RUBBER INJECTION MOULDING

IMPROVING ON SOPHISTICATION

Papers from a one day conference organised jointly by Rapra Technology Ltd and European Rubber Journal

The Liffey Suite, Tara Hotel, London W8

28th October 1988

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FOREWORD

Rubber injection moulding was one of the first processes adopted by the rubber industry capable of meeting the growing demands for truly automated production of relatively simple parts. But this adoption barely dates back more than a decade while such equipment has formed the basis of the plastics industry virtually since its inception.

While the traditional conservatism of the rubber industry was undoubtedly part of this slowness in adoption of the new technique, the largest problem was simply that rubbers, being curing systems, were not so readily processed in this way. But, as the European Rubber Journal has described over the years, the machinery, materials and process developers persevered and eventually developed equipment, elastomer types and curing systems capable of making rubber injection moulding a viable, practical technique.

Even then, however, things were not straightforward. In the early days rubber injection moulding was described as the fastest way of making rejects automatically!

But the scene has now changed dramatically. There are often rows and rows of rubber injection moulding machines in many of the world's most advanced rubber companies, and even the most sophisticated polymers can now be processed using the technique and yielding uniformly reliable products at rates undreamed of in the industry's history.

Progress continues, however, and today you will be able to hear some of the thoughts behind the latest developments from the companies making them.

More sophisticated control systems offer yet higher degrees of reliability and convenience in use of the technique. Computer prediction of flow characteristics of elastomer systems and the potential application of CAD/CAM methods are also progressing by leaps and bounds. Elastomers of all types can now be processed using rubber injection moulding. Truly integrated product manufacture is a reality in some of the most advanced rubber processing companies in the world.

That is why we at European Rubber Journal and Rapra Technology Ltd. are pleased to be able to welcome you here today. We firmly believe that sharply focussed meetings of this sort provide the vital interchange of ideas necessary for progress. Again, we have deliberately tried to give the sessions a practical flavour so that attendees will leave the meeting with a better appreciation of what rubber injection moulding can do for them and their companies.

Best wishes for your future endeavours,

David Reed
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Rubber Injection Technology

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SUMMARY

It is barely over 20 years since rubber injection first appeared in the industry. Since then it has progressively ousted the traditional compression technique in the production of moulded elastomeric items because of the productivity and quality improvements induced.

During these 20 years also, machines and proceedings for the injection of rubber progressively diverged from those used in thermoplastics injection. Today, the injection of rubber has become a self-sufficient technique with specific materials.

1. INJECTION MOULDING PRESSES

1.1 The injection unit

The first attempts to inject rubber used the screw-plunger system as injection unit, such as is widely used in the injection of thermoplastics. The results thus obtained could only be disappointing for that reason that there is a practical impossibility to have an absolutely tight check-valve between the screw and the injection cylinder. It resulted in back-feeding between cylinder and screw, an unprecise dosage, the appearance of precured particles in the injection cylinder, all drawbacks that were still increasing with a rapid check-valve wear. Today, the screw-plunger method is only just used for low capacity units to inject very 'tolerant' compounds.

We should mention, still, the plunger-screw unit (SACOMAT system called 'first-in, first-out'). This theoretical advantage is counterbalanced by the practical difficulty to ensure good thermal control at the extremity of the screw and the injection cylinder. Developing this concept for practical utilisation was limited by this drawback.

The injection unit type design today is characterised by separate plasticising and injection functions. We shall take the injection unit used on REP presses as an example.

The raw rubber strip is plasticised by means of an helicoid sleeve driven by an hydraulic motor. The material is heated up and plasticised through mechanical shear. It is then transferred to the injection cylinder through a check-valve, pushing the piston upward at the same time. When the quantity of material wanted is available, plasticising stops.

During the injection phase the material is transferred from the injection cylinder to the mould through a feed nozzle. The injection pressure ensures holding in closed position with a perfectly tight check-valve. No material is back-fed into the injection unit. The system ensures thus high precision dosage and perfect repeatability.

Thermic regulation of the injection unit (screw, injection cylinder and connecting block) is achieved by means of circulating oil from a regulator. It must be placed as close as possible to the injection unit to reduce the volume of circulating oil, which allows rapid and precise regulation, without inertia. That regulator also ensures safety cooling in order to avoid unwanted cure in case of a lasting material stagnation in the injection unit.

On presses, the injection unit may be positioned either at the upper part or at the lower part of the machine. The last positioning has the advantage to reduce the machine total height. However, it is not so easy to approach the injection unit for maintenance purposes. Screw feeding occurs in an area where scrap and other particles often accumulate and may be carried along with the rubber strip.

A top positioning of the injection unit offers numerous advantages in tool design and tool kinematics.

Injection in the parting line is a technique mainly used with multistation machines or several machines in line. Except in particular cases, this solution is not to be retained to fill the mould cavities.

1.2 Closing system

The mechanical step and knuckle closing system is still utilised by some manufacturers of horizontal, small-sized presses. Its main advantage lies in rapid idle moves, its drawback in the instability of the clamp force depending upon the more or less important expansion of the press columns. This is particularly to be feared in rubber injection, considering the high mould temperatures attained.

The quasi-totality of modern injection presses are fitted with hydraulic closing. It may be a two-step closing system: approach cylinders for opening and closing strokes, direct cylinder for clamping. This solution is frequently retained for clamp forces up to 150 tonnes.

For higher clamp forces, a three-step closing system is frequently used: approach cylinders for opening and closing strokes, insert of a blocking wedge, wide low-stroke cylinder for clamping.

1.3 Vertical presses — horizontal presses

To date, the big majority of single-station presses for rubber are of the vertical make. This positioning is practically indispensable to produce items with inserts. It generally offers easier access to the mould area for hand stripping operations, extraction of runners and cavity cleaning. Floor space is reduced.

The verticality also makes easier the automatic production of items which remain on a cavity-plate or on cores when the mould opens.

Horizontal presses, utilised where productions can be 100% automated, make the evacuation of moulded items easier. They are frequently equipped with rotating brushes that clean the two half-moulds between each cycle. Their use with complicated moulds with middle plates, etc. remains delicate. Their application field is the clamp force range lower than 250 tonnes.

1.4 Single-station presses — multi-station presses

To produce very large series, the utilisation of a rotary system has long been retained. The modern industry is more orientated towards flexibility, short runs, where rotary presses do not really fit. Today still, it predominates in the shoe industry.

