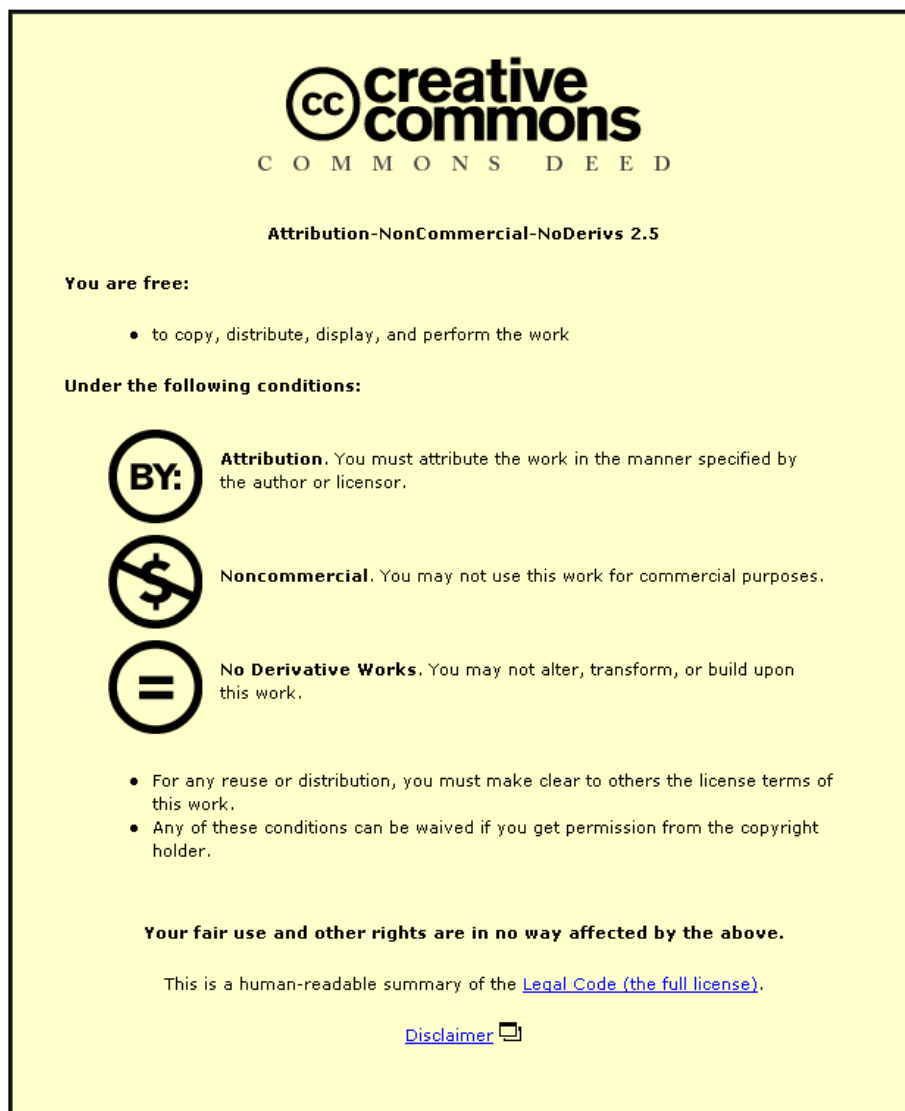


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A REVIEW OF
SOME ASPECTS OF MOULDING AND CASTING IN SCHOOLS
IN RELATION TO RECENT INDUSTRIAL DEVELOPMENTS
SUPPORTED BY PRACTICAL APPLICATIONS.

by

ARTHUR MAW

A Master's Dissertation

Submitted in partial fulfilment of the requirements

for the award of

Master of Philosophy of the Loughborough University of Technology.

1983

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I N T R O D U C T I O N

Foundry work was first introduced into schools some thirty years ago. At this time aluminium alloys were generally used, LM4 and LM6 being the most suitable. Some schools were a little more adventuresome and involved themselves with casting iron and brasses, but the high temperatures, obnoxious gases, noisy furnaces and inadequate extraction, coupled with length and cost of melt and the necessity of close furnace supervision, proved too much of a handicap for most. Few persisted for long in their attempts to introduce these materials into school. Progress was virtually halted when legislation placed school workshops under the jurisdiction of factory inspectors. This had several very desirable effects in the long term and, although working conditions in schools still lag far behind those of industry, several positive developments were made. Standards were raised by the insistence on adequate ventilation, efficient extraction systems and a general tightening of safety in all its aspects.

Prior to this, in the workshop area, educational suppliers had paid little heed to developing educational needs. Initially, in the foundry field, the options were to purchase small industrial gas and air furnaces, or for the enthusiast to design and construct his own. Such initiative

has, thankfully, always been in abundance amongst Craft/Design teachers. In many instances teaching staff involved lacked basic foundry training, balanced valves were not available and several blow-back explosions were recorded. All round foundry care in schools lacked the control necessary to bring it up to desirable safety standards. But, as is so often the case, the enthusiasts had focused attention on an area new in education worthy of development.

In the last thirty years there has been much progress, new alloys have been developed and the need for support in schools has been recognised by industrial concerns, in both a supportive role¹ and in the development² of equipment specifically designed for educational needs.

This has not been the case in all aspects of industrial development. There has been little communication between the pattern making industry and schools. The demands made on the pattern maker are still as great as ever. He is still one of the most skilful of engineers, working to very fine tolerances, producing complex laminated structures, designed to counteract shrinkage in high grade soft woods. This work still consumes a large proportion of both his training period and productive time, but he now uses many new materials in his craft. The numbers involved in such work have decreased dramatically, due, to a large extent,

¹ Appendix I Foseco. Page 20.

² Appendix II Flamefast. Page 21.

to changing technology within the industry. The ability to copy and make patterns in polymers, resins and plasters has developed significantly, but these changes have not yet percolated extensively into the educational field.

Developments in plasters¹ too, have advanced at some pace. To date this has been of little interest to those outside related industry, but some of these developments have educational significance.

There must be a constant search to improve the tools of learning. When untried materials and processes, new or old, present opportunities to simplify or accelerate the learning process, children must be given the opportunity to use them. The resultant reward of success can only drive them on to achieve heights they would not otherwise have attained.

It is in the interest of both children and teacher that the potential of such materials and processes be made known.

¹Appendix III Page 22.

C H A P T E R O N E

AN EARLY INTRODUCTION TO THE PRINCIPLES OF MOULDING AND MOULDMAKING.

It has long been common practice to stimulate thought by providing children with scissors, paper, card and various building kits in problem solving situations, but plastic modelling materials, clay and plasters are too frequently confined to the junior school level. Without access to these materials a creative void may develop; such materials add a three-dimensional depth to thinking, allowing relationships to be established which in two-dimensional expression are often not manifest, or, at best, very obscure.¹

The use of plasters² in school to develop design thinking presents several advantages. Numerous techniques can be employed to produce casts to illustrate the basic principles of moulding. Mould cavities can be easily fashioned using paper, card, timber and sand to assist in the difficult concept of thinking in reverse. Producing moulds from simple male patterns and encouraging visual comparison between the resultant cavity and the original shape reinforces this concept. Vinyl moulding

¹Appendix IV Page 27.

²Appendix III Page 22.

materials¹ are ideal for this purpose, their flexibility providing the facility for negative draw, their texture eliminating the need for separating agents, and their recycling capacity making them cost effective.

In the industrial situation the need for a high quality precision pattern is of paramount importance. Pattern production is very time consuming, especially if industrial standards and techniques are applied.² The old adage that the quality of the cast can only equal the quality of the mould which can only equal the quality of the pattern still rings true. Educationally the precision, quality of detail and general finish associated with industry is rarely necessary. The production of patterns for school use need not be a time consuming occupation and need not follow the methods of the professional pattern maker. There are many materials that can be easily fashioned to form the patterns necessary to produce mould cavities. Plasters lend themselves to the production of simple shapes either as cast or carved. Plasticine³ and other modelling media are easily moulded and when refrigerated are sufficiently rigid to hold fine detail when moulded in sand. Using this simple technique the basic principle of casting can be speedily

¹ Appendix V Page 38.

² Appendix VI Page 40.

³ Appendix VII Page 43.

illustrated and the more complex concept concerned with the casting of voids is easily explained by the introduction of plasticine cores and core prints.

To lay a foundation in the basic principles of casting early in the stages of the design thinking process, using materials which give rapid results, develops an awareness of a process which frequently receives only scant attention in schools.

With such a foundation the way is clear to develop the more advanced techniques necessary to enable students to consider the advantages of cast components in future design developments.

CHAPTER TWO

PATTERN MAKING

MATERIALS AND TECHNIQUES

The objective of the pattern-maker is to produce accurately dimensioned stable shapes, which with the aid of a parting fluid or powder release easily from the moulding media leaving a clean detailed cavity to accept the casting. The moulding media is frequently a bonded sand and the casting is generally metal.

The cost of such pattern work is very high, the work involved being both intricate and time consuming. The life of the pattern must be such, that its cost can be recouped by its continual use. To this end great care is taken in its construction in order to attain the strength required to withstand the rigors of moulding. Traditionally timber has been the basis of all pattern making, high grade softwoods generally being preferred. The unstable nature of timber presents problems of its own in pattern design, where the dimensions must remain constant to a few hundredths of a millimeter, in spite of the continual shrinkage and expansion of the timber. This is particularly important where cylindrical shapes are concerned.

To overcome these problems the pattern maker follows a set of basic rules, all patterns made in timber being laminated in segments in such a way that only the side grain of the timber is exposed to the moulding media.¹ This produces a pattern that retains its shape and is extremely strong. It also has the added advantage that all end grain is concealed, eliminating the moulding problem of pattern drag that frequently occurs when the end grain of timber contacts damp moulding materials.

As with most other craft skills, new materials and technologies have changed the work style of the pattern maker, and although the traditional materials and technique are still extensively used, ploymers, resins and foundry plasters are frequently preferred. The introduction of these materials has brought new skills into the industry. It is generally accepted that these are not as demanding as the old; the production of duplicate and match plate patterns,³ for example, requires little training.

Most of the materials used in this work have little application in school, they are either too expensive, obtainable only in bulk,² or are of such a toxic nature that health hazards make them unsuitable. Their use in industry is none-the-less thought provoking and, bearing in mind that educationally, pattern

¹Appendix VI Page 40.

³Appendix XVIII Page 68.

²Appendix VIII Page 44.

life, accuracy, and general durability are not always an important factor, less expensive and safe materials are available to enable children to follow more closely today's industrial practices using materials that bring rapid results.

Water Fillable Polyesters¹ for example form the basis of a number of cost effective workable materials for use in this and other craft/design areas. These emulsify easily: a one-to-one ratio of resin and water, with the addition of hardener, produces a material with the working qualities approaching that of wet sycamore. Other advantages are that surface detail can be cast, or blanks with minimal machining allowances produced thus reducing material wastage.

Water Fillable Polyesters possess very good working properties,² responding well to most conventional manipulative techniques associated with wood and metal working tools and machines. The texture of the material is such that tools maintain their cutting edges for much longer periods and results are more speedily attained. The material itself is very stable, ideally suited to many aspects of pattern production and the water captivated during emulsification prevents the dusting which is normally

¹Appendix IX Page 45.

²APPENDIX IX Page 46.

a hazard when working polymers.

The use of pattern plasters¹ can also be very rewarding, producing results and allowing design thoughts not otherwise possible. Pattern plasters are produced by Fosco specifically for the foundry industry. This range of hard plasters formulated primarily to withstand the high compression loads in the mass production of sand cores, resin, oil bonded and CO₂ shell moulds, is ideally suited to withstand the ravages of the novice moulder, damaged patterns being easily replaced from the preserved master. Such plasters are only available in industrial quantities and being autoclaved products are expensive. There are, however, occasions when such expenditure can be justified, (see Chapter 3), but for general use where pattern life is of little importance and children are involved with one-off castings, finish plasters beyond their shelf life, used in the building trade are generally adequate.

¹Appendix III Page 22.

CHAPTER THREE

THE USE OF ZINC ALLOYS IN SCHOOLS

Foundry plasters are more expensive than the plasters normally used in schools, but their occasional use can be justified. The detail these produce and their durability make possible the production of permanent metal moulds. This, in its turn, allows zinc based alloys to be considered as a craft/design media. The processes involved have a number of advantageous educational features.

