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A SURVEY OF PLASTICS MATERIALS AND THEIR POTENTIAL EFFECTIVE UTILIZATION AS BUILDING MATERIALS AND BUILDING APPLICATIONS[1] FOR DEVELOPING COUNTRIES UPDATED TO 1971

by

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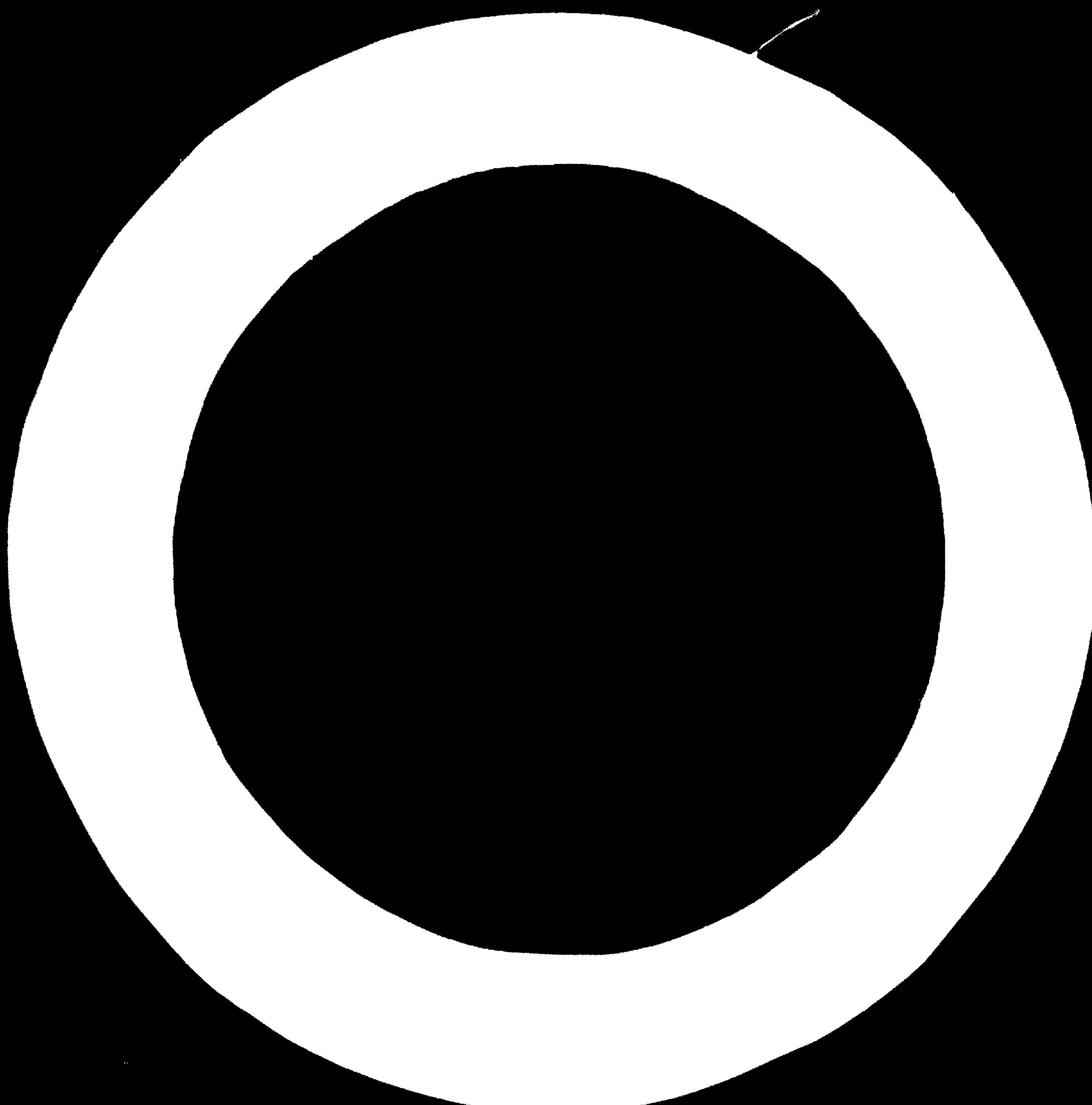

The purpose of this updated survey is to present an encapsulated and brief view of what has been done since the 1969 paper was completed. It is by no means complete as new uses of plastics as building materials are constantly being developed. Hopefully, ideas for a more contemporary and innovative continuation of uses for plastics in the future will be put forth, looking toward a time when architects and builders can have the freedom to use imagination, foresight and ingenuity.

