked up by the molds and moved away for the inflation, cooling and ejection phases of the cycle. Blow molding units are frequently operated in conjunction with a separate extrusion or injection unit like that shown in Figure 17 which forms the parisons.

Good design, construction and finish of the molds used for blow molding are equally as important as those for compression and injection molding, however they need not be as strong since the air pressure used for blow molding seldom exceeds 100 psi. This permits low mold clamping pressures which are produced by pneumatic or hydraulic systems.

EXTRUSION

Extrusion is a continuous process for converting powdered or pelletized thermoplastic materials into sheets, film, rods, tubes and filaments. Plastic film for packaging and plastic pipe as a replacement for the heavier metal pipes are responsible for a large part of the current increase in the use of plastics. Extrusion accounts for the largest percentage of consumer plastics being produced today. This percentage will increase still further with the acceptance of items such as extruded plastic house sidings which are currently being introduced to the building trade.

Though very substantially constructed, extrusion equipment is much less complicated than that required for injection molding. Its greater simplicity is due to its operation not having to be so precisely coordinated with auxiliary equipment An extruder consists of a heavy horizontal heated cylinder with internal screw which extends the full length of the cylinder. The dry plastic charge is fed through a hopper into the cylinder where it is plasticized by heat while forced through the cylinder and through a die at its end by action of the screw. A schematic

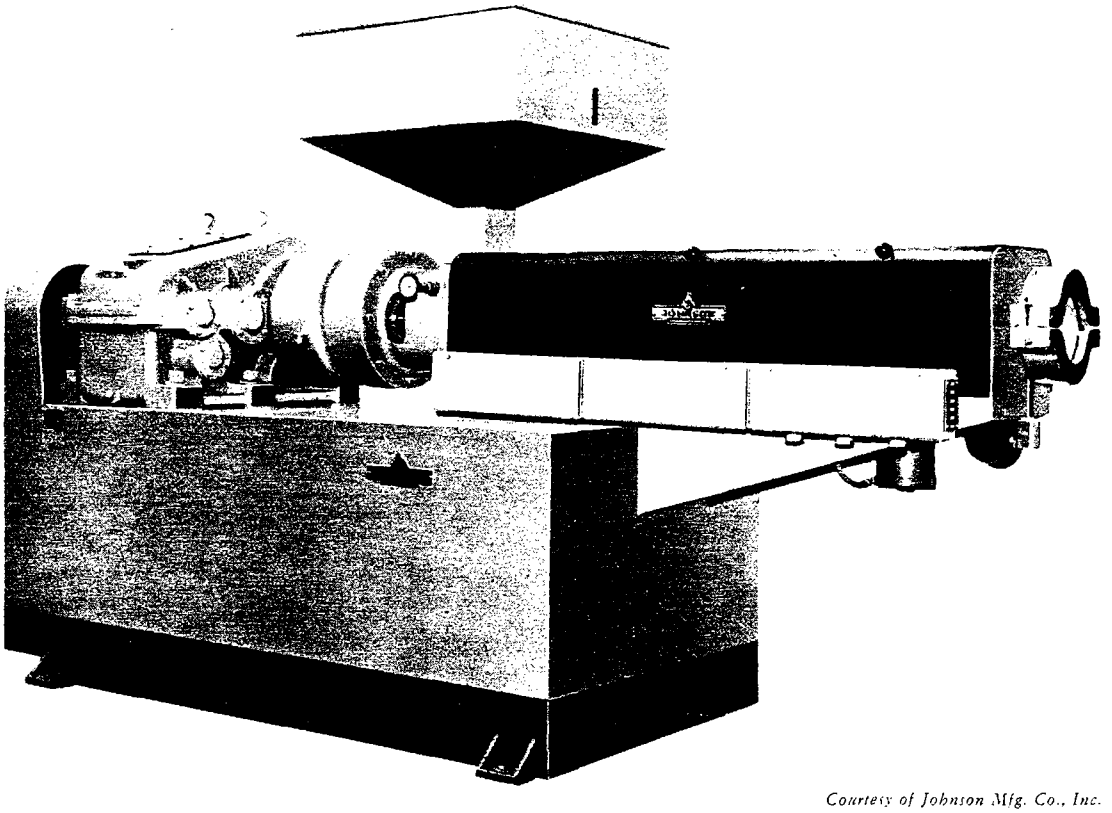


Courtesy of Modern Plastics Encyclopedia, McGraw-Hill Inc. and E. C. Bernhardt (DuPont)

