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Symposium on the Development of the Plastics Fabrication Industry in Latin America

Bogotà, Colombia, 20 November - 1 December 1972

SUMMARY

MOULD DESIGN AND MAKING 1/

by

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The history of the development of moulds for plastics fabrication is traced from its rudimentary beginnings to the fully automatic moulds, embodying the simultaneous movement of multiple cheeks and slides, employed today. The design of modern sophisticated moulds is dominated by the need for complete co-ordination between the injection machine and the mould.

In the design of moulds the vital factors of machining, surface treatment, guidance and support of slides and cheeks are considered together with such aspects as gating, heating and cooling and multi-platen moulds.

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The basis of selecting mould materials is described in terms of relating the material to the plastic for which it is employed.

The successful combination of these factors is illustrated by a number of examples of moulds for crates, containers, furniture, automotive accessories, refrigerator parts and sanitary ware.

The lay-out of the Krauss Maffei mould making shop is described and suggestions are made for mould making shops suitable for firms in the Latin American countries.

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MOULD DESIGN AND MAKING 1/

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CONTENTS

I. INTRODUCTION

1.1. If we look back in the time about 30 to 40 years ago, we can see that in those days plastics was used only occasionally, mainly as a replacement for expensive metals, such as copper, bronce, etc. Since that time plastics material has become to be the main basic raw material for a great number of items and in many cases it has proven to offer real advantages above conventional materials. This development has entered into all branches of to-day's industry. Some of the most important branches to be mentioned are: the domestic sector, automobiles, chemical installations, furniture, packaging.

1.2. The first moulds that were made were just simple dies consisting of a core and a matrix to which the plastic material was injected and which could just be opened and closed. It was the simple process which had always been used for the casting of iron and steel, with the only intention to save fashioning work, but with still rather low economic efficiency.

1.3. The first step with economic development was the procedure of cooling or tempering the moulds with the effect to reduce the production cycle. In most cases water temperatures between 9° and 14° C are sufficient. Sometimes, with moulds which are to work at maximum speed, temperatures below 0° C are also applied.

A further step in the development of moulds was the production of mouldings with undercuts, which require that the mould be equipped with moving parts such as cheecks and slides. The moving parts have to be put into corresponding relation to the opening and closing movements of the machine by means of special controls. This may be either mechanic, by means of inclined guide pins, or of the hydraulically operated type.

Other controls are necessary for the ejection. According to the shape of the moulding, these movements may necessarily be independent of each other.

Electric control instruments and safety devices must be installed to care for correct sequence of the different movements. With all these additives and controls, such a mould is quite comparable with a complicated machine.

1.4. From the above description it may have become clear that the good operation of such a mould and its highly economic efficiency is only possible if it is used on and controlled by an injection moulding machine equipped with the necessary controls and functions for its perfect operation at minimum times. Therefore, the injection moulding machine and the mould to be used on it, are considered to be one complete production unit which requires a very close cooperation between the manufacturers of both elements.

II. LAY-OUT OF MOULDS

2.1. The production of injection moulds is considered to be high precision engineering. The tool makers must have high quality of imagination which allows them to read well all the details shown in the drawings and to realise from them the different three dimension elements of the moulds.

A speciality of the production of injection moulds is the fact that no tolerances can be given neither for the parting lines nor for the moving surfaces of cheecks and slides. All locating surfaces have to be brought almost to zero, because - according to the plastic material to be used - already the slightest gap of a few hundredth of millimeter may cause unacceptable marks on the mouldings. For this reason, the assembly of injection moulds is done by spot-grinding. In most cases, special spot-grinding presses are used for this purpose.

The surface quality of the forming surfaces is of utmost importance. The quality of the finish depends on the purpose of the moulding. Ultra-finish with a mirror effect, is the maximum surface quality. Its production is a very tiresome work, because there is no technical equipment available, but it is mere handwork. The time required for these enormous works depends entirely upon the ability of the tool maker.

Another important point is the required strength of the steel, on which further details will be given later.

Each mould consists of two basic elements, which are the core and the matrix. Concerning the core, it has to be considered that it is exposed to the high pressure flow of the plastics material into the mould by which the core may suffer a displacement. For this reason, the core and the basic plate of tool should be made of one part. Should this be impossible by reasons of design and machining, the lining of the core into the basic plate is a very important part of production. Another important point is the alignment between the two basic elements of the mould. Normally, this can be achieved by means of bevel edges which are reinforced by hardened gibs. Further guiding rods are applied which are placed unsymetrically, so that the halves of the mould can only be joined in one - which means - in the right position to each other. Further care must be given to a good guidance of moving cheecks and slides. Guides should be very long and with sufficient support, so that any floating during the injection is avoided.

