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PROCEEDINGS OF THE FIFTH NATIONAL SCULPTURE CONFERENCE

MAY 9, 10, 11, 1968
THE UNIVERSITY OF KANSAS

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NATIONAL SCULPTURE CENTER
THE UNIVERSITY OF KANSAS
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FOREWORD

Interest demonstrated by the plastics industry organized by Felix Arnold nurtured plans for the Fifth National Sculpture Conference in spite of a dirth of financial support. Once established, plans drew excellent participation on both program and conferee levels.

Program participants were asked to supply papers for publication in the *Proceedings.* To retain the atmosphere of the meeting, transcriptions were supplied to participants led by conference circumstance from their prepared texts, as well as to panel members who were asked to edit their participation for clarity and accuracy. We are grateful for the fine cooperation received.

Physical and financial assistance provided by the community, though token in terms of the total effort, was infinitely important to moral sustenance. We appreciate the cooperation of the Canada Council, which expanded participation by Canadian sculptors. We remain particularly grateful to the Kansas Cultural Arts Commission for financial support, which made possible the participation of John Canaday as well as the printing of these *Proceedings.*

Elden C. Tefft, Chairman
Fifth National Sculpture Conference

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INDUSTRIAL DEVELOPMENT OF PLASTICS

FELIX ARNOLD
IMCO CONTAINER COMPANY

As the result of a growing shortage of elephants and a demand for ivory billiard balls in 1868, the plastics industry is this year celebrating its centennial. One hundred years ago, John Hyatt discovered the first synthetic material. This plastic was called celluloid. Hyatt had set out to make a synthetic from which billiard balls could be manufactured. Hyatt had combined nitric acid, cotton, and camphor to form this first plastic. His discovery became an immediate success. Consequently, industry and elephants are most happy.

It is interesting to note that the original celluloid plant has been in continuous production during the past 100 years. This plant had since become a part of the Celanese Complex in Newark. When touring the original plant site, the things which will impress you the most will be the fire stations—not just a fire hose, but a fire station at each corner of the building.

Needless to say, cellulose nitrate is highly flammable. During the years that followed its discovery, cellulose nitrate gave way to an entire family of plastics called cellulosics. Then, in 1946, cellulose nitrate found a new use as a sheathing for rocket powder. Now both powder and sheath burn to propel the rocket.

Some 40 years after Hyatt's discovery, an American chemist, Dr. Leo Baekeland, in search for a better varnish discovered the second plastic, phenol formaldehyde. Dr. Baekeland, through his process, was able to control the normally violent reaction which occurs when combining carbolic acid (phenol) and formaldehyde. Dr. Baekeland really didn't know what he had discovered until Richard Seabury, a rubber manufacturer, became interested in this new material. Using Dr. Baekeland's material, Mr. Seabury molded some electrical parts. This uncertain beginning gave birth to "Bakelite" the trade name of the company founded by Dr. Baekeland, the Union Carbide Company.

It seems Dr. Baekeland had blown up half the countryside trying his reaction and was asked to please leave Belgium. He did, and later became a citizen of the United States.

This story of Dr. Baekeland's problem with the reaction in Belgium may or may not be true, but it sounds good.

During the next 25 years, the plastic industry was dormant relative to new discoveries. Then, in 1926, the tempo of the industry began to quicken and the following outline can be introduced:

In 1919 Adolph Skitler discovered casein. It is the result of reacting the protein of skim milk with formaldehyde, and is a thermosetting resin. You will best recognize this material as "Elmer's Glue."

In 1926, the alkyds. This material is a thermosetting polyester. Currently the alkyd family is being closely studied. It is expected that some major breakthroughs will be made with this material in the near future. The aniline formaldehyde resins were also developed in 1926.

In 1927 two materials were developed. Cellulose acetate and polyvinyl chloride. With the discovery of cellulose acetate, the cellulosic family began. Unlike other common synthetic plastics, cellulosics are not manufactured by polymerizing a monomer. They are produced by chemical modification of cellulose, a natural polymer. Polyvinyl chloride ranks third in annual sales volume behind polyethylene, and polystyrene. Vinyl sales for 1967 were over two billion pounds. There are three basic types of vinyl polymers. Suspension, dispersion, and co-polymer resins. Suspension resins are the most common and can be recognized as seat covers, tablecloths, and shower curtains. Dispersion resins are a liquid phase, a plastisol or an organisol resin and can be molded by hand or by other similar processes. Dispersion resins would, of course, be of interest to you because these materials can be hand formed, then heated and caused to be a solid. The co-polymer resins are best recognized as floor tile.

In 1929, urea-formaldehyde

In 1935, another of the cellulosic family, ethyl cellulose was introduced.

In 1936, acrylic. Acrylics are a water white substance available either as a polymer or co-polymer. Scientists first isolated the acrylic monomer in the early 1800's. It was through a normal course of events that the acrylics became commercially available. This material is commonly referred to as methyl methacrylate, lucite or plexiglas. Also in 1936 polyvinyl acetate was developed.

In 1938 four plastics were developed. Cellulose acetate. butyrate, polystyrene, polyamides and the acetal group. Cellulose acetate butyrate is another member of the cellulosic family. The styrene monomer is one of the oldest synthetic resins. The monomer having been first isolated in 1831. This material ranks second in annual sales volume. Styrene sales for 1967 were over two and one half billion pounds. The polyamides you will know as nylon. Mr. W. H. Carruthers of the Du Pont Company first invented nylon. One year later nylon was commercially available as hosiery yarn. During World War II nylon played an important role in the making of parachute cords and glider tow ropes. The acetal resins also you will know as delron. This resin is water white in color and is available as a co-polymer or a homopolymer. It is a strong, highly crystaline formaldehyde derivative. The Acetal group is the result of an attempt to develop a cross link thermoplastic. It was hoped that this new material would replace the die cast metals. They have served their intended purpose but are not a truly cross linked substance.

In 1939, two materials were introduced. Melamine formaldehyde and polyvinyllidene chloride. Melamine formaldehyde is the result of extended work on Dr. Baekeland's phenol formaldehyde. This material, because of its natural color, permitted pastel coloring in a thermoset material. This material moved directly into the tableware industry and you will best know it as Melmac dinnerware. Polyvinyllidene chloride is further development in the polyvinyl chloride group and is best known as seat covers.

In 1942 two materials. Polyesters and polyethylenes. Polyethylenes rank first in annual sales volume, and sales volumes for 1967 were well over three billion pounds. This material was planned, developed, and manufactured with a definite purpose in mind, that of an insulator. This material was developed in England and used during the blitz to insulate buildings and high line cables which had been bombed. You will best recognize this material today in squeeze bottles.

In 1943, two more materials, the silicones and the fluorocarbons.

In 1945, cellulose proprionate. This is another member of the cellulosic family.

In 1947, epoxy. This material became immediately popular as an adhesive and was used for tools and fixtures and this type application used with fiberglas. Also this material is sometimes confused with polyester.

In 1948 Acrylonitrile-butadiene-styrene. This is best recognized as uphostery and inner linings for airplanes because of its impact strength.

In 1956, the acetal resin.

In 1957 two more materials were introduced, polypropylene and polycarbonate. Polypropylene is probably best known as the material of the living hinge. The polycarbonate resins were developed primarily for safety gear. The impact demonstration for polycarbonate fire helmets was to place the helmet on the floor and drive the fire truck over the helmet.

Then in 1959 chlorinated polyether was developed.

In 1964 polyphenylene oxide and in 1965 the ionomers came into being. The ionomer resins constitute a family of thermoplastics materials. The term ionomer was coined by the Du Pont Company to describe polymers which are linked by ionic forces, as well as, covalent bonds. The ionic association modifies crystalline structure in such a way that most of the ionomers are highly transparent resins with excellent toughness and solvent resistance normally associated with a cross-linked polymer.

Being Specific

At this point it had become virtually impossible for me to keep up with material developments. Mainly because I could neither spell nor pronounce the generic names of these many materials. Not only were these new materials cause for concern, but old materials with their many modifications became a new problem in themselves. As an example, there are now well over one hundred different kinds of polyethylene. To more completely exemplify my point, a leading manufacturer makes this note about styrene. Because of the ever-increasing changes recently among the styrene polymers, it has become virtually impossible to compile a complete listing of all materials on the market today. The reader is, therefore, advised to consult the individual manufacturer for specific information. The point is you must be specific about the material to which you are referring.

The sculptor has long since discovered the attributes of traditional materials and has expressed these in his design—the weight of clay or stone, the grain of wood, and so on. But his palette of materials is fast enlarging while the limitations of materials diminish. For a sculptor to discover the essentials of a material, it will soon be necessary for him to have some knowledge of its molecular structure. He will need to speak in chemists' terms in order to acquire the material of his choice. And perhaps tomorrow he will call for the molecular structure which his design requires.

What About Tomorrow?

It is predicted that the growth of the plastic industry during the years between 1965 and 1980 will be well over seven hundred per cent. As a guide, world production of plastics during 1965 was 24 billion pounds. During the past year, 1967, plastics production was greater than that of all nonferrous metals. Now a point of clarification. Those materials such as nylon, orlon, and dacron used in the textile industry are not considered as part of the plastics industry.

Now that we are current, and understand even the most minute detail of the development of the plastics industry, it would seem proper to define the subject with which we plan to work. But first, I wish to assure you there are still plenty of elephants.

Plastic and Plastics

In an attempt to lessen confusion, the plastics industry distinguishes between plastic and plastics in the following way: Plastic in the singular form refers to those things such as clay, paint, etc. Plastics in the plural form refers to materials and products of the plastics industry.

Now what is plastics? Plastics is a group of materials that contains as an essential ingredient a substance of high molecular weight which is solid in its finished state, but sometime in its manufacture it is soft enough to be shaped usually by heat and pressure. As you begin to explore this industry, keep an eye on this ever changing definition, especially as new and more exotic materials are being introduced to the market.

Industrial Technology

The terms with which you should begin to acquaint yourself are: Monomer is a substance not in its solid state which contains single molecules of low molecular weight. Polymer is the name given to monomers which have been caused to have high molecular weight. Polymerization is the process by which monomers become polymers. Co-polymers or heteropolymers are the combination of two or more polymers. Plasticizer is a chemical agent added to a polymer to make it softer or more flexible. Elastomer is a material, which at room temperature, stretches under low stress to at least twice its length and snaps back to its original length upon release of stress. A homopolymer is a polymer consisting of single types of repeating units.

I should like for a moment to dwell on polymerization. There are two types of polymerization. The first is addition polymerization. It is carried out by breaking the carbon to carbon bond with heat, pressure, and a catalyst which causes two sites for other active monomers to attach. Polymers produced by this process are all made from the same type of monomer—the ethylenic molecule.

The second is condensation polymerization. It is typified by the splitting off of a small molecule by-product such as water at the time of the monomer linking. Special note: Condensation polymerization does not yield a continuous chain of carbon but an intermittent chain with a small inner-molecular linkage.

How Are Plastics Manufactured?

The elements most commonly used in the manufacture of plastics are derived from coal, petroleum, salt, limestone, water and some natural oils. There are other isolated cases, but these we will not discuss.

To better understand the chemistry and manufacture of plastics, we shall take a relatively simple and unmodified basic material as our subject—General Purpose Polystyrene.

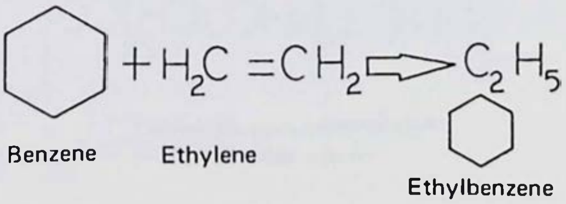
In industry the subject material is referred to as styrene. It is colorless and has clarity and sparkle. It is available on the market in transparent, translucent, or opaque colored forms. Special effects such as pearlescent and metallic colored forms are also available. Certain grades of polystyrene can be purchased which have ultraviolet stabilizers additives in the resin. Styrene may also be purchased as an impact grade material and could contain a latex filler.

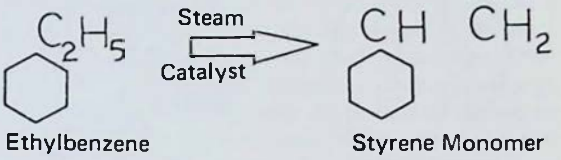
The chemistry of polystyrene: As the name implies, polystyrene is a polymerized product of styrene monomer. Polystyrene is produced by mass suspension and solution polymerization techniques. The initial step in the process is the combining of benzene and ethylene to produce ethylbenzene. Benzene is an oily liquid obtained from coal or petroleum. By catalystically dehydrogenating ethylbenzene, that is by heating it to a high temperature in the presence of steam, two hydrogen atoms are removed and ethylbenzene is converted to styrene monomer. Styrene monomer can also be found in its free state in coal tar but cannot economically be removed at this time.

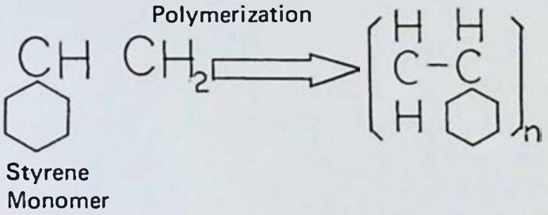
Polystyrene is finally formed by polymerization of the styrene monomer. Polymerization again implies constructing a chain of these molecules by linking them together. A simple arrangement for polystyrene is a long chain of alternating methylene and benzene ring.

The structural formula for the manufacture of polystyrene is illustrated as follows:

STRUCTURAL FORMULA FOR THE
MANUFACTURE OF POLYSTYRENE

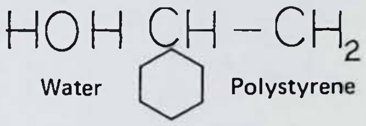






There are two types of chemical formulas most commonly used in the industry today.

The Structural Formula:



The Imperical Formula: H_2O Water C_6H_9 Polystyrene

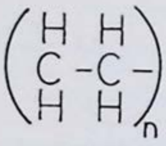
In some remote cases other types of formulas could be used. We will not discuss these.

To more completely equip you in your understanding of the formulas which follow, there are currently seven elements which go into the making of plastic materials, and they are:

Name	Symbol	Valence
Carbon	C	4
Hydrogen	H	1
Oxygen	O	2
Nitrogen	N	3
Chlorine	Cl	1
Fluorine	F	1
Silicone	Si	4

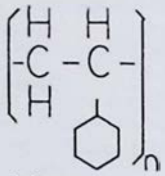
On the several pages which follow, some of the more popular plastics and their chemical formulas are illustrated.

SOME POPULAR PLASTICS AND THEIR CHEMICAL FORMULAS

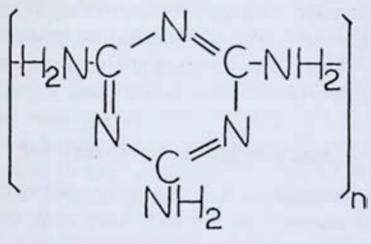


$$\left(\begin{matrix} H & H \\ C- & C- \\ H & H \end{matrix}\right)_n$$

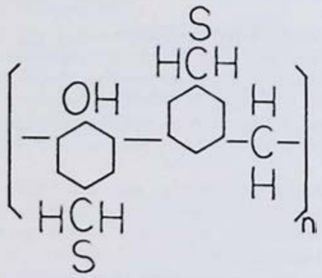
Polyethylene



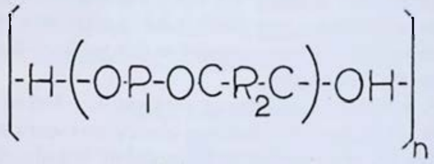
Polystyrene



Melamine Formaldehyde



Phenol-Formaldehyde

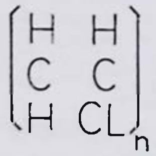


$$\left[-H-\left(-OP_1-OC-R_2C-\right)-OH-\right]_n$$

Polyester

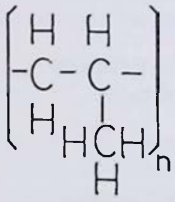
(linear Polymer)

R1 & R2 are organic groups

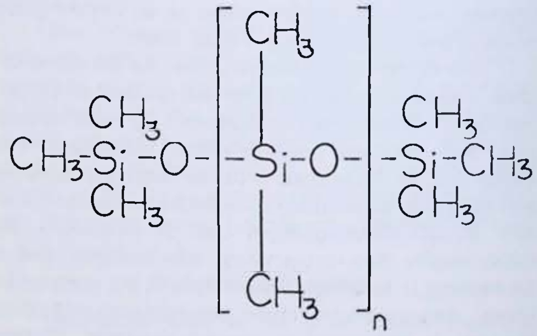


$$\left[\begin{matrix} H & H \\ C & C \\ H & CL \end{matrix}\right]_n$$

Polyvinylchloride

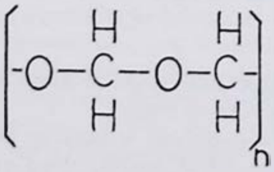


Polypropylene



Silicones

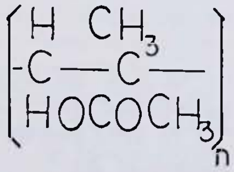
(Basic Dimethyl polysiloxane structure)



$$\left[\begin{matrix} & H & & H \\ -O- & C & -O- & C- \\ & H & & H \end{matrix}\right]_n$$

Acetal

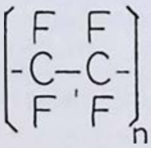
(Delrin)



$$\left[\begin{matrix} H & CH_3 \\ -C & -C- \\ HOCOCH_3 & \end{matrix}\right]_n$$

Methyl Methacrylic

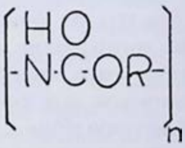
Acrylics



$$\left[\begin{matrix} F & F \\ -C- & C- \\ F & F \end{matrix}\right]_n$$

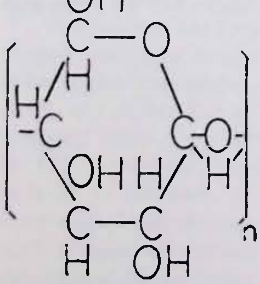
Polytetrafluaroethylene

(Teflon)

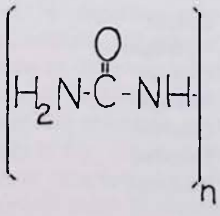


$$\left[\begin{matrix} H & O \\ -N & COR- \end{matrix}\right]_n$$

Urethane

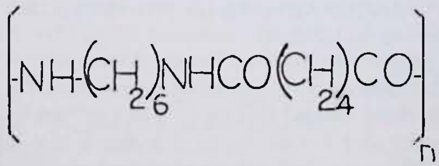


Cellulosic



$$\left[H_2N-\overset{O}{\overset{\|}{C}}-NH-\right]_n$$

Urea Formaldehyde



$$\left[-NH-(CH_2)_6NHCO(CH_2)_4CO-\right]_n$$

Polyhexamethyleneadipamide

(Nylon 66)

Trade Names

To this point in my presentation we have been concerned only with generic names of the many plastics. To lessen confusion for you I have assembled the trade names of the many materials, their generic names, and the material manufacturer whom you may consult.

Rather than awaiting the publication of these proceedings this information has been made available in the National Sculpture Conference publication, *The Syllabus of Plastics for the Sculptor,* a handbook prepared as a simplified introduction to basic industrial processes.

Types of Plastics

All of the materials, which we have discussed, fall into one of two categories. They are thermoplastics, or thermosetting plastics.

A thermoplastic material is similar to the wax of a candle, in that when we light the candle the wax melts and solidifies and we can then take this wax, remelt it and form a new candle so that the only apparent change in the properties of the candle have been a physical change. Thermoplastic materials are similar to this candle. We can heat and melt the material, then cool it and cause it to solidify even with no apparent change in the physical properties of the plastics material. Some examples of a thermoplastic are: polystyrene, polyethylene, and polypropylene.

Thermosettings plastics are similar to an egg. If we take a fresh egg and boil this egg in water and cause it to become hard boiled, there is no way that we can cause this egg to return to its original liquid condition. We have within the egg caused a chemical reaction to occur through the heating process. Thermosetting materials also undergo a chemical change. Once they are heated under pressure and caused to become a solid there is no way that we can cause this material to revert to its original molding condition. It has undergone an inner-molecular chemical change. Examples of a thermosetting material are: phenol-formaldehyde, melamine formaldehyde, and the plastisols or organisols.

Summary

In this presentation, I have talked about elephants and rockets, reactions, chemical formulas, technology and so on. Even more important to you now is how and why should we use a specific plastics. This, of course, leads us into the next topic. The difference between the candle, candles and the egg, "Physical Properties" of Plastics.

Information for this paper was accumulated from publications of the S. P. E. and the S. P. I.; also from the many publications and periodicals of the plastics industry.

Felix Arnold

PHYSICAL PROPERTIES

PAUL CAMPBELL
PHILLIPS PETROLEUM COMPANY

Felix, I will add one bit to your story about the billiard balls. You know, cellulose nitrate is also the basis of gun cotton, and I understand they had some very exciting games in the Old West, especially the Southwest where it was good and dry. Those cellulose nitrate billiard balls would explode on the table.

We were given a big assignment: to discuss the properties of thermoplastics. Of the types of plastics that Mr. Arnold flashed on the screen, I counted, I think, 35. Over half of these are thermoplastics. So, we obviously cannot cover all of the different types of thermoplastics. We have tried to pick and choose types that we think you would be interested in. Now, whether or not we succeeded, I do not know. We ask ourselves the question, "If we were not connected with the plastics industry and wished to use plastics in our work, what plastics would we be most interested in?" We have selected about half a dozen thermoplastics that are the most common ones and are the most readily available. We also decided that you wouldn't be interested in numbers. In other words, it would make little difference to you if I said that this plastic has a flexural modulus of over 400,000 pounds per square inch. So, we have tried to compare one plastic with another on some practical basis. Where possible, we have tried to use relative scales. Other places we have tried to use words to describe the plastics. When we get through, we hope you will know a little something about thermoplastics and by knowing something about thermoplastics, you will be able to use them. We hope to give you some answers, and we know that we will also create some questions in your mind. Perhaps there will also be some things that you could do that we will not mention or things we should tell you not to do.

We will go through a few slides and attempt to give you a relative picture of the six plastics which we have selected. You realize these are generalizations, and that one of my colleagues, who will be up here later, will likely give examples of formulations that do not exactly fit the picture that I will have drawn. As Mr. Arnold says, there are even many many different classes of the same material. We mean to give you at least a relative look at the six thermoplastics.

Here (Fig. 1) we see the six plastics we are going to examine: Polystyrene, cellulosics, polyvinyl chloride, acrylics, high-density polyethylene, and polypropylene. First we will look at the appearance and the color of the material. For example, let's take the cellulosics-acetate, butyrate, and cellulose proprionate. Generally, they are very transparent materials. As such, then your color possibilities are almost unlimited. You can go all the way from a transparent color to translucent and opaque. You are most familiar probably with cellulose acetate as blister packaging, the items you see in the hardware store that are difficult to open. This is a blister packaging material, a very clear cellulose butyrate. It's straw colored material, so a real blue might appear a little greenish because of the yellow. Cellulose acetate butyrate is used considerably in signs. It is good for outdoor use: signs, street light globes, and the things where vandalism is a problem. Cellulose acetate butyrate has a good impact strength.

The next class of materials we see on the slide is HDPE. That is the abbreviation for high-density polyethylene. And as Mr. Arnold said, polyethylene as a class has tremendous sales each year, about three and one half billion pounds. You are familiar with high-density polyethylene as bleach and detergent bottles. Probably every one of you has seen these in the stores or used them at home. High-density polyethylene is a white milky looking material; so, the only colors possible are the opaque, no translucents, no transparents, just opaque. But you can get some very bright, vivid colors even though they are opaque.

The next class is polypropylene. This material borders the translucent range, so that by pigmenting in certain ways, you could get some translucent colors, though, mainly you end up with opaque colors. You may be familiar with this material as your water ski rope. A lot of the small plastic rope used in water sports is made out of polypropylene. It is used in some fabrics and carpets. There is a big trend in indoor-outdoor carpeting, and this is polypropylene fiber. It is very resistant to staining.

The next class we have is PVC, polyvinyl chloride. Again you can get this in very clear sheet form. It is fairly thin, but you have possibilities here for the complete range of color, opaque, translucent, and transparent. The rigid material, of course, is what I am talking about. This goes into plastic pipe and some even into siding for buildings.

Another class of materials we have is polystyrene. Styrenes form a tremendous field. You can have all kinds of combinations, impact grades, and so forth. This group of materials varies considerably in properties. General purpose polystyrene is crystal clear. It looks like glass. You are more familiar with this material as inexpensive housewares and toys. It is, probably, the material that causes people to think of plastics as breakable because it is rather brittle. Also, it's used a lot in disposable items such as drinking cups. On the other end of the polystyrene range, the impact styrenes are utilized in refrigerator door liners and so forth, but I know you are going to hear more about that later on.

The last group is the one that you are probably most familiar with and certainly I can see why. The sculptor or artist would be very much interested in the acrylics. We are talking about methyl methacrylate which was mentioned earlier. Lucite or Plexiglas are two trademark names. This is a crystal clear material and it can be cast or you can get it in sheet form, rods, tubes, and various shapes. It has greater than 92 per cent light transmission. It is very, very clear material, and very beautiful, as you can see by the art objects in the back corner of the room.

The next property I would like to talk about is hardness (Fig. 2). In other words, what about the permanence of the surface; What about the stiffness or the rigidity of the material? And I would like to point out that for rigidity and for hardness also, this slide represents a relative scale. Again, as I said earlier, I am sure that we could move these scales up and down a little bit by the formulation, but generally I think, this scale would hold true. If we look at the rigidity, we see it and hardness go pretty much hand in hand. The acrylics of these six types are the most rigid and have the hardest surface. If you ever buy acrylic sheet, Lucite or Plexiglas sheet, you know that it comes protected by a paper with a stripable adhesive on it. This means that even though it is mar resistant, say with a fingernail (and it has a very beautiful surface) it can be abraded if not properly protected.

The softest and most flexible of these materials is high-density polyethylene. To give you a relative scale, high-density polyethylene can be scratched or marred with your fingernail. This doesn't mean you would actually take material off the surface, but you would make a mark that you cannot get rid of. On the other hand, polypropylene, right next to it on the scale, could not be marked with your fingernail. If you look at it in those terms, the only one of these materials you can mar with a fingernail is high-density polyethylene. The others will stand the normal handling although the surfaces will abrade or scuff.

You can use a textured surface on the material. This is usually molded in with an embossed roll or with a sheet of metal that has a texture. You will not see the marks that undoubtedly are made on the embossed surface. Embossing can be a good method of avoiding unsightly marring as well as a good method for obtaining an interesting surface.

The next property that I want to talk about is softening temperature and heat formability (Fig. 3). The softening temperatures are not relative. These are the actual softening temperatures that you find in the literature. I want to stress that the significance of this to you is not so much the exact numbers, since you usually work with materials a little bit above the softening point. In other words, when you work with polystyrene, you usually will not work with it at 265 degrees F. On a machine you might work with it at 300 degrees F. or 325 degrees F. The significant thing I want to bring out here is not the actual softening temperature of these materials but the fact that we have two classes of materials. This may not be obvious from looking at this slide. We have two materials, high-density polyethylene and polypropylene. The significance to you is the fact that when these materials soften, you get a quick viscosity change. You can't work with these materials at 260 or 255 degrees F. in the case of high-density polyethylene. You can't heat it in an oven at 255 degrees F. and then bend it into some permanent shape. It must be heated above 260 degrees F. This is not true of the acrylics or polystyrene which are very easy to handle by hand. I have not rated the heat formability of materials on complicated production equipment because all of the materials can be formed very beautifully with heat and a little bit of pressure. Here we are talking about just what you could do in an oven or in a garage or in your laboratory with crude equipment. In summing up, we have the two polyolefins, high-density polyethylene and polypropylene. We have them rated as only fair. They are difficult to handle. On the other hand, we have PVC and polystyrene that you can probably handle pretty easily. The materials that are very easy to work with are the acrylics and the cellulosics. They soften over a wide range and you can work with them. They hold their viscosity and do not change rapidly. They change so gradually that you can almost pick the point at which you wish to work them.

One thing you ought to remember when we're talking about softening points is that these temperatures are the point at which the plastic will deform under a zero load. If you have a material, say, high-density polyethylene, heated to 260 degrees F. and you place a load on it, it will deform. Materials like high-density polyethylene will hold their shapes usually, if there is absolutely no load on the material. If you had a light diffuser panel made out of an acrylic plastic, and for some unknown reason you got a temperature up to 300 degrees F. on that diffuser, it would probably drop out of the fixture because of the weight of the sheet. The weight of the material itself would cause deformation. So, when you are working at elevated temperatures or with a plastic that is to be exposed to any kind of an elevated temperature, you have to support it. Also, you would not normally expect a material to operate indefinitely near the softening point. Again, I use high-density polyethylene because it is the material I know the most about. High-density polyethylene, for example, we would not expect nor would we tell anyone to use in a continuous operation above 180 degrees F. This does not mean that these are operating temperatures. This scale indicates softening temperatures.

I have already said something about the heat formability, and all of these materials can be formed.

Now, I would like to schematically show you forming. This is the way it is done in the laboratory. This is called vacuum forming. A sheet is clamped between two electric heaters and heat is applied. Just below the sheet is the mold. When the sheet has been heated above its softening point, the mold is moved up to contact the softened sheet and the vacuum is used to literally pull the material down into the mold. This is called vacuum forming. Even wooden molds may be used (however, a wooden mold cannot be used with high-density polyethylene or polypropylene). You can get away with making half a dozen parts, but because these two materials shrink a lot (even if the mold is made out of hardwood like oak) the material, as it cools, will tear it apart. With some other materials you can use some pretty crude molds for forms.

I would like to go next to paintability and weatherability (Fig.4). Let's take paintability first. High-density polyethylene and polypropylene are very difficult to paint. Bleach and detergent bottles are decorated extensively, but printing and decorating is a lot different from painting a big piece of polyethylene sheet, particularly if it is to be exposed or flexed. On pointed or printed bottles, the surface has been oxidized with flame or with an oxidizing acid, but even then you might be able to scratch the paint off with your fingernail. If you are looking for a permanently painted surface, one that can compare with wood or concrete, then you would not use polyethylene or polypropylene. Even acrylic spray paint will not adhere to polyethylene or polypropylene. You can prove it to yourself. Just spray it on a sheet; let it dry; flex it once, and the whole thing peels off. Also, you certainly would not want to take it outside and leave it exposed to the elements, because eventually the paint would be gone. You really have no problem with painting these four other materials. Lacquers and paints stick to them beautifully. It is no problem at all. Simply contact a supplier of these materials or even a hobby shop. Of course you are familiar with model airplanes. They are all made out of styrene and there are all kinds of colors that you can paint on them successfully. Also, the acrylics and cellulosics can be painted.

Now, weatherability. Again, we are talking about more or less the general purpose materials that are not specifically formulated for weather.

Any of these materials can be protected if they are opaque to the sun's rays. But being organic materials, ultra-violet light will cause them to break down and oxidize. This usually shows up as crazing or failure of the part. Polypropylene is probably the most unstable to the sun's rays. A sheet of the natural material 6/100 of an inch thick, left outside for six months weathering through the summer will pop in your hand. It will crack like a soda cracker.

Any of these materials can be protected, but certain ones weather best. Certainly, the acrylics rank very high. In fact, it has been reported that five years of weathering only changes the light transmission of acrylic sheets by one per cent. When talking about clear plastics, this is what we have to contend with. The styrenes will yellow slightly. You can buy weather-resistant formulations of these materials from suppliers. Black is the best, but who is interested in black? I imagine that most of you are more interested in colors, perhaps even very bright colors. I want to show you a couple of applications where polyethylene has been used, which illustrates it can be protected. Here is a wire fence. It is one of these chain link fences that has two different colors of high-density polyethylene sheet woven into the fence to give privacy. This has been out for around eight years in Oklahoma where it gets pretty hot. Here is a cooling tower panel of the corrugated sheet. This has been out for about ten to twelve years. This is a very dark color with some carbon black in it and also some green pigment. One of the quite extensive applications is stadium seats. Here is the Los Angeles Colosseum that has around 55,000 of these seats. They are coded by color, as you can see, yellow, red, green, etc. Here is another installation, Our Lady of the Snows Shrine, in Bellview, Illinois. Now these, we expect to last six to eight years under normal use. I don't know what normal use means, but it's a good term.

The last thing I want to cover very quickly is welding and bonding (Fig. 5). In other words, how do you put these materials together? The same property that makes the polyolefins difficult to paint makes it almost impossible to adhere one to another with anything except heat. They can be welded like metal, using a welding rod made out of the material and a hot gas welder or a gun that puts out hot air. You would not want to use a flame because these materials will burn. However, this is kind of a difficult way to put them together. As for the other plastics, if you have a solvent that will dissolve the material (polyethylene and polypropylene will not dissolve) you can put them together. Use either a pure solvent or dissolve some of the plastic in the solvent and use that or a different type of adhesive like an epoxy or alkyd to stick these materials together.

If you have a piece of plastic you can't identify, remember all plastics burn with a characteristic flame. I want to take this gas torch and a couple of these materials and show you what I mean. The only class of materials that I talked about here that will not burn, that is, will not support combustion, is PVC. I have a small sheet that is very thin. As I put it in the flame, first, it melts; then it burns rather brightly as I hold it in the flame, but the minute I take it away, it goes out. That is the only one of the materials that I showed you which will not burn. It chars and you get a very acrid smell. It will really clean your sinuses if you get a good whiff, because it gives off HCl. Polymethyl methacrylate burns with a very sweet odor. Although this is such a big room I am sure you can smell it. It spurts when it burns and you can actually hear it crackle, and it will continue to burn when I remove it from the flame. It doesn't drip. I mention this because some of these plastics will. High-density polyethylene burns with a yellow flame and you will actually see it drip as it burns. It drips and the drips are flaming. These are simple tests. I don't imagine anyone would want to tear up a big art object to do this, but at least this is one way to quickly and easily tell one plastic from another. Polystyrene burns with a very, very yellow and dirty flame.

I also mentioned heat joining of plastics. Here are two pieces of high-density polyethylene of different colors. An edge of each piece has been placed against a hot steel plate and then stuck together. This is a very effective way to join plastics, and most of these plastics can be joined in this way.

In conclusion, I would just like to mention one thing further before I turn it over to Stafford Collie, my colleague, from Phillips. When we were preparing for this, Staff said, "Paul, there is one thing that these people will want to know. If they work with plastics, how long are they going to last? It is not whether they are going to last ten years or twenty years, but a hundred years, when they will be discovered as famous art objects." Well, I don't know the answer to that because the plastic industry is only one hundred years old this year. But, if somebody would like to try, in maybe one hundred years from now, we can find out. Now, I would like to turn this over to Mr. Stafford Collie, who will talk about some art objects and applications of these materials.

Figure One

THERMOPLASTICS, APPEARANCE AND COLOR

Material	Appearance	Color
Cellulosics	Transparent	Transparent, Translucent, Opaque
HDPE	Opaque	Opaque
Polypropylene	Translucent	Translucent, Opaque
PVC	Transparent	Transparent, Translucent, Opaque
Polystyrene	Transparent & Opaque	Transparent, Translucent, Opaque
Acrylics	Transparent (92% Light Transmission)	Transparent, Translucent, Opaque

Figure Two

THERMOPLASTICS, HARDNESS AND RIGIDITY

Material	Relative Hardness	Relative Rigidity
Cellulosics	65	55
HDPE	35	30
Polyrpopylene	60	47
PVC	70	87
Polystyrene	74	67
Acrylics	100	100

Figure Three

THERMOPLASTICS, SOFTENING TEMPERATURE AND HEAT FORMABILITY

Material	Softening Temperature	Heat Formability
Cellulosics	260	Excellent
HDPE	260	Fair
Polypropylene	325	Fair
PVC	285	Good
Polystyrene	265	Good
Acrylics	300	Excellent

Figure Four

THERMOPLASTICS, PAINTABILITY AND WEATHERABILITY

Material	Paintability	Weatherability
Cellulosics	Excellent	Good
HDPE	Poor	Must be protected with additives.
Polypropylene	Poor	Must be protected with additives.
PVC	Excellent	Good
Polystyrene	Excellent	Yellows slightly
Acrylics	Excellent	Excellent

Figure Five

THERMOPLASTICS, WELDING AND BONDING

Material	Heat	Solvent	Adhesive
Cellulosics		x	x
HDPE	x		
Polypropylene	x		
PVC		x	x
Polystyrene		x	x
Acrylics		x	x

PHYSICAL PROPERTIES

STAFFORD COLLIE
SEALRIGHT INC.
SUBSIDIARY OF PHILLIPS PETROLEUM COMPANY

Ladies and gentlemen, before the day is over this panel will have covered, in a general manner, all of the physical properties of various plastics.

You will know about heat sealing, melting temperatures, molding, light transmission, and all the necessary information from which you can get started.

It would be quite impossible for us, within the given period of time to go into detail on any one material or even attempt to answer all of the questions that you may have. My own experience tells me that even if time did permit we would not know the answers to many of your questions.

As a matter of fact, we are at present discussing materials which are so new that none of us can profess to be experts. Six of these new plastics, HDPE, polypropylene, clear rigid PVC, clear impact acrylic, phenoxy and ABS were developed within the past 12 years and we are still in the process of investigating and familiarizing ourselves with them.

The basic physical properties of these materials remain constant or unchanged; however, the application of these properties vary considerably to obtain infinite end results. So infinite are the effects or end results that can be obtained by applying these basic properties in various ways, that the only boundaries that I can think of are those that are imposed by the extent of one's creative imagination.

Most of us can tell you that to make a suitable industrial thermoformed HDPE container, we must heat the material to 350 degrees F., but I doubt whether any one in this room can give you an answer on what will happen or what the end result will be if this same material were heated to 700 degrees F. and poured onto a pattern of colored stones.

It is just as well that these materials are in their infancy and that new discoveries are the rule rather than the exception as it is this unknown factor that generates excitement and allows us an open field for experimentation.

Now a word of caution, you must approach this new world of plastics in an organized manner; limit your experimentation to one material at a time or confusion will result. Master one material and get the feel for it before moving on to another. Most of these plastic products are so unlike the conventional materials you are accustomed to working with, and will look interesting no matter what you do with them, that we have to be very careful and constantly on the watch not to let the medium outshadow the art form.

The battle between the artist and his medium is perhaps the greatest difficulty that you will face in this new world of plastics, not only because of your unfamiliarity with the materials, but greater still is the test of your skill in selecting from a wide variety of products most of which are made in very vivid colors with surfaces that reflect the light like a mirror.

One's technique in bonding, bending, cutting and finishing of these modern materials requires more care and skill than most standard materials. Too much heat in bonding will give you a piece of spaghetti, and too much adhesive or solvent will ruin the light reflecting surface of the material.

Now I want to show you some slides which I believe will illustrate, in a nontechnical way, some of the physical properties of these materials.

(Slide 1.) One of the newer plastic materials that is still not available commercially is Phillips "Engelite," a low to medium density polyethylene foam. This product has a very decorative surface to it which can be varied to give the appearance of anything from a satin like finish to a heavy leather.

(Slide 2.) The light transmission qualities in thin sheet form are limitless and can be varied according to the color of the sheet and the thickness and size of the bubble injected into the material.

(Slide 3.) Having a lot of air cells, the material is very buoyant, yet it has a hard surface and can be easily tooled.

(Slide 4.) This is a low pressure material which means that it can be injected into an experimental inexpensive mold by simply holding the mold to the extruder opening.

(Slide 5.) We are still romancing this product and having lots of fun finding new applications for it.

(Slide 6.) I am sure you will add to this list of ideas before the day is over.

(Slide 7.) Polyethylene is a Phillips product. Here is an example of how we utilized one of the physical characteristics of this material to devise a novel industrial application. We know that this material has a lot of recovery or memory to it and that it will stretch or bend and want to come back to its original form, so we made continuous bands or belts of this material with small lugs formed in the band.

(Slide 8.) These bands were then cut off in various lengths for various diameter plates and heat sealed together to form rings. The plates were then snapped into the rings. The plastic stretched to accommodate the plates, then recovered to grab the plates tightly.

(Slide 9.) This novel package could only be made with plastic. It suspends the plates within the container, eliminating breakage. It also allows for complete visibility of the product when displayed on the shelf.

(Slide 10.) We used the same memory feature of HDPE to devise a novel cup package. Here you see two thermoformed parts made from the same mold that are heat sealed together in the middle. The package bends to allow the consumer to remove the cup for inspection,

(Slide 11.) and snaps back to its original form when the cup is replaced.

(Slide 12.) This is a decorative sculptural form constructed from sheets of HDPE which were heat sealed together. A frame was probably used for extra support; however, HDPE in thick sheet form would be strong enough to support its own weight.

(Slide 13.) This floating form was designed by a student who made his own bar heat sealer and experimented with various shapes made from polyethylene film. He is now trying to float these forms with light in them.

(Slide 14.) These mysterious forms utilized HDPE sheet wrapped around a mandrel.

(Slide 15.) This bas-relief art form made from HDPE sheet was designed by Tom Wesselman of New York for the members of the Friends of Art of the Nelson Art Gallery. The subject matter was formed over a mold and the back of the sheet was masked and spray painted. When placed in a back-light shadow box the overall effect is interesting.

(Slide 16.) These amorphous forms were made by injecting HDPE in a molten state into a polypropylene basin. The basin was then inverted and the material slowly fell into these flowing shapes. A certain amount of control was obtainable.

(Slide 17.) As you can see the shapes obtained varied according to the viscosity of the material and the way one manipulated the basin.

(Slide 18.) This is polypropylene. The material has excellent hinging characteristics as is evidenced by this form in an upward position and in a downward position.

(Slide 19.) It has good machining qualities.

It is about as stiff as HDPE.

It is quite brittle at low temperatures.

Under sunlight it has a tendency to craze, but one can obtain weather resistant grades.

It requires a little more heat to melt than most thermoplastics.

It is about as hard as acrylics.

It can be obtained in translucent or opaque colors.

It is bonded together by heat.

We took the hinging feature of this material and developed this closure that you can see on the screen for bottles containing powdered material. The closure is seen here on the right in a downward position,

(Slide 20.) and here it is on a bottle being pulled in an upward position.

(Slide 21.) When in an upward position, it allows the powder to flow from the bottle. When pushed into a downward position, it seals the bottle and prevents the contents from coming out.

(Slide 22.) Here, we used this same hinging feature to develop a new concept in packaging. This experiment shows a polyprylene container for soap. The bottom of the container is formed in an upward position.

(Slide 23.) When the soap is packed, it pushes the bottom of the container into a downward position.

(Slide 24.) The container is then closed with a heat-sealed lid.

(Slide 25.) When the heat-sealed lid is removed by the consumer and the bottom of the package is pushed into an upward form, the soap pops up. This container concept utilized a characteristic that is only found in polypropylene.

(Slide 26.) Polystyrene. This material is very stiff but generally brittle and tears in thin sheet form.

(Slide 27.) You can get detailed definition with this material when it is formed over a mold.

(Slide 28.) Another important characteristic is that you can obtain deep draws and still get a rigid part.

(Slide 29.) These are deep drawn forms for speakers.

(Slide 30.) It can be obtained in crystal clear to opaque colors. The crystal sheet is very brittle.

The machining qualities vary from fair in crystal form to excellent for the more opaque colors.

It has less resistance to heat then HDPE.

It yellows if exposed to sunlight.

It can be solvent or adhesive sealed.

(Slide 31.) Plexiglas or Lucite. Plexiglas is a Rohm & Haas trademark, and Lucite is from Du Pont. I am sure that many people in the audience are relatively familiar with this material.

(Slide 32.) It has excellent color stability,

(Slide 33.) and will withstand weather and outdoor exposure without discoloration.

(Slide 34.) It has a lot of strength and is used to span large areas, and is available in a wide variety of colors: translucent, transparent and opaque.

(Slide 35.) It can be molded and extruded,

(Slide 36.) and cast from acrylic monomers.

(Slide 37.) It can be machined, cut, heated and bent to any desired shape.

(Slide 38.) It can be silk screened and back lit, engraved and embossed.

(Slide 39.) It is sometimes laminated with vinyl and other plastic.

(Slide 40.) In closing I'd like to show you this last interesting slide, which was taken not far from our Bartlesville Plastics Research Center. It shows a nest that a bird has made from a scrap of high density polyethylene film. Gentlemen, the end uses and applications for plastics is limitless and not just for the birds!

APPLICATION OF PLASTIC MATERIALS

ALFRED J. ROCHE
MONSANTO COMPANY

Plastics play a vital role in peace and defense. They were instrumental in the development of the automobile, airplane, missile and communications. The lifelines of all communications—telephone, radio, television, radar, sonar, telestar—are based on plastics as insulation and other vital components. The comfort of our homes is increased in countless ways through foamed cushions for furniture, easy-to-clean upholstery, protective coatings for the home and industrial equipment, soft illumination for translucent lighting, floor coverings that are resistant to spilled liquids and foods. All of these and many more can be attributed to resins and plastics. Without them we might soon be back in the "dark ages."

The continuing development of new plastic materials broadens the industry's field of applications. Even more, it is indicative of plastics' ability to produce equally good products at a lower cost, better products at the same cost, or products that could not be manufactured without them.

World War II gave great impetus to the industry. In meeting exacting defense service requirements, plastics demonstrated their versatility and wide range of important properties. They proved their high tensile and impact strength, lightness, resistance to corrosion, low moisture absorption, resistance to salt water and many chemicals, transparency, adaptability to varied climatic conditions, and flexibility even at low temperatures.

Designers, engineers, and architects constantly analyze material and performance requirements of varied products to determine the suitability of plastics for new end uses, and plastics materials are being formulated with scientific precision and skill to meet these new market applications. Today, plastics are accepted as basic materials used by designers and engineers. They take their place in industry along with metal, glass, wood and paper.

Plastics are a family of materials—not a single material—each member of which has its special advantages. Being man-made, plastic raw materials are capable of being variously combined to give most any property desired in an end product. But these are controlled variations unlike those of nature's products.

The widespread and growing use of plastics in almost every phase of modern living can be credited in large part to their unique combinations of advantages. These advantages are light weight, range of color, good physical properties, adaptability to mass production methods and, often, lower cost. Some plastics can be sterilized.

Aside from the range of uses attributable to the special qualities of different plastics, these materials achieve still greater variety through the many forms in which they can be produced. They may be made into definite shapes like dinnerware and electric switchboxes. They may be made into flexible film and sheeting familiar as shower curtains and upholstery. They may be made into sheets, rods, and tubes that are later shaped or machined into internally-lighted signs, and airplane blisters. They may be made into filaments for use in household screening, industrial strainers, and sieves. They may be made into netting in a variety of patterns and sizes. They may be used as a coating on textiles and paper. They may be used to bind together such materials as fibers of glass and sheets of paper or wood to form boat hulls, airplane wing tips, and table tops.

The above are all practical applications utilizing the properties of specific plastics polymers. Let me demonstrate some real parts that are now in specific applications for specific end-use reasons. I will talk about thermoplastic applications by product type and to exemplify the many applications of each product, I will show parts in which these materials are used by various markets:

Polyethylene is the largest of all plastic materials in production and sales volume. In 1967, four and one-half billions of pounds of polyethylene were used in many and varied applications. PE has many interesting and desirable properties. Heat resistance, electrical characteristics, chemical resistance, FDA approval strength and flexibility have created many volume applications.

One of the larger volume market applications is in the Wire and Cable Industry. Here is a single copper wire strand coated with PE; when many of these wires are accumulated in a bunch, it makes a telephone cable. The exterior of this cable is also coated with PE. This industry uses PE for its electrical insulation properties but just as important is the PE resistance to weathering, and extreme temperature conditions. The PE can be foamed and maintain the same desirable properties. The wire can now be buried and maintain the same properties as exposed cable. Coax cable is used extensively in the television and aerospace industry, again utilizing the excellent electrical properties of PE.

I have also mentioned that PE is odorless and tasteless, has FDA approval and is flexible. These properties make it an excellent choice for packaging applications—particularly food packaging. Examples are the thin-wall freezer bags, the potato bag, and the 50-pound industrial bag. Make this bag a little larger and you have a garment bag. This same material can be coated on paper or film to provide moisture-proof boxes for the large pre-mix applications. These are tainer, eliminating breakage. It also allows for complete visibility of the product when displayed on the shelf.

(Slide 10.) We used the same memory feature of HDPE to devise a novel cup package. Here you see two thermoformed parts made from the same mold that are heat sealed together in the middle. The package bends to allow the consumer to remove the cup for inspection,

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It is quite brittle at low temperatures.

Under sunlight it has a tendency to craze, but one can obtain weather resistant grades.

It requires a little more heat to melt than most thermoplastics.

It is about as hard as acrylics.

It can be obtained in translucent or opaque colors.

It is bonded together by heat.

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(Slide 38.) It can be silk screened and back lit, engraved and embossed.

(Slide 39.) It is sometimes laminated with vinyl and other plastic.

(Slide 40.) In closing I'd like to show you this last interesting slide, which was taken not far from our Bartlesville Plastics Research Center. It shows a nest that a bird has made from a scrap of high density polyethylene film. Gentlemen, the end uses and applications for plastics is limitless and not just for the birds!

APPLICATION OF PLASTIC MATERIALS

ALFRED J. ROCHE
MONSANTO COMPANY

Plastics play a vital role in peace and defense. They were instrumental in the development of the automobile, airplane, missile and communications. The lifelines of all communications—telephone, radio, television, radar, sonar, telestar—are based on plastics as insulation and other vital components. The comfort of our homes is increased in countless ways through foamed cushions for furniture, easy-to-clean upholstery, protective coatings for the home and industrial equipment, soft illumination for translucent lighting, floor coverings that are resistant to spilled liquids and foods. All of these and many more can be attributed to resins and plastics. Without them we might soon be back in the "dark ages."

The continuing development of new plastic materials broadens the industry's field of applications. Even more, it is indicative of plastics' ability to produce equally good products at a lower cost, better products at the same cost, or products that could not be manufactured without them.

World War II gave great impetus to the industry. In meeting exacting defense service requirements, plastics demonstrated their versatility and wide range of important properties. They proved their high tensile and impact strength, lightness, resistance to corrosion, low moisture absorption, resistance to salt water and many chemicals, transparency, adaptability to varied climatic conditions, and flexibility even at low temperatures.

Designers, engineers, and architects constantly analyze material and performance requirements of varied products to determine the suitability of plastics for new end uses, and plastics materials are being formulated with scientific precision and skill to meet these new market applications. Today, plastics are accepted as basic materials used by designers and engineers. They take their place in industry along with metal, glass, wood and paper.

Plastics are a family of materials—not a single material—each member of which has its special advantages. Being man-made, plastic raw materials are capable of being variously combined to give most any property desired in an end product. But these are controlled variations unlike those of nature's products.

The widespread and growing use of plastics in almost every phase of modern living can be credited in large part to their unique combinations of advantages. These advantages are light weight, range of color, good physical properties, adaptability to mass production methods and, often, lower cost. Some plastics can be sterilized.

Aside from the range of uses attributable to the special qualities of different plastics, these materials achieve still greater variety through the many forms in which they can be produced. They may be made into definite shapes like dinnerware and electric switchboxes. They may be made into flexible film and sheeting familiar as shower curtains and upholstery. They may be made into sheets, rods, and tubes that are later shaped or machined into internally-lighted signs, and airplane blisters. They may be made into filaments for use in household screening, industrial strainers, and sieves. They may be made into netting in a variety of patterns and sizes. They may be used as a coating on textiles and paper. They may be used to bind together such materials as fibers of glass and sheets of paper or wood to form boat hulls, airplane wing tips, and table tops.

The above are all practical applications utilizing the properties of specific plastics polymers. Let me demonstrate some real parts that are now in specific applications for specific end-use reasons. I will talk about thermoplastic applications by product type and to exemplify the many applications of each product, I will show parts in which these materials are used by various markets:

Polyethylene is the largest of all plastic materials in production and sales volume. In 1967, four and one-half billions of pounds of polyethylene were used in many and varied applications. PE has many interesting and desirable properties. Heat resistance, electrical characteristics, chemical resistance, FDA approval strength and flexibility have created many volume applications.

One of the larger volume market applications is in the Wire and Cable Industry. Here is a single copper wire strand coated with PE; when many of these wires are accumulated in a bunch, it makes a telephone cable. The exterior of this cable is also coated with PE. This industry uses PE for its electrical insulation properties but just as important is the PE resistance to weathering, and extreme temperature conditions. The PE can be foamed and maintain the same desirable properties. The wire can now be buried and maintain the same properties as exposed cable. Coax cable is used extensively in the television and aerospace industry, again utilizing the excellent electrical properties of PE.

I have also mentioned that PE is odorless and tasteless, has FDA approval and is flexible. These properties make it an excellent choice for packaging applications—particularly food packaging. Examples are the thin-wall freezer bags, the potato bag, and the 50-pound industrial bag. Make this bag a little larger and you have a garment bag. This same material can be coated on paper or film to provide moisture-proof boxes for the large pre-mix applications. These are only a few of the flexible packaging applications.

Suppose you need a more rigid package. You can still use PE; process it differently and generate an entirely new application—the squeeze bottle. The largest market for these bottles is the synthetic detergent market which takes advantage of the chemical resistance of PE. FDA approval allows its use in one-half gallon milk bottles or ice cream containers. Polyethylene has been used in housewares, flexible irrigation pipe, unbreakable toys, and items such as garbage cans, car bags, drums, etc. Polystyrene is the second largest volume polymer with 1967 production and sales volume of two and one-half billion pounds.

Styrene, unlike polyethylene, is a much more rigid material and also, unlike PE, this material has the advantage of clear transparency or unlimited colorability. This product can also be easily painted, lacquered, cemented or plated. It has good dielectric properties and good strength characteristics at high and low temperatures.

How has industry put these benefits to good use? Let's look at some of the market applications: *Lighting*—Clarity and transparency of this product makes it an ideal product for lighting fixtures or room dividers. *Refrigeration*—The colorability, rigidity and cold temperature strength of styrene allows its use as breaker strips, meat trays, and shelf fronts. It still is used by many manufacturers as inner door liner. *Packaging*—The clarity and rigidity of styrene plus the FDA and MID approval makes this an ideal packaging material. Most recent application is the clear plastic meat tray. This material can be foamed to make the foam meat tray and other designs. This material is also used in blister packing to protect expensive items and yet allow potential customers to see the product.

Radio and TV—Polystyrene can be modified to obtain high-heat resistance without sacrificing rigidity or strength. Here is a small television cabinet that has passed all the UL tests. It is colorful, well designed, and provides long term in-field performance. The dielectric constant of styrene housings makes this much safer for consumer use with the high voltage potential in a TV set. Transistor and table model radio cabinets utilize styrene for the same reasons.

Furniture—With first quality wood increasing in cost due to the larger demands on our diminishing forests, polystyrene has been called upon to fill this need. The ingenuity of the designers and engineers have created wood grain effects that make it difficult to distinguish the plastic from the real thing and at the same time, it does not have the problems of the natural wood products. Plastic parts are easily cleaned, chip, and stain resistant and are produced at equal or lower costs.

This breakthrough in technology has greatly impressed the television manufacturer who utilizes wood for the console models. Presently under tests are high-impact polystyrene parts that have been wood grain finished to replace wood in the television, stereo hi-fi consoles. The furniture manufacturer is now looking at the low shrinkage factor of styrene materials to replace wood for furniture drawers. The plastic material would eliminate the sticking and swelling characteristics found in wooden drawers. The total impact of styrene usage in this market has generated the enthusiasm and excitement of a rather old and staid industry. Several large manufacturers are now casting coffee tables, end tables, credenza fronts and credenzas from wood-grained styrene materials. This industry is expected to use about twenty-six million pounds in 1968 with an anticipated growth of 75 million pounds by 1970.

Styrene materials have also found applications in the housewares market, toys, and battery cases. This is a battery case made from high-impact styrene and is a component used in the Gemini missile program. Styrene batteries are also being introduced into the commercial automotive battery to replace the very heavy rubber modified battery cases. Housewares have utilized the entire color range and rigidity of styrene for cake covers, left-over refrigerator dishes and drinking tumblers.