Multi-station presses in line also appeared, fed by one injection unit only travelling from one press to the other. This system shows the same drawbacks as the rotary. It mostly applies to low capacity presses, used for instance in the bonding of angles of windshield seals.

Thus, the single-station machine meets today most of the industry requirements. The manufacturers standard models range between 50 to 600 tonnes clamp force and 0.1 to 8 litre shot capacity. Presses with higher features are special machines made on order for particular applications.

1.5 Operators' safety

Decisive progress has been made over the last years to reinforce the operators' safety. Several independent devices were made obligatory to prevent any access to the mould area during press opening or closing operations. Numerous panels draw the operators' attention to potential dangers and specially to risks incurred through the dismantling or the neutralisation of safety devices originally fitted. Entering into the European legal system clauses relative to the 'Strict Product Liability' can only further reinforce the measures to be taken by manufacturers for the operators' safety.

2. CONTROL AND REGULATION

2.1 Microprocessor and closed loop regulation

Part quality of items produced on injection presses depend, to a very large extent, upon the consistency and precision of settings, specially of temperatures. Decisive progress was made these last years through the implementation of microprocessors. They allow a centralised and computerised control of all parameters that play a part in the injection process: strokes and speeds of the closing system, strokes and speeds of the injection unit, injection pressure, temperatures of the injection unit and moulds, temporisations etc. All parameters of the analogical type can be set in closed loop, which achieves precision and perfect repeatability of setting values.

All setting parameters corresponding to one mould and one particular compound (often more than 50) are entered into the machine with the help of an alphanumerical keyboard. They are recorded in the system memories and can be automatically printed by calling up the corresponding mould number when re-starting a production run. The increase in the size of memories available include parameters corresponding to up to approximately 20 moulds in the machine. Also, it is possible to store these parameters on external memories or badges when the quantity of moulds exceeds the machine memory capacity.

2.2 Mould temperature

Setting mould temperatures to a precision of the degree in closed loop regulation involves good knowledge of four coefficients usually named 'P.I.D.T. coefficients'. An a-priori determination of these coefficients by calculation proves delicate as they depend upon numerous factors such as mould thermal inertia, place of thermocouples, installed heating power, etc. Some manufacturers have therefore developed specific softwares to enable the experimental determination of these coefficients when pre-heating the mould on the occasion of its being put in production for the first time. P.I.D.T. coefficients calculated by the machine microprocessor are automatically recorded with the other parameters of the corresponding mould. This makes it possible to obtain a mould temperature value strictly in accordance with the selected value without high amplitude oscillations as may happen when the P.I.D.T. regulation coefficients are determined the empirical way.

2.3 Injection pressure and speed

During the injection phase it is possible, thanks to the microprocessor, to define a speed or pressure that will be reproduced cycle after cycle. It is recommended during the initial cavity fill time, to work with 4 or 5 successive speed levels, and 2 successive pressure levels during the final pressure holding phase. Mastering the injection phase enables a trained adjuster to ensure the filling of the mould in the shortest possible time without too much self-heating that would cause scorch when the material flows in the cavities and without abonormal pressure peak that would produce flash.

2.4 Diaglogue operator/machine

The use of a cathodic screen connected to the machine setting microprocessor allows to improve the dialogue man/machine. It is thus possible to have printed on the cathodic screen, page after page, the setting value and the instant value for the totality of parameters: we shall then have a page for temperatures, one for speeds etc. It is also possible to bring together on the same page on display only the essential parameters that decide the good course of the process and print out signals in case one of these parameters should deviate from the set values out of the programmed tolerances.

In the future, diagnosis and breakdown identification softwares will be developed to print out the default cycle phase or component.

Today's trend is orientated toward the utilisation of extra-flat graphic screens, which ensure high legibility and strong stability to both text and images shown on screen.

3. COMPLEMENTARY AUTOMATION

The injection technique and the precision of its regulation enable to reduce, in great proportions, the items cure time when compared to the former compression technique. The lead for an increased productivity makes it necessary to also reduce the other times involved in the complete cycle of a production run. Improvements were made in the course of past years regarding in particular the environment of the press itself and by-operations in stripping matters.

3.1 Rapid production change

Series to be produced which are shorter and shorter, in particular for automotive parts, require that changing from one production to another be made in the shortest possible time. As we have seen, the use of a microprocessor enables to call up all at once the setting parameters of a mould with a substantial time saving. Mould pre-heating devices using heating by induction allow to reduce considerably the mould heating-up phase before starting production. Lastly, mould quick latch systems bring back to a few minutes only placing, centering and blocking a mould under press.

3.2 Ejectors under press — ejectors outside press

Classical, mechanical ejectors are more and more frequently completed by hydraulic, synchronised, top or bottom ejectors under press. These ejectors whose strokes and speeds are adjusted by the machine microprocessor are of particular interest when using complex moulds with centre plates.

Their programming associated with degassings, and especially with the injection-transfer technique, allows very elaborate kinematics.

They are often completed by outside ejectors that may be positioned at the front or the back of the machine, either at the upper part or at the lower part. These devices are fitted with auxiliary cylinders that ensure the movement of the centre plates outside the press, to position them under an ejection battery to simultaneously extract all the items. The same devices can be used to ensure the translation of centre plates where metal inserts are placed outside the press, or even of moulds lower parts.

The whole of these devices allow in numerous cases to have a completely automated cycle, or nearly so, with a vertical press.

3.3 Robots and manipulators

One step further toward integral automation can be made thanks to manipulators or robots.

Pneumatic or electric axle manipulators can be used in particular to place inserts, extract runners or the mat in the case of injection transfer. Considering how little place they require and their limited price, there is, in general, one manipulator per press that can be placed in the press enclosure itself.

Robots offer much larger possibilities (number of axles, strength) and can be used for automatic stripping operations for certain items. One robot generally serves two presses.

One should not undervalue the time necessary to develop applications implementing a manipulator or a robot. Their use can be justified only in a minority of application cases today.

4. MOULDS AND MOULDING TECHNIQUES

4.1 Classic moulds

Significant improvements have been made in that field too, and techniques specific to rubber have been developed as some of the devices employed for the injection of plastics cannot be used in rubber injection: this is the case, for instance, for pushers which act as ejectors and are located inside the cavity.