EUROPE: WESTERN GERMANY

In mid 1970, a Swiss Architect Franz Dutler, in association with Badische Anilin - & Soda - Fabrik AG built an experimental filament-wound glass reinforced polyester vacation house. First displayed at the 1970 Hanover Fair, this house is a tubular structure mounted on four metal stilts.(Figure 1). The tube is 15 meters long and 4.92 meters in diameter (free standing height is 3.55 meters), with 70 square meters of floor space (754 square feet). It is made by superimposing one filament-wound tube over another smaller such tube and separating them by means of an insulating core of rigid expanded plastics foam. The attractively spaced interior, complete with plastics furniture (Figures 2, 3 and 4),is divided into an open balcony, livingroom, dinette, study, kitchen, bathroom and

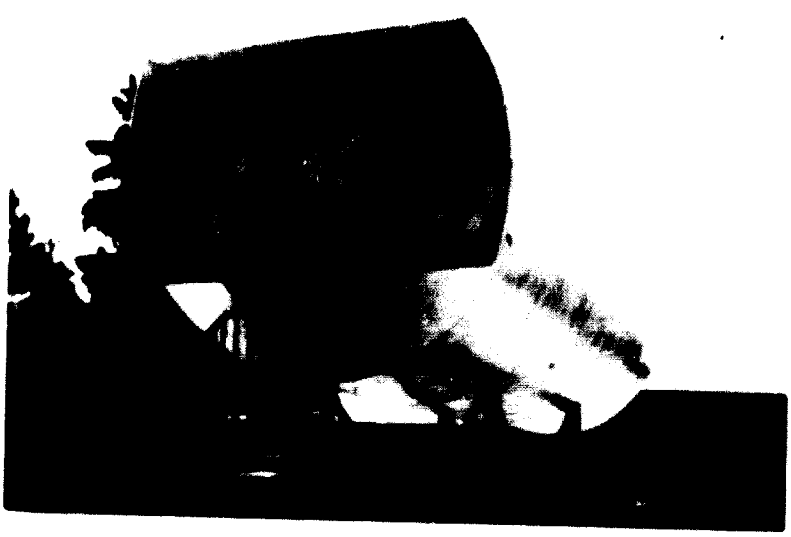

Figure 1

bedroom. Spacious and airy, it can be heated or air conditioned with minimum effort or experse. Electricity, water and sewage is carried in or out through the hollow metal stilts on which it is mounted (Figure 5).

Figure 2

Figure 3

Without furnishings this house is planned for sale in the United States at $19,000 -- with a hoped for drop to $14,000 once mass produced.

An even more recent German housing concept has been developed by Wolfgang Feierbach GmbH in Altenstadt called the "FG-200". This house is made of polyesters and urethanes manufactured by Beyer A/G (Leverkusen) and glass reinforcement by Gevetex Textil Glas GmbH (Dusseldorf). "FG-200" is made up of 39 panels. 13 roof 32 feet by 4.1 feet are supported by 26 wall panels 11.7 feet high by 4.1 feet wide.

This 1600 square foot unit is not inexpensive. Its cost varies from $18,000 to $75,000 depending on location, finishing and furnishings.