The growth of the styrene market has been enhanced by the modification of styrene with acrylonitrile to form styrene acrylonitrile products. This is a higher impact, higher rigidity type of material with much higher heat distortion properties. Automotive engineers have utilized these properties primarily in the dashboard lenses. They have found that the clarity and low shrinkage factor with temperature makes this part an ideal application for SAN. With the advent of increased usage of computers and the necessary storage of computer tapes, the industry has found SAN to be advantageous in the storage of reels and storage boxes for these valuable tapes. Also in the packaging area, the high order of chemical resistance to food stuffs of SAN materials plus the clarity have made this material ideally suited for packaging oleomargarine and such items as vaseline. Since the oleomargarine is packaged hot and then quick frozen, this material must have strength characteristics from 200 degrees F. to a minimum of -40 degrees F.

The high optical clarity of the SAN plus its high rigidity makes it applicable for institutional items such as tumblers, serving trays, and the like. Household refrigeration has found this material suitable for the replacement of glass in the vegetable pan covers. These materials are continuously finding newer applications in the market.

By the addition of rubber (butadiene) to the SAN material, another product, terpolymer, called ABS (acrylonitrile butadiene styrene) is generated. This material has high rigidity coupled with high-impact strength which makes it a material for engineering construction. It still has the unique quality of high-heat distortion and low temperature strength properties plus outdoor weatherability. It also has high chemical resistance to food stuffs plus FDA approval for packaging food stuffs. The three major markets utilizing these properties are refrigeration, automobile and communications.

In the refrigeration market, major producers use ABS's for inner door panels. As you can see, this door panel incorporates the butter door, the cheese compartment, the egg rack, and the shelves as an integral part of the panel. This project has been so successful that several manufacturers are now, or will be, utilizing the advantages of ABS for a formed inner cabinet of their refrigerator. This material replaces the high-cost enameled steel liners that the industry has used for years. This application alone represents an increase of approximately twenty five million pounds per year.

The automotive industry has used the unique structural properties of ABS to make one-piece dashboard panels, insert paneled parts, arm rests, and air conditioner ducts. The most intriguing application to date has been this part, which is the console between the bucket seat of a sports car. You can see the engineering and design properties incorporated in this molding. From these samples, you will also note that the ABS materials can be chrome plated, wood grain finished, lacquered, or, if necessary, colored to suit the application requirement. This lacquer ability of ABS coupled with its structural properties generated a new approach for the manufacturers of womens' shoes. The spike heel, which was once vogue, was made possible by the structural strength and lacquer ability of the ABS..

The communications market has found the ABS materials to be ideally suited for the most popular and widely used communications instrument in existence, the telephone hand set. Western Electric alone has used an excess of 20 million pounds for this application. The advent of the brightly colored phones were made possible only through the use of the colorability properties of ABS. Also in the communications industry, the television cabinet manufacturer is quite interested in the structural properties of ABS to make the first portable television cabinets. These television cabinets, as in the case of high-impact styrene, have passed the very stringent tests demanded by the Underwriters Laboratory.

ABS materials have also found acceptance in other areas of structural demands, such as the Ford camper, Coleman's camper trailer, and other mobile home applications. Samples of this application, of course, are much too large to bring to the seminar, but I am certain that you can view these applications at your nearest dealer. ABS materials are forecast to be forty to fifty million pounds in volume in the construction field alone by 1968.

Luggage is another market that has used the structural properties of ABS. This attache case is only a small sample of the total luggage product line. Samsonite has developed an entire luggage component system of the three suiter, two suiter, overnighter, cosmetic, and train case in ABS. Again, the strength and colorability of ABS has made this a desirable application.

Polyvinyl Chloride is another volume polymer which is expected to reach the three-billion pound level. This represents a growth of 50 per cent over 1965 volumes. The major gains are expected in packaging, small appliance and upholstery markets. You are already familiar with several of the packaging applications such as, the Vitalis, Helene Curtis, and Alberto shampoos and several of the cosmetic bottles. The very recent FDA approval for the rigid vinyl material has opened new horizons for food packaging applications. These applications will replace glass in salad dressings, salad oils, and vinegar, where the extreme chemical resistance of rigid vinyl makes this application possible. The inherent clarity chemical resistance, and the toughness of rigid vinyl produces all the key properties of its usage and acceptance. Rigid vinyl has been used in the construction field, in home sidings, gutters and down spouts, and in pipe due primarily to the outdoor weathering and resistance to fade in the sun light.

Vinyl has another unique property in self-extinguishing characteristics. This is one of the few plastic materials that carry the Underwriters Laboratory requirements of self-extinguishing or non-flammability. This unique feature of rigid vinyl will find newer applications in the small electrical appliance and electrical hand tool markets.

In the communications field, vinyl has been used as a wire coating compound because of its electrical properties and its self-extinguishing characteristics. Vinyl is used as a wire coating material primarily because of its electrical properties and self-extinguishing characteristics. It is used on indoor applications of wire, replacing polyethylene where self-extinguishing is demanded by building codes. Vinyl resins have been used for years in the floor tile market, in combination with asphalt or alone as a complete floor covering. Vinyl can be extruded into thin film and used as a wall covering or as drapery and upholstery material. The automobile and furniture markets will use upwards of five hundred million pounds of vinyl as upholstery coverings in their industry.

Refrigeration and automotive will take advantage of the very flexible, long-wear characteristics of vinyl compounds as a gasketing material, replacing rubber and neoprene. The flexible vinyl is also used extensively in garden hoses.

From medical science, the vinyl producers have found methods of marketing their compounds. Certain vinyl formulations are extruded into tubes which are used extensively in the medical field. These are samples of catheter tubes which are used to trace artery problems to the heart and in some cases are used to replace certain artery canals in the human body.

Vinyls are used to produce plastisol coatings which are used as water-proofing materials in the textile industry, as slush moldings for toys, such as the dolls and doll heads which have become so prominent in the last few years. The use of vinyls is wide-spread in the coatings market, particularly paint, where resistance to weathering conditions is most important.

The use of vinyl continues to grow and with this application growth will come increased production capacities to service the needs of industry. The textile industry has increased its demand for use of plastic materials to the point where it is difficult to obtain industry's figures on the use of the many plastic materials now in existence in the textile industry. Nylon, acrylic, polyester, polypropylene, polyethylene fibers all serve a need for the textile applications.

Rather than cover all of the products used, let me speak primarily of the oldest and still one of the most widely used materials, nylon. Stockings and lingerie have used the properties of nylon for many years to glamorize this textile market, but do you realize that the same nylon can be molded into gearing systems that have found widespread usage in the automotive and appliance industries to eliminate the need to lubricate the bearings and gears. Here is a nylon gear that is being used in the automotive industry, and here is a nylon fan blade that is being used in the refrigeration industry, and here is a nylon battery that is being used in the telestar satellite. These are molding applications, but if you would take the same nylon filament and weave it into a rope, you would have a strong resilient cord. Although the nylon growth has been retarded by the advent of many new and more exotic textile plastic materials, nylon continues to grow in volume. The other plastic materials fill certain voids that the nylon produces, but each material fills the needs and the demands of the consumer through the ingenuity of the designers and the engineers of the industries.

There are many other materials with specific properties and goodly volumes, which we have been unable to discuss because of the time limitation. These materials are the acrylics, polycarbonates, the butyrates, polyurethanes, the phenoxies, the acetates, and the entire thermoset lines of plastic products. These may all be strange names or peculiar identifications to you, but in some applications you may come in contact with these materials each day of your life.

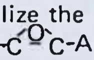
It is the desire of the consumer, the creative imagination of the engineers and designers of consumer products, and it is the technical ability of most material suppliers that will make this industry grow beyond the bounds of our imagination. It is the combination of your arts and skills to sculpture the needs of mankind to a commercial reality through the man-made materials of plastics that will make the future world of our children a truly plastics world indeed. It is the realization that the properties, the value, and the cost of plastic materials will make the major breakthrough in bringing food to the hungry of the world, education through television to the uneducated of the world, and possibly through these two means of communications, it may bring peace to the world.

LIQUID RESINS—EPOXIES

RICHARD F. DICKHAUT
UNION CARBIDE CORPORATION

Earlier you were exposed primarily to discussions of thermoplastics. Now, we will look at *thermosetting* resins. A thermoset obviously is a material which when reacted establishes physical form which cannot be changed by further heating or reaction. It can be degraded, carbonized and almost obliterated, but it cannot be reformed. In this way it differs from thermoplastics. Polyester and epoxies are thermosetting materials. I will discuss epoxies, and, if we have time, I will briefly mention the foundry applications of phenolic resins, because this falls within my area of discussion and business.

Now, what causes these thermosetting materials to be permanently formed? Basically, it is a chemical reaction, a cross linking of molecules one to the other into a final form. This is why epoxy is such a good adhesive. It creates not just a physical bond, but a chemical bond. Epoxies depend on a curing agent. You may refer to it as a catalyst, a kicker, (and a nuisance) but you must have a curing agent. This can be qualified by reaching into the "wild blue" and saying that we do have evidence that an epoxy can be cured with gamma radiation, but I doubt that very many of you have gamma radiation available in your studios. Most of us are familiar with epoxy in terms of what we may find at a hardware store; a little card with two tubes on it and the popular instruction to mix parts of tube "A." to equal parts of "B." The resin with a filler material is in one tube and a hardner with other fillers in the other tube are brought together in a room temperature curing system to form an adhesive.

Visualize the typical carbon linkage which forms a triangle.  $-\mathrm{C}\overset{\mathrm{O}}{-}\mathrm{C}-$ An epoxy depends on the breaking open of this ring to form a cross link to another molecule. It is made from Bisphenol A or Bisphenol F: two phenol rings and epichlorohydrin which contains this ring configuration. By reaction, we create a diglycidol ether of Bisphenol A or F.

Now, the *curing agents.* The two-tube system I described, which you commonly find in your hardware, paint, or craft store, employs a straight chain carbon aliphatic amine curing agent. In addition to this we have aromatic amines, a ring configuration, and acid anhydrides.

Where do you use each one? Based on the questions I received this morning, I assume that most of you who have worked with epoxies are working with aliphatic amines because you do not have an external heat source available to you. For your purposes an aliphatic amine is quite satisfactory. However, for putting a man on the moon or putting a Boeing 727 in the air, the systems using aliphatic amine cures do not develop the strength and desirable properties that can be achieved with other curing agents.

Some commercial planes have in excess of 1,000 lbs. of epoxy on them because using epoxy in conjunction with fiberglas, or other fillers, we can achieve parts of great strength with very little weight. Obviously with aircraft, light weight and excellent strength is necessary, and so the manufacturers use epoxy resin systems. We'll have more details on this later and show you *where* on the plane the epoxies are used.

A frequent question this morning involved the various materials that were on display—asbestos, Cab-O-Sil, etc. These are classified as *fillers.* Normally, and particularly at room temperatures, epoxy cures are "hot" reactions. You can increase strength and slow down this reaction until it can be handled in larger volumes by adding fillers. As a conservative rule of thumb in an epoxy system on a weight basis, you can increase strength and slow down a reaction by adding fillers up to sixty per cent by weight of the resin system.

A *diluent* is a material used to dilute a resin system, and this also slows down the reaction. When "loading" a system, (this is the term used when putting in asbestos, sand, or anything added as a filler) you can't start off with a material that has the consistency of maple syrup in January. It must have a low viscosity. So, if you are starting from scratch with your own resin system, a *diluent* may be needed. Diluents will slow down your reaction, but they may also weaken the system. This, however is a relative thing. If you were looking for the great strength necessary for an aircraft, you would have a noticeable weakening when using a diluent. However, in a typical casting application, where there is no stress or strain on the completed casting, this may be irrelevant.

In line with that, for most purposes you will want to go to some epoxy compounder in your home town to get a castable epoxy material. An unfilled epoxy resin system can be extremely dangerous to the untrained user. I can show you a very small casting that reacted so hotly that it is completely crazed throughout. The reaction is dependent on mass in an epoxy system. If you're going to cast 20 pounds and are using a straight resin and an aliphatic amine hardener, I would suggest that you spend about ten seconds mixing, then get completely out of the room. This exothermic reaction which is related to mass can be very violent. So, again I suggest that you go to a compounder who adds material to slow down this reaction. But, be careful! In the laboratory situation, any work with an unknown quantity of resin or unknown resins and hardeners is always done behind a shield. The knowledgeable chemist has a great respect for his working tools.

In this slide of a Union Carbide Product data sheet, you will see ERL-2774 which is a commonly used resin. Shell Chemical Co. manufacturers a similar resin as do other companies. ERL-2795, is basically 2774 that has a lower viscosity.

For purposes of comparison ERL-2774 is the consistency of Karo syrup. It looks very much like syrup. The 2795 is much more akin to water than to syrup. The difference is in viscosity. With the 2795 you can "load" the system very heavily with asbestos or other filler and still have a workable system. The 2774 system, when heavily filled will be thick and unworkable. If you want to cast it, the material will not flow properly into a mold. These are things that you should be aware of when you purchase materials for your epoxy work.

To illustrate further, the use of diluents, fillers, etc., I would like to show you this cast epoxy pipe joint, as compared to this crazed resin system sample. First of all compare them as to mass; remember the reaction is dependent on mass! This pure resin system got so hot that it "crazed." The pipe joint resin material, obviously of much larger mass, was filled with sand, asbestos, and pigment. It was cast with no "crazing," whatsoever. We can go up, using various fillers, to castings that weigh 2000 pounds. This morning, someone asked how thick I would recommend making a certain casting? My comment was that I could never answer that without knowing all the conditions involved. There are too many variables. Let us assume, that you use sand as a filler. If it has a metallic substance in it, this could work as a catalyst and cause a very hot reaction. You must experiment. Start slowly and build up. But again I say, if you want to get into casting, check with your local epoxy distributer. He knows the properties you want and can offer a suitable material.

This is a filament-wound pipe. And when we say "filament-wound," picture a tubular mandril the size of the inside dimension, and a fiberglas winding machine that goes back and forth along the length of the mandril. The machine continuously winds fiberglas that has been dipped in an epoxy resin system. When sufficient wall thickness is built up, heat is applied and the epoxy is cured. Obviously, this is a very costly type of operation. You might ask, why such a pipe? In an oil well or corrosive situations where a cast pipe will completely disintegrate in a few months, this will stand up indefinitely. You can apply this to your own situation. If you need corrosion resistance, good weathering, epoxy is one of the materials that you might choose for a casting.

In addition to the diluents and fillers, there are other resinous modifiers. Epoxies are not only rigid, there are epoxy systems that are flexibilized to the point where they will exhibit a noticeable flexing under pressure in your hand.

What can you expect in terms of properties from an epoxy system? A typical epoxy system will give you 8,000 to 12,000 pounds per square inch in tensile strength. Compression strength runs 15 to 30,000; flexural, 18,000; rockwell hardness, plus or minus 100.

Epoxies are self-extinguishing.

Electrical characteristics depend entirely on the resin and the filler. One large power company in this country is planning to build their cross country electrical power towers of special filament wound epoxy pipe because of its electrical characteristics. Many electrical units are encapsulated or sealed in epoxies.

Chemical properties might become applicable in sculpture where there is an exterior situation in an area of heavy air pollution. The epoxy systems are, generally speaking, resistant to all but the very strongest oxidizing acids, most caustics and most solvents.

In addition to the casting of these materials, we have various other applications that may be of interest to you. The so-called "wet lay-up," as we know it, is a wet resin system applied to fiberglas mat or cloth and laid up against a mold until it cures. It has many applications. I'm sure this will be covered in the *polyester* section.

We have spoken of adhesives previously. When I mention a two-part system I am sure some of you will indicate that you have seen a one-component epoxy system. In such a case, the epoxy contains a small amount of latent catalyst which requires the presence of air for reaction. It may come in one container, but it's still a two-component system.

Another area of application is that of coatings. Epoxy coatings, because of their good weathering characteristics, are in very common use. Here again, go to a compounder if you're looking for a coating. Don't go to the manufacturer of epoxies. These are compounded materials. We, as a company, sell resin or hardener to a compounder. He, in turn, puts in the fillers and then sells it to you as a coating.

Frequently, the alleged health aspects drive people away from epoxies. I offer an opinion that this is primarily psychological. To illustrate: I was just recently called in by a company who uses epoxy materials. The plant manager said, "We are going to change from one epoxy system that you people make to another. We have had a rash of complaints from people that this or that illness has cropped up all because they are using epoxies. You and I know that the new material is no better as far as potential health hazards, but I'll bet you that these problems clear up." And I checked with him about a month later and sure enough they did.

Now, where are the real health hazards? In describing the hardener, I mentioned amines. Certain amines potentially can cause dermatitis, a skin disease. A rash, probably as severe as poison ivy, might be caused. Let's look at the positive aspect of it. I have experienced severe cases of poison ivy and not even walked through the plant. Yet I have dipped my hands in epoxies and amine hardeners and have never had a problem with dermatitis.

The answer: the safe use of epoxies lies in the proper use of good preventive and sanitary measures. Use polyethylene gloves or one of the various protective creams that are on the market. It's like putting on any hand cream and it doesn't interfere with your work. Always remember, when becoming involved with epoxies or *any* material containing chemicals with which you are unfamiliar, use a protective hand cream and bathe when you're finished using them.

Don't inhale solvents. Now, this does not refer to epoxies but you may wash equipment with certain organic solvents. Don't inhale these solvents anymore than you have to. There are certain organic solvents that are potential health hazards. In most cases it would involve taking a "bath" in the solvent for a long period before there would be any problem. But it is a cumulative thing; so if you're using solvents day after day after day, remember the potential hazard. I mention these things, not to frighten you, but to point out that safety precautions are necessary.

For your convenience if you don't want to ruin your clothing, wear a lab coat. They now have paper disposable coats, which you can wear for a week and throw away. If it becomes heavily saturated with an epoxy hardener or resin, throw it away, because it's going to be uncomfortable anyway. The important thing is *cleanliness*. This will do more to prevent any possible dermatitis than anything else.

Several letters which came in before the conference, were forwarded to me and I was specifically asked to cover the health hazard aspect. There it is. *Use common sense, and clean up after you use the material.*

Foundry Application of Resin Coated Sand

In industry, the trend in the foundry (the commercial foundry) is toward the use of shell molds and shell cores. I have here a shell core. This is millbank sand with about four per cent by weight phenolic resin on it. Now, for those of you who are not acquainted with the operation, let me try to describe it. If you can visualize a metallic casting for which you need a specific inside dimension as well as a specific outside shape, a sand coated with resin is placed up against a master pattern and heated. As it heats, the resin flows over the sand granules and fuses and takes on the shape of the pattern up to a desired thickness, which is usually about one-fourth of an inch. The rest of the sand hasn't gotten hot enough for the resin to flow, so it drains away freely. Now, you have a sand pattern that you use on the outside or a core pattern that you use for your inside dimension. The molten metal is poured between an outside and inside sand mold. As the metal hits the resin, it is hot enough so that the resin begins to disintegrate. It holds its shape just long enough for the molten metal to take the shape of the mold. Then, the resin loses its strength and the sand just falls away. With a little shaking you have a casting with no pattern either around or inside it. This is done with urea formaldehyde resins and with phenol formaldehyde resins, ("phenolics," as we call them.)

One final note! I am a great believer in plastics publications. Anyone interested in plastics should subscribe to one of the better plastics magazines. Also, if I were in your position, I would get a good epoxy text. Most contain a lot of technical detail that you will have no interest in, but some of the practical applications and illustrations in these books make them worthwhile. Is there a real fast question?

Question: Can you tell me why epoxies are so much more expensive than polyester resin . . . ?

Answer: I think you're probably referring to a compounded material rather than a raw resin system, as we refer to it? Part of the cost is the compounding and part is due to the fact that the raw resin is more expensive. The latter in turn, is due to two things: the cost of raw materials that go into it and to some extent the volume of manufacture. Polyesters have a variety of uses where great strength is not involved. Thus in terms of volume, there is a much larger volume of polyester being sold and this always helps to bring the price down. Epoxies receive a more limited usage. They are limited to situations where certain properties are desired.

Another thing I might mention: if you have a situation in which you wish to reproduce very exacting detail from a flexible mold, the shrinkage characteristics of epoxies are much better than polyester. Polyester tends to shrink where the epoxy doesn't. So, in some cases, its worth the extra money. You must be the judge of that. Now Larry Chirpich will take up polyesters.

Thank you.

LIQUID RESINS—POLYESTERS

LARRY CHIRPICH
COOK PAINT & VARNISH CO.

Before I begin my presentation, I would like to say in response to the numerous inquiries I have had regarding these large brochures, "Polyesters; Their General Applications," I'm sorry, but the supply I brought is out. If you wish to obtain one, you can write to our Kansas City office. I'm sure they'll be happy to send you one.

Polyesters are a thermoset plastic. In other words, once they react, they are solid. You cannot heat and melt them. Heat will destroy them. Polyesters are generally thought of as being in the reinforced plastics field. The two major resins used in this field are epoxies and polyesters. There are advantages and disadvantages in both. In polyesters, probably the biggest application is the boat industry, fiberglas boats. Here is a case where you have a plastic replacing a natural material, and you obtain better strength and better weathering characteristics. Another growing field for polyesters is the automobile industry. You are probably all familiar with the Corvette and some other cars of the future that employ plastic bodies. The majority of the parts of the Shelby Mustang, some special Cougars, and the American Motors AMX cars are made of fiberglas. This is a growing field. You are seeing a lot more plastics being used not only in the transportation industry but in almost all industries. The growing markets in the future are going to be the furniture and the building industries.

Let us take a look at what a polyester is. A polyester is made up of a number of raw materials, small components or building blocks. The ones in general use are malaic anhydride, phthalic anhydride and a glycol of some type. Glycol is basically a di-alcohol. These reacting together under heat form a chain structure. If these are cooked together and poured out, on cooling it will become a hard mass. In this particular state, it is a thermoplastic; you can heat it and it will become liquid again. But you want a polyester in a liquid form, so you dissolve it with a solvent—if you want to call it that. We prefer to call it a monomer—and this is generally styrene or a homologue such as alpha methylstyrene or chlorylstyrene. There is a basic chemical reaction between the monomers or solvent. The reduced polyester base resin is unstable. If you take a resin that has been cooked and dump it into a monomer, in a matter of hours this will harden and you cannot use it. Therefore, it must be inhibited. An additive is used which will stop the reaction. You have to make a compromise. If it is inhibited too much, you can never use it, and it is this characteristic of unstability that makes polyesters useful. So what you do is add a catalyst and an accelerator to control the stability, and this is basically what's done with polyesters.

There are basically three stages in the curing of a polyester. It starts as a liquid and as the reaction proceeds you get a gelatin-like mass or a gel state; then this gel state becomes a hard substance. The chemistry of this is a little involved, but you can visualize the principle very easily by considering two pieces of cardboard the backbone structure and staples as styrenes. When the cardboards have no staples in them, you have the liquid state. They are free to move around. Now, when you start stapling and have put in a few, these cardboard pieces are still free to move somewhat; this is the gelatin stage. But as you keep stapling, you eventually wind up virtually with one piece of cardboard.

Let us take a look at some of the common accelerators and catalysts that are used. The catalysts generally used in industry are methyl ethyl ketone peroxide or benzoyl peroxide. The peroxides by themselves degrade to produce the reactive molecule which starts the reaction, and by controlling the amount of catalyst you can control the speed of your reaction or the time it takes to go from a liquid to a solid state. The catalysts by themselves decompose, but the rate is not fast enough for industrial uses, so you must use an accelerator and you get what is chemically known as a red-ox reaction. In other words, the accelerator acts upon the catalyst. The catalyst decomposes in this case at a very fast rate. Now one thing I should mention here is that you never want to mix a raw catalyst with raw accelerator, because you will find it all over the ceiling. It explodes very violently. So let us take a look at some of the systems.

Room temperature systems are in the area where you would be working. The basic one is MEK peroxide and cobalt. These are usually cobalt salts, cobalt naphthenate, cobalt octoate. Let me give you an idea of the concentrations of the two you would normally use. For an accelerator, you would normally use, probably .05 per cent up to about .4 per cent. If you exceed or go below this, you are in trouble. You never drop below one half per cent or go above four per cent catalyst. If you go below, you do not have enough catalyst to make your reaction go. If you go above four per cent, you have too much catalyst and your reaction proceeds at a rate so fast that you wind up with a cheesy mass. In room-temperature systems, besides cobalt and MEK peroxide, you can use another peroxide, the benzoyl peroxide and analine system. Now, this is a system that is normally used in what we call a dual gun system, where you will have two barrels of resin. You will double accelerate one, double catalyze the other, and you will pump these together in equal portions and mix them, similar to some of your epoxy systems. Now, all accelerators are not accelerators for every type of peroxide. If you mix cobalt, and benzoyl peroxide (BPO) together you will get virtually no reaction. If you mix analine and MEK peroxide, you will get virtually no reaction. But there are some interesting side effects. You take a system which is made up of MEK peroxide and cobalt and add analine to it, the system will react faster. In this case, the analine does not react with the MEK but actually reacts with the by-products of the reaction of the cobalt and MEK peroxide producing more active cobalt for the system.

The other area of curing systems is heat catalysts. In this case, the most common one is benzoyl peroxide. This is normally used with heats of 250 on up to about 275 degrees Farenheit. These are used mainly where you want a fast cure system. And by a fast cure system I am talking of anywhere from 60 seconds to 90 seconds. With room temperature systems you have a working time, normally of 15 to 20 minutes gel time or the time it takes to go from a liquid to a gelatin state. Most heat systems are automated. In these systems the catalyzed resins at room temperature are stable for three or four days, but when you apply heat, it goes off very rapidly. I cannot, in the time that we have, go into exact curing systems, but if you will look into this bulletin, it is pretty well explained. There is a wide variety and they generally depend on how much time you want to work with a sample.

Let us take a look at a few of the products that are made with polyester coatings. This industry is fairly new and we are not quite organized, so we do things backwards. When you normally build something, you build it from the inside out. We do just the opposite in this industry. We build from the outside in. This is a small mold similar to the type used in production. Normally we spray a gel coat. This is the exterior surface which gives you coloring in most fiberglas parts of hand layup systems. Most gel coats are formulated to spray. Although there are a few that are formulated to be brushed, in industry time is money and the spray is faster as well as easier to control than the brush.

This is a part pulled from a mold. The black exterior coating is the gel coat. This is our final surface. Now, just what goes into a gel coat? You have your resin, diluted down with styrene, plus your pigment. These pigments are usually pretty well checked out by the manufacturer of polyesters for a number of characteristics: curing, weatherability, and compatibility with the system. Also flow agents are included for a nice smooth finish when spared. There is also what we call a thixotrope material. As in epoxies, we use cab-o-sil to a great extent. This material gives false body. In other words, a can of this material undisturbed looks very heavy, thick, and viscous. But as soon as it is stirred, it thins down like water. As soon as you stop stirring it, it becomes thick again. Now, this is a very desirable property with a lot of your resins because these are to be sprayed onto something and you do not want them to run off. Paint, you probably will spray on one to three mils at the most and this will give you a good covering. A mil is 1/1000 of an inch. With polyester the normal range is 15 to 19 mils. This is a fairly thick coating as far as paints are concerned. So you must have something in the material to assure it will stay when you spray it on a vertical surface. But at the same time, it must be thin enough to go through the spray gun. As soon as the pumping is started it thins down. Then as soon as it hits the mold, it bodies up and stays there. There are a number of types of spray equipment that are generally used. For small applications a quart to two quarts pressure pot are used. For large applications, there are catalyst injection guns. Let me mention some of the requirements for a spray gun used with polyesters since they differ quite a bit from paint. Let us consider a little quart pressure pot, which is used to spray small or limited production items. The material is catalyzed in the pot before spraying and you must know your gel-time. You must have time to spray your part, come back, clean out your gun. In industry a catalyst injection gun is used. It is basically the same principle. The material is pumped from a large pot, a drum. But in this case, the material is not catalyzed in the drum or five gallon pot, but the catalyst is picked up in the atomization air and is introduced into the polyester in one of two ways. Either it is an internal mix, mixed inside the gun, or it is mixed externally, just as it leaves the gun and is being broken up. These are very handy, because you can do a lot of spraying. You never have to worry about pot life or your gun gelling when you are finished. Use a simple solvent flush or wipe the gun head off and you are done with it. You can set it down until you are ready to use it again.

Now, some of the characteristics of the gel coat? The first one, naturally, is flow. You want the material to flow a little bit in order to form a nice smooth finish, especially against your mold. It must be non-draining. For this thixotropic agents are used. Then you must have your hide. Most pigmented coats are formulated to give you complete hide. In other words, if you stick your hand behind a part that is gel-coated, you should not be able to see it. Most are formulated to give a hide of about fifteen to eighteen mils without producing an expensive, hard-to-use gel coat. The reds and some yellows have a relatively poor hide. Most of the gel coats are made to be patched by a gel coat. There is no part, or I have yet to see a part made industrial-wise, that does not have a flaw in it somewhere either in pulling it out of the mold, in handling, or in just sitting around the plant. Somewhere, it is going to have a defect. Therefore, you have to have patchability. When you patch, you should try to always use the same batch of gel coat you sprayed the parts with. There is no way to control minor color differences between batches of gel coat. You can get two different batches, and they may look perfect to you. But even a small variation may show up when you try to patch.

Weathering is another good characteristic of polyesters. After a number of years, it will chalk a little bit as almost anything exposed to the weather will erode. But the beauty of the system with polyesters is that with a little rubbing compound and a little wax, you can get it back to your original sheen with no problems. The importance of curing the gel coat is a little different from laminating resins. You do not want a gel coat to go hard before you can laminate on it. But you do not want it so soft that your glass pattern will show through. You do not want your laminating resin to attack your gel coat causing it to pop loose from the mold giving it a rather wrinkly finish. Most Cook Paint and Varnish gel coats are made with a pot life of about fifteen to eighteen minutes using about one and one half per cent methyl ethyl ketone peroxide. It will be ready to lay up on or laminate between forty five minutes or an hour. The simplest test to tell if a gel coat is ready to lay up is to stick your finger on it. It should be sticky, but the coloring should not come off on your finger. If it comes off on your finger, you must wait. You want this tack to insure good bonding when you start laminating.

Let us go on to laminating resins, the resin that you use to bond the glass together. This is where you get your strength. Polyesters by themselves are not the strongest materials in the world. You normally try to fill them endeavoring to obtain strength from bonding different types of fillers together, generally fiberglas. There are a number of types of glass and the type you choose will depend on the strength necessary for your part. You can use small chopped fibers of glass. You can use a chop mat which is something like a piece of cardboard, except it is made up of small fibers, normally one inch or two in length, bonded together with a small amount of binder or you can use roving. This is glass fiber, manufactured in such a way so that it simulates binder twine. You can use woven roving. This is taking pieces of binder twine and weaving them into a cloth-type arrangement. Or you can go into a cloth mat which is smaller, like string woven together. Now, I will not mention too much about the strength characteristics of the different types of glass as the gentleman from Owens-Corning is going to talk on this.

Let's take a look at what goes into a laminating resin. Styrene is used to thin it, and a thixotrope is used to give it body. Normally you want it to wet the glass fairly fast, but you also do not want it to run out. Now, you do not put the same amount of thixotrope, or cab-o-sil in a laminating resin as you would in a gel coat. A gel coat will have something like two to four per cent cab-o-sil while laminating resin will generally be in the one per cent range. If you get it too thick you will have air entrapment. Laminating resins come unaccelerated and accelerated. By this I mean, if you have an accelerated resin, all you have to do is add the catalyst. If you have an unaccelerated resin then you have to add the accelerator. Stir this in first. After that is completely stirred in then you add your catalyst. A few things that you have to watch in laminating is the ratio of glass to resin. For most shop parts where you are using glass mats, your ratio is about thirty per cent glass to seventy per cent resin. This gives you fairly good strength. Now, as you go into some of the other types of glass, such as the glass cloth, you may use as high as sixty to eighty per cent glass and normally you get better strength. The more glass, the more strength you will get. All of the different laminating systems I will be talking about must be rolled with a metal roller. The reason for this is that you will entrap air in the resin as you mix in the catalyst and as the glass is saturated. The use of the roller is very important, because if an air bubble is trapped next to the surface or gel coat, you wil have a defect which will show up.

There are a number of systems used in laminating. The most common one is hand laminating. For this a chop mat or cloth is used. A quart or a gallon of resin, depending on how fast one works, and the pot life is catalyzed, poured, rolled, or sprayed on the mold. In some cases glass roving or twine is chopped up into predetermined lengths anywhere from one-half inch to four inches and are sprayed on with the resin. This is excellent for a large number of parts, but I would not recommend it for somebody who is going to make a part a day or a part a week. It is too expensive. Right now the price is up to about two thousand dollars for the complete setup.

Getting back to my model. After spraying the gel coat, we laminate behind it. You just lay this in as the finishing coat. Because some people do not like the rough surface of fiberglas, what is known as a polyester enamel is sprayed on. It is basically the same thing as gel coat except it is formulated in such a way that when you spray it, it will dry tack free in the presence of air. Enamel is used to give a better appearance to a part.

Now, let us take a quick look at how you go about making molds to be used with fiberglas. A wide variety of mold materials can be used including fiberglas itself, epoxies, and metal. Most of those I have seen used in the industry are either metal, fiberglas, or epoxy. Epoxies and wood are generally used for a master plug. This is the part from which you will make a mold. This part usually requires a lot more precise work than the general laminating. The reason for this is any defect in your master will show up in every part you make and there is no way to get rid of it.

compound. The resin filled with glass is bodied up by a false means and formed in sheets. As it is placed in the die and heated, it becomes liquid again and then goes on to cure. Another of these is the low profile system. It is an incompatibility system where one resin fills in the voids of another. Both of these systems are designed primarily for the transportation industry to be used in matched metal dies. Unfortunately, the cheapest press system costs $10,000 and I have seen some as high as $150,000.

Now briefly a bit about casting resins. Basically, this is just a straight resin diluted down with styrene and accelerated. These resins are designed to be filled not so much by glass reinforcement but a calcium carbonate, crushed limestone or rock aggregate. Normally, two grades of filler are used: a coarse filler, something like sand in size, and a finer filler, something like a talcum powder. The reason for this is to avoid resin-rich areas which will cause warpage. The combination is used because the fine material fills in between the coarse so more filler can be used. Fillers are important for economy, because you are talking of a difference of 25 to 30 cents a pound for resin compared to one cent or less a pound for fillers. Now, there are a number of types of molds used, fiberglas, formica, stainless steel, and glass. Each has its own advantages and disadvantages.

Water white systems are clear casting resins designed to be used without fillers. To our particular company, this was a novelty item, not a large volume material, maybe ten drums a month. While with our other resins, we speak of tank cars a week or month. This particular resin is designed to be poured into a mold usually to encapsulate something. It is a slow curing resin. The reason for this is that it is not reinforced and if you cure it too quickly it will crack. Normally, you will cast segments three fourths inch thick. Now, this can vary somewhat depending on your part. It is pretty hard to generalize when you come to casting resins, because your part is going to determine how many pours you are going to have to make to cast your part. When embedding there are a couple of things to watch out for. We found out the hard way. If you have a solid object such as a coin or a rock you want to soak it in resin first, just briefly. This is to ensure when you put it into your mold that you will not have air entrapped in it. Now, if you are going to use something that is porous, such as an insect, you want to make sure that it is dry, that is there are no body fluids in them. These should be soaked overnight in the resin. The reason for this is if there is air or liquid other than polyester as the polyester cures and gives off heat, the gases or liquids will expand and literally explode inside your part.

Like most organic coatings a polyester is safe if you do not abuse it. The same is true of epoxy or any resin. If abused, it becomes dangerous. There are a few precautions you must take. First of all you should never mix raw catalysts and raw accelerators. They explode violently very quickly. You also should work in an area where you have good ventilation, because the fumes given off, which are mainly styrene, also the solvents, mainly MEK, acetone, and others used in clean-up are flammable. You should watch your scraps because polyester kicking off does produce heat and if you allow a number of scraps to form a pile, they may burst into flames. Polyesters being organic materials are also flammable. When you are going to laminate polyesters, or almost any organic coating, you must make sure you have no open flames and that your electrical equipment is non-sparking because it does not take much to set off vapor-air mixtures. In fact, this is more dangerous than the liquid. This is why ventilation is very important.

A number of odds and ends I can think of off hand. One is the fiberglas itself. You will find working with this very itchy. It gets on your clothes so you will not want to wear good clothes when you work with it. I have seen customers use an airhose to blow glass off. This is very dangerous. You can blow the small, minute glass fibers—this is what they are no matter how soft they feel—directly into your skin. They could get into your heart or brain. If you want to remove glass fiber, there are a number of ways you can do it safely. One is use masking tape, take it off like you would lint. Another is a real good cold shower. There is a little trick we picked up. If you have glass where you cannot tell where it is, but you feel it every time your clothes move, what you can do is to take a little sandpaper and just lightly sand the exposed edges off. This stops the itching. There will be a little glass in there, but eventually it will work out. One other thing, if you have cuts or scratches, as soon as you stick your hand in solvent or polyester, you will find it will burn like mad. Catalysts are a skin irritant, as are some of the solvents to some degree. Your polyester and your styrene will irritate you so if you spill anything on you, wash it off with warm soapy water real quick. I suggest that anytime you run into something new read the label. We find a lot of people do not read the label. In industry, this is half my job correcting people who have forgotten how to read labels. Labels are placed there for a reason. They are very important. Almost any manufacturer of any type of material that is in any way organic will be happy to supply you with a sheet or tell you where you can get information on the hazards of particular products. The suppliers have sheets on this. If they cannot help you, contact the maker of the material directly. They will send you the information.

This is briefly my talk. For more detailed information use this bulletin, *Polyesters: General Methods of Application*.

Question: What types of paint will adhere to polyester?

Now, how do you make a mold or plug? Let us say we wanted to make a mold for a boat. We can do it in a couple of ways. We can make a wood plug, or if we know someone who has a boat that they do not mind if we play around with, we can use it. First you would polish it, buff to the sheen you want, because polyester gives a mirror finish to your mold. After all the imperfections are worked out, release coat is applied. Normally, this is a non-silicone containing wax. Silicones are nice, but the problem is that they cause polyesters fish-eye. In other words, they will pull away in small sections from the minute parts of silicone. A straight wax, such as you polish your car with will work. Wax it three, four or five times to make sure you get a good coat. If you have a rough or pebbly type surface and this is the type of part you want, you can spray on a PVA (polyvinyl alcohol) parting solution. This is to give you added protection. The gel coat for this varies a little bit from the normal one. A tooling gel coat (mold-making is generally known as tooling) is a very rigid, hard material. It is this way for a couple of reasons. First of all, the part probably is going to have to be sanded from time to time to take out the scratches that develop. The gel coat is rigid so you can come back and buff it easily. The normal gel coat is a compromise between a rigid and a flexible gel coat. With a rigid coat, you have good mar resistance, but it cracks very easily. With the flexible coat, you have good crack resistance, but it mars easily. So most good gel coats are a combination of a flexible and a rigid resin. To give you the best properties that can be obtained from both, you spray your gel coat on and let this cure. Then you come back with either vail (a very thin soft fiberglas) or with glass cloth. Cloth and vail are used to give a smooth surface next to the gel coat. Cloth must be rolled to remove the air because air pockets on the mold will show up on all your parts. After this is set up, you start slopping in glass mat or woven roving or anything you want. The reason you let it cure is that if you try to laminate the part all at once, you must roll pretty hard and you may get the glass pattern showing through onto your mold, and this glass pattern will then be transferred to the part. After the first layer cures up, put on whatever reinforcement you want to use. A mold is built up more than a normal part. Most boats will run a thickness of from one-eighth to about three-eights of an inch, and in rare segments they will go up to half inch. You usually build up a mold pretty substantially, because it will take a lot of abuse. After laminating you may even want to reinforce it. You may use steel, a pipe, or a flat bar. Place it where it is needed. A couple of laps of fiberglas over it will bond it into place. You may use air pressure to break the mold loose. Then after polishing out the rough defects you have a mold. There is a special procedure for breaking in a polyester mold. I am speaking mainly of finish. The polyester is somewhat porous; it has very small pores and cracks in it. If you do not break the mold in right, you can lose it and the first part you make. The polyester will bond to the polyester mold. How do you prevent this? You go through a break-in process. After your mold has been buffed to perfection, it is waxed four to five times. After waxing, it is sprayed with PVA (polyvinyl parting film). The first part in most cases is horrible. It is a reject part, and this is normal. But the exotherm of the part melts the wax in the mold and starts to fill in the surface. After three or four parts, the minute holes will be filled, and you can do away with the parting film. At this stage, you can make anywhere from ten to even a hundred parts without rewaxing with only buffing here and there in small spots.

Briefly, I want to go into an area that not too many of you can afford to get into, but it is interesting. This is an automated matched metal die system that produces a large number of parts very quickly. This process employs very large hydraulic presses, two dies, male and female usually of chrome plated steel. They will run five or six thousand dollars apiece. These dies, normally heated to between 250 and 270 degrees Farenheit, come together with precision. The cavity is usually about an eighth of an inch. With this type of system, the cycle time—the time it takes to put the material into the mold and get it out—is often two to three minutes. This is where you start using heat catalyst, benzoyl peroxide. Specialized catalysts are usually adapted or developed for a particular system or a particular part that is to be manufactured.

The most common molding operation is what we call a wet mix; resin and filler are mixed together. Fillers are used in this case for strength as well as economy. Mostly, fillers that are used in the matched metal die industry are either a clay or calcium carbonate. The resin, filler, and catalyst are mixed together, often 500 to 1000 pounds at a crack. A measured amount of resin is poured over the mold, and the glass, which has been cut to the shape of the part is dropped in the mold. The mold is closed normally from sixty to ninty seconds, and the part when it comes out is completely cured. All you have to do is trim it.

Another approach is called gunk molding or pre-mix. In this, resin and catalysts are mixed with the filler and glass. Chopped glass is used, even asbestos occasionally but not normally, because asbestos gives false body. A predetermined weight charge or ball is thrown into the press. The press comes down and squashes the charge and it flows out over the part. Examples of a gunk molding are vacuum cleaner housings and helmets. To give you an idea of these parts production-wise, a company in Michigan which is making helmets for motorcyclists averages for one shift a production of 2,000 a day.

There are also some interesting developments coming into this field. One is called sheet molding

Answer: Well, first of all, polyester itself if you sand it down a little bit, can be put on a polyester surface. Epoxies work very well. Now, if you go to some of the other paints you have some problems. You not only have to sand, but you also have to prime. The kind of prime I am talking about is either epoxy or vinyl wash.

Question: (Inaudible)

Answer: On the Corvette these are sanded down lightly. Actually, the part itself comes out black. They pigment these. Matched metal die pieces are usually internally pigmented. They sand down and spray on a special acrylic lacquer for this. In some cases they prime the part, depending on what it is.

Question: (Inaudible)

Answer: Transparent? Clear? First of all, it sounds like you have got a gel coat that has a water spotting problem. In other words, someone tried to use a cheap color to cheapen the gel coat. Usually, if you start out with good materials, you will not have this problem. You can get away with polishing the back. Now, with clear material, you use a clear gel coat or you can come back with, I believe, a clear urethane finish. Now, I am not absolutely sure of that. It is something you would just have to try. Urethane will stick to just about anything.

Question: (Inaudible)

Answer: Plexiglas? First of all, Plexiglas is absolutely clear. We have tried to make clear polyester panels with good strength and you have to get glass in there and the glass does give you some opacity. Now, Plexiglas, being clear and not filled does not have the strength characteristics that you can get with polyester.

Question: (Inaudible)

Answer: Laminating? Stained-glass? In other words you want to combine Plexiglas with fiberglas. The best way would be just to laminate directly onto the Plexiglas.

I have been asked to make a very important announcement. We are going to have a break right now. If you have other questions, I will be around later in the day.

FLEXIBLE MOLDS

A. S. CROUSE
GENERAL ELECTRIC COMPANY

Silicones are a family of man-made materials having their origins in silicon, a rock-like substance derived from quartz, and organic materials of the hydrocarbon family as are commonly found in petroleum products. Because their origins are in both the mineral and vegetable kingdoms, they have inherent properties common to both.

Pure silicon is a gray solid, very brittle, and metallic in appearance. You can make pure silicon by reducing silicon dioxide, commonly called silica or sand. Silicon is found in practically every rock, in all natural waters, in the atmosphere and even in plants and animals. It is never found free in nature, and it was not until 1854 that H. Saint-Claire de Ville first crystallized it from its alloy. Simply stated, you might think of the silicon atom as behaving in a manner similar to the more familiar carbon atom. From this basic silicon we make silicones in our plant at Waterford, New York. Silicones are not new to the consumer field. All of you have probably seen the word silicone listed as an ingredient in car and furniture polishes, protective lotions, beauty products, automotive compounds and a variety of other products.

Just what exactly is a silicone? A silicone is a synthetic polymer and is composed of the elements silicon, carbon, hydrogen and oxygen. These silicones are used to make rubbers which are similar in appearance to the petroleum oils, resinous materials similar in appearance to petroleum based varnishes, and grease compounds similar in appearance to petroleum greases. But here is where the similarity ends. Like their rock-like ancestor, silicon, silicone materials are extremely inert. This gives them a greater resistance to aging than hydrocarbon based materials. A silicone rubber will last 30 years, which while an ordinary synthetic rubber will crack and dry out in about six years. Silicones can withstand temperatures up to 600 degrees F. Most other rubbers are not much good after 200 degrees F. On the other end of the temperature scale, silicone materials withstand freezing at extremely low temperatures. Silicone rubbers are flexible at minus 65 degrees F. Fluids can be poured at the same temperature and greases stay soft at this temperature.

Silicones have other outstanding properties too. The oils and greases have lubricating properties at all temperatures, although they lack certain lubricating capabilities. That is, they are designed for sliding friction and not for heavy loads such as in bearings. The greases are waterproof, non-corrosive and they are not harmful to rubber.

The commercial history of silicones dates back to the early 1940's when General Electric conducted research in the field. Of the major types of silicones—rubbers, oils, and resins—General Electric researchers made the basic inventions at the company's research and development center in Schenectady, New York.

Today there are more than one thousand different grades of commercial silicones. They are sold into every basic industry as sealants, adhesives, chemical processing aids, release paper coatings, high temperature paint additives, high temperature electrical insulation, and for a variety of other purposes. Some of the major markets are: aviation and aerospace where silicone sealants, gasketing, insulation, and hydraulic fluids and lubricants are used; medicine where artificial heart valves are made from silicone rubber; industry which uses all kinds of silicones where temperature resistance and long life are required; the construction field where high performance silicone construction sealants provide permanent elastic sealing against weather, and the consumer and marine markets for the same reasons.

This completes our background concerning the general products you might expect from silicones. Today's talk will be confined to two particular families of silicones which may be beneficial to you. Let us go back to the silicone molecule.

The part we are interested in is that Si-O-Si linkage because we are primarily concerned with silicone elastomers that can be used by you in the sculpture field. It is this linkage that introduces a degree of resistance to heat that is not found in chains composed only of carbon atoms. We can make this chain grow linearly by the proper choice of ingredients and this is essentially what happens when an elastomer is made. You might think of it as stretching out like elastic. As General Electric progressed in their knowledge of silicones, a special product appeared on the market. It was called RTV, which means Room Temperature Vulcanizing silicone rubber.

There are two RTV families that are widely used in the mold making industry. The conventional type developed initially, is confined in our discussion to RTV-11, 60, and 88 while a new high strength type recently introduced is called RTV-662. The conventional family was developed by mixing silicone oil with reinforcing fillers (Such as iron oxide, silica, and others) cured with a metal soap catalyst. So polymer plus filler gives us a liquid RTV base. A catalyst is added to cure this liquid. Let's talk about the catalyst, since you will want to vary the catalyst to suit your own sculpturing needs. It is always a metal soap such as tin octoate under the trade name of Nuocure-28 or a dibutyltindilaurate, known as Thermolite-12. The choice of catalyst gives the user greater leeway in controlling the cure. The slow one is Thermolite-12. This one permits the pot life to vary from one hour to eight hours at room temperature. Another word for pot life is working life. This is defined as the time interval from when the catalyst is added to the point at which the RTV ceases to flow. Working life then is exactly as the word implies, the time allowed to you to work with the material before it gels. The cure or firm time is the time required to obtain a firm rubber of a half-inch thick sample. So you see, knowing the catalyst is important to you. The fast type catalyst where the silicone RTV has working life of five to sixty minutes is tin or stannous octoate. Manufacturers who have mechanical mixing and dispensing equipment and wish to have the RTV cure quickly on a production line assembly use this catalyst system.

Another way to control the cure rate is to reduce the chances of error by diluting the metal soap catalyst with silicone oils and fillers to produce a paste. These are available as RTV-9910, RTV-9930, or RTV-9950. Since the paste represents the diluted version of our RTVs, you will need a greater weight of the paste when you weigh it out before adding it to the RTV base compound. As you can see, your chances of error in controlling cure are lessened should you choose to use this system. The paste is also popular because it comes in colors which contrast with the base RTV material and allows the user to have a color change so that it can be easily determined when mixing is completed. Any color streaks would indicate inadequate blending.

There are also other techniques available for modifying the pot life and curing times. Cure characteristics of RTV compounds can be controlled by varying the cure temperature. Low temperatures increase the pot life. Higher temperatures up to 150 degrees F. accelerate the cure. This permits considerable application flexibility. For example, even after a curing agent has been added, the RTV can be stored under refrigeration for several weeks, and when you decide to use it again it can be cured in a moderate temperature oven in less than one hour or cured at room temperature. Controlling working time then, represents one of the benefits of silicone RTVs in their use as flexible material for molding plastic parts.

RTVs not only yield excellent surface detail but are also simple to use, non-toxic, low in shrinkage, very flexible, heat stable, available in various viscosities and eliminate the use of parting agents in some instances. While there are at least twenty different viscosity grades available, only a few are used for molding. These particular RTV materials were originally used as high temperature sealing, caulking and encapsulating for industrial, aerospace, and transportation markets. It was not until later that some of these same RTVs became valuable in mold making.

The viscosity of RTVs range from an easily pourable liquid to a thick paste. Three grades, RTV-11, RTV-60, RTV-88, are particularly good for molding. Our RTV-11 is slightly higher than paint in consistency, while RTV-60 is like molasses. RTV-88 is a thixotropic paste which can be buttered on a vertical surface with a knife or spatula. To make molds of heavy, difficult to move objects where the pattern is on a vertical plane, RTV-88 paste can be spread over the surface without material sag. The liquid grades are used on surfaces with intricate detail. So you see, your choice among these three is dependent upon your own application. Another advantage of silicone over other synthetic compounds is heat resistance. For example, the RTV-60 is resistant to 600 degree F. temperature permitting oven cure of high temperature type epoxy resins in the mold.

RTVs are noted for their ability to transfer excellent surface detail of the model. Parts such as epoxies, polyesters, or urethanes can be reproduced exactly from the mold. These compounds have a shrinkage as low as 0.2 percent, making RTV suitable for virtually all molding requirements and since silicone rubbers have a built-in release agent, in many situations a parting agent is not required for even the most complex parts. This results in faster fabrication of models and elimination of mold build-up of the release agent. Because of its flexibility, the RTV can be used again and again for a limited number of parts, depending on the complexity of the casting being formed and the resin system being used.

How to Use RTV as a Flexible Mold Material

The following steps illustrate the simplicity of preparing and applying conventional RTV flexible mold material. While these basic steps will meet most molding requirements, they may be varied to meet specific applications.

1. Preparing the Master Pattern

The master pattern may be constructed of wood, metal, plastic, clay, or any material which has a surface firm enough to be painted with RTV. Since RTV will reproduce even the most minute surface details, care should be taken in preparing the master pattern. Blemishes should be removed or filled. Master patterns made of porous material can be sealed by spraying with several coats of clear lacquer. Waxing and polishing the patterns surface will give a high lustre to the plastic reproductions.

2. Measuring RTV

Pour RTV into a container—cardboard will do—for measuring and mixing. RTV should first be measured to determine the correct amount of curing agent to be added. For controlled cure rates, measure RTV on a triple beam balance or equivalent-type scale. Otherwise, the amount of RTV need only be estimated.

3. Adding Catalyst

After weighing, the RTV catalyst is added. For a relatively fast cure and excellent release, the most widely used catalyst is dibutyltindilaurate. Here RTV-9930 paste catalyst is being added at 10:1 ratio. This is equivalent to 0.3 per cent of the liquid or concentrated dibutyltindilaurate or T-12 which is shown in the left foreground of the slide. As little as 0.1 per cent T-12 may be used to increase or lengthen pot life. For an extra fast cure, tin octoate or Nuocure-28 catalyst is suggested. A standard medicine dropper is adequate for measuring if a liquid catalyst is selected.

4. Mixing

After carefully weighing the RTV and curing agent, both should be thoroughly mixed together for a uniform cure. Mixing can be performed by hand, using a spatula, paint stick, or a power mixer. Regardless of the mixing method, best results require that the curing agent be mixed thoroughly with RTV and the sides of the container be scraped clean several times during mixing.

5. Vacuum Treatment

When mixing catalyst into the RTV compound, air entrapped, if not removed, results in voids when the material is cured. Since voids cannot be permitted, it is suggested the compound be subjected to a vacuum treatment. After thoroughly mixing the catalyst into the RTV, the material should be placed in a deaerator and vacuum applied. The time and pressure to be used will depend upon the volume of mixed compound being evacuated. When vacuum is applied, the mixture will rapidly "froth" and increase in volume, eventually reducing to its original level. Vacuum should be maintained until this frothing action ceases and all bubbles collapse. A suggested evacuation procedure for one pound of RTV-60 in a wide-mouth container is 15 minutes under a vacuum of five to ten millimeter of mercury pressure.

6. Pouring the Mold

Some type of container should be placed around the pattern prior to pouring. A metal can, wooden box, or cardboard container is satisfactory. A thin stream of RTV poured slowly will help keep the number of air bubbles that may form during pouring to a minimum. For best results, the overall size of the mold should not be a great deal larger than the master pattern. Patterns with dimensions under one foot should have a mold base and wall thickness not exceeding three eighths of an inch.

7. Curing

A mold having a wall thickness not exceeding three eighths inches will have cured sufficiently to be firm and can be easily separated from the master pattern within eight hours when cured at room temperature. Heavier molds will require a longer cure time, depending upon the specific size and weight required. A more rapid cure can be obtained by the application of heat. In the event that an oven is not available, a conventional heat lamp may be used.

8. Precision Reproduction of Model Detail

This is a conveyorized assembly fixture, used in automatically assembling motor switch components. It was originally machined from laminated plastic. With this method, holes had to be jig-bored for locating pins since the center distance between the pins had to be held to plus or minus .002 inches. The cost of each of these fixtures amounted to $175. A newer and vastly improved method, shown here, utilizes a two-piece RTV mold cast from a master pattern. This complete mold can now be made for less than $50 and the parts cast complete with pin inserts for only $10 each—a saving of over $150 on each fixture.

To further illustrate the high degree of model detail available with conventional RTV silicone rubber, a special RTV mold was made from an original 331/3 RPM master recording. In turn, a demonstration epoxy record was cast from the RTV mold. The exacting degree of reproduction of detail is proven when the epoxy record is played. The result is an amazing degree of fidelity. The conventional RTV silicone rubber mold reproduced every groove in exact detail.

The next series of slides show a technique of how to use RTV-11 and RTV-88 in an economic manner without having to remove the entrapped air from the catalyzing cycle. RTV-11 may be applied by brush and allowed to flow over the entire sculpture without the formation of air bubbles. This may be done in more than one coat to provide a firm foundation for the following coats. To facilitate bonding of one coat to the other, the preceding coat is allowed to cure until it is tacky to the touch before the next application is started.

The more viscous white version of RTV-88 catalyzed with RTV-9930 stays where it is placed without slump or flow, however, it is easily spread. Gauge may be laminated between two applications of this material for additional reinforcement. Plaster back up is applied to make two half shells for support in the casting operation. The plaster back up is removed and the mold cut in this instance, from the top of the head down through the middle of the back and the pattern removed.

This completes our first system of RTV. Remember you will choose this conventional system for making molds from which you expect to cast only a limited number of pieces. Furthermore, this type system can be used only when exposed to air and if heat is added to hasten the cure time, it must be gentle and should not exceed 200 degrees F. The reason the system must be open to the air is because moisture in the air hastens the cure reaction and because the harmless by-products given off during the curing can more easily escape.