Flash can be reduced through a judicious design and shaping of tear-trims. They will be efficient only with a highly precise dosage and precise adjustment of the pressure holding phase at the end of the injection process. However, the production of flashless rubber items still remains a difficult matter.

Flashless rubber may be produced by means of some particular techniques which involve expensive toolings and also an intensive maintenance work.

Correct cavity filling, especially in moulds with long flow paths, can be greatly improved by pulling the air from the cavities. Yet, this technique is not an easy one to achieve, especially to maintain good tightness qualities long enough which conditions the system efficiency.

4.2 Cold runner blocks

Placed between the injection nozzle and the mould, this device mainly aims at reducing considerably the material loss represented by runners in classic moulds, as for certain items the runners may weigh as much as the items.

To be efficient a cold runner block must be perfectly balanced to ensure equal feeding to the various secondary nozzles. Its temperature must be balanced so that the various cavities are filled with a compound at the same temperature. Lastly, floating secondary nozzles allow for a good nozzle-in-contact and correct tightness at the mould junction, regardless of various expansion between the two parts.

4.3 Injection transfer/cold chamber

This moulding technique allows for an injection in a circular or rectangular chamber when the press is closed but not clamped. After clamping the material contained in the transfer chamber is injected directly into each cavity. When demoulding a remaining cured compound pad, which is tenth of millimetres thick, must still be evacuated, thus causing a loss of material.

For some applications and especially in the case of expensive compounds, it is possible to transform the transfer chamber into a regulated chamber ('cold' chamber). This is done by inserting an insulating coating between the chamber bottom and the mould on the one hand, and an oil circulation in the chamber bottom on the other hand, maintining the temperature of the compound stored at a temperature nearing the storage temperature in the injection cylinder. Hence, the chamber contents cannot be cured and there is no more loss of material. However, to be efficient, this technique requires very good control over the compound flow inside the chamber in order to prevent ill-timed prevulcanisation in 'dead areas'. This technique remains thus rather delicate.

The injection transfer process was developed especially at Uniroyal, a company which took out several patents for the so-called flashless moulding, or even wasteless moulding. These patents are now public matters.

4.4 Injection compression process

This moulding technique has quite the same kinematics as the injection transfer process we just talked about. However, in the case of injection compression the rubber is injected directly into the parting line. This technique is used for precision parts, generally 'revolution' parts. One type rubber part produced through this process is the O-ring seal.

It should be noted that all presses must be fitted in standard version, both with injection-transfer and injection compression programmes and their corresponding variable parameters.

4.5 Calculating compound flow

Recent developments in softwares allow to simulate and visualise on the computer screen the compound flow in the runners and the cavities feeding inlets (Fillcalc, Rubber Soft, etc.), even in the cavities themselves with the Catgum software. To operate these softwares one ought to know the physical and rheological properties of the compound at the mould working temperatures with special regard to viscosity. These data are rarely precisely known, and their experimental evaluation is expensive. Nevertheless, these softwares can be of invaluable help for mould studies, especially when the cavities feed runners are not all the same length. One avoids thus much trial and error and correcting adjustments at mould production start.

5. COMPOUNDS

5.1 Compression compounds — injection compounds

Rubber moulded parts manufacturers are nowadays aware that a compound which is suitable for compression moulding cannot, as a rule, be injected. Hence the requirement for the basic rubber compound to be adapted to this new processing technique.

Two features call for particular attention: the viscosity of an injection compound must be as low as possible in order to allow the proper flow of the material into the runners and cavities, especially for thin items with long flow paths. To avoid any commencement of cure before the injection chamber is filled, scorch time at storage temperature in the injection cylinder must be long enough.

5.2 Compound ageing

It is well-known that any prolongated storage of a compound, mostly during a hot season, results in its ageing. This has particularly bad consequences on compounds as it will increase their viscosity and reduce scorch time, as these factors will affect their injectability as we have seen above. Hence, we recommend to check the compound conformity by means of a rheometric curve plot before it is used in the moulding shop in order to obtain constant quality for the parts produced.

5.3 Automatic self-adjustment of the cure time

Whatever the reliability of control and regulation systems of modern injection presses, a few important process parameters may be submitted to a momentary disturbance engendered by external factors. A slight drift in the compound viscosity, a change in the compound container, draughts or temperature variations in the mould shop may result either in a variation in the compound temperature at mould inlet, or a temporary variation of the mould temperature itself.

Then the self-adjustment of said disturbances will allow for the correction of the cure time from one cycle to the next one: the latter function is for instance achieved by the Curetrac software which was developed by REP.

6. INTEGRATED PRODUCTION LINE

6.1 On a local network

The previous chapters have been considering each rubber injection press as a unit, whereas the rubber industry nowadays tends to regard all the machines working as a production line and to ensure its centralised management on local information networks. It will be convenient for us to introduce the REP-NET network as it was developed by REP.

Each press, i.e. every microprocessor rack on the press is connected to all the other microprocessor racks as well as to a central microcomputer unit. That is to say, that a maximum of 20 presses may for instance be linked to the same microcomputer and that they will dialogue.

The transmission of data thus makes both the production management as such and the quality control easier.

6.2 Computer integrated manufacturing CIM

The hard disc of the microcomputer may store up to 1,000 various mould adjustment parameters. Thus one is able to load these parameters from a distance whenever each mould starts a production. The operator can also introduce these setting parameters on the microcomputer keyboard if he wishes to record them on the hard disc.

Every machine sends out for each cycle data pieces on the central unit such as the operator's code, the encoding of the compound, the order number, the amount of parts to be produced, etc.

Other information pieces are related to the machine status, e.g. the running status, the adjustment status, the waiting for compound, the maintenance, etc. Hence it is obvious that the data processing simplifies the moulding shop production management. Moreover the data pieces are likely to be transmitted to another computing network in order to be processed by the central managing department of the plant or even by the whole company.

6.3 Towards a zero default ratio: S.P.C. calculations

The present analysis of the quality of the rubber parts produced is based on the following theory which has been largely applied in the car industry. One favours the production of cheap quality parts instead of controlling the quality of the parts produced. In other words, this theory amounts to a control of the production process instead of a control of the parts, which is known as the Statistical Process Control (S.P.C.).