Most zinc alloys require a quick chill in order to give the solidified metal the small grain size essential to its mechanical strength. In industrial die casting¹, where zinc based alloys are the most widely used, the steel dies chill the metal in seconds. Where permanent metal moulds are involved in gravity casting the same occurs, sometimes the chill is accelerated by water cooling. At first it may appear that neither of these industrial processes have any application in school, the precision and technology involved in the manufacture of steel dies and the cast iron moulds placing them out of the reach of educational application.

The use of hard pattern plasters², however, makes it possible to cast reversals of existing patterns without

¹Appendix XVII Page 62.

²Appendix III Page 22. and Appendix XVII Page 64.

loss of detail or significant change in dimension. These plasters in turn can be used as patterns for casting permanent moulds in Aluminium. The resultant metal cavity will provide sufficient chill for Mazac 3 to solidify quickly, producing castings with small grain size which give a mechanical strength very close to that of a commercially produced die casting.

The pouring systems should form an integral part of the pattern and ^{be} cast into the plaster reversal, careful consideration being given to the design of these systems and to the method of ejection of the cast from the mould¹.

The use of permanent metal moulds opens up new opportunities for all children,³ and is especially beneficial to those in the lower ability range; threads, bushes, and other inclusions can be produced prior to casting,² and placed in the mould cavity. This can eliminate many exacting and time consuming machining operations which are beyond the capabilities of many children, giving them the satisfaction of the practical realisations of tasks otherwise beyond their capabilities. The precision, quality and ease of the production of such castings, leads to a much speedier turn over of work, giving greater stimulus and satisfaction.

¹Appendix X Page 48.

²Appendix XI Page 49.

³See accompanying Video.

The designing of the moulds demands a close understanding of foundry principles and allows the introduction of techniques which closely resemble the industrial practices related to the casting of zinc alloys. The commercial and industrial importance of these alloys, and our dependence on them can then be more easily emphasised. Such an awareness, coupled with the practical means to cast zinc alloys can only add a realistic dimension to the design thinking process.

The main problem associated with the use of zinc alloys in schools revolves round the need for a rapid chill of metal. Although the use of permanent aluminium moulds² makes this possible, and the process itself opens up new opportunities for children, zinc alloys normally associated with the pressure die casting industry are totally unsuited for sand and investment casting. It is recognised that all schools will not have the facility to produce permanent moulds. Recent research, however, has made available new zinc alloys that have the versatility to be cast in virtually any mould cavity. The mechanical strength of these alloys, which is comparable to cast brasses and bronzes, is not affected by the period of solidification. Kayem 12¹ produced by Mazac Ltd. is such an alloy. This alloy has many of the properties of Mazac 3. It is simple and economical to use with low melting costs, virtually

¹Appendix XII Page 49. \

²Appendix XVII Page 60.

no dross, no fumes and is not susceptible to gas pick up below 520°C . It produces clean castings with fine reproduction of detail and, if necessary, thin section; is relatively free from shrinkage and gas porosity, is easy to machine, accepts painted and plated finishes, has good corrosion resistance, and with proper foundry care has a recycling capacity of 97% without loss of metal quality. Unlike Mazac 3 this alloy can be cast in sand moulds.

The capability of Kayem 12 to maintain its mechanical strength irrespective of cooling rate gives it other potential for use in school. Cast into hot cavities even thinner sections and finer detail becomes possible, permanent aluminium moulds can be used hot for repetitive casting, oil bound sands used as shell moulds, filled directly from the oven, and the insulating¹ properties of investment plasters can be used to great advantage in the development of techniques giving greater precision and quality to casting in schools.

¹ Appendix XIV Page 54

CHAPTER FOUR

SIMPLE TECHNIQUES TO IMPROVE THE RANGE AND QUALITY OF CASTING IN SCHOOL

The precision and quality of industrial casting is often such that it seems unrealistic to aim for such standards in schools. Die and investment castings are frequently produced to be used as cast, eliminating the necessity of costly machining and finishing processes.

With the aid of foundry and investment plasters, together with the alloys now available, it is possible to develop techniques in school to produce castings that approximate very closely in quality and detail to those of industry. Such a capability allows the development of more sophisticated design thoughts and presents the practical possibility of true representation at the stage of realization.

When preparing normal clay bonded moulds it is necessary to rap the pattern in order to release it from the sand, the draw then allowing removal. The rapping of the pattern and the need for draw makes it impossible to produce either square faces or identical components. Draw is essential in all casting processes involving sand and permanent moulds. Using a combination of casting plaster

and investment plaster, it is possible to produce precision castings that require no machining, with very accurate matching vertical faces and undercuts. A vinyl or silicon rubber¹ reversal of the master pattern provides the facility to produce disposable plaster duplicates of the original. These sprayed with cellulose and coated with a separating agent² can be invested in casting plaster³. On solidification the investments, broken with a small punch and hammer, can be easily removed; the resultant cavity being filled with the selected alloy.

The use of wax as an investment in schools is normally associated with centrifugal casting and art forms, but it is also widely used in industrial precision casting, generally in connection with refractory moulds⁴. Of the many waxes available dental wax⁵ is the easiest to manipulate; as a three-dimensional tool to develop small scale design thoughts this is extremely useful. Proposed die cast parts modelled in this way, invested in investment plaster for gravity casting in Kayem 12 produce very accurate prototype castings accelerating and simplifying design realization.

Pressure in the mould cavity greatly improves the detail of the finished cast. This can be applied either mechanically, by air, vacuum or steam. It is estimated that five to ten pounds pressure on the surface of an

¹Appendix V Page 38.²Appendix III Page 25.³Appendix III Page 25.

⁴Appendix XIV Page 54.⁵Appendix XV Page 55.

aluminium cast gives a 50% improvement to surface finish. This principal is applied industrially when making match plate patterns in herculite metal casting plaster.¹ The insulating properties of herculite and investment plasters are worthy of note - not only can the moulds be used hot, the heat loss is such that the metal remains molten in the cavity for relatively long periods allowing ample time for the cast to be sealed and pressure to be applied.

The design of pressure castings is dependent on the required capacity and availability of pressure. For small work a simple steam press² will probably suffice, for larger casts vacuum plates may be fitted to existing moulding boxes or a pressure chamber attached to investment moulds.³ The pressure source for such castings need be no more sophisticated than a foot pump with a pressure gauge.

¹Appendix III Page 25.

²Appendix XVI Page 57.

³Appendix XVI Page 58.

C O N C L U S I O N

The unifying factor of the materials and processes researched lies in the relationships they form with each other, in solving problems revolving round the production of patterns, making moulds and filling mould cavities.

Educationally the usefulness of this activity is primarily in the area of communication, providing a tool for three-dimensional thinking, an area where many find great difficulty¹.

The ability of children to develop thoughts and communicate them forms the foundation of design thinking. It is frequently the difficulty to communicate rather than the inability to produce constructive on-going thoughts that restricts design development. This is particularly the case amongst younger and lower ability children. The need to be seen to make progress is of paramount importance in the learning process. The way in which the brief is presented to children,² and the selection of the tools for learning determine, to a large extent, the progress made.

It is in this area of design teaching that

¹Appendix IV Page 27.

²Appendix IV Page 31.

mediums capable of producing three-dimensional shapes with the minimum of manipulation come into their own. Thoughts expressed in two-dimensions are invariably restricted by an inability or lack of proficiency in communication. This problem can be greatly reduced by the introduction of three-dimensional aids into the process of design thinking.

APPENDICES

A P P E N D I X I

Fosco Foundry Services Ltd., of Tamworth, Staffordshire, have supported the development of foundry work in schools for over thirty years. Advice is freely available on request.

A P P E N D I X II

Flamefast Limited, Pendlebury Industrial Estate, Manchester, have developed a number of foundry appliances specifically for school use. Their tilting furnace is of particular interest eliminating the need to remove the crucible. This gas and air furnace lacks temperature control as do all other low cost furnaces; gas pick up still remains a problem and close furnace supervision is still necessary. The extraction units produced by Flamefast are both versatile and efficient, a definite improvement on units normally fitted in schools.

A P P E N D I X I I I

All plasters are manufactured from naturally occurring gypsum mineral. In the U. K. British gypsum have the monopoly of its production, transport costs and short shelf life of the finished product making importation impractical, although small quantities of specialized American and European plasters do find their way on to the British market.

Plasters are manufactured by one of two processes. The simplest and cheapest of these produces the softer 'beta' plasters. The rock is crushed, ground, and heated in large kettles to drive off a percentage of the water of crystallisation which is chemically bound up in the mineral. This process is known as calcination and produces plasters with relatively long and irregular shaped crystals.

The hard 'alpha' plasters, produced under steam pressure in large autoclaves, have very short crystals which sit tightly together and require much less water to obtain a pourable mix. This is a more costly process.

In the 'alpha' process, the crushed gypsum is first converted into wet slurry. The slurry is driven up to production temperature by superheated steam. This is then dried very rapidly before chemical set takes place, resulting in short uniform crystals.

The quality of plaster is also affected by the purity of the quarried gypsum, which contains variable amounts of inert impurities. The gypsum is classified in three groups; Superfine, which is at least 99% pure; White, which has a purity between 95% and 99%; and Pink, used mainly for finish plasters in the building industry, where the purity is between 75% and 83%. Below this level the mineral is used mainly for agricultural purposes. Only the purer grades are used in the production of 'alpha' plasters.

British Gypsum produce over fifty different plasters, each formulated to fulfil a particular need. The basic variations being in hardness, compressive strength, setting time and their ability to withstand temperature without structural deterioration. Some plasters manufactured in the U.K. are not sold under the British Gypsum label. These are formulated using British Gypsum crystals by other industrial concerns. In this way Foseco produce their special foundry plasters.

The one common characteristic of all plasters is that they expand on set. The control of this expansion is one of the most important factors of the formulation. The mixing of plasters is covered briefly in Appendix XVIII, page 65 where the importance of clean water and clean utensils is stressed, together with the need to follow precisely, the recommended ratio of plaster to water. The reason for this is not always appreciated by the user. When a plaster is formulated to fulfil a specific need, for example, to have an expansion rate to equal the contraction of a particular casting media, the expansion will only meet that stated in the specification, if the recommended proportions of plaster to clean water are strictly adhered to. Failure to follow the manufacturers' recommendation, will lead to changes in expansion, probable loss of surface detail, lengthening or shortening of setting time, and changes in hardness and strength.

In many cases, when using plasters in school, not all of these factors are important. It is possible through experience, to increase the hardness by reducing the water input to the mix. In this way, a normal casting plaster from the school Art Department can be used successfully for pattern production.

The foundry plasters fall into two basic groupings; firstly those designed to give high compressive strength, coupled with fine surface detail and a controlled expansion rate; and those formulated to withstand the temperatures of shell moulds used for precision casting in the foundry.

The precise constituents of these plasters are not generally known, but it is acknowledged that the hardness of pattern plasters is derived from ceramic particles, and that reduction in expansion is achieved through additives that absorb the normal expansion of the gypsum crystals.

Additives to the high temperature investment plasters consist of fine refractory fillers and for Herculite Plaster M.C., used for match plate production in aluminium and zinc alloys, refractory wool fillers have replaced the asbestos fibres that were in use until recently.

The release of patterns from plasters frequently poses unnecessary problems. Correct release agents are important. Either Ambersill Formula (1), Strip coat (1), both supplied by Foseco, or two or three coats of warm patidium jelly, applied to well sealed surfaces will solve most problems. Compressed air, even a bicycle pump, applied through a small vent to the back of the pattern will assist in release.

The importance of the timing of the release is generally overlooked. During the cure, the heat produced should be used as an extraction indicator, especially when difficulty is expected. A thermometer placed in a small hole on the reverse of the cast will show when temperature starts to fall. During the rise in temperature of the cure, excess water is being driven out of the plaster on to the face of the pattern, this acts as an additional release agent and has its maximum effect when the cast reaches its maximum temperature. As this begins to fall the water is re-absorbed into the plaster and is no longer available to act as a release agent.

A P P E N D I X I V

Few children in their early years have the ability to express themselves coherently when using the written word. When a rapport is developed between a child and an adult which is appropriate to his age and development, it is obvious that his oral capacity to express himself is in excess of his capabilities to cope with similar problems using the written word. Yet as he develops the converse becomes true. It is a well established fact that in later life the written vocabulary far exceeds that of normal conversation, and generally becomes far more explicit, concise and expressive.