As the market required a higher tear strength compound for the more complex molds designed for mass production, a mold from which hundreds of releases could be expected was needed. General Electric developed this second RTV family and called it the RTV-600 line. This represented a significant advance in flexible mold technology. It is a new high strength family specially developed for rapid fabrication in applications such as plastic processing, mold making, potting, encapsulation, and functional molded parts. As with the conventional RTV family previously described, these RTVs are also a blend of a particular silicone polymer plus filler. However, they differ from the initial conventional RTV system in that another silicone fluid for curing rather than a metal soap catalyst was used. The new advantages of this system over the RTV-11, RTV-60, RTV-88 types were:

1. *FAST CURE WITH HEAT* - Cures in 30 minutes at 300 degrees F. or 48 hours at room temperature. A short post bake after room temperature curing is recommended for optimum physical property development.
2. *REVERSION RESISTANCE* - Under processing conditions of both high pressure (5000 PSI) and high temperature (350 degrees F.), RTV-662 exhibits excellent durability.
3. *THICK SECTION CURE* - The cure mechanism utilized in RTV-662 permits cures in deep sections in completely closed molds. There is no exotherm and linear shrinkage is less than 0.2 per cent.
4. *ABILITY TO WITHSTAND PRODUCTION ABUSE* - The high tear property of RTV-662 makes it ideally suited as a production tool.

In comparing products of each family, we can see that, although the hardness and tensile or toughness are the same, the elongation which is the stretchiness or flexibility, is increased but, all importantly, the tear resistance is more than twice that over the conventional RTV family. The following should serve to illustrate the extreme utility of RTV-662 in a difficult flexible mold situation.

The application in more detail is concerned with the production of 100 coil magazines needed to automate machine loading and quality control testing of coils used in a grid relay assembly. The brass is first cleaned with solvent and then washed with hot water and Dreft.

Silicone rubber is self-releasing from most surfaces. In certain situations where there are deep undercuts or draws, it is expedient to apply a release coating. In this particular case, the master is dipped with a mold release called Maraset No. 5. Excess material is removed by blasts of compressed air.

RTV-662 is a two component system and we recommend a blend ratio of ten parts RTV-662/A to one part of RTV-662/B. In container selection, allow for a volume expansion of four times the quantity being deaerated in a vacuum for a one pound blend is 15 minutes at 5mm of mercury. The vacuum should be removed two or three times to break bubble formation. Notice the RTV-662 preparations for this mold bears a striking resemblance to the conventional RTV mold preparation.

The deaerated blend is loaded into an air cartridge and gun injected into various holes and slots contained in the brass master. After filling cavities, the balance of blend is poured into the mold and the RTVs allowed to cure for 48 hours at room temperature. To obtain maximum physical property profile, a post cure is required. Cure cycles of one-half hour at 350 degrees F. or two hours at 212 degrees F. is suggested. Oven residence time is usually governed by the mass of RTV required for the application.

A pressure cooker is adequate for developing full physicals of RTV-662. Cycle time for this application is eight hours at 212 degrees F. and one hour at 350 degrees F.

Air ports in the brass master provide a means for using air pressure to break the seal between the RTV and brass. Care is exercised in removing the mold due to the number of thin vanes comprising the surface.

Prior to casting the epoxy, the RTV mold is immersed in Maraset No. 5 mold release. This step is taken to assure good release of the epoxy when it is given an eight-hour cure at 200 degrees F. Epoxy compounds that require an elevated temperature cure are prone to generate considerable adhesion to the mold surface.

A class H High temperature epoxy is used as the casting resin since the magazines must withstand a 400 degree F. degassing operation routinely performed on the coils.

Like RTV-662, the epoxy is also a two-part system and it must be deaerated prior to cure. Supplied as a one to one mix of A and B components, the B component is first heated to 200 degrees F. to lower viscosity and provide easy blending with the A component. *Please Note:* Preheating an epoxy component can aid in blending. This procedure is not recommended, however, for RTV-662 since this particular silicone, once blended, is easily cured when subjected to heat.

Dimensional accuracy in the casting is assured by providing structural support with a retention ring and tie bars. Epoxy is first syringed and then brushed between projections and inner webs of the RTV-662 mold. Cure cycle on the epoxy is eight hours at 200 degrees F. The epoxy casting is slowly stripped from the RTV mold. Result: A finished casting which is an exact duplicate of the original brass master.

Estimated cost to produce these magazines by machining was $480 each in units of ten or more. If a zinc or aluminum die casting method was substituted, tooling cost would be $1700 plus $10 per casting resulting in a cost of $27 per unit.

Initial efforts with conventional RTV failed due to excessive tear occurring in the silicone upon extraction of the epoxy casting. Replacement of conventional RTV with high strength RTV-662, yielded sufficient castings to give final cost of less than $10 per unit.

Recently, we have directed much of our efforts in mold making into furniture mold designs. The present demand for our material in this market increases daily. Here is how we make these flexible rubber molds for use with polyesters and urethanes. These are the most prevalent plastics which can be made to simulate wood materials. Here are a few typical examples of parts cast from RTV-662 flexible silicone rubber molds:

This slide shows a lamp base that is to be produced from rigid urethane foam. First a wooden dowel is fastened at each end to hold the wood pattern in the proper position when RTV-662 is poured. The mold, a rectangular, hinged wooden box, is placed in a horizontal position and RTV-662 is poured into the half which holds the pattern. The RTV is allowed to cure at room temperature over night.

The mold is closed and the RTV is pumped through a hole which had been previously drilled though the top of the box. The pumping can be done either by hand operated or by an air pressured caulking cartridge. There is a small air vent drilled at the opposite end of the box to allow the entrapped air to escape as the RTV is forced in the mold. Again the RTV is allowed to cure overnight.

The pattern is removed and the mold reassembled. The amount of urethane required is calculated and then poured in the hole at the top of the base. A rubber plug is inserted to confine the material during its reaction and hardening time of 15 minutes. The most intricate of designs can be reproduced in a similar manner and the casting is literally "popped out" of the mold. Several hundred identical releases can be expected before mold breakdown occurs. Even when breakdown does occur, the old RTV mold can be masticated and re-used as back-up fill in future molds.

Sometimes it is necessary to use a specialized technique to prevent an incomplete cure caused by the various substances, particularly undried wood, when employing RTV-662. The pattern may be brushed with a silicone barrier coating to prevent cure inhibition that sometimes occurs with this RTV-662, but not with conventional silicones. Cure inhibition is described as a condition that occurs at the interface between the RTV and the master pattern. RTV subject to contamination will possess a gummy surface to a depth of approximately twenty mils. The barrier coat provides an inert continuous film between potential resin bleeding sites and chemical finishes that are prevalent in some woods, used in master patterns. The barrier coat also facilitates the stripping of the mold away from the pattern.

The production of a furniture leg is an illustration of the casting of a complex design. The first half is poured as in the lamp base. After curing overnight, the RTV-662 is brushed with a barrier coat to prevent sticking of the RTV when the top half is poured. The mold is closed by matching up the halves and with the two aligned pins located at opposite ends of the molds. The RTV-662 is then pumped into the mold until it flows out the opposite end. Then pressurized very slightly by placing a flat plate over the opposite end and then relieving the pressure. This procedure assures that all crevices and grooves have been filled.

After curing the mold, the RTV pattern is easily stripped from the RTV. And again, as with the lamp base, the volume is calculated, then the urethane systems are mixed in proportions suggested by the manufacturer and poured through the opening located at the top of the mold.

Since these finished pieces have no grain, nails can be embedded very close to the edges without any splitting. Something that cannot be done on many type woods.

The abbreviated open type mold shown here contains an intricate picture frame pattern with many undercuts. The original picture frame was made of wood with the outer surface made of a fragil plaster-like material that chipped very easily. It was prohibitive to ship by normal commercial methods and the cost per foot was very expensive. Here's how an exact replica was produced from silicones at a fraction of the original cost.

The RTV-662 was mixed with a curing agent and the air generated during the mixing cycle removed through vacuum. Then it was poured with continuous flow at one end of the mold which was elevated at a slight angle. RTV was allowed to flow at its own pace while pushing the air ahead out and up from the many undercuts, crevices, and cracks. When the pattern was completely covered, the RTV-662 was filled to three-eighths inches above its highest point.

This slide depicts a section of the actual large mold used to make these reproductions. After the urethane is poured into the mold, a board is clamped firmly on top of the frame containing the RTV mold and the urethane is allowed to set 15 minutes before removal. The center piece is the master pattern while the bottom piece is a section of a urethane reproduction that has been gold painted.

In summary, you will probably agree that the RTV-662 is best for mold making as it represents advanced technology and gives better tear resistance and consequently considerably more mold releases. The conventional or RTVs 11, 88, and 60, are more appropriate for making molds that require fewer releases. Both types give excellent reproductions and it should be re-emphasized that each has its particular place in specific molding applications. Economics will determine which mold material you choose and it would seem unlikely that any one would choose to make an RTV-662 mold if he expected to make only a few castings from it.

Conventional RTVs are recommended for the individual sculptor who will find them easy to use and who can expect to encounter no curing problems. On the other hand, those of you engaged in sculpture production will find the RTV-662 is meant for you. However, you must be ready to make refinements on certain pattern surfaces that are found to interfere with the curing of the more sensitive RTV-662 system.

Regardless of which system you may choose, you will no doubt be pleased with the casts from your initial efforts with silicone molds as these two families of RTVs open up new possibilities for you in sculpture molding.

REINFORCEMENT

WILLIAM GAYDOS
OWENS-CORNING FIBERGLAS CORPORATION

As you know, neither glass nor plastics, in themselves, is new. Man-made resin of various types has been around for the past 98 years. Glass, in various forms, types and applications, has been with us through recorded history. What is new, however, is the combining of these two basic materials and the end uses developed by creative people such as yourselves. Yes, you are the people, creative, imaginative and inquisitive, that have made the basic engineering of these materials come alive, perform, benefit and leave their mark on the future. This is why I'm so pleased to have this opportunity to speak to you and to show in a general way what has been done. I leave it up to you to show what can be done and what will be done in the days and years ahead.

Glass fibers were first developed and formed in 1933. Polyester resin, a thermoset, was developed around 1945 and 1946. The processes and parts which I'm going to show, with few exceptions, are thermosets rather than thermal plastics. I have found that the simplest way of distinguishing between these two families of resins is by the fact that thermal plastics is like a wax candle that can be melted, shaped and reshaped over and over again while all the thermosets, such as polyesters and epoxies, are pretty much like an egg; once you've boiled it you can't convert it back to its original form.

There are about fourteen different processes for manufactured reinforced plastic parts. The simplest is hand layup and the most sophisticated is object molding. All processes benefit by using glass reinforcements.

To my left is continuous fiberglas roving. It has 60 strands, 230 individual filaments per strand. This material is used in various processes such as sprayup, pre-form, filament winding, pre-mix compound, sheet molding, milled fibers, and a manufacture of mats, woven roving and fab mats.

To my right you will see woven reinforcing mat. Reinforcing mats are made by chopping strands in various lengths, two feet up to twelve. These chopped strands are gathered on a moving conveyor belt, the speed of which determines the eventual thickness and weight. The chop strands are held together by a resinous adhesive binder. The mat ranges from three-fourths to one-half ounces per square foot. Woven rovings are coarse, heavy, drapable fabrics which give high strength to laminates and are lower in cost than conventional fabrics. Fab mat is a combination reinforcement consisting of a one ply woven roving chemically bonded to one ply chop strand mat. The two components are bonded together with a highly soluble polyester resin powder binder to form a strong but drapable reinforcement that combines the bi-directional orientation of the woven roving and the isotropic orientation of chopped strand mats. Fab mat is used extensively in the marine industry where large shapes are formed. It not only strengthens the laminate but saves time, particularly when two layers are placed in the mold in a single operation.

Fabrics are the most expensive. They are woven from the yarns of various twists and plies constructed into a wide range of types, weights and widths. The weight of fabrics varies from two and one-half to forty ounces per square yard. These materials are used for reinforcements when great strength to weight ratios are required. Fabrics come close to duplicating the strength properties achieved in use of continual parallel strands.

Surfacing mats are not a reinforcement. They are a plain fiber mat often used with other reinforcements for appearance and weather. This mat covers the irregularities by drawing a slight excess of resin to the surface next to the mold. The resin richness provides a smoother finished surface by covering the coarsest fibers of the basic reinforcement.

Continuous extrusion. Continuous strand roving or other forms of reinforcements are impregnated in a resin bath and drawn through a die which sets the shape and controls the resin content. Final cure is effected in an oven through which the stock is drawn by a suitable pulling device. Fishing rods, golf club shafts, vaulting poles, aeroshafts, pipe, and a few other items are made by this method.

Centrifugal casting. Round objects such as pipe and small tanks can be formed using this method. Chopped strand mat is positioned inside a hollow mandril. The assembly is then placed in an oven and rotated. The resin mix is then distributed uniformly throughout the glass reinforcement. Centrifugal action forces glass and resin against the walls of the rotating mandril prior to and during cure. Hot air is passed through the oven to finalize the cure. Parts made in this process are storage tanks, water softener tanks, etc.

Injection molding. This high production process is designed for use with thermoplastic materials. A mill fiberglas and resin molding compound is introduced into a heated chamber where it softens. This mass is injected into a mold cavity that is kept below the softening temperature of the resin. The part then cools and solidifies. Injection molding is normally used where you have intricate parts such as gears, auto instrument panels, coil forms, fans, etc.

Continuous laminating. Fabric or mat is passed through a resin dip and brought together between cellophane covering sheet. The layup is then passed through a heating zone and the resin is cured. Laminate thickness and resin content are controlled by squeeze rolls as the various ply are brought together. This happens to be a sheet for printed circuitry. Polyester resin in itself has a high di-electric strength and is a nonconductor of electricity.

Filament winding. In this process continuous roving is used to achieve the efficient utilization of glass fiber strength. Woven or single strands are fed from a reel through a bath of resin and wound on a suitable designed mandril. The glass is laid down in a pre-determined pattern until the right number of layers have been applied to give maximum strength. The wound mandril is cured at room temperature or, if the vessel is small enough, an oven is used. This process is used to manufacture rocket motor cases, chemical tanks, pressure bottles, even shotgun barrels and missile bodies. Incidentally, it's interesting to note regarding the shotgun barrel that you actually start with a very, very light gage steel tube and it is the wound filament that supplies maximum strength.

Match metal die molding. This is a mass production method for manufacturing many reinforced plastic parts. It consists of a male and female mold placed in a press. Mats, fabrics, or pre-form reinforcements are combined with the resin mix either just prior to or just after being placed in a heated mold. The part is formed and cured at 100-300 PSI. Molding temperatures usually range from 225 to 300 degrees Fahrenheit depending on the thickness, size and shape. Cure cycles range from slightly under one minute to five minutes. Here is an under body of a Corvette and the Corvette finished. It's interesting to note that you can get tremendous automotive finishes if enough lacquer and time is applied to them.

Appliance and automotive parts, switches, gears, and pump housings are typical of some of the things that are made by pre-mix molding. Pre-mix compounds are mixed as you would dough, combining the reinforcement, resin, clay filler pigments for color and catalyst. It can be extruded into a rope-like form or used in bulk. A quantity of the material is weighed and dropped into match metal die for forming.

FRP is used extensively in space capsules. Most spectacular, of course, is the heat shield. Because it is made from reinforced plastics, it obliviates. When a space capsule returns to the earth's atmosphere, the tremendous heat that is generated starts to burn to reinforced plastic, but as it burns it chars and as it chars it insulates thereby protecting the capsule itself and its occupants.

Again, here is something with which we are all familiar. Reinforced plastics has actually taken over the marine market. I would say roughly ninety per cent of all the boats manufactured today from dinghys up to 60-foot yachts are manufactured of reinforced plastics.

This has been most general. Much of it is not even related to your field of endeavor. But I hope it has pointed out design flexibilities and physical properties not available with other materials. These materials give you, along with design freedom, color, translucency, lightness, airiness—you name it. It is unlimited. Owens-Corning Fiberglas Corporation has sales offices located in just about every principal city in the United States. You can get almost any sort of technical information merely by calling them. Incidentally, a manual has been put together very recently by our advertising and sales people. It is called "Fiberglas Reinforced Plastics." It is a guide to hand layup and sprayup, prototyping and fabrication. I would suggest that if you contact your nearest Fiberglas Co. office they will provide you with this particular manual. It is very, very thorough. It gives you the physical properties that can be achieved by the various types of glasses and also discusses resins to a degree. We can also provide advice and assistance on unusual problems. We maintain a 20-million dollar research and development facility which is devoted entirely to pioneering new products, new end uses for glass and glass reinforcements.

In closing I would like to quote the words I read the other day of a Canadian sculptor, Robert Downing. "I have gone about one tenth as far as I'd like to go in the use of fiberglas reinforced plastics. The use of fiberglas reinforced plastics is changing the face of the planet quite literally. This is the 20th century and if you ignore reinforced plastics in this age, you've got a hangup." Thank you for your attention, ladies and gentlemen.

EXPLORATORY DIALOGUE, PLASTICS
ALL SPEAKERS FROM INDUSTRY

ARNOLD: The first question is: Do any of our companies contribute materials to art schools?

CAMPBELL: The answer is yes. We do furnish materials, a great many pounds per year, but I am sure there are so many schools that some never see these materials. Also, companies over a period of years have obsolete equipment which is never sold or traded. This equipment is donated to universities across the country.

ARNOLD: It would be well to remember that the industry must approach this from the business point of view; they must know the monetary return. Incidentally, most of the companies that are represented here do not sell to individuals. You would contact converters. I am sure these people will help in in every way they can.

CHIRPICH: On the question of samples, all the companies do provide samples for schools and other institutions, but they must draw the line somewhere. Production could be tied up for weeks just making samples. A company must make money. Otherwise they will have the stockholder on their necks. It is a matter of economics from this standpoint. Companies usually tend to give where there will be a return benefit. We don't expect to sell a pound of resin to you sculptors here. Our sales are large volume. You will, however, be working with architects and others and thinking plastics. These people will in turn start to think plastics and finally, it will get back to us.

Q: What is the most economical way of creating a vacuum for RTV since vacuum cleaners don't work?

CROUSE: Obviously this question came up earlier. One technique is by painting it on. You must build it up in thin coats. It's not like latex. You can control the cure; you don't have to wait a week before one coat dries. You can do it in an hour. The owl that was shown on the slides was done in this manner, two coats of RTV 11 and two coats of white RTV 88. You can also use positive pressure for obtaining void-free molds. Some air is squashed out, but most of it is just compressed and you obtain a void-free mold by curing it under pressure. Void-free molds can best be obtained by removing the air in freshly mixed RTV with a small vacuum pump attached to a bell jar. After material has been deaerated ten minutes at a minimum of 28 inches of mercury, it is poured over the pattern and cured at room temperature. A void-free mold is always attained from this technique.

Q: Doesn't making a mold take a good deal of time when you are working large and a large quantity of material has to be deaerated?

CROUSE: Most people will buy a Binks or DeVilbiss steel tank and/or they will buy a five and ten store plastic pail. You do not have to see what is happening. All you have to know is that the volume expansion is four times the original. If you fill a quarter of the container, it'll just about foam to the top. This system will produce eight pounds of void-free RTV in 15 minutes.

Q: Why doesn't a vacuum cleaner work as a vacuum assist with RTV?

CROUSE: It just doesn't draw enough vacuum.

Q: How thick do you build up RTV, 3/16 or 3/8 inches?

CROUSE: This varies a lot. You can use a cheaper back-up material for rigidity and if you are painting it on, less material can be used by following the contour of the pattern.

Q: What types of ventilation system would you recommend for epoxies or polyesters? For example, for a studio for ten or thirteen students, approximately 20 x 40 feet, what volume of air should be moved through per minute?

CHIRPICH: This is, for me, pretty hard to say exactly. Our materials are used in a spray booth. We have a large one which is ten feet deep by about twelve feet wide. The back wall is made completely of filters to trap any spray particles. If you want specific recommendations on this, I would suggest you contact either the Binks or DeVilbiss Co. They both make spray booths and they can give you excellent engineering figures on what you would need and cost figures at the same time.

Q: I have a question here concerning fillers for polyester and epoxy resins. It asks for a rule of thumb which will assist in their selection and determining their safety.

GAYDOS: There are fillers used as reinforcements and fillers used in gunk molding which actually create a thicker laminate at a reduced cost. First the use of glass reinforcements in polyester and epoxy depends upon the manufacturing process that is employed. In hand lay-up and spray-up, use mats, and the fab mats or the woven roving. These vary in weight, the selection of which all depends again on the thickness of the laminate and the strength that you wish to achieve. As far as glass reinforcements are concerned, they are not harmful in any way, shape or form because glass has been proved soluble in the bloodstream. So the only thing you may get is a rash or an itch occasionally, but they are not harmful. Now, the real fillers as used in gunk molding (as in pre-mix molding compounds) are either a calcium carbonate or alumina silicate (clay). I haven't heard anything over a period of years that suggests they may be harmful other than the fact that they are messy.

CHIRPICH: Cab-o-sil, which is aerated silicas, is a popular thixotropic. Aerated silica will seem harmful or hard to breathe, because it is a very water-loving substance and if you breathe it, it will dry your nose out and make it itchy. Actually, you will probably eat more aerated silicas than you will breathe from polyesters. You have all probably eaten salad dressings. Do you know what makes it thick? Aerated silicas. Have you used jellies or hair cream? Do you know what makes them thick? Aerated silicas. There has been exhaustive studies done on this and there is yet to be a case recorded of silicosis because of its use.

Now, I am not too familiar with asbestos, so I really cannot say what the health hazards are. Again, it is a fiber; it can get into your skin. A little side remark here. If you have roaches and you want a good roach killer that won't do any harm outside of being a little messy, Cab-o-sil is beautiful. It sucks all the moisture right out of the bug.

In terms of a thixotropic material, if you are thinking of thickening agents, several have been mentioned. I recommend that you consult a periodical such as *Modern Plastics* which contains a large number of advertisements every month and these are readily discernible as thixotropic materials.

Q: Are thixotropics clear?

CHIRPICH: There is no known absolutely clear thixotropic material as such. Cab-o-sil gives you a light haze. Thixen E, which is used to some extent but has some undesirable characteristics, gives you a fairly clear solution. The only other one that could possibly be of significance, if you are not worried about plugging up a spray gun, is Union Carbide's asbestos Thixotrop. The only problem we found is trying to strain it for spray gun use. This material is used in very small amounts.

Q: What type of heat can be expected in a polyester laminate one-eighth inch thick?

CHIRPICH: This will depend on two things: how hot you catalyze the system and the type and amount of accelerator. Your anilines used with cobalt and MEK produce more heat than straight cobalt. It will also depend somewhat on your gel time. If you have a shorter gel time, you will have a faster heat build-up. Temperatures will be in the range of 150 degrees Centigrade. Now, actually polyesters, most of them, will have what we call a peak exotherm temperature in a large mass up to 210 degrees Centigrade, some higher. It depends on the resin. A flexible resin has less exotherm than a rigid resin.

Q: Is this heat build-up tolerable to a mold?

CHIRPICH: This depends on the mold. Fiberglas molds are usually made with a high heat distortion resin. These are commonly used in the industry along with stainless steel. You will have no problem with either. I don't believe you have too many problems with RTV when casting polyesters. Parting agents are another problem. Now, with polyester molds, stainless steel molds and formica molds, just a straight carnaba wax that is silicone free can be used. I have been asked a lot about plaster of Paris molds. First, they are porous. They are made with water and the porosity is natural. Your coating will sink in and grab hold. Secondly, the water will inhibit the cure of most polyesters unless specially accelerated. You must seal a plaster of Paris mold with something like an epoxy or urethane just to get a sealing coat between the plaster of Paris and the polyester you want to apply. This coat is not too durable. Three or four parts and it will start to flake off and you will have to recoat. As for using special mold releases on plaster, although you can use wax over a sealing coat and get a fairly good release, in some cases you will have to go to a parting film PVA which is sprayed on and must be dry before applying the polyester. Now for the trade names of PVA, polyvinyl alcohol. Reynolds puts out a good one. In Kansas City, Sherwood Solvents, Sakco No. 10 release agent is pretty good.

Q: Has any process been discovered recently to increase scratch resistance of Plexiglas?

ARNOLD: When a material is modified to such a degree that the physical properties of the material are changed, we should at this point look not at Plexiglas or methyl methacrylate, but something like an ionomer. If we change or modify the structure of Plexiglas to obtain a hard, tough outer surface, the lighting characteristics of Plexiglas would consequently be changed. You would have an entirely different material.

Q: I am trying to find a method to form a sheet of 5 mil. (.005") acetate into compound curves. The sheet has detail on the surface which must be preserved, though it can be distorted.

COLLIE: The detail on the sheet is cut or engraved into the sheet and then it is heated and formed over the top of a mold. The possibilities are that you would be better off actually making the cuts in the mold rather than in the sheet if you are expecting these cuts to remain when heated. You will lose an awful lot of definition by heating the sheet. I would suggest that you make your detail on a female mold rather than a male and that way your detail will be on the outside part of your sheet.

Q: What would you suggest for a mold material to get that kind of detail?

CHIRPICH: Maybe I can asnwer that. Around the first of the year there were articles in the trade journals, *Modern Plastics* in particular, on embossed molds. I think you can find a world of information on this and probably the writer could give you quite a bit more information. Most of these steel molds have been either acid etched or tooled. *Modern Plastics* is a good magazine. It carries almost all the plastics and the technology. Every year they put out an encyclopedia with the basic properties and the basic systems of all plastics.

Q: Would you discuss the relative compatibility between various forms and the various resins.

CAMPBELL: Well, I can't really speak with a lot of authority on compatibility of everything, but normally, every time you mix one plastic with another of a different type you end up with a compromise and many times the blend is not as good as either one of the materials you have blended. And another thing when you are working with foams, such as styrofoam or polyurethane, the styrofoam is formed by a solid being incorporated into the bead, and the polyurethane is formed by the use of a chemical action that gives off carbon dioxide. So you would have a little bit of a problem working with these two foams. Of course, if you had styrofoam and you wanted to do something with styrene, the compatibility would be good, but I can't imagine what might be gained by a lot of mixing. Certainly polyethylene is very incompatible with many other materials. So it seems to me that you ought to work with one material at a time and not try to mix them.

Q: What are the solutions needed to treat Plexiglas to destaticize the surface?

CAMPBELL: Most plastics can be destaticized at least temporarily and if they are not handled it would be more permanent. Use a one percent Joy solution in water and just wipe the surface with it. If you are looking for optical properties on a piece of Plexiglas, this might leave a bit of film on the surface and you might see this if it were lighted in some way. But this will keep dust from being attracted, although some plastics contain antistatic additives. I don't think that the acrylics would because in the first place, anything you add is going to destroy the optical properties. These additives depend on a bleeding to the surface forming a film.

Q: Could you also utilize eyeglass antistatic as well?

CAMPBELL: The silicone papers that they use? Yes.

Q: What causes little ringlets? I think they are air bubbles.

CAMPBELL: It is probably the magnetic charge on the Plexiglas itself that causes this to form in a pattern. The reason I say this, and I am sure that Felix Arnold can vouch for it, is that in the detergent and bleach business now, everybody uses polyethylene bottles that contain antistatic additives and one of the ways to check for effectiveness is to place this bottle in what we call a soot chamber and if no additive has been used, fingerprints will appear almost every place you have touched the bottle. The soot will actually cling in a pattern, patterns that you would not believe. This is why I feel that this is a magnetic field created on the surface of this Plexiglas.

Q: Is there a glue or solvent for Plexiglas which can be applied like EDC, ethylene dichloride, but is stronger? Not plexiglas cement but of equal strength. Plexiglas cement leaves a mess to finish.

ARNOLD: I don't know of one. I am sure an epoxy cement would do an excellent job, but there you might create a joint that wouldn't be very neat or may also show up as an opaque surface rather than the optical surface that you want.

Q: It is not very strong. Under stress it snaps right off.

ARNOLD: Do you obtain a homogeneous joint in your weldment? You see, it is a physical weldment you are effecting with ethylene dechloride. Really, if you are experiencing a strength problem, I would like to chat with you later on.

Q: To remove bubbles from RTV, would a centrifuge work as well as a simple vacuum chamber?

CROUSE: No.

Q: How about a vibrator table?

CROUSE: The answer would be no again. It is must faster with a vacuum chamber. A vibrator is much too slow and you can never be sure when all the bubbles are out.

BILL PHILYAW: I would like to add that when working with RTV we use a low-air pressure to blow the RTV down against the pattern. This eliminates a lot of bubbles.

CROUSE: Right, positive pressure can be used, because all you are concerned about is the pattern surface. You don't care what happens one-eighth or one-sixteenth inch away. You are interested in the smooth surface against the pattern.

Q: Can you explain the pros and cons of RTVs at four dollars and five dollars a pound to other elastomers at about seventy cents a pound?

CROUSE: Silicone molds are used to obtain plastic casting because they can withstand the high exotherm of plastics which include polyesters, polyurethanes, plastisols, etc. Also, they have a long mold life when used with certain release agents or base coats. Non silicone RTV materials such as urethane elastomers are cheaper but do not last as long, reproduce substandard pattern detail and cannot withstand temperature above 240 degrees F. like the silicones.

Q: Where can we get a vinyl rubber mold?

ARNOLD: You are talking about a plastisol or an organisol?

CROUSE: I would say Firestone and Goodyear would be two big manufacturers of plastisols and the Federal Insulation Co. in Chicago.

Q: Is there a printed summary of information on RTV or will it be published in the conference notes?

CROUSE: As I said before, I am sorry we ran out of literature. I will be glad to take your name and send you what we have.

Q: How about a cheap mold material for vacuum forming Plexiglas.

ARNOLD: The vacuum forming process itself does not lend itself to Plexiglas. This is my experience. It is less fluid in its semi-fluid state than is styrene or some of the other materials. It doesn't move as far as rapidly; it takes a lot more heat. In other words, you have to leave it over the form and let it stretch and form.

Q: Well, the only problem I had was I got very fine texture. Otherwise, it formed great, right to the edges, with very sharp detail.

ARNOLD: A kind of crazing? Yes, this is the intermolecular stretch, and this is why I say it doesn't lend itself well.

Q: What new product can be looked forward to in the very near future?

ARNOLD: I would say the ionomers. The others will not agree. I will tell you a little secret. Normally, a company will not tell you exactly what they are working on until they have all the bugs worked out. The problem is you let it out a little bit and everybody wants to try it, so you are pushed if you do not have a system completely checked out; you may really fall flat on your face, and it hurts. So until a system is completely secure, we rarely talk about it. To go on with that question just a little bit, most of the plastics publications are in process some two years. Some six months after the actual development we have generated a paper, then about a year later it is published. So the published data that I related to you today is about three years late. The material was actually being developed about three years earlier.

Q: Can you use a glass that has the same refractive index as a polyester to give you an invisible reinforcement?

CHIRPICH: There has been work done on this, but to my knowledge, there is nothing right now that is completely invisible. You have two problems. First, if you can get resin and glass fairly close together there will be a slight variation from batch to batch in the processing. The control necessary to overcome this is not economically feasible right now. Second, your Fiberglas mats are held together with a binder. This binder content will change slightly from batch to batch by the way it is applied. To my knowledge there is no exact way of applying binder in exactly the same amount, and both of these will affect the refractive index.

Q: Are there any other fibers more related to polyesters that may be used for this purpose?

CHIRPICH: When you get into the polyester fibers, maybe this is what you are referring to. These would be the closest things. However, a polyester fiber is completely different than a polyester resin, though they are basically made from the same type of material. You still have a problem of controlling the material. You can get general degrees, but something like a refractive index is pretty hard to keep consistent. The only way is if you would take one batch of polyester, make filaments out of it and put it right back in the same batch.

Q: What family of plastics would be best for joining by a welding method using plastic rods of the same material?

CAMPBELL: Well, if you are going to use polyethylene you want to use polyethylene rods. I think just about any of the thermoplastics could be welded this way. However, if I had a choice between using a solvent, cement or some sort of adhesive and welding, I think I would use an adhesive and use heat welding only when absolutely necessary. This would be with the polyethylene or polypropylene.

ARNOLD: To continue just for a moment, it might be well to introduce sonic welding. This is a process by which two pieces of plastic material like styrene and some of the others are vibrated to such a degree that they become a fluid mass and are welded together. It is called ultrasonic sealing. This does get a bit expensive. Each horn, as they are called, has to be definitely calculated for a given job.

Q: How can plastic surfaces be sanded and then brought to a polish? What grades of paper should be used for sanding? Order of use.

CHIRPICH: On polyesters in particular you do use a fine wet sandpaper, usually a 400 or 600 grit. This is to remove large, fairly bulky segments that you want to take off, especially in patchwork. Then you come back with an automotive rubbing compound or as fine a compound as you can get hold of. Follow with wax and you will get a fairly good luster.

Q: What is a good brand of polish for epoxy?

DICKHAUT: Actually epoxies are somewhat unique as you might well imagine. When you realize that today we are using epoxy terrazzo (and those of you who have seen terrazzo ground can appreciate the coarse wheel that must be used in grinding it) and yet they get a very high polish. So in this respect they are unique. But I will go along with the various rubbing compounds we have discussed as being suitable for epoxy once a smooth surface is established.

AUDIENCE: Instead of carefully rubbing polyesters with toothpaste for hours, I would suggest using acetone or a nail polish remover and heat it exposing the polyester to the vapor. It comes out crystal clear. The only reason not to actually put it in the solution is that the erosion is too rapid. I don't know if this would work on an epoxy, but . . .

DICKHAUT: I rather doubt that this would work on epoxy. It is an entirely different animal and your solvents just don't work on epoxies the way they frequently do on polyester. It is much more inert once it has set and a physical buffing is really much more effective than a solvent.

ARNOLD: As for using acetone vapors, I would do it outside and have a fire station handy. Secondly, if you had a very sharp square corner you might lose that corner because of an erosion process. It will work, but I wouldn't try it except under very controlled conditions.

Q: Can you give the name of a firm which will plate plastic sculpture?

ROCHE: I would go to *Modern Plastic's Encyclopedia.* They have a whole list of them.

Q: Is there a size limitation?

ROCHE: Yes, the size of the vacuum chamber. But you saw some of the automotive applications of plated plastics and they are pretty big. There are several operations. One, in Chicago, is the MSL Co., which actually chrome plated several of the parts that I showed this morning. In St. Louis, there is an operation called Segal Roberts, which is limited in size because of their chrome plate baths. In Detroit they are quite prevalent. I don't know all of them, but everyone in the automotive field is now installing equipment. Furniture City and Enthone, who supply the chrome plating materials, would give you a lead to people that use the process in your vicinity.

Q: Can any plastic be electroplated?

ROCHE: No, not all plastics can be electroplated. The most prevalent materials being chrome plated now are ABS type materials. The polysulfones and vinyls, to the best of my knowledge, are not being chrome plated, but they are being vacuum metalized. This is a very thin coating of metallic material that can be put on. It is not the same as a plated part but it would give the same effect. The answer would be that all plastics can be metalized, but we are talking about two different processes.

Q: Is vacuum metalizing very complicated?

ROCHE: Vacuum metalizing is not too complicated, but it is rather expensive when it comes to the basic equipment necessary to do the vacuum metalizing. It requires an autoclave with vacuum and temperature. And immediately after the vacuum metalizing is completed, it must be oven cured so it would require an oven. If you are interested in the vacuum metalizing process, Monsanto has a brochure that goes into great detail on the equipment and the cost of equipment necessary to vacuum metalize.

Q: Are hydrogen and oxygen the combination for flame polishing? If so, what are the ratios and what gage pressure is necessary?

ARNOLD: Only thermoplastics materials can be flame treated and not all of them. The acrylics are the ones which you are most likely to consider for this treatment. I think that there would be other methods that would be a little more efficient for your purposes.

Q: In connection with this polishing of polystyrene, what would be wrong with just simply making a solution of polyester and painting it on after you have sanded?

CHIRPICH: Since polyester is a solvent for polystyrene, you usually have to add a barrier film, normally a wax of some type or another type additive and this will immediately give you a dull surface. Even with a barrier film, air coming in contact with the polyester will make it cure unevenly, giving you a rough surface, so you have to go back and polish. There are no parts that I know of made at room temperature that do not have to be patched or polished somewhere if you want a good looking part, even in polyesters. I am thinking mainly of the boat and automotive industry. These people are producing surface areas that are extremely large. A boat 24 feet long and about six feet wide is tricky to pull out of a mold and not get a scratch somewhere.

ARNOLD: Tonight these company representatives will be available at their booths for other questions that might come up. Remember that our prime purpose was to get *you* into the ball park so that you will at least know that when you come to us for information, you must be specific, because we cannot adequately answer a question about a material unless we know exactly what that material is and exactly what you want to know about it. It is the same procedure you use with your students and colleagues; you must know what is needed before you can offer guidance. So, with that, we will see you tonight.

COMPUTER SCULPTURE

ROBERT MALLARY
MASSACHUSETTS

Robert Mallary of the University of Massachusetts delivered a slide lecture on computer sculpture Thursday, the evening of May ninth. The lecture was arranged at the last moment and was not taped. What follows is a summary compiled from the speaker's notes by Colette Bangert who attended the lecture. The speaker has also reviewed and edited her summary.

Mallary opened his talk with the recommendation that sculptors formulate a clear attitude towards today's technology, first because it dominates our civilization, and second because it increasingly is providing them with their tools, materials and technical processes. Sculpture has always reflected the technology of its time; for instance, bronze casting in classical civilization was, in a sense, the advanced space technology of that day. But science and technology are not unmitigated blessings either socially or in their effects on art. Admitting to a somewhat ambivalent attitude on his own part Mallary belittled what he termed "the mystique of the technologically way-out." He denied that technological art must indefinitely restrict itself to a "spit-and-polish, 'Brave New World,' reductive, and precisionist look." He also emphasized that technology is not an end in itself but a means of serving more important values in art, which ultimately are psychological and expressive. But in the period just ahead, if sculpture is to respond to the times, there will necessarily be more attention given to technical matters—probably to the detriment of humanist values, at least as these have been defined in the past.

He then went on to discuss the computer and its burgeoning role in technology and modern life. The rapid development of the computer in the short space of fifteen or twenty years has been extraordinary. By extrapolation it is reasonable to predict that our civilization (assuming, of course, it does not incinerate itself out of existence) will be dominated by a cluster of new technologies which will include both the computer and techniques for genetic manipulation. The next fifty or a hundred years will bear the imprint of these as the nineteenth century was dominated by steam and the early twentieth century by the internal combustion engine and electricity. Most applications of these latter "primitive" energy sources can be thought of as extensions of various human capabilities such as locomotion and manual manipulation. But the impact of the computer will be even more drastic because, as an extension and objectivization of attributes which are uniquely human, it will project the technological squarely into the realm of the mental. Consequently it is difficult to believe that anything both as "mental" and technological as the visual arts can remain immune to its influence. Mallary does not believe that the computer will take over the artist's role unless the artist wants it to. Rather, the computer will be a tool among others but a tool of a remarkably versatile and powerful kind. It will give birth to new sculptural and kinetic media and intermedia which can be only vaguely conceived at this early stage or cannot be imagined at all.

But what the computer can do now for sculpture is limited, because the computer itself is so new and its application to the visual arts has hardly begun. Just as the first automobiles looked like carriages and the first airplanes like motorized kites, it will be some time before the computer sculpture looks markedly different from the kind of abstract sculpture we see today. But it was an achievement for the first automobile even to keep up with a galloping horse and for the first planes to fly at all. Therefore, the first sculptures made with the aid of the computer should be judged charitably taking into consideration the technical obstacles surmounted (though the pioneers of computer sculpture should make the best use they can of their limited resources).

The slides: The computer was originally an elaborate calculating machine which soon acquired the ability to do more interesting things such as solve logical problems and serve as a designing aid. In this latter connection it has given rise to the new field of computer graphics used by engineers to develop all kinds of products ranging from small hand tools to automobiles, ships and bridges. The first slide showed an example of the "peripheral" graphic equipment used with the computer to do this sort of work. Shown was the CRT (cathod ray tube) display which looks something like a TV set but is "on line" with the computer and allows for "man-machine intercommunication." The function of the "light pen," which is an adjunct to the CRT, was also explained. This device permits the engineer actually to "draw" on the face of the CRT and control what is happening inside the computer. Mallary showed slides of various "plotters" which automatically make technical and perspective drawings on the basis of elaborate programs which have been prepared for the computer. Shown were mainly drawings of airplane sections which were translated by computer calculations into various types of graphic projections (isometric, oblique, perspective, etc.). The plotter also has the ability to draw the image from any specified degree of rotation and viewing angle. It has this versatility because the input information is fully three-dimensional. Another series of slides demonstrated the application of this capability to making animated films which simulate such real-life situations as a jet landing on an aircraft carrier.

Subsequent slides demonstrated the absolutely essential digitizing process by which a drawing, graph, map or blue print is translated into numerical values using an automatic, or semi-automatic, graphing and digitizing apparatus. The result is a coded drawing on computer punch cards, paper tape or magnetic tape. As coded information the original "data" can then be manipulated and processed by the computer.

Mallary emphasized that computer programming requires knowledge and aptitude. The programmer must know how to set up a logical series of detailed instructions for the computer, none of which can be left out and all of which must be exactly stated and arranged in the correct order. In general, computer programming breaks down into three aspects: 1) input, 2) transformation of the input by the stored program, and 3) usable output. However, unless there is a radical change in the nature of the task, the program generally does not have to be revised with each new task assigned it. Generally what changes is only the new input or data. Because most of the programming is reusable it can be worth the time and expense of compiling it. This section of the lecture was concluded with slides showing computer graphic installations at the General Motors Corporation in Detroit and the experimental unit at M.I.T. in Cambridge.

Mallary then discussed briefly his personal involvement with computer sculpture and "art and technology" in general. In the 1940s he had been interested in the problem of new technological media and intermedia and particularly in new approaches to three-dimensional projection, which he thinks is the ultimate technical solution to kinetic art. He developed his basic ideas of plastic embedments, contour laminations and building up three-dimensional forms by means of contour "slicing" and "stacking." About a year ago he applied these concepts to computer sculpture and began to work out the approach he has since developed more fully. On joining the staff of the Art Department of the University of Massachusetts last September, he circulated an outline of his ideas among experts in the engineering and computer science areas. Encouraged by their response he formulated a research project and was awarded a small "seed" grant to develop his ideas.

Mallary himself is not a programmer; for this he has relied on a group of talented students including his son Michael Mallary who is a graduate student in physics at Cal. Tech. But Mallary provided the initial concept and most of the ideas which underlie the programming, i.e., he has set the "chores" which the computer is called upon to perform and suggested, in general terms, how it might go about accomplishing them. To young artists interested in computer art he suggested they take the trouble to learn a computer programming language such as Fortran and associate themselves with a college or university which will make computer time available to them. He briefly discussed computer "time sharing" which permits CRT and other computer graphic equipment to be located in a university art department to share with other departments and colleges the services of an all-university central computer.

Mallary's computer sculpture program (called TRAN2) has three aspects which correspond roughly to the aforementioned structure and functioning of the computer itself—namely, input, processing and output. First the three-dimensional object must be described both numerically and three-dimensionally if it is to be used by the computer. This is done by translating the continuous three-dimensional sculptural form into a regular series of contour cross sections or "slices." This procedure is comparable to slicing an orange or a sausage into a series of very thin slices then tracing these onto graph paper. Points are selected at close intervals along the contour tracing each of which is then designated as "X" and "Y" Cartesian coordinates—generally between thirty and sixty points can adequately describe a contour eight or ten inches in diameter, although more closely spaced points make for a more accurate definition. In effect, the continuous form has been translated into a regular series of two-dimensional planes. The individual planes or slices, become three-dimensional once again when they have been reassembled in the computer and oriented in relation to an axis running through them. This is designated as the "Z" coordinate in the total three-dimensional description. More, rather than fewer, of these slices also makes for greater accuracy and definition of the form. But a computer can only accept as much information as it has the capacity to store and manipulate. This varies from machine to machine and sets limits as to how much data can be loaded into it and how elaborate the operational program can be. Another consideration is that more computer time is required to work with a greater amount of data and computer time is expensive. (With large computers it can exceed $400 an hour.)

Mallary and his principal student assistant, Robert Weiss, designed and constructed an apparatus called a "contour grapher" which transcribes the contours from a three-dimensional prototype form; this was the first input mode used in the TRAN2 program. Since then two additional methods have been developed. One makes use of geometric primaries and the other synthesizes a continuous three-dimensional form from profile information. This latter has proven to be particularly useful.

The second aspect of the TRAN2 program has to do with what the computer does with the input information. Here Mallary's concept of computer "form transformation templates" provides the means whereby the computer generates variations and permutations on the input data. In this connection a series of slides showed how a drawing was graphed and transferred to computer punch cards by digitizing the coordinates. The sketch was a simple, biomorphic sculptural form reminiscent of Hans Arp or Henry Moore. The shape was then stretched and/or compressed into a variety of new shapes, some only slightly different from the original and others extremely different. The source of these slides was drawings made by the Smith College 1130 computer and plotter. Other slides reproduced tracings of computer generated drawings in which the lines were thickened by hand for graphic clarity. In these, the original shape shown in one color was superimposed on the transformed shape shown in another color.

Diagrams showing various kinds of transformation templates which have yet to be programmed to enlarge the capability of the TRAN2 program were also projected. Some of these were quite complex and based on logarithmic instead of arithmetical increments of expansions and contractions. Another diagram demonstrated Mallary's concept of the "variable field transformation template" in which zones of no change in the form are combined with zones of change. When this kind of template has been programmed for use with the CRT display, it will be possible to continuously "model" a portion of the sculptural form while leaving the remainder unaffected. The general purpose of all this is to transform the computer itself into a sculptural shaping tool which first either draws or projects the form onto a display then provides the precise specifications, or "blue print," for constructing it. Eventually the computer will produce a paper tape to control a machine tool to do the carving. The slide series concluded with a photograph of a styrofoam "prototype" form, the first to be traced with the contour grapher, digitized and transferred to punch cards. This first prototype was broken down into one hundred contour slices requiring approximately four hundred cards for the complete numerical description. In contrast the "profile" subroutines specify only 48 contours, and there is no need to begin with and digitize an original prototype form.

Displayed to the audience were three small sculptural forms identified as computer generated variations on the original form shown in the slide. In one, the form had been stretched on the "X," in another on the "Y." In the third it had been stretched at the top of the form and compressed almost to a point at the bottom. Mallary expressed his reservations as regards the aesthetic quality of these forms but affirmed their usefulness as demonstration pieces. They are, in fact, the first computer sculptures made with the TRAN2 program and among the first made anywhere by any program.

Mallery then returned to a more general discussion of computer sculpture. He predicted how the computer sculptor of the future might use the computer and what its capabilities might be. The sculptor will have the option of some kind of stereo presentation in order to better view his three-dimensional form. It will also be programmed for light and shade (several of the slides showed the first experiments along this line at the University of Utah and elsewhere) as well as for color. A touch of another control and a machine tool of some kind will produce tens or hundreds of variations of a given idea in some appropriate material. The sculptor will have the option of total control, semicontrol (or quasi-randomness) or "total" randomness—qualified with the observation that absolutely total randomness contradicts the basic idea of computer programming. Emphasizing the importance of control, at least as a choice open to the sculptor, Mallary developed some of the implications of the "heuristic" capabilities of the computer, predicting that eventually computers will be programmed to "learn" and remember the sculptor's style and approach to the creative process in order to generate indefinitely works "in the manner of." Mallary thus anticipates the possibility of an artist, after his death, continuing to produce his art posthumously by means of the computer and his legacy of accumulated programming.

Mallary observed that it is becoming evident that a distinction will come to be made between computer *aided* sculpture and computer *generated* sculpture, although the distinction will not be hard and fast. In computer aided sculpture the computer will be one tool among others, supplementing more conventional methods (for example, it will be used in a way analogous to pantographic and "pointing" equipment as a stage in the enlarging and execution of a model). As a step beyond this it will provide precise data for executing works conceived on various systems of symmetries and asymmetries (the TRAN2 profile subroutines have this capability up to a point). Computer generated sculpture will mean that the work is mainly or entirely the product of computer programming and that the imprint of conventional creating and forming methods will be negligible "untouched by human hands." Random generated sculpture will remove the work even more from the *direct* control of the sculptor although he will continue to specify the parameters within which the randomness will operate (a form of *indirect* control).

The computer will contribute to sculptural techniques in ways that are only vaguely predictable at this time. In the beginning, at least it will extend and in effect reintroduce into sculpture the role of drawing (the use of the preliminary, developmental, "idea-clarifying" sketch). But this will evolve and change until at some point the sculptor will be simulating more directly the experience of making sculpture but at a rate hundreds of times more rapidly than is now possible. He will be able to test and reject many more alternative solutions in a way analogous to the "iterative" designing which has come to be an important feature of computer graphics in its use by engineers.

The sculptor will be able to rapidly and systematically generate hundreds and thousands of permutations of an underlying sculptural idea, a related series of ideas, or a combination of them, and select the best, either as terminal products or as candidates for further computer processing. He will know how to "prime" the computer to come up with better rather than worse "offerings" while sharpening his own ability to discriminate between these. He will be able to program "spontaneity" and unexpectedness into the machine with random and quasi-random programs —in effect demanding of the computer "Well, what do *you* suggest?" Finally the computer itself will be programmed to exercise discrimination, either on the basis of its "coaching" by the sculptor using it or on the basis of more objective and "universal" criteria.

REINFORCED POLYESTER PLASTIC AND ACRYLIC COLOR FOR SCULPTURE

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The traditional classic materials of sculpture were stone, wood, fired clay and metal. Less frequently used were bone, crystal and, to an even less degree, glass. All these materials were known for thousands of years and the history of their discovery is lost in the childhood of time. Prior to the twentieth century only a few new materials were added to this list. There is the stucco technique of the Romanized Gandharans, the hollow lacquer technique of eighth century Japan, and cast concrete introduced about the turn of our century. Recently, however, within the last forty years, a new revolutionary substance, or rather a group of substances referred to by the general term, plastics, has become a dramatic addition to the sculptor's choice of materials.

Plastics are unlike any of the traditional materials used throughout the ages. When first discovered, however, they were frequently employed to duplicate known substances such as wood, metal, clay, stone and even glass. An outstanding example of this was the use of celluloid (proxylin) to imitate ivory. And at the end of World War II, many unknowledgeable American soldiers who had been stationed in China returned with oriental statues claimed to be carved in genuine blood amber. Actually they had been cast in transparent red plastic. Of course, honey colored amber was the most commonly imitated of all.

But plastics' main value is not as cheap substitutes for other materials. They each have their own typical varied properties and their application potential is stupendous. Few materials employed by sculptors offer the multiple advantages of light weight, strength, ease of shaping, full range of texture, color, and transparency. The number of plastics already available is extensive. They include acrylics, epoxies, vinyls, polyesters, polystyrenes, polyethylene, silicones, urethane, and foams. These constitute a fantastic array of new materials for present day sculptors. The limits to their use is probably fixed only by the limits of the sculptors' imagination.

Today, plastics are steadily encroaching in fields where metals formerly reigned supreme. The development of lamination has led to the use of plastics for high load structural applications as well as for unusual sculpture configurations. Laminated plastics are even used for gears and bearings in heavy machinery. They are also used for car bodies, hulls of boats, and beams to support large buildings. And all of this evolved simply because plastics were superior to other materials for doing the specific job.

The discovery and development of plastics is primarily the result of the chemist's understanding and ability to control the carbon atom. Carbon possesses the property that enables its atoms to build up into long molecular chains or polymers. And it is this chemical feature which establishes the ultimate foundation for the formation of all plastics. To use a highly simplified explanation, this is accomplished by starting with materials made up of uncombined single molecules, called monomers. Under the action of heat, pressure, catalyst, or a combination of these, the molecules are then induced to combine. Once these molecules start to combine, they do so with great rapidity. Certain polymerized molecules may be in the form of chains that contain as many as several thousand molecules of the original monomer. The eventual setting or curing of a plastic occurs when the long thread-like polymer molecules are joined or cross-linked together by chemical bonds so as to prevent the free movement or slippage of these threads relative to one another.

My own interest in plastics as a sculpture medium dates back many years to the introduction of polymethal mythacrylate by Rohm and Haas and the Du Pont Corporation. In order to promote the use of this sensational, crystal clear plastic in other fields than the manufacture of backs and handles for hair brushes, Rohm and Haas initiated a sculpture competition. The light transmission and reflection properties of this plastic so fascinated me that I retain to this day on my desk one of the original sample pieces of Plexiglas supplied by the manufacturer to the sculptors. Although the material was easy to carve, the fact that stock sizes were limited and information about casting properties scarce, kept many sculptors from further exploring its possibilities at that time.

My first actual work in plastic was a cast in transparent Gemstone, made in a rubber mold and cured or vulcanized at moderate heat. Gemstone is a phenolic casting resin with transparency and reflecting properties approaching but not equal to those of acrylic. The appeal of this experiment was purely aesthetic. It occurred before World War II, and it was not until 25 years later that I turned to plastics once more.

This second involvement had little to do, in the beginning, with aesthetics; it was mainly practical. I was looking for a way to avoid the back-breaking problem of moving heavy stone and cast metal sculpture in and out of my studio, or constructing heavy crates for shipping them to exhibitions. The idea of a light weight, hollow, reinforced sculpture material, easy to manipulate and requiring no unusual machinery or equipment kept drifitng in my mind. Then I recalled having seen a picture in a magazine of a well known New York sculptress walking along 57th Street carrying a life-size figure under her arm. The statue was hollow and made of reinforced polyester resin.

Polyester resin was first introduced in 1941, shortly before Pearl Harbor. Its chief practical application at that time was in the fabrication of reinforced shells for aircraft fuel tanks. But it was not long after, that industry as well as art began to further explore its possibilities. The chemicals that produce this remarkable plastic consist of unsaturated polyesters linked with a monomer such as styrene. In the resulting chemical reaction which is triggered by a catalyst, the double bonded carbon atoms of the polyesters polymerize with those of the monomer to form cross-linked molescules. This results in an insoluble and infusable thermoset material. The internal heat (called exotherm) generated during this reaction, cures the resin, first changing it to a jelly, then a soft rubbery substance and finally into an irrevocably unyielding solid.

Polyester plastic can be formulated to meet almost any requirement. Varieties can be made rigid or flexible, non-burning, impact resistant, crystal clear, translucent, opaque, thixotropic, slow or fast setting. The material cures at room temperatures without releasing gases. It has good weathering resistance, heat and flame resistance, and can be stabilized against the effects of sunlight. Added to this are excellent dimensional stability, ease of handling and ease of coloring.

Cast polyester resin by itself has practically no tensile or impact strength. To adapt it for structural purposes it must be reinforced, much in the manner that concrete is reinforced for engineering use. The most successful and widely used reinforcing material for this purpose is fiberglas. Considered from a strength to weight ratio (i.e., tensil strength per pound) fiberglas reinforced polyester resin is probably stronger than any commonly used commercial material. Fiberglas which is made up of glass filaments with a tensil strength of over 200,000 psi, add tremendous impact and tensile strength to reinforced plastic. It also makes it impervious to rot, mildew, or oxidation, and resistant to acids (except hydrofloric or hot phosphoric) and weak alkalis.

A recent article in *Science News* states that fiberglas reinforced plastic is to be used on the foredecks, fins and superstructure of British submarines. The reasons are that this material is one-seventh the weight of an equivalent amount of steel, is resilient, non-corrosive and has a longer life. If reinforced plastic is strong enough for the British Navy, it certainly is strong enough for modern sculpture.

The concept of combining a high tensile strength reinforcement, such as matting or textile, with a low tensile strength binder for constructing hollow sculpture is not new. Twelve hundred years ago the Japanese sculptors developed a reinforced lacquer technique that was used extensively for their large hollow temple statues. It consisted in building many layers of lacquer soaked hemp cloth over an armature, or in the case of a head, over a more closely shaped configuration in damp clay. With the drying of the natural lacquer, the cloth layers became stiff and the result was an extremely light, strong, rigid shell that could withstand heavy impact. Statues of this material were so strong that they suffered only surface scars or dents when knocked from their pedestals by the frequent Japanese earthquakes.