This process consists in the transmission of the data required for each cycle and for each press by a local network on to the central computer unit where it is stored on the hard disc.

Said pieces of information are mostly the setting orders and the measurements for the following parameters: cure time, temperatures, pressures, speeds, etc., i.e. all the parameters which influence the quality of a production.

These values can also be displayed on the screen for each present or past cycle. Moreover, messages will be automatically displayed if one of the given parameters is off the setting values on one of the presses. Thus the operation can be permanently checked on said production line.

And, lastly, it is to be quoted that a specific programme will allow for statistical calculations for each parameter and display corresponding deviation curve or Gaussian curve for a preselected number of cycles, which can then be issued on a printer. Thus one can check that the S.P.C. conditions were continuously satisfying during the production

6.4 Flexible production line

The demand for small part series which can be delivered within a short delay without requiring their superabundant storage tends to favour the more frequent use of moulds with a limited number of cavitites which can be assembled on small machines. Hence the development of the 'flexible production line' theory.

Said solution consists in the juxtaposition of up to 20 similar presses which are interconnected on a local network which ascertains their centralised supervision. As these presses are attached because of their little space requirement, one press line can be operated by a limited number of operators. A quick production change can be achieved thanks to special equipments which enable a quick removal of the mould. A microwave mould pre-heating device allows for a further reduction of the time devoted to the production change.

7. CONCLUSION

We have drawn a general view on the improvements which have taken place in the course of the last 20 years for the production of injected moulded parts. The present available equipments, tools and today's techniques contribute to the achievement of the treble target of modern rubber industry, i.e. to the reduction of both costs and delays and to the improvement in the quality of the production.

Rubber Injection Machine Concepts

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Due to quality requirements, process controls, requirement for automation and cost reasons, the injection moulding of elastomers is becoming more and more important in the rubber industry. Various rubber injection machine suppliers offer machines with different designs and different concepts, from machines with very small clamp forces and small shot sizes (Figure 1) up to huge rubber injection machines for special purposes with clamp forces of up to 1,200 tons and shot capacity of 25,000 cm^3 and even more (Figure 2). Following are possibilities of machine concepts which all offer advantages depending on the specific manufacturing purpose.

Machine sizes

Several main factors have to be considered to determine the correct machine size.

The required platen size is determined by the dimensions of the articles to be moulded with single- or multi-cavity tools. As bigger the heating platens are as more cavities, of course, could be used in the mould if possible with regard to the clamp force and injection volume of the machine.

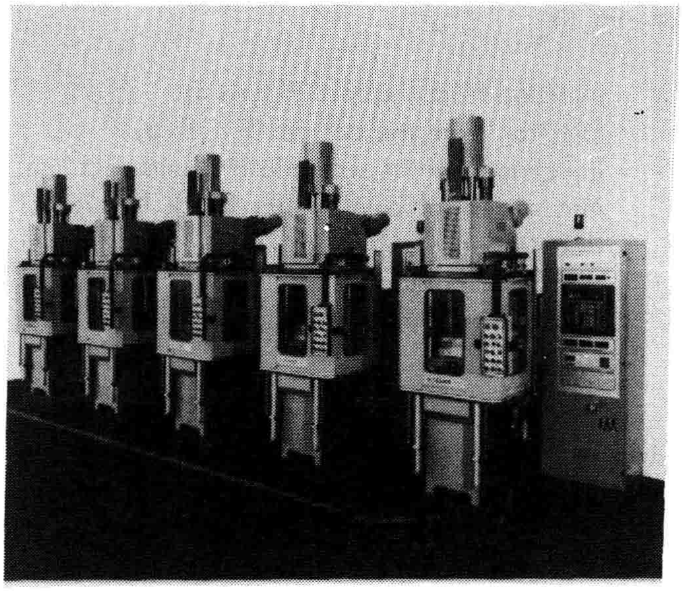


Figure 1 Small single-station rubber injection machines D966.054-ZO with 50 tons clamp force and 460 cm^3 injection volume

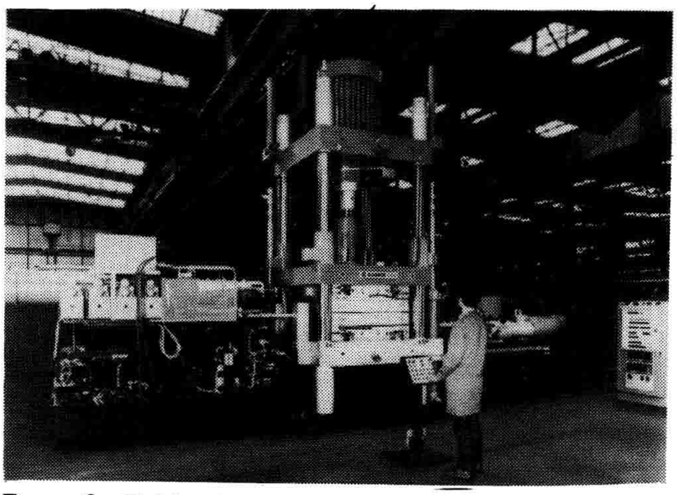


Figure 2 Rubber injection machine D962.900 with 930 tons clamp force, 1.500 x 1.500 mm tie bar spacing, with 2 injectors with 12.500 cm^3 injection volume each

For use of multi-platen moulds with or without cold runner systems and/or for use of double-deck moulds, the daylight and opening stroke of the machine should be sufficient for easy handling by the operator.

Unloading tables are available to slide-out the bottom mould half. This, however, would be of no use if double deck moulds are used, but actually would hinder the access to the top mould deck as the bottom mould half is in the way of the operator and would not allow a good access to the cavities in the upper mould deck.

With regard to the access to the mould it is of great advantage for the operator if the machine has a three-sided safety guard which allows the operator to reach the mould from three sides (Figure 3). This becomes more important the bigger the machine gets and if multi-plate moulds make the access to the cavities in the rear of the mould very difficult.

In this case a swivable key-board is a must to allow the operator to start the cycle from each possible position at the machine. Three-sided access to the mould might be necessary also for certain robotic systems for removal, cleaning and loading inserts.