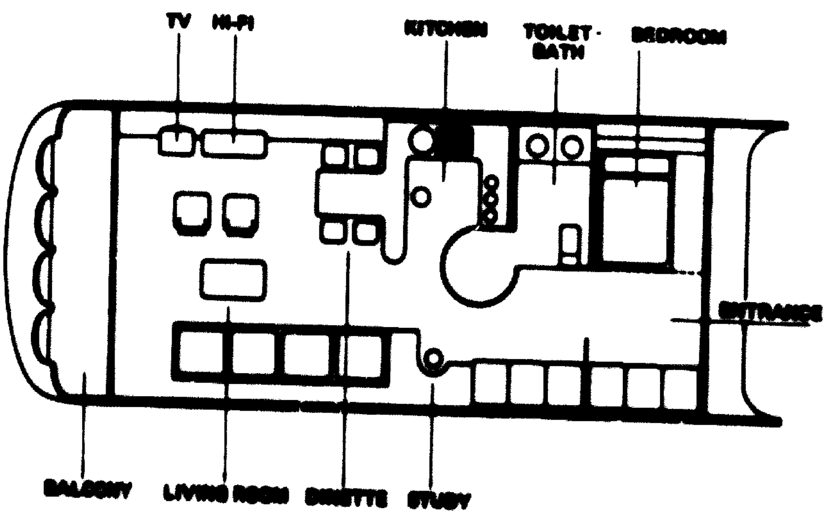

Figure 4

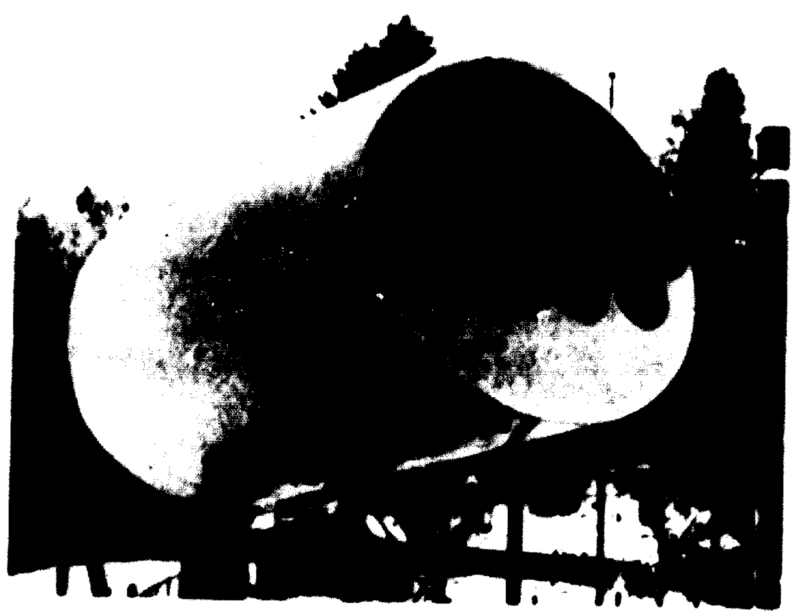

Figure 5

ENGLAND:

A new and important use of plastics in English high rise buildings has been the curtain walls in the Greater London Councils' High-

Rise Flats. Composite sandwiches of 2" glass fibers were used to reinforce polyesters as outer shell and were epoxy bonded to foamed concrete cores. A weather resistant polyurethane coating was added to this exterior surface. The inner facings were reinforced gypsum also bonded to the core. Panels that weighed one-fifth the weight of standard construction also provided the necessary fire-safety requirements, low thermal transmission and high acoustical impedance.

The High-Rise Flats were so successful that the sponsor, The Greater London Council, completed two more such buildings....each 25 storys high. No exact figures are available, but Council officials state that the costs are competetive to conventional construction.

Lately, in England, several large glass reinforced polyester structures have been erected: a planetarium roof dome 27 feet six inches in diameter has been built at South Shields Technical College; a reservoir cover dome, 25 feet in diameter has been constructed in Ware (Herfordshire); a swimming pool enclosure 100 feet long with a 50 foot span has been erected in Lincoln.

ITALY:

In Italy today, many polyvinyl chloride (PVC) extrusions are being used in building as partitions, doors, window frames, shutters and curtain walls. The 1969 report noted that PVC extrusions (Figure 6) were being used as interior-exterior walls. Today, larger (2-3 inch widths by 7-8 inch heights) and more complicated PVC versions are in use (Figure 7). Even extruded PVC "lumber" up to an inch thick is being produced (Figure 8) with structural corners (Figure 9) in order to establish the ease and validity of these vinyls as low cost building materials. These extrusions can be easily and rapidly prefabricated or assembled in the field. Easy to cut and/or cement with the appropriate solvent, these units are ready to receive

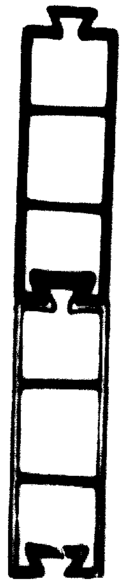

Figure 6

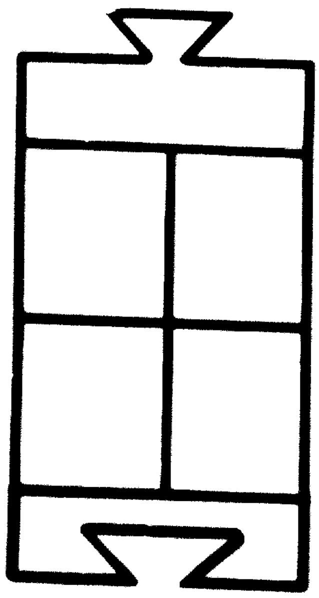

Figure 7

piping, ducting or wiring which can be threaded into the wall apertures of the extrusion profile. For additional insulation, urethane foams can be similarly frothed or sprayed into these same areas. Such operations can also be done in-plant or on site.