The complexities of human language take time to assimilate. A child first learns to communicate through sound on his mother's knee, long before co-ordination between hand and eye is developed to any significant degree. Then from the gross manipulative skills develop the finer skills necessary to produce letter shapes, which have ultimately to be related to aspects of environment such as touch, taste smell, sight, sound, shape and colour. These skills are stored in the long-term memory and enhance the learning process.

The relationship between the different aspects of communication development are dynamic. Any one of the oral,

gestural and manipulative areas may be more developed than the others at different stages of individual learning patterns, the level of development interchanging.

An analogy between the development of human language and that of graphic skills can be drawn. Graphic skills generally lag far behind the vocabulary factor of expressive language development. These skills may never be used with facility and ease in an individual's lifetime. The first crude drawings of small children in two-dimensional form, with no semblance of perspective, illustrate an early stage of development. This development occurs in most instances between the age of five and eleven, a current illustration of this being the children's weather pictures on television. Attempts at three-dimensional pictures expressed in a two-dimensional form at this stage are the exception rather than the rule.

Most experienced Art teachers attach little importance to the development of three-dimensional expression in this form i.e. single point and two point perspective, until the age of thirteen. Only then do they consider that the majority of the group have the ability to cope with the concept sufficiently to be rewarded with success. This of course is again a generality. Just as some children learn to read early, or gain an early grasp of number, as

with other concepts, the ability to express a spatial awareness can appear earlier or later and, sometimes, never develops at all.

It is important to realise that children should not be put under stress by asking them to solve problems in a way which is in advance of their natural development. There is a logical sequence to developing skills. A child must learn to count before he can add number. To ignore this sequence would be a folly, leaving the child floundering, destroying what should be natural enjoyment, depriving it of the reward of success, the satisfaction of progress, and retarding development generally. In the same way when problem solving in the design field, children should not be asked to express themselves in a way which is beyond their capabilities. The introduction to three-dimensional sketching as a means of expression should be co-ordinated to the level of achievement in the group i.e. only when the average achievers within the group have shown that they have some mastery of this mode of communication.

How should children be asked to communicate their spatial awareness when they are first introduced to design/
thinking problem solving? This question is probably best answered by posing another. How do children show and first develop their spatial awareness?¹ This is achieved through

¹Appendix XIX Page 68.

play, first by touch - the ball is round and slips out of the fingers; the toy is soft and easy to hold. A few months on and a child begins to co-ordinate hand and eye, manipulating shapes into matching holes, enjoying the reward of parental praise. Cubes placed one on the other form vertical towers to be quickly demolished. Geometrical and abstract shapes in plastic and felt make pictures. Plasticine is moulded into forms representing futuristic and prehistoric animals, the more adventuresome develop modelling skills in plaster of paris and papier mâché. Cardboard boxes are transformed into forts, dolls' houses and creatures from outer space, and in the supportive home there is always a rainy day box full of string, paper, cardboard, glue, beads and materials to make sure things happen.

Both child and parent reap the reward during this rapid period of development, the parent by observing the response to the stimulus given, and the child through his own development and success, strengthened by the approval of his audience.

It is not unrealistic to work towards such a situation in the Creative Design area, where stimulus and response lead to mutual reward, for both teacher and pupil; but before considering how to approach this objective there

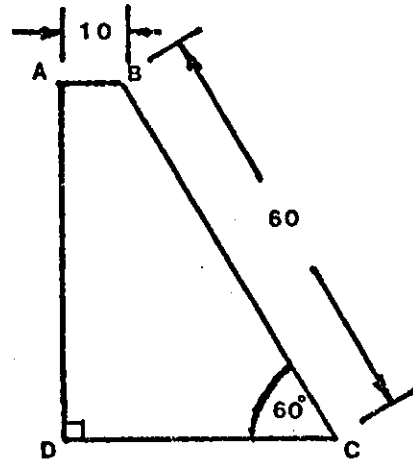
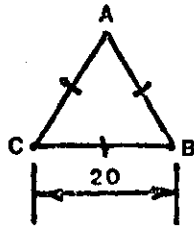
are other considerations to be made.

When attempting to develop spatial awareness, the way in which the question is posed is of paramount importance. Observations suggest that there is frequently a low correlation between intelligence and the capability of resolving problems of three-dimensional and two-dimensional relationships. In intelligence testing, this fact is frequently used to detect personnel with possible practical traits. It is, therefore, logical, when preparing a brief, that great care should be taken not to cloud the issue in hand in a way that intelligence, rather than the ability to solve spatial problems, is being tested.

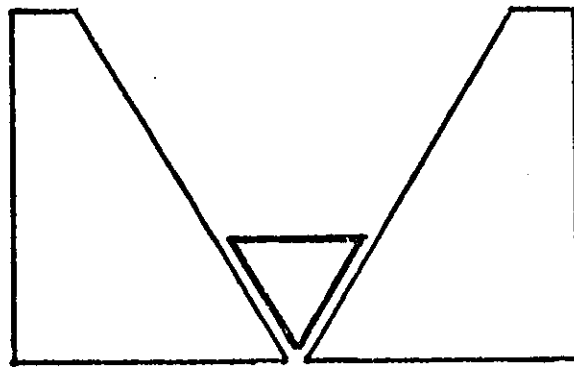
This can be illustrated by posing the same question in different ways:

1. Construct an equilateral triangle with side length of 20mm; relate this triangle in as many different ways as you can, forming regular patterns and solid related shapes, with a quadrilateral A B C D where A D is perpendicular to D C, angle D A B is 90° , A B is 10mm and angle B C D 60° and B C is 60mm.

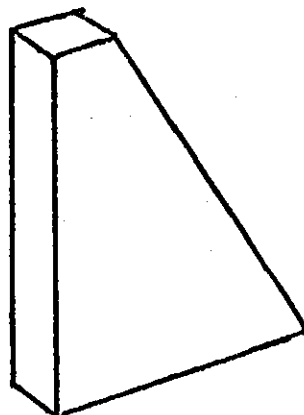
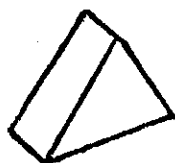
2. Arrange the shapes illustrated to form regular patterns and solid related shapes, either with duplicates of themselves or each other.



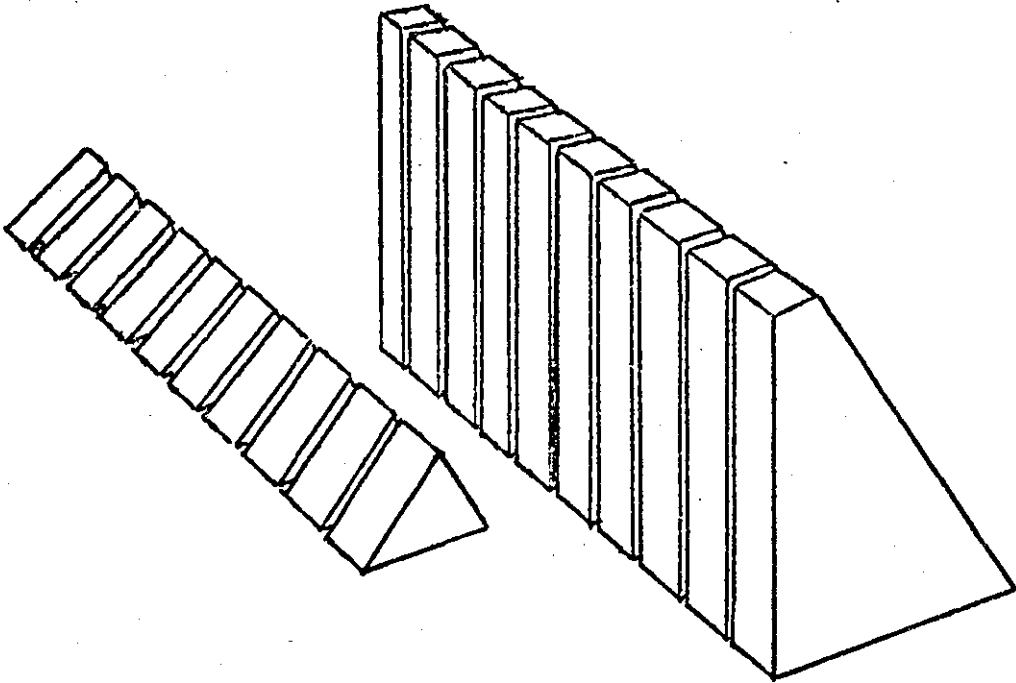
3. As above but with an example as a starter e.g.



4. Present the client with a three-dimensional model of each shape: Arrange the blocks given to form regular patterns and solid related shapes either with duplicates of themselves or each other: and give the same starter.



5. Present the client with numerous three-dimensional models of each shape:- arrange the blocks given to form regular patterns and solid related shapes, either confining your solutions to one shape or working in combinations of both: and give the same starter.



To test the hypothesis a group of twenty five post-graduate students were posed the question as set out in 3. A pilot study having established that presentation as in 1 and 2, with a number of clients, required further clarification; the addition of the starter seemed to clarify the issue.

Each student worked independently without knowledge that others had performed the same task. An initial time limit of three minutes was set in order to apply an element of pressure. At the end of three minutes most seemed to be struggling for ideas; at the end of five minutes, in all


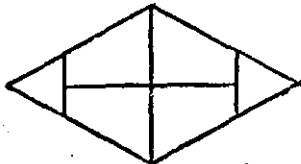


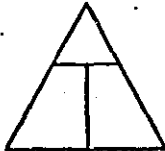


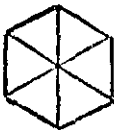

but three cases, response had come to a halt.

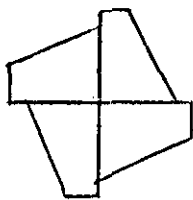
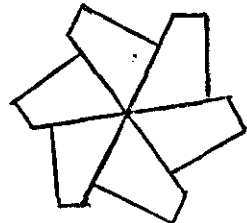
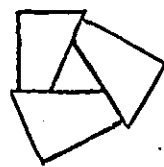
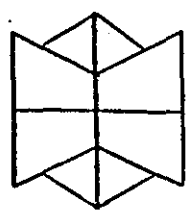
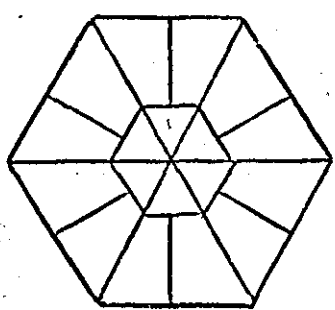
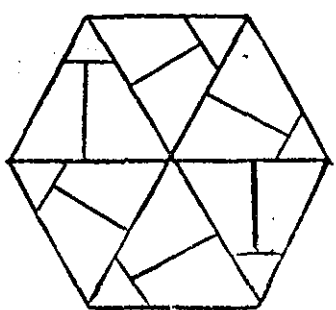
At this stage a further stimulus was introduced; the client was presented with accurately dimensioned shapes as in 5 and asked if manipulation of these would motivate any new thoughts. Immediately more complex combinations began to appear. Up until this point most clients had confined their solutions to combinations based on right angles. When manipulating manually 60° relationships became apparent to all. It was also very noticeable that during phase one of the exercise, although conducted in a very friendly informal atmosphere on a one-to-one basis, tension developed under the pressure of time. After a period of two minutes a negative statement was made 'You aren't making much headway' this seemed, in many instances, to bring a reaction of frustration and annoyance at not being able to progress with what seemed a simple task.

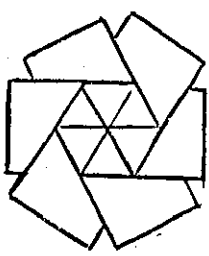
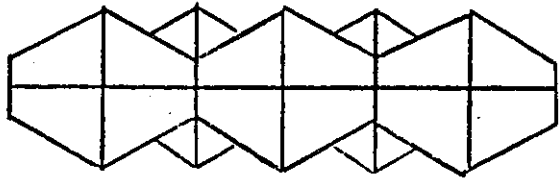
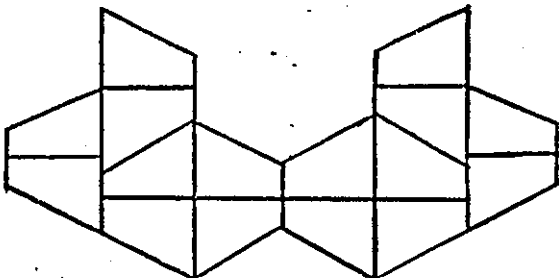
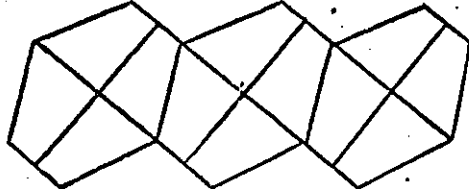
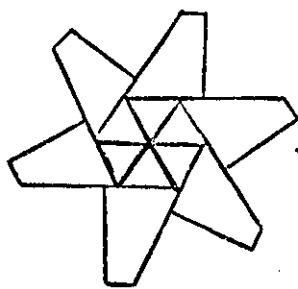
The tension and frustration disappeared immediately physical manipulation of the blocks occurred. As each client proceeded to discover new combinations involuntary statements were made which indicated both relief and disbelief at what now seemed so obvious.