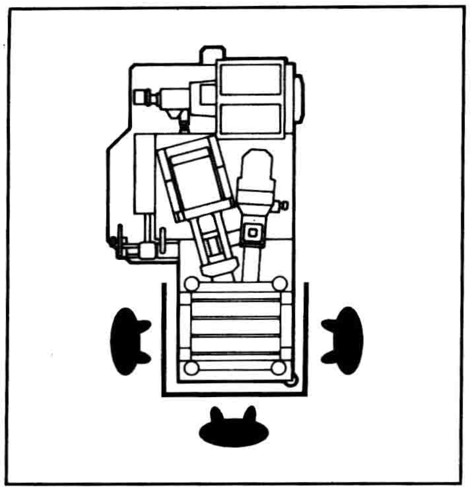


Figure 3 Possible operator's position for unloading, cleaning and, if applicable, load inserts on standard machine

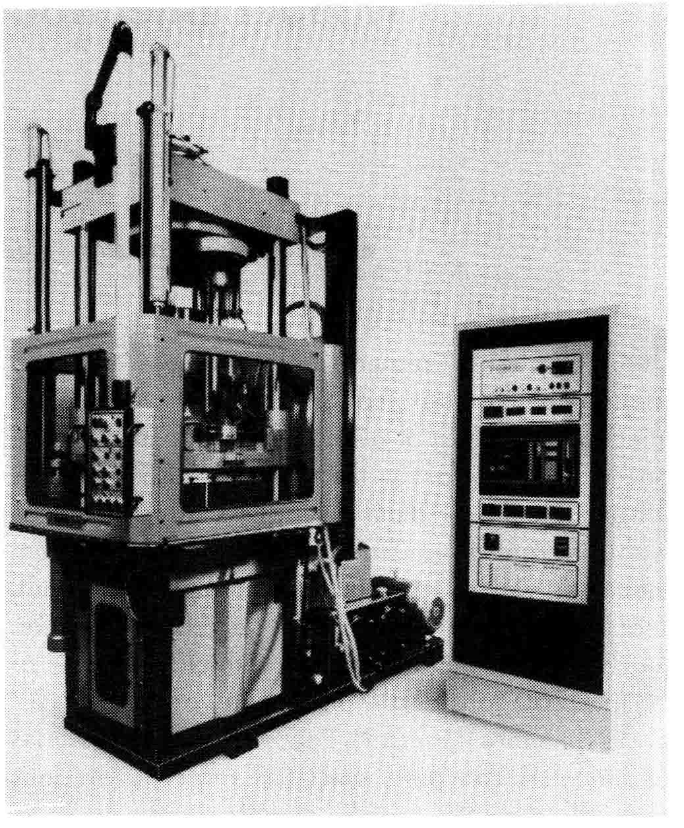


Figure 5 D966.220-ZO - Bottom injection

The clamp force of the machine should be chosen in accordance with the projected area of the articles in the mould. The maximum allowed mould inner pressure during injection depends on the article thickness, flow length of the runner and article, runner/gate system and the compound used. Too small clamp forces would result in the undesired opening of the mould carrier during injection and would create flash and possibly variations in the wall thickness of the articles in case of thin walled rubber parts with tight tolerances.

The injection unit of the rubber injection machine should be chosen with an injection volume which offers flexibility also for later productions. It should be considered that in case of a later use of cold runner blocks the injection pressure should be high enough to compensate pressure losses in a multi-nozzle cold runner system. For some, fluoroelastomer compounds processed through multi-nozzle cold runner blocks an injection pressure above 2,000 bar is necessary.

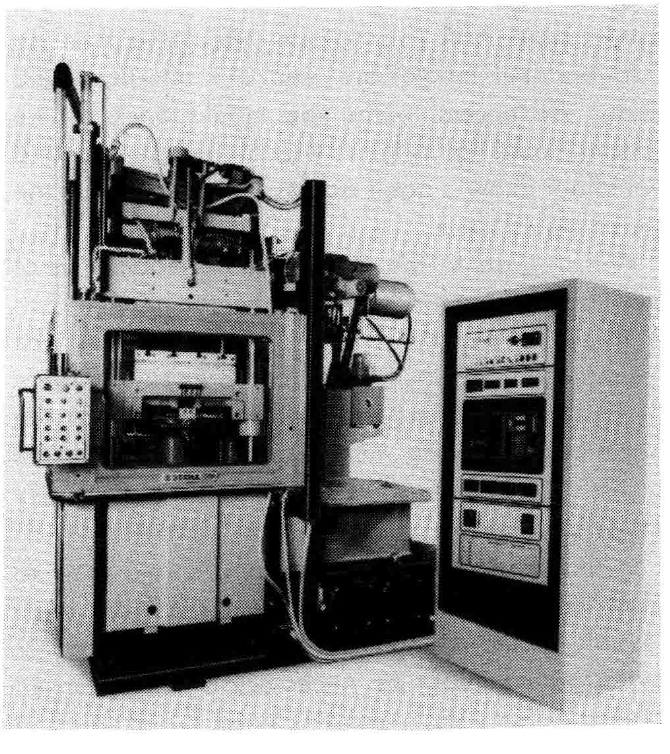


Figure 4 D966.220-ZO - Top injection

The position of the injection unit on vertical rubber injection machines can be selected by the user. Three possibilities:

- injection from the top (Figure 4)
- injection from the bottom (Figure 5)
- injection from the side into a mould split line, into a central cold runner block for use of double-deck moulds or into a cold runner distribution block optionally used for injection of bottom or top injection moulds (Figure 6).

Each injection method offers their advantages, whereas the top injection certainly is of advantage for moulding of products with inserts while bottom and side injection certainly have the advantage of good accessability to all components for easy rubber feed, maintenance and repairs. Also granulate hoppers, powder caoutchouc feeding devices and liquid-silicone mixing metering units can easily be installed if desired.

The machine size will also be determined by desired/required number of cavities to be used in the mould.

Smaller injection moulds with few or even single cavity certainly offers the advantage of:

- high accuracy
- lower investment and maintenance cost
- quicker tool change due to easy mould handling
- shorter production cycles due to quick unloading/loading times

To use the maximum possible number of cavities in moulds on the other hand, result in high outputs per cycle and therefore short production runs and minimum possible number of machines.