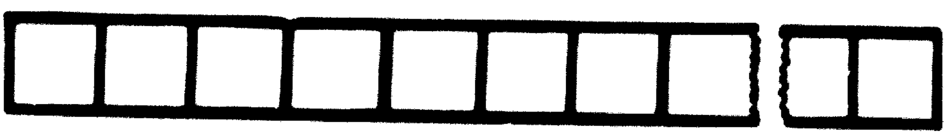

Figure 8

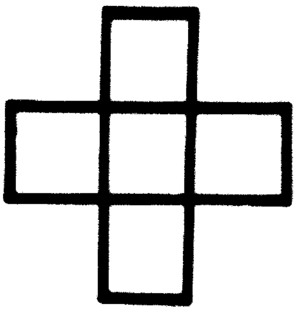

Figure 9

Renzo Piano of Genoa, a pioneer in the use of plastics as building materials has recently undertaken extensive and very ambitious programs for reinforced plastics materials. He has erected a 50 foot span by 80 feet in length woodworking factory structure. He designed a 120 foot span pyramidal factory roof and a 35 foot span by 60 feet in length sulphur ore factory. These first three structures are in Rome. He also has seen his design for a prestressed reinforced roof 200 feet by 135 feet erected in Genoa. Mario Scheichenbauer designed a reinforced market roof in Torino made up of 200 individual units and covering an area of 25,000 square feet.

NETHERLANDS:

Glass fiber reinforced polyester bungalows have been experimentally built in Breda and today the The Hague Market has a reinforced polyester roof made in 66 units with a clear span of 80 feet by 10 feet each. This market was designed by P. Huybers of Delft.

AUSTRIA:

Gernot Halbach of Vienna's Technological University has recently designed a mobile home which provides flexibility in size and room configuration. He allows for three basic sizes which can remain independent of each other as complete units -- or may be united to form a larger shelter. It is designed so that it can be folded to less than one quarter of its size. Thus, the full-sized, rather large home can be towed without much difficulty. The units can also be stacked.

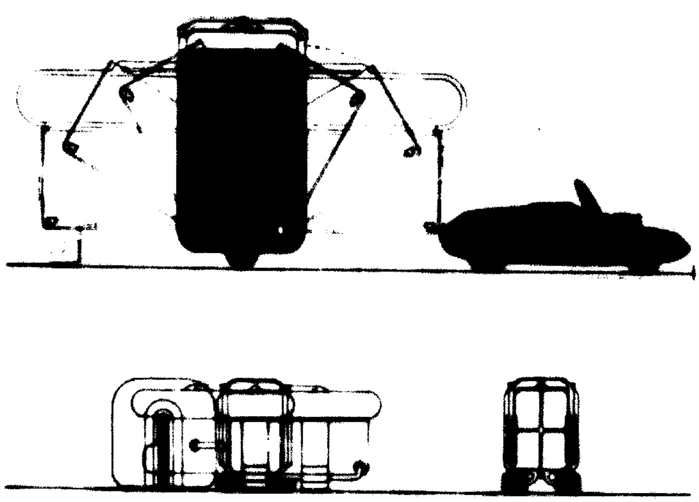

Figure 10

FRANCE:

Reinforced plastics have taken hold in French building, today. A market roof at Fresnes is made of 18 interconnected "umbrellas". A similar roof in Ivry is made of 1,620 square feet of glass fiber reinforced polyester sections. S. du Chateau has designed a most beautiful and spectacular 100 foot clear span hypar shell market roof in Argenteuil and many other such roofs have been built in Epinay-sur-Seine and Arceuil. Many new projects are also using these materials--among the more notable being the multi-story facades for high-rise buildings including schools and the Petrole D'Aquitaine Works. FRP pipes are now being used in French sewers.