The final stimulus was to suggest a practical application for the shapes:- display plinths for a sales or exhibition area. This promoted new thoughts with 50% of the clients with evidence of more linear development.

The main responses are listed in order of frequency.

R E S P O N S E	First Stimulus.	Second Stimulus.	Third Stimulus.
STARTER. 	25		
	22	1	
	22	2	
	21	2	
	20	3	
	20	2	
	15	5	
	15	4	
	14	6	

RESPONSE	First Stimulus.	Second Stimulus.	Third Stimulus.
	12	8	
	4	10	
	3	8	
	3	7	
	-	15	
	-	10	

R E S P O N S E	First Stimulus.	Second Stimulus.	Third Stimulus
	-	6	
	-	2	10
	-	-	8
	-	-	5
	-	-	3

A P P E N D I X V

Vinyl moulding materials are available from a number of suppliers under different trade names. Three grades are generally available with temperatures ranging from approximately 140°C to 180°C; the higher temperature vinyls are more rigid. All are prepared in the same way - the vinyl block being cut into small pieces and heated slowly over a low heat source. A domestic non-stick pan is ideal for this purpose, and a continual stir essential.

The relatively high temperatures involved and the adhesive nature of molten vinyl make this a very hazardous process; it is only suitable for mature children and must be closely supervised. Vinyl moulds are ideal for use in conjunction with plasters, the oily surface makes it unnecessary to use release agents and the flexibility allows versatility in design, undercuts presenting no problem. The mould should be cleaned with soapy water between casts.

Damaged, or worn out moulds, can be recycled up to thirty times before the loss of elasticity makes the material ineffective. Almost any rigid material can be used as a pattern for mould making, as long as it will withstand the temperature of the molten vinyl. Porous materials must

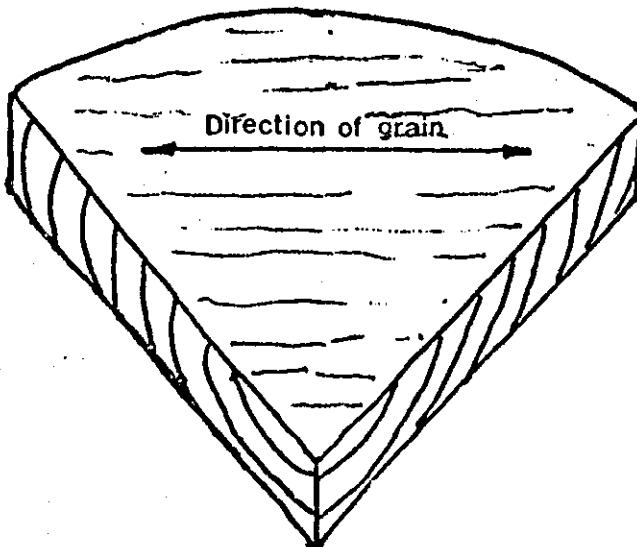
be well sealed, otherwise the expanding entrapped air will produce a bubble formation in the mould. Metal patterns should be warmed before use to counteract premature chilling of the vinyl.

Silicone rubber is a much more versatile material than vinyl mould and safer to handle, eye protection and disposable gloves, worn when adding the catalyst and working the uncured mix, being the only precaution necessary. The range of pattern materials is greatly extended when using silicone rubber. Wax, for example, is not affected by the temperature of the cure. Moulds produced in this material give much finer detail. The slow cure, generally twenty four hours, gives ample time to deaerate the catalized mix using a vacuum of 29 Hg. The moulds are much more rigid and some silicones will withstand temperatures in excess of 450° C, producing mould cavities suitable to accept low temperature metals. Unfortunately the cost of silicone rubbers is such that their use is not generally viable in school.

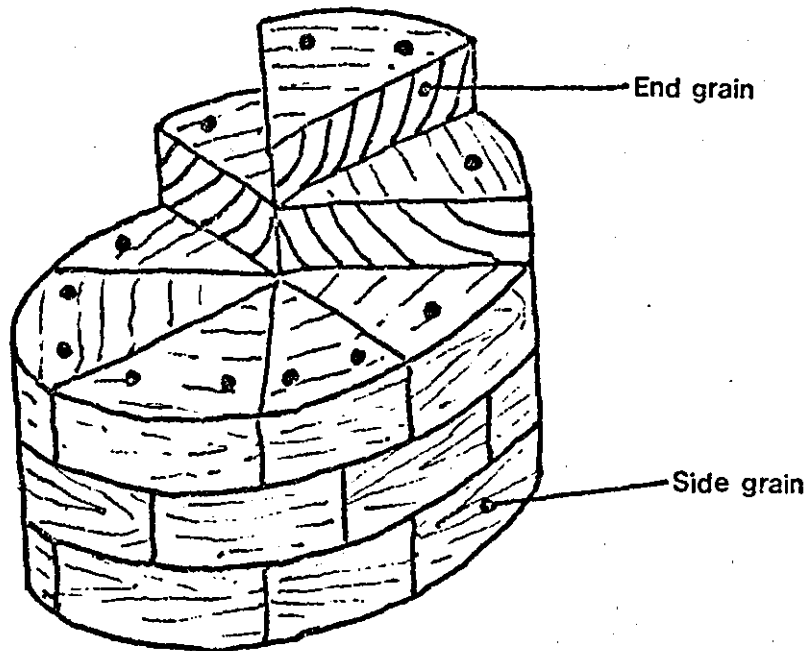
A P P E N D I X VI

Pattern making is one of the most demanding branches of engineering. The traditional skills of this trade call for the pattern maker to produce precision components in timber that retain their dimension and shape. They are constructed in such a way that the end grain of the timber is never exposed to the surface of the pattern.

To achieve this, laminated constructions exposing only the side grain of the timber form the basis of all pattern structures. The majority of these are produced from cheese shaped segments illustrated below.



These are glued together in layers and secured with screws.



When the glue has dried the screws are removed from consecutive laminations and replaced with wooden pegs. Such a shape when turned is very stable, shrinkage leading to dimensional changes and distortion is impossible. Similar constructions are used in the construction of non-cylindrical shapes.

The material costs of patterns made in this way is very economical, and where accurate long life patterns are required in schools it is advisable to adopt these well established principles. Industrially these labour intensive methods of pattern making have led to the consideration of alternative materials. Epoxy resins are easily cast into

intricate shapes, have a very high shock resistance, are dimensionally stable and are easily blended with metal fillers. These qualities make them ideally suited for pattern production; reproduction; and for press tools, used in conjunction with high volume mould and core manufacture.

The use of such material now makes many aspects of the craft a semi-skilled operation, but the cost of Epoxy resins is such that they are outside the range of materials available for schools. Similar processes, however, can be developed using hard casting plasters for mould and core making in schools.

A P P E N D I X VII

Plasticine and similar modelling media are very useful to illustrate the basic properties of metals, their behaviour within the temperatures of 0° to 70°C being similar to many metals. They show increase in malleability with increase of temperature, and demonstrate simply hot and cold shortness across the heat treatment range.

Strips of plasticine rolled together, when sectioned, illustrate the grain flow of bent and forged metals, elasticity and stress fractures being easily demonstrated.

Prototype castings are easily modelled in these materials, with a fair degree of accuracy, and when refrigerated are sufficiently firm to mould in normal foundry sand.

A P P E N D I X V I I I

British Gypsum produce fine casting plaster for use in schools. This is ideal for simple carving and casting work, and is available in 50kg quantities. Some of the more expensive 'alpha' plasters are supplied in 2kg packs. Foundry plasters are available in 25kg sacks and like all plasters have a short shelf life. This is a manufacturer's safeguard, and where industrial users are concerned with very close quality control, this is of paramount importance. But this should not deter schools from purchase. With careful storage, the recommended shelf life can be tripled without any detectable loss in quality.

A P P E N D I X I X

Water Fillable Polyester Resin is generally referred to as W. F. P. This is a very exciting and versatile material with considerable potential in many areas of craft and Design education.

W.F.P. resins are special polyester resins which are readily emulsifiable with water and when cured are white in colour. They can be readily cast producing excellent detail, in a variety of mould cavities. The vinyl range of moulding media is very suitable. W.F.P. can be cast into W.F.P. The degree of extension can be varied, a one-to-one ratio of water to resin being recommended. Fillers will further increase the volume and add hardness and rigidity to the cured resins. Calcium carbonate is ideal but does lead to some deterioration in machining qualities.

When emulsified with water on a one-to-one basis, the cured resin has excellent working properties, responding equally well to the hand and machine tools associated with both wood and metal working processes.

W.F.P. has been used in the Aerospace Industry for some years for proving N.C. Tapes prior to release for

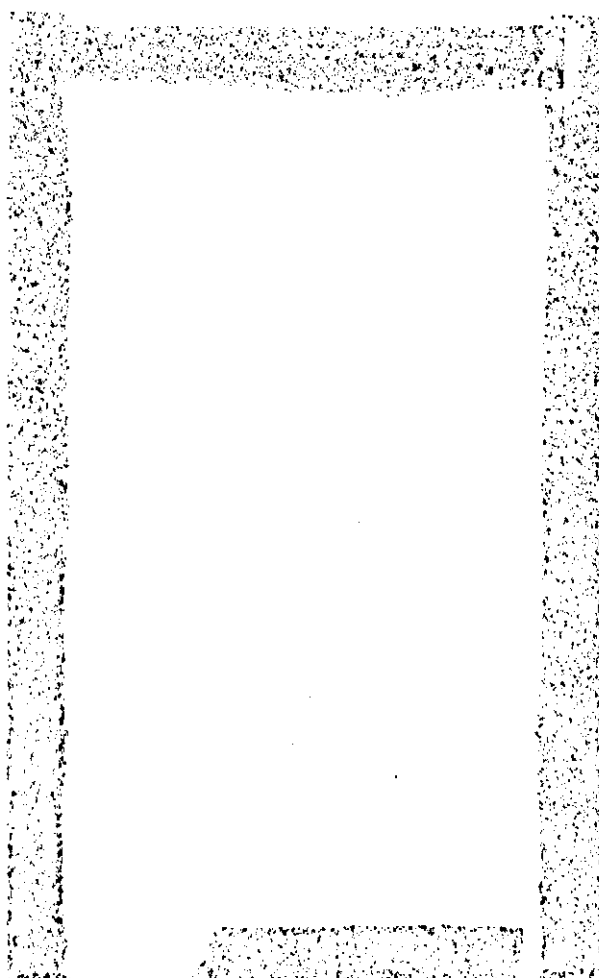




Plate I. The ribbon-like swarf of W.F.P.

production, when fine detail machining runs are being tested. One of its unique properties is that the water captivated within the cured resin acts as coolant, lubricant, and binder, producing ribbon-like swarf. (Platel) Thus the health hazards generally associated with the machining of polymers and high density urethanes do not occur. This is of vital significance in schools where extraction systems for airborne dust are virtually non-existent.

Production of rounds, squares, flats and irregular blanks for machining or bench manipulation, with the minimum of waste, presents no problem. These are easily cast in simple cardboard moulds.

The cost of W.F.P. is such that its use would cut significantly capital expenditure, reducing the consumption of both steel and timber.

The recommended shelf life of W.F.P. is six months. If after this period resin remains, it should be emulsified and cast into stock sizes for future use.

The controlled use of this material in schools would lead to :-

1. Reduction in material costs.
2. Reduction in tool damage and tool wear.
3. Increase in safety to inexperienced machinists.
4. Reduced machine maintenance.
5. Increase in confidence of the trainee operator.