Figure 18 — Schematic cross-section of typical standard single screw extruder.

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Courtesy of Johnson Mfg. Co., Inc.

Figure 19 — Johnson 3½ inch extruder.

diagram of an extruder is shown in Figure 18, while commercial units are illustrated in Figures 19 and 20. As it emerges from the die, the plastic is hot and soft, and can be easily deformed, consequently a conveyor belt (not shown) is provided to carry away the extrusion at the same or greater speed as ejected. Hardening of the extruded form is accelerated by either water immersion or air cooling.

The finished extruded product does not necessarily conform to the die dimensions but may be smaller to a variable degree. This is controlled by the speed at which the soft "extrudate" is drawn away from the die by the conveyor belt. Higher speeds result in greater "drawdown" or decreased cross-sectional area. The same effect is obtained in the extrusion of film from circular dies by blowing up the very thin tubular extrudate to a larger diameter by internal air pressure before it cools.

The greatly increased demand for extruded products, the extrusion of larger forms, the varying properties of the many new plastics available and the demand for closer tolerances on the finished articles have resulted in many refinements to the extrusion equipment. The critical factors involved are greater production, feeding rate, temperature control, screw design and take-off equipment. These are all interrelated when considering the efficiency of the extruder operation. In order to insure uniform feeding which is essential to temperature and pressure control within the cylinder, positive metering devices have been developed for feeding the pelletized charge to the hoppers. These permit variable charge rates which are necessary when processing plastics of different thermal properties. Screws are also modified in respect to pitch and channel depth to insure more efficient plastication. Interchangeable gear drives are provided in some designs to vary the screw rotational speed. The installation of melt temperature thermocouples permits continuous control of this factor which is even more critical in extrusion than injection molding.

The application of the extrusion process to metals, rubber and other thermoplastics has been touched upon in previous issues[2,3] of this publication.