An end view of a laminated lacquer subject shows the shell to be made up of about ten layers of impregnated cloth. The small details such as jewelry and hair were evidently cast separately of paste made of lacquer stiffened with sawdust, punk or rice powder, and fastened to the surface with an adhesive. The outer surface was finally filled, rubbed down, primed, colored, and gilded. This technique was used in the construction of a large number of the most famous eighth century temple figures in Japan, many of which are still extant in Nara or in the national treasury. With this historical precedent for inspiration, I embarked on my first adventure with reinforced polyester resin.

Reinforced Polyester for Sculpture

Before continuing, I should like to make it clear that I have no illusion that there is anything novel or new about working in reinforced polyester resin. Sculptors have been using this versatile material for more than twenty years. And any sculptor who has not worked in plastic but has read Thelma Newman's excellent book, *Plastics as an Art Form,* will appreciate this point. My purpose in giving this talk, is to share with you my own experiences in the application of this material to my sculpture, and the development of techniques to adapt it to my own form concepts.

I had been working for some time with foam plastic as core material for compositions to be cast in bronze. The lightness of this material was the deciding factor in my choice. Without using armatures it is possible to pile foam to incredible heights or cantilever it considerable distances. Most, if not all, sculptors are undoubtedly acquainted with this feature. The cubic module was the basis of much of my composing at this time—it helped solve the problem of mass and repetition—and was used in many of my compositions developed for plastics. The foam cubes were notched and integrated into a volumetric design, a small maquette being followed for overall image effect. After several trial positionings a final arrangement was reached and the units were fastened together with a contact, or rubber-like cement formulated for foam.[1] The joints were built up and shaped with a filling compound.

To prevent the foam from being attacked and dissolved by the polyester resin, it was given three or four coats of white vinyl glue. Later experimentation showed that a layer of Resorcinal glue or a coat of catalized epoxy resin can also serve as a barrier coat. For constructing the sculpture shell over the foam core, Fiberglas cloth was used as the reinforcement with the resin, and each strip was wound completely

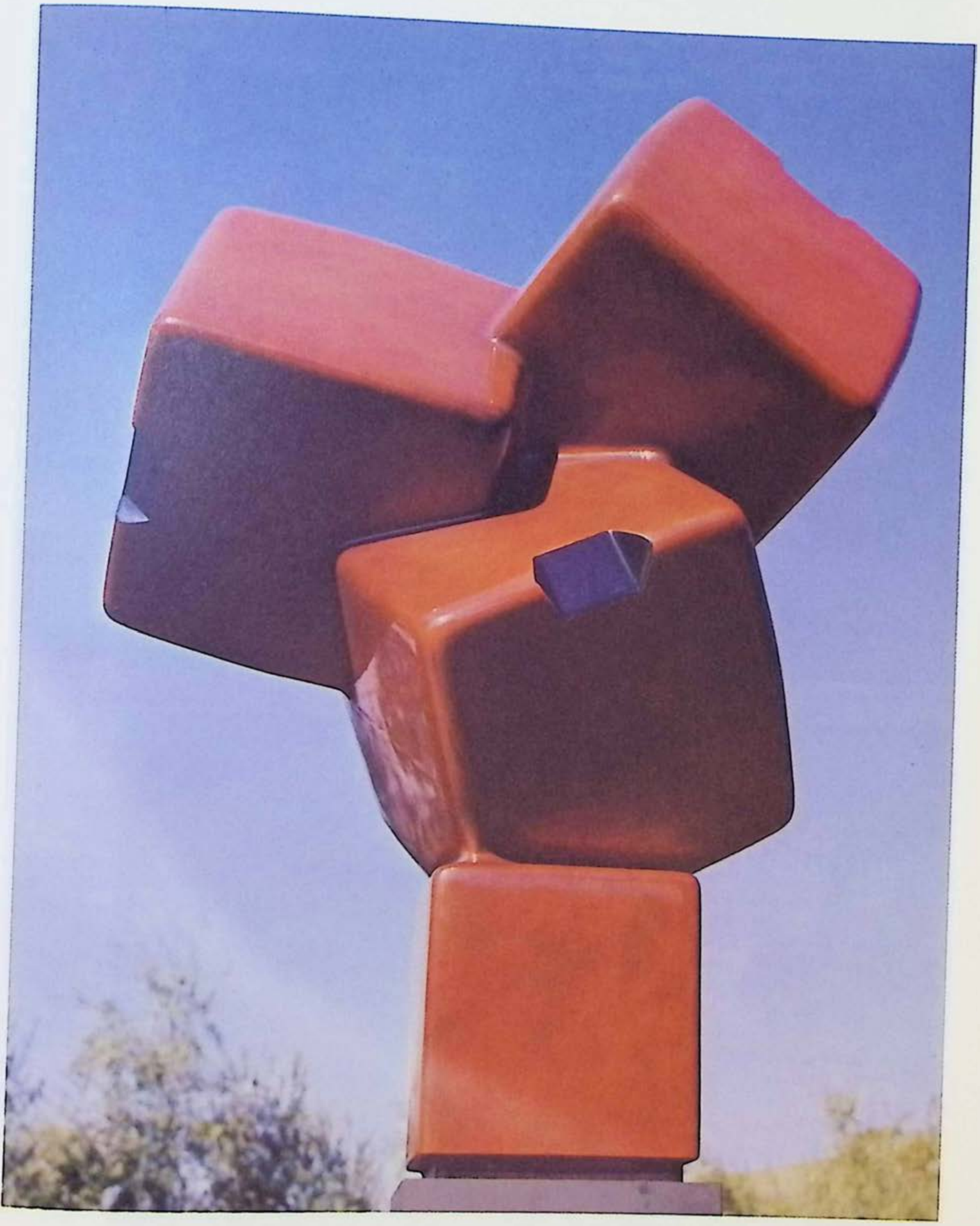

Plate 1. Composition 1, laid up with reinforced polyester resin and sprayed with acrylic color.

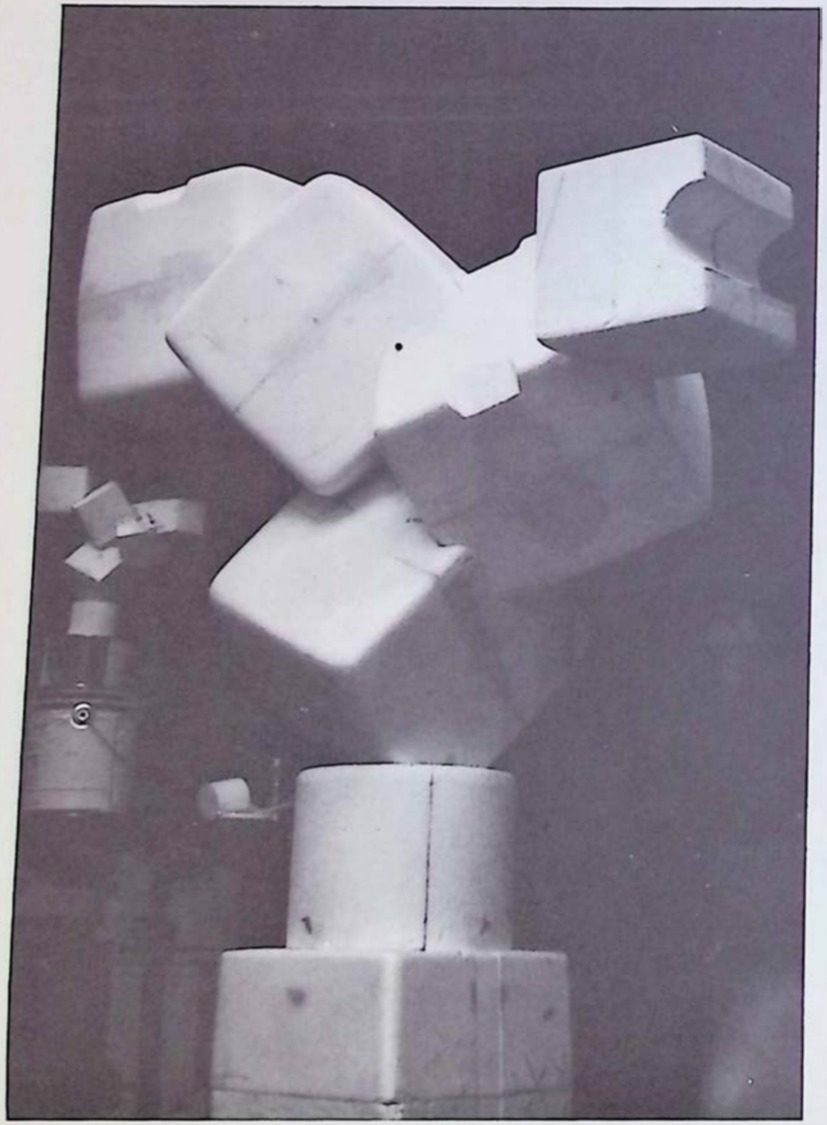

Plate 2. Completed styrafoam core for composition No. 2. Elements temporarily held together with wire pins.

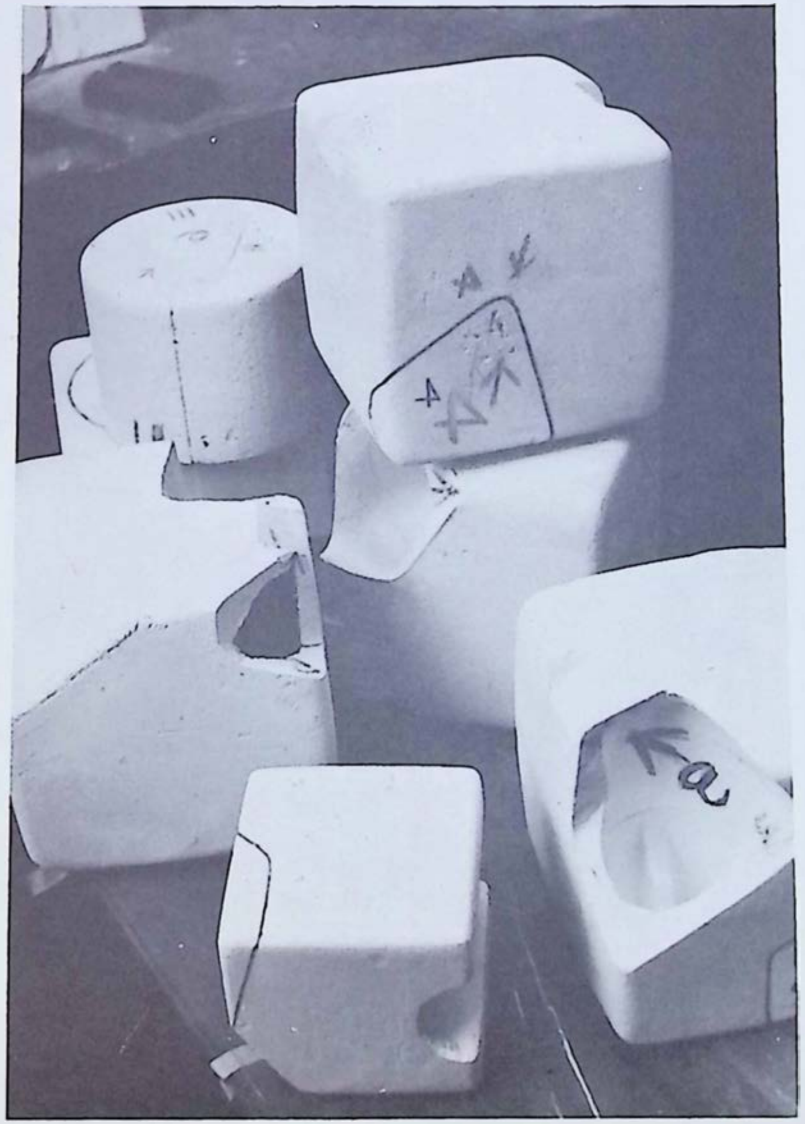

Plate 3. Elements of composition No. 2 disassembled. This procedure considerably facilitates lay up and sanding surfaces with pneumatic tools. Prepared elements are fastened with resin mixed with milled glass fibers.

around its core section. The resin itself was of the industrial or structural lay-up type which contains some thixotropic agent to reduce dripping and run-off from vertical surfaces. Actually it was impossible to avoid drips and to retain the original smooth surface of the core. This led me to radically revise the lay-up procedure in later compositions.

I am reminded here of a passage dealing with polyester resin in a handbook on new materials for sculpture. The author states, "the process is so simple, that one can proceed virtually with the laminating brush or roller in one hand, and the instruction book in the other." Contrary to this author's advice,I found it far more practical to have both hands free, especially when catalyzing the resin. The exact amount of catalyst for polymerizing a given amount of plastic for a certain kind of lay-up work is almost impossible to obtain from a book or formula. Differing manufacturers' products seem to take differing amounts of catalyst and during a hot day less is required than on a cold day. The configuration of the surface and also whether glass mat or cloth is used, directly effects the time elapsed during lamination, and consequently, the amount of catalyst to use. All this is best determined by experimentation with very small quantities of material in the general proportion of ounces to drops, in order to determine the necessary ratio for a predetermined bench life of a larger quantity.

From charts in handbooks on plastics, we get an idea of the strength of reinforced polyester. When reinforced with glass mat the tensile strength ranges from 10,000 to 25,000 psi. It is considerably higher, from 30,000 to 50,000 psi, when glass cloth is used, since the fibers are more directional and continuous. I take these figures to represent ultimate rather than working strength. Not every resin labeled polyester is similarly formulated or has the same physical properties. For example, in comparison with laminates made of conventional polyester, the ultimate tensile strength of *isophthalic polyester* laminates range from 6,000 to 9,000 psi higher.

In order to insure maximum saturation and adhesion between laminates, some resins are made to remain slightly tacky. Because such resins never completely harden, they cannot be sanded. They therefore require a final overlay of a special surfacing resin that cures to a hard dry surface. This latter contains wax which rises to the surface and forms a barrier, thus permitting a complete cure. To provide a bond for priming or painting, the wax is removed by sanding.

To fill any surface low spots, I used an automotive type body filler. The rate of cure of this material is also controlled by the amount of hardener that is added. But this is relatively easy to gage. After the filler sets, shaping and smoothing was done with files, sureforms, and sanding.

To prepare the surface for color spraying it was first primed with a compatible primer coat. A black primer has the advantage of showing up surface defects, especially pin holes in the underlying plastic. These small irregularities were filled or "glazed" with a rapid drying lacquer putty and wet sanded with No. 320 grit abrasive paper.

The final coloring of the plastic composition was achieved by spraying with acrylic automotive lacquer. The kind used with Du Pont's Lucite brand. By smoking or fog spraying a combination of colors, it was possible to control the intensity of the base color and to increase its depth (plate 1). Since sunlight or rain does not effect the transparency or dimensional stability of acrylic, it is an ideal surfacing and color medium for outdoor sculpture. Aside from ceramic glazes and fired enamels, it is probably the most permanent, although not the hardest, coloring material available today. Later I shall return to acrylic coating when I take up at greater length the subject of color in sculpture.

The construction of the composition described above was a valuable experience. From it much was learned about manipulating plastic and reinforcing it. Ideas for improved handling of the medium suggested themselves. And it is to the application of these ideas in subsequent compositions that I now turn.

For the second statue, a core of foam was used as in the first experiment. Again a maquette was made as a guide. Instead of brush coating with vinyl glue, the surface was sprayed with a barrier coat[2] formulated especially for polyester on styrofoam. Spraying is a far more efficient and rapid method than brushing. Coatings are more uniform and take much less time to dry. The elements or units were temporarily fastened together with wire pins or nails instead of gluing them (plate 2). This was the principal innovation in this composition and was a great advantage, since it enabled me to disassemble the elements and lay them up separately.

In the first composition the Fiberglas cloth was wrapped around the shapes, much as an ace bandage is wrapped around an arm and then was saturated with polyester resin. The resin's exotherm caused it to become thin and runny. Flat horizontal surfaces were not effected much, but on vertical and bottom surfaces, the dripping caused considerable irregularities which required much filing and sanding to level out the resin. Anyone who has worked with polyester resin is, no doubt, well acquainted with this characteristic of the material. The fact that the elements had been permanently fastened before the plastic shell was laid up, limited the use of power tools. Many of the areas had to be tooled and sanded by hand.

To overcome this problem, the elements of the second composition were taken apart (plate 3) and laid up separately in sort of an assembly line order, one face (i.e., top face) at a time. By the time all top faces had been laid up, the resin was sufficiently set to turn the shapes to another face. To thicken the shell, thereby increasing its impact strength, Fiberglas mat was used in conjunction with the glass cloth. All edges were reinforced separately. I should insert here that the entire strength of build up sculptures such as this is in the reinforced plastic shell. The entire foam core could be removed if necessary without substantially reducing the structural strength.

Even where flat horizontal planes are covered, the resin does not usually level out to the smooth type of surface required for exact finish coating. Flat and curved coarse rasps or Stanley sureforms were found most effective for reducing the high points and leveling out the runs, after which forty grit aluminum oxide paper in an pneumatic sander prepared the surface for the spot filling with body filler. This stage of surface preparation was greatly facilitated by the fact that faces of the disassembled units were easily accessible to the files and especially the power sander.

Once the units were assembled, a paste made of milled glass fibers and catalyzed resin was used to fasten the elements together. Perhaps "welding" is a better term to describe this fastening process since the resin-paste fillet functions more or less like a welded metal joint; it fuses with the surface it joins. Curved rasps and round sureforms helped smooth these joints after they had been patched with body filler.

The completely assembled and sanded composition was now ready for its prime coat.[3] Pinholes and other irregularities overlooked before priming were filled with glazing compound and the entire surface wet sanded with No. 320 grit paper in preparation for the acrylic color coating.

Color

Before continuing with the final color treatment of this piece, I wish to make some general observations on the subject of color. Amongst the myriad of ways for handling the aesthetics of color in sculpture, a number can be singled out. For example, there is the monochrome approach; this single color approach is the simplest and may materially aid in unifying an otherwise complex sculpture composition in other situations. Another approach is to color separate elements differently—to use a combination of colors much as is used in the colored sculptures of Chamberlain, Weinrib and Paolozzi. A combination of colors—polychrome—can also be used on single sculpture element or a sculpture consisting solely of one shape.

When using acrylic as a finish, however, there is a property of this material, in addition to its color tone, that is of considerable significance. Acrylic lacquer is made of a transparent methal methalcrylate base in a highly volatile solvent. The coloring of this base is achieved either by adding opaque pigments or transparent dyes. By using the transparent colors and then polishing the surface, it is possible to obtain a glossy depth comparable to transparent ceramic glazes. The aesthetic advantages of such a finish are: (1.) bright highlights, (2.) fractured shadows superimposed on the reflected image of the surroundings, (3.) one or more foci of light appearing on crests, echoing the light sources of the environment.[4]

I believe it is these aesthetic features that part of the appeal of the great colored sculpture-like domes of the Persian mosques lie. The shape and color of these domes are certainly their dominant aesthetic attributes. But to these should be added the reflecting property of the ceramic glaze of the tile veneer. Compare, for example, the aesthetic appeal of the uncolored, dull-finished Turkish domes of the mosques in Istanbul, with the dazzling glazed tile domes of their Persian counterparts in Isfahan. A comparable reflecting surface can be obtained with acrylic by using an extra fine rubbing compound. The resulting glossy surface has an aesthetic quality like polished crystal.

For coloring my second composition, I used a base coat of opaque yellow, which was lightly fogged with a black mist, followed by a number of coats of transparent warm yellow acrylic. The final coats were clear acrylic. Regular hand rubbing compound was used to produce a final polish and transparency.

The preceding compositions were fairly simple with more or less flat planes. But the same technique can be used for more complex curvilinear designs. For example, instead of using expanded polystyrene for the basic core, the latter can be made of flexible polyurethane foam rubber. The shell in this case, is then reinforced with fiberglas surfacing mat instead of regular glass mat. Being very thin and light weight, (almost like tissue paper) surfacing mat more readily followed the irregular configuration. By the same token, many more layers are required to achieve sufficient structural strength. The color and polish are obtained exactly as in the other pieces.

Conclusion

On the basis of the many successful works that have been completed to date, we can safely say that for strength, permanence, light weight, and dimensional stability, glass reinforced polyester resin is one of the most versatile and economical materials available to the modern sculptor. By means of spray coats of acrylic base lacquers over the reinforced plastic shell, transparency, high polish, and a brilliance of color equal to that of ceramic glazes can be obtained to enrich the basic sculpture concept.

Notes

1. Russco No. 50 Adhesive, Russ Simpson Co., 21906 Shoenherr, Warren, Mich.

2. Rud Polystyrene Barrier Coating No. 75-75, and Barrier Coating Solvent No. 75-76, Rudd Paint & Varnish Co., Seattle 99, Wash.

3. Du Pont Primer Surface No. 70.

4. Spear, Athena Tacha: Sculptured Light, *Art International*, Vol. XI, No. 10, pgs. 29-49.

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STUDIO APPLICATION OF PLASTIC TECHNOLOGY

FRANK GALLO, ILLINOIS
BRUCE BEASLEY,CALIFORNIA
ROGER BOLOMEY, NEW YORK

Slides of the work of the panelists were shown during an introduction. Then slides of all three were shown simultaneously. Mr. Gallo opened the session by showing and discussing more of his slides.

GALLO: The most important part of my work is in the clay, and it's most important element is the figure. The techniques and the plastic to me are secondary. I thought you might be interested in how my sculpture proceeds from the clay through to the finished piece.

I will run through the slides quickly. This is about a fifty-inch figure. I am always thinking of the plastic—what it is going to look like—so I paint the model with water paint. All of my first castings are done from plaster molds. I am not much of a craftsman or technician, because I am primarily interested in the figure. Here you can see the interior of the mold and the color which transferred off the model. At this point, the plaster is dried in an oven, sealed with shellac and lubricated with Johnson's paste wax. Then a slurry of epoxy is poured into it. I use colloidal silica to create a thixotropic material so that, ideally, I can pour in two or three pounds of epoxy and rotate the mold and get a consistent coating over the piece. I try to achieve a slight translucency through the epoxy. The material I start with is almost a water-clear epoxy, and I use industrial pigments to get the appropriate color. I have invented for myself an entire kind of criteria for the use of plastics as I work with them. I am interested in the subtle qualities of the material. The plaster is, of course, a waste mold. What comes out of it is pretty crude.

This is the interior of the epoxy shell after it is catalyzed or polymerized. I pour polyurethane foam into it. Now this, I have found, is a lot quicker than reinforcing with fiberglas cloth. The stuff is very adhesive. It foams up and fills all these minute cavities inside. It has a second purpose. It reflects light through the translucent epoxy shell. I am very concerned that the pieces do not come out like a piece of furniture—opaque. I am very concerned with translucency. If you are familiar with Medardo Rosso's work, he used beeswax over white plaster and achieved somewhat the same effect. His things are very much alive and reflect light from within.

Here is the first final casting. The dark areas are a result of carbonizing the surface with an acetylene torch. It is a less cosmetic approach in that it is natural to the material to turn black when you burn it.

This, too, is polished. I am not so wild about polished surfaces, but it is the only way to get the light in and out of the surface.

In doing editions, as I do, I use latex as a permanent mold. Since seeing those silicone 630's yesterday, I think I will try that again. In the past, I have used almost everything you could think of as molding materials. I worked with the USI Chemical Company and developed something they called ethylene copolymer resin which is a thermal melting stuff. It is a semi-rigid material which can be painted on the fresh clay prototype. But, in the end, nothing holds up as well as latex, and I still use it.

This shows another casting fresh out of the mold. In this case, I was using plastic and Utrecht Linen which is pressed into the plaster and backed up with the same materials, epoxy and polyurethane. It seems to expedite what goes on inside the casting, and I like to get that over as soon as possible. They would be much stronger if they were made with fiberglas cloth, but I am not really concerned about strength. Sometimes they fall over and break, but art objects should not be treated like boat hulls, you know. So, they are somewhat delicate objects, but the effect is there. It would be difficult to get the same effect with opaque white back-up coats and cloth. There is an awful lot of sanding and finishing on the surface, and this takes a tremendous amount of time. In clay, you can only go so far with the surface. The rest must be done in the cast state.

Here are some shots of a kind of hermaphroditic thing. She is astride a turnstyle. One of the members projects out between her thighs. I have been interested in this idea for a while. It has a great precedent in art history, you know.

Polyurethane foam cannot be used on flat pieces so well. This slide shows a big panel reinforced with fiberglas cloth.

I used the same method here; a translucent shell of epoxy was coated on the plaster mold followed by a back-up coat of opaque white to reflect and an opaque dark surface to keep any light from being transmitted through the panel. About two or three layers of fiberglas cloth and some electrical conduit were used to stiffen it up a bit.

I smash my pieces over with a hammer once in a while for this reason. The thing about plastics is that you cannot identify it as a natural material, but if you can see how it is destroyed, it gives you empathy with the material. You can see from the shattered surface that it is brittle. It is kind of a degenerate way to treat it, but it appeals to me. As long as it is reinforced with fiberglas cloth you can jump all over it and get these wonderful cracks.

I don't beat up some of the smaller pieces so much. This sculpture is only about eighteen inches high. From here on the slides show a progression of pieces that I have done. In doing an edition, it takes about five pieces to entirely exhaust the different ideas that I have about it. Maybe they aren't so evident to you, but I spend a lot of time with small quantities of color trying to get something just right.

This is both a kind of relief and a three-dimensional piece. The head and parts of the knees are filled with polyurethane foam. But the rest of it is reinforced with fiberglas cloth. They are very light weight, of course. I don't like pristine surfaces. They get sterile if you don't throw something into the plastic like sawdust and cigarettes to bastardize it a little bit because the stuff is so clean. Maybe it pays off with Beasley's stuff; it has to be clean there, but not so much here. It does not work with the figure sometimes.

As you can see, in this piece there is a lot of reflected light. For my shows, I prefer that the gallery is not brightly lighted. The pieces will glow quite a bit. To me translucency gives them more of a presence or life than possible in an opaque substance. When I first started, I worked with everything trying to find a material with a light value, so that I could use graphic surfaces. Bronze, wood, and all this stuff is like every substance surrounding it. It does not transmit light. Human beings do reflect some light.

In this piece, I have used polyester and epoxy. I slushed a little polyester in. When it became tacky, I shot in some epoxy and got a kind of interesting treatment on the face, warmed it up considerably—probably not a good manufacturing process.

TEFFT: Mr. Gallo will be back for questions after the other panelists have presented their work. Mr. Beasley will be next.

BEASLEY: I can't really present a completely worked-out technology because I am still muddling around in the dark. I have had the idea of transparency perking on the back of the stove for the past five or six years. Three years ago, I became angry with my dealer, and she with me. We cancelled the show. So, I decided all of a sudden that I had time to work on some new things. I thought glass was the only thing that was really clear. I started messing around in glass, and that was really a drag. I wanted to cast big stuff, and it involves problems that I didn't want to deal with. Therefore, I thought in terms of polyester resin. That was the only casting plastic I knew about. I would buy some, take it home, pour a big chunk, and find it wasn't clear enough. The manufacturer would say, "Oh, our stuff is clear." And I would say, "Look, it's not; I want it *really* clear." And they would say, "Oh, you want it *really* clear." And I would say, "Yeah, that's right; I want it *really* clear." And they would say, "Well, it isn't." And I would say, "Yeah, I know." And they would say to me, "What you really want is acrylic, but of course it can't be cast in thick sections." After about the fortieth plastics dealer told me that, I became mad and I decided I would have to learn to do it. So I went to the big companies that make acrylic. There are a few that do. They not only wouldn't help me, they lied to me. That really made me mad. I spent about a year in the lab just trying stuff, dumping one thing into another. Finally it started working—sort of. And that is about the point I am now. So I can show you some things that work—sort of.

That big object is called an autoclave. It turns out that part of what is necessary to do this thing is pressure. You have to squeeze the heck out of it. This is a great big thing, 30 feet long, 6½ feet in diameter and weights 30,000 pounds. This portion is a steam boiler. It runs inside through tubes. You can't fill the autoclave with steam, because it will contaminate the plastic. It must be dry.

Acrylic is the same material that Jacques Schnier talked about using as paint. It is one of the oldest plastics materials around. Actually, I hate the word "plastics," polymers is what we should call them. Plastic is not a noun; it is an adjective. Acrylic is one of the oldest man-made polymers. It was discovered before the turn of the century and has been in commercial production since about 1930. In a way, it is like a beautiful woman. It is expensive, capricious, difficult, but gorgeous. Acrylic has a lot of problems that polyester does not have. Stress is a big problem with this material. It is fantastic and you have to get rid of it. Annealing is absolutely critical at all stages. You must anneal at the beginning; you must anneal at the end; and probably when they bring your piece back from wherever you have shown it, you should anneal again.

This is a home-made annealing oven. Ovens, as you probably know, purchased out of a catalog, are very expensive. There is a junk yard next door. One day when I looked out the door they were pushing some coffee dispensers off a truck. I had just at that time been designing an oven and I thought, what the heck, a coffee dispenser is a big insulated box. That's all an oven is. So I bought one. It has a nice glass door so I can see what is inside. It cost eight bucks. But the program controller in the side is expensive. You can't really make one. At least it would take more time than earning the money to buy it. In the annealing, you have to maintain a certain temperature for a while and then very slowly cool it. Very slowly means over a period of maybe two days. It must come down only a few degrees an hour. If it jumps all over the place, the stuff bursts apart. It is a big problem so you must have one. It is really just a sort of clock. You cut a plastic cam for whatever you want the temperature to do, and as it rotates, an arm follows its contour and throws switches on and off in the oven.

The material comes in drums. It is sort of expensive which is one of the problems. Here is a piece after it has come out of the autoclave. You can cast into anything that will hold a liquid. There is no big thermal problem. It only goes up to about 200 degrees F. You couldn't cast it in wax, but it can be cast in anything that is clean and will not be dissolved by the material—wood, steel, plaster, glass; the casting will come out just like the mold. The problem is you need a surface you will not have to do too much work on. So far, I have had to do a heck of a lot of work on them. This piece is painted with rubber so that the tool, when I drop it or it skips across the surface where I don't want it to, doesn't dig up the surface. The tool is just a regular air-rotary file. The face mask is mandatory, because the stuff picks up a static electric charge and these little particles cling to things. If you get one in your eye, it is difficult to get out.

This is a closeup of an area that's being worked on. You can see the tool marks. The problem is getting from this point to a polish. You can use machine tools, because you are actually removing material. The polishing is a big problem because the surface smears very easily. If any of you have ever tried polishing Plexiglas or Lucite (those are just trade names for acrylic) you will understand. The material has such poor thermal conductivity that one spot may be so hot it is destroying itself, while right next to it, it is cool. It can't get rid of its heat. Anytime high-speed rotary buffing equipment builds up too much heat, it burns or smears. I have yet to come up with a way to mechanically go through the sanding and finishing process that does not involve too much speed. This is really a problem.

This is the piece which I assume most of you have seen here in the museum. In this slide it is partially completed. The opaque areas are where it is still being ground. The polished ones are starting to come up.

The next slides show how the feeling of the sculpture changes under different light conditions. They show bright sunlight, shade, sunset, and moonlight.

Although the material itself is completely colorless, color becomes an important element in the sculpture. The acrylic acts as though it were a color magnet and picks up and reflects throughout the sculpture the colors of whatever is near it.

Much of the sparkle and brilliance is due to its unique property of piping light. This means that once a ray of light enters the acrylic it can only leave if it hits the surface at a certain angle. As a result the light rays are bouncing around inside with some of them hitting at just the right angle and causing highlights.

On the chemistry of it, like almost all of the polymers, it is a liquid as it comes; this is the monomer stage. That means the molecules are not lined up together. It is the polymerization process that makes it hard. It is not a melting process. You cannot turn this into a liquid by heat. It burns; it sublimates; it goes from a solid to a gas without going through a liquid state. So the problem is the same as with a polyester, getting the molecules to line up. Like polyester, it is exothermic. That is where the problem lies. It gives off heat. It is a runaway reaction. The molecules don't want to start lining up, so you give it a catalyst and a little bit of heat. Then it starts going fast, and you can't stop it. If you put recording pyrometers inside a chunk, as I did, and start heating it, it will go along for two or three hours not gaining more than four or five degrees. Then, in a period of five minutes it will gain 200 degrees F. At that point you have a foam instead of clear plastic. So it is holding down the reaction that is the problem. It is like a car starting to roll down a hill. It picks up speed and goes faster and faster. At a certain point you can't stop it. The same thing happens with the polyester; however, it starts cracking while the acrylic turns into foam. As I said, I am still getting foam part of the time. But when everything goes just right, when you use just the right amount of temperature and just the right amount of time (it varies, incidentally, from four hours to four days), it comes out clear. I can't give you a formula for it now, because I am still working on it. I do one piece and it comes out. Then I use exactly the same techniques, the same amounts of everything, and the next one won't come out. You use catalysts in almost imperceptible amounts in terms of parts, one part in ten thousand up to one part in a thousand. This means measuring very minute quantities, a thousandth of a gram, and this is difficult to do with accuracy. But it is fun. And, like I say, I am just like a kid with a new toy. I can't tell you how to do it except to just buy some and start dumping catalysts in it and see what happens, because maybe the atmosphere of your place is different than mine and the results will be different. That is acrylics!

TEFFT: Now Mr. Bolomey will continue.

BOLOMEY: I regret one thing in this conference. It seems that many of the plastics people, who were here yesterday to talk about their products, are not here today. I think they should be here, because I would like to tell them how much I and many of us, who are experimenting with plastics, need their support—not in cash, but in material. My biggest struggle in the early beginnings, was to obtain polyurethane. Just as in banking, where I never learned to make money, I never really succeeded in getting a company to give me the samples of materials. I had to buy every pound of polyurethane, and at that time, it cost me $2.50 a pound. If I bought 100 or 1,000 pounds, it would come down to $1.80 a pound. That is quite a bit of money, especially when much of it ends up in the dump. If you are very critical with what is happening in your work, you end up throwing much of it away.

Since these conferences have dealt mostly with casting, I should like to say right now that I have never been interested in casting. The technique of casting is too cumbersome for me; it takes too much time; I have to do things rather fast. I must find means that do not involve too much labor, because I feel that what is most important in my approach to art is to do—to create—to go on. The final product, for me, is secondary, and this is probably one reason why I have thrown away so much of my work and only kept what I felt were gems—the things that I liked to live with.

In 1959, after a series of paintings which dealt essentially with an illusion of a three-dimensional surface, I decided to look for a material that I could use in a three-dimensional way. It was a strange six months of trying all kinds of materials. I tried to mix styrofoam with latex and found that the styrofoam would float on the surface and not stick to any backing. I tried all kinds of combinations, mixing flour with styrofoam and latex; I even tried to bake the things in my wife's oven. The kitchen smelled terribly bad, and my "cookies" were just too heavy. They were small; I wanted to do large things.

Most artists who are not affiliated with schools are one-man operators. Since I was one of them, I wanted to find a very light material that would allow me to handle my work alone. I discovered polyurethane: While walking in the streets of San Francisco, I saw in the window of a store selling mattresses, samples of rigid polyurethane. What intrigued me was the sight of a cup over whose edge a material had foamed just like a head of beer or yeast dough expanding over the edge of a pan.

My interest for many years was in observing matter in natural environments, mainly rock formations on beaches and in mountains. I have done a lot of mountain climbing in the Alps during which I have had great esthetic experiences. There were very beautiful things to observe from those lofty heights—the way the rocks had cracked and fallen into chaotic situations down in the valley. I felt that in these chaotic environments there could be found some kind of pattern. All this interested me very much and excited my imagination. The idea was to find a material that could recreate for me, for my own enjoyment, these kinds of situations.

When I found polyurethane, I asked, "How can I use it?"; and when I explained what I wanted to do, I was told it couldn't be used that way. I said, "Well, can you give me some material to try out?" "Yes, at $2.50 a pound." I bought 25 pounds to try. Fortunately I had been told that polyurethane is a great adhesive and shouldn't be poured on the floor, because it sticks very strongly to any surface. So I poured it over an ordinary piece of plywood.

The material comes in two liquid components. One, a resin, the other a catalyst, or catalyst and resin which also has an agent, freon, mixed in it which acts as an expander when you mix the two components together. Within two minutes the material begins to foam, and within three minutes it is hard. Now you see that the expansion and the hardening of the material is extremely fast. You mix it for about fifteen seconds, the reaction starts, you pour it and there you are: two minutes later you have a hard substance. This was extremely exciting, but what could I do with that; how could I control it? For awhile I was just overwhelmed by the quality of the expanding material. I thought why not just do a series of work and discover what I could do in this manner.

(Slide 1959) This work is built on a plywood surface. It is a small work 3 x 4 feet. The foam has been poured over the surface various ways and in various rhythmic movements. The result didn't recreate the feeling I wanted, the feeling I had experienced in areas above timberline. So I tried to burn the surface with a torch, and the work went up in flames; it was a terrible fire. Later, I found that the material could be bought with a fire retardant added to the resin; you can still burn that surface, but the flaming stops when you remove the torch, and that is a great comfort I can assure you. William Morehouse, in California, used the same material without burning the surface; he mixes colors into it; his esthetic feeling is obviously very different from mine. If he burnt his surface, his work would look very much like this (Slide) except it would probably be a little more colorful. When you burn polyurethane, much of the color disappears due to charring.

(Slide 1959-60) This work is from a series of that same period. The hollow space of circle is where I burned a little longer with the torch. You can burn a hole through this material without the whole piece bursting into flames as my first experiment did before I used fire-retardant foams.

The background here is a mixture of latex with sand and vermiculite. Any substance that has weight can be mixed with latex. Later, however, I felt that these background panels limited me to something that resembled a painting which had come alive and burst into the third dimension. I then decided to do away with the background support.

When moving East from California, I had one of my pieces on top of the car. Crossing hot desert in a black car, this proved helpful as effective insulation. As we stopped in Yellowstone, a man noticing the work on top of the car explained to his son, "See, this is a big piece of lava." I didn't destroy the dream. But I felt that my work should be something else than a resemblance to a piece of lava. I felt strongly the need to control the material; I didn't want the material to take over completely. Now came this new development (Slide 1962) in my search for something I could control. The way I did this piece was to make a frame that would support the polyurethane. Then I used a sheet of polyethylene, 9 x 12 feet and laid it on the floor placing the frame on top. When finished, the piece could not only be easily removed from the floor, but the polyethylene could just be peeled off.

Control, I am afraid, is a problem for anyone who would like to work with polyurethane. It is difficult and time consuming to arrive at making components that will answer your needs in every way. You have to experiment by varying the amounts of resins, catalysts, retarders, etc.; it would be good to know a chemist who could perhaps help.

Each company you buy from seems to have a different type of polyurethane. When you buy a two-pound density polyurethane, you do not have too much of a problem. You can find one that expands in about two minutes and perhaps one that will expand slower, in about five minutes. You might find a semi-rigid polyurethane. This is basically the same material to which castor oil has been added in the amount of about thirty per cent. Also, you might find the foam from which mattresses are made; there is up to 80 per cent castor oil in that mixture. This you can find, but when you want harder densities of 10, 20, 30 pound, it might prove difficult to find exactly what you want. At least in 1961-62 it did. Each company developed a formulation that suited their needs, and it was very difficult to find what I myself wanted. I did find what I was searching for at the American Latex Corporation in Hawthorne, California. (Lately, however, when I requested them to send some material to Casper, Wyoming, where I was to give a demonstration, they wrote back that they were not producing the material any more and that I should contact the Polytron Company in Richmond, California.)

In order to build up an understructure to my work and thereby controlling the shape of the work, I decided to make polyurethane slabs of two to five-pound density foam. I proceeded by making a mold out of two pieces of three-quarter inch plywood reinforced with 2 x 4's. I emphasize "reinforced," because the expansion is so great that even this mold would expand somewhat in the center—probably an eighth inch on both sides. These slabs were about 3 x 4, or 4 x 5 feet. To separate the polyurethane from the mold, I used polyethylene sheets stretched on the inside of the mold. This mold was a sort of box that I clamped together each time I wanted to pour a slab. Subsequently, I found that I could open my mold when the material was half-hardened and take out my slab, bend it, hold it in a bent position for about two minutes, and it would solidify in the shape I wanted it to have. Afterwards, I would build up my piece on the floor, welding the various parts together with small amounts of polyurethane or plastic adhesive, then pour over this structure a slow-foaming polyurethane of high density in which dry black pigment had been mixed. The liquid would flow over the surfaces, down on the sides of the structure like lava over a landscape, then slowly gel and solidify. At that stage the work looked organic, as if a slimy skin had grown over the basic structure. The burning of the surface with a benzomatic torch transformed this appearance into one resembling soil, but a soil of an unknown kind.

In 1961 I won a competition for a relief to be placed on the Art Building of San Jose State College in California. It was a great moment for me. A large work, 12 x 7½ feet, the first in polyurethane, was going to receive the test of time, sun and weather exposure. I did not know if it was going to stand up, and accepted the commission with mixed feelings. I was very happy to hear recently that the work holds up very well. Since then I have had works that traveled quite a bit, that have been exhibited outdoors in temperatures far above and below zero, and there seems to be no change in the material. So I would say that it is safe to use polyurethane for works to be exhibited or hung outdoors. It is still difficult to convince architects and others that it is safe to commission works in this material. I have a very large commission going on now for New York. But the material specified is bronze and aluminum. I tried to sell plastics but couldn't.

(Slides) These are other variations of my work. I believe the dates are about 1963. The red is dry pigment that you can buy in any form and add to the liquid polyurethane, not to exceed ten per cent of your liquid formula.

After this series, I felt the need to incorporate materials which the polyurethane would move as it flowed and gelled in directions that would simulate natural process.

(Slide) "Skygate" was my first three-dimensional piece. I mean three-dimensional in the sense that you can walk around it. It was an environmental piece about twenty feet wide, six feet deep, and nine-and-a-half feet tall. As you walked straight in, you were faced with big slabs of aluminum combined with polyurethane.

Then my work became more simplified. In looking for greater simplification, I felt that polyurethane was no longer the material I could use. I had to change, to move into another material.

Much can be done with polyurethane. It depends very much on your esthetic sensibility. It can be cast as some of the English sculptors have done. It is a very good material to use as a core material. I was glad to hear that Frank Gallo uses it instead of fiberglas when possible; Bob Howard in San Francisco used it as a filler in his plastic constructions. If you want to use it as an esthetic material, you'll have problems. I will, however, encourage anyone to use it experimentally to see what he can do with it. The process in using results can be worthwhile. The process in using polyurethane is very simple. I would like to caution people on the danger of the fumes. Believe me, yesterday I was ready to raise my hand and talk about precautions. I am afraid that the plastics industry is overly sensitive on that subject. It is afraid that with too much cautioning, people will be unwilling to use the material. As it was properly said, it is not very dangerous if used properly; one must remain very clean. Like with any hazardous material, you must be careful. I worked outdoors for a while in California. I began to breathe these fumes and didn't like it. So I decided to wear a mask. Later I learned through reading articles on safety and precaution in the use of plastics that the material is really very toxic; it could have been too late. This is why I would like to caution people, "Use a mask with at least an organic filter that hangs onto the side, away from the work in process." The fumes have a tendency to drift to the floor. They are heavier than air. Therefore, you should have an opening at the bottom of the place where you work and a fan that will clear up a space within a minute or so. But still, use a mask, it is very important. I have been sensitized somewhat, so that I am now bothered even by epoxies. If I make a little mix of epoxy, I immediately have a stomach ache. It doesn't last very long, but it is a nuisance; one doesn't like that. So I use a mask for any small amount of work having to do with plastics. This is *not* psychic as we were told yesterday, believe me, it is *not*, no matter what these companies say! Epoxies might be less dangerous, but polyurethane is very dangerous.

You can build a chamber big enough to handle your work, such as I had in my studio in Hoboken. The walls were covered with polyethylene so that I had light coming through all the walls. I worked in the chamber with the fan going. The real danger moment is when the foam expands. The open cans before mixing are probably somewhat toxic but not to the extent that the material is when it begins to foam; then it is really toxic. Very simply, you must work with a good mask on. I dare say, nobody would stand in front of these materials as they foam and try to breathe in the fumes; it just knocks you out.

I will stop here, and if anyone has questions, I will be glad to answer them during the session following. Thank you.

Studio Application of Plastic Technology

Question Session

GALLO: He asked why my work is so successful in light of the absence of the popularity of the figure today. I am torn between saying, "I haven't the slightest idea" and, "it must be the quality of the work."

AUDIENCE: Was I correct in understanding that once acrylic is solid it cannot be converted back into liquid?

BEASLEY: Yes, that is correct. Technically it can be distilled, ground up and distilled under vacuum, but for all practical purposes, it cannot be.

You know, in a way, this is unfair because this is your time, but I have something I would like to say. Yesterday when I was sitting where you people are sitting now and listening to the industries giving their presentations, I began to realize that everything was backwards. They should have been out there taking notes, and we should have been talking to them. I think it is typical of what industry has done to plastics. They are unimaginative and in many cases uninformed. There are people in this audience who know so much more about our use of polyesters than the speaker did yesterday that it is a joke. I think that we are the greatest research and development potential in the world. Industry is spending millions of dollars hiring unimaginative engineers and chemists to do things that we are doing in our backyard studios. If they would spend one tenth of what they now spend, give us materials, and not tell us what they won't do, but let us tell them that they will do, they would be ahead and we would be ahead also. I think it is time we start telling them about their materials, because they don't know about them.

AUDIENCE: I would like to understand why one must anneal acrylic sculpture after every show. What will happen?

BEASLEY: Well, actually, that was a little bit of an exaggeration. The material develops stresses in it, much like glass does, internal stresses that will suddenly let go and cause cracking. It is also particularly subject to solvent crazing. Any of you who have worked with Plexiglas will know that if you buff a piece and then try to glue it with a solvent glue, little surface cracks develop. Well, that is the stress letting go. If you display a piece of acrylic outside and a gardener or painter spilled something on it, the surface would crack if it hadn't been annealed. Like all man-made polymers, this material is also subject to ultra-violet contamination which will increase stresses. If I did not anneal my sculpture, it would not just destroy itself; it would *suddenly* destroy itself. It would be fine until someday the temperature drop would be just the right amount of change or somebody would say just the wrong thing and it would go bang and crack in half. So annealing is very important.

AUDIENCE: What about tempering?

BEASLEY: Tempering is putting in controlled stresses to make something harder. What you want to do is get stresses all out.

AUDIENCE: How does the pressure in the autoclave help the process?

BEASLEY: I apply pressure during the process of polymerization. As I put the piece in the autoclave, I start heating it. I have only to heat it for a little while. It is a trigger. Once it starts, it is the same as with epoxies and polyesters. It maintains enough heat in itself to keep the reaction going. I haven't found a way to hold back the heat once it starts going off, so what the pressure does is allow the material to accept that heat without pulling itself apart.

AUDIENCE: How much pressure?

BEASLEY: Well, that is one of the variables. Under thirty pounds isn't enough pressure. It seems that the more you have the better. The more you have, the more it costs. That is one of the problems. Unfortunately, it is above the pressure of canning and sterilizing, for these are the only sources of cheap autoclaves.

AUDIENCE: Have you had much problem getting rid of the inhibitor?

BEASLEY: It comes with the inhibitor in it as does polyester, because it will go off by itself rather explosively. Yes, getting rid of the inhibitor is a problem, although it looks as if we may be able to use it by overcoming the inhibitor, rather than removing it.

AUDIENCE: How large a statue can you visualize making?

BEASLEY: I am working on one now that is going to weigh 20,000 pounds. I may be crazy. Industry thinks I am. They thought I was when I started. The only size limitation is basically money.

AUDIENCE: What parting agent do you use in a latex mold and what kind of latex do you use?

GALLO: I don't use a parting agent when working with latex and epoxies. If you work with the polyesters and the latex, it is probably essential that the latex be properly cured of all free sulfur. If you are using methyl-ethyl-ketone peroxide, it is necessary to boil the mold or cook it long enough, say at 200 degrees F. overnight, to make sure all the free sulfur is gone. If you are really worried about it, it is a good idea to rinse it with a solution of soap, castor oil, or vegetable oil, not petroleum, to put a scum on the surface to protect the mold somewhat. It should be good for several castings that way. But then you have to be careful of heat with latex. It breaks down over a few hundred degrees. I don't know what kind of latex I use. I buy it from different places. It is not all exactly the same. Some have more solid rubber particles than others. Some are pre-vulcanized. Most latexes you buy today are pre-vulcanized latex particles in a solution of ammonia and distilled water. I think Cement-Tex in New York has a most scientific approach to their latex. They have a lot of published literature that goes with it that is very helpful. They have different recommendations for different kinds of casting problems, and they really know what they are talking about. I have visited them.

AUDIENCE: Regarding flame polishing . . .

BEASLEY: Flame polish on acrylics? Yes, that can be done. They call it polish. It is what you see on most of these little name plates. They do the edges that way. You can get sort of a shiny surface on saw cuts. I don't think it is really polished. What you are doing is just melting the first surface. It is okay, but it is not really polished. I mean, if you want a really cherry surface, you have to buff it.

GALLO: May I ask a question of Mr. Beasley? Is this superior to acrylic modified polyesters as far as clarity? Is that your biggest issue?

BEASLEY: Yes, if you take a chunk of this stuff, three feet thick and polish both ends, you can read a newspaper through it. There isn't any other material except crystal glass with which you can do that. In a sheet it looks the same. As it gets thicker, the more you begin to realize how opaque or translucent polyester is.

GALLO: Wouldn't it at times be more simple to carve the piece from a solid block of plexiglas?

BEASLEY: Well, no. The only company in this country that makes large acrylic castings charge for a round piece, 18 inches in diameter and one foot high, $1000. That is for approximately $40 worth of material so you are paying them $960 to polymerize it for you. Just for curiosity, I asked the same company to give me a bid on a six-foot cube. They said they had never made a six-foot cube and it would be very expensive. I said, "Okay, but how much?" They quoted me a quarter of a million dollars and one year delivery. That is why I am not carving it out of blocks. (Laughter)

AUDIENCE: Do you pour polyurethane into the epoxy before or after the epoxy shell comes out of the mold?

GALLO: It is absolutely essential to pour the polyurethane foam while the piece is still in the plaster mold because of the tremendous amount of pressure. It would certainly split the epoxy shell in many places. It should be wrapped up tight with wire and nylon tape to withstand the pressure. But it doesn't seem to move after that. I warm up the mold in a heat booth, in advance, before I pour the urethane to get maximum expansion so that later when I burn some part of the surface, there isn't an additional expansion as the epoxy is softened by flaming it.

AUDIENCE: Do you have trouble with the seams as far as color goes?

GALLO: Yes, I do. It is sometimes very time-consuming if I want to eliminate the seams on a very small, very delicate piece. If the seam is opaque, as it is sometimes, and loses its translucence because of the amount of cab-o-sil used, I have to route it out, coat the bottom edge of the routed surface with a white pigment and then recast it with transparent tape and hypodermic needles to try to simulate the cast surface that I had in the mold. It is sometimes very difficult to completely obliterate any evidence of joints.

AUDIENCE:

BOLOMEY: I try to avoid the breakage problem for very specific reasons. Unfortunately, I did have one disasterous experience, but this was not due to the material itself, rather due to human handling of the work. Polyurethane does harden quickly and then tends to continue its hardening process, becoming more and more brittle. The curve is very strong the first week but levels after the first week. Once you have a slab of polyurethane, whether you try to break it after a year, two years or after that first week, the breakage will take about the same amount of pressure. It is brittle so of course, if a piece falls from the wall four feet to the ground, such as happened at the Carnegie International, the work naturally breaks. This piece really didn't break very much, but it broke and I repaired it. It seems that the repair created another tension and the polyurethane cracked elsewhere. Now, I am talking about a two-pound density polyurethane, about one and a half inches thick with an additional coat of 20 lbs. density one-fourth inch thick over that. Another piece broke when it was blown down by the wind, probably not secured to the wall. If a piece of marble falls and breaks, it is too bad, but one restores it. You see the crack and even the crack becomes an esthetic part of it. I like very much the feeling of the texture in Frank's work—the lines, the cracks, the time element in it. But in a surface like the one on my first work which you saw today, you cannot accept a repaired crack. A repair in this surface will always show unless I shave the whole hard density surface, repair the base and pour the surface over again. But this is such an enormous work that I am not willing to spend the time. I am more interested in the next work. I want to make it clear that for me art is a process of evolution. This is very different from making a work and spending much time on the technical processes. This is something entirely different. What is important to me is to make the work.

GALLO: Could I interject something for just a moment? I would like to express my thoughts about this conference and all the interest that is prevalent in new media like plastics. This will undoubtedly have some effect on the idea of art as an immortal object and it may bring about a change in attitude about what an art object is. When all these pieces eventually depolymerize about thirty or forty years from now or are destroyed by ultraviolet rays before ultraviolet shielding can be completely guaranteed, how are people going to feel about it? It really does not concern me a great deal that maybe my pieces have a life span, especially when I think that Michelangelo's "David" probably wouldn't have stood the weather much longer out-of-doors. A lot of people question me about permanency and I don't really care that much about how long it lives. All these things can be reproduced.

AUDIENCE: I want Mr. Beasley to clarify just a little on stress. You said it was an exaggeration that when a piece comes back from the gallery you would stress relieve it.

BEASLEY: Yes, that was a little bit of exaggeration. However, I think probably it would be a good idea for it to be done every two or three years. It won't be, but I think it would be a good idea.

AUDIENCE: Well, can you explain that? I don't understand why, once it was stress-relieved, it wouldn't hold.

BEASLEY: Well, because it gets new stresses back in. A sudden temperature change, someone leaning on it, a lot of UV excites the molecules and they pull against each other. All of these things result in stresses. Buildings build up stresses. Architects would love to be able to stress relieve a building every few years. Most materials get stresses in them.

AUDIENCE: Well, when you first stress-relieve a piece, do you have some way of knowing that the stress is relieved?

BEASLEY: Well, some stresses can be seen under poloroid filters, but basically, you know that the process of polymerization causes stress. The stress relieving process is pretty well published. Such as how long it takes for each thickness. Of course the thicker it is the longer it takes, and this is published by the Rohm & Haas Company. I just followed those directions.

One thing about what Frank said, I agree completely about this business of permanence and in many ways, although it sounds frivolous, I think it might be an advantage to everyone if sculptures automatically went poof after about twenty or thirty years. The museums would have a lot more room for newer things and we wouldn't be constantly wearing this albatross of old junk around the neck of our civilization. It would make a lot more room for a lot of new artists. (Applause)

BOLOMEY: We have microfilms now which they didn't have in Michelangelo's time. We can keep the works of art in the Library of Congress.

TEFFT: If there are no more parting comments from the table, since we have kept these gentlemen quite a while, I would like to thank them for a lively and interesting discussion.

EXPLORATORY DIALOGUE, LARGE SCALE CONCRETE SCULPTURE

ALBERT S. VRANA, FLORIDA
BERNARD FRAZIER, KANSAS
KENYON PHILLIPS, PORTLAND CEMENT ASSN.

VRANA: I am sure you are all familiar with sand casting. There has been enough sand casting around the country for the nature of these forms to be recognized. However, for those who have some questions, I will explain. The impressions are pushed or carved into sand and then concrete is poured on top. We make impressions in the sand, pour concrete, and the panels are taken in order and attached to the building. I have experimented with different forms and texture. You can see, if you look closely, the sand on the surface of the concrete. I do want to say something about the method of casting these panels. I, like some people who were speaking earlier, went to the experts and asked how to cast concrete. They told me what I could do and what I could not do, but I went ahead and tried it anyhow. These panels are cast dry. By this I mean the concrete was dry when placed in the molded sand. The water was percolated down through the top right into the sand pattern. I was told by engineers that this is impossible, but not being too knowledgeable myself, I just went right ahead. It was not impossible, and I have picked up impressions impossible to pick up any other way.

The Professional Arts Center, Miami, Florida, has panels cast of concrete in styrofoam models. The sculpture covers about five stories, 23,000 square feet of cast stone, as we prefer to call it. It wraps around the entire structure. This is a view from the parking lot in the back. Some of these panels weighed as much as ten tons. The relief here is only two inches in thickness. I did not have to remove the mold in one piece. I had a disposable type of a mold which I just tore off when I was through. The sharp contrast between the high part of the mold and deep incision creates a sharp shadow.