Three different injection unit designs are available on the market:

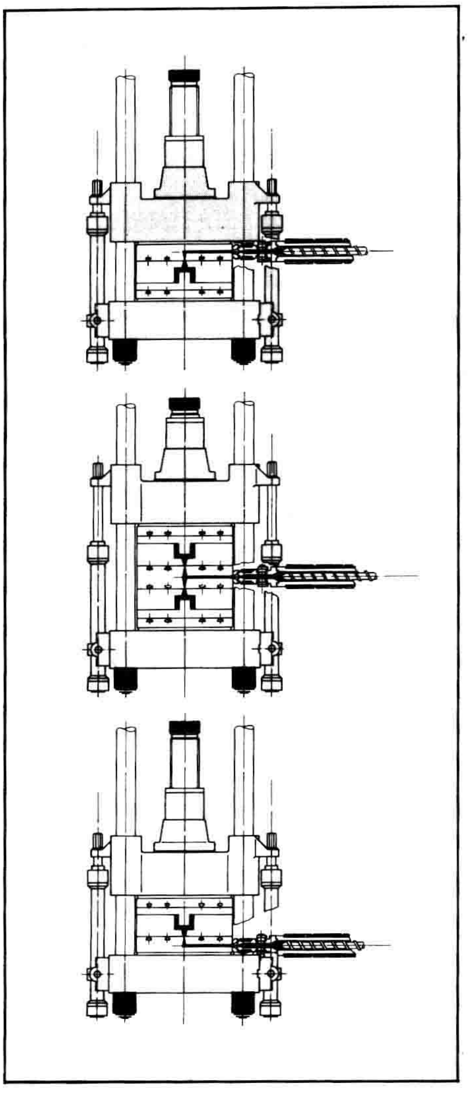


Figure 6 Using a heating plate with integrated cold runner nozzle (side inject, centre exit nozzle injection into the top or bottom centre of a mould is possible. Or using a cold runner block with nozzles up and down, for injection into 2 article decks

Plunger injection unit with screw plastification (Figure 7)

The material is fed into a separate plastification cylinder and the material is plasticised and transported into the injection cylinder by an extruder screw. When the required injection volume is plasticised the extruder screw stops the plastification and the material is injected by the injection plunger. A check valve between plasticising and injection cylinder prevents the stock flowing back into the plasticising cylinder.

This injection type is mainly used on single station rubber injection machines only as the required time for plastification of the material can easily be made while the already injected material is curing in the mould.

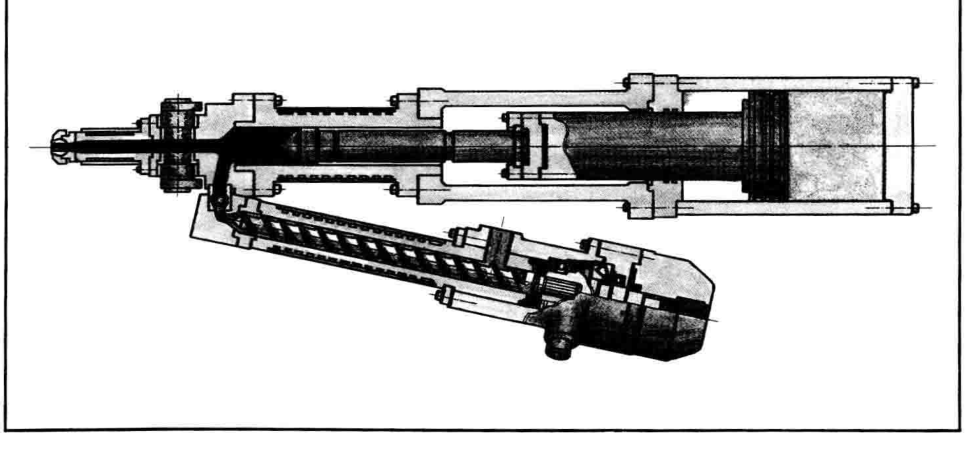


Figure 7 Plunger injection with separate screw plastification

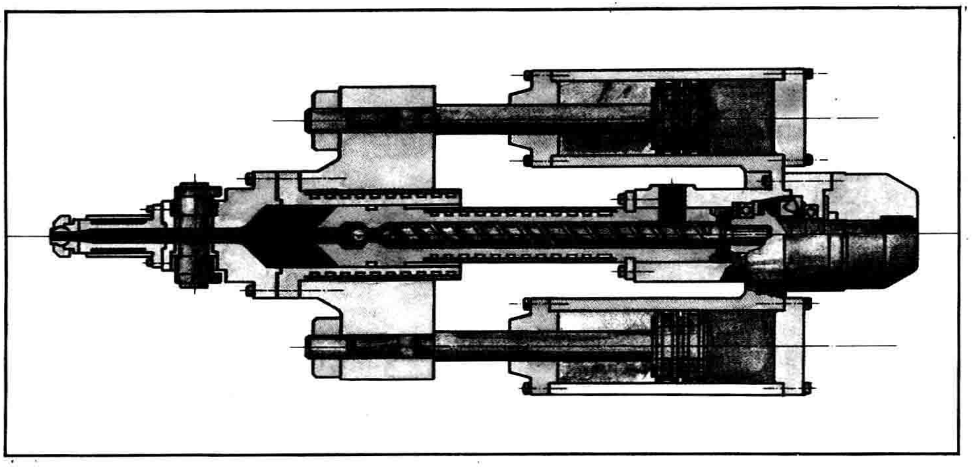


Figure 8 Cylinder-Piston injection unit (CYP)