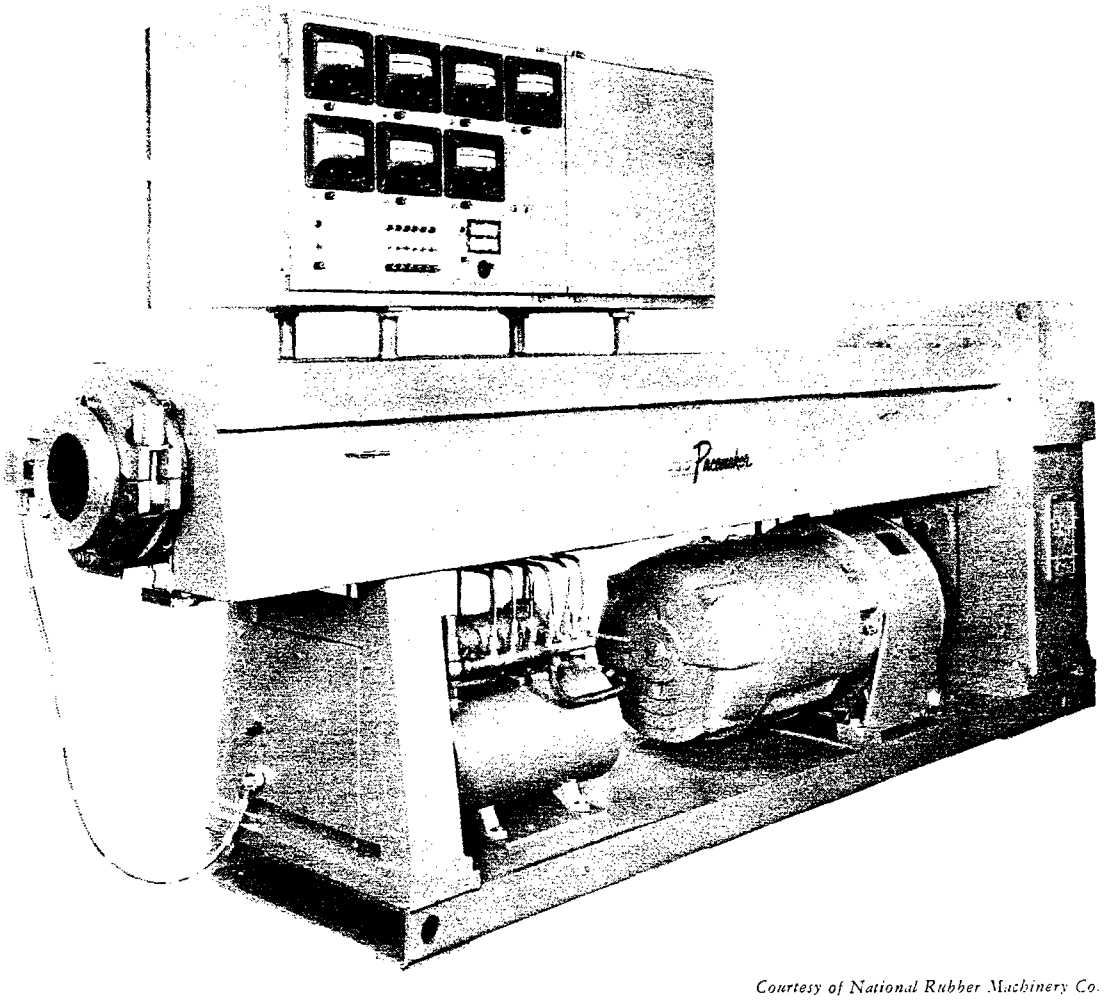
Extruder Lubrication

Extremely high pressures are required to force most plastic materials through the die at a satisfactory commercial rate. These are transmitted back to the screw thrust bearing and gear train which

[2] Magazine Lubrication, March '63, "Extrusion."
[3] Magazine Lubrication, Jan. '63, "Rubber."

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Courtesy of National Rubber Machinery Co.

Figure 20 — Pacemaker resistance-heated water-cooled 4½ inch extruder.

must be properly lubricated to minimize wear. A mild extreme pressure lubricant having a Saybolt Universal Viscosity at 210° F. between 110 and 170 seconds should be used for the main screw radial and thrust bearings, enclosed gear drives and feed roller gears and bearings.

Motor bearings of the sleeve type require a high grade oil having a viscosity of about 300 SUS at 100° F.

Extruders are normally driven through flexible couplings[4] which are grease lubricated. Greases of NLGI Grade Numbers 1 through 3 are used depending upon the speed and temperature of operation.

CALENDERING

Calendering is used to convert thermoplastic materials into continuous sheets and films and to apply a plastic coating to textiles. Although there are many varieties of calenders available,[3] those used for plastics processing are normally of the 4-roll inverted L type or the 4-roll Z type.

In the calendering operation a "bank" of hot plastic compound is fed into the "nip" between the first and second rolls. The plastic emerges from these two rolls as a sheet which is then fed between the second and third rolls and subsequently between the third and fourth rolls to size it. The finished sheet coming from the calender is passed over and around four or five cooling rolls and then proceeds to a "festooner" and windup equipment.

In a coating operation the material to be coated is introduced between the second and third rolls along with the plastic sheet from the first two rolls. The material coming from the calender will have a

[4] Magazine Lubrication, Oct. & Nov. '61, "Flexible Couplings."

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plastic coating on one side. If both sides are to be coated, the sheet will have to be passed through the calender again.