These are the main points to be considered with the production of injection moulds. In this general paper it is difficult to state all possibilities which can arise. Every mould is a prototype which means that with every new mould the tool maker is faced with new problems which he has to solve.

2.2. The difference of temperatures of the plastic material when injected into the moulds and the moulded part when it is ejected is somewhere between 150° and 300°C, depending on the type of material that is used. The faster the material can cool down from the high injection temperature to the low ejection temperature, the faster is the production cycle and the higher the hourly output. Too fast cooling, however, can result in a decrease of the quality of the mouldings, such as interior stress, distortion, sink marks. The consideration of these facts is of utmost importance for the tool maker, who has to make the moulds for high quality production.

The different parts of the mould may require different cooling effect. The most efficient cooling is required in the zone in which the hot plastic material is injected directly. Other parts of importance under this aspect are those which are relatively thin and which are surrounded completely by plastics material.

Guidance of the cooling water is to be made in a way, so that the cold water, i.e. the entry is led to the critical points. The further flow of the water is led parallel to the flow path of the plastic material. The more the cooling channels are divided up into different circuits, the better it is to control the temperature of the mould.

As cooling medium usually water is used. Some plastics materials require that the mould temperature is not going below a certain minimum. If this is not more than 80° C, water can still be used. If mould temperatures of around 120° C are required, oil is used.

Special care has to be given that the cooling channels are acting on the whole surface of the forming parts of the mould. General rules can be given on the design and the machining of the cooling channels, but the most important features can be gained only by experience of the mould maker.

This refers also to the different types of material to be used, among which berillium-copper is taking a special place, because of its high thermal conductivity, for which reason it is used as a cooling medium of critical parts for high speed production of thin-walled moulding, such as packaging items.

2.3. According to the characteristics and requirements of the moulding, the designer has to decide which way of gating, which means introducing the plastics material into cavity he intends to apply with the mould. We wish to give some characteristics of the different types of gating:

2.3.1. The bar-type gating is the most simple method which should be preferred whenever possible. Its disadvantage is that it leaves a relatively big mark on the moulding which has to be removed mechanically. Another disadvantage is that it may leave interior tensions in the moulding.

2.3.2. The film-type gating is used whenever no gate marks must be seen on the moulding. Another advantage of this type of gating is that it can be made with different thickness along its total length by which the injection speed at each spot can be influenced. In order to obtain utmost equality of flow into the mould, the gating at the more distant points is made thicker. The disadvantage of this type of gating, however, is that the runner leading from the nozzle into the mould is relatively long and has to go through angles, and therefore in most cases must be equipped with heating like a hotrunner.

A special version of the film gating is the so-called umbrella gating, which is used if the moulding has a hole in the centre which allows the gating. This is also used for the injection of pipes.

The bar-type gating, as well as the film gating allow easy venting.

2.3.3. Tunnel and pin point gating. They are used in cases in which gating on the surface of the mouldings is allowed, but gate marks should be as small as possible. It is also used for moulds which are expected to run completely automatic, so that no additional work for the removal of gates from the moulding is necessary. If the mouldings are bigger, tunnel or pin point gating can be manifold.

2.3.4. For manifold gating, a separate runner system is supplied which leads the plastics material from the central injection bush of the mould to the different cavities and gatesof the mouldings. This runner system is placed between two plates of the mould. When the mould is opened, the complete runner system is falling down also, but independent and parallel to the down-fall of the mouldings. The material falling down from the runner system is scrap. For the mould designer it is important to provide ejectors not only for the mould, but also for the runner system.

2.3.5. An important step of development from the afore-mentioned lost runner system, is the hotrunner system. By this the runner system is not falling down after each shot, but is kept closed in the mould and surrounded by heater cartridges which keep the material inside the runner system always plastic. Equal distribution of heating is most important, and the temperature must continuously be controlled. According to the size of the mould, the hotrunner system may be divided up into different heating circuits, and the more complicated the mould is, the better must be the control of its heating system. Another important matter for the design of hotrunner moulds is the avoidance of dead angles in which material may remain accumulated.