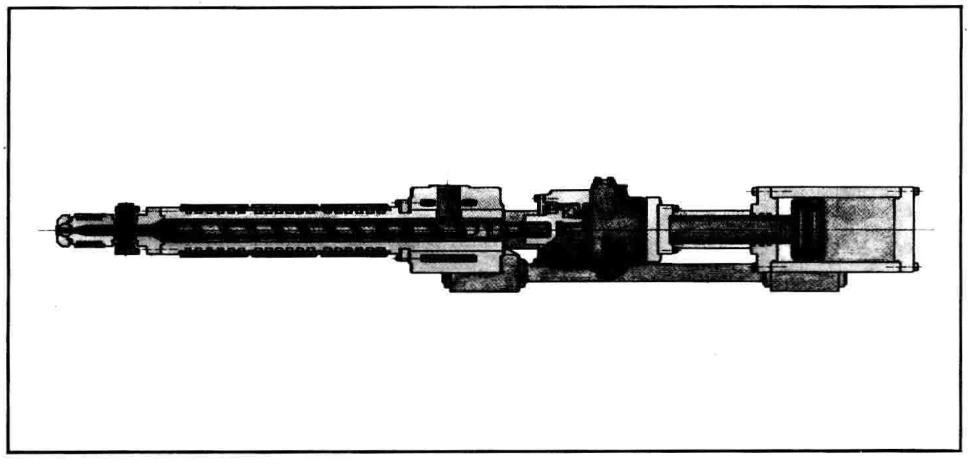


Figure 9 Reciprocating screw injection unit

An alternative is the cylinder-piston injector (CYP-injector) (Figure 8). Also this injector has a separate plasticising screw, however, the material is plasticised into an injection chamber (reservoir) in front of the plasticising screw. The screw cylinder is used as an injection piston. A check valve prevents return flow of the material. The big advantage of this system is that the material, which is plasticised, first will also be injected first (first-in, first-out) and therefore the stand time of the stock in the injection cylinder is the same for the whole shot plasticised, irrespective whether plasticised first or last.

The first in, first-out principal also applies for the reciprocating screw rubber injection units (Figure 9), as used on rotary table rubber injection machines. These units are known for their fast plasticising time which is necessary in case of using a multi-station machine with short shot-to-shot cycles. The injection volume has to be plasticised within a short time only to allow fast cycle times of a few seconds only.

There are three different basic machine concepts available:

1) Horizontal rubber injection machines (Figure 10) are perfectly suited for the production of articles which can automatically be ejected or brushed out. Single or double deck moulds can be used.

For certain products where, e.g. inserts have to be placed or where an easy ejection is not possible, horizontal rubber injection machines would not be chosen

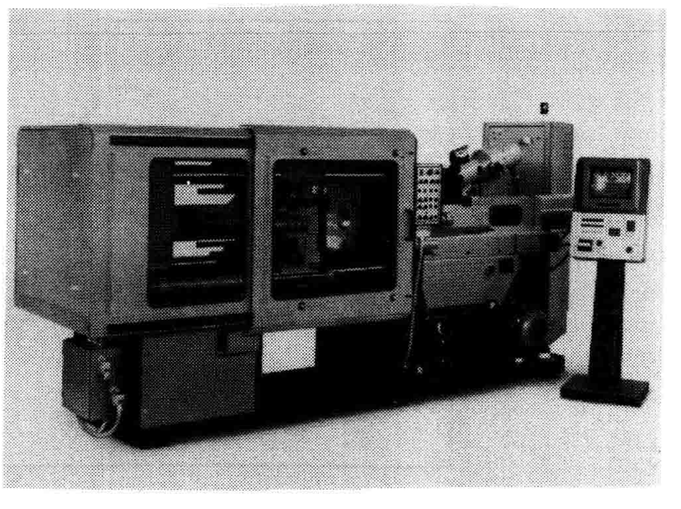


Figure 10 D967.220 - Horizontal rubber injection machine

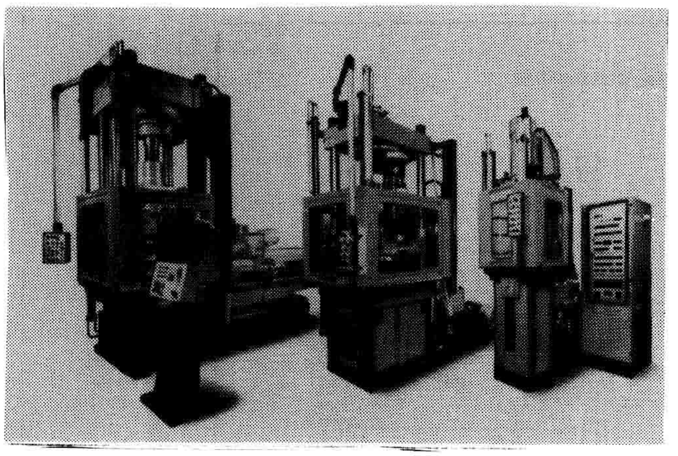


Figure 11 Various sizes of vertical rubber injection machines

2) Vertical single-station rubber injection machines (Figure 11) offers the biggest flexibility for the user. For moulds/products where manual handling by operators is necessary, the best access is given by vertical rubber injection machines, especially if large tie rod spacing, large daylight/opening stroke and access to the mould from three sides is given.

Vertical machines can be equiped with standard automatic handling devices which also makes an automatic production like on a horizontal rubber injection machine possible.

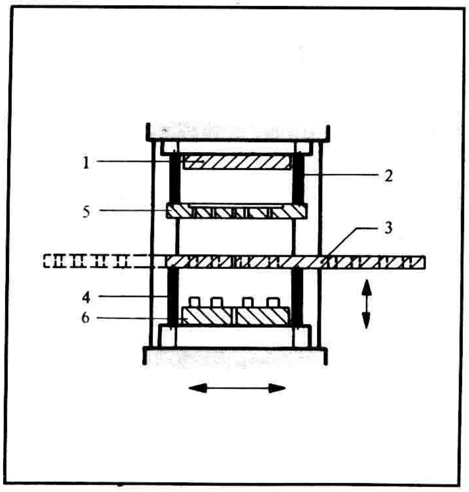


Figure 12 Middle plate sliding device with a double middle plate: injection runner plate (1), Intermediate mould plate (5). Double middle plate (3). Bottom mould plate (6). Hydraulic lifting devices (2 + 4)

Vertical rubber injection machines offer the possibility of installing accessories for an increased output:

A) Core/middle plate sliding device (Figure 12) for use of a double set of cores or middle plates.

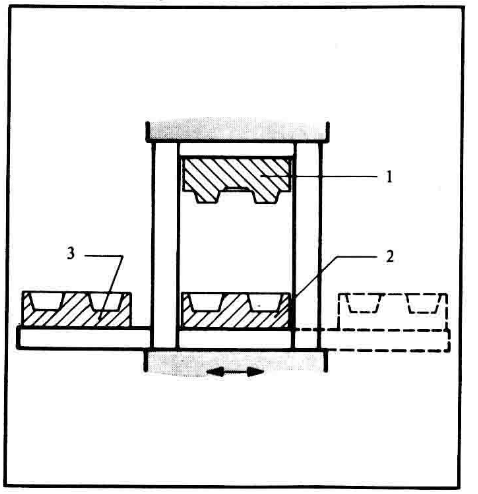


Figure 13 2-sided sliding table: Injection runner in the mould parting line. Upper mould plate (1). Two identical bottom mould plates (2 +). Hydraulic lifting device and/or hydraulic centre ejection on shuttle tables possible. (D966.080 G)

While one set of cores or one middle plate is in the main station for injection and cure, the second is outside for stripping. This could be made automatically, however, it has to be considered that automatic devices are required on either side. The cores or middle plates have to be equipped with additional heaters to prevent down cooling while outside. The machine has to be equipped with safety guards to protect the operator.