Calender rolls are usually made of chilled iron and the surface may be either smooth or matted. Some of the newer calenders are equipped with rolls as large as 36 x 96 inches and can produce up to 158 yards of sheeting per minute. The rolls are usually steam heated to maintain the desired plasticity of the material and are driven by an electric motor, with power transmitted through gear stands connected to the rolls by universal spindles.

Calender Lubrication

Some calender rolls are equipped with precision roller bearings while others have plain sleeve-type bronze bearings. Considerable pressure is exerted on the bearings and they are usually water-cooled to prevent them from becoming so hot as to cause softening of the bearing metal. Older types of calender bearings are lubricated by compression grease cups, grease pockets in the top bearing caps or by heavy oil. Modern calenders provide for automatic lubrication of the bearings by either a mechanical force feed lubricator or by flood lubrication of the journal boxes with a circulating pump, oil cooler, filter and reservoir.

The viscosity of the oil required for calender bearings depends upon the journal temperature. Where temperatures do not exceed 140° F., an oil with a SUS viscosity between 75 and 125 seconds at 210° F. is suggested. Above this temperature a heavier oil with viscosity as high as 330 seconds at 210° F. is recommended. For grease lubricated bearings, the Number 2 or 3 NLGI grade of a heavy duty grease that has been compounded with a fairly high viscosity mineral oil is acceptable.

LUBRICATION PRACTICE

Plastic processing machines are heavy, precision units operating under high loads and at relatively high temperatures. These factors dictate the use of lubricants of good quality to minimize costly unscheduled shut-downs. In order to obtain maximum benefits from premium lubricants it is necessary to store, handle and use them with care. This is especially true of today's lubricants as most of these contain additives which impart specific properties to the lubricants for specific purposes. Careless handling may result in contamination, loss due to leakage, or loss of identification with subsequent misapplication. This could result in damaged machine parts, work stoppage and high maintenance costs, each of which defeat the purpose of improved lubrication. Experience has proven that it pays to take good care of operating equipment. Frequently this is learned the hard way. A program of preventive maintenance, well planned and properly executed will pay handsome dividends. This should include the following salient points:

1. Simplify the over-all plant lubrication by using a minimum number of oils and greases. While this normally upgrades the quality of product for some particular application, substantial over-all savings are usually obtained with a Simplified Lubrication Plan.[5]
2. Provide locked inside storage for lubricants[6] which is accessible only to those responsible for lubrication.
3. Set up a definite schedule for mechanical inspection and lubrication and adhere to it strictly.
4. Assign responsible men to this job who are familiar with lubricants and who are thoroughly acquainted with the operation of the equipment.
5. Establish a card record for each piece of equipment. The cards should indicate the location and number of lubrication points, the lubricant to be used at each point, the frequency of lubrication, and a record of any mechanical repairs made.
6. Clean equipment before lubricating it to insure that no lubrication points are missed and to prevent contamination of the lubricant with abrasive grit at moment of lubrication.
7. Maintain a stock of those machine parts that experience indicates must be replaced fairly frequently, and of parts like oil filter cartridges which are replaced by schedule.

SUMMARY

The remarkable and highly adaptable properties of modern synthetic "man-made" plastics frequently enable them not only to replace less satisfactory conventional materials, but to be used also in entirely new applications that are beyond the capabilities of ordinary materials. Because plastics processing machinery must usually employ a combination of very high pressures and fairly high temperatures, quality lubricants of higher than usual viscosity and containing antioxidant and extreme pressure additives are recommended. The continued precision operation of high pressure hydraulic systems is assured by the use of rust and oxidation inhibited hydraulic oils. As in most other plants, the establishment and operation of a good Simplified Lubrication Plan will largely prevent breakdowns and decrease operating costs.

[5] Magazine Lubrication, June '61, "Simplified Lubrication."
[6] Magazine Lubrication, Sept. '55, "Handling of Lubricants."