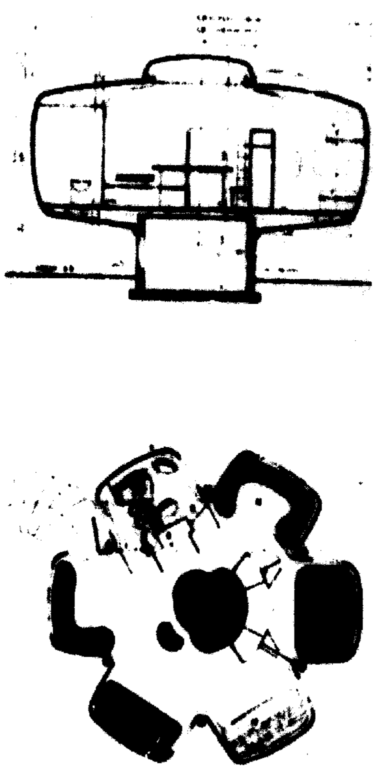

Figure 11

A newly constructed French vacation house costing the equivalent of $10,000 American has been designed by Jean Maneval and is being produced by Aquitaine-Organico Plastics Subsidiary of Société Nationale Des Pétroles D'Aquitaine. The compact house, referred to as a "six hull bulb structure" (Figure 11) is prefabricated in six hulls which are transported to site and mounted on a preconstructed pedestal. The shells (hulls) are glass fiber reinforced polyester sandwiches over a foamed polyurethane core. Once the pedestal is erected, the house can be assembled in about four hours. An electric motor rotates the unit so it can "follow the sun" or change the view.

Parisians have only recently adopted the use of rigid vinyl sheeting to cover large athletic fields. Once this practice has been accepted, more widespread usage will follow.

SWITZERLAND:

Marcel Lachat of Geneva improvised a nursery made of a reinforced polyester sphere. He suspended it from his apartment window (Figure 12) because they needed the extra space. Unfortunately, the Geneva Fire Department made him remove it, claiming that it was a fire hazard.

Figure 12

This use of plastics materials (Figure 13) brings into focus the almost universal demand for plastics applications to meet today's living and environmental needs.

YUGOSLAVIA:

Recently a kiosk and street furniture system was designed by Sasa J. Machtig and has been adopted for use in the streets of Ljublana. The basic modules are urethane cored reinforced polyester sandwiches (Figure 14). They are red with black panels and awnings. Interior fittings are white. The floors are covered with black rubber matting

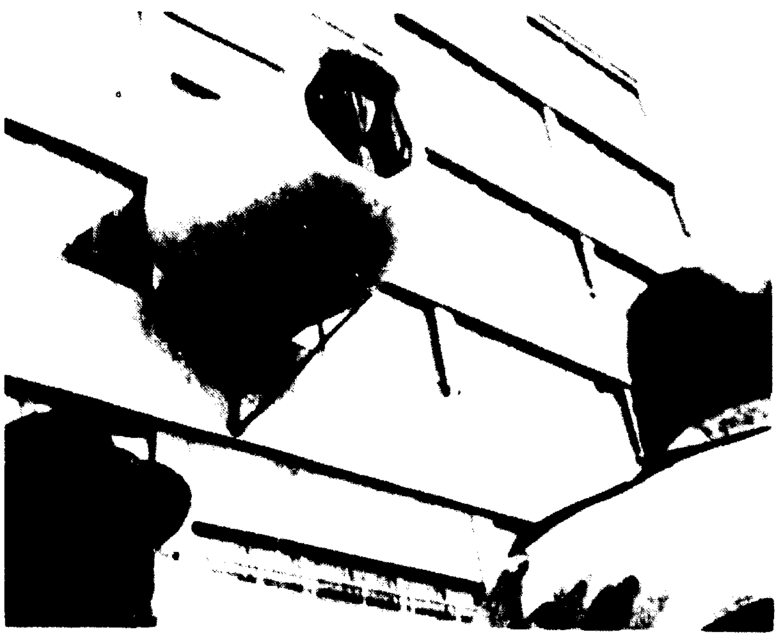

Figure 13

and joints and windows are also sealed with black rubber. Metal blinds are used inside and out. The units can be combined in numerous configurations -- and stacked to a height of five storys. Present Present applications are news stands, shops and stand-up eating establishments (Figure 15).