We move now to Jacksonville where the Federal Government built an office building. They contacted me and asked if I was interested in doing a relief for them. This is the building. You can see how the sculptured frieze or relief is set in under an arcade and, unfortunately, the sun never gets there. I had to think in terms of creating shadow by intensity of colored aggregates, and I used what they call in the concrete business a retarder. This retarder is really a preventer. It prevents the concrete from getting hard in areas that are adjacent to it. I am really talking about the cement in concrete, not the concrete itself. Here we see a man sweeping away the cement so the aggregate will be exposed.

Now, we have a close-up. The dark areas are the areas where the aggregate is exposed.

Can we start the film? These panels are an integral part of the building. They are not an artistic form that's brought in after the construction takes place. This can be a problem for the artist. For example, in a six-story office building, I signed a contract with the owners of the building before the general contractor signed his because, I had to start out six months before the contractor to produce the molds so that when the concrete pre-cast yard began casting, they could continue without any interruption.

Here we are back at the library in Miami Beach. This is an auditorium by the way. The architect took the air cooling tower off the top of the building and created this pool of water which became a combination cooling tower and a reflecting pool, a unique approach.

Unfortunately, the night photography didn't turn out the way we expected. But you can see the reflection of water on parts of the building wall. Here we are back at the Professional Arts Center which is an office establishment. Here, again, you see the aggregate is exposed in certain areas.

In my studio. This is an early shot of me working on my drawings. I start out with a model and then draw from the model and work into the molds.

What you are about to see now is the progression in the making of molds out of styrofoam for the Jacksonville Federal Office Building. These drawings are blown up scaled to full size in the old fashioned way using a grid system. If you will look closely you can see on the drawing different colors of lines going across the black lines. These are a color-code system. Here I am enlarging from my small drawing onto the full-scale slab of foam. These indicate the height of the relief at this particular point. I build up contours like rice paddies setting them in place with an adhesive and then cutting them down with a grinder.

Here is a tool that may interest you. I have taken a kitchen knife, split the blade and attached it to a soldering iron. When one pulls the trigger, it heats up to about 350-400 degrees Fahrenheit. It cuts the styrofoam material like cheese and saves the trouble of taking this material to a cutting device. You can handle a sheet of any size. This chain is another little innovation. In order to transfer the drawing from the pattern on the floor to the underside of the slab of foam, I use this chain which will take any shape at all. When I hold the slab of foam up to the light, I can make out the line embossed by the chain. I go over this with a crayon. Then, I go back to my knife. This cutting tool saved me a fantastic amount of time. There is no sawdust from it. It makes a nice clean cut. You can see the nails used here. I was interested to see someone else earlier in the program use nails to peg foam in place. I use these nails to hold the different levels of foam construction in position until the glue is dry. Then, I remove the nails and go into my grindings. I use a slow speed grinding machine because a high speed one would eat up the foam too fast for adequate control.

These are shots in the pre-cast yard showing the casting of the panels using slabs of styrofoam. The two panels in the rear were test panels. You can see their size. Don't fool around with small panels as tests.

Certain areas of the molds are colored and this helps the men in the yard to determine which areas to cover with certain types of concrete. The face material is white cement concrete used with an expensive aggregate. The backing is ordinary gray cement with a high PSI (pounds per square inch). I decided to show the gray as well as the white. Since we have two colors, why not make use of both colors?

Here I am painting on a retarder in the areas that are going to show the aggregate of the panels. This particular corner panel has a twenty-inch corner on it. I do not like to see a panel terminate at a corner because from across the street a panel six inches thick looks like about an eighth of an inch thick. So, I went to the trouble of having the panels cast with this return to create a feeling of massive form. The concrete was mixed at a pre-cast firm where they weigh everything. Aggregates have to be kept soaked at all times so you have a consistency in weight. If the days are hot as they are in the summer time in Florida, you can lose a great deal of weight in aggregates.

This aggregate is brick. I crushed 35,000 bricks at eight cents apiece which kind of shook everyone up because they thought, well, why can't you use a used brick or a six-cent brick? Must you use the most expensive? I ran a series of experiments and found that a good hard ceramic could give me a lot more material that was usable than one which, when crushed, turned to powder.

You see how careful the workmen had to be in order not to put heel marks in the surface of the foam as they applied white aggregate cement to the color-coded areas. Other areas received gray structural material without aggregate.

I textured the surface of the foam mold with a solvent. About one hundred gallons of thinner was sprayed on with a sprayer such as you might use in your garden. You have to be extremely careful, because if a little too much falls on styrene foam, it's gone, just like that. I didn't want a manufactured type of appearance. I wanted to develop a form that looked as if it had been there for a while rather than a smooth surface.

Here you see the reinforcing steel going in. These hangers are plates that will be welded to a beam on the building. This particular concrete is an extremely strong material. It ran up to about six thousand pounds PSI. We usually stripped the outer forms after 24 hours, but occasionally we would have to wait from Friday to Monday. Between the time it was cast and the time it was stripped, the concrete on the top edge became so hard that occasionally someone would cut his hand on a flash of concrete.

This slide shows how easily the foam comes off, although styrofoam has a tendency to really stick to plaster and cement. Now, I think if you'll look carefully, you can see the areas which are retarded.

After the panels have been stacked they are laid down on the faces and cleaned with an acid wash. I think I should have told you that the aggregate in the top half of the panel is expanded shale or solite. I believe you people in this area produce part of the solite that is used. Now, occasionally, we have oil spotting due to the machinery in the yard. During a rain the cement will run from one section of the design to another and streak, so before they're loaded on the truck to be transported to the site, we have to go over them again and clean them with acid. A single panel is about eleven feet by sixteen feet. The relief on this building was 16 feet high and 480 some odd feet long. It was quite an undertaking. Now, if you can see the small figures at the bottom of the panel, you'll notice that I did a peculiar thing here. I changed scale in the middle of the piece of sculpture for the reason that you can see. This piece of sculpture will be seen from the parking field or from 25 feet away. When you're so close to big forms like this you don't seem to be able to associate with them, but you can associate with these small people-like forms which are, like you, a viewer engrossed in what is going on. So you get pulled into the panel as you begin to search out these forms. From the street these little forms don't seem to be noticeable. I used brick and solite, because the floors in the area were all brick. Now, I'd like to show you some finished shots of the building. I was kidding our friend here from Portland Cement, suggesting that they didn't really complete the film because the fiscal year was over before the film was ended. But they will go back and shoot a film on the completed work. We're running out of time. May I turn it over to you, Mr. Frazier?

FRAZIER: Since we are short on time, we will go through my slides as fast as possible.

The first is Temple Israel in Tulsa, Oklahoma, 1953. Percival Goodman of New York City is the architect. These sculptures are monolithic concrete—actually the building wall, the total bema area. This is the Pillar of Fire. I believe it is 45 feet high. The molds, or forms, as we should call them when we're speaking in terms of construction, were built mostly of wood. Only about ten percent of the mold surface was plaster. The final concrete surface is untreated in any way. We started out with the idea of producing a very natural concrete in its very natural and rugged form. Seven inches of cameo and seven inches of intaglio were used. In other words, fourteen inches of relief in all.

Here the forms are in place and I am up about forty feet, sealing off the form, ready to build the wall fourteen inches back of this.

Another panel showing the first commandment. The letters, of course, must be read backwards in order to read frontwards after the cast. This demonstrates how I built the negative forms of two-inch lumber using band saws, hatchets, chisels, axes, and whatever to build up the relief by carving, sawing and laminating.

The four forms were raised into place onto the building by a mobile crane. Each form was over twenty-two feet tall and, if I remember correctly, 14½ feet wide. Here you can clearly see the relief of superimposed layers of wood.

The 45-foot sculpture was poured in four sections. This would make about twelve feet at a time. The concrete was run out of a mobile truck into a bucket on a crane and hoisted up to the top. It might interest you, if you want to go into something like this, my contract read that I was responsible for everything concerning the cast. The cast was the wall and the wall is the temple. In other words, about a million and a half dollars. You can imagine me down inside there with my toes and fingers punching concrete in places. It wasn't actually necessary, but it made them feel better. The fact is, that with that much weight of concrete you are not going to have bubbles. We vibrated it very little. We poured it gently through a tremie, which is a tube—an elephant trunk-type of thing, so it wouldn't splatter the form all the way down from the top, but rise up from the bottom. Each 12-foot lift was poured as the building progressed upward.

This is a smaller project in Wichita, Kansas on a Lutheran church. In this case, a lift-up slab was poured horizontally. The subject is a large pair of hands as you see. All the forms, again, were built of wood with a minor amount of plaster. Here is the form which is a boat-shaped affair. The components were made in my Tulsa studio and assembled on the job. It is interesting that quite on my own in Tulsa I developed a color code which seems to be much like Mr. Vrana's. You see the blue and red on the pattern, one meaning cameo, the other intaglio. The parts were put together. The 37-foot slab was cast and after proper curing was picked up by two mobile cranes and set in place against the arches you see in the background. I might mention one thing. Most of my projects are originally suggested by architects. I find them most cooperative in every way. In this case, the architect was glad to punch a hole through the roof to allow light to stream in onto the sculpture. By the way, the architect for this project was Cliff Raney of Wichita.

This slide shows the Methodist Church in Wichita, Kansas. The ceramic mosaic covers a 24-foot by 72-foot exterior section of the cylindrical sanctuary. The sculptured concrete wall was poured into reinforced plaster forms produced in our Lawrence studio. The sculptured area with eight inches of relief was first modeled in oil-impregnated sand by modular system of 8 x 8-foot rolling platforms. The surface of the platform was an exact radius of the building and could be leap-frogged around to achieve design continuity. We will show you by a series of process slides including a few concerning the mosaic element placed over the concrete cast.

This shows some mosaic detail. We made all the ceramic tesserae for this. My wife was the chief hand, producing acre after acre of ceramic tesserae, employing a nodular sort of glaze which we worked out.

Now, this is how it is done. A model was made in clay, cast in plaster and painted to approximate the mosaic colors. The small figure is for scale, showing the architectural circumstance. I want to say that Mr. Vrana and I talked about this yesterday, and we agreed that there is no such thing as operating professionally in large scale without quite a series of models. Here is the first little model, which we later painted. This shows the clay of the final working model which is to exact quarter scale. I took my measurements off this to produce the final sculpture.

This is a detail of the working model in the clay showing my study of the faceted placement of the mosaic tesserae. I wanted to do this mosaic in what I shall call the classic manner, not one where you paste the mosaic tesserae on a paper, tap it into a mortar background with a flat board, and then wash off the paper later on. These were placed from a scaffold directly into the mortar on the concrete wall. The reason we wanted to do this is simply I wanted the quality of the great part of the old mosaics, the faceted placement which refracts light randomly. In other words, we wanted to avoid the bathroom look.

The molds for this were modeled in sand—fine sand saturated with oil. I may try some styrofoam some day, but I'm not sure that I will. I want more relief. I feel that concrete is best with very, very rugged relief in most cases, and the sand allows it. I can move it with shovels, tromp on it, and bat it with boards. I model quickly as a matter of fact. I modeled an 8-foot square module each day. I don't mean the panels were cast in that size, because the whole thing was cast at once. In fact, it was an eight-hour pour for the whole 72-feet by 24-feet. Our forms were that size, and each day, I modeled an 8-foot square section. Each evening with the night crew we made the plaster mold on that 8-foot square piece. The forms were never assembled until they were assembled onto the building. As each section was cast, its dolly would be moved down the line in position for the modeling of the next section.

This slide shows the oil sand. Sand from the Kaw riverbank happens to be a very, very fine grade of sand which, when mixed with oil, models well. This, incidentally, is not the mosaic project. We have no slides of the sand being modeled on the mosaic project, so we are using slides out of the other projects to show the sand in action. That is Beverly down there helping with the work. Here are the mold sections ready to be placed upon a trailer to be hauled to Wichita in order that the construction firm could build them into their walls. We never had many around. Most would be on the highway to Wichita. The contractor wanted sections which two men could handle. A sort of corn-crib like structure was built on the curve, and the molds were hoisted up by a common rope and pulley and put in place according to my code numbers. Incidentally, to produce any kind of form so you can pour 24 feet of concrete in eight hours, the forms have to be very, very strong.

The forms were stripped off very easily. A winch truck took them all off in about a day. Here is a shot of the raw concrete. Those seams would have concerned us except that it was going to be covered with mosaic. If it had not been a mosaic job, we would, of course, have treated all of those seams so that they would not show.

Now, placement of the mosaic tesserae is beginning. This scaffold, designed to go all the way to the top, was constructed on a track that would roll around the cylindrical building. We followed courses of design movement around the full perimeter of the wall not working yard by yard from one corner.

This is a shot of some of the tesserae showing what the coursing could do for us. You notice that my coursing was not always color. Sometimes it was texture; sometimes it was the size of the mosaic tesserae. The tesserae range from about one-fourth inch to about six inches square. We picked them off the layout boards and set them with thin-set mortar onto the wall.

This shows the scaffold but not all the way up. We could add levels as we needed them. The little shed on the street level held our supplies and work clothes. We would carry tesserae up on our backs, somewhat laid out on the boards. We once figured about seventy thousand tesserae were placed on this mosaic, each one of them handled many times through the process of making them (glazing, firing, etc.) and then contemplated for selection.

Frazier: Thank you for your patience. We were going to talk among ourselves, but I believe we had better go right to the questions because this would be the best way for you to get the word.

Q. What special type of cement was it that had that high PSI? You mentioned 6,000. . . .

Vrana: Well, it was high early. This is a kind of a cement that reaches within 24 hours a greater proportion of its overall strength. If you were to plot it on a time-strength chart, it would go up real quickly and then taper.

Q. How long was the time from the beginning of your sketches to the finish?

Vrana: On which job?

Q. The five-story building.

Vrana: Two years. But a great deal of that time was spent with the architect and in general discussion, disagreements with the owner, etc.

Q. When you're using dry concrete, how do you add water and how do you know when it is enough?

Vrana: I percolate it down through the top and it seems that concrete is a great deal like clay. It is a collodial type of material. In other words, it will accept all the water it can use and it rejects anything beyond that point so you can just pour it in as long as you don't stir your mixture.

Q. Mr. Frazier, what kind of oil do you use in your sand?

Frazier: I hate to let out this secret, but we used crankcase oil.

Q. I am sorry, I came here late, I don't know if you spoke about this, but I have had problems in pouring concrete when I come to a corner. The water, I guess, comes out the corner. It does not give me a straight hard edge.

Frazier: That's a job for Portland Cement, wouldn't you say, Mr. Phillips?

Phillips: You find that the corners are breaking off?

Q. Not breaking off, but the concrete is not compact at the corner as it is no flat surface.

Frazier: This sounds like it would probably take a little hand work to work this into the corner.

Q. I use vibrators, and I still have that problem at the corners. Could the water be leaking out of the joint of the mold at the corner?

Phillips: It could be water that could be working to the corner. Did you try placing the concrete in the corner first? This might help.

Q. These are huge forms you are pouring from a truck and you use a vibrator. You go to the corners and everywhere and you open up the form two or three days after or a day after, and you have this water problem—frail structure of the corners.

Vrana: Can I inject something? It might be shrinkage.

Q. Can it be stopped?

Vrana: Polymer glue can be mixed in. Now, for the percentage I would have to go back to my files, but a certain amount of this material, which is the Elmer's glue type, can be used in casting to prevent shrinkage or excessive shrinkage and this sounds like shrinkage to me.

Frazier: Mr. Bolomey, you may have noticed that on mine there were no right angles or corners. They were all curves for this reason.

Q. In using dry concrete in your first slides, is this just plain cement or cement with a sand mixture or just how do you water it?

Vrana: Well, it's white cement, and if I remember correctly, it's about two to one. In other words, about two parts of sand with what we call screenings which is a very small stone about half the size of a pea. Two parts to one and it is placed very carefully on top of the sand. The reason I use this instead of pouring in, is because if I began to pour, I would lose the sharp edges in the sand, because when you pour into a sand form, the concrete is extremely heavy, and it can collapse. Now, you percolate your water through the top with a hose in a fine spray and you can't overdo it. It is not critical. The water will continue to pass through the concrete but will not pick up the matrix or the cement and carry it into the sand pattern underneath or contaminate the sand underneath. Just the water will go through.

Q. Is this plain sand or oil sand?

Vrana: Just ordinary sand.

Q. Mr. Frazier, what sort of adhesive do you use to adhere your regular mosaic base on a panel?

Frazier: I'm not sure I understand, but I think I do. We used, on the Wichita mosaic, thin set mortar. I understand there are several brands. But at that time there was a company in Dallas making L.M. Thin Set Mortar. We gave this a great many tests even to asking the owner and the architect and any innocent bystanders to chisel off a small section of mosaic. They didn't go very far before they said they were satisfied. It has been five or six years now, and I haven't heard of nor noticed deterioration.

Q. Inaudible.

Frazier: Hold it to the form surface? I see. Then my other answer was not the right one. Actually, I've not done this. Mr. Phillips, do you know what should be used for this sort of thing?

Phillips: Well, I think he is asking if you are going to fix the aggregate or the tile to, say, a sheet of plywood and you're going to pour concrete against this, imbedding the aggregate, then you want to remove the sheet of plywood without tearing the tile off, correct? You will need a glue that is soluble in water, so that when the concrete begins to heat up and the water is rejected, it will infiltrate and soak your tile, releasing it from the glue and allowing the form to be pulled away. This is the kind of thing I would have to experiment with.

Q. Mr. Vrana, do you paint the retarder directly on the styrofoam or will it absorb into the styrofoam?

Vrana: Well, this is a problem when you work with plastics. You always have the problem of compatibility. The majority of the commercial retarders that are on the market will attack the foam. Anything that has petroleum in it, like automobile grease or vaseline or kerosene will attack the surface of styrofoam, especially at high temperatures. I've found out that in the early days they used a basis of sugar retarder. I bought about five cases of Aunt Jemima's pancake syrup and made my own retarder.

Q. If you'd used urethane, you'd have been all right, wouldn't you?

Vrana: Far too expensive, far too expensive.

Q. Can you put cement over styrofoam if you have a block of styrofoam and you put steel around it to reinforce it?

Vrana: You mean with a pallet knife or a trowel?

Q. Well, I wonder how strong the cement would be, whether it would change how it dries or . . .

Vrana: You're talking about an armature which you're going to . . .

Q. No. I'm talking about playground sculpture where you might have some large pieces.

Vrana: And the core would be a foam?

Q. Or you could put sand in it or something like that?

Vrana: And you want to know . . .

Q. What will happen to the cement?

Vrana: It's completely compatible and they adhere well too, if you don't put a parting agent on it.

Frazier: We are ten minutes overtime now and another discussion is coming. We need to give way if they are ready.

THE OCULIFORM IN NORTHWEST NATIVE SCULPTURE*

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* Author's Note: When presented at the Fifth National Sculpture Conference, this paper was supported by 35 illustrations and over half of these provided visual evidence upon which the hypothesis was based. Since the cost of reproducing such a number of illustrations would be prohibitive, this paper has been reduced in size and scope, hopefully not at the expense of any stimulation it might generate.

Most cultures attach great importance to the eye, whether it be of man or beast. Certainly the eye motif is the predominant design element occuring in the tribal art of the Pacific Northwest coast (Fig. 1). After reviewing numerous interpretations advanced by highly regarded specialists such as Adam, Boaz, Christiansen, Holm, Inverarity, MacIllwraith, and Swanton, all of whom have commented upon the eye formations peculiar to this art form, one question persists: What factors within the aboriginal environment could have contributed to such distinctive styling?

In this study a number of factors have been examined, some of which may be dismissed as incidental, and others which appear to have direct bearing on the question. Visual analysis of a typical specimen of Northwest Coastal Art most certainly eliminates the possibility of the stylized eye having been based on racial characteristics or on anatomical knowledge of the muscles comprising the orbicularus oculi. From a chronological point of view it may be noted that this particular formation, hereafter referred to as an oculiform, does not appear in prehistoric stone carving from the Pacific Northwest which was predominantly related to the great river basins of the interior. Geographically we are herein concerned with the aboriginal maritime cultures dating from the early 18th century through the 19th century.

Other factors appear to be more relevant to the problem. The oculiform, although used to represent the eye of man and beast, was also used to indicate the mouth, navel, the vulva, and various joints of the appendages. This wide distribution has been interpreted by Boaz as an all-embracing symbol of power and articulation. On the other hand Holm has observed in his study of the Inner Ovoid Articulation that several stylistic variations are to be noted in representations of a specific animal form, e.g., the head of the Salmon Trout. Furthermore it should be recalled that the oculiform was used in connection with painting, weaving, and combined media as well as the traditional materials of the sculptor, namely wood, stone, horn, and bone. Considering the range and scope of native Northwest art it should be acknowledged that the highest percentage of production can be classified as sculpture in general and carving in particular. Indeed it is this investigator's considered opinion that wood was the predominating material in the economy as well as the artistic production of this culture, and that the wood-carvers, more than any other artistic agency, set the style.

It would be sheer folly to classify this theme and its infinite variations on physical phenomena alone, for certainly religion and magic were pre-eminently active in the commissioning and conditioning of native art. Thanks to the patient research of MacIllwraith we have a better idea of the secrets of the Bellacollas; however, this same authority more than intimates that the interactions betweeh tribal art and society are a reflection of the total environment. Within the reference frame of our limited knowledge and perspective relative to pre-literate tribal art, we are on safer ground when attempting to reconstruct the physical rather than the spiritual conditioners.

Returning to sculpture (and this investigator may unduly magnify the importance of his calling) it is highly possible that the native sculptors were at least intrigued, if not fascinated, with such natural forms as abound in this region, namely fossilized shells, sedimentary concretions, and with the structural and aesthetic composition of native trees. In the geo-cultural area under reference we have a littoral of about 1200 miles ranging from Oregon on the South to Alaska on the North. In the coastal rain forests there is an abundance of Douglas Fir, White and Yellow Cedar, and Sitka Spruce. While visiting the several shores of this region the author has observed and collected hundreds of wood knots that bear an astonishing likeness to the oculiform motif (Fig. 2). The skeptic is at liberty to insist that these forms abound today due to modern logging operations throughout the region. However, the knot forms under reference were not reformed from dressed timber.

The metamorphosis of these sculpted knots originates high above the coastal area, for the glaciers produce the water that cascades down the escarpments, dislodging trees from the rainsoaked forests, and flushing them out the estuaries. Subsequently, these giants are victimized by coastal currents, tides, and winds; they are battered, ground, and shaped by offshore rocks and finally deposited on the peaceful shore. Knots, being the most compact and resistant parts of the tree, are best able to endure this violent treatment, and they may be returned in a complete form (Fig. 3) or the core may be dismembered leaving an orifice framed with tough fiber that is highly suggestive of an "eye" or a "sphincter-like" shape (Fig. 4).

However dramatic and intriguing the processes and the processed involved in this gigantic power play, the resultant forms could conceivably assume more than a physical association. If there were a relationship between the oculiform motif and the reconditioned cedar knot and/or socket, it may be conjectured that the relationship was interpreted to symbolize biological phenomena such as growth, articulation, and recreative power. Indeed there are in the oculiform knots themselves powerful rhythms of line and texture that are amply suggestive of the strong design qualities evidenced in most specimens of Northwest native sculpture.

Considering the visual evidence, only a modicum of which is illustrated in this report, it is conceivable there was not only a bio-morphic relationship between shape, form, and symbol, but that one may also have existed between the oculiform motif and organic growth patterns found in the "reconditioned" cedar, fir, and spruce. We have here a device whose *raison d'etre* may be positioned between an environmental determinative and a cultural imperative. If this hypothesis is considered worthy of further development by others, let it be remembered that imagination has been a generating force in the lore and art of all primitive cultures.

Fig. 1

Ceremonial headdress, Haida, 1890.
Collection: Portland Art Museum.

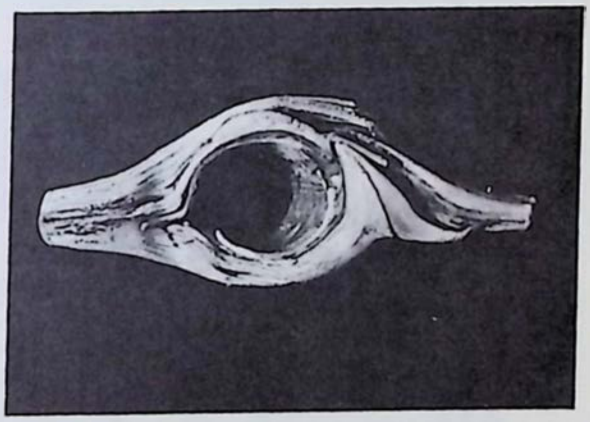


Fig. 2

Cedar knot frame that resembles
The oculiform motif.
Coast of British Columbia.

Fig. 3

Cedar knot and frame, profile.
Washington coast.

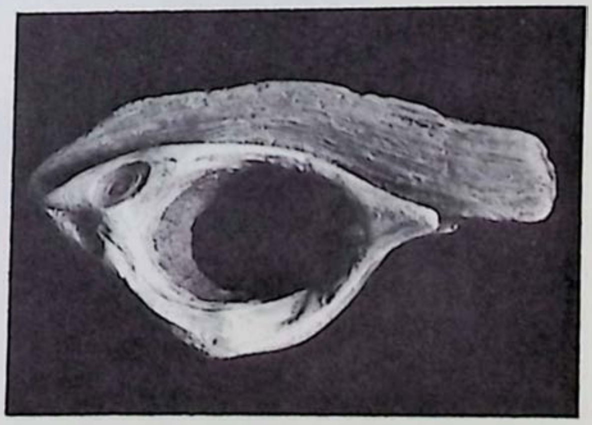
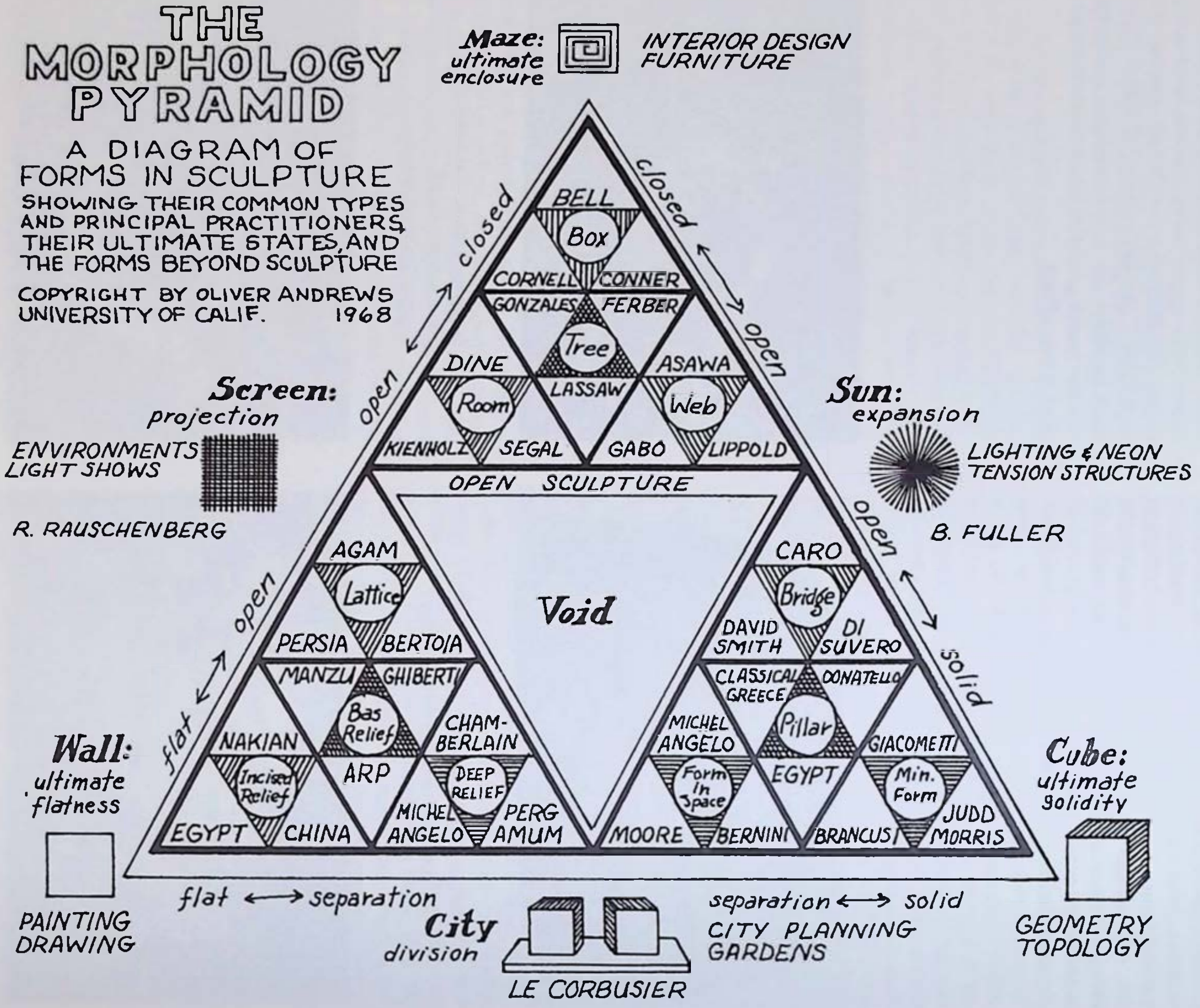


Fig. 4

Oculiform cedar knot frame.
Oregon coast.



THE MORPHOLOGY PYRAMID

A DIAGRAM OF FORMS IN SCULPTURE

SHOWING THEIR COMMON TYPES AND PRINCIPAL PRACTITIONERS, THEIR ULTIMATE STATES, AND THE FORMS BEYOND SCULPTURE

THE MORPHOLOGY PYRAMID

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The Morphology Pyramid is a diagram in the form of a large equilateral triangle made of three smaller triangles. The three triangles represent solid, relief, and open sculpture. As these three types of form develop towards their simpler denser states, they are represented as moving further and further from the center of the diagram until at last in the furthest corners they reach their simplest states. In the opposite direction, forms are visualized as expanding and amplifying until the forms in the three triangles encounter and merge with each other at the points where the triangles touch. In this merger new forms are created which differ radically from those inside the diagram.

Since this form diagram deals with the continuity of forms in time, I have named it the Morphology Pyramid. Once laid out and equipped with its symbols, the Morphology Pyramid can be used to catalogue all sculpture of whatever style or period. It also suggests where sculpture may be going in the future.

There have been many attempts throughout history to devise conceptual diagrams to frame the elusive principles of the visual world. The result of this activity during the early Renaissance was the sudden invention of perspective, which completely changed the course of western painting. Today perspective has fallen out of favor in painting, because science has ended the linear phase it began in the Renaissance, and has begun a new phase where it is interested in all-over or field relationships. It is appropriate, then, that we should at least be able to see all the forms of sculpture as related parts of a total pattern, rather than as individual examples of certain styles.

Western artists have always been interested in scientific diagrams as well as in the pictographs found in ancient works on Neo-Platonism, the Kabbala, Astrology, and other bodies of knowledge in which the nature of the universe is described in diagrammatic form. These ancient diagrams were produced by applying the patterns of early mathematics to the pictures which religious thought used to describe the universe. Today artists are comparing to these old patterns the new patterns which they find in analytic geometry, topology, mathematical model-making and electronic programming.

A recent and persuasive argument for the historical analysis of all man-made objects in terms of their own evolution, rather than as the results of the style wishes of individual artists and craftsmen, has been presented by George Kubler of Yale University in his book, *The Shape of Time: A History of Things*. Dr. Kubler's work is strongly grounded in mathematics and biology. A further application of the laws of structure to the dynamics of human society, as well as to artistic problems, has been carried out most persuasively by Buckminster Fuller, the famous inventor of the Geodesic dome. His philosophy, Transegrity, has to do with the far-reaching implications of the principles manifested by structures in tension.

Of all the fascinating and often complex visual systems, one of the simplest and most intriguing is the color wheel. It is invaluable in understanding basic color terms like "hue," "value," and "intensity." One need only consult the standard works on color theory, those of Hilaire Hiler or Joseph Albers, for instance, to realize that, like all simplified explanations of organic phenomena, the color wheel has certain limitations. Even the most complicated color wheel cannot explain the difference between colored pigment and colored light or tell us why certain colors affect us as they do. It is important to remember that any diagram, or computer program for that matter, can only describe those aspects of the world which are already in its own terms. That a diagram can be a good picture of anything at all is because the diagram is part of the same world it is describing.

Like the color wheel, The Morphology Pyramid has its limitations. The main one is that it can deal only indirectly with problems of interpretation and content. However, those who can read the language of form will realize that form is always talking about meaning.

The diagram does illuminate a particular aspect of sculpture which has to do with the relationship of form to materials. As we have seen, there are certain materials and processes admirably suited to the expression of certain varieties of forms. As one gets to know a material one begins to sense that each material has a certain "feeling" because of the kind of form it "wants" to become. This contest between the "desire" of the material and the will of the artist often has a role to play in the way a new style is born. Just as the establishing of a reliable supply of paper and the invention of movable type made possible new forms of literature in the seventeenth century, so the development of metal-rolling mills and the invention of the welding torch made possible the new forms of open sculpture which characterize the twentieth century. Both the technique and the will-to-form had to exist at the same time.

In a broad and general sense we can say that there have been two principal types of sculpture in the past, solid standing sculpture, and the relief. In the Morphology Pyramid these two types are represented by the two lesser pyramids forming the bottom of the main pyramid. A third type of sculpture, which has always been with us but which has developed mainly in the twentieth century, is the open sculpture which branches out into space like a tree or encloses space like the frame of a house. This open type of sculpture is represented by a third pyramid resting with its base supported by the apexes of the two bottom pyramids. Just as there are three primary colors, there are three primary types of form: solid, flat, and open. On this premise the whole world of sculpture can be represented by a large pyramid made of three smaller pyramids framing a fourth empty pyramid in the center. This empty pyramid forming the center of the diagram is particularly appropriate, I think, because it reminds us that form is an interaction between solid and void. The negative, or open, spaces in a sculpture, and the space around a sculpture which it animates by its presence, are as important as the forms in the sculpture which are solid.

Each of the three primary pyramids is subdivided into four triangles representing the four main variations possible within each primary type. The center triangle in each pyramid represents the typical or representative type for that pyramid. Thus the typical solid sculpture is the standing figure as represented in classical Greece and the Renaissance.

Some interesting things happen at the transition points where the three main pyramids touch each other. The sculptures which are represented by these areas are always energetic expanding forms in which there is a great deal of interplay between solid and void, and dark and light. As we go in the opposite direction just the opposite thing happens. The forms represented by the diagram contract towards a state of density and rigidity as they move towards isolation at the three outer corners of the diagram.

Let us take as an example of expansion the fusing of relief and solid sculpture at the center of the base of the Morphology Pyramid. As relief sculpture develops three-dimensionally, the forms tend to become more separate with deeper space between them, though the forms are still united by a common background plane. From the other side solid sculpture develops deeper hollows and larger openings as it goes in this direction and finally separates into multiple solid forms united by a base plane. This development is very clear in the sculpture of the seventeenth century or, in our own day, in the evolution of the work of Henry Moore. At a certain point, represented on our diagram by the touching inner points of the solid and relief pyramids, high relief sculpture and separated solid sculpture merge with each other. The ultimate form of this transformation is city planning and garden design where the base plane becomes the whole landscape. The appropriate materials for this kind of work are the materials of the landscape itself, earth and stone, and, above all, reinforced concrete. The energy released at these transition points by the transformation of one kind of sculpture into another often tends to demand an architectural scale. Thus the perfect example of the expansion of scale taking place at the solid-relief interchange point is the architecture of Le Corbusier. The volumes of his building are handled as sculpture in the chapel at Ronchamps, and finally the articulation of an entire city is achieved at Chandigarh.

The transition point between solid and open sculpture is approached when the beams and girders of expansive solid sculptors like David Smith and Anthony Caro, whom I call the Bridge Builders, become more complex and open-ended. From the other side the webs and branches of the open sculptors reach out further and wider. The result of the transition is the sculpture of ultimate expansion and radiance, symbolized by the sun and exemplified by the work of Richard Lippold. We can trace the development of Lippold's work from the early closet-sized *Moon* in the Museum of Modern Art to the room-sized *Sun* in the Metropolitan Museum to the recent giant commissions for the Pan American buildings in New York and the Art Center Theatre in Dallas. Undoubtedly sculpture of this kind will find an expression in the future on an even greater scale when sculptors become involved in the design of electronic networks and highways. Wires and ribbons of metal are the materials called for there, and in the future neon tubing and rows of lights will be increasingly used.

The third transition point is where the pierced relief or lattice merges with the open environmental sculpture. Here we again have a great release of energy as manifested in the audience-participation-environment-happening type of phenomenon where cinema, projections, stroboscopic light and other optical effects may be used. Only a few of the many artists practicing in this realm today are Robert Rauschenberg, Allan Kaprow, and Ed Kienholz. The symbol of this activity is the Screen. The materials are fiberglas, mular, neoprene, Plexiglas and the rest of the plastics.

At the three corners of the Morphological Pyramid, as we have stated, there appear symbols for the ultimate types of form which result when the three types of sculpture become simplified and reduced to their minimum expressions. The whole idea is summed up in Mies Van der Rohe's famous dictum: "Less is More."

In solid sculpture the end result of this process is the perfect geometric cube. Today sculptors like Robert Morris, Donald Judd and Ronald Bladen are working deep into this corner. The game is to see by what minute inflections of sculptural sensitivity one can bring into existence a sculpture rather than a mathematician's model. It is possible to make a few observations about this rather forbidding type of sculpture now that we can see it in the light of the diagram. One is that the Egyptians have been here before. Another is that Giacometti and Brancusi both came a long way in this direction but kept their simplification from going beyond the limits which would allow them to represent human or animal states of being. When minimal sculpture is successful it has a kind of Egyptian austerity and inevitability which go beyond its position as a fashionable mode.

In relief sculpture the final result of the surface becoming flatter and flatter is ultimately the blank wall, symbolizing an undifferentiated surface extending in every direction. Within the tip of the triangle at this corner we have all art forms which are as flat as they can possibly be while still existing as real objects. Here is the painter's blank canvas, flat but still possessing texture, edge thickness, and a definite shape. It is only very recently in the history of painting that painters began to look around the edge of the canvas and realize that they were painting on a thing, rather than making a window opening into an imaginary world. A little further inside this same triangle is the incised Egyptian relief, where the figures are not raised from the background, but separated from it by a modeled line. It is not surprising to find the Egyptians in this corner of the pyramid, as well as in the right hand or minimum solid corner, since it was they who discovered the way to monumentality through drastic simplification.

At the apex of the Morphological Pyramid we have a triangle containing forms which result from the closing in of the branches of the tree-like shapes characterizing open sculpture. As the branches come together they form the enclosures, corrals and jungle gyms of contemporary sculptors like Sol Lewitt and Forrest Myers. Further enclosure produces the box, a form which has interested a great many sculptors of our day. The master of the box undoubtedly is Joseph Cornell, artificer of compartmented, mirrored shrines for nostalgic fragments. Here too we find the twine-bound packets and wax-sealed packages of Bruce Conner.

Standing just above the upper point of this triangle is the symbol of the ideal state aspired to by these boxes and packages as they reach their final state of enclosure. This symbol is the Maze or Labyrinth. The three-dimensional form of the Maze is the Chinese Puzzle containing an infinite number of boxes within boxes. Appropriately enough this is the symbol of the old-fashioned city of yesterday which grew inward on itself and became constantly more congested at the center. The symbol of the new city is of course directly opposite the maze, standing just below the center of the base of the pyramid. At this point a directed ordering and balancing of solids and spaces produces the radiating city of tomorrow.

Now that the main outlines of the Morphological Pyramid have been sketched in, we can look at it for a moment as a whole, before proceeding with a description of some actual sculptures which typify the developments within each portion.

If the diagram is really an accurate picture of all the variations of which form is capable, how is it that this rather simple solution has never been presented before? Part of the answer lies in the fact that only with the astonishing outburst of sculptural forms during the last five years have all the spaces in the diagram finally been filled with actual sculptures. In fact, most of the corner triangles have been occupied only within the last twenty years, indicating the emphasis during this period on a systematic exploration by artists of all the more extreme form possibilities. As the completion of the pattern of possibilities became imminent, there has been a sudden frenzy of excitement and experimentation.

How do we know that the diagram has been filled, that this is the final picture? Won't someone invent something new next year which will change everything? I doubt it, because today we can already see that all the parts fit together to form a whole. Everyone has been aware for some time that there are solid sculptures, relief sculptures, and open sculptures, but the outlines have been dim. No one really knew how one kind of sculpture turned into another or was aware of the surprising things that happen when these transformations take place.

It is at these points of transformation that the future of sculpture lies. But there is something that needs to be said here. Even though the categories of sculptural form have all been described and occupied, this does not mean that there can be no further original and moving work in these areas. On the contrary, there is as much mystery in, say, the interaction between visual and plastic values in a relief by Giacomo Manzu as there was when a paleolithic hunter drew the shoulder of a bison around a muscle-like projection on the wall of his cave.

And yet it would seem that the great inventions yet to be made in sculpture will not result in objects which can be put on a pedestal in a museum and conveniently illuminated with an overhead spotlight. There are three limited directions in sculpture symbolized by the cube, the wall, and the maze. There are three directions in which sculpture transcends itself: in the creation of landscape forms (the city), in the projection of forms by light (the screen) and in the dissemination of forms by energy transformation (the sun). The work in these areas is already under way and will gather momentum as we understand that the forms we now call "cities," "movies," and "highways" are all, equally, art forms. Beginning by forming the material around him into objects, man will soon arrive at the shaping of the entire earth and the sky. And after that he will reshape himself.

THE MELT-OUT PROCESS

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In 1953, sculptor Julius Schmidt was involved in using linseed oil bound sand molds which were, at first, cured by heating them in a core oven. Wax was rammed up in these sand molds with no facing and the heat used to cure the mold also melted away the wax. The first successful piece was a twelve-inch bronze done in that year. Schmidt temporarily abandoned this process in favor of sand piece molds. In 1957, during a summer session at the Cleveland Institute of Art, he continued his melt-out experimentation. This time he used CO_2 sand molds. Between '57 and '58 he was at the Kansas City Art Institute where he used a commercial water-base face coat and CO_2-bound sand molds. He was casting up to five-hundred pounds of iron using melt-out molds. As the sodium silicate used in CO_2 molds will not break down as easily as the binder I'm using, they were able to melt-out at 500 degrees F. They melted out for twelve hours at a commercial foundry here in Kansas and then cast the pieces in iron. I studied with Schmidt at Cranbrook Academy of Art between 1965 and 1967. The wax melt-out process is Schmidt's . . . not mine.

In 1962, at Cranbrook, the students began using furfuryl alcohol molds. Since the government was using this chemical for military purposes, it was seldom available, and it was thus necessary to secure a more common binder. In 1966 two products became available which facilitated further experimentation. One of these products was Quick-Cure, a two part system comprised basically of linseed oil and a catalyst. Quick-Cure is manufactured by Baker Products Co., Core Oils Division, 10236 South Forest St., Chicago, Illinois. (It is also distributed by C. D. Gallagher and Company, 428 Stinsen Boulevard, Minneapolis, Minnesota, and by Wolverine Foundry Supply, 14325 Wyoming St., Detroit Michigan). The other product was a facing called "Ceramol" (trade name), a FOSECO Product.

In 1967 at Cranbrook, we started experimenting with Ceramol as a wax-pattern facing (Ceramol consists basically of particles of zircon suspended in alcohol). It's really great, much faster and more efficient than the previously used Terra-paint (a water-base FOSECO facing). We added graphite to allow permeability of gases through the facing and into the mold. Ceramol comes in five gallon cans of 100 pounds and cost nineteen cents per pound, not including delivery from FOSECO in Cleveland, Ohio. As manufactured, Ceramol is a semi-flowing paste. It's too thick to use in this form, so we cut it with industrial grade isoprophyl alcohol. Once cut, Ceramol may be applied with a brush or sprayed. This slide shows me spraying a section of a wax pattern with a spray can put out by Obermeyer (available from most foundry suppliers).

After the whole piece has been carefully sprayed, I begin the ramming procedure. (Slide) Here you see that I am pouring wax onto a sheet of plywood. The wax pattern is then set into the still liquid pool and allowed to cool. We thus attain some rigidity so that we don't have to hold the wax while we ram. (Slide) The first coat that was applied by spraying was pure Ceramol, which acts as a facing, preventing metal penetration of the sand, and picks up the surface detail.

Now the mulling is started. As you can see in this slide, we are using a common dough mixer like those found in bakeries, to which we have added a premeasured load of washed and dried 60-mesh silica sand. A trough is scooped out in the sand, and the binder, W-10, is poured into the trough (the trough simply prevents the oil from sticking to the interior of the muller). The W-10 is mulled until, upon inspection, no more lumps can be found. It takes about three minutes with a muller of this sort to make it smooth. The muller is now stopped and our premeasured dry additives are placed in the batch. The red iron oxide is added in the amount of one and one-half per cent to two per cent of the weight of the sand. The red iron oxide helps prevent metal penetration of the mold during pouring and gives the mold "hot-strength". The other addition is one and one-half per cent to two percent of Jordan Clay (or any air floated bond clay). The clay gives the batch a certain amount of plasticity which facilitates ramming on a relatively steep incline. The dry additives are mulled for about one minute and then the catalyst, No. 2, is added by burying it like we did the W-10. When the batch is a consistent color and a smooth texture, we know it is properly mulled. (Refer to binder/catalyst-sand ratio chart herein). We now have about a twenty minute bench life and will start ramming immediately. At one and one-half per cent (the proper percentage for melt-out molds), the mulled sand really doesn't set up for quite some time (about eight hours), so, if we rammed a flat sheet of this stuff and picked it up in an hour, it would probably warp. This condition is not true with all binder systems.

Now we're ready to ram. In this slide we are painting on the secondary sand-aggregated coat and ramming at the same time. By the addition of sand in the secondary coat, we insure maximum adhesion between the secondary coat and the molding sand as we thus create a "tooth" for the molding sand to stick to. This is important as you don't want the Ceramol to detach itself from the mold cavity after the wax is evacuated. The pressure required during ramming is similar to "finger-tucking" a green sand mold when casting styrofoam by the direct-pour method . . . in other words, pretty hard. If your molds are coming out too hard after following the binder/catalyst-sand ratio carefully, then you may be ramming too hard.

This slide shows us partially up the mold after several flasks have been filled with sand. You see that the brushing of the secondary coat is just a little above what we know is the extent of that batch of sand. One cubic foot of space is occupied by every 100 pounds of sand. We measured ahead of time and know that if we mull three 200 pound batches, we'll have enough for the whole mold. You'll note that the flasks are made of wood one by three's to facilitate accessibility to the pattern. This slide shows the top of the mold. You see that there is nothing visible except the cup and vents. Wax drains on the bottom of the pattern coupled with the permeability of the sand will allow sufficent heat penetration of the mold for wax evacuation. If the piece was smaller, we could have done it without any wax drains and just turned the mold upside-down in the kiln so the wax would drain out the cup and vents. I would probably have used more vents if this were the case, in order to allow more heat circulation (not necessarily to assist gas release after pouring, as the permeability of the sand promotes gas absorption by the mold. The wax drains were plugged with shaped core-sand "corks" which were core-pasted into place after the mold was taken from the kiln and before it was rammed with dirt, prior to casting.

(Slide) Here is the finished mold. At this point the mold is allowed to set-up overnight. The following morning, the wooden flasks are removed. The mold, if it is large, is then wired with "core-wire" (12 gage basic black annealed wire). Loops are made in the wire so it can be tightened for maximum strength. If you have a small mold that you're able to do in one batch, I don't think it's necessary to wire it. The problem of breakage comes when you allow one batch of sand to slightly set before ramming the next batch. It's just like investment; when you let one layer of investment set up, you get a flashing between the layers. You might pick the mold up by hand or with a crane, and it could come apart unless you have a complete mix for each mold which is often impossible on larger pieces. Wiring will help prevent this situation.

(Slide) This is the front of the casting. You'll notice that there is a small flashing caused by mold breakage; otherwise, it's pretty clean. The sand mold is rammed up in flasks with foundry sand; just in case you do have a crack the damp foundry sand will chill the metal flow and stop a potential run-out. After casting, the mold is removed from the flasks and taken to your shake-out area. The mold will break up into conchoidial fractures which are very sharp-edged pieces, usually pretty big. As the heat from the metal breaks down the binder and makes the mold weak, the only time you have to dig mold material out is when you've got this kind of linear finger-like form which I use or a deeply recessed core. In these cases, you may have to remove the mold with a rod or chisel because hammering on the mold pieces may bend or break the casting. It took maybe ten minutes to shake this out. That's only carbonization of the Ceramol on the surface which rubs off . . . no fire scale . . . it's beautiful!

(Slide) Here's another shot of the back. Notice that the piece was sprued for bottom-pour. Melt-outs work with direct (top-pouring) spruing systems too. (Slide) On this close-up you can see my fingerprints.

Here's a slide of a piece by Chuck Henry, a Cranbrook graduate student. This is a 500-pound iron melt-out casting of his which we poured there. In this slide you can see holes he cut in the wax original at the top to facilitate ramming the core. The core and outside mold were rammed simultaneously in order to avoid crushing or warping the wax. The pipe is the core-vent and goes all the way down the interior of the piece. Notice the core pins, used similarly to standard investment molding. It took an hour and a half to ram this piece. This next slide shows the same mold after its been rammed. He cut cost and time corners by making the flasks fit the contours of the piece allowing about two inches between the wax and the flasks. This piece was rammed on a kiln bed so it didn't have to be moved. The kiln bed has a solid floor to avoid any flames touching the mold (refer to drawing). The burner ports are already positioned. This is a linseed oil base mold and will break down at over 400 degrees F. so the kiln temperature is maintained at 300 degrees F.-350 degrees F. After the mold has set up, the flasks are removed, the mold wired, kiln burners installed, and the kiln built around the mold (refer to drawing). The kiln is very inexpensive and variable. If you don't want to build burners, ones similiar to these can be purchased from any gas products company. (Slide) This slide shows the iron casting that came out of that mold.

This slide shows a piece by Dave Flaharty, a former Cranbrook graduate student. The piece was done in a self-set sand piece mold. (Slide) This is the plasticine original with graphite brushed on it as a parting agent. (Slide) This is the rammed up original or positive. (Slide) There's the mold interior. (Slide) Now, into that mold you lay a one-fourth inch slab of plasticine or else staple three-sixteenths to one-fourth inch pieces of rubber (like that used under rugs) which after ramming the core, will determine the wall thickness of your casting. The sprues and vents are simply drilled through this core. The mold in this instance was rammed in fine sand, about 120-mesh (for more detail). The core can be rammed in a coarser mesh sand.

This next slide is another Flaharty; a face about four and one-half feet high to be cast in aluminum.

This illustrates the rebar reinforcement necessary to make a relatively thin sand mold of this size. The rebar will also facilitate handling of the mold sections. (Slide) Here's a shot of the mold after ramming with a bar going through loops made in the reinforcing rebar projecting through the top of the mold so that it could be transported to the foundry. He's using furfuryl alcohol sand molds which turn the mold a greenish-black as it cures.

(Slide) This slide illustrates another application of self-set sand molding. This is Julius Schmidt working on one of his molds. It's rather like a three-dimensional jig-saw puzzle. He numbers each section after determining his desired composition, takes them apart, lines them with rubber, puts them back together, stuffs his core in, takes all the sections off after the core has set, takes out the rubber, paints a face coat on all metal contact sections, and puts it back together again using core paste and core wire in assemblage. He then attaches the exterior sprues and vents to a predetermined system, rams up the mold in foundry sand, and pours (a gross simplification, but I think you get the idea). (Slide) Here is the mold almost ready to pour. You can see the numbering system he uses. (Slide) Here he's shown cutting off a little excess so he can get a flask over the mold. (Slide) Here's a detail showing the application of the rubber I was referring to for predetermination of wall thickness. This method is very fast.

In this slide, you'll notice he is using a bottom-pour sprue system with secondary gates to feed the upper sections of the casting as the metal fills the mold. The mold sections, sprues and vents are glued together with core paste, which you can make out of lacquer (as a binder) and flint (as a filler). Core paste is also commercially available, but is not as cheap and often will not set as fast as studio produced core paste.

This is a shot of the Cranbrook foundry on a day that we were pouring iron. You can see some very large piece molds. The one at the back took 2400 pounds of iron. The one in the front, 1000 pounds. (Slide) This slide is the core for the piece shown in the background of the previous slide. The wall thickness was determined with rubber and one-fourth inch plywood. (Slide) This is the same mold being rammed up. We wired it up as we were ramming the mold with foundry flasks filled with moist sand. You can see on the right that the cupola is going. You can see the fire from the observation ports.

(Slide) The next series of slides shows another operation with a smaller cupola. It has an eight and one-half inch inside diameter. This machine will melt 150 pounds of iron in 30 minutes. (Slide) Here we're ready to "tap out" (get the metal out of the furnace). The two guys shown are on either end of a ladle shank ready to catch the iron in the ladle for pouring. The tap hole is sealed with a refractory that has had sand added to it so it will break apart more easily than the inside refractory wall of the cupola. The gauge on the front of the cupola is an air pressure indicator. With a cupola of this size it is necessary to have four ounces of air pressure.

The bottom section of the cupola is called a well. The well stores the melted iron until there is enough to warrant tapping out. The middle section that has the vacuum-cleaner motors and air pressure gage on it is called the melt zone. It is in this area that the iron is melted. The top section is the chimney where consecutive layers of iron and coke was preheated prior to entering the melt zone. This cupola cost about twenty dollars to make. The air pressure produced by the vacuum cleaners heat the coke. Calcium carbide is added to the charges to increase the heat produced through the creation of acetylene gas. Limestone is used as a fluxing agent. In this slide I am "botting" or stopping the flow of iron. I am using a rod with a cone of clay rolled in seacoal which is squished into the tap hole. The seacoal prevents the clay from popping upon contact with the metal.

(Slide) A 600-pound aluminum casting done at Cranbrook.

(Slide) Iron. This is that 2400 pounder. Notice the smoke coming out of the top of the mold? That's gas escaping from the core vent.

(Slide) Here we are tapping out of the No. 0 Whiting. The capacity of the cupola is 1500 pounds every 40 minutes.

(Slide) Here we are tapping out of a tilt-furnace back in California.

(Slide) California again, pouring aluminum double-up.

(Slide) This is a melt-out that blew. It happened that all the wax was not evacuated from this mold and the hot metal contact with the residue caused this to blow.

(Slide) This is a piece mold being poured. They pour very cleanly.

(Slide) This is a transfer from a big ladle to a small one so two people can pour different molds at the same time, assuring hot iron for both molds.

(Slide) Dropping the bottom of the cupola. At the end of an iron pour, it is necessary to remove the partially unmelted iron, residue coke, etc., from the cupola. This is done by tripping a bottom door, allowing gravity to drop the unused material to the floor where it is cooled with the water.

(Slide) This is the core vent of that 2400-pound iron casting several hours after it was poured. It's still burning interior gases.

(Slide) Shake-out.

(Slide) Mold retrieval.

(Slide) This is the casting.

(Slide) Small castings, after shake out . . . pretty good detail. They were all done with a Ceramol facing.

(Slide) This is the 600-pound aluminum casting we saw poured a little while ago, being shaken out. You notice that the "bottom-pour" sprue system goes down both sides of the piece for thorough metal-feeding. This is one of Flaharty's pieces, "Spirit of the D. E. W. Line." You can see that the sand mold is just about two inches thick in some places and that rebar was used for mold support. In this case the core was established first and then plasticine laid over the core to determine the one-fourth inch wall thickness and allow him to model details. The outside mold material was then rammed up against that plasticine to pick up the surface detail and, after curing, create a mold. The mold was then simply taken apart, the plasticine removed, and the metal contact surfaces pre-coated with Ceramol. The mold was then put back together again, care being taken to assure proper registration of the parts, the sprues and vents pasted and wired in position, pouring cup attached, the mold then rammed up in foundry sand and filled with molten aluminum.

(Slide) This is the finished piece. It's eight feet tall.

(Slide) This is a piece I did while at Cranbrook. The top-most section was done in a piece mold. The left and right-hand sections were cast in nickel-silver and thus are white, the rest of the piece is brass painted a maroon color. The base was done in a piece mold. The sections were welded together. Height is five feet.