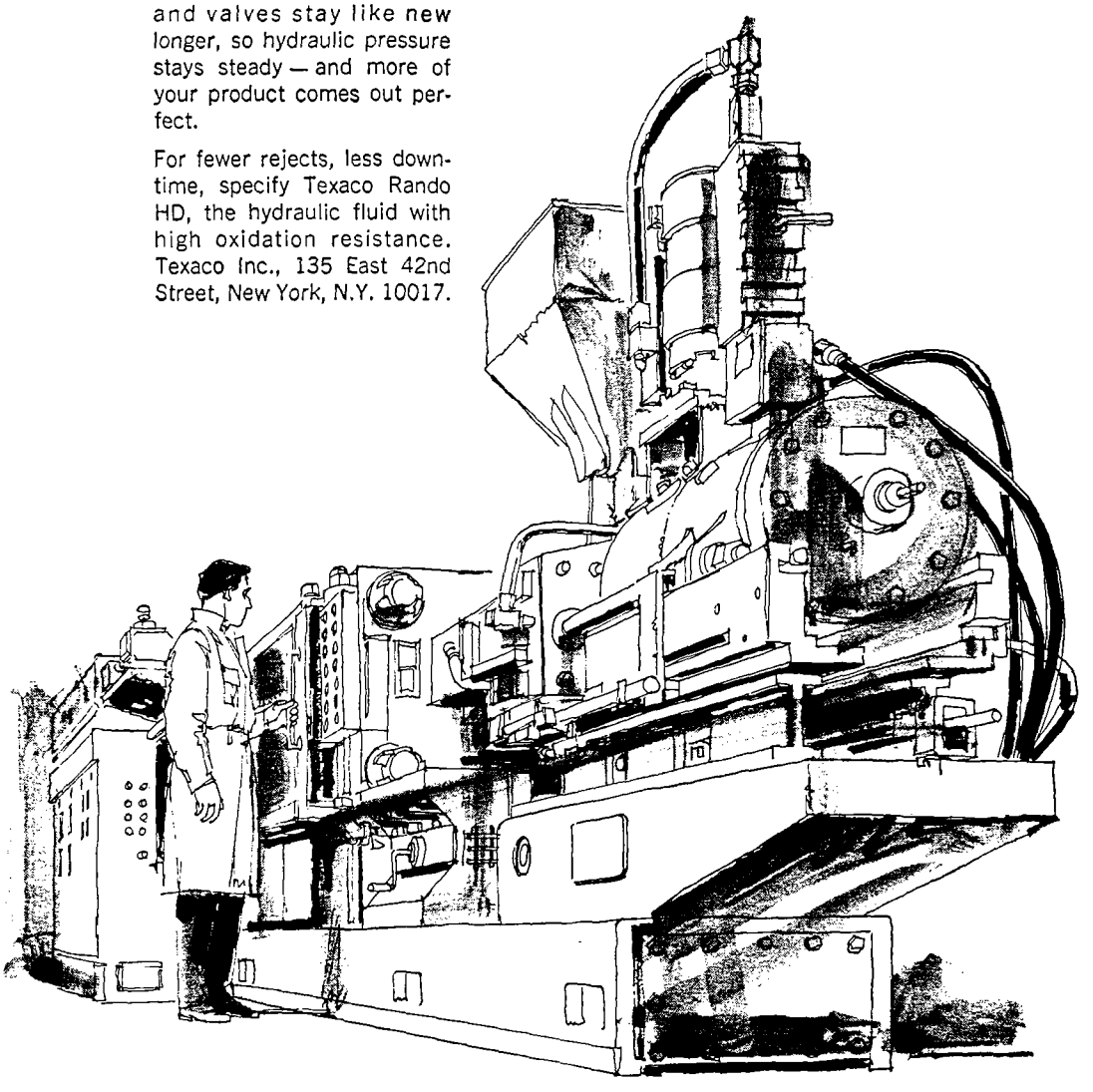
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