W.F.P. is manufactured by Scott Bader Synthetic Resins Ltd., and only supplied in industrial quantities. Authority bulk buying and distribution, however, could easily make it available to schools.

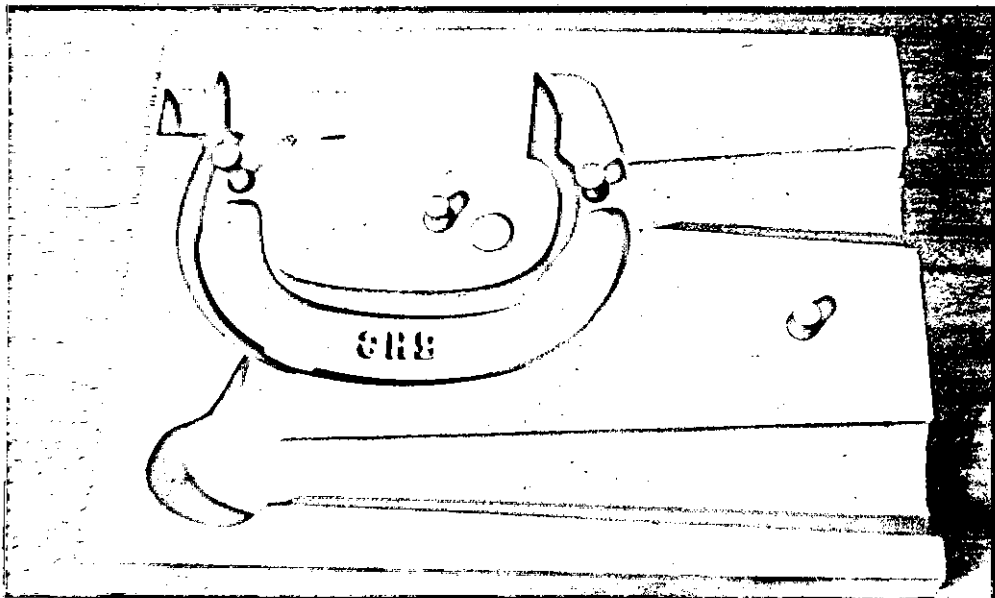
In many respects this is a superior teaching material to steel and at the current market price one twelfth of the cost.

"Toysteel" recently marketed by Denford Machine Tools, for use in school is currently three times the price of W.F.P. This is a very inferior material with a very limited application, and, in the absence of efficient extraction units a health hazard. Urethane dust can cause severe irritation.

A P P E N D I X X

When aluminium is cast into aluminium a heavy carbon or plumbago deposit is necessary to prevent mould scorch.

Speedy ejection is essential (within seconds of solidification), shrinkage occurs very rapidly and unless removed the cast will cling to the cavity and shrinkage cracking will occur. Ejection pins strategically placed will effect this ejection, as illustrated below, and in the accompanying video. The weight of the mould on the foundry floor is generally sufficient to operate the pins.



A P P E N D I X X I

Sand cores can be used very effectively in conjunction with permanent metal moulds; bushes are easily cast in situ and casts can be made round fixed components. See accompanying video for illustration of these techniques.

A P P E N D I X X I I

Early in the 1960's The International Lead Zinc Research Organisation recognised the need for a zinc alloy that would be acceptable for use in the gravity casting field. Copper and aluminium alloys were already widely used, but the zinc compositions available required rapid cooling to develop satisfactory mechanical properties. These were only suitable for high volume die castings, where the steel dies, sometimes water cooled, ensured rapid solidification resulting in the small grain size necessary for mechanical strength.

The two sponsor laboratories and the one contractual laboratory involved in the research project reached agreement on the superior properties of a new zinc gravity casting alloy which became known as ILZRO 12. The findings were published in April 1966 in a paper prepared by Mr. Donald C. Henschafft, the metallurgical project manager for ILZRO inc.

This alloy, unlike standard zinc compositions used for die casting, was relatively insensitive to cooling rate, and when gravity cast, developed mechanical properties closely duplicating those of pressure cast zinc alloys. These characteristics, plus lower costs when compared to copper based alloys, suggested three possible areas of application;

these were listed in the paper as:-

1. Replacement for more costly gravity casting in cast brass or bronze alloys.
2. Use as a prototype alloy to prove out design feasibility of die cast zinc alloys.
3. Limited production runs where quantities preclude the use of pressure die casting.

In these areas ILZRO 12 proved outstanding because of its excellent castability, machinability, ease of finishing and the ability to reproduce fine mould detail.

The optimum nominal composition of the alloy was 12Al; 0.75 CU; 0.02Mg with the balance made up of zinc.

ILZRO 12 was not produced on a commercial scale, but as a direct result of the research programme a number of similar alloys were launched.

Mazak Ltd. now market KAYEM 12 which is very similar in composition to ILRZO 12 with virtually identical properties. Cost compares favourably with LM4 & LM6 by weight, but with a much greater density it is more expensive. Its recycling capacity, however, is such that much of the initial cost is offset. Its low metal loss and low melting costs further reduce expenditure. It produces virtually no fumes and

with sensible foundry care extraction units are unnecessary. Sand, casting plaster, high temperature silicone rubber, and permanent moulds all make acceptable cavities and no fluxing treatment is necessary. It exhibits excellent fluidity at 475°C and the relatively high aluminium content reduces dross to almost nil. The long freezing range alleviates most shrinkage porosity and there is no gas pick up below 520°C.

These factors make this alloy ideally suited for use in schools.

A P P E N D I X X I I I

Where small accurate 'as cast' components are required in school, a viable technique is to invest disposable patterns, made in foundry or other available 'alpha' plasters, in investment plaster.

Such disposable patterns are easily made in vinyl moulding materials, or even more accurately in silicone rubber moulds. These, when sealed, can in turn be invested in investment plaster, removal being facilitated by carefully breaking the plaster patterns and blowing out the pieces with a compressed air jet. In this way perfectly mating castings can be produced, draw on the pattern not being necessary; even small undercuts are possible using this technique.



A P P E N D I X X I V

One of the values of investment plaster lies in its capability to accept high temperatures. This provides the facility to pour metal into hot moulds. Where alloys such as KAYEM 12 are involved that are not affected by a slow cooling rate, the insulating properties of the plaster prevent rapid solidification. The charge remains molten for long periods giving ample time for atmospheric or vacuum pressure to be applied, resulting in surface finish and fine detail not otherwise possible.

A P P E N D I X X V

The industrial use of waxes as a pattern for precision investment casting in ceramic moulds is a fast developing technology. Microfusion, based in Gennevilliers, France, with branches world wide, are one of the leaders in this field.

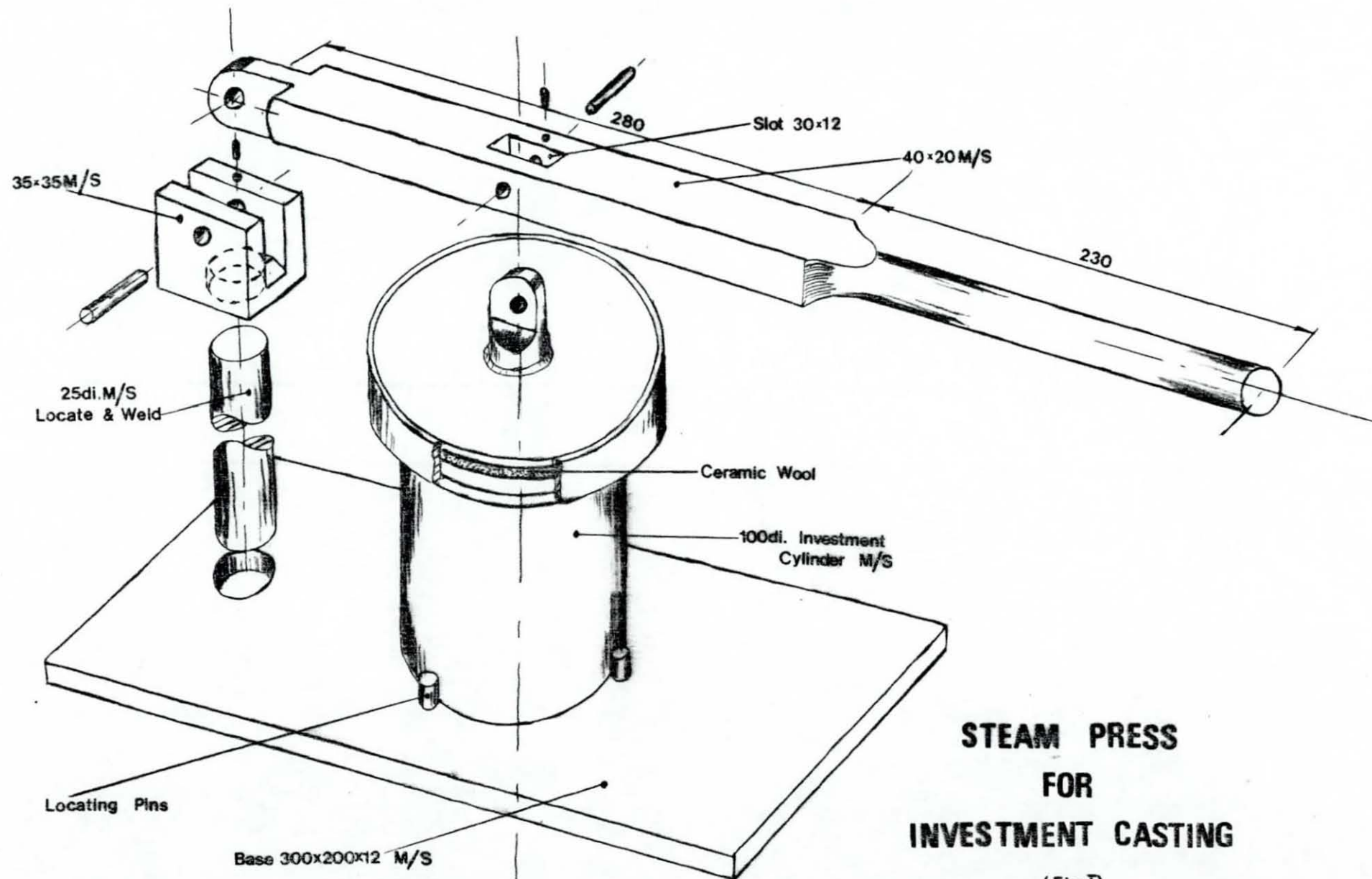
With this process economical high volume production is possible with many technical advantages. Complete suppression of machining and the casting of components, which have been traditionally forged or fabricated, is now commonplace, allowing design engineers a much greater latitude of thought.

In the past thirty years the process has progressed to the use of much more sophisticated alloys. In 1973 (after a three year research programme) titanium based alloys became a commercially exploitable proposition, and such alloys are now used extensively by Microfusion in the production of high class castings for the Aerospace industry. 'As cast' turbine blades, for example, are now produced in this way.

Waxes used in conjunction with this and similar processes vary considerably in hardness. This is of little consequence when selecting waxes for use in school, any available injection or dental wax will meet all requirements.

Dental wax can be worked with considerable precision.

Frequent immersion in cold water is necessary to maintain rigidity when working, and completed patterns, awaiting investment, should be stored in water. With practise a very High glaze can be imparted to wax patterns by rotating them close to a naked flame.