All moulds must have venting facilities to allow the air to escape from the cavities. Small channels and grooves are provided whereever such vents are expected to be necessary. When making the mould, they may still be kept closed, but opened after the first tests as far as this appears to be necessary.

2.4. The different movements of the mould must be controlled in accordance with the opening and closing movements of the machine. This control can either be mechanic or hydraulic and electric. If operation of the mould is completely mechanic, usually no additional electric control devices are necessary, because all movements are mechanically driven and limited. This system is preferred mainly with smaller moulds and it makes them run the most simple way and independent of the control of the machine. This system, however, is usually not sufficient for medium size and big size moulds in which hydraulic cylinders for movements must be installed, with their necessary controls and operation equipment, in coordination with the movements of the machine. Electric impulses for movements and the limitation of movements are given by means of limit switches which are placed at the necessary parts of the mould and the machine.

III. MATERIAL

As to the choice of material of which the mould is made, one has to differ between small moulds, medium size and big size moulds. Another aspect may be the plastic material with which the mould has to run.

Small moulds are usually made of case-hardened steel or through-hardened tool steel. With these materials, however, the problems of torsion-free hardening and a necessary additional machining of uneven surfaces by grinding are involved.

Medium size and big size moulds are normally made of heat-treated steel with a strength of approximately 100 to 110 kg/mm^2. Surfaces exposed to wear, like those for the alignment of the mould halves are provided with hardened gibs for protection against getting worn. The moving surfaces of slides and other movable parts which cannot be made free from wear by

hardening, can be produced of a contrast material, such as bronce. Another possibility to increase the strength - however, limited to applications in which not too much stress or pressure are involved - is the nitrating treatment. A variation of this procedure is the denifering which is faster. For this application it is essential that heat-treating steel is used.

An important point of view for the choice of the material is the request that in most cases it must be well polishable. Usually, the heat treating steel types are alloyed with chrome, nickel, manganese, vanadium, etc.

For big size moulds in many cases alloyed steel casting is used. It has to be considered, however, that boring of this material can produce a rough surface on the moulding. Therefore, the use of steel casting is not very frequent.

The design of moulds to be used for the application of the structural foam procedure is the same as those for conventional injection moulding. Only in the choice of the material of which the mould is made normal engineering steel with a strength of 40 to 50 kg/mm^2 can be choosen, because the interior pressure inside the mould obtained by this procedure is much lower than that with normal injection.

IV. EXAMPLES

4.1. A very important line of products with constantly growing new application and quantities are packages for the most different types of products. At first, simple moulds were used without considering much about the economic effect. In the meantime, however, the requirements concerning the outside aspect of the packaging as well as the cheapest possible price and minimum weight, has created a need for the development of a very high-grade tooling technology, in order to obtain minimum wall-thicknesses and minimum cycle times with fully automatic operation. Nearly all these moulds are hydraulically operated.

provided with hotrunner injection system and fully automatic injection, so that the mouldings fall down on a transport tape which passes through the bedding of the machine and leads them directly into the packaging department. For this sort of mouldings, all possibilities available for high quality mould making are necessarily applied, in order to obtain the maximum output at minimum costs.

Packaging items of ever growing importance in all countries of the world are crates for bottles, fish, fruit and vegetables, container pails for oils, greases, oily, thick or viscous media, and food.

4.2. Another important line of mouldings are pieces of furniture, such as chairs, easy chairs, tables, parts for cupboards, etc. The most important problems for the mould maker are the finish of these mouldings for which the steel quality and the quality of the surface are most important. An important detail to be considered under this aspect, is the choice of the gating, which must not to be seen on the moulding and must not leave any mark, but still allow the perfect filling of the mould. Because of the required quality of the finished surface, it is important to control well the flowing procedure of the material from the machine into all the ends of the cavity. Joint marks and air bulbs are not acceptable. In order to obtain a perfect moulding, not only stability, but also the flow technique pays an important role.

A basic point of these moulds are the parting lines. They must be carried out with utmost precision so that no additional finishing work is required. For such kind of moulds it is recommended to use the electro-erosion procedure for the machining of the parting line.

Many pieces of furniture, such as chairs are moulded of plastics material filled with glass-fibre. This material is highly abrasive and attacks the surface of the mould, which has to be considered when choosing the material.

4.3. A very large field of application is the production of the most different kinds of technical parts of which only a few like radiator grills for cars, parts for refrigerators and dish-washing machines, radio, television, telephone and phono industries, illuminators, car batteries are mentioned here.