B) Two-sided sliding table for shuttling of two bottom mould halves (Figure 13). This concept often is used in case of producing rubber-to-metal bonded products where time intensive removal and loading of inserts is unavoidable (Figure 14). The access for

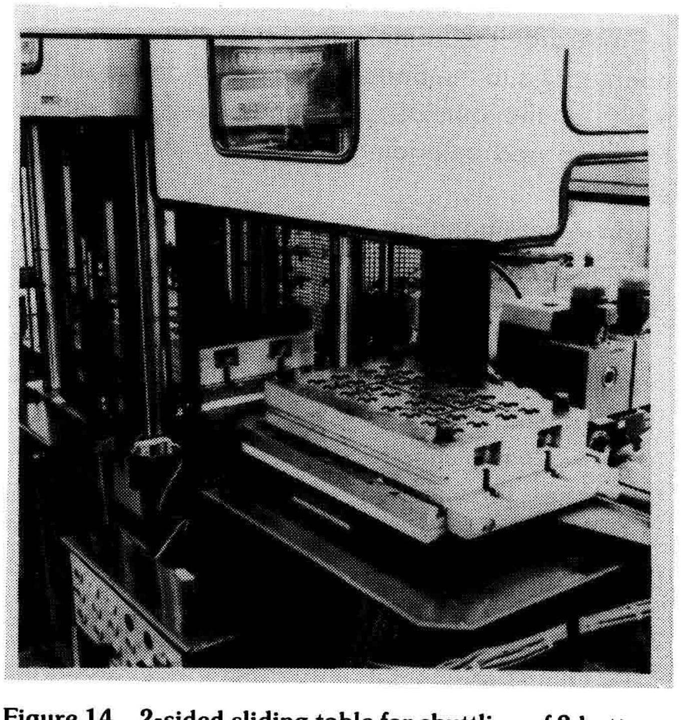
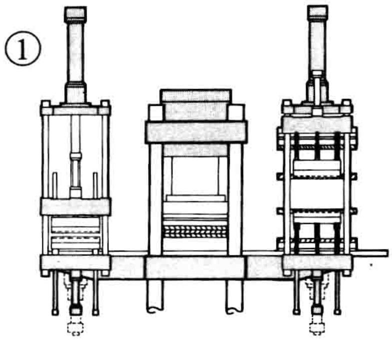
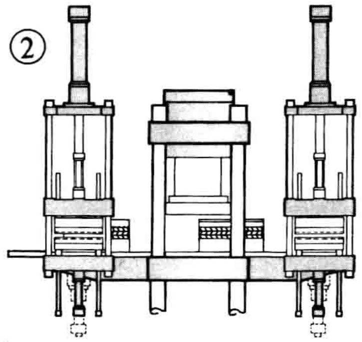


Figure 14 2-sided sliding table for shuttling of 2 bottom mould halves

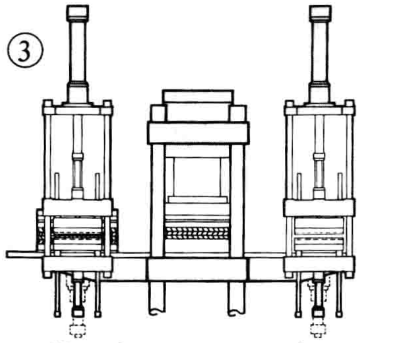
Sequence of work positions:



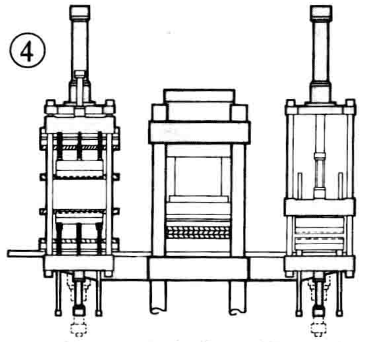
Mould 1 in the injection position for injection and first approx. 2/3 of total required cure time. Mould 2 open in the demoulding position after having gone through the remaining cure time, product removal from mould 2.



Shuttling the moulds: centre clamping unit open, mould being moved.



Mould 2 in the injection position for injection and first 2/3 of cure time. Mould 1 closed in the shuttle outstation while going through the remaining cure time.



Mould 1 open in the demoulding position, mould 2 in the injection position.

Figure 15 Double shuttle machine (shuttling 2 complete moulds)

the operator is extremely good from three sides. The open access to the bottom mould half on the sliding table at the outside also lends itself to various handling and unloading devices for an increased efficiency.

However, handling devices on either side or moving handling units for automating operation of the two sides of the sliding table are necessary.

Lifting and ejection devices can be installed. The handling time on the sliding table does not influence the total shot cycle of the machine as the handling takes place while the second bottom mould half is in the station for injection and cure.

C) *Shuttle outstations* for shuttling of two complete moulds and possibility to split the cure time to increase the output considerably. Thereby approximately 2/3 of the required total cure time would be under full clamp in the main station after which the clamp force is relieved and the station is opened without opening the mould (Figure 15). The closed mould is then shuttled out to the outstation, remaining closed for the remaining cure time which is still required before it is then opened in the outstation for removal of products, mould cleaning and, if applicable, loading of inserts. At the same time the other mould has been injected and is already curing in the main station. With a special mould opening device installed on the outstations the machine then becomes an effective two-station machine. It is very interesting that besides products requiring a long cure time this effect is also achieved even for parts which require a relatively short cure time, but longer demoulding time as could be caused by moulds with a bigger number of cavitities as, e.g. also moulds with two article decks.

The mould opening stroke on the outstation of the machine is identical to the opening stroke of the standard machine, thus same good access is possible even in the case of double deck moulds consisting of three or four platens.