Most of the series of Schmidt's which I am about to show are the results of molds taken off of balls, globes and an inflated aircraft inner-tube.

(Slide) This one's only about five feet.

(Slide) Very small, fifteen inches.

(Slide) This is a big Schmidt (fourteen feet), two sections each taking 1600 pounds of silicone bronze. Piece mold, all piece mold! With this one, Schmidt used a weather balloon for his master pattern to do this piece.

Regarding the technical information for the melt-out. The cost factor is much lower, I think, than with an investment molding set-up. Say you're using an Alpine ceramic kiln for burn-out. If you fired it for two and a half days at 1,000 degrees F., it would cost $12. (approx.) in gas charges. A big melt-out mold, say 1,000 pounds, would be melted out overnight (about 14 hours) at 350 degrees F. The gas consumption is minimal. For each 100 pounds of sand rammed, you're spending about a dollar, so it comes out to be a relatively inexpensive molding procedure. The cost of a 500-pound mold goes like this: $1.18 for sand, $2.77 for W-10, which is the binder, $1.02 for the No. 2, which is the catalyst, 50 cents for red iron oxide, 30 cents for clay . . . comes to $5.77 for a 500-pound mold. Not bad!

The binder is supplied by Baker Products Company as previously mentioned. A 55-gallon drum containing 430 pounds of Baker Bond Oil, serial No. 1561-W10 is $159., but that'll coat tons and tons of sand. To catalyze the entire drum would require almost two five-gallon pails of No. 2 additive, and that would cost $61.88. These prices do not include cartage. Red iron oxide is cheap and readily available at foundry suppliers at about five dollars per 100 pounds. Say you are mulling up 100 pounds of sand . . . it would take 24 ounces of W-10 to pre-coat all the sand particles, and 4.8 ounces of No. 2 to catalyze the batch (at one and one half per cent . . . see binder-catalyst ratio sheet). It becomes gummy after twenty minutes, and you can't really use it. You have to have on hand some sprue forms, which consist of a couple of pieces of one inch by three inch pine with a one-inch pipe going down the center and through holes in each wooden end piece. These forms, once rammed, will create a hole in a piece of square sand. You use these for your outside sprues.

There are numerous other catalyzed sand systems. G. E. Smith and FOSECO, Inc., each make one. CO_2 and sodium silicate can be used. You don't have to worry about warpage with CO_2, as it sets as soon as it's gassed. In a flask set-up like we use in melt-out, you would mull the sand with sodium silicate and ram the pre-coated wax pattern. The CO_2 line would then be attached to a quick-disconnect which goes through a hole in a piece of plywood. This plywood is then placed on the topmost flask and the gas introduced. As the gas spreads across the mold surface, under the plywood board it permeates the sand as it sinks down through the mold (CO_2 being heavier than air), thus catalyzing the mold. It's very fast. The problem there, however, is that the wax seems to set up a barrier so the CO_2 won't go around overhanging shapes and back up again. Burn-in can occur under such shapes.

Q.: Can you use a lance in that case?

A.: Yes, but then, because you don't know where your piece is after you ram it, it would be hard to hit these areas without the assistance of an X-ray.

Q.: How about cores?

A.: We haven't developed, or at least we haven't used anything that will facilitate easy shake-out in melt-out molding. The most important thing with melt-out, cored pieces, is the shake-out while the piece is still hot, before the wax cools and makes the sand hard (50 per cent plus of the wax is absorbed by the mold while in the kiln). For a core in a piece mold, instead of adding red iron and Jordan clay, you ram up the silica sand with one per cent wood flour. The wood flour then burns after pouring, which breaks down the core, facilitating easy shake-out. You can put a vibrator on the cup sometimes and out comes the core. Very nice! A core of this type would break down during melt-out and become useless, so we have a fully consistent mold using red iron and clay in both the core and exterior mold.

Q.: What were the particulars on the facing you use? What is it called?

A.: Ceramol. The product's name is *Ceramol 55.* It's distributed by FOSECO, Inc., of Cleveland, Ohio. I would suggest you write for leaflet No. C-16-E. The address is FOSECO, Inc., P. O. Box 8728, Cleveland, Ohio, 44135.

A typical Ceramol mixture, both in the sand aggregated secondary coat and the face coat, goes like this: you have to have an ounce scale and a bunch of cans like fruit cans. Dump 32 ounces of Ceramol in large can, as it comes from the manufacturer (a semi-liquid paste) . . . these measurements are all approximate. To that you add about 12 ounces of isoprophyl alcohol. Thirty-two ounces of Ceramol and 12 ounces of alcohol, well mixed, is just about right for brushing. (When you receive a shipment of Ceramol from FOSECO . . . stir prior to using.) A couple more ounces of alcohol added to the mix and you can spray. I would suggest, to start, that you could use a spray fixative atomizer and air from a small compressor. Of course, if you don't have that, you can brush it. That will take care of your first, detail coat. For the secondary coat, add about five ounces of graphite to the original mix (standard foundry plumbago). Then add enough sand so you can still brush the mixture.

Q.: What sand are you using?

A.: We're using a clean, dry, washed silica, 60 Mesh, about two pounds to the above proportions.

Q.: How do you determine the temperature of your kilns?

A.: Well, we know that linseed oil starts breaking down at 400 degrees F., so we always hold the maximum on the kiln at 300 degree-350 degree F. A nice kiln to get hold of would be an electric core-oven from a used foundry supply, like AAA, in Cleveland. It's an electronically operated and controlled oven with a fan to circulate the heated air. Then you'd know for sure that the mold has been completely evacuated of wax.

Q.: Do you ever use chappletts to hold your cores in position?

A.: You can use little squares of metal cut to size and pasted in position or chappletts on really big piece molds. We usually use core pins with the melt-out process.

Q.: How thick are the molds?

A.: The sand mold should encapsulate the wax so that you have a minimum of one and one-half inches between the wax and air.

Q.: How hard do you ram the thing?

A.: You finger-tuck it. If you've ever rammed styrofoam in green sand, it's about that hard. You use all your fingers and push the sand in all those different little tiny directions.

Q.: In relative comparison, about how would you say it would compare in weight to the traditional investment?

A.: An investment weights less after you burn it out than a sand mold does after its kiln time because there is no moisture loss. You get a heavier mold with melt-out, but have much less kiln time. If you ram it right you have a monolithic block which you can handle by a chain hoist (with straps) with none of the worries you have with an investment.

Q.: What about the core paste?

A.: The homemade core paste formula is lacquer and silica-flour. Just add silica-flour until you can squeeze it out of a mustard squeezer. You can add a little red iron oxide, which makes it a very visable pink.

Q.: How do you determine your wall thickness?

A.: To predetermine wall thickness of a casting, you can do one of a number of things. One thing you can do is roll out quarter-inch thick plasticine slabs. Remember the face with the knobs? Remember when it was shown with the core area up? You just lay plasticine sheets (coated with parting compound) into that thing, and ram your core on top of the sheets. The thickness of the plasticine will be the thickness of the metal. When the core sets up, you take it out of the mold, remove the plasticine, pre-coat the surface which is going to be in metal contact. While the core is removed, you drill holes for sprues and vents; very simple, very direct type thing. You just go in one side and out the other, one sprue and one vent in that instance. Then you put the mold halves back together again, attach cups and pour. The type of rubber used under rugs can be used if its pretty smooth; it's about one-fourth inch thick and very nice. Take your piece mold apart, get a staple gun, cut the rubber to fit the shape of the sculpture, and staple it in. Then put the mold together, allowing yourself a hole in the top through which the core is rammed.

Q.: When you take the wood off, you have the mold there, and you pour. Don't you have any support there to prevent it from breaking apart? Or is the wire sufficient?

A.: Oh, the sand is very strong!

Q.: It won't break?

A.: No, it won't. It's a chemically bonded mass, very nice, very hard. Of course, as I have mentioned, the molds are rammed up inside of large flasks filled with foundry sand.

Q.: How hot is the burner?

A.: The melt-out, as differentiated from the burn-out, has a maximum temperature of 300 degrees F-350degrees F. (using Baker Bond Oil). With sodium silicate, you can go higher . . . to 500 degrees F., for a faster melt-out. A chemically self-setting sand binder that does not require gassing and uses sodium silicate goes by the trade name of Sil-Bond, and is manufactured in Cleveland, Ohio.

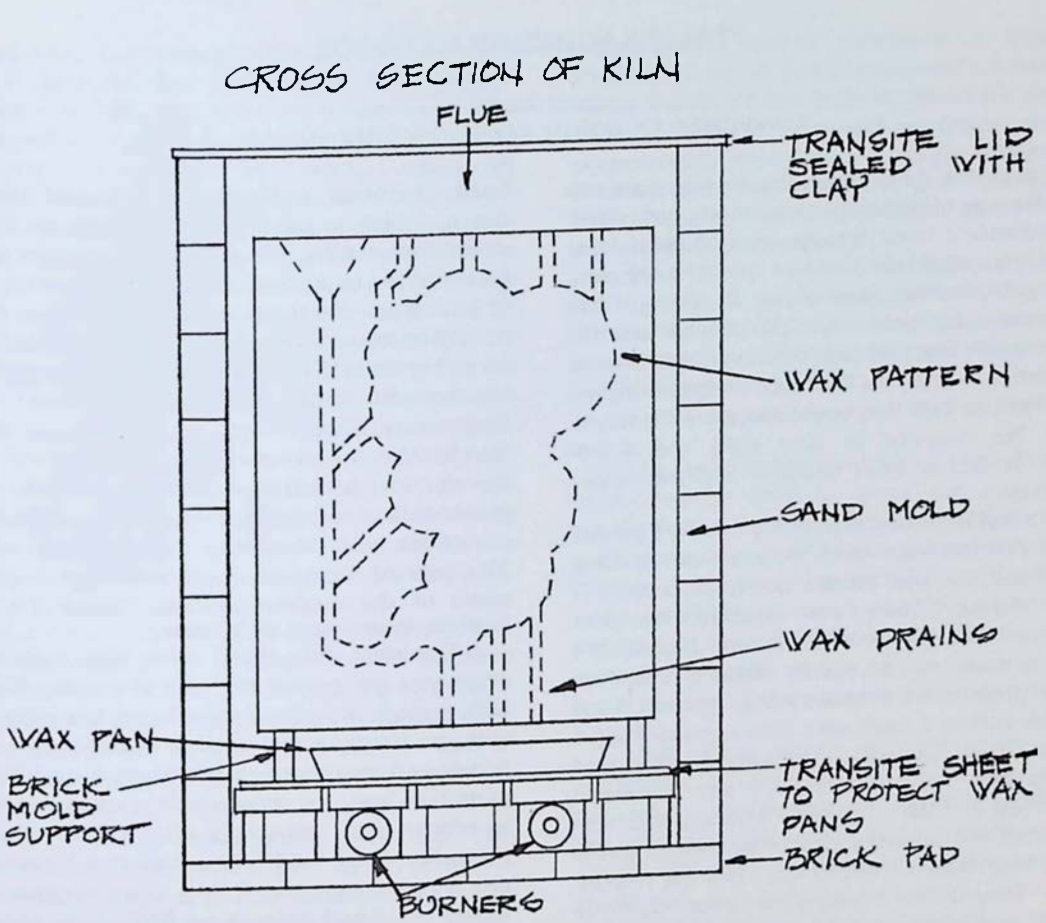
Q.: Do you pour when the mold is still hot?

A.: Yes.

Any more questions? Thank you very much.

Since I delivered the above information at the sculpture conference in Kansas, I have found that Baker Bond Oil W-6 or W-3 will yield increased bench life, which is quite useful for complicated pieces. I also found that a cement mixer with the blades removed and about a dozen three-inch ball bearings or square chunks of iron will mull up to a 150-pound batch beautifully.

I also find that a rich, creamy mixture of straight Ceramol and industrial alcohol, sprayed or brushed on the wax works as well, if not better, than a thin coat and a sand-aggregated secondary coat. I have not used a second coat for some months, and am having better luck. I also have been cutting down on the melt-out kiln time. I recently poured a 400-pound mold (sand weight) after a total of six hours in the kiln.


CROSS SECTION OF KILN
FLUE
TRANSITE LID SEALED WITH CLAY
WAX PATTERN
SAND MOLD
WAX DRAINS
WAX PAN
BRICK MOLD SUPPORT
TRANSITE SHEET TO PROTECT WAX PANS
BRICK PAD
BURNERS


TOP VIEW OF KILN BED
SPACE BETWEEN BRICKS TO ALLOW HEAT CIRCULATION
NO SPACE BETWEEN BRICKS TO AVOID FLAME CONTACT WITH WAX PANS AND MOLDS
1" PIPE
4" BELL REDUCER
1/16" HOLE
GAS
1/4" PIPE
AIR
CAP WITH 1/10" ORIFICE
SHEET METAL AIR REGULATORS
DETAIL

P.H. McMAHILL

ITALIAN FOUNDRY METHODS

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Most of the things I'm going to relate are not new in the way of technique or approach, but I think the experience I went through may be helpful for some of you, especially those of you who are planning on going to Italy some day to do casting. I had two purposes for going: one professional and the other personal. The first one, of course, was to do as much casting as possible. The second was to bring my family along so that they could also enjoy the stay in Europe. We remained in Italy eight and a half months. It was a most pleasant and memorable experience.

Since it was the first trip for my family, I wanted a central location from which we could visit as many of the historical and artistic points as possible. I selected Rome. There are excellent foundries throughout Italy—Florence, Milan, and Naples, so I know one could have an equally valuable experience in any of these cities. I arrived rather ignorant. I did not speak Italian. I speak very little now, so I had a language barrier. Secondly, I had some suggestions of foundries but nothing definite. I also discovered inflation had hit. Many of you, I am sure, have been there before and probably recall how cheap it was to live and how cheap it was to cast. This has changed radically. Italy is now a prosperous nation. So if you are going there solely for a bargain, I do not think you ought to plan on that aspect. I first went to the Bruni Foundry, which is probably one of the best known foundries in Rome. We arrived in January, which I thought would be perfect because there are only a few tourists and many of the sculptors who can only do their casting in the summer have not arrived. In spite of this, there was a tremendous back-log of work at the Bruni Foundry. Nicci has the same problem. There is a tremendous amount of encouragement and support by the church and by the government for commissions. These local foundries have all the business they want. If you do give them a piece, there is the problem of waiting maybe several months before they finally cast it.

I did work with Bruni for about a month. He is an excellent craftsman, certainly, a most pleasant person with whom to do business. However, his prices at that time were slowly increasing. In relation to my available finances, I soon realized that I couldn't work there long. By chance, I ran into Paul Suttman. Some of you probably know him. At that time, he was at the American Academy at Rome, and he mentioned a fellow who was outside of Rome, off the Via Flaminia. It was called Founderia Gino.

The other problem I would like to point out is that if you are going there on a short-term basis, for less than a year, finding suitable living space for a family becomes expensive. In the old section of Rome, which is the cheapest section to live in, a studio was renting for about sixty dollars a month plus. And if you know Italian living, there are all sorts of surcharges—the street cleaner, the grocery boy, and the postman, and everybody else comes by for some sort of gratuity. This is something that you must take into account. So the studio space became a problem. Fortunately, Gino allowed me to work in a corner of the foundry. I do not think there was another foundry in Rome that would allow this to occur. I moved in and set up shop for eight months. This was one of my most productive periods. I was able to do 22 pieces of sculpture, some relatively small, but in terms of the quality of work that I was able to execute, it was more satisfactory.

The other thing that I think you must deal with when you are there is the idea of pricing. Pricing, at best, is never a pleasant experience, but when dealing with the Italians it is beautiful! If you keep a sense of humor and you have tenacity, there is no telling what quotation you can finally come up with. It was a wonderful game, especially after you learn some of the rules of the road. The prices that I received—I'll give you an example: For a piece roughly twenty inches tall, Bruni charged me $120. Gino charged me $80—almost half. After I got to know him and worked there, everytime I gave him a piece, the piece would be larger, but his prices would be smaller.

There was a lot of good will shared since there was only a five-man operation at this foundry. As you know in a normal foundry the sculptor leaves his piece and returns when the wax is ready. He usually doesn't see the processes in between. But when you are there constantly, it not only allows you to have control over every step your piece goes through, but also you are there observing other sculptors' work and its treatment. In the eight and one half months that I was there, there was not one other American that came into the foundry. Probably the most famous sculptor who used this foundry was Amelio Greco. He taught at the Academy of Naples and would commute up to Rome to use Gino.

Prices quoted include making the mold, investing, chasing—the whole process. The prices have gone up a lot, but I still think you are better off casting in Italy in terms of quality. By the way, I was surprised how cheap shipping is. Ocean freight is inexpensive in terms of what we normally expect when we ship freight. As you may know, the international agreement of shipping agencies has various classifications. There are three classifications by which you can ship cargo. One is a regular scheduled line. One is an irregularly scheduled line, and another is a non-scheduled line. The non-scheduled line is cheapest, and it is roughly half the cost of the regularly scheduled line. The only thing to remember is that the ship will not conform to a time schedule. But if you are not in any rush for your work, I would urge you to ship the non-scheduled line. As an example, I shipped from Naples my 12 crates of sculpture. The price quotation I received was something like $670. Then I shipped by a non-scheduled line into Wilmington, North Carolina, which meant that I had $22 of truck freight from the port of Wilmington to Greensboro. The total shipment was $240 for 12 crates, so this gives you some idea that ocean freight is not expensive at all. You can get a standard insurance policy. The only thing that the non-scheduled lines will not do is guarantee a delivery date. They will guarantee good handling. One piece was broken and this was at the dock, so I really had no trouble collecting insurance. Customs people were very very good, and I had not a bit of trouble.

I might also mention that as you travel around the country, there are a number of smaller foundries that are not well known. They are set up to do very small decorative work, but they are very good craftsmen. I was surprised to run into a couple down in Palermo that did beautiful work. It is a marvelous city and probably the cheapest place in Italy.

One thing to remember is that everything shuts down in August. That is the month when all Italians and most Europeans take their holidays. So, if you are planning to go, try to get there in June or July so you can get some work done.

The foundry faces the Tiber river surrounded by farm land and small industry. Physically, it is an old stable, though I doubt if you could stable a horse there. There is no running water, no electricity, no power tools whatsoever. No compromise with the twentieth century.

Their investment material was basically the traditional type of one part plaster, one part luto, and one part brick dust. In terms of metal, I never saw an ingot in the entire eight and one-half months. It was all reclaimed metal from one source or another. Apparently a good part of the Italian Navy is still at the bottom of the Bay of Naples and there is a thriving second-hand metal business coming out of that body of water. Often an old ship's bell would be thrown into the pot. Every rule normally found in casting books was broken at this foundry. Everything seemed to be done intuitively. When questioning the workmen why they did that or how the proportion was determined, their answer was always just "Because." The man who operated the foundry, Gino, had started in foundry work as an apprentice at nine years of age. At that time he was about 52. The apprenticeship system is still very much in existence in Italy.

In his foundry, the investment material was mixed dry and then water added. This would be whipped to a creamy consistency in large plastic buckets. It was all done by shovelfuls. I never saw a measuring device or a scale except an old meat scale to weigh bronze. There was no precise method of proportioning except by eye. Maybe because of this intuitive experience they did good casting. Sometimes, I think, we are encumbered by all the standards and tests that we follow.

The burn-out kiln was fired by wood. This was a bee-hive kiln, a muffle type that is built up around the investments. Often investments were stacked one upon the other. Sometimes if it was a big piece, they would dig a trench outside and then build a kiln right at the spot where they would also pour the investment.

The melt furnace was nothing more than a large brick-lined pit fired by wood and coal. Burnout usually lasts three days. They use the standard test of putting a mirror over the vent to see if they have any moisture deposits. The formulation of metal was again something I cannot describe because it was judged only by an experienced eye. Brass and bronze were intermingled. Again we are told "don't stir metal because of air-entrapment," but they stirred it a great deal.

Most of us would not pour without safety equipment, but their precautions consisted of open-toed sandles, rags wrapped around their hands to hold the tongs when they lifted, and the shank when they poured. The most unusual person in the foundry was an old man. With a chasing tool, chisel, and a hammer in his hands, he had the most delicate control. He could not see the surface too well, but he could touch it. He could tell where there was a slight imperfection. With the plaster original as a guide, by feel he was able to match it up perfectly.

You can work in any manner you wish. I work directly in plaster, clay, and sometimes in wax. If you give them a plaster piece it is examined and cut in parts to facilitate easier casting. The piece is placed on a work table, divided in half by a wall of clay. Then the entire piece is covered about an inch to one and one-half inches thick depending on the size of the piece. The clay blanket will be removed later after a plaster cap is formed. Into this vacant space is poured melted gelatin.

After the clay blanket is placed, the edge is shaped and trimmed maintaining flat planes. A ridge or small step is formed around the pattern. This indentation when it becomes a gelatin will fit in around the pattern and will not fall out of the plaster jacket mold. Small mounds are made on the high points which allow for the pouring in of the gelatin. The little ones are for risers to prevent entrapped air.

After the plaster jacket is dry it is pulled from the pattern. The clay is removed and the inside of the plaster is sealed with diluted shellac and olive oil. The plaster jacket is carefully placed over the pattern again and gelatin is poured into the void left by the clay. This provides a negative, an accurate impression of the sculpture.

Gelatin is an inexpensive, reusable molding material that is hardly used in this country but still very popular in Europe. Its limitations are that it is susceptible to deterioration by age and heat.

The remaining half of the pattern is treated exactly in the same manner. The usual keys are cut on the plaster jacket to provide an accurate fit of the two halves. Then into the gelatin mold is painted a wax. The wax is formulated by the foundry and never commercially made. They use a three-portion mix. One is old church candles. The half-used candles are melted down with bee's wax. A small amount of paraffin or resin is mixed for stiffener. Also added is a pigmentation to obtain a lighter or darker colored wax. The wax is usually painted in at first, and then they build up at the high edges by hand, keeping quarter-inch thickness. Finally wax will be slush-cast into the entire cavity. I am quite impressed with gelatin. I know it is hardly ever used here, but it is a fine material. It is certainly the most inexpensive material that is available, and I have started to use it again. It will break down under heat. It does not have a life long enough for a large edition, but I think for one or two pieces it is most satisfactory. It gives you good detail. It is reusable and, as I say, extremely inexpensive. Dark colors are used on the surface area and backed up with the natural colored wax.

Some sculptors, who would like a perfect mold, can go to a professional mold-maker. There are a number of very good ones in Rome, and they will do a mold relatively cheap. This way you have the mold permanently in your possession. You can leave your mold with the foundry. Most of the foundries will keep your mold on file. If you come back to the States and want to do an edition, you can write and they will do it from your mold. But you have to make that arrangement before you leave. This is, of course, the only drawback in gelatin—it has a short shelf-life and tends to deteriorate. Instead of soaking the mold in water, as some do to part the wax from plaster, this is separated with an oil solution which is usually just olive oil. Olive oil allows the wax to pull away.

You can add almost any pigmentation you want to for the color that you like to work with in the wax. The tools are heated over a very simple alcohol lamp. They have only hand-fashioned tools. It is amazing what they make by forging their own tools. Almost all their chasing tools are hand-fabricated. Some pieces are over-sprued by apprentices. The final cast will be quite nice because the chasing was very successful. Time and labor were not critical. Plugged risers are used as a standard method. A number of risers are formed of wax and attached at the top of the pattern. Occasionally rolled newspaper dipped in wax are used for sprues and gates. A rolled paper in a cone shape and dipped in wax is used as a pouring cup. Otherwise, all the sprues are rolled out on a marble slab. Just a little bit of oil is used to cover the slab. It is done very fast. This gave you a rather irregular sprue, but it does not seem to affect the flow of the metal. I might mention that spruing is the only step that the so-called master-founder, in this case, Gino, would do himself. Most of all the other processes the other men could do. But he usually wanted to do all the spruing himself. I think we have all found from our own experience that spruing and gating are the most important steps in the whole casting business.

Question: Do the sprues go down?

Answer: The sprues lead down to the bottom of the pattern and then feed up. Common nails are inserted through the outside wax to the core.

A cylinder of stiff investment is built around the piece and then liquid investment is poured in. If it is a large complicated piece, they will splash it on, building layer upon layer. Before finally immersing the wax pattern in the liquid investment, it is raised up and down, agitated to get the bubbles out and driving them to the surface. To fortify the investment, wire is wrapped tightly around the cylinder and covered with a final layer or outer coat of investment. As I mentioned, large pieces are invested outside because they are burned out and poured in place. Sometimes on a large piece, a three-inch pipe is rammed down in the center of the core for strength and heat distribution. The investment wall is built up by hand around the piece. Sprues and runners are used for support to hold the investment up until it sets.

The burn-out kiln is made very simply—old bricks and stones with investment for mortar. Sheet metal forms the roof. They start the fire in the morning and keep it going all day and all night for three days. They constantly feed scrap wood to it and on the third day check for water vapor. All their wood was salvaged lumber. The roof, a sheet iron and a cross angle iron support is used again and again. There is no cement used between the bricks at all. The center channel of the kiln could be used to collect the wax, but they just use it for air flow. The channels on the right and left are the fire chambers.

The crucible is old. I doubt if any of you would use it. They probably get the longest life out of crucibles that you will ever see. They have cracks in them, they are thin, but they are still used.

Taken directly from the burn-out kiln, the investments are capped with bricks and placed on the earth surrounded with steel plate and rammed hard. It is nothing more than an earthen floor to begin with. A hole is dug and the investment is burned, rammed in tight.

They tried all sorts of things to flux out their metal but mostly they used broken glass bottles. They sometimes would put in a birch stick and stir it around a couple of times. Temperature was determined by sight. After the metal cools, the investment is removed from the earth. The old investment is broken away and reused. It is called luto. They screen that through very simple meshes until they go down to about 40-60 mesh.

Cleaning up and finishing the casting is done completely by hand. With the exception of the oxy-acetylene torch, there is not much that represents the twentieth century.

Gates and risers are usually removed by a cold chisel but for thick sections a hack-saw is used. Conventional tap and die are utilized to plug core pin holes with the sprues of the cast being saved, filed down, and threaded. This procedure allows for a good match between the metals.

Chasing seems to be the most skillful of any of the operations since a variety of surfaces can be duplicated so that it is next to impossible to identify any changes. Time is no problem with days being lavished on treating the surface of even a small sculpture.

Patinas and their formulation are as usual done rather freely. This casual attitude still produces the requested color or tonality. A novel finishing treatment is simply the rubbing of the piece with the palm, with the hand oil producing a soft luster.

The foundrymen of Italy are hard working and sympathetic to the artists' needs. It is their honest effort to satisfy you and do it in a manner that shows sincere interest and warm feeling.

PROBLEMS IN CERAMIC SHELL

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PATTERN PREPARATION/PROBLEM: Avoiding breaks in sprue gate system, giving support to pattern and preparing it for slurry coating.

Because sculpture forms are so diversified in shape, it is necessary to consider the best gating system for each individual form. Often, so much concentration is placed on the gating system to the pattern that the necessary support for handling the pattern during ceramic shell coating is neglected. Attaching gates and runners by melting the points of contact on the pattern sometimes leads to unfortunate results. Often, the pattern becomes so heavy due to shell lamination build-up that pouring cups and gates break off. It has been noted that a two-pound wax pattern covered with five coats of ceramic shell will weigh some six pounds—three times its original weight.

With traditional investment casting techniques a softer wax is usually used for gating. This allows a quick runout of gating wax during burnout so as to leave clearance for the main pattern to drain out. This is not necessarily advisable in ceramic shell cast pieces since softer wax does not give ample structural support to the pattern being prepared for casting. This lack of support becomes most evident when the pattern is in excess of 12 inches. Although a harder wax (melting . . . 165 degrees F. or above) does expand more readily than softer waxes. It is recommended for necessary support of the pattern due to the handling that takes place during ceramic shell coating.

Gating support may be added by inserting a short wooden match stick or bamboo pin in the gate before fusing the runner to the pattern (Fig. 1).

Since this supporting pin is usually in direct alignment with the pouring cup, it will drop directly out during the dewaxing procedure.

When large diameter runners are necessary in gating a pattern, (one-half inch or larger), it is possible to use hollow wax sprues which allow internal expansion of the wax during de-waxing. This helps to avoid shell cracking due to external expansion of the wax.

If breaks continue to occur at the gates, where the downsprue is connected to the main pattern, additional support may be made by reinforcing the connecting point with a strip of fiberglas. The strip of glass is first dipped into the shell slurry and carefully wrapped around the gate on top of the first or third shell lamination. Be certain that the lamination is thoroughly dry prior to applying this support to the gate. An undried coat of shell lamination will only crumble if it is aggravated by handling.

An armature within a wax pattern is often helpful in giving support to the piece during the handling of shell coat applications. Natural organic materials, which are readily combustible, serve well in supporting wax patterns. Materials such as bamboo, hemp rope, raffia, and balsawood, burn up quickly and easily leaving little or no ash residue within the shell mold. Hardwoods and similar materials create difficulties in being reduced to ash and require hours rather than minutes in the furnace to dispose of carbon fragments which may obstruct the flow of metal.

It is not advisable to use metallic type materials for armatures (e.g., brass rod, copper wire, etc.), since they can rarely be removed after the dewaxing operation. They are likely to hamper the pouring of metal by becoming an obstruction within the shell mold. The result would be a casting that exposes the metallic armature on its surface. This is because the armature has leaned against the inside facing of the shell mold due to lack of support from the wax which

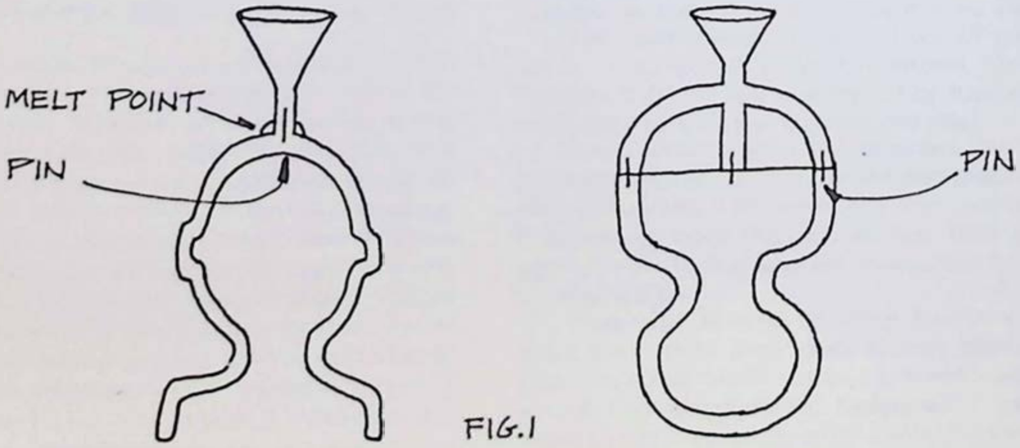


FIG.1

has now been drained out. While this is usually a detriment, it is possible to take advantage of this to create experimental pieces of sculpture.

Extended appendages on a pattern are vulnerable to breaking off during the laminating process. If possible, these appendages should be tied into the main body of the pattern to avoid breakage later on. If this is not possible, then secondary runners should be used to provide support for these appendages. With some forms, it is possible to use a supporting element other than a runner during the laminating process. This support could be removed if need be, prior to casting (Fig. 2).

Once the pattern has been properly gated and is ready for coating with ceramic shell slurry it should be cleaned with brush and denatured alcohol. This will remove body oils from handling and other surface impurities that tend to resist the initial slurry coating.

At this time the pattern should be weighed and converted into a figure representing the total weight of the metal necessary to fill the form. Normally, one pound of wax will convert to ten pounds of bronze. The final conversion figure may be inscribed on the inside of the pouring cup to provide a tally of metal needed at the time the patterns are being prepared for dewaxing and pouring. Also, a tally of each shell coating may be kept inside the pouring cup of each pattern. This prevents confusion over how many coats of shell have been applied when a number of pieces are being processed.

PREPARATION OF CERAMIC SHELL SLURRY/ PROBLEM: Mixing procedures: excessive bubbling and proper adhesion to wax pattern surface.

In preparing the ceramic shell slurry for application on the sculpture pattern the description of methods stated in manufacturer's manual on its product (e.g., Nalcoag Colloidal Silica, Syton 200-1C Colloidal Silica, and Ludox by Du Pont . . . Ludox H. S. Colloidal Silica) provides general guidelines to go by. However, these manuals direct attention to specific manufacturing requirements, and little information is available which has practical application to the individual sculptor's needs or facilities.

Slurry will settle into a hard form unless constantly stirred. Since it is unlikely that an individual sculptor or sculpture studio would possess the sophisticated mixing equipment needed to keep the slurry in suspension at all times: It is best not to make up more material than can be used in a 12-hour period. Thus, in the case of covering several patterns with several coats of slurry each, it may be necessary to make a new batch of slurry for each additional coating. Once the slurry has been mixed thoroughly, by hand or hand mixing machine, the wetting agent may be added. Control of the proper amount of wetting agent (e.g., "Ultrawet") is made by testing the slurry for good adhesion and lack of air bubbles in the following manner:

1. Add three to five drops of wetting agent to slurry batch (e.g., three and one-half to five pounds Nalcoag slurry) and stir in thoroughly.
2. Hand dip a small wax sampler into slurry container, withdraw, and watch it drain off.

If the slurry, after draining off, leaves a film over the entire face of the wax scrap, it is a proper mixture. As a further test the scrap of wax may be washed off with water and dipped into the slurry again. If the slurry remains on the wax surface as before in spite of having a water wet surface, it is in proper condition to use for coating. Should the slurry *not* adhere to any portion of the wax scrap sampler, another drop or two (not exceeding two) of wetting agent should be added to the slurry batch. The new mixture is then retested in the same manner. An effective wetting agent for the slurry batch is a biodegradable liquid (provided by Amway Products as L.O.C., or "Fulsol" produced by the Fuller Brush Company).

Excessive bubbling or foaming becomes evident in the slurry when too much wetting agent has been added to the mixture. It is best to avoid this by being conservative in adding the wetting agent. However, this condition may sometimes be corrected by mixing a new batch of slurry and adding it, without wetting agent, to the original. Another approach to this problem is simply to add a defoaming agent such as *octanol* (recommended by Monsanto Technical Bulletin 1-199 or Syton 200-1C, provided by Alexander Saunders and Company, Cold Spring, New York).

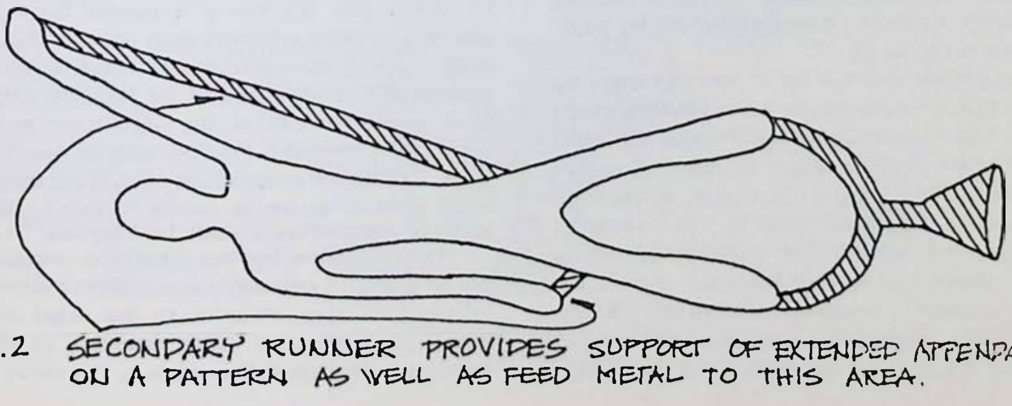


FIG. 2 SECONDARY RUNNER PROVIDES SUPPORT OF EXTENDED APPENDAGE ON A PATTERN AS WELL AS FEED METAL TO THIS AREA.

APPLICATION OF CERAMIC SHELL SLURRY/ PROBLEM: Practical methods as applicable to sculpture forms.

There is rarely any duplication in sculpture forms being prepared for a ceramic shell coating, and each form presents unique problems. Brushing of the slurry coats on the pattern sometimes has advantages over methods of dipping or pouring. Regardless of the method used to apply the slurry, it is important to realize that the application of the first coat is most critical in effecting a good definition of the pattern surface. It is not difficult to achieve a casting which vividly shows such details as fingerprints on its surface, provided the initial coat of slurry is properly applied.

When the initial coat is applied to the pattern, the piece should be inspected carefully to identify any small air cavities trapped under the coating of the slurry. These conditions are frequently found near undercuts or surface textures of the pattern, such as eye contours on small human figures. Sometimes air is trapped within these minute undercuts and is not visible. Therefore it is advisable to either blow air against the pattern in the area of undercuts or use a soft broom straw to poke into the undercut area and break the air pocket, thus allowing the slurry to fill in the depression. The neglect of these actions during the initial coating will result in a cast metal bubble which is difficult to remove later.

Although brushing the slurry can be tedious work, it has the advantage of thoroughly covering all contours of the pattern. With patterns which have hollow areas that must be coated, the brush technique can be used in combination with the pouring of slurry into the cavity. All of this can be handled with relative ease using small containers and making up another batch of slurry as needed. After the pattern has been coated with slurry, a stucco grain (usually fused silica) is applied while the slurry is still wet. When a coat of shell has dried thoroughly it is necessary to prime the dry coat with liquid colloidal silica before brushing on another coat of slurry. (Slurry itself is a combination of colloidal silica and fused silica powder). Priming prevents the slurry from caking on the surface of the shell and adds to its mechanical strength as it dries. The brush method usually gives a pattern substantial strength for pouring bronze in four coats.

The greatest disadvantage of applying slurry by brush is that it necessitates excessive handling of the pattern. This is particularly crucial during the initial coating where it is important to maintain surface resolution of the pattern. Experience in brush-on techniques is the biggest asset to this method of application. Frequently a form may be held entirely by the downsprue leading from the cup to the pattern, provided it is securely attached and the form is simple and small. Every portion of the pattern, excepting the cup and downsprue, may be coated. The downsprue and cup may be left uncovered for the first two or three coatings until the shell on the pattern is strong enough to be handled. Then the cup and downsprue can be coated with slurry. This same technique may be used in larger patterns, (twelve inches to fourteen inches) depending on the size and shape, by covering only a portion of the pattern while using another portion of the pattern as a handle. Care should be taken not to break the surface of the shell while it is thin. The brush-on technique is not advisable with elongated forms over twenty inches.

The dipping method of applying slurry requires a substantial amount of slurry in a relatively large container. This is practical only when there are several patterns to be coated or when there is a turn-table mixer available which can keep the slurry in suspension. (Note: Alexander Saunders provides a mixer and a timer for this purpose.) The dipping process greatly decreases the time spent on preparing a pattern with ceramic shell and virtually eliminates excessive handling. However, dipping also creates some problems in covering all necessary undercuts. Unless the pattern is inspected carefully during the process of dipping to assure that all areas are covered with slurry, undercuts and small internal areas can sometimes be bridged by the solution resulting in a loss of a part of the pattern in the final casting. In the case of forms having large internal cavities to coat, such as a portrait head, it is best to pour the slurry into the cavity and drain it out rather than to simply dip the pattern.

Slurry may also be applied by pouring. The pouring technique provides a compromise between brushing and dipping and has the advantages of both. A small amount of slurry may be made to cover a good sized piece (larger than fourteen inches to twenty four inches) when used in conjunction with a large catch pan. Depending on the configuration of the pattern, it may be either suspended over the catch pan with one hand or with a hanging device or placed directly in the pan while the slurry is poured over the piece from a smaller container. The pattern can then be repositioned in the catch pan several times and the slurry repoured over areas that were not covered previously. Each time the pattern is removed from the catch pan the slurry is poured back into the smaller container which is used again and again. The method allows considerable freedom in covering complicated forms that cannot be handled extensively. When small surfaces of the pattern are continually missed, a small brush may be used to touch up these spots. The usual precautions should be taken in the initial coat of slurry to locate minute undercuts or textured areas where air may be trapped.

When using either the dipping or pouring methods of coating a pattern, it is possible to eliminate the intermediate step of priming the dried shell with liquid colloidal silica as is necessary in the brush technique. To bypass the priming, the slurry must be thinned out slightly (consistency of cream compared to molasses consistency for the first coat). With the slurry in this condition, it will flow over the pattern quite readily and be quickly absorbed by the previous layer of dried shell, thus decreasing the drying time between coats. It is sometimes advisable, however, when bypassing the priming, to use one additional slurry coat on a pattern for total strength.

REINFORCING THE PATTERN BEFORE DEWAXING/PROBLEM: Buckling, splitting, and cracking during ceramic shell coating. Problem shapes.

Several different pattern configurations in sculpture forms seem to require additional reinforcing during the shell coating process in order to assure successful dewaxing and casting. Extremely elongated forms, in excess of twenty inches, tend to present numerous problems and often need reinforcing during the coating process. (When possible, pieces should be limited to thirty inches, including pour cup.) After the second coat of shell is applied, small sections of an elongated pattern may show signs of buckling. Since the ceramic shell is not flexible once it has dried on the pattern, it will buckle and split whenever the pattern moves out of alignment during handling. This is most apt to occur if a piece is held in a horizontal position even briefly. Buckling of the shell on the surface of the pattern can sometimes be corrected if caught early, before it begins to split, by priming the area with colloidal silica and gently wrapping a swath of fiberglas cloth, predipped in slurry around the fault. Once the fiberglas swath has been laid down, the buckled area may gently be pressed back against the surface of the pattern. It is important not to touch the entire form again until the repaired area has air-dried completely, allowing the fiberglas to bind itself to the shell. When cracking has occurred, due to buckling or other means (leaving a coated pattern in sunlight will expand the wax enough to crack the surface of the shell), it may be necessary to begin afresh on that area. Remove the fragments of shell and spot the area with a brush using slurry that is somewhat thickened. Cover the area with stucco, moving the pattern as little as possible. (A small fan may be directed to the area of repair, to speed drying.) After drying, the repaired area should be reinforced with a layer of slurry-dipped fiberglas. Most faults of this nature occur during the first three coats of slurry application. In this case, it is best to repair the fault with fiberglas, allowing the entire pattern to be coated with another layer of slurry, and then reinforced once again with fiberglas. Stainless steel wire, such as fishing line, serves as an excellent supplementary reinforcing device.

Buckling and cracking, as well as splitting of the ceramic shell, can sometimes be anticipated by studying the configuration of the pattern to be cast. Elongated forms which have appendages that are going to be vulnerable to faulting during coating application can often be bound together with fiberglas cloth in order to strengthen the overall pattern and prevent it from flexing as the weight build-up of the slurry coating continues (Fig. 3).

Depending upon the form to be prepared for casting, it may be easier to reinforce an elongated figure than it is to dissect it into two or more pieces, cast separately, and rejoin with a weld.

Individual pieces measuring thirty six inches in length have been successfully cast after precautionary reinforcing. There is some question, however, as to the efficiency in preparing this kind of a pattern in contrast to preparing two eighteen inch pieces that are later joined.

Other basic configurations in sculpture which tend to present problems are flat forms or reliefs that arise from one surface of a flat form and are usually rectangular or square in shape. The crucial problem in these forms occurs during the casting process rather than during the coating process. The density of molten bronze during the pour builds up such immense pressure against the walls of flat pieces that the edges of the shell mold frequently give way and split open. This condition is most apparent when flat forms are gated for pouring in vertical positions. It is necessary, in these cases, to greatly reinforce the edges of flat forms during the coating process by means of fiberglas overcoating and additional slurry build-up in order to prevent splitting and outpouring of metal during the casting.

The fiberglas reinforcing during the coating proc-

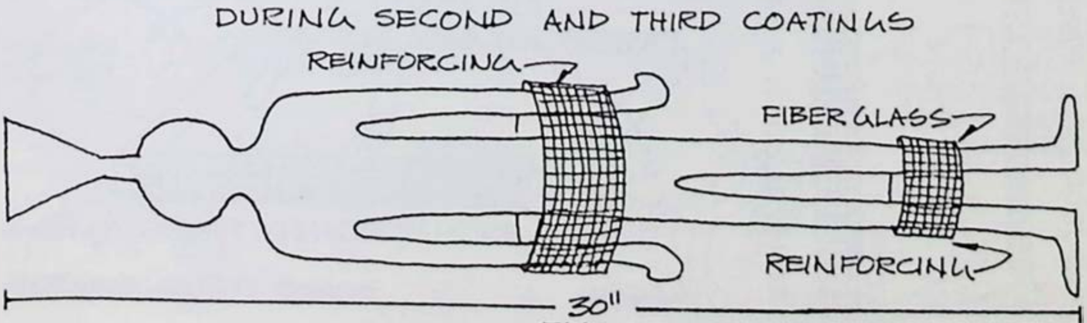


FIG. 3

ess may incorporate stainless steel wire around the entire form as well. It should be noted that incorporating the fiberglas in between coatings (between the second and fourth coats) adds to the total strength of the mold.

Another approach to remedying this problem has been to gate a flat form from one side only in a horizontal position. Although this presents some difficulties in handling during the slurry coating, it seems to alleviate the pressure against the edges of the shell (Fig. 4).

Runners and gates should be extended to outer edges in order to assure a fill of the corners of the form. Secondary runners may be placed directly downward under the pouring cup at locations immediately behind relief areas to assure metal feed at crucial sections of the relief. This type of flat pattern may be coated with shell using a two operation overlap method. One side is coated, stuccoed, and allowed to dry; then the other side is treated in the same manner. This provides easier handling of the form rather than trying to coat the entire piece in a single operation.

REINFORCING THE PATTERN AFTER DEWAXING/PROBLEM: Cracks and fractures due to wax expansion, broken pouring cups, appendages and internal areas.

Small fractures that occur on the shell usually appear as hairline cracks and may be easily repaired by brushing or rubbing fresh slurry over the surface of the break. The dewaxed dried shell absorbs the moisture from the slurry quickly and binds the material to the shell surface. The shell may be placed immediately into a preheat furnace with the repair areas still moist as there is no longer the problem of wax expansion. Because the shell slurry acts so rapidly in binding itself to the mother shell-mold, broken cups—which are sometimes knocked off due to mishandling—may be propped back into position at the point of the break and repaired with a tourniquet of fiberglas first dipped into slurry. Normally, it is not necessary to prime the shell mold with colloidal silica liquid prior to placing fiberglas cloth on the severed part. Precaution should be taken, however, not to move or joggle the shell mold after the repair has taken place until the repair has air dried and made a mechanical bond. The repair area may be further reinforced if needed. Any appendage which has been severed and has left a relatively clean break may be repaired in this manner, thus making the shell mold acceptable for casting. A small flashing of metal will normally show up on the casting beneath the repaired area, but this is not difficult to clean off after the shell is removed.

After a piece has been dewaxed it is good practice to shake the shell mold and listen carefully for the sound of loose particles. There should be none. If a few minute particles appear to be within the mold and if they can be removed by an easy shaking, it is probable that the casting will come out well enough. However, if many shell fragments appear to be within the mold it may be necessary to correct the problem differently. Constant falling out of shell particles during the shaking of a shell mold may indicate that an internal shell facing has broken open and the shaking process is continually breaking off more particles. With some molds, depending on the form of sculpture, the shell may be literally cut open with a hacksaw, exposing the internal rupture. The broken internal area may be repaired by means of any device earlier suggested and then the dissected portion of the shell mold replaced and reconnected to its location with fiberglas cloth and stainless wire. An additional device used to "plug-a-hole" where metal

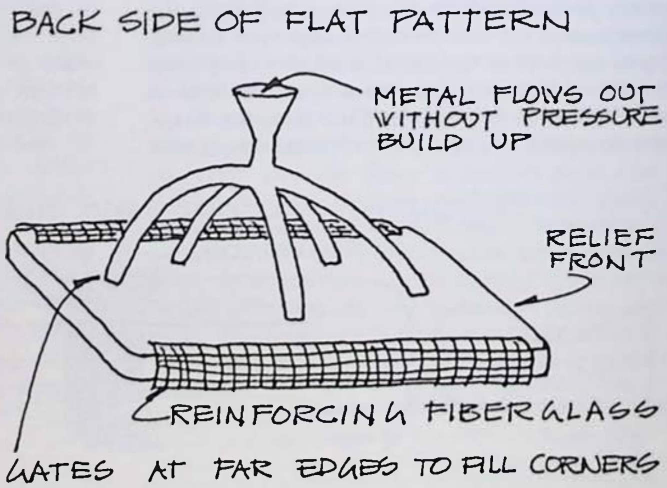


FIG.4

might flow through is to use Kaowool for repair. (Kaowool is Babcock and Wilcox ceramic fiber made of alumina-silica and withstanding extreme temperatures (Fig. 5).

When the shell coating has not reached an interior surface, as shown in the above diagram on the left, the shell mold may be dissected into two pieces and the inner face of the upper portion recoated with wax (using a brush to build up a thickness). The wax is then recoated with slurry and stucco before rejoining the two sections of the mold externally with fiberglas cloth and stainless wire. The piece must be dewaxed once more before being ready for casting.

SHELL REPAIR METHODS AFTER CASTING/ PROBLEM: Identifying incomplete mold castings and redeeming damaged sections of a casting.

Because the shell surface tends to pop off of the casting almost as soon as the metal solidifies in the mold, there usually is little question as to whether the mold filled correctly or not. The only exception to this rule concerns very small or narrow sections of a mold where the shell sometimes does not spall off. Caution should be taken when large sections of a shell mold do not spall off to reveal the metal as there is the possibility that the cavity may not be filled. To be too ambitious in manually removing the shell coating with a hammer or chisels may destroy an opportunity for correcting the problem. On occasion, entire sections that did not fill with metal can be broken off cleanly at the point where the metal froze and cast individually by simply placing a downsprue and a cup at the open end. After the casting, the cup, and the downsprue may be cut off and the end of the piece contoured to fit the incompleted section of the sculpture. The two sections are then joined by welding.

Mishaps in castings sometimes create more complicated problems of repair. Such is the case when a mold section, which has not filled is unknowingly broken off of the mother shell mold into several pieces . . . some small, some large. In cases of this nature it is important to identify those particular fragments from that section and not allow other shell fragments to be included in the scraps. It is quite possible to glue shell fragments from an incompleted mold section together with small amounts of fresh slurry, let dry, reinforce with fiberglas cloth and recast by means of placing a cup and downsprue on the section. In some cases, it is necessary to build a wax surface back on the fragment and then proceed with dewaxing and recasting. Flashings will appear on the surface of the redeemed piece, but this is of no consequence compared to the entire loss of an important section of sculpture.

Extremely small detailed portions of a shell mold occasionally do not fill with metal. This can be due to many factors, ranging from the shell becoming too cold before the casting took place, to improper gating. When crucial details have not cast, another approach may be used toward redeeming these sections. The incompleted section may be "steam-cast" individually to assure that all details come through. This is accomplished by a simple means of placing the section, well propped, onto a welding table, preheating the shell with a torch until it is glowing white hot (2,000 degrees F.), and hand melting a sprue-rod from the casting into the cavity. After the cavity is filled with molten metal and the shell remains glowing, a large wad of wet rags is thrust down upon the heated molten section and pressed firmly in place for a few seconds. The reaction of the molten metal in contact with wet material creates steam which drives the metal instantly into the cavities, thus filling in all detail. Since such small sections do not afford enough area for gravity feed, some means of enticing the metal to fill the cavities must be used. The same perfection of result may be accomplished by means of centrifugal casting of the incompleted section. It is sometimes more efficient to dissect detailed areas of a sculpture prior to shell coating, casting them separately, either with a centrifugal casting device or steam cast method, and weld back into place after the sculpture proper has been cast.

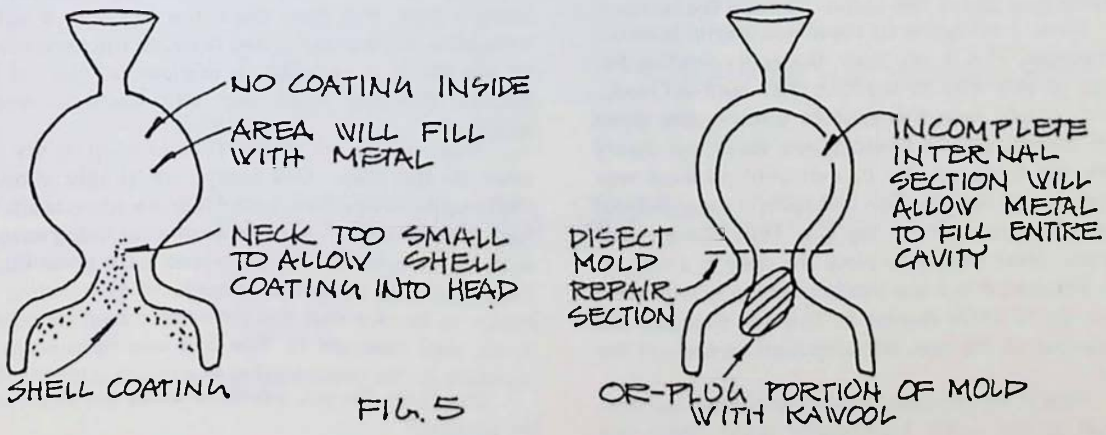


FIG. 5

PROBLEMS IN CERAMIC SHELL

THOMAS WALSH
SOUTHERN ILLINOIS UNIVERSITY

I think that most of the slides you'll see illustrate a situation where I am dealing with a great many patterns. In this slide we have a Lightnin' Mixer plugged into a timer which is set to mix the investment slurry for two minutes every quarter of an hour. We mix 25 to 30 gallons of slurry at a time. I'd like to emphasize the importance of a proper slurry consistency for the facing coats. Whether you mix the dry ingredients with the binder by weight or by volume, the resulting consistency is critical for exact surface reproduction. It is also important to mix the ingredients thoroughly to insure a homogeneous consistency. With a 30-gallon batch of slurry we mix for six or seven hours before applying the initial facing coats to the patterns. If the ratio of dry ingredients to binder is inaccurate or the facing slurry isn't thoroughly mixed, you'll get castings with a great deal of 'plus metal' at best. I might add one more point. Regardless of where you get your materials, from Nalco, Du Pont or wherever, read their literature carefully. Most of the casting flaws I've seen and experienced were simply a result of not reading the manufacturer's instructions.

This is an example of one of our drying tables at Southern Illinois. You can see how some of the pieces are sprued. At this point the patterns have two to three coats of investment on them.

I use styrofoam cups when spruing. After the shell has been built up to a thickness that I feel is sufficient, I use a body grinder to grind down the top (where the shell has overlapped the top of the cup pattern) in order to expose the styrofoam. It is well to wear a respirator. We were grinding the cups on 50 to 60 patterns and silica permeated everything.

The next step is to burn out the styrofoam cup as we're doing here with an oxyacetylene torch. During the process of dipping the patterns, a lot of slurry builds up on the inside of the cup; it is necessary to pop it free before we begin the burnout.

Now, I am going to show you several burn-out techniques. This is, probably, the most primitive. For those of you who do not have shell burn-out equipment, simply turn the invested piece upside down (cup down), use an oxyacetylene torch and slowly work the torch up the pattern until no more wax comes out of the cup. This method will remove about ninety-five per cent of the wax from the invested pattern. Next step is to place the shell in a kiln. In this instance, it is a top loading electric kiln which is taken up to 1600 degrees F. This will eliminate the remainder of the wax and also burn carbon off the shell.

Here is a more sophisticated technique, and one, which at this point, I personally prefer. With this method we place the shell, cup down, on a 'rack' (see illustration) which is elevated eight inches to twelve inches from the floor. Under the rack is a large pan filled with water. Two portable immersion burners are aimed at the piece, one at the cup and one a little higher up. The burners are slowly elevated until the piece is de-waxed. For a twelve-inch shell the process takes about four minutes. We still must place the shells in a conventional kiln to finish the job. Since it is preferable to pour while the shells are hot, it is necessary to somehow remove them from the kiln without burning yourself. You can use tongs or fire suits or whatever else you can devise. At Southern we have one crew pulling the crucible and skimming the metal while another crew removes the shells from the kiln and sets them up for the pour. We have got it down pat; about one to two minutes elapse from the time the shells are removed from the kiln until they receive the metal. We have also designed a kiln at Southern which is a type of shuttle kiln. This will eliminate the necessity of entering the kiln bodily and will also facilitate the handling of large fifty-inch to sixty-inch shells. Presently, at the Kalamazoo Art Center Foundry, in order to handle large shells they use a very large cylindrical kiln which moves vertically on two pieces of channel iron and has a permanent, elevated pad with holes in the bottom. A large pan of water is placed under the pad to catch the burning wax.