When moulds for radiator grills are manufactured, the machining of the surfaces for the rips always presents some problems to the mould maker. These grooves in the mould can be machined by grinding or by milling or by spark-erosion. Lately, the last procedure has been used increasingly, but it has presented some disadvantages, because the spark-erosion procedure produces some undercuts, the removal of which is difficult and has to be done by handwork. Therefore, it is more interesting to use grinding, for which duplicating grinding machines have already been developed, or normal milling with end milling. For this type of moulding usualy manifold tunnel gating is used.

Most of the biggest type moulds produced in the KRAUSS-MAFFEI Mould Making Shop were those for the inside cover of refrigerator boxes. For such big parts, the gating technique is most important. So is the bedding of the huge core. For this type of moulds only the core is made of forged steel, because it is forming the visible surface of the cover, whereas the matrix can be made of alloyed steel casting, because the rear part of this moulding is not seen and the inside walls are filled up with foamed material.

Beyond the most complicated and also the biggest moulds there are those for the production of the inner container of dish-washing machines. It is intended to include in the moulding the possible maximum of the mechanism, for which reason the moulds are complicated and the cores are divided in two different parts. For the ejection the mould parts must carry out relative movements to each other. This also involves special problems as regards the control of the different movements and the equal distribution of cooling effect.

For radio, television and phono sets, the housings are more and more made of structural foam, because of several advantages, such as better accustic effect, lower weight and price, no sink marks, etc.

Very interesting moulds are those for the production of long light pannels which are fixed to the ceilings in offices, department stores, etc. In earlier dates, these light pannels were made by compression or by vacuum forming or by combining different parts by melting. The light effect of parts made by one of these procedures is not very good, because no exact edges can be produced. For this reason, one has started to produce such light pannels by the injection moulding procedure. The main problem is the complete undercut around the whole part of this moulding and the consequent difficulty with its ejection. KRAUSS-MAFFEI has developed a special lay-out of moulds for this purpose which, is protected by patent and is supplying such special tools to customers in many countries.

Another important product are car batteries. The conventional battery boxes of ebonite is replaced by a housing of polypropylene, which is produced by the injection moulding procedure at cycle times of 40 to 45 seconds each. In addition to the much faster production cycle compared with ebonite, the injection moulded polypropylene cases have also the advantage that walls of only 2 to 3 1/2 mm are needed, which means that with the same outside dimensions, more electrical capacity can be installed.

The design and making of moulds for battery boxes presents special problems to the mould maker. Because of the relatively deep and thin walls between the cells of the battery, there is the danger that the high injection pressure which is necessary to fill the cavity entirely, produces a lateral displacement of the cores with the effect that wall-thicknesses become unequal. Such boxes cannot be used for the assembly of the battery.

In cooperation with an American customer, KRAUSS-MAFFEI has developed the special design of such moulds which permits to prevent the cores from lateral displacement and results in equal thickness of the walls. Because of this know-how KRAUSS-MAFFEI is the leading producer of moulds for this kind of product.

4.4. Under the aspect of public health, another kind of items are now made of plastics, such as garbage cans of different kinds and dimensions. The small cans are used to be placed in households, hospitals, etc., the bigger ones are placed outside the premises for collection by the public garbage removal service. Moulds for such items are usually not very complicated, but it has to be cared for that the handles are made of a design which is safe and handy for the user, and at the same time simple from the mould makers point of view. All moulds must be provided with intensive cooling system, best injection methods and perfect ejection system, in order to obtain short cycling and a good quality of the products to resist mechanical wear and stress produced by atmospheric conditions during a long time. This is not only a question of the plastic material, but also of moulding technique.

V. DESCRIPTION OF MOULD SHOP

The Mould Making Shop of KRAUSS-MAFFEI is laid out for the production of injection moulds with weights between approximately 1 ton and a total of 40 tons. The equipment of this mould making shop, mainly under the aspect of the production of biggest moulds, is supposed to be unique in Europe.

Although KRAUSS-MAFFEI being a big company with a staff of more than 5,000 people, the organization of the mould making shop had to follow the lines which are usual for a small factory, in order to correspond to the need and characterisitcs of mould making. This has been achieved by concentrating

at one place all departments which usually belong to such type of manufacturing, such as working out of quotations, lay-out and design of moulds, production planning and routing, machining and assembly, so that there are only short ways from the offices to the factory floor. Such an organization is fast and flexible, and capable to meet with all requirements of such type of production.