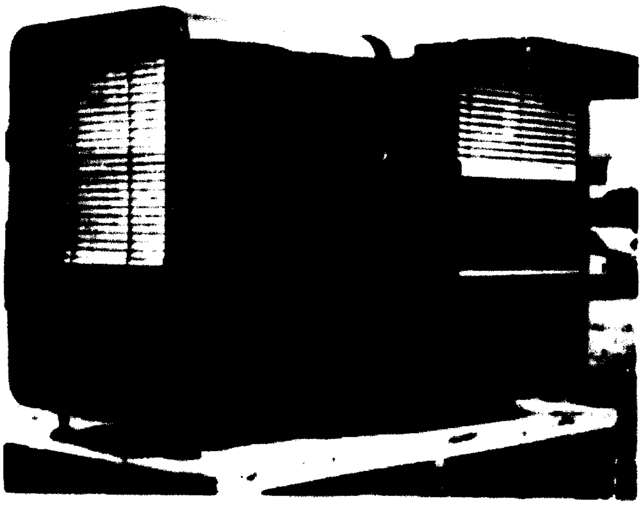

Figure 14

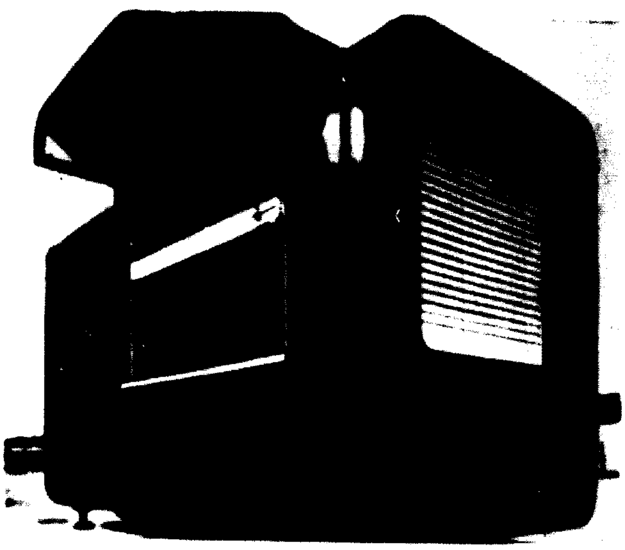

Figure 15

NORTH AMERICA: UNITED STATES

The United States Quartermaster Corps at its Natick, Massachusetts Proving Grounds has conducted numerous experiments in air inflated structures. These developments grew out of World War II experiments at the Goodyear Tire and Rubber Company in Akron, Ohio and work at Cornell University Aeronautical Laboratory some 25 years ago. More recently, the field of air inflated structures has become a commercial development championed by the Birdair Structures, Inc. [illegible], New York. [illegible], [illegible] bags are [illegible] to the ground [illegible]. [illegible] the bag is kept air tight, the bag [illegible]. A small air pump provides a constant source of fresh air. [illegible] the top of the bag to allow [illegible]. [illegible], or turnstile-type doors, allow [illegible] loss of air. Constructed of vinyl [illegible], these dynamic structures can vary in size from small [illegible] approximately 20 feet by 100 feet by 15 feet high to [illegible] enclosures large enough to hold a dozen football (or rugby) fields. Clear plastics can be laminated in appropriate areas to allow for light or see-through qualities.

Winzen Research, Inc. of Minneapolis, Minnesota has developed a system for making inflatable rooms which differs from the traditional air inflated structures. These rooms are based on sealed vinyl or other film composite bags being blown up as free standing beams or walls from which film walls or partitions can be suspended (Figure 16). This system does not require the pumps or air lock doors required in the standard air inflated systems.