Personally, the shuttle kiln is the only method which makes sense to me. With it I can handle a great many small shells or several large ones. It is safe and convenient and provides the easiest means of transferring red hot shells from the kiln to the pouring area.

This slide indicates the reduction atmosphere in a traditional burn-out process. To circumvent this problem and to minimize the possibility of molds cracking due to wax expansion, we use the immersion burners first, and then place the shells in a kiln. A reduction atmosphere is bad because the permeability of the shells is reduced; a gradual burnout is fatal because the wax expansion will result in cracked shells.

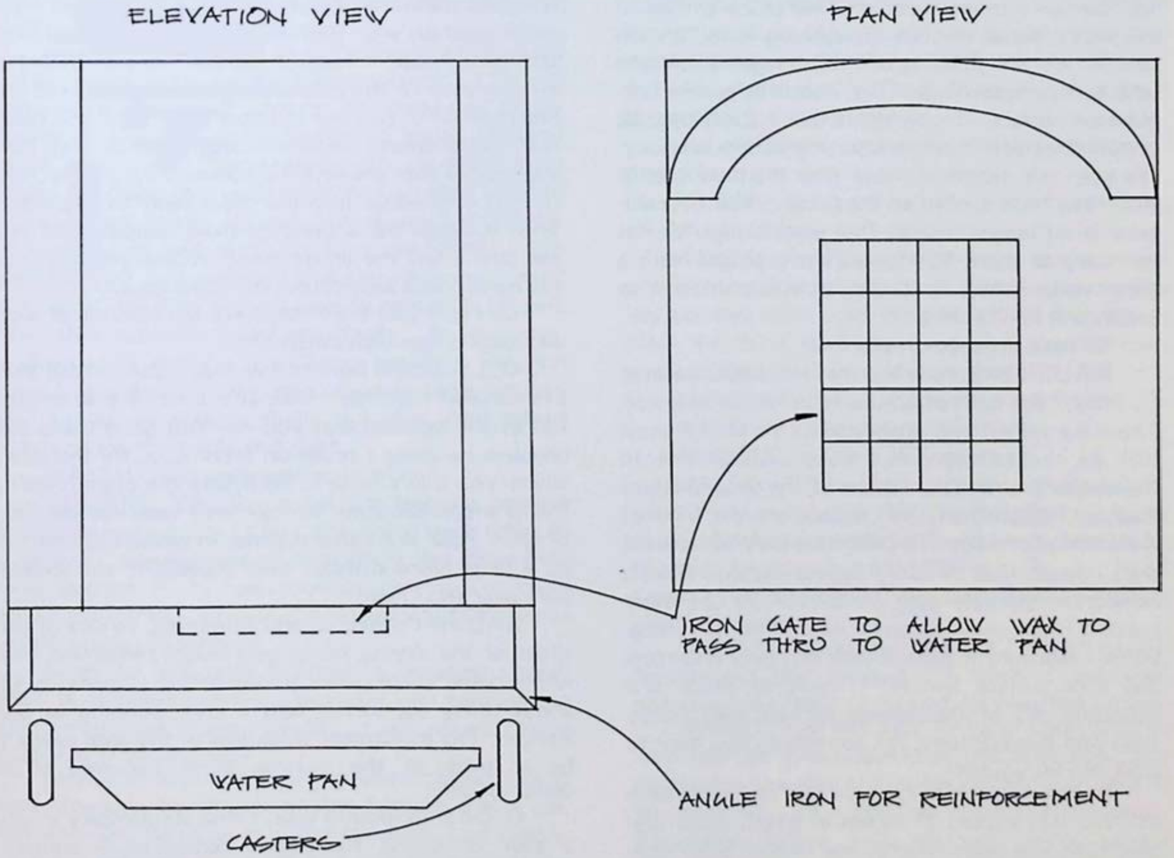
These shells are about to be set up in dry sand prior to the pour. Ordinarily, we simply prop the shells up on a dry sand bed. Here are some shells that have been rammed in moist sand after being wrapped with aluminium foil. These pieces were done for Bill King, and the people in charge of the casting had reason to believe that the shell had a hairline crack in it, so they rammed it. The foil was to prevent the moisture in the sand coming in contact with the shell.

Question: Do you brush or spray the slurry onto the patterns?

Walsh: Both. I also dip patterns if I can. You can apply slurry to the patterns with a spray gun if you're casting in aluminum. A proper slurry consistency cannot be handled by most guns. By thinning the slurry down you run the risk of making weak shells and if you are casting with bronze you will reap a multitude of problems, the biggest one being castings with scabby surfaces. I have heard that Binks has developed a spray gun that will handle ceramic shell slurry. If this is true, you could spray patterns that were intended for bronze, iron or stainless steel.

We have purposely cut this slide segment to a minimum so that we can field questions that you have concerning ceramic shell. So may we please have the lights?

BURN-OUT RACK



ALL DIMENSIONS ARE OPTIONAL — CAN BE REINFORCED OUT OF CASTABLE OR INSULATED BRICK AND REINFORCED WITH ANGLE IRON

PROBLEMS IN CERAMIC SHELL

QUESTION SESSION

FRANK COLSON, FLORIDA
THOMAS WALSH, ILLINOIS

Q: You mentioned a Zahn cup? What is it and how do you use it?

WALSH: A Zahn cup is an expensive device used for measuring the viscosity of the slurry. Industry uses them all the time. It is the best means of insuring the proper slurry consistency for your facing coats. Using a No. 5 Zahn cup, the procedure is to fill the 46 ml. cup with slurry. It takes a certain number of seconds (you can get the data from your manufacturer's literature; it varies depending on the products) for the slurry to drain out the hole in the bottom. If the slurry passes through the opening faster, it's too thin; if it's too thick, it will take longer. You make adjustments accordingly. The idea is to get the consistency perfect. If you don't use a Zahn cup, be certain that you measure your ingredients carefully. It's been my experience that after the third coat of slurry has been applied to the pattern, slurry consistency is no longer critical. One more thing: It's not necessary to spend $30 for a Zahn cup. Sears sells a paint viscosimeter. It shouldn't be too difficult to calibrate it for the shell.

Q: What products do you use?

WALSH: Well, I use Nalco's products, sometimes Du Pont's. For most of us, cost is an inhibiting factor. There are refractories applicable to the shell process that are much cheaper than Nalco's Nalcast line. In the choice of a refractory material, the considerations involved, other than cost, depend on the kind of sculpture you make. My pieces are very convoluted with a great deal of heavy surface texture. Nalco's Nalcast is relatively easy to de-vest. On the other hand, if I were using zircon I'd have a time de-vesting. When I confront a pattern with no heavy undercuts and little surface texture, I resort to zircon and malochite. All of the refractories have their advantages and disadvantages; it's something you have to work out for yourself.

Q: In a complex wax, I have a lot of trouble with patterns that exceed 21 inches in length while dipping. Have you beaten that by any method other than spraying such as air floatation or something? As the wax gets to be 21 inches long, it gets too heavy for the early applications of shell and breaks as you're handling it. It chips off. Do you have any problems with this?

WALSH: You can use internal armatures, highly combustible plastic rods, etc. Depending on the problem, you can go to a more rigid or more flexible wax. After looking at Frank's slides, I think he probably has some additional information.

COLSON: If I may bring in another point of view, I think what you're speaking of is in the shell coating which starts buckling on you.

AUDIENCE: It's a very heavy wax, something like a foot wide.

COLSON: Yes, a 36-inch wax does present problems. A two-pound wax normally with five coats of shell will end up about six pounds plus. The buckling effect is due to the springing action of wax even if you have an armature in it. This piece had a wooden armature inside it. You have to reinforce it. You can reinforce these long pieces or big pieces so that they don't bend on you. Rather than go into a lot of time and detail now, I have prepared a paper that I'm turning over to the conference and it will be in the *Proceedings.* If you use stainless steel wire and fiberglas reinforcement between coats and if you have appendages that are hanging out on a long piece, you tie that appendage into the main body of the piece. Then it keeps the appendage from bending and you can strengthen the entire piece before you get into the tremendous weight past the third coat.

Q: Have you tried handling ten pounds of wax on a twenty-one inch pattern?

COLSON: I'll have to say that I don't recall that I've handled that much wax at a time in that length. I'm of the opinion that you can still get around the problem by using a brush-on technique, for instance, where you don't have to be lifting the piece. Again, this is a consideration to take into view—brush, dip, or pour. Pour is another manner in which you can set up a large piece without ever moving it and simply pour over and under.

WALSH: I'd like to add one thing. In one of the slides of the drying table, you might remember one rather large piece with a horizontal dimension of about thirty six inches and a core opening at the bottom. The investment thickness of the core needn't be as thick as the outside since the core is in compression.

Q: On a ten-pound wax, I find it necessary to use a plus or minus five-degree temperature control. Apparently, the small things don't require it. Were you using temperature control as you were building up the shell?

COLSON: In regard to temperature control, again, this is a thing where you just have to kind of wing it; you have to go by the feel. In Florida, we have a lot less control because of the humidity factor. Dehumidifiers and things of this kind are important to adapt for this purpose.

AUDIENCE: I've been using a lot of flat planes and right angles, and they crack along the edge.

COLSON: Well, flat planes and right angles are things you'll have the most problems with. Because when you have a sharp corner to turn, you can really get cracking or buckling or splitting often before de-waxing. Again, I recommend laying in a fiberglas layer after the fourth coat. After it's de-waxed, go back and inspect it. If necessary put another layer of fiberglas over the edges. Then it shouldn't split during casting. It is at these edges that hydraulic pressure builds up during casting and splits develop.

WALSH: It may be that you can sprue your piece at an angle. Instead of pouring the pattern vertically, pour at an angle. This circumvents many of the problems you run into with patterns that have a lot of right angles.

Q: Did I understand you to say that you heat your molds before you pour? That is to say, some pour in as much as 1600 degrees F., and the molds are heated to that temperature.

COLSON: In regard to preheating the shell mold before pouring, let me recall an experience. I had, in some ways, the good fortune of having one of the chemical engineers who developed Nalco products retire in my area. He worked with me supplying a whole chemical approach from the first time I started working with shells. He didn't have much knowledge of metallurgy, and as he built my confidence in the shell product, one question that came across my mind was "Are you sure I don't have to preheat?" He said, "No, they take the metal beautifully." As you know, preheating is really a metallurgy problem. The first time I cast shells, I was doing them in large groups—ten, twelve, or sixteen shells at a pour. And, boy! I was blowing them left and right.

WALSH: You were getting misruns?

COLSON: Yes, the metal was freezing, because the shells were cold. In fact, the Nalco book refers to a drop in temperature of something like three hundred degrees F. in two seconds after you've taken them out of the furnace. So preheating has become pretty much operational.

Now, let me pose a problem. Heating a small shell is relatively simple. How do you heat one in which you want to pour 70, 80, or 100 pounds? What sort of kiln do you use?

Now, this to me, is a very simple problem, as you may conclude by the de-waxing furnace that I use. This can also be done in other manners. Last conference I mentioned Kaowool as a lining for a furnace. I'm speaking theoretically here, but I'm almost certain that it will work. You can do your de-waxing all in place without ever moving your mold by slipping a 50-gallon drum or two 50-gallon drums insulated with Kaowool over a very high mold and setting up your burner system on the ground on a suspended refractory bed. Bring it up to heat; pull your drum or drums up. The two drums won't weigh any more than the actual sheet metal of the containers plus this one-half inch blanket material which is negligible in weight. You draw it up on a pulley and move it out of the way, pour your metal and never touch the mold. You can have it as hot as you want.

Q: Now, for 100 pounds, how thick do you build the wall? I've found that the metalostatic pressure is just too great for some thicknesses.

COLSON: I think that this is entirely relative to the shape of the pattern.

AUDIENCE: I am thinking of plates.

COLSON: Plates are the biggest problem. Tom and I have talked about this and we agree. Anytime that you are pouring a flat form—let's say a one-sided relief-type form—in a vertical position, hydraulic pressure is built up to such a point that the mold will split. I have had occasional successes in reinforcing this type of form, but I still have problems. And I think, again Tom and I both are in agreement. There is only one solution for this. You have to pour them flat gating from behind with an almost spider-like runner system so that the metal flows out sideways and over the plate. You have to be sure that your runners run out to the corners.

Q: I still have trouble with breaking when pouring horizontally.

COLSON: We have had no problem when we reinforce the edges.

WALSH: As Frank mentioned, you can use fiberglas mat to reinforce your piece. You can also use stainless steel wire. Wrap it around the pattern after the third or fourth coat of slurry has been applied. What metal are you casting with?

AUDIENCE: I'm pouring manganese bronze.

WALSH: At what temperature?

AUDIENCE: About 2150 degrees F.

WALSH: Well . . . that's hot. One of the beautiful things about shell is that you can eliminate many of the shrinkage and gas problems encountered with the solid investment method by pouring your metal "cold." This presumes, of course, that you're pouring into red-hot shells.

AUDIENCE: I realize that, but I've had trouble figuring out how to heat the shells. I have used nichrome wire, but that doesn't get them hot enough.

WALSH: You will have to build a kiln. You've seen four or five possibilities this afternoon. Just choose the one that will do the job for you. Then if you have help, it's a situation where you first take a pyrometer reading. Let's say that you're pouring silicon bronze and the temperature is 1960 or 1970 degrees F. Send the help off to get the molds. Give them about a minute. Then, pull the crucible, skim the metal and pour.

AUDIENCE: You're lucky you're pouring silicon bronze. Don't try manganese bronze. It makes a difference in sculpture. You must have your mold hot, because it cools too quickly.

COLSON: I can shut off my preheat furnace when my molds are around 1800 degrees F. By the time I'm ready to pour more they are still around 900 degrees F. If you can do better than that, by pulling them out flowing hot, this is even better.

Tom and I have poured with practically every metal. I started out with the same old route—you know, the old scrap business, because it's cheaper. Boy! I learned the hard way! It isn't cheaper. By the time you lose pulling all the slag off and cleaning the metal up, it just isn't cheaper! It seems to boil right down to silicon bronze again.

Q: The way that you use the oil drums, is it possible that you could just lift the cover off your burn-out furnace and pour?

COLSON: Oh, yes. Again, let me say a little more about the de-waxing system. The whole front is built on a completely flexible system. The legs on which it stands can be unclipped and lowered right down to ground level with your shells inside. I often even take my shell and put it in a bucket of sand. I put the bucket of sand and the shelf inside the de-waxing furnace which is now a preheat furnace (because the bottom is closed) and heat it up. I sometimes burn a galvanized bucket right away, but at least it's still holding the sand in while the sand is still hot and the bucket is only being used as a prop. You could take the lid off and pour it right in. I haven't done this, because I haven't had the need. I have a few brochures here on the Kaowool. I'm not a representative of the company, but I believe in the stuff so much, I mentioned it in the last conference. I don't quite understand why people such as ourselves who have such a fantastic knowledge of technical approaches and materials, haven't really gotten into using this stuff. I've been using it since it came out. It was developed for the fireboxes of the Atlas missiles. Its working properties are 2300 degrees F. and its melting point is 3200 degrees F. That is a one-half inch fiber material—a little thicker than your thumb—a blanket material. It has innumerable uses. I can use a piece of it by placing it underneath something when I'm welding. You can weld a metal joint against a ceramic surface by insulating with a hunk of this. It's unlimited.

AUDIENCE: Tell us more about it.

COLSON: It's called Kaowool. This is the product name. It's produced by Babcock and Wilcox. Now, I have about a dozen of their brochures here that I will make available to first-come-first-serve. In the back of the brochure is a listing of their offices all over the country and rather than name them all to you, I think the people who get the brochures should at least let the others get the address. But Babcock and Wilcox is a national firm and their main office is in New York. You can make inquiries through any refractory source. Carbide Company also produces a similar product. This is an aluminum silica fiber. They produce a product they call by trade name Fiberfrax. It's a similar-type product. These, the Kaowool and Fiberfrax, come in numerous forms. They come in a blanket, a powder, and in a can. You can paint the stuff on. I have converted the thermal characteristics of a refractory brick in a kiln to the thermal characteristics of an insulating brick by simply painting the liquid Kaowool right on the surface. The difference is that the refractory brick absorbs heat and radiates it back whereas the insulating brick reflects heat. If you have a kiln made of heavy refractory and you want to get this reflecting heat characteristic, just paint the surface of it with this material, and of course your consumption of fuel is cut down to half.

Why don't I give you addresses for some of these products? This will by no means exhaust the list. The work you saw on the screen—the ceramic shell process—used a silica-sol binder. So, first of all, I'll give you the address where you can get another kind of binder, and ethyl silicate. Write to Stauffer Chemical Company, 380 Madision Avenue, New York, New York, 10017. (All of these addresses are in any foundry magazine.) The Nalco binder is Silica-sol. They also have the refractories. The address is Nalco Chemical Company, 9166 South Harbor Avenue, Chicago, Illinois 60617. If you write Casting House Supply in New York City at 62 West 47th Street, they can send you information on the ceramic shell process using Du Pont's Silica-sol binder and molicity zircon refractories. Alexander Saunders has information also, and their address is Alexander Saunders and Company, P.O. Box 265, Coldspring, New York 10506. They all have a great deal of printed information. Jacques Schnier's lecture in the Third National Sculpture Casting Conference four years ago was very definitive. I think, using what he said, using what you saw today, and reading this material, you'll be ready to go.

Q: This is for Tom. You don't use your furnaces because of the reduction atmosphere. That's why you went to the immersion burners, right?

WALSH: Right, that's why I did it. It's not as great a problem with small pieces, but I'm more interested in casting patterns in the 36-50-inch range. The immersion burners solved a lot of my problems. The large patterns are also my reason for going to a car kiln type of set-up. It minimizes the amount of wrestling you have to do with hot molds.

AUDIENCE: One thing, Tom, there's a wax put out by Cereta. It's a fiber lengthener for microcrystalline that you guys might be able to use. I don't know the address.

WALSH: A what?

AUDIENCE: A fiber extender. You know, that linear stuff. It never melts in the summer. It's a Cereta product. The wax paper industry also has a fiber lengthener for micro-crystals which they use for wax paper. It seems to me that it would minimize your expansion problem.

COLSON: Well, there's another wax brew company, Yates Company. It produces hollow waxes so that you can eliminate this expansion problem in breaking your shells sometimes because it collapses inside.

Q: Do you use any surface coating with your waxes?

WALSH: It's absolutely essential that you clean your wax surface thoroughly with a good solvent. I use isopropyl alcohol. It's also very important to allow the wax to completely dry before you apply your first coat of slurry. If you don't, the alcohol that remains on the surface will function as a catalyst causing the slurry to dry quickly and unevenly. The result will be plus metal defects on your casting.

Q: Have you had any success using plastics in your patterns?

WALSH: Foamed styrene and urethane have been a snap. Some of the students at Southern have been experimenting with polyetheylene, high impact styrene, etc. Once we started reinforcing the molds with fiberglas mat; we've had good success. Some of the plastics leave a dusty residue in the mold which has to be rinsed out with a solvent before casting.

COLSON: Is anyone interested in the hollow wax material? Here's a diagram of what they send you. This is the Yates Manufacturing Company at 340 West Muron Street, Chicago 10, Illinois.

Yes, this is a microcrystalline. For the gentleman who raised the problem about flat pieces, I think that if you'd investigate zircon and molocite, you might solve that plastics bit.

Q: About different refractories, have either of you used the silica flours that Nalco is recommending?

WALSH: I've been using them for seven years.

Q: Oh, you use zircon too. What's the difference between the silica flour and the fused silica.

WALSH: Well, the silica flour is nothing more than air-floated silica; fused silica has been expanded and treated. There are a good many refractories you can use. One of the variables you must watch is that they are not equally immune to thermal shock, and the burn-outs must be handled carefully or you'll blow the shell right off the pattern. Zircon is exceptionally strong. As I mentioned previously, it's tough to de-vest.

Q: What about breathing the silica flour?

WALSH: Bad. That's why we wear masks. You can develop silicosis. If there are no more questions, I think we will wind this up. If, in the future you develop problems in regards to shell, write me in care of the Art Department at Southern Illinois University in Carbondale. Thank you.

PLASTICS, THE NEW ART MEDIA

DR. THELMA R. NEWMAN
NEW JERSEY

Man's technological progress in the last half century has been accelerating at a pace never before known to mankind. Just the past few decades he has unlocked the atom, harnessed the electron, broken through the gravitational limits of earth, walked his first probing steps in space and is seeking ways of pulling other planetary bodies toward earth for expansion-room. Man's imagination is having trouble keeping up with the potentials offered by our technological knowledge.

We have come a long way since early man took his first exploratory look at nature's resources. Materials have played a fundamental role in the evolvement of civilizations, indirectly determining what man could do at every stage in history. This depended, of course, upon what he knew about the properties of matter. Even historians recognizing the vital role performed by these substances labeled early stages of man's development by the Stone Age, the Bronze Age, the Iron Age.

Exploitation of nature's products led to new possibilities as man learned to change and combine materials, to transform them into more suitable elements.

In his first efforts with inorganic matter such as stone, he fashioned workable but crude forms that became arrows and mallets. Later chipping and forming took on aesthetic characteristics. Textures, colors and designs appeared. Thus, the first users of materials became known as craftsmen and artists.

Craftsmen saw matter as substances they could transform and shape. These were empiricists, people who knew about properties of matter before the scientist. Indeed, for the first time in history of man's transformation of materials into useful, mystical or purely satisfying form, we have a group of substances that never touched the artists hands. These are man-made plastics, synthetic polymers. This is a departure. Whether stone, clay, bone, wax, wood, leather, fiber or reed, metal or glass—all have found their way into contemporary production through a long history of evolvement by craftsmen.

And that is the basis for the dilemma we are in about plastics. In looking for guidelines for using plastics, too often design and property considerations were stretched or overlooked. They were sacrificed to cost factors and the immediate impact of surface appearance.

Plastics, when evaluated against other materials, is temporarily an infant. The only standards one could set for use of the first man-made plastics were those already known and attributed to other materials. Engineers took processes unique to wood, metal and glass and transformed them to manufacturing methods using the new "miracle" polymers. Property testing and evaluations were scanty at that time. Little was known as to how a material would behave in productions and trial. Hence products broke, cracked, warped and faded.

Gradually guidelines were established but not until "plastics" earned a reputation as cheap and temporary substances. Lack of heritage was one obvious failing, but another factor was plastics own amazing versatility and ability to be used in place of ceramic, wood, metal, etc., thereby inadvertently casting polymers into the chameleon-like role of imitator.

Instead of creating a new design form that utilized plastics uniqueness, the die was cast. It was too easy to use the materials as replacements for other substances. Not only did polymers substitute for other materials but they were forced to imitate these in assuming their exact color, texture, hardness, as well as counterfeiting their design form.

Today, scientist-engineers are creating plastics for a particular use. This is an improvement over earlier designing. Intensive studies have been made and particular properties are known and well documented. Unfortunately, this information is couched in difficult technical language, discouragingly impossible for the art person to understand.

Some artists though, struggled through the literature; some had technical assistance from sympathetic scientists, others just explored man-made plastics as their forefathers did with nature's own materials. Their results are exciting and creative. Artists are not bound by the limitations of industry. Artists may make use of the accidental and uncommon in their expression unlike the manufacturer who has to produce exact duplicates of designs. Flaws in manufacturing relegate objects to the reject department but not for the artist who may delight in the "accidental" and the "uncommon" result. Most emphatically, however, artists consider plastics for *their own sake,* as valid materials to transport an expression, not as imitation or substitute materials.

Artists create mainly with their hands. Even mechanical tools are hand controlled. The entire process is manipulated and wielded from beginning to end by the artist. Craftsmen have always seen as a whole, a gestalt—the material he had selected, tools and processes for transformation, a final form and eventual use. The manufactured product, on the other hand, is fragmented into different processes often without any worker seeing the whole until the very last process is completed before shipping time.

The promise from these divergencies in thinking between the artist and the manufacturer lead to whole new directions as scientific knowledge is translated for the artist-user. Inventive minds have only explored a small part of plastics potential.

It is difficult to think that man's precocious creation is an infant. Yet plastics are merely on the threshold of its course. The first plastic, cellulous nitrate, was discovered in 1868. The greatest growth in this field is really within the past 30 years. Look around you. No matter where you direct your eye, no matter what you touch, some plastic product is nearby. Nylon stockings, button, eyeglass frames, shoe heels, fabrics—your dacron shirts and blouses, walls, floors—all are plastic. This is a revolution. Every area of life has been invaded by some form of plastics. The spaceman is sheathed in plastic; his first moon-walk propellent could be made of vaporized plastic; even chickens are wearing rose-colored polyethylene glasses. It makes them more placid. Ball players will be chasing those balls over synthetic grass in Texas. Jewel collectors protect their jewels by embedding them in crystal clear resin. Polypropylene is being planted around the southern coast of Great Britain to prevent erosion, by absorbing the energy of the sea. If you are a space traveler you will be able to partake of such gastronomical delights as bacon and eggs, fruit juice, chicken bites, applesauce, pot roast, and so on, that have been specially packaged in nylon and fluoro-carbon film. All you need do is insert a water dispenser through an opening, knead the package and voila! reconstituted food. If the package breaks, the gunk will merely float around you in your space ship. And speaking of gunk, that whipped cream on your pie, the substitute whip or the squeeze-cheese that becomes a canape—this is plastic. It is a wonderful high bulk, low calorie appetite appeaser. So you see, plastic can be not only our outer covering, our bones and organs, but also hunger pacifiers.

Indeed, the plastics revolution promises to free man from the limits of traditional patterns. Its potential is to provide an environment meeting modern man's high speed, mobility, and quick changing needs.

Some artists saw plastics potential almost from its outset. Laszlo Moholy-Nagy in his book *Vision in Motion* prophesized in the 40's: "The new artist working with plastics inevitably has to take up scientific studies or else wait decades until knowledge about plastics becomes commonplace." But Antoine Pevsner had enough foresight in 1924 to use celluloid, man's first plastic for his sculpture "Torso."

His brother Naum Gabo worked with the new acrylics a year after introduction in 1937. "Spheric Construction" is his first success. He was able to mold space without defining it with solids; no traditional material would permit a solution to Gabo's significant forms.

Leo Amino was another early user of plastics. Soon after polyester resin was created, Mr. Amino began casting it in 1945 into amorphic forms that became alive with internal movement. He was imbued with new concepts that a transparent vehicle permitted. In sculpture, transparency goes beyond surface. Capable of richly decorated "skins" and projections into the background, there is simultaneous perception at different depths into different spatial locations. The top surface can become a tantalizing barrier that is visually penetrated to reach depth elements while one also sees the inner and outer whole at the same time.

Alexander Archipenko carved into solid acrylic in 1947 to create "Modeling of Light." He took advantage of a phenomena common to optically clear materials, called "edge lighting." Light entering a piece of acrylic is transmitted by internal reflection to its opposite edge, unless carved or scratched, then it will "leak" light at those points causing a glow.

Getting back to essentials:

What are plastics?

They usually are composed of various combinations of carbon, oxygen, hydrogen, chlorine, fluorine and nitrogen. The polymer chemist takes natural resources apart, breaking them down to their basic molecules and atoms. With these building blocks he uses heat, pressure or chemical action causing these building blocks to combine in order to create a new polymer. The linking of these molecules is called polymerization.

The chemistry of plastics is very much like baking a cake. Most cakes are made up of basic substances, such as flour, shortening, water, salt, milk and sugar. Whether the baked goods becomes biscuit, cake, pancake, pie or doughnut depends upon varying the quantity of the respective ingredients as well as the methods of mixing and cooking. So the chemist, by maneuvering comparable variations in ingredients, mixing and processing, creates a specific polymer. Organic chemistry, however, is far more complex than this simplified description infers because organic substances are remarkably numerous, large and complex.

Simplifying, for our purposes, plastics can be grouped into two basic categories: thermoplastics and thermosetting plastics. The distinction is important for us to know. Thermoplastics behave like metal. When heat is applied, they melt and when cooled, become hard again. This process can be repeated many times until the material is "fatigued." Essentially, the material can take many different shapes in the span from softening to hardening.

The thermosetting plastics, on the other hand, react like ceramic materials. They are plastic or moldable until heat is applied. Then upon cooling they will always retain their shape and cannot be easily softened again. Whether a plastic is thermoplastic or thermosetting, therefore, will determine in part what the artist can do with it.

Before fabrication, all plastics start as liquids, pellets, granules, powders, sheet or film. Whether pellet, powder or liquid, it is still the same plastic with the same properties.

Color and texture can be added in a variety of ways—with paper, glass, sands, dyes and pigments.

Plastic can be used as a means to an end. As a mold material, or as Arline Wingate used styrofoam in her 5' x 6' sculpture "The Key" as a form to be cast in bronze. The foam is vaporized out of its mold by the heat of the hot bronze that replaces it.

Plastics can be used for their own sakes as in this painting "Athenian Freeze" by Michael Lenson.

. . . Or cut into shapes, decorated and incorporated into weaving as in Ted Hallman's wall hanging.

Plastics can be rich in color.

They support impasto textures as in the panel by Sara Reid.

. . . Or capitalize on pattern and color.

They can be used as a transparent and translucent material. Harriet FeBland uses a clear acrylic sheet for her translucent painting.

Some plastics permit utilization of edge-lighting.

. . . Or combined with fiberglas to form a tough, easily moldable material. The chair by Eero Saarinen for Knoll Associates revolutionizes furniture design.

When selecting a plastic suitable to artistic expression, there are three basic questions. First, what kind of plastic; what form would it have; could it be a liquid, sheet, paste, powder, pellet or film? Second, what kind of cure would be practical: room temperature, heat lamp or over? Third, what processing methods would be feasible?

When I first began my research in plastics just a handful of artists confessed to using plastics. In the recent Museum of Modern Art show "The Seeing Eye" at least half of the work on display utilized plastic.

Acrylic can also be combined with polyester resin, as I do in my favorite manner of expression.

Using a vocabulary of techniques with polyester resin, serious works can be created.

Epoxy can be used in the same way as polyester resin. Although it is much more expensive, it is also stronger and will take outdoor exposure better than today's polyesters.

Another promising group of plastics are the foams—from styrofoam to flourocarbon foams.

Another area undergoing dramatic change is in the useful and structural arts. The surface has only been scratched. Potential for good design needs the art person's leadership. Unfortunately, local building codes and public taste have not followed in pace with technological progress. Man's abode, its furnishings, centers of industry and commerce are often bound by these regulations that have become confining straitjackets of tradition. Our style and taste is compounded of bits and pieces from our aggregation of existence on earth, with vestiges of the Renaissance tenaciously holding on.

It is vitally necessary for the artist and designer to make an effort to match environment to the needs of modern living.

Some artists have pointed the way. Here are some projections: Albert Herbert imagines a house that can be a basic structural box made of fiberglas, insulated with foam and fitted with plastic moldings. Parts could be glued into place. Window openings would react to light like light-sensitive sunglass, that would automatically react to the quantity of outside light.

Units could be shipped to the building site and glued together.

Vladimir Kagan in thinking of mobile America designed mobile-collapsible furniture made of vinyl that can be engineered into blow-yourself couch and chair shapes.

Michael Lax speaks of flexible fibers stretched into shapes for furniture and made permanent and structural with coatings of synthetic resins. Or cellular plastics, blown into foam and foamed in place with spray-up techniques. Fast-reacting foams can become self-supporting in minutes.

If these materials are within our horizon, whole new avenues are awaiting exploration: New polymers such as vinyl-acrylics (co-polymers), thermosetting acrylics, allyl diglycol carbonate, new light stable polyvinyl chlorides and acetates with built-in enzymes for room temperature curing, silicones and a host of other plastics shows much promise as art materials. One does not have to be prophetic to be able to predict the creation of new substances and processes in the near future. There are still other dimensions to be exploited—if mind-setting approaches custom-made for the old and mistailored for the new can be discarded; if industrial leaders can have enough foresight to support small-user markets; if engineers and scientists can work with artist and craftsman—we will see a freshness and vitality emerging from not only the artist-craftsmen users of polymers, but from the designer and manufacturer too.

All the art work we have seen here is unusual inasmuch as each artist has embarked on a search into a forbidden land. Through his creative insight and ingenuity he has given us a new vision. The dynamics of new plastics becomes an exciting aid to help meet the need for individual expression of an expanding, mobile, horizon-less population.

QUESTION-DISCUSSION SESSION

DR. THELMA R. NEWMAN

Questions were asked about the availability of various new plastics and aspects of process. The following outgrowth of this interchange was considered by Dr. Newman to be very informative:

Newman: I have a question for you and I wonder whether you would care to explore it. Bruce Beasley brought it up today when he spoke and this kind of dialogue might give us some answers as to what we may do and perhaps how we may expand the idea into some kind of organized thinking. Have you people been successful in involving industry in helping you with your work? (Several "no's" from the audience).

Conferee: I've gotten all my materials free, everything for the last four years.

Newman: How did you do it?

Conferee: In the beginning, I would ask for the boss, the man who has all the plastics. What I do now ask for the shop foreman or plant manager. Maybe this is peculiar to the Midwest, but they are just dying to cooperate. I get enormous amounts of scrap and even new materials. Two summers ago I received from Upjohn two barrels of A and B Duratane, which is something like $600 worth. I vacuum form almost exclusively now, and I get all of my plastics simply, because I contact the people who are involved with the actual process. Stay away from the people in the offices. The people involved with the actual processes, the men who manage the workers, not the engineers, seem to be anxious to do something to help.

Another Conferee: The people who work with the materials are proud to see their "chiffon" dishes turned into something that they would rather look at.

Conferee: I have had trouble. Chemists are tremendously helpful and interested. They will fabricate a quart of something to see if I like it. Then, ironically I can get samples, even 50-gallon drums, but you can't buy the stuff in usable quantities.

Newman: I'd like to talk about that in a few minutes. There is something that we might be able to do about this.

Conferee: The approach that I have often used is to tell the sales people what I am looking for. Often they will send samples of the materials that the company doesn't know what to do with. They are extremely interested in having people experiment with their laboratory materials in order to receive a feedback.

Another Conferee: I have been having pretty good luck since I have been in the Midwest area. Some of it has com from people who have expressed interest in the EAT project (Experiment in Art and Technology) through the Milwaukee Art Center. They have a man at the Center who is trying to coordinate these activities, but it hasn't really gotten off the ground. When I obtained the names from him and followed them up I received incredible technical help and materials. I think one of the real keys is a change in attitude, and not just on industry's part. A lot of it must be on the artist's part. This feeling, you know, that it's me against industry. Your attitude is important when you talk to these people whether it is the salesman, vice-president or janitor. It takes a lot of getting out of your studio and being willing to confront this whole business world that may have been kind of frightening to us. But it's there if you are willing to butt your head against it. I just can't believe how successful I've been and I don't think my successes are unique or unusual. But they're not going to come to you.

Another Conferee: I have had great success with the metal companies but never with a plastic company. I get aluminum, as much as I want, well not a 1000 pounds but really quite a bit from Reynolds, Kaiser and Fortran. The people who make Fortran are really willing to help out with metals. Now this may be different, because I was on the West coast and actually on the East coast the world is quite different from the Middle West. You may be stopped at the receptionists office, but if you get to know where to write your letter it may be answered by a subordinate, salesman or someone who definitely has more answers.

Newman: Maybe it's the kind of questions you ask. If you ask a specific question don't they answer? People restate a general outline of my book and ask "Would you give me some more information about plastics?" If I replied to this type of inquiry it would be just like writing a term paper. I don't have an answer for that kind of query. If somebody asks me a specific question, I might even do some research to find the answer if I don't know it. You can help by carefully considering the kinds of questions you ask.

Conferee: Like the other fellow was saying, I have been turned away by the executives and then with five minutes back in the shop it is surprising what I have found out about materials. Of course, I read up beforehand on what I needed and spent some time on common shop terms.

Another Conferee: People are intimidated by a large company. They feel they must go through the office or write formal letters.

Conferee: Vocabulary is very important. I know a lot of people here were turned off by the series of technical lectures on the first day of the conference, as if they were talking in some foreign language. In a sense, they were. We may never be able to understand this language completely. We can't spend the time necessary, but there is a middle point where they can understand what your intentions are. You can't say "I'd like some stuff that does this." They can't possibly think that way.

The big corporations, the really big companies, are the ones that are ultimately going to make the big difference. They are the ones that are going to cooperate with EAT. Right now, the individual may do much better going to a little one-man shop where they will say "ok" you can use that tool in the corner. That's fine, but the big corporations are the ones that can really help. They are the ones who can really do something. And you also have to realize that the scientist may not understand you either. There's some point where communication has to be more conscious and deliberate.

Another Conferee: Yes, I'd like to put in my little pitch for EAT, because if any of you know any scientist or any industrialist who is at all interested, get him to join EAT, because this organization is made up of 80 per cent artists and less than ten per cent are people involved with industry. It's extremely important to try to balance this. It is a very important organization, very new. And I strongly advocate something happening.

Newman: There's another point that was touched on before, and I think it is most important. Consider that you have the knowledgeability. You know how to do it. Now, you have to get materials in small quantities. This is a big problem and is one of the reasons why styrene color pellets for example aren't used in spite of their possibility. One has to buy them in carload quantities of each color. Otherwise, the cost is exorbitant when you have to have them custom colored. An econmoic factor enters into this and it really doesn't pay. This happens with quite a few materials that are experimental and new. Polycarbonates, for instance, fall into this classification. Quantity has a lot to do with it and there might be a way to overcome this. You might think about ways and perhaps EAT could help here in finding sources of supply for the small user market.

Conferee: Does anybody know the address?

Newman: EAT is at 9 East 16th Street, New York, New York, 10003.

Conferee: May I have the address of your book company in New York City?

Newman: Yes, Chilton Books, 401 Walnut Street, Washington Square East.

Conferee: How much is that book?

Newman: *Plastics As In Art Forms* is $12.50.

Conferee: Could you tell us a little more about EAT?

Newman: EAT is a symbiotic organization where scientists and artists work together. The scientist feeds the artists information about technology and technically helps. For instance, there are artists who are working with the laser beam and those who are working with hollagraphy. Some innovations that seem incredible, but they are being used and it is because of the help of the technologists who belong to EAT that this is possible.

Conferee: Do they have a publication?

Newman: Yes, they do. You can become a member by writing to EAT.

Conferee: Everyone ought to join it or write to it or support it. But the other thing that I think is important when everyone talks about EAT is to mention that it can't be looked at as the artist trying to get something from technology. Ultimately, it has to be approached as a real symbiosis, a real exchange. Right now you don't want to say that I will be worth so many dollars to you ultimately or make something you will be able to use.

Newman: Don't you think, though, that the artist, in describing his problems can also get across some esthetic values to the men who are creating the design?

If there are no more questions, then we can go on to the slide showings.

Tefft: Yes, I think we have already taken too much of an advantage of Dr. Newman . . . I would like to thank her for her participation and for leading this interesting discussion.

THE SOURCES AND CONTROL OF LIGHT

TERRY McGOWAN
GENERAL ELECTRIC COMPANY

This presentation was originally billed as something having to do with lighting aesthetics, but after sitting in on some of your sessions yesterday, it seemed more to the point to talk about the tools of light rather than how to use it; so what follows will be directed toward the devices used to generate and control light leaving it to you to ask any questions relating to any other aspect in which you're interested. Since this apparently is also the first time lighting as a topic has been on your program, your questions and comments will also help me tell you what you want to know.

Let's start with light sources. If you want to control light optically, the ideal light source is infinitely small, infinitely bright, lasts forever, has excellent color rendering properties, gives off no heat, and is dispensed free at all hardware stores. The lighting industry is probably closer to meeting that list of requirements than ever before, (except perhaps the last one) especially in terms of physical size and long life.

Wrapping different reflecting surface shapes around a small source illustrates the control idea. If the reflecting surface is specular (shiny) and parabolic shaped with the source at the focus, the light rays coming out will be parallel (Fig. 1-a).

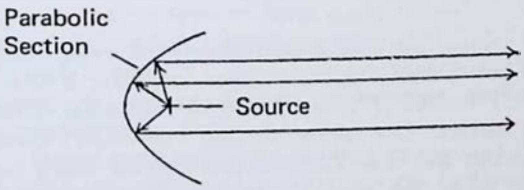


Fig. 1a

If the surface is spherical, the rays will be refocused on the source (Fig. 1-b).

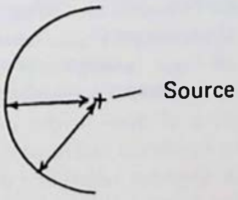


Fig. 1b

If the surface if ellipsoidal, the ray will converge to a second focal point then diverge into a broad beam (Fig. 1-c).

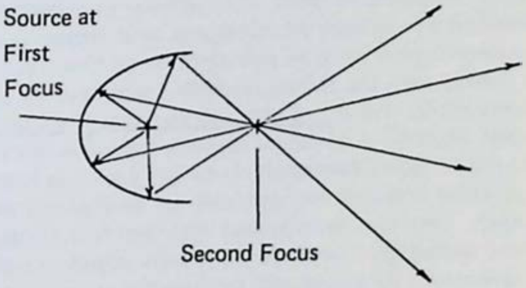


Fig. 1c

Combinations of these basic shapes produce beams with combined characteristics such as this one (Fig. 1-d), which is a combination of parabolic and spherical surfaces. Also, by displacing the source slightly from the focal point some variations can be produced.

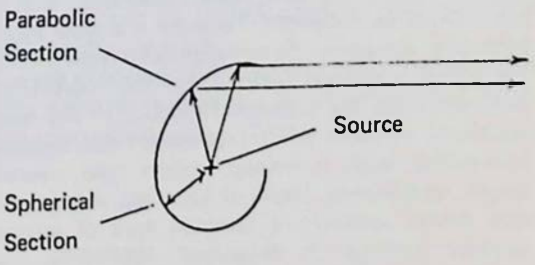


Fig. 1d

You could think of numerous applications of these ideas such as incorporating the reflecting surfaces into sculpture to respond to and reflect incoming light or by placing the light source in the sculpture to produce controlled patterns of illumination as part of the sculptural effect. Some "light sculptures" of course utilize these principles.

Unfortunately, common light sources are not "point" sources but have rather large physical sizes—especially those which must generate substantial quantities of light. This makes the optics less precise.

You'll be concerned mainly with two general types of electric light sources: incandescent and fluorescent.

Incandescent Sources

This source is similar to Edison's first incandescent lamp in that it basically consists of a coil of wire (today it's usually tungsten) inside an envelope of glass. To satisfy the needs of various lighting applications there are thousands of variations available. Size, wattage, input voltage, filament shape, color, bulb shape, and socket type account for most of them. Lamp catalogs are usually just lists of lamps which may need to be interpreted if you want a particular lamp type, however, this is easy to do. For example, incandescent lamps designed to operate on standard voltages (120 volts) are designed as follows:

WATTAGE-BULB TYPE-BULB SIZE / COLOR, FINISH, OR LIGHT DISTRIBUTION. A standard 100-watt household lamp would then be listed as (Fig. 1).

100A21

Wattage

Bulb Type
A=Arbitrary
P=Pear
G=Globular
T=Tubular
C=Cone Shaped
PAR=Parabolic Aluminized Reflector
R=Reflector
S=Straight Side

Bulb Size
(at widest point in eighths of an inch)
2 1/8 = 2 5/8

Fig. 1

In this case no finish is indicated which means a frosted lamp. If the listing were 100A21/CL, a clear bulb would be indicated. To make it a little more confusing, sometimes for common lamp types part of the listing is omitted. Actually for the 100A21/CL just mentioned the listing is 100A/CL. In any case, additional columns in the catalog provide detailed information such as voltage, socket type, over-all length, approximate hours of life, light output, etc. One further example—a common type of colored outdoor floodlight is designated: 100PAR/G. 100 watts, *P*arabolic *A*luminized *R*eflector/Green color. In this case, the detail columns would indicate the bulb size as 38 or 38/8= 4¾ inches in diameter at the widest point. Obviously spending a few minutes studying a lamp catalog page will be helpful.

Applying what I said a moment ago about optical control to practical light sources results in several incandescent lamps which can produce highly controlled beams of light. These lamps have a compact powerful filament exactly at the focal point of a parabolic reflector. The filament itself is shielded by a small spherical black cap reflector so that all of the light generated by the filament is directed toward the parabolic reflecting surface. The larger this surface is, the greater the optical control and the more intense the beam, therefore, these lamps use either a PAR46 (5¾"), PAR56 (7"), or PAR64 (8") diameter reflecting surface. The PAR64 version (120PAR/1 6-volt) develops well over 200,000 candlepower using only 100 watts and was originally designed for use in optical devices which measured cloud heights. In your work these sources might be used to produce brilliant beams of light without stray glare to highlight or spotlight small areas. Arranged to graze light across a surface, they bring out texture and detail in vivid relief.

One particularly important characteristic inherent in the incandescent source is the tremendous ability of the bright filament in a clear bare lamp to attract attention. Undoubtedly you have seen electric signs or patterns of clear lamps (ex.-holiday decorations) which attract attention immediately because of the glitter and sparkle of their bright points of light. In fact, the way the eye-brain combination works you often look at these displays whether you consciously want to or not. The human eye is naturally attracted to dramatic changes in brightness and a clear incandescent lamp with its sparkling filament is one of the most powerful tools available.

Experimenters working with light in this way have up until now been limited to clear or frosted lamps since no colored lamps were available except those with highly diffusing coatings. These coatings markedly reduced the brilliance of the bright filament and absorbed a lot of the light.

Recently, however, a new series of incandescent lamps has been developed which have colored transparent coatings so that the bright filament can be seen along with the colored light. Actually, the coating is really two coatings—one of colored cellulose acetate butyrate plastic covered with a thin layer of Lexan to make the lamps resistant to moisture and weathering. When these coatings were designed, we carefully formulated the colors so that if specific lamp wattages are used in a certain combination, all colors will appear equally bright. With ordinary colored lamps using a mixture of colors (such as you might see on a Christmas tree) the further you get away from them, the more they tend to merge into a muddy yellow-red mass. The blues and greens fade rapidly with distance because of their low light output. Using the transparent colored lamps, however, in the proper combination all the colors stay crisp and clear. The magic combination of these lamps is as follows:

40 watt blue	(40A21/GR/T/B)
25 watt green	(25A19/GR/T/G)
25 watt red	(25A19/GR/T/R)
15 watt orange	(15A15/GR/T/O)
11 watt yellow	(11S14/GR/T/Y)

In the ordering abbreviations "GR" stands for Group Replacement—a type of lamp made for electric sign service, "T" means transparent color, and "B", "G", "R", "O", and "Y" are the colors, blue, green, red, orange, and yellow. The rest is consistent with the description given previously.

If you work with light and become involved with patterns, you might be interested in a low cost way to use these transparent colored lamps. A smaller version the 10S11N/T/* (insert B, G, R, O, or Y for color at the asterisk) fits into an intermediate size socket—the kind of socket usually used for outdoor Christmas string sets so you can produce any number of colored effects investing little more than for lamps and inexpensive cord sets.

Smaller incandescent lamps like those used for indicators, decorative lighting, instrument panels, and other applications where small physical size and low light output are required often operate at low voltages such as the six or twelve volts provided by batteries or transformers. These incandescent lamps are usually only designated by number. To find out characteristics of these sources some type of catalog is always needed although part of the information is usually stamped on the glass or the base of the lamp itself. A typical example would be a flashlight lamp such as a Type 245 which, from the catalog, turns out to be designed for two standard flashlight batteries, provides almost one candlepower and lasts about fifteen hours. Almost all of these lamp listings and numbers are standardized throughout the lamp manufacturing industry.

A newer member of the incandescent lamp family uses quartz instead of glass for its outside envelope and is now generically known as a "Tungsten Halogen" lamp. General Electric calls their version Quartzline because of the outer envelope material and because the lamps themselves are usually long and slender (about the size of a mechanical pencil).

Quartzline lamps are useful where you need to produce large quantities of light in small spaces and where high temperatures won't cause problems. These lamps are hot—well over 500 degrees F, but because quartz can take thermal shock without breaking, water, or even ice thrown on them while operating will not damage the lamp.

In a lamp catalog Quartzline lamps are listed just like standard incandescent lamps except their ordering code is prefaced by "Q" (Fig. 2).

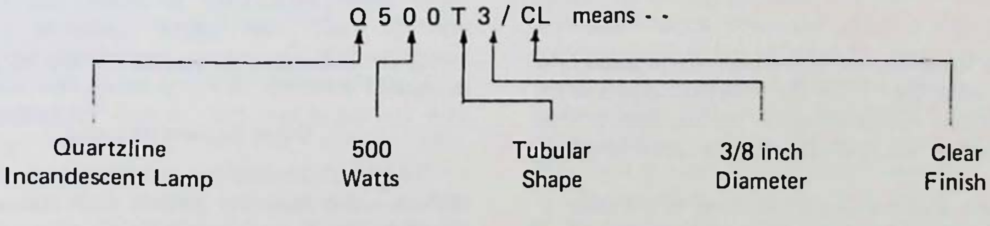


Fig. 2

Fluorescent Sources

The other main type of light source is the fluorescent lamp. From an optical standpoint, the fluorescent source is diffuse—more like a surface of light than a point. It can't be controlled very well with reflectors and its brightness per unit area is much lower than incandescent light sources even though it emits more than three times more light per watt of input energy. Using fluorescent lamps is also a little more complicated, because they require an extra electrical device or two in their operating circuitry. Compared to an incandescent lamp circuit it looks basically like (Fig. 3).

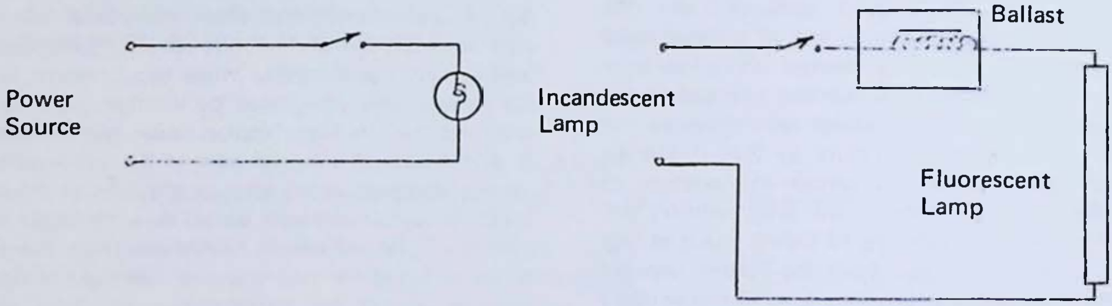


Fig. 3

A ballast is required in all fluorescent lamp circuits to control the power to the lamp and insure reliable starting. Without it the fluorescent lamp will try to absorb all of the power the circuit can supply quickly destroying itself in a flash of light.

A surprising number of different shapes, sizes, and colors of fluorescent lamps are manufactured, but because of their specialized applications you don't often see them. The so-called "blacklight" or ultraviolet fluorescent lamp is a good example. It is basically a standard fluorescent lamp made with special coatings and filters so that only light energy at the deep blue and violet end of the visible spectrum is emitted.

You'll usually see the fluorescent lamp in its common 4-foot long 40-watt version. In a lamp catalog the listing will look like (Fig. 4).

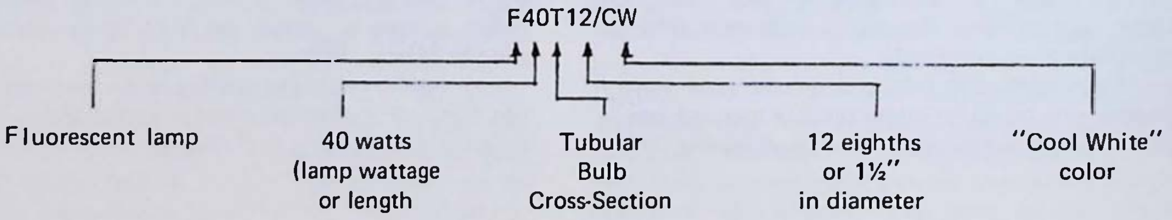


Fig. 4

Generally speaking, for 40-watt lamps and below, the numbers after the "F" in the ordering code stand for lamp wattage. Above 40 watts the numbers in that same position will indicate nominal lamp length in inches.

Notice that the end letters refer to the color of the lamp. There are a variety of these too. Cool white, warm white, white, soft white, cool green, blue, deep blue, gold, pink, red, and black light among others. There's no way to tell you about the differences; you'll have to experience each one of them to understand the difference. Fluorescent lamp colors are important to you as I'll try to point out shortly.

Other Sources of Light

If you go beyond the utilitarian aspects of light sources—using them for general illumination and on to using light as an integral part of your work, there are several other types of sources that will be of interest. The first is a brand new one just out of the laboratory called a "solid state" lamp. These are about the same size and appearance as a transistor (about the size of a match head) and produce a dim green or red glow which is best seen in dark surroundings. Although they're not very bright, they do have some interesting characteristics. One important one is that they seem to have unlimited life without growing dim as time goes on. A possible use of an unlimited life light source like this might be to permanently cast it in plastic or some other translucent-transparent material where it could be permanently sealed inside without concern about replacement.

Light sources used for industrial and outdoor lighting applications such as streets and parking lots belong to another general category called "high intensity discharge" sources. You probably won't need to know about them unless you want to generate very large quantities of light. Being discharge sources they too require auxiliary circuitry in the form of a ballast.

One special type of discharge source is of interest because of its ability to turn on and off rapidly—appearing to stop motion. This produces the so-called stroboscopic effects. These lamps which are called flash tubes emit a brilliant flash of white light at a controlled repetition rate which can be adjusted with external controls and circuitry. They too require a ballast-power supply arrangement.

Electroluminescent sources look like flat sheets of light made out of plastic about the thickness of construction paper. Several colors have been made—green, blue, white, and yellow, but the optimistic predictions made for these sources a few years ago haven't come true. They remain expensive, difficult to make, and limited in life, and brightness. You'll still see them occasionally for night lights and special applications, but I wouldn't suggest using them as one of your tools.

Light and Color

Every major type of light source is unique in one important respect, and this is its ability to render colors. Incandescent lamps for example render colors in familiar ways—we are used to the rather warm character of the light, and we realize almost automatically that colors seen under incandescent light will appear different when seen outdoors in daylight. Since fluorescent lamps have become widely used, however, the story has gotten more complex. There are about ten colors of fluorescent lamps which produce a so-called "white" light. Each of these lamps renders the colors you see in slightly different ways which can result in rather dramatic changes in the appearance of objects. Most people just say they make things look "funny," but that's only part of it.

One way around this problem might be to make a light source that renders colors exactly like daylight. This makes sense and indeed such sources are available. The problem is that daylight itself varies tremendously from hour to hour, season to season, and from changes in the weather. Even north skylight which seems to be much desired by the artist is subject to these variations so that a picture whose colors were carefully chosen and painted by daylight would not look the same at all if viewed under incandescent illumination. Some sculpture is affected in a similar manner of course especially where several colors are used in the same piece.

One solution to color rendering problems is to view the work under the same light as used to produce it. At least the results are predictable although different people would probably have their own ideas as to which light source they prefer. The point to remember when choosing a light source—especially a fluorescent one—is that for "good" color rendering the light source should produce substantial quantities of each color throughout the visible spectrum—red, orange, yellow, green, blue, and violet. Lacking that a source should at least be rich in the primary colors of light, i.e., red, blue, and green. In the technical publication *Light and Color* (TP-119), which was passed out to you, is a selection chart indicating which colors are enhanced or dulled by the various commercially available light sources. Rather than go into detail here, though, take a look at page 24-25 which summarizes the main effects when you have the opportunity.

Boiling it all down, there are two or three fluorescent sources which are good to excellent from a color rendering standpoint. These are:

Cool White Deluxe—"Cool" character much like daylight without sunshine. Most colors and complexion tones look healthy and natural. Probably the best choice for all-purpose color work. Standard 4-foot 40-watt version is designated (F40/CWX).

Warm White Deluxe—"Warm" character blends fairly well into incandescent sources. Tends to make skin tones and bright colors ruddier. Appears to make neutral colors warmer in appearance. (F40WWX)

Chroma 55—A new source developed for color critical applications. Light produced is similar to clear north skylight which is quite "cool" in character. Appears to slightly enhance complexions and most colors (F40/C55).