The main type of machine tool which limits the capacity of a mould making shop, is the milling machine, which determines the maximum size of the mould which can be made. The copy milling machine is included under this aspect. Normally this type of machine tools are equipped with vertical spindles, very variable in its movements, such as with a swinging spindle head, swinging table. The shop is completed by the other necessary types of machine tools, such as drilling machines, horizontal boring mill, cilindrical and surface grinding machines, spark-erosion machine and a spot-grind press which are necessary for a modern mould making shop.

The mould maker at the shop board requires a sufficient number of spot-grinders for which mainly the small high-speed machines are useful.

For moulds made of the above-mentioned weight as manufactured in the KRAUSS-MAFFEI Mould Making Shop, a sufficient number of lofting gears and cranes is essential.

Further, good leading personal is required. The average is one highly qualified leading person for about ten trained workers.

VI. GENERAL IDEAS

for a Mould Shop suited to be put up in Latin American countries.

6.1. Two different sizes are being suggested:

a.) A shop capable to produce moulds up to outer dimensions of 500 x 500 mm and a height of approximately 350 mm. They can be used for the production of mouldings up to a weight of approximately 700 to 800 grams polystyrene, or the equivalent of other materials.

b.) A shop capable to produce medium size moulds up to the size of approximately 800 x 800 mm, and a height of approximately 700 mm, which includes usual moulds for the production of bottle crates. Possible weight of the mouldings up to approximately 2.000 grams.

6.2. In the case of the smaller mould shop (suggestion a.) the investment necessary for machine tools are estimated to be around US-Dollars 400.000,--. 14 to 16 trained workers are required, two leading technicians (engineers) and 1 commercial assistant. With one shift operation, corresponding to approximately 2.000 working hours per year, a production worth about US-Dollars 250.000,-- to 300.000,-- can be estimated.

In the case of the bigger mould making shop (suggestion b.) the investment in machine tools is estimated to be around US-Dollars 700.000,--. 20 to 23 trained workers are required, as well as three leading technicians (engineers) and 1 design engineer. Further, one commercial assistant. Possible production is estimated to be around US-Dollars 500.000,-. to 600.000,-- per year.

These estimates are based on actual costs and circumstances in Germany. Costs for the premises are not included in these figures.

6.3. In order to give a clear picture of the types of worker, who are required for such a shop, it has to be looked at how this has been developed in our country. About 15 to 20 years ago, even in Germany there were no trained specialists for the making of injection moulds available. What we had, however, were tool makers or highly qualified mechanical engineers. Among these the personal was selected and trained for this new job. It has to be added that in Germany a man who is called tool maker is understood to be capable to make moulds for cutting and stamping and equipment for boring and milling, which means generally, all the auxiliary tools for the production. If such trained workers are available, the special training for making moulds for injection requires - according to his ability and previous experience - a time between 2 and 6 months.

Among the trained workers, normally called fitters, the best are those who have experience with the making of engines or machine tools. The training of a hand fitter is less suitable. Up to a certain extent, an instrument maker can be good, mainly for the making of small moulds.

As it has been mentioned before, the special worker who wants to be trained in the making of injection moulds, must have high imaginative faculty, capable to think in three dimensions and to read the drawings. According to his ability and previous training and experience, he can pass an additional special training in mould making at the KRAUSS-MAFFEI Mould Making Shop during a period between 2 and 12 months. The result of this training depends, of course, on his skill and intelligence.