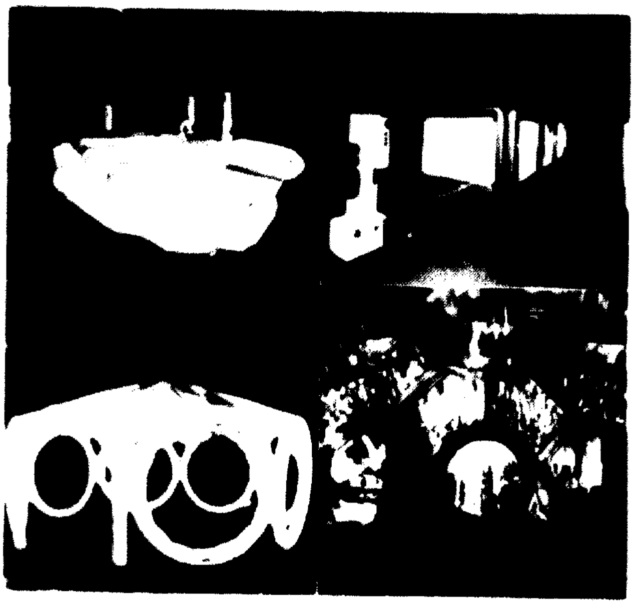

Figure 16

The ever increasing awareness of the use of plastics materials in building or as building components has caused numerous small concerns all over the United States to become involved with many phases of this industry. These small firms produce everything from structural elevator cabs to church steeples, from building cornices to total facades, from structural domes to radomes, from canopied shopping centers to swimming pools.

A recent development in the United States is the extrusion of vinyl clapboard for housing exteriors and which can replace wood or aluminum. Produced by Extrudyne, Inc. of Amityville, New York, these thin PVC profiles are colorful, strong,weather resistent and non-flame supporting.

CANADA:

Polyfiber Limited of Renfrew, Ontario, in cooperation with the canadian Federal Department of Public Works, designed and built a glass reinforced polyester sandwich panel structure known as the Frobisher Bay School in the Northwest Territory of Canada. The school is for Eskimo teenagers who reside less than 200 miles south of the Arctic Circle. The two-story building used a steel framework with reinforced panels throughout. Designed by Montreal Architectural firm of Papineau/Gerin-Lajoie/LeBlanc, it was ready for occupancy this year and will serve over 475 students from the Baffin Island and Keewatin regions.

Flame retardent polyesters were used in association with flame retardent urethane cores. The 384 panels used were constructed by hand lay-up techniques and are 14 feet six inches high, six feet in width and have thick FRP skins on both sides of a two inch urethane core -- making a total thickness of two and one quarter inches. The panels were made white to eliminate glare. The 40,000 square feet of wall surface was built to withstand 100 mile per hour blizzards and cold spells of $-50°F$. Weather resistance to wind whipped sand and gravel demanded a heavy gel coat.

The panels were erected by a five man crew, using only a long ladder and hand operated rope blocks. Thirty-five working days was all that was required. Gasketing was done with polyurethane foam saturated in polybutylene.

The physical characteristics of these panels used in this most unusual condition are as follows:

Tensile strength....................	12,000 - 17,000 psi
Flexural strength..................	28,000 - 35,000 psi
Shear..............................	9,000 - 14,000 psi
Flexural modulus...................	2.5 to 2.9×10^6 psi
Thermal expansion..................	1.86×10^5 $70°F$ to $-50°F$
Young's Modulus (modulus of elasticity in tension).........	$0.8 - 1.5 \times 10^6$ psi
Thermal conductivity...............	1.8 to 1.9×10^{-7} BTU/hr./ft./in./°F
Barcol.............................	45-50 (on gel coat)
U Factor...........................	0.05 BTU/ft.^{2}/hr./° F
ASTM E-84..........................	Under 25

MEXICO:

Although the glass fiber industry is scarcely more than a dozen years old in Mexico, it has shown an amazing growth -- and construction markets are just beginning to realize its benefits. Reinforced plastics in construction is now over 18% of their market -- with much of the product going into molds, pans and column molds for concrete.

A glass fiber reinforced polyester house, however, has been developed in Durango and that State is now planning to produce units patterned after this prototype as both low cost housing and as motels in resort areas.

Another Mexican building worthy of mention is the Polyforum Cultural Siqueiros in Mexico, D.F. The building, in four levels: parking, commerce, lobby and mural exhibition, has a floor area of 23,000 square feet. The most impressive part of this building is the 35,000 square foot mural painted by David Alfaro Siqueiros. This priceless mural is protected by a false ceiling , roof and polychrome exterior building walls -- all made of glass reinforced polyester. The false ceiling alone is some 11,000 square feet and its complex shape and immense size could only be successfully constructed in these materials.

Finally, the "structural Gold Medal winner" of Mexico's 1968 Olympics was its Sports Palace. Its 230,000 square foot geodesic dome was sheathed entirely in copper. After the Games, it began to lose its reflective beauty and a protective coating was needed. Unfortunately, the realization of this need was late in coming. Smog and corrosion had caused considerable damage. Only one experimental section which had been covered with an acrylic lacquer remained in tact.