Be sure to specify the color you want when ordering fluorescent lamps. Otherwise, you'll probably get the standard Cool White which is the most popular, but which is quite poor at rendering colors. Don't be fooled either into buying a "Daylight" fluorescent lamp. It was one of the first fluorescent lamp colors developed and has very poor color rendering.

Incandescent lamps are not "good" color rendering sources since most of their light is produced in the red-yellow-orange region of the spectrum. This makes them warm in character and good where you want a flame-like atmosphere, but if you're using blues, greens, or other cooler tones, incandescent lighting will tend to gray them considerably.

You can obtain colored light from light sources in either of two ways. First by starting with a broad spectrum source such as incandescent and filtering out all of the colors you don't want; or second, as in the fluorescent lamp, adjusting the chemical composition and electrical operating characteristics of the lamp to generate only the wanted colors. In either case color filters are sometimes used to further enrich the desired color.

An interesting new type of color filtering material has recently been applied to the glass of some incandescent lamps resulting in greater color saturation and better optical control of the light. The filter is called a multi-layer interference film or dichroic filter and has the peculiar property of passing certain wave lengths (colors) of light while reflecting others. Conventional color filters pass certain colors, but absorb the rest turning the light energy into heat which in turn heats up the filter material. Dichroic filters can be adjusted to pass or reflect any desired colors of light and some even operate beyond the visible spectrum and on into the ultra-violet and infrared. Dichroic filter lamps or "Dichro-Color" lamps are available in red, yellow, amber, green, and blue and are manufactured in the PAR bulb shape. The red version would be coded as follows: 150PAR/SP/R or 150 watts, PAR bulb shape, spot distribution, red color.

Certain types of glass can be processed to obtain different types of dichroic color filters some of which produce unusual multi-color effects. You might find it interesting to explore the possibility of using dichroic films and surface coatings as one of your sculptural materials. Bausch and Lomb Optical Company can supply you with further technical information.

I have belabored color somewhat to make the point that this is an important variable of your work that can substantially influence the result. In fact light itself—or more specifically the control of light is a prime determinant which, when you take everything else away, enables your work to be experienced. Some sculptors realize this of course. Others are fascinated by the possibilities and are experimenting with light. Still others couldn't care less. The point is this. Light is an important tool of yours since it turns out that humans receive 90 per cent of the information about their surroundings visually. Electric lighting allows you to control a good bit of that 90 per cent input.

Maybe the sculptor should control the light throughout the whole process from idea to finished display of his work. At any rate, it seems as if he is the one who should decide how it is to look, what line, texture, color, or form should be seen or hidden, but that's not a new idea. You just have more opportunities to carry it out now than you have ever had before.

EXPLORATORY DIALOGUE: LIGHT AND KINETICS

ROBERT MALLARY, MASSACHUSETTS
ZBIGNIEW BLAZEJE, TORONTO

Frazier: I want to summon Mr. Mallary and Mr. Blazeje. Mr. McGowan, I hope you stay. Are you an artist, Mr. McGowan?

McGowan: No, but increasingly our company is working with artists. We feel very strongly that this will become an important part of our activitity, particularly at Nela Park, our research center. In some ways, it is a research center for the arts, the art of lighting at least. If there are questions, I will be glad to help in any way I can.

Frazier: At the far end of the table is Mr. Robert Mallary and next to me is Mr. Zbigniew Blazeje. You know, Mr. McGowan. We'll start by having a few slide projections by Mr. Blazeje.

Blazeje: This is an example of one of my large paintings that is done in fluorescent and phosphorescent paint. I used a system using a color organ in black light and electronic music to stimulate it. It's part of a group that formed an environment, and people sort of walked into the room and experienced music. Next slide.

This is an example of my more recent work which is getting involved in the use of light and plastic and complex electronic systems. There are photo-electric sensing devices around the piece that activate various areas of the light and sound sources so that the sculpture responds to the movement of people around it and forms a continuous art event as people pass it. The next slide is a view looking up that long red tube. It gives infinite reflections. That gives you a general idea of my work.

Frazier: Thanks Mr. Blazeje. Mr. Mallary do you have slides? You don't? All right, Mr. Mallary you may begin.

Mallary: I am going to touch on several issues which are relevant to light and kinetics and, therefore, to Mr. Blazeje's sculpture as well, but are not confined to them. I am a little ashamed to confess this is the first time I have actually attended one of these sculpture conferences, though I have followed them for years by hearsay and by acquiring and reading some of the transcribed proceedings; these latter have proven to be essential items in my small technical library on metal casting. However, I am particularly interested that the conference seems to be moving away from its original concentration on metal casting and entering the broader field of what is coming to be called (somewhat clumsily) "art and technology." Certainly, one of the most significant developments on the art scene at the present time is the burgeoning interest in the use of plastics, light, electronics, kinetics, the computer, etc. for sculpture. I would say from the little we have just seen of it that Mr. Blazeje's work represents this trend very creditably. The trend may be recent, but the issue itself is not; since the twenties a few sculptors have been aware that sculpture must ultimately come to terms with science, technology, and with the social environment these are shaping. However, the recent upsurge of interest, in this country at least, must be credited almost entirely to EAT (Experiments in Art and Technology, Inc.). I am a little surprised that EAT is not represented here officially. Perhaps this will be rectified at the next conference. Although I am a member of EAT enrolled in the Cambridge chapter, I am strictly a rank-and-filer and would not presume to speak for the organization.

I am certain that many of you were present last Thursday night when I presented my slide lecture on our computer sculpture project at the University of Massachusetts. This talk was mainly technical, though I could not resist a few speculations on the future of computer sculpture. But here we seem to be dealing with a more general topic and my remarks will also be more general.

To begin with, I believe the trend linking art and technology should be welcomed, and it deserves all the encouragement it can get, though I doubt it will get as much help as it deserves—I mean in the way of direct financial subsidies to underwrite research and creative work. It might surprise you, therefore, that despite my interest in the matter (or more precisely *because* of my interest in the matter) I harbor some misgivings about "art and technology" and the direction being taken by some who are involved with it. Not all that purports to be "art and technology" is serious, relevant and important. My concern is that too many half-baked and misguided efforts in this area can generate such misleading ideas as to what it means that it will come to be taken less seriously than it is now. In short, there are "traps" to be avoided. And while a "trap" will not arrest a trend as inevitable as "art and technology," it can make for confusion along the way and for delays in realizing its goals.

The first of these traps has to do with the fact that sculpture is the highly technological art that it is. For example, it is indeed difficult, as Mr. Canaday observed last night, to imagine painters organizing such a conference as this and sitting out three days of talks, slides and discussions on technical matters. Yet, the technological character of sculpture is precisely one of the reasons it is flourishing as vigorously as it is and that its prospects for the future are even better. Sculpture more than painting is susceptible to a technological revolution. And sculptors more than painters are in a favorable position to expand their technical resources and to cull a great number of useful techniques from science and technology. The first trap, therefore, is that with sculpture it is all to easy to *over-emphasize* the purely technical aspect and be satisfied with creating a work which, assuming it to be at least technologically ingenious and innovative, might have little else to recommend it. It is also a needless limitation to confine such art to the bare technological "look"—I mean, to a cold, immaculate precisionism and reductionism. Certainly, most of us are attending this conference primarily because of our technological interests, which is as it should be. But, as we know, the technological is only one aspect of art; there is also meaning, content, expression and the rest of it. I am not suggesting that in future conferences the emphasis be shifted away from the technical to something else—far from it. What I am suggesting is an occasional, somewhat ritual-like reminder and acknowledgement that the technical is subordinate to the formal, expressive and other aspects of a work of art. Its meaning is always contextual and cannot be assessed apart from the work as a whole.

A second trap also follows from the technological emphasis; it might be called "the mystique of the technological." I am referring to the all-out, mindless celebration of *anything* technological. The fallacy of this is evident if we but consider the pollution of air and water in this country and the technology induced dislocations in nature or if we consider such things as chemical and biological warfare and hydrogen weapons. The former are eroding the "quality of life" and the latter threaten our very existence. Technology misused can also pollute the atmosphere of art, with the important qualification that in art what is or is not pollution is seldom self evident. In art the most dubious concept must first be made before it can be evaluated and of necessity we must put up with a measure of "pollution" in order to be sure it *is* pollution. What I am urging is the need to make sound evaluations *at some point.* What I am pointing out is the irresponsibility, both social and aesthetic, of "buying" just about anything as long as it is wrapped in a "technological package."

A third trap follows from the intimate connection between art and technology and the concurrent trend towards intermedia and multimedia. Painting, sculpture, dance, theater, cinema and music will increasingly be joined in various combinations for a more total and unitary experience. But it is a mistake to deny these arts a continuing autonomy as integral identities or to deny them continuing viability or significance apart from their use in mixed media combinations. In fact, the arts can function most effectively as intermedia *when* they retain a measure of their original autonomy or when they alternately lose and regain their autonomy within an ongoing, intermedia situation. In short, the distinctions between two and three-dimensional art, and between kinetic and non-kinetic art, will continue to be real and meaningful. Advances in technology will transform music, sculpture, etc. as autonomous arts while they are also catalyzing further developments in intermedia and multimedia.

The fourth trap involves the contention there is something inherently superior in a three-dimensional art over a two-dimensional art or more "advanced" in a kinetic art as against one which is static in space and time. On the contrary, I would contend that the very immobility of a painting or sculpture can be especially attractive and meaningful in an age of frantic speed and run-a-way change; that (hopefully) I will continue on occasion to contemplate and examine a sculpture in my own fashion and at my own speed without a constant change of viewing angle being thrust upon me (or without the work being suddenly yanked from my sight entirely) is a "limitation" and a "defect" I will continue to cherish. I am contending that the relationship of the spectator to non-kinetic art can be more active, dynamic and creative than it is to kinetic art. When the work is immobile the spectator exercises more choice and freedom in experiencing it. Technology will prove to be a boon to the evolution of kinetic art. In fact, it will ultimately provide the means for a *true* kinetic art more-or-less completely electronic and freed from the shackles of hardware and mechanical movement. Painting and sculpture may eventually be down graded, but they will never be obsolete.

The fifth trap is not really a "trap." It is an unresolved issue. It has to do with the "thereness" of the work of art, with the meaningful distinction to be made between the work as a concrete existent object and the subjective experiencing of it. Art and technology increasingly will provide us with the means of experiencing art in its new ways—possibly as some kind of illusory, even hallucinatory and (I *hate* to say it) "psychedelic" experience. The perceived image will *seem* to be there in a most convincing fashion but will not be in fact or it will be "there" in a form other than the way it is perceived (as is the case now with the hologram). This is admittedly very speculative. What I have in mind is something on the order of a vastly sophisticated means of three-dimensional projection far superior to any conceivable improvement on stereo-projection, perhaps on the order of Aldous Huxley's "feelies" as described in his novel *Brave New World,* possibly wires into the brain—that sort of thing. A legless person occasionally feels the presence of the missing limbs as an absolutely convincing fact. In the future the "spectator" might be in effect programmed to experience vividly a work of art which has no physical reality except as electronically coded signals on film, wire, or disk. The intangibility of light suggests a faint premonition of such a medium, but nothing existing yet really points to it.

Mr. Blazeje's slides were especially interesting as examples of what he, Tony Martin, and others are doing in an area that might eventually expand so as to become involved with this sort of thing. The issue is this: the light provides a slightly hallucinatory experience of the kind I have just suggested, but the apparatus generating the experience is plainly on hand and visible as a concrete object. It might be said to be "disappointingly" matter-of-fact in its sheer physicality. I am baffled as regards the intended relationship between these two aspects. Are they aspects of a bi-polar and tensioned multimedia art experience? Or would it not be better if the mechanical and electronic paraphernalia were hidden or disguised so as to allow the illusory and hallucinatory aspect to come across more convincingly? As a sculptor I cherish the physicality and "thereness" of the object. But (as an ex-painter?) I also respond to the magic, intangibility and ephemerality—to the "not thereness"—of the kinetic light. My difficulty is integrating the two as a unitary experience which I, at least, am called upon to do if I am to respond favorably to the work. But I am ready to acknowledge that my failure to cope with all this just might be *my* problem—not Mr. Blazeje's.

The sixth and final trap is the most serious in my mind. It has to do with the use or rather the *misuse* of art and technology for publicity seeking and reputation making. I will not be too specific here, because it is risky to cite black and white examples and it is always inadvisable to question the motives of an artist. But I believe I am correct in saying that it is all too easy to trivialize and sensationalize art and technology and also to abuse intermedia and multimedia art.

For instance, it would be both trivial and sensational (from a strictly art-and-technology point of view, that is) if Claes Oldenburg were to rent one of those mammoth steam shovels to dig a wider and deeper hole to bury a bigger and better invisible Claes Oldenburg sculpture. It would be a gross misrepresentation to contend that Dan Flaven's purchase of fluorescent lighting units in a hardware store and their installation in a gallery or museum amounts to more than a trivial contribution to art and technology —apart from whatever other significance his art might have. It would only be a futile deception to put together a non-functioning *assemblage* construction of electronic gear in the manner of junk art (but cleaned up and made precisionist) and assert claims for this as a serious contribution to art and technology. The other day at this very conference I was approached by a fellow from Minneapolis and we engaged in a brief but stimulating conversation. He told me he has been using an "imaginary" computer and that it provides him with an abundance of ideas. This young fellow just might have something going for him. He may, in fact, be ripe and ready for launching by some New York gallery. But this is not "art and technology"—at least not as I understand the phrase.

I am of the opinion that in some cases, at least, the artist and engineer teams put together by EAT in New York have been too quick to trot off to a gallery to show off the very first products of their collaborations. There have been reports of malfunctions and break-downs. Lawrence Alloway put it to me this way some months ago: "The least you can ask of a venture in art and technology is that it not blow the fuses."

Perhaps this sort of thing is inevitable as a beginning. It also makes more sense if one bears in mind that the art and technology upsurge received its first serious impetus from the happening—like and theatre-oriented performances called "Nine Evening: Theater and Engineering" staged in New York in October, 1966. What I propose is a shift in emphasis from the theater back to the *non*-performing arts. I am also proposing a more routine, even humdrum, "research and development" approach such as has been carried on for years in university, industrial and government laboratories—bold, far reaching and imaginative as regards goals but plodding, practical and unostentatious in the manner of pursuing them. At least I hope this will be *our* style at the Center for Experimental Media we are now establishing at the University of Massachusetts. I should also add in passing that I fully credit Mr. Blazeje with the kind of seriousness and professionalism I am advocating here.

Frazier: That is great, Mr. Mallary. I wish I had said most of those things and in some cases I have. Mr. Blazeje, would you take over?

Blazeje: Well, one thing that Mr. Mallary has said is that the sculptor is faced with the problem of changing sets of values occurring all the time. Such as, do we relate to sculpture as being an object or is it going to become our total environment? This is an aesthetic problem for the future. My work is involved with exploring these areas of creating an aesthetic environment. I'm not just involved with creating sculpture as an object. I'm doing a lot of research in exploring what might be called the inside of sculpture. I'm working in environmental chambers or rooms in which the entire surface, floor, ceiling, and walls are all part of the sculpture, and in some cases these may be contained in architecture that exists, or more desirable, would have to be specially built external structures that are sculptures, plus internal sections with different relationships to psychology, to explorations of color and form. What I'm talking about is going into rooms and going through different experiences. In modern cities we've got these huge colossal buildings and long empty corridors which is what we consider the sterility of 20th century life. The problem of the artists is how to relate to what's already in existence, try to create something which is a great work of art for the people of the time plus being a direction for the future. Our society is going more and more into this cold, analytical approach to technology and art. Maybe it could become a little more humanistic in its relationship. I'm exploring these things. I have various plans for sculpture which are to be incorporated into large buildings which are integrated with, let's say, external or built-in lighting systems and these would be, for instance, triggered by people moving around the building. As for computers, I envision for the future cybernetic approaches using computers, to program different light events but in relationship to the movement of people. If there's nobody around, nothing is happening. But as soon as somebody walks by the building or within the area of the piece, a certain amount of activity takes place. It's more of a direct relationship between the work of art and the person because he activates it. He gets more involved. For example, you can walk by and see a piece, but if you walk by and it starts doing things, starts speaking to you, or playing music to you, or starts moving toward you, this is a confrontation. My desire is to do it on the highest aesthetic level possible. My whole work is geared to research in this direction. I think that's all I've got to say right now.

Mallary: In view of what he has just said, I would like to confront Mr. Blazeje with an issue which, for me at least, seems very important for kinetic art, art and technology and the rest of it. I am referring to the concept of a structured as opposed to a random art experience. In the case of his own sculpture he informs us that the spectators are meant to circulate around the work as well as in and through it, and that in the course of their movements they trigger various sequences of kinetic and auditory events within the sculpture. Well and good. What we have here is without doubt a kind of interaction between the spectator and the sculpture or between the spectator and the sculptural environment. What I wish to point out is that the spectator in this situation is in fact quite helpless as regard the *kind* of relationship he establishes with the sculpture. He is passive in that he is unable in any way or degree to *willfully* determine the character of its response to him as the activating agent. Even assuming he is alone with the work and that his efforts to manipulate it are not complicated and frustrated by similar efforts on the part of other participants, and assuming that he spends a good deal of time testing the work, ascertaining, for instance, that by standing or moving here that such and such happens and that by standing or moving over there something else takes place—assuming all of this, Mr. Blazeje could still frustrate the spectator in his efforts to master the situation or even to relate to it more or less on equal terms by programming automatic revisions into the control circuits every few minutes or so. The spectator wouldn't stand a chance!

Blazeje: Isn't that a good thing in terms of involvement?

Mallary: You mean that the spectator finally assumes control or fails to assume control?

Blazeje: Well, my work isn't strictly a programmed thing.

Mallary: That is precisely the issue, whether the work is programmed or not programmed, is structured or not structured, not only in terms of the artist himself but in terms of the spectator as well. I acknowledge that the kind of environmental kinetic sculpture you describe offers a kind of simulacrum of how the average person normally experiences and makes contact with his world—who, if he has any philosophical bent at all, is aware of *affecting* events but only occasionally of determining them or controlling them, even in respect to his everyday, one-to-one interpersonal relationships. The widespread feeling of helplessness and ineffectuality that people all over the world feel today—the *anomie* and sense of alienation the psychologists and sociologists speak of—have their source to a considerable extent in this fundamental limitation of the "human condition." This applies in particular to the political situation; as citizens of this country, we feebly and remotely *affect* what goes on in Washington but fail to *control* the significant events there in a truly democratic fashion. So I am asking, do we, either as artists or as spectators, really want and *need* additional doses of this kind of daily frustration doled out to us in our art experiences? What I am suggesting is that your spectator might be given the opportunity to control, at least to some degree, the character and sequence of kinetic and light events in the sculpture you describe or at least that he be encouraged to believe he is active and not passive in the situation—all in a spirit of irony or of romp and play perhaps. In my computer sculpture I am interested in randomness as a potential resource and capability of the program, but I am more interested (at least in the beginning) in control and in control over the various kinds and degrees of randomness. Finally, it all amounts to control—an explicit affirmation of the classical notion of form and structure. . . .

Frazier: Quite close to this idea of the difference between the structured experience and the unprogrammed happening, I feel that we had better leave that sort of thing to nature, because it's done superbly in the thunderstorm, lightning and erosion and all that sort of thing. Since man has been working for these many thousands of years on the business of structured existence, this is our path, our opportunity, and actually our obligation.

Blazeje: Well, I agree to a certain extent, but I disagree in terms of imposing limitations. I think that there is great room for exploration in random approaches. The sort of philosophy of John Cage used within works of art has unexplored possibilities. The classical approach to art is to structure something. The Oriental influence on art has caused in our century the relatively new idea that randomness can be a possibility. Nature is our finest example of that form of art. You would agree with that?

Mallary: Nature is not random. Nature is operating according to patterns and laws, even when statistical indeterminancy is operative (as it always is) at the ground level of physical events. Even in erosion, which is a destructive, disintegrative process there are structured erosion patterns.

Blazeje: Right, if you take it at that level. Then, of course, nothing is random. So, you know, you are defeating your own argument. I don't like to impose any specific dogma on art. I feel that to be vital, it has to grow, and it's vital for an artist to impose dogma on himself in order to create something but to impose dogma on the conception of art I think is wrong.

Mallary: Who's imposing a dogma? I'm not imposing a dogma.

Audience members: Yes you are. You are too. You certainly are.

Blazeje: I think that you know there is great potential for both. The classical approach to art really hasn't been explored that much either. There are structural qualities and relationships yet to be explored. If he's working in kinetics, he is working in time pieces. He may be programming a computer to turn out a certain number of events. Eventually, there will be a repetition unless you want it to be random . . . In that case, it doesn't appear to have repetition. In my work, I'm ranging degrees, in a way, like in that piece you saw. It's a very simple piece. It has four elements, four triggering units. It has four sounds that come out of it, and four lights are activated. After a while, you might say it becomes repetitive, because the events do tend to re-occur on a human, sort of psychological level. But, in actual essence, they don't repeat and basically they have a random quality to them, and this is what I feel. They can have both without one necessarily destroying the other.

Mallary: I have been accused of being dogmatic. So I say again: I *am* interested in randomness but with the qualification that, in our computer sculpture project at least, the randomness functions within the context of an ultimate control. Mr. Blazeje has just affirmed that "there are structural qualities and relationships" and our points of view are not so far apart in other respects as well. Accident, randomness, indeterminancy—these are complex theoretical matters which pilosophers and physicists have been debating for years and have yet to resolve. I have questioned experts in the computer field as to what they mean by randomness—by "random search," for example. This has to do with the way in which the computer extracts data from storage. On the basis of the answers I have received, and as nearly as I can determine, "random search" means that the computer, in effect, opens and examines sequentially every single locker in Grand Central Station to find one parcel or all the parcels that are yellow or all the parcels that are yellow with owners who have come from Los Angeles within the last twenty-four hours, and it does it this way instead of keeping track of keys and locker numbers. For the computer this is a practical way of going about the job, because it can perform the whole operation in micro seconds. But I fail to see the randomness of it. However, I should add in passing that there are other computer operations which are more clearly of a random character; for instance, its ability to print out a string of random numbers.

I should also point out that the word "control" need not imply restriction, sterility, or dogma. In fact, most kinetic art today is both technologically primitive and aesthetically a bore precisely because the control is so rigid, restricted and cyclical and the permutations are so limited.

The most exciting developments are going to take place between the extremes of rigid, cyclical control at the one extreme and complete randomness at the other. We are going to discover there are innumerable kinds and degrees of randomness. We are going to discover the many possibilities of control based on transductive interchanges. We will have many kinds of what I am calling "transductive art." Transductive comes from science, from "transducer" and refers to an intermedia situation in which structured signals from one medium (from art or from the physical world) determine, or at least influence, the structured patterns or events in another. Note again my emphasis on the word *structured.* I first became aware of these possibilities when I attended a musical happening—like a performance at U.C. Davis in California last year where David Tudor was using a harmonium (a kind of accordian) to trigger visual kinetic patterns on an array of television screens. A hypothetical example might be if a group a dancers moving *coherently* around, in, and through Mr. Blazeje's sculpture were somehow to imprint the organized character of their movements on the kinetic operations of his sculpture. This I would *buy*. A remaining question is whether structured signals originating in one medium invariably and necessarily generate structured signals *of an aesthetic kind* in another medium. Normally, I would not expect them to do so—given a random unstructured situation, i.e., how to arrange for this transfer of structuring to take place with at least an increase in the statistical probability of such occurrences is one of the many projects I think we should begin to concern ourselves with.

I will close my remarks by pointing out that the control versus randomness issue is reflected in the permutations of the happenings since their inception some ten years ago. Some "happeners" plan and structure their performances to such an extent that the word "choreograph" would be more appropriate. Others devise and follow a loose script, somewhat as the early film makers used to do. Others have moved out into the streets and into everyday life where very little of what takes place can be programmed or structured. I suppose there is room for all these varieties, if you happen to like happenings.

BRAINSTORMS AND PROPHECIES

BERNARD FRAZIER, MODERATOR

PARTICIPANTS*

Frazier: This is going to be a jam session like jam sessions that occurred on the east end of this campus in the twenties and thirties when that great and now famous group of Kansas City jazz musicians came here to work out their newest ideas. Important things happened though we didn't know it then. We, here and now, are going to create a jam session directly out of our sculptors' brains, an aesthetic free-for-all, if you know what I mean. Mr. Mallary, will you lead off?

Mallary: I would like to say a couple of things about my concept of what the future of kinetic art is, the direction in which it might lie. I feel that for the future kinetic art is an enormously important area, because it represents, let's say, three dimensions: movement, color and the possibility of abtraction and representation. I propose a visionary medium that I think could set a task for technology somewhat comparable to the task of getting on the moon, a medium which would make it possible to project images with three dimensions (the movement of which could be programmed, controlled, developed, and inspired by an artist, an artist in interaction with other artists or possibly presented in random happening-like situations) in which the spectator would not be sure whether he was seeing real people in the room or projected images of them. Now, this is a visionary thing, but if our technological civilization does not blow itself up in nuclear war shortly, that is; if we resolve our problems so that we can validly speak of a future like 25 or 50 years, I think there is going to be a merger in the arts in the sense that the theatre, dance, and sculpture may share the same technological medium. Whether it is considered sculpture, dance, or theatre will simply have to do with the use to which this all-purpose medium is put. In computer phraseology this is called simulation. In other words, a simulated situation in which the spectator would not know whether he was viewing a real person, a real event, or a projected image of it.

Frazier: Mr. Stankiewicz, do you want to say something at this moment?

Stankiewicz: I don't quite see how I can connect, like one boxcar to another, to Mr. Mallary's remarks. But perhaps I can go back a little to some of his previous remarks. I feel rather negative about a certain amount of the more recent art, particularly some of the kinetic art and some of the art that reacts to the spectator, and in general, a good deal of the art which exists not as an object but as a performance. It is a matter of temperament really and not a matter of theory of dogma. Some people like to put on the lampshade for a hat, and other people like to sit in the corner in quiet conversation.

When something assaults me, so to speak, or accosts me in the street, my reaction is to withdraw reflectively. If I want art, I'll go and find it whether I have to go to a museum or a back alley. I don't feel that I ought to be in the position of passive existence. I don't want to be turned on; I don't want to be turned off. I'm not a household appliance, you see. And if I want to do something, I'll do it. I don't have to have it done to me by somebody I don't know or something I don't know. I'll search out my kind of art. I don't want it to come at me from behind in the streets. Particularly, since the state of the technology of (call it energetic art or kinetic art) is too crude. There isn't enough feedback. The darn things know I'm there, and then they respond and act in a certain way but without any degree of sensitivity whatsoever. And they don't know who or what I am. A panhandler or a con-man or somebody on the street who just wants to borrow a match makes some fairly complicated sizings-up before he approaches and says something. But these stupid machines in the galleries do not know how I am feeling. When I come on the scene, I come all burdened with pre-occupations and moods, maybe tears and maybe gripes. But this stupid machine doesn't know anything about that; the mere fact that I'm there will make it respond and it will do something that might make me want to smash it and spoil my whole day. That is the kind of art I don't want to have anything to do with. It irritates me and puts me in a bad temper.

Sometimes it's useful if there's a point to it, if there's an idea behind it. But most often there isn't, and so, just to keep life simple for myself, most of the time I'm satisfied with art as an object that I can make if I'm an artist, or as a spectator, come to when I'm in the mood.

These remarks suggest all sorts of other things like the existence of the contemporary museums as show biz. I nostalgically remember the museums of my childhood as sanctuaries from the problems of being alive. You could go to a museum and lead a different life for an hour or so. But now the museums are like the streets and the show places. That is another subject, but perhaps some of these remarks will stimulate others.

Frazier: It stimulated me. I like that part about the show biz of the contemporary museum.

I have a thought here. I'm afraid that it is not going to be very popular. I am even afraid you might think it sounds a little like the ministry of the gospel. But it amounts to this: I'm somewhat concerned about all of us and our times on this point. Are we lapsing into a situation where we mainly exist to amuse and deal with each other? Or are we putting out something? Is there some spin-off which is actually adding something to the stream of culture to which we belong? Are we apprehensive enough about this? What are we doing for Tom, Dick, and Mary? Do they know we are doing it? I feel that we ought to all pay a good bit of attention to this because of obligation, which I think is a nasty word in most current groups. I do want to bring this up. Having had the privilege of existing as a human, I think that there is an obligation for me to do what I can to make the next human in my line a little better off. Is this our obligation? I hope the rest of you will comment on this when you have a chance.

Blazeje: Now exactly on this point, I think that one of the prime obligations of an artist is to contribute to the cultural development of civilization. I'd like to disagree with Mr. Stankiewicz in reference to the point he made about the response thing. Sculpture can be made as works of art as such, just like that one piece of mine. It is not always on; it is on only during the night. You can walk around it during the day and look at it in the same way you usually wander around "David" by Michelangelo or any sculpture. It has that same relationship of viewer to sculpture. Now, it also has a relationship to our advanced society, a technological relationsip and symbolism involved in the use of light and of, let's say, sensitivity. We can trigger it, but we don't have to. The thing I'd like to point out is that I hope that art goes in a democratic rather than a totalitarian way. I think that we should be given a choice of doing what we want.

Zach: I would like to give attention to that part of the discussion concerning the sculptor as the center of society. He has always been part of the environment, and he has created the environment. I don't believe that environmental research is something new; sculptors have always respected the environment. What we have today, which has remained from past cultures, demonstrates the fact that the sculptor has had this respect. I don't believe that we should make traps for the people. I think we have to be careful to keep in our research all the seriousness which I'm sure Mr. Blazeje has in his work. We have to keep it in our studios for quite a long time to be sure we don't get so far from the reality as to trap people.

Frazier: Thank you, Mr. Zach. There's a question back there.

Unidentified: I'm not a kinetic artist, but I have noticed there is a great deal of fear about it around here. Getting the feeling of fear from a lot of people makes me wonder if there is more to this kinetic business than has met my eye. It makes me interested. Can anyone explain this?

Blazeje: I'd like to make one remark. I think everybody has taken some of what I've said maybe a little too formally. I was giving a sort of general statement regarding, for instance, buildings activated by spectator response. It doesn't have to be on the stroboscopic, psychological, fear-inducing level. It can be on a very subliminal level so that you don't notice it. But you notice it.

Stankiewicz: Speaking for myself and jumping up with a very hasty denial, I would ask you to make a distinction between annoyance and fear. And I think I can make the protest, because about fifteen years ago I was making kinetic sculpture, wire things that were revouncy. This coming season (next year) the Museum of Modern Art is going to have a show which is going to be called *"The Machine."* I will have a kinetic sculpture in it which was made from a Stockholm exhibition about four or five years ago. It was done as a half joke. But anyway, I claim to be a little bit consistent, because my machine (although it moves very violently and makes a great deal of noise) doesn't come at you. You have to put money into a box before it will move. So, speaking for myself I would say that I am not afraid of movement. But I want movement when I want it and at my discretion, and I allow the audience the same before my sculpture moves.

Mallary: It seems to me that the slight conflict between Mr. Stankiewicz and Mr. Blazeje can be resolved very easily. I think people can simply know where they can go for a kinetic experience. As they go into a building, they can be informed that if they enter these portals anything might happen to them and be assured that in moving through other buildings or halls that things aren't going to jump out at them and frighten them. I don't believe that is a great problem. I don't know whether or not the speaker who spoke of fear was talking about me, because I had just finished saying that the medium of the future is going to be kinetic. I was merely establishing a very elaborate and possibly far-fetched standard of what it could be like and what its capabilities would be.

Lorcini: I came in toward the last few moments of this. So I will probably repeat what someone else has said, but I feel much on the side of humanism. If we cannot make choices in our selection of the art we are going to be participating with, then something is far wrong. I would not like to be attacked by a foreign element. I would like the choice of selecting what I am going to experience. I would like to think that I am open to new experience but would prefer that I put myself in the situation, open to experience, rather than have the experience come to me. I think that if one took this to the logical conclusion of a total environment situation over which the spectator has no control, then he becomes the tool of the machine rather than what I believe should be the reverse where we would use the machine for our purposes.

Stankiewicz: This relationship between the spectator and the art reminds me of another point, a slight gripe that I have, and it refers to a remark about democracy that was made a few moments ago. Democracy might have been an ill-chosen word. Perhaps what was meant was choice. But I think, categorically, democracy is a word that has no place in art in the relationship between the artist and his medium and the artist and his art and the spectator. I'm very skeptical. I think, wherever art is democratic, it is rotten art. You do not make masterpieces by committee or by compromise. One of the things that really offends me and my autocratic tendencies is to see these adjustable art works in the galleries where the spectator is invited to come up and readjust the elements. That makes me so mad I almost go out the window. Because I think an artist's job is to imagine as many ways as possible of doing a thing and choose what he thinks is the one best way. Anybody who meddles with that should really get hit, you know. This whole business of throwing the sticks on the table and letting the random event happen or let the spectator democratically intervene is, well, it is total abdication of your function as an artist; it's artistic suicide.

Blazeje: I disagree completely.

Stankiewicz: Well, I know you do. Go ahead.

Blazeje: I think that is defending the classical approach to art, which is static. You are completely eliminating kinetic art because kinetic art does have movement.

Mallary: How about structured movement? Like classical dance? I mean if something moves, it doesn't have to be chaotic.

Stankiewicz: Right, then you structure it so that it moves slightly. You don't have to have complex movement to have a structure.

Mallary: I think that the entire range between static and completely free art is valid. I'm not saying that it is the only thing. I'm just saying that it is valid.

Stankiewicz: May I make one remark on randomness here? In physics, when dealing with very small things, one can't deal with the things in themselves. They have to be dealt with statistically. I think it was Einstein who decided that if a thing behaves at random, it never gets anywhere. I think his example was that if you took a blind man leaning against a lamp post and set him off and let him walk random distances in random directions, he would always be coming back to that lamp post. In other words, randomness doesn't go anywhere. I really question whether there is any sensible motion in randomness. Is there any such thing as progress or is it just a hysterical movement? It always adds up to zero. I think the imposition of structure, plan, and decision, is, after all, only a reflection of human nature. At least it goes somewhere and I don't think that is static.

Frazier: I want Mr. Colson to settle this.

Colson: Thank you for the honor. Two words come to mind which I believe can be a bit conclusive in this discussion. Two very basic words which I apply to the entire social structure of our society, our American society. The two words are COMMUNICATION AND CROSS-COMMUNICATION. I am amused to see how very involved we are in ourselves. This was highlighted with great personification the first day, in which we had a battery of experts here who were so involved in themselves talking about the technology of plastics that they didn't communicate with us. I think this was brought forth by Mr. Gallo and others on the panel yesterday. We're involved in the same thing here again. Who buys art? How many live on it? Theatre or any other creative media? It is people. I do not believe that we are such a large group as to be self-supporting, either as artists or even in the broader term, "creative people," regardless of the medium-dance, literature, cinematography, or whatever. It is true that many of us feel that it is the artist who buys art, but we are not entirely that self-supporting. I think we need to broaden out in terms of cross-communication, being able to get across the point that we are trying to express even in some cases with ourselves.

In concluding I think that we are all in agreement that our entire American society has been built on technology. This was brought home to me recently when visiting the Edison home in Naples near Fort Meyers, Florida. This man, a totally creative person, was really one of the forefathers of our technological society as it is today. He filed some 1700 patents and I think all of them but two are still in use today. We are going at such a fantastic momentum in this technology that we are all jumping on this bandwagon. I think one of the greatest contributions to the world is our society's technology. But so many people are being swept away with it that we are not in touch with the human value. So, in conclusion, these words come to mind: Communication and cross-communication into other areas.

Frazier: Mr. McGowan, you have heard this. What, from your experience with light, might you add from your viewpoint?

McGowan: I'll be brief. I have already had my say. Light, of course, is a very human thing. We do lighting for humans and for no one else. One of the reasons I am here is to look for ideas by which to make light more human. In other words, it is rather like fidelity and sound. We can have light which is rather crude, awkward, and uncomfortable or we can have it very much oriented to the human. What I'm looking for are ways to do this better, both inside and outside. I was interested in a couple of comments about buildings that seem to be responding to people. We do this crudely now with the lighting of a building. There are buildings that react or are programmed so that as you go by shop windows, they light up. This along with signs, of course, is being done by technicians who feel this is one way to get a message across. Could I ask you to take a look at this and to possibly become involved designing building flood lighting systems and signs? I personally would rather see you people do it than some of the people who are doing it today.

Frazier: Mr. McGowan, Mr. Stankiewicz has a question.

Stankiewicz: I don't know if your company has ever worked with NASA, but do you think it will ever be practical to imitate the aurora borealis so that we can have equitorial displays up in space-fogs of illuminescent particles so that we can make sculpture compositions between here and planetary orbits, perhaps?

McGowan: I become worried about things like this after sitting on the phone listening to someone who has a bright flashing light across their bedroom window and doesn't like it. There are a lot of phone calls like this. I think there is no question that we have the power and handling capability to do such things if we want to do them. I'll leave it up to you people. You must philosophically decide whether or not you want to do them. I think I ought to have the right, of course, to pull the blinds.

Frazier: I wonder if there is anyone in the audience who has been close to the experiment going on in the Museum of Art here at the University of Kansas where electronic equipment placed under the rug did something in the way of charting the viewing.

Bangert: I am a computer person. So my artistic judgment should be taken with many grains of salt, but here is a quick description. The experiment was conducted primarily by Dr. Robert Bectal. The floor of a small room with drawings, paintings and prints in it was wired. Problem: How many people look at a given print, and what is their pattern of movement? Make a numerical description of how people watch art. The experiment was successful in that it obtained for Dr. Bectal his Ph.D. thesis, a patent and much interest from at least museum people. The point I would like to make is that it has also received a certain amount of negative comment. The gentleman mentioned fear with respect to kinetic art. One expressed fear is, "Oh good heavens, here is a scientist measuring art." May I speak as a scientist? For heavens sake, don't be afraid of this. People really do look at pictures. If I as a statistician happen to come a little closer to knowing the percentage of people that look at a particular picture, this only sharpens my sensitivity, and if I can communicate it to an artist, it sharpens his sensitivity. It should be better to know as a matter of fact, than to guess that a show is popular. You simply know that much more. That is my personal point.

Frazier: Professor Robert Green, do you have a question?

Green: I was just going to say that nowadays it seems as though we can no longer look at Niagara Falls in the moonlight. We have to have artifical light in all different colors on it. We have to look at the pyramids of Teotihuacan in different colors. It seems rather strange, I think.

Frazier: It seems rather strange to me too, Bob. Bravo!

McGowan: Let me just talk about one word, artificial light. There's nothing artifical about electric light; it's just as real as any other kind of light. Maybe we could clear that up.

Green: I think it's real in the proper context, but I don't think it belongs . . .

McGowan: I think that I agree with you, as a matter of fact. Maybe our approach should be like the French. If you want to see the monuments lighted, you stick a quarter or centime in the box to light them up. This might be the solution. This is exactly the point I was trying to make in connection with doing an aurora borealis in the sky. I'm sure some people wouldn't like it, and this is why we're legislating against signs and the like today. I think there is a lot that needs examination here again.

Frazier: I hope the aurora borealis comes to pass, because actually we prophesized it here two years ago. We want to try it out at least. There's a voice in the crowd. I can't see you. Speak up, please.

Muick: In regard to primary sculptures, light sculptures, etc., so much of this is futile gesture against the richness of contemporary architecture. I think the idea of incorporating light into the building in itself is great, but I don't think this so-called object in front of it adds anything to the building day or night.

Blazeje: I'm not interested in adding anything to the building.

Muick: Then why is the piece there?

Blazeje: To add to the pleasure of the people around the building.

Muick: We need art, but my point is as Canaday pointed out last night, so much of our technological equipment is in itself commercial—sculpture, buildings, signs, etc. The idea of putting a three-dimensional personal object in front of a building seems to be juvenile and infantile. So many of the structures that were placed in New York during September and October of last year were lost in front of the buildings. The building itself is a sculpture.

Blazeje: Sculpture in front of any building is lost?

Muick: No, not in front of any building. I mean contemporary architecture like the architecture in front of which your sculpture is placed. I think the sculpture is lost there and that building itself is rich enough with all that's going on in it. But when you start putting objects there, like cubes, I think that they are futile whispers.

Blazeje: Well, all I said was that the projected piece was not a piece set in front of the building. It was illumination on the building and from the building.

Unidentified: It's not always the sculptor's fault. Architects are very anti-art. For the most part, it's very difficult for them to understand what sculpture is all about. The relationship of sculpture to architecture is not understood by architects, whereas it is far more understood by sculptors. This is a problem in communication. Unfortunately, it hasn't been solved yet. Maybe it isn't his fault he didn't have $500,000 to do the sculpture.

Unidentified: Why do a sculpture when the building itself can be a sculpture?

Blazeje: In a case like that I would be more of an architect-sculptor, rather than a sculptor, because the piece would be the building. The response of people around the building I referred to was to the building.

Muick: That's fine. That's great. I will support that aspect of what you said, but what I'm questioning here is in reference to an outdoor exhibit in New York last September and October. My point is the same as that which Canaday was alluding to last night when he talked about airplane terminals. Since these buildings are themselves sculptures, why go ahead placing objects in front of them. The buildings are a superior gesture!

Blazeje: Are they all that fantastic though? Will the future generations in America consider the architecture available today as the living end?

Muick: I didn't say the living end, but some aspects of architectural design are very good.

Frazier: Let me say as a professor in the School of Architecture that this is quite a problem in the world of architecture. They're beginning to be, shall I say, a little apprehensive. On this idea of what is actually good for buildings, how good can they make the building and do they need sculptors? Of course, *we* know they do, but we're going to have to think about this very carefully. I believe you are thinking about it carefully, but it is a problem before us, because architecture has been the springboard of so much sculpture during all the ages and I hope during all the future. We must be sensitive about this and play fair, because we cannot attempt to steal the show. We must definitely be a part of the esthetic complex of the building, and of course, I'm repeating what you've all said a great many times. But let us not forget this.

McGowan: You talk about the buildings being the sculpture and then you talk about this thing that's placed in front of the building. Isn't this smaller thing just bringing it down to a more personal level?

Frazier: Yes, Mr. McGowan, I don't want to call buildings sculptures. It's better to call them buildings, because they are buildings. They are architecture and we can, shall we say, clarify, intensify, or do something about a certain factor of it. We can bring the spirit of the building down to human scale. We can do many things, but it is not our mission, shall I say, to put on a private show in which we try to upstage the whole affair. When we fit into it, we are richer. There was another hand back there.

Van Voorst: Mr. Mallary brought up a point a while ago—the fact that painting and sculpture should be categorized quite differently, and in that way they would be more compatible in combination. I would say the same thing is true of sculpture and buildings. Let's not call them sculptures; they are buildings, functional in that sense. The other point I would like to bring up is very basic. All of life, all experience to me, is a constantly expanding thing whether accidental or purposeful. I really think when we get to the point where we are afraid to include new experience, then we are getting to a point of being stagnant.

Frazier: Thank you, Phillip . . . Mr. Wolfgang Behl of Connecticut.

Behl: One other person here used the term, "being afraid," in a sort of negative sense, and I just wonder if this is proper. Let's just explore what we mean by being afraid. Is being afraid a negative reaction? For instance, if you go into an area that's infested with a certain disease, I should think that being afraid would be a very positive reaction. And I think what we've been talking about is not so much being afraid as being apprehensive and exercising judgment as to the use of things in their proper place. I think the words, "being afraid," have been used as a tool of intimidation. In a way, they are implying that certain people do not want to accept certain art. I don't think this is at all true. I think all the men who have been talking here this morning, by their actions, by what they have done, have certainly proved that they have accepted and have expanded the use of contemporary art. And to abrogate our duty to be afraid, to be abjectimental about our environment (about those things that are available to us), I think, is making us somewhat less than creative artists.

Frazier: Bravo, Mr. Behl! I switched to apprehension a bit ago.

Unidentified: I brought up the subject of fear and I think that I should clarify myself. I was not talking about fear of the objects. I can understand that as a person's right. I saw the Seymour Lipton sculpture over in the museum, and if it were crawling on my floor, I would step on it. It's a scary thing. I'm talking about this moralistic fear that was brought up when it was said that randomness is something we should stay away from, as if here is an area that is taboo. That is the kind of fear I was talking about, and I think that the man from Denver here made a good point; a new experience should be embraced. Then if you end up saying it scares you, that's something else. But saying I'm not going to look at it because it's, it's . . .

Frazier: Let me clarify this for you: I'm going to look at it; I'm not afraid of it.

Behl: I think it's a matter of choice. I think we are already living in an age in which we are confronted with a lot of involuntary experiences. I am thinking, for instance, of this horrible experience that I have every time I enter certain elevators in New

York where music is being piped in on me. There are many other ways in which, I think, many of you have certainly experienced annoyance. Sometimes these are not programmed annoyances, but these are by-products of our age. I think we have only recently become aware of the fact that some of the by-products of our age are detrimental to our mental, physical, and general well-being. I think pollution was mentioned earlier. There are many things which we daily gripe about: the kind of burdens we have to shoulder, the kind of impositions that are placed on us in so very many ways. I think we must be careful that what we intend as a creative gesture, as an enriching experience in twentieth century life, does not become just yet another burden that detracts rather than adds to our life experience.

Stankiewicz: I'd like to embroider on a couple of those remarks. I lived in New York City for a long time, and then about five or six years ago, we moved out in the country. We live in the mountains of western Massachusetts now, and on the face of it, the people in New York City and the people out in the country are very different. According to stereotypes, the country type is slow-witted, meandering across the landscape, and the city type is very sharp, quick and so on. Maybe, if you just walk down the streets of Manhattan, a great deal of motion, a lot of excitement, and noise is going on. Fumes are blowing around and everybody has shut this off, because if you pay attention to all of that all the time, you're going to go out of your mind. Everybody walks around with this invisible capsule around him, and he preserves himself by excluding everything but his most immediate preoccupation inside his head. There is some connection with this observation and with being assaulted by involuntary stimulation. And in the country, where you don't have all these distractions, the noises are almost subliminal and devoid of meaning: The rustling of vegetation, a few animal noises, once in a while a car passing. The people are not as closed off from their environment. If a woodchuck scurries across the field, it is noticed. If a car drives by, one looks to see whose car it is. If you're driving and another car goes by, you look to see if the person in the car is somebody you recognize. You don't do that in the city. You know it's going to be somebody you never saw before. And so, lessening the mass of stimulation, I think, improves the alertness and receptivity of people; whereas overstimulation, I think, clogs their receptors and cuts them off from life. It's just an observation, not an argument.

Frazier: May I join you as a country man? Mr. Roukes, can you settle all of this?

Roukes: I'm from Alberta, Canada and we don't have this problem of large masses of people up there, I must say. But I've noticed just in traveling from Canada to Europe that we live a type of capsulized existence. We leave our capsule home, jump into a capsule car, get to a capsule office; we keep ourselves capsulized continually and keep from ever coming in contact with our environment. I think it's very interesting that in Europe, in Amsterdam, particularly, it's kind of a walking civilization. You see things, you slow down and can perceive. I think it is just a matter of excessive speed as far as the problem of perceiving our environment.

Blazeje: I'd like to make a comment on this problem of too much stimulation. I don't know what the solution is to the making of man capable of perceiving information at that particular rate. Selection will have to be there, but he will have to, let's say, function on the next level.

Lorcini: By function, do you mean *for* him or will he have the choice to . . .

Blazeje: *For* him. Well, this is what I mean; he has a choice, but giving him the capability to have a choice. If you're stimulated on all your senses simultaneously with continuous information, you still have to be able to cope with it. A computer can cope with information because it was designed that way.

Lorcini: Do you see that in order to survive in the future, we would all need our pocket computer?

Blazeje: No. Maybe not such an eerie science fiction device as that, but we will have to have some help. We may do it through genetic reconstruction of man, that is, increase his brain power and his capabilities. The theory is that man uses only 15 percent of his brain. If he could be taught to use 90 percent, that would be a step in the direction I'm talking about.

Frazier: This is very interesting, but we must get to Mr. McGowan and the questions you've had logged for him.

McGowan: If your interests are in the direction of light, I will be here to answer questions individually.

Frazier: All right. In the absence of Elden Tefft, I will officially close the conference. Same time, same place, two years from now, something like that. See you all.

PARTICIPANTS:
ROUKES, ALBERT CANADA
BLAZEJE, ONTARIO CANADA
LORCINI, QUEBEC CANADA
McGOWAN, NEW YORK
STANKIEWICZ, NEW YORK
MALLARY, NEW YORK
ZACH, OREGON
COLSON, FLORIDA
BANGERT, KANSAS
GREEN, KANSAS
MUICK, VIRGINIA
BEHL, CONNECTICUT
VAN VOORST, COLORADO

WHO'S WHO AT THE CONFERENCE

SCULPTOR PARTICIPANTS

Oliver Andrews
Born 1925 Berkeley, California. BA Stanford University. Has had many group and several one-man exhibitions. Awarded numerous individual grants for research in sculpture in the United States and abroad. Has executed several sculpture commissions. Work represented in public and private collections. Professor of Sculpture, University of California, Los Angeles.

Bruce Beasley
Born 1939 California. Studied at Dartmouth. BA University of California, Berkeley. Has had one-man shows in California and New York. Work represented in major museums and private collections. Some purchase awards through competition in the United States and abroad. An independent sculptor.

Zbignew Blazeje
Born 1942 USSR. Emigrated to Canada. Self-taught artist, attending an electronic music course at the Royal Conservatory in Canada. Works in environmental multi-media including painting, sculpture, and music, utilizing plastics, light, and kinetic systems. Work represented in numerous one-man shows and group exhibitions in Canada.

Roger Bolomey
Born 1918 Connecticut. Banking education in Belgium and Switzerland. After studies in Switzerland and Italy, began career as painter, worked and taught on west coast. Launched sculpture career, 1960. Has had numerous group and one-man exhibitions. Work represented in collections of several major museums. Awards through competition in both studio and architectural sculpture. Teaching, Hunter College, New York.

Frank Colson
Born 1931 France. BFA Claremont College, MS Syracuse, New York. Work exhibited in the United States and abroad. USAID, foundry workshops in the United States and South America. Taught Tallahassee, Florida State. Founded Colson School of Art, Sarasota, Florida. Lectures and conducts seminars widely.

Stephen Daly
Born 1942 New York City. Studied at San Jose State College and Cranbook Academy of Art. Participated in regional and national exhibitions by competition and invitation. Awards in two regional shows. Teaching, University of Minnesota.

Bernard Frazier
Born 1906 Kansas. BFA University of Kansas. Attended Chicago Art Institute, Chicago School of Sculpture, apprenticed Larado Taft. Works extensively in the Midwest on architectural sculpture. A number of first awards in the national competition. Many lectures and art jury assignments. Exhibited in most major museums. Work in public and private collections. Director of Philbrook Art Center six years. Sculptor-in-residence, University of Kansas. Professor, School of Architecture, University of Kansas.

Frank Gallo
Born 1933 Ohio. BFA Toledo Museum of Art, studied at Cranbrook Academy of Art, MFA State University of Iowa. Has exhibited extensively. Work represented in several major museums and private collections. Numerous one-man shows, awards in national and regional competition. Heads graduate sculpture program at the University of Illinois, Champaign.

Mark Sponenburgh
Born 1916 Michigan. Studied at Cranbrook Academy of Art, L'Ecole des Beaux Arts, Paris, University of Cairo, University of London. Has had Tiffany fellowship, a Bok Research Grant, two Fulbright research grants in Egyptology. Work shown in several major museums and numerous private collections on three continents. Taught in Pakistan and London. Teaching, Oregon State University.

Richard Stankiewicz
Studied under Hofmann, Leger and Zadkine. Has had one-man shows in New York, Boston, Chicago, London, Amsterdam, Paris and Stockholm. Work represented in museum collections in New York, Chicago and Dayton. Professor of Art, State of New York University, Albany.

Albert Vrana
Born New York City. After a career in building construction, became interested in sand casting done in Europe. Has had several large scale concrete sculpture commissions in Florida. Work in numerous one-man shows. Has been awarded a Louis Comfort Tiffany Grant.

Thomas Walsh
Born 1937 Chicago. BFA, MFA University of Michigan at Ann Arbor. Drawing and sculpture exhibited in 50 national shows and 130 regional shows and received 30 awards. Work represented in ten museum collections. Lectures on metal casting. Teaching, Southern Illinois University, Carbondale.

Gino Lorcini
Born 1924 England. Emigrated to Canada as a member of a paint firm. Studied with Arthur Lismer and began painting and teaching. Initiated sculpture career in 1960 with exploration in construction. Has had large public commissions and one-man shows. Teaching, McDonald College, Quebec.

John Kehoe
Born 1927 Michigan. BA Wayne State, BFA University of Michigan. Many one-man exhibitions in Southeast. Work represented in public and private collections. Exhibited in Michigan and New York. Professor of Sculpture, University of Georgia, Athens.

Robert Mallary
Born 1917 Ohio. Studied and worked in California, Mexico City, New Mexico and New York. Many group and one-man exhibitions, traveling exhibitions in the United States and abroad. Work represented in major public and private collections. Awarded Tamarind Workshop, Guggenheim Fellowship, awards in national exhibitions. Teaching, University of Massachusetts, Amherst.

Thelma R. Newman
Born in the United States. BBA City College of New York, MA New York University, EdD Columbia. Studied with Lipton and Tony Smith. Lectures widely, author of *Plastics As An Art Form.* Work represented in college museums and private collections. Executive Director of Classroom Renaissance, J. J. Senior member, S.P.E.

Jacques Schnier
Born 1898 Rumania. Graduated, Stanford University 1920, Civil Engineering. Began sculpture career independently, MA University of California, Berkeley, 1939. Work in thirteen public collections in the United States and abroad. Studio and architectural sculpture. World traveler and lecturer. Author of books on sculpture, articles for art and psychoanalytic journals. Continues sculpture and research as Professor Emeritus, University of California, Berkeley.

INDUSTRIAL PARTICIPANTS

Felix Arnold
Research project manager, IMCO Container Corporation. Twenty-one years experience in the plastics industry. Attended National Academy and University of Kansas. President of Kansas City Chapter of Society of Plastic Engineers. Active in civic affairs.

Paul Campbell
Manager of Technical Services Information, Plastic Division of the Chemistry Department of Phillips Petroleum Co. Seventeen years experience in the plastic industry. MS in chemistry. Member of S.P.E. and A.S.T.M.

Larry Chirpich
Research chemist in the Polyester Laboratory of Technical Services, Division of Cook Paint and Varnish Co. BA in chemistry. Presently in the armed services, after four years in the plastics industry.

Stafford Collie
Manager of the Creative Design Department of Sealright Co., a division of Phillips Petroleum Co. Six years experience in the plastics industry formerly in paper packaging. Industrial Design graduate from Pratt Institute, Brooklyn, New York.

A. S. Crouse
Technical Service Specialist for Room Temperature Vulcanizing Silicone Rubber for General Electric in Waterford, New York Division. Seventeen years experience with General Electric, six years in the silicone molding section. BS from Rensselaer Polytechnic Institute.

Richard F. Dickhaut
Area representative of Union Carbide Corporation for the Midwest. Thirteen years in the plastics industry. Undergraduate and graduate work, Purdue University.

William Gaydos
Branch Manager of Owens Corning Fiberglas based in Tampa, Florida. Seventeen years experience in the plastics industry, began in operations and now in management. Attended Ohio University, Alexander Hamilton Institute and UMKC. Active in professional and civic groups.

Terry McGowan
Illuminating Engineer in the Lighting Development Division of General Electric of Nela Park, Cleveland Research Center. Eight years experience in measurement, generation and control of light. Attended Case Institute of Technology. BS in Electrical Engineering. Member of Illuminating Engineering Society and International Commission on Illumination. Presently involved in coordinated study, "Light in the City."

Kenyon Phillips
Structural Engineer for Portland Cement Association for the Midwest. Member of Concrete Institute, the American Society of Civil Engineers, the National Society of Professional Engineers. Awarded Outstanding Young Engineer of the Year by the Professional Society.

Alfred J. Roche
District Sales Manager of Monsanto Chemical Corporation. BS chemistry, University of Detroit, 1950. Eighteen years experience in the plastics industry.