A P P E N D I X X V I

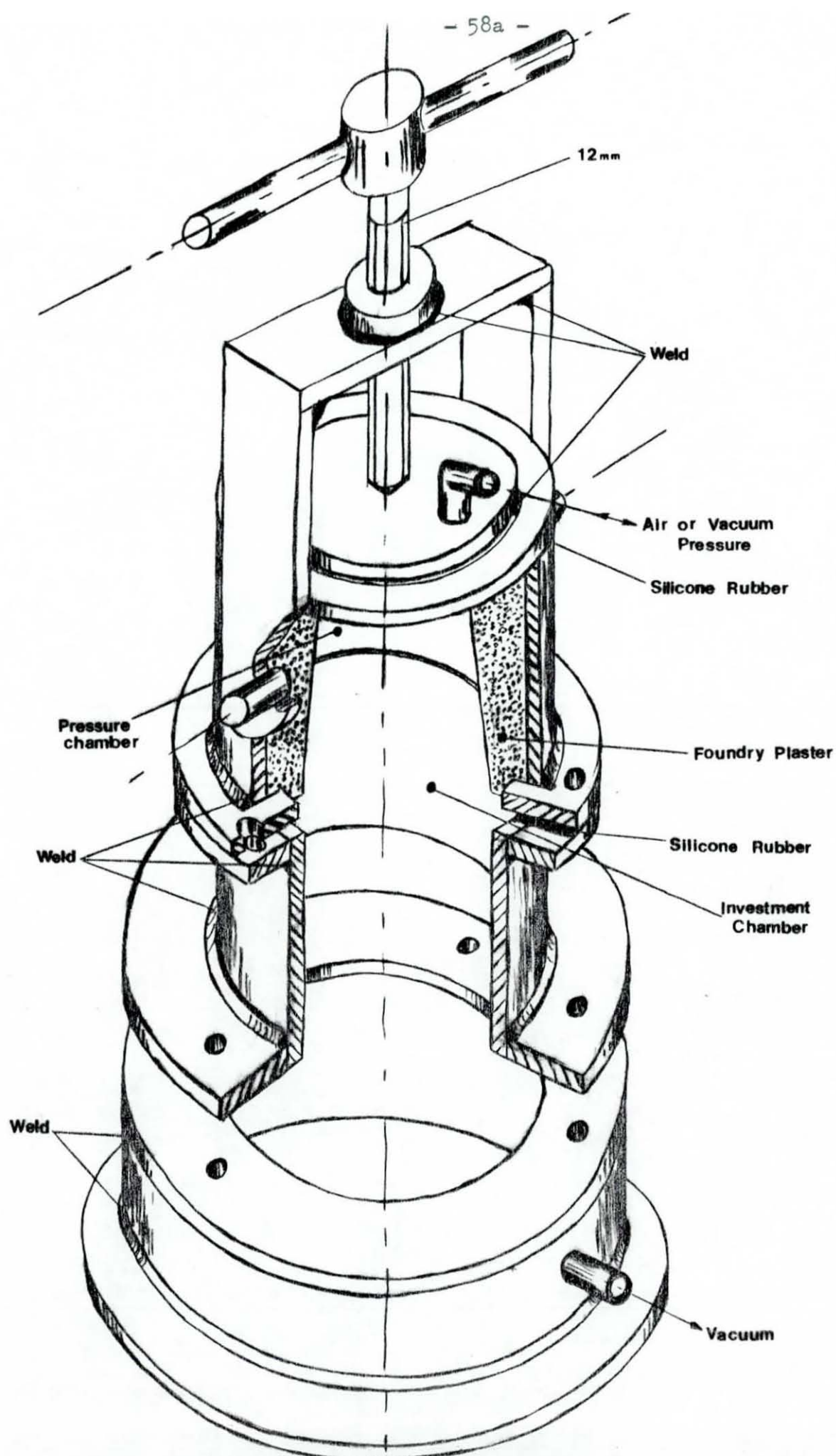
The basic concept of pressure casting is frequently misunderstood. The high pressures involved in die casting give rise to doubts in connection with workshop safety.

To be effective the pressures involved in this process need only be very small; minus five or plus five atmospheres being sufficient to give significant benefits.

Such pressures can be applied by centrifugal force, a process generally associated with precious metals, by steam, vacuum, or air.

By far the simplest technique is a steam press as illustrated in Figure I. The investment chamber is removable for stoving and positioned by locating pins on the base plate. The loose lid which is raised and lowered by the lever, captivates a pad of ceramic wool. This is moistened with water and lowered on to the charged chamber, pressure being exerted by the expanding steam as the moistened pad contacts the molten metal in the sprue.

The design of pressure casting systems is very much a matter for the individual, the size of the investment chamber being the determining factor. This must be stoved



**LOW PRESSURE OR VACUUM
CASTING CHAMBER**

(Fig. II)

in an oven capable of 700°C. The capacity of the oven, therefore, dictates overall dimensions. The system illustrated in Figure II is designed for both vacuum and air casting.

When air is used the bottom chamber is removed. The investment chamber is generally used hot at a temperature just below that of the molten charge, the pressure chamber is secured to the Investment chamber, a high temperature silicone rubber ring forming an airtight seal. Note the tapered Herculite plaster lining, this allows removal without damage should there be any overflow of metal in the riser. A ceramic diaphragm is generally recommended between the chambers, scored with a central cross. This holds the charge of molten metal. In this case the top chamber should be pre-heated. When charged and sealed pressure is applied, this ruptures the diaphragm, molten metal entering the mould cavity. Pressure should be maintained during the period of solidification.

In practice the use of a diaphragm frequently causes problems, ceramic inclusions may be washed into the solidifying casting or the diaphragm may fail to rupture. A pour directly into the pre-heated mould avoids such problems, and the insulating nature of the investment plaster gives ample time to secure the top of the pressure

chamber and apply pressure before the onset of solidification.

Should a vacuum system be preferred the bottom chamber is secured, reduction of pressure occurring simultaneously from both sides of the investment chamber, the porous nature of the investment facilitating extraction of air through the plaster.

A P P E N D I X XVII

The pressure die casting process produces accurately dimensioned parts by forcing molten metal under pressure into split metal dies which are opened, allowing rapid ejection via strategically placed ejection pins. The principle was established well over a hundred years ago, the first patent being taken out in 1849 by Sturgiss.

At this time alloys of lead and tin provided the charge; although these were easy to cast their limitations of low mechanical strength presented severe limitations on their use.

The extension of the technique as a commercially viable proposition was delayed until the development of strong alloys suitable for die casting. High melting point alloys were tried but were too severe on the expensive steel dies.

Dependable zinc alloys were developed in the early 1920's. Brauer & Peirce discovered that the impurities tin, lead and cadmium were the root cause of the disadvantages from which the zinc alloys were suffering. When the commercial production of zinc of purity exceeding 99.99% began in 1930 really stable zinc alloys were produced. The manganese content was reduced down to 0.04%. This still off-set the

effect of any trace elements of tin, lead and cadmium and in addition improved the hot shortness that had been a problem with alloys with higher manganese content, the resultant castings being far less liable to crack when hot. The zinc alloy used in die casting today contains approximately 4% aluminium and 0.04% magnesium, its composition being strictly controlled by British Standards.

Zinc is by far the most widely used die casting metal. When subjected to the high injection pressures of industrial production it produces castings of fine detail finish and dimensional accuracy and the rapid chill in the die cavity ensures a solidified structure of small grain size and optimum strength.

In the school environment such a process has little or no application but a number of the principles and the alloys involved have a place in the educational field, and a working knowledge of them is helpful in developing design thoughts. Zinc alloys present fewer health hazards than many of the other metals smelted in schools. The melt should be rapid, the furnace and pot being pre-heated before charged. Care should be taken not to exceed the recommended pouring temperature, as gas pick up leading to porosity occurs at around 520°C and constant supervision

of the melt is, therefore, essential. Where a thermostatically controlled furnace is not available, the crucible should be removed on reaching the recommended pouring temperature. If left in the furnace, even after close-down, the residue of heat will cause unnecessary temperature rise.

Mazak 3 produced for the pressure die casting industry is suitable for use in schools. Its melting costs are low - there is very low metal loss, virtually no dross; degassing is not necessary, castings are clean, providing good detail; it is relatively free from shrinkage and gas porosity, there is no gas pick up below 520°C , it is easy to machine and with chromate primer takes a paint finish well; it is corrosion resistant and has more than adequate tensile strength and hardness, all this providing it is cast in metal mould cavity, and rapid chill ensues. Sand is an environment totally unsuitable for this alloy.

The precision steel dies used industrially, frequently costing tens of thousands of pounds to produce, captivate the molten metal under high pressure so precisely that flash is almost non-existent. In school this precision is not possible and the pressure is not desirable. We must, therefore, rely on gravity if zinc is to be cast in schools. The quick chill must come from permanent metal moulds.

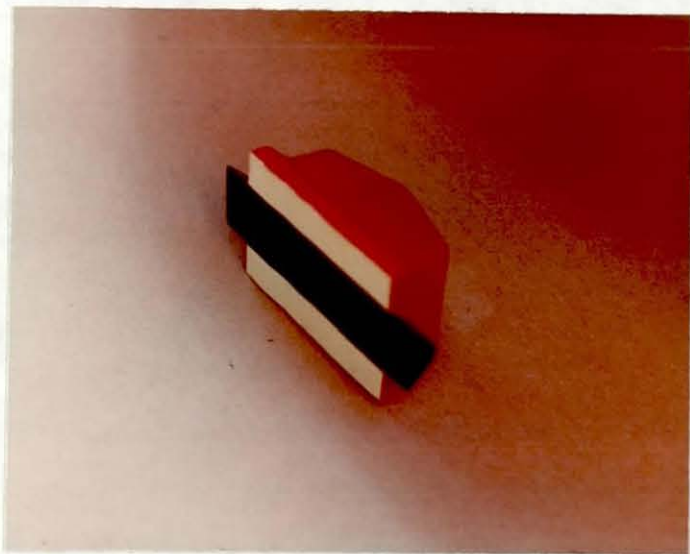


Plate 4. The colour coding of patterns.



Plate 5. An odd side pattern.

These are easily made by a reversal process using foundry plasters and existing patterns. A variety of these are generally available in schools; some are more easily adapted than others.

The simplest patterns have draw from one face only (Plate 4), note the colour code; this is British Standard. The red represents the main body of the casting; the black represents the core prints which locate the cores and the yellow indicates the surfaces to be machined - all important information to the moulder.

The odd side patterns have draw in two directions and the parting line is not always in the same plane. The moulding of these is a little more difficult and involves setting up the pattern first in a throwaway box. (Plate 5)

The pattern located by brass dowels (Plate 6) is known as the split pattern. The cope sided half with the female locations is moulded first with its mating side removed.

Most split patterns can be mounted on plates. This is frequently done industrially to speed the moulding process; to reduce the amount of skill required in moulding,

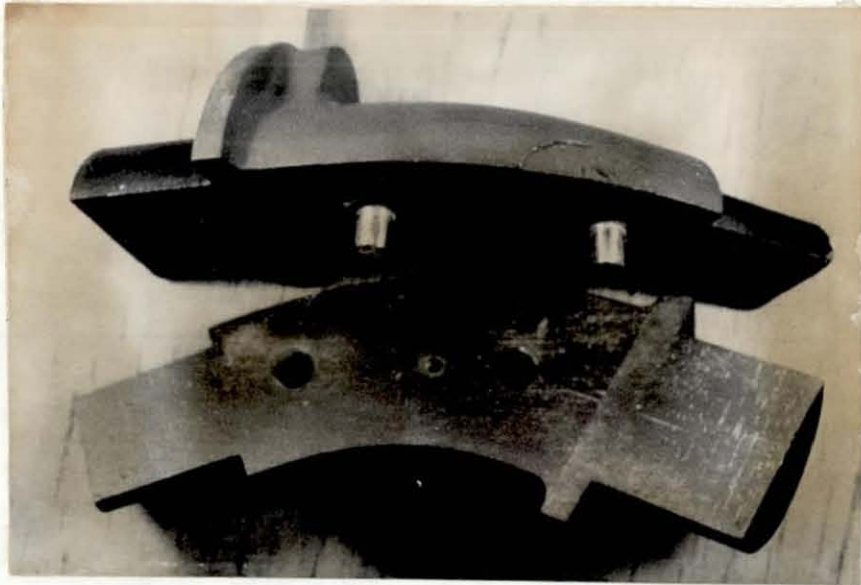


Plate 6. A simple Split pattern.