Fortunately, last year, its Architect Felix Candela working in association with the Mexico City government, the International Copper Research Association and Rohm & Haas Company of Philadelphia, Pennsylvania solved the problem by having the dome cleaned and the entire surface covered with a protective acrylic coating. The 1970 refurbishing job has given back splendor as "the Palace of One Thousand Suns" and again plastics materials have made a new inroad in the building field.

AUSTRALIA:

[illegible] Pty. Limited, 221 Miller Street, North Sydney, N.S.W. is in the process of building two revolutionary high-rise office buildings: one in North Sydney and one in Perth (Figures 17 and 18). These structures designed by Vittorio [illegible] utilize some of the most progressive building techniques and probably the greatest use of plastics materials in any single commercial building.

The basic structure of the 22 story building, 27[illegible] feet high, is unique. The whole of the horizontal wind load is taken by the service core and the north wall which have been constructed in reinforced concrete with a slip form method. The floor slabs are pretensioned. Each floor is approximately 76 feet wide and 1[illegible] feet long with no internal columns. The minimum floor spans are [illegible] feet in the center and 75 feet at the east and west ends of the building providing a total net office space of almost 7,000 square feet per floor (Figure 19).

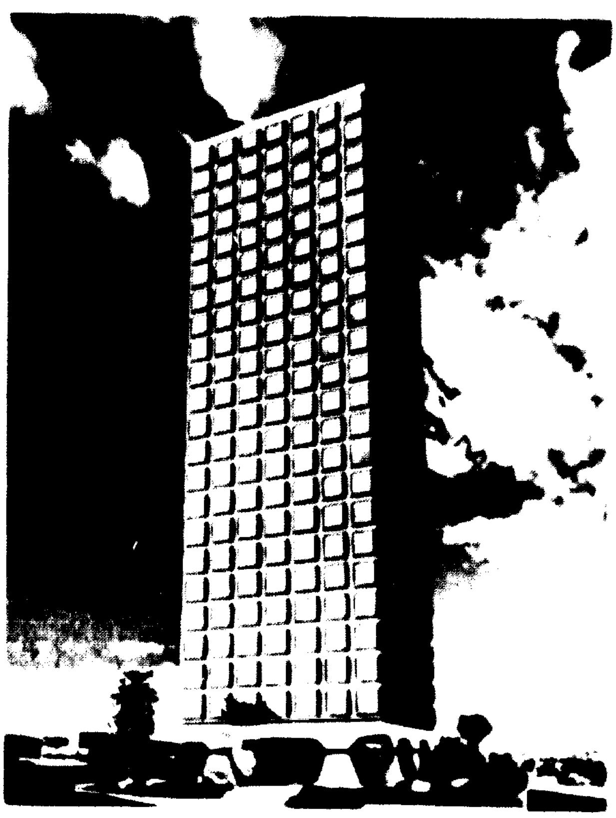

Figure 17

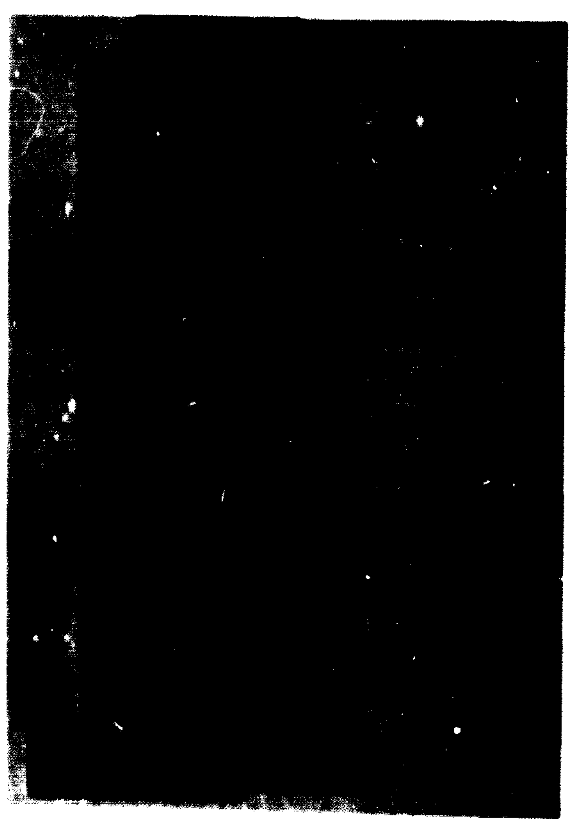

Figure 1[illegible]