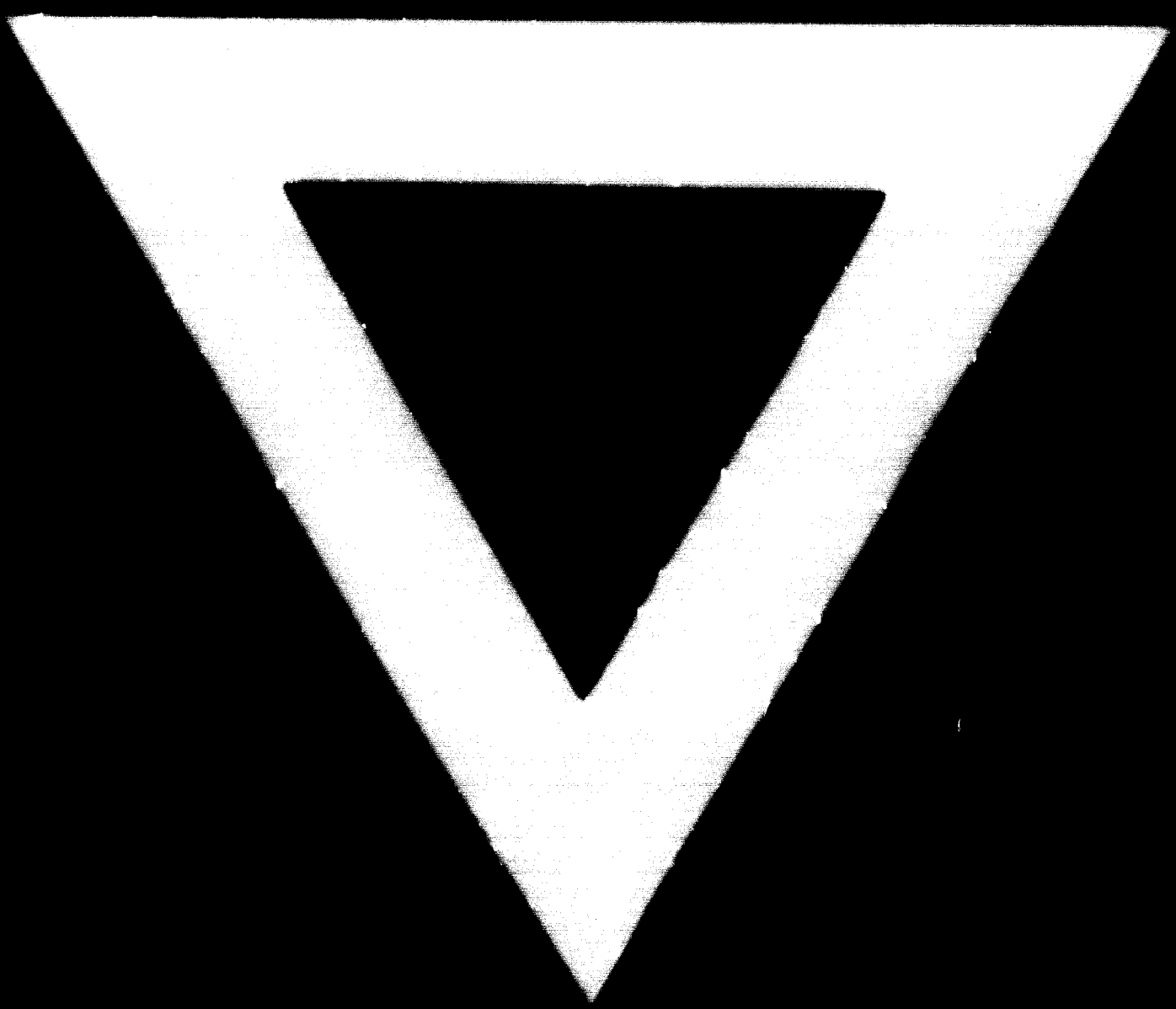
Details and conditions of such training including the costs involved must be fixed in an agreement between the interested party and KRAUSS-MAFFEI.

Apart from mould making, KRAUSS-MAFFEI is one of the world's leading manufacturer of injection moulding machines, which cover a range of injection weights from 30 grams to 16 kilograms, and locking forces from 25 to 3000 metric tons. In the Plastics Processing Laboratory of KRAUSS-MAFFEI, there is a complete line of injection moulding machines available for the testing of moulds, materials, as well as for development and demonstrations.

In addition to the special training in mould making, there is the possibility to train the mould maker in this Plastics Processing Laboratory with the operation of injection moulding machines and the processing technique with the different types of plastics materials. This training can be included into the agreement of cooperation.

6.4. KRAUSS-MAFFEI is willing to supply his know-how with the erection and the complete installation of a mould making shop, with the principles of design, machining, calculation and time studies involved with making moulds for injection of plastics material.

All this service must be subject to a special agreement to be concluded between the interested party and KRAUSS-MAFFEI in which the conditions and costs are fixed.
Interested parties are invited to contact the KRAUSS-MAFFEI company and to specify their own ideas and requests as detailed as possible, so that KRAUSS-MAFFEI is in a position to submit a proposal that would offer the partner the best possible cooperation with his own intentions.



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