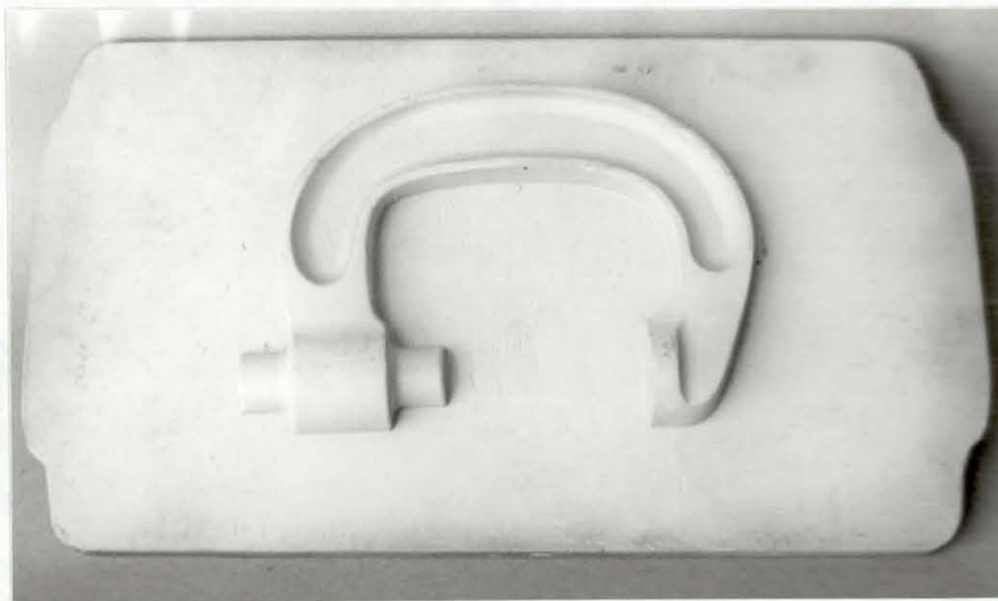


Plate 7. An aluminium match plate pattern.

or to adapt the pattern for machine moulding. The plate fits between the faces of the moulding boxes and forms no part of the mould. These plate patterns are the most convenient patterns to use when making plaster reversals to mould and cast permanent metal moulds for use in schools. The illustration (Plate 7) is in fact a match plate pattern, so called because it is the copy of an existing plate pattern. This particular match plate is cast in LM6, but could be made with equal success in a variety of resins or with a foundry plaster some of which are capable of holding very high compressive loads. A further advantage of presenting patterns to children in this form is that the originals, which may have taken many hours to produce are not subjected to the ravages of the novice moulder.

When preparing a plate pattern for a plaster reversal to produce a permanent mould, it may be necessary to extend the plate in order to build in the pouring system. (Plate 8) As a general rule the ingate should be at the lowest point of the mould cavity and the riser at the highest. In this way the air in the mould cavity is expelled by the natural displacement of the metal. A pouring and feeding system such as this produces a more versatile mould allowing a number of different alloys to be considered to fill the cavity. Once the pouring system is incorporated in the plate pattern it should be

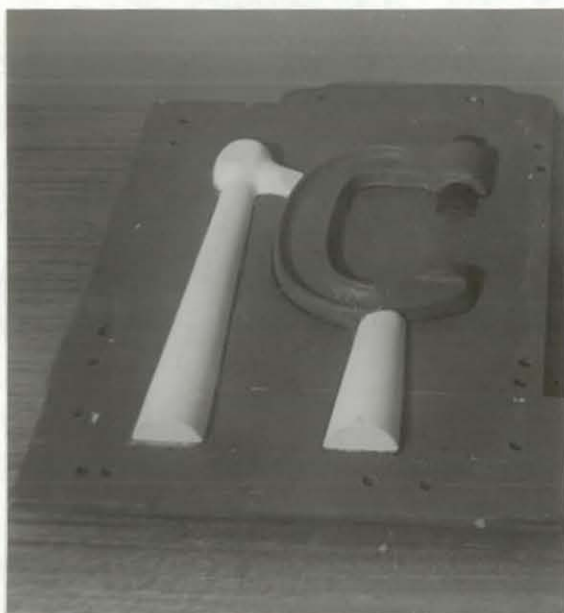


Plate 8. A plate pattern for a permanent mould.
Note built-in pouring system.

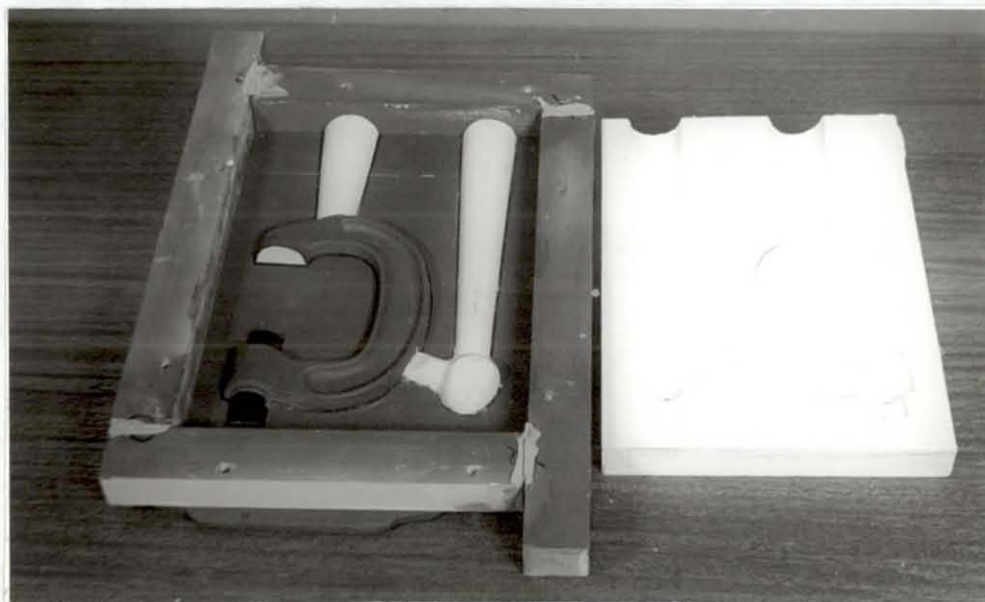


Plate 9. Plate pattern, prepared for a cast in foundry plaster.

surrounded by a frame, and sealed in readiness to accept the plaster. (Plate 9)

The Patrix range of plasters supplied by Foseco Ltd. are specially designed for foundry work. Their use is clearly set out in the Foseco leaflet number M9. As with all types of plasters for the best results the mixing ratio of plaster to water should be strictly adhered to.

Patrix 1, Patrix 2 and Patrix 100 are all suitable for use in schools. They all mix in water and set with high dimensional accuracy. With Patrix 1 expansion is negligible; with Patrix 2 and Patrix 100 the slight expansion is of little consequence for the degree of accuracy required. Patrix 100 is the hardest of the range and for this reason is arguably the best for educational use.

When mixing plasters cleanliness is essential. Dirty water and dirty utensils will affect both expansion and setting time; plaster should always be added to the water in the correct ratio, never vice versa, and allowed to soak for the prescribed time, generally one minute. Stir from the bottom, preferably with the hands avoiding turbulence, which would lead to the entrapment of air and a porous structure. The pour into the mould, coated with a stripping

agent (Stripcoat 1 or Ambersill 1 are both suitable) should take place within five minutes of mixing and be smooth and steady away from the important detail of the cast. Gentle tapping of the mould prior to the initial set will release any air bubbles which may have been trapped.

All the Patrix plasters have approximately the same setting time and can be removed from the mould after one hour. At this stage the plaster is soft and can be patched if necessary, and carved with ease, making any minor alterations or repairs possible. After drying with free circulation of air for twenty four hours the compression strength can be improved further by stoving at 60°C for one hour.

With careful use and storage, the life of these cured plasters is many years. To ensure this the manufacturers recommend that they be coated with shellac and stored in air-tight containers.

An alternative to this is a cellulose spray. This has the additional advantage of improving the surface finish. Sealed in this way, even stored on open shelves, plasters have still been perfectly sound after a fifteen year period. After two years they are subject to a detectable dimensional change, but this is of little consequence in school.

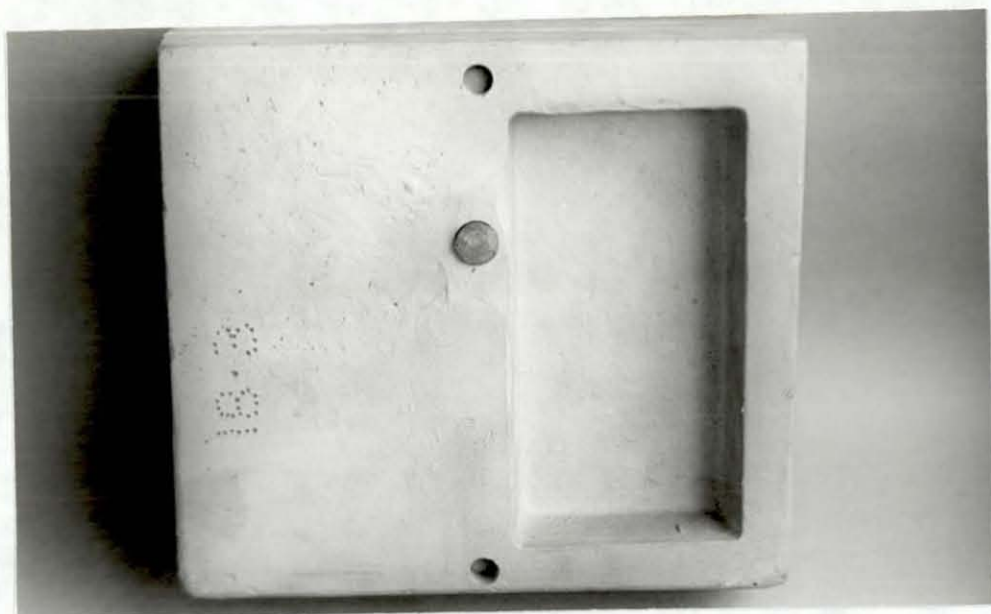


Plate 10. A sink in the back of a permanent mould reduces the bulk and gives a more uniform cross section of metal.

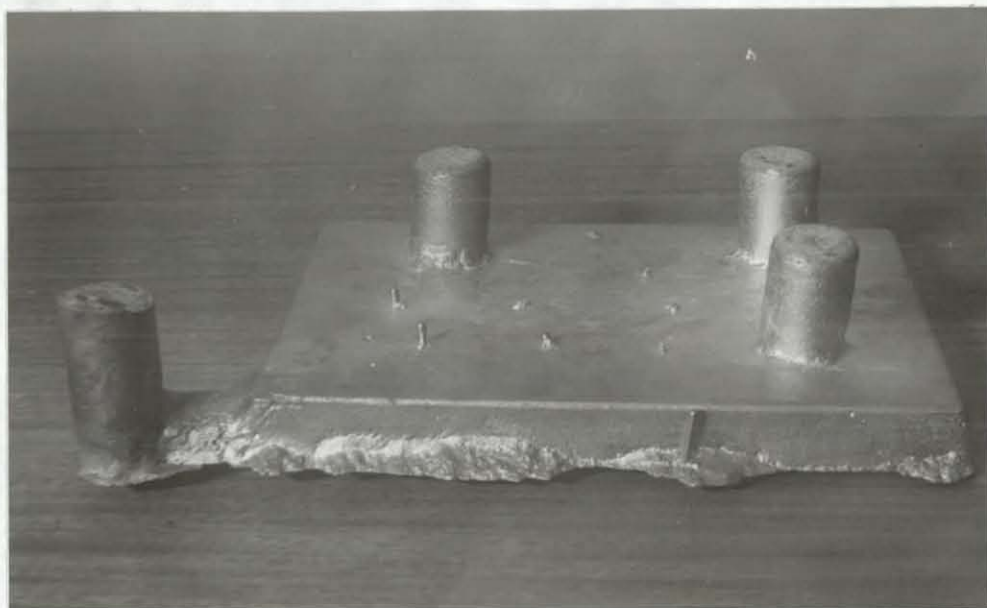


Plate 11. The use of feedol eliminates the need for large feeders, effectively increasing the capacity of the crucible.

The moulding of the pattern is straight forward. Lifting plates can be cast into the back of the plaster, but this is not necessary; with a sensible draw on its edge its own weight will leave it on the moulding board when the box is lifted. The main problem in school generally revolves round the bulk of the casting. This is frequently such that the capacity in the crucible is close to its limit and short runs become a possibility. Casting sinks in the backs of the plasters can often overcome this. (Plate 10) This has the added advantage of giving a more uniform cross-section to the casting resulting in fewer shrinkage and warping problems.

Shrinkage problems, during the solidification of aluminium, have in recent years been greatly reduced. The foundryman's old adage that the weight of metal feeding the casting should equal that in the mould cavity no longer applies. Exothermic burns in the risers activated by the application of feedol, maintain a liquid head to the freezing metal and eliminate the need for huge risers. This is well illustrated in (Plate 11) Note the relatively heavy section of the cast and the small risers. The casting is sound throughout and the top surface is perfectly flat, showing no sign of shrinkage. The use of feedol effectively increases the crucible volume in excess of 25% making more metal available to fill the mould cavity and less scrap to recycle.

A P P E N D I X XVIII

Damage to patterns is an ever present problem in all foundries, and in school the novice moulder is capable of causing irreparable damage even when closely supervised. It is advisable to use aluminium copies whenever practical. Where dimensional accuracy is important a double shrinkage allowance should be made on the original pattern. Very accurate copies of existing patterns are easily made in normal sand moulds, an oil sand facing will produce even finer surface detail.

The production of aluminium patterns is common industrial practice. These are generally in the form of match plate patterns. Industrially these are frequently cast in Herculite Metal Casting Plaster in conjunction with a low pressure chamber. This is not a very viable process. The casting plaster is not available in small quantities and the cost of the lengthy stoving necessary for success makes its general use uneconomical. Gravity sand cast plate patterns are more than adequate for use with children.

The plate patterns produced for the production of permanent metal moulds explained in Appendix XVII are also useful to reproduce in this way. These aluminium plates,

with the pouring system incorporated, can be used to illustrate a number of casting processes. They provide the facility to make shell moulds using oil bound, self setting, CO₂ core sands, and casting plasters.

A P P E N D I X XIX

Where foundry work is practised in schools, patterns representing hundreds of hours of work frequently languish in cupboards, or gathering dust on store room shelves. As a teaching aid these are invaluable and should be made available for children to handle. The drawing office is the obvious place for this to occur. The ability to visualize the reversal of a mould cavity incorporating cores and overhangs should be encouraged; tasks involving the translation of such mould cavities into the resultant casting, through orthographic and three-dimensional representation help to develop three-dimensional awareness. The availability of cost effective materials, such as Water Fillable Polyester Resins and their bulk fillers, presents the opportunity to prepare realistic aids representing a wide range of complex moulding cavities for children to handle and translate. Only by familiarisation can they begin to understand the concept of an aspect of design thinking that is too frequently ignored.

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B I B L I O G R A P H Y

Technical literature and research papers:

British Gypsum Data Sheets.

Downland Machinery & Materials for the Reinforced Plastic Industry.

Flamefast Ltd. Technical Publications.

Foseco Foundry Information Sheets.

Foseco Product - Data Sheets.

Kayem 12 - Gravity Casting Zinc Alloy Properties and Applications Imperial Smelting Corporation.

Low Melting Point Alloys Properties & Applications. Frys Metals Ltd., (Technical Publication LM 12)

Mazak Zinc Alloy for Pressure Die Casting - A booklet for designers.

Mecrofusion and Technical Data on precision lost wax casting.

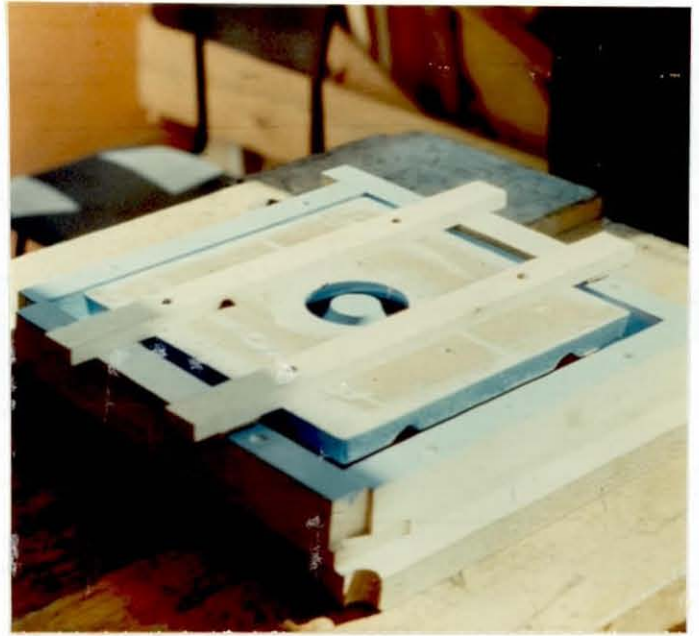
Research Paper ILZRO 12 - Mr. Donald Herschaft International Lead Zinc Research Organization Inc. 1966.

Scott Bader Technical Bulletins.

Toysteel Denford Machine Tools Ltd.



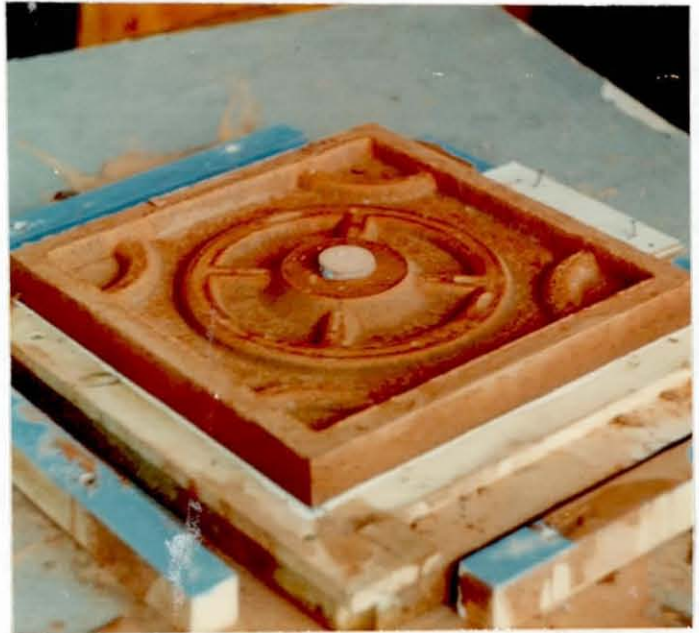
Open mould for patric cast.
Note recesses to give
uniform metal section.



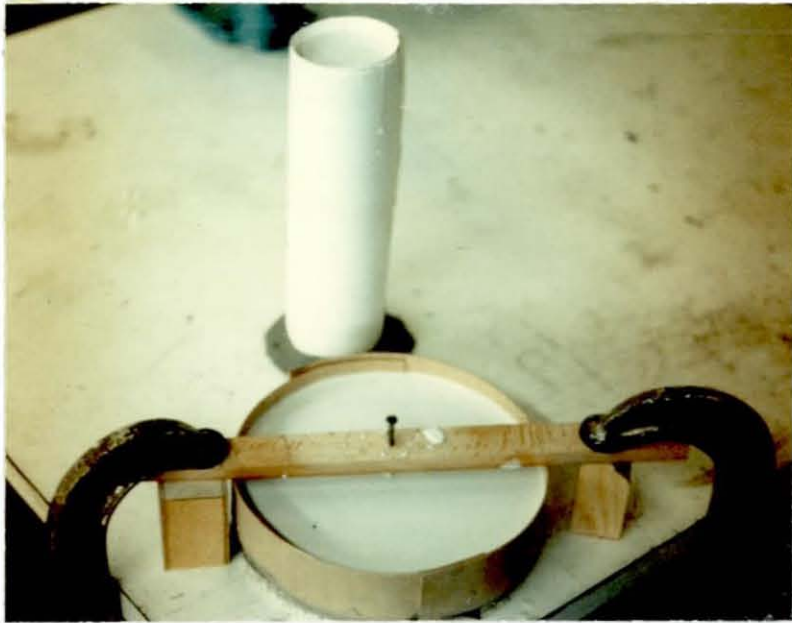
Mould closed ready
to accept plaster.



Plaster pattern for
permanent metal mould.
Wooden pattern removed.



Reverse of plaster pattern
showing sinks to
equalise metal section.



Casting the inside of
shell mould in W.E.P.



Cast complete, with pattern,
also in W.E.P., removed.



Completed shell mould in
W.E.P., note thickness
gauges - small brown dots.



Traditional shell mould
in laminated timber.



Very fine detail is possible
in W.E.P.



The ring on the left located
on a W.E.P. pattern.



W.E.P. can be worked by all hand and
machine tools: note the shavings
made by this smoothing plane.



Mould for bench end made in
G.R.P. and timber. Impression
of school crest taken from
plasticine original.



Concrete cast from mould
on the left.



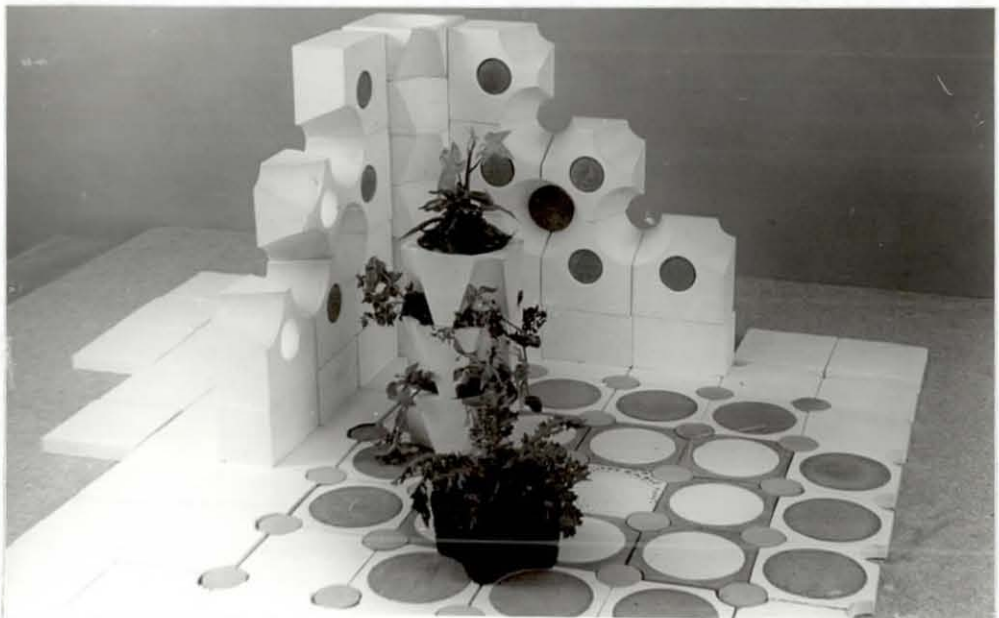
Wrought iron forging of stylized Impala,
on clay plinth, later used as a pattern
to cast brass base.



Permanent metal mould in LM6 - resultant
castings, resting in mould cavity, made in KAYEM 12.



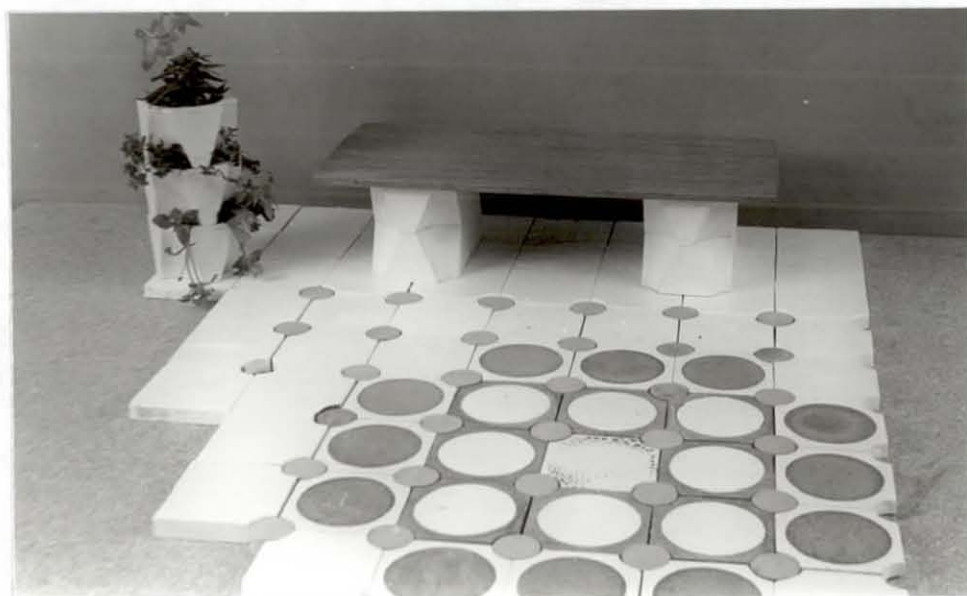
Time lapse film in progress, illustrating the use of three dimensional tools to develop design thoughts.



Ornamental planting pillar.



Further design thoughts (garden furniture) - motivated by the use of three dimensional aids.





Lost wax gravity casting in
KAYEM 12



Wax sculpture of the above for
investment nearing completion.



Wax for stylized Impala ready
for investment; note built in
feeder to horns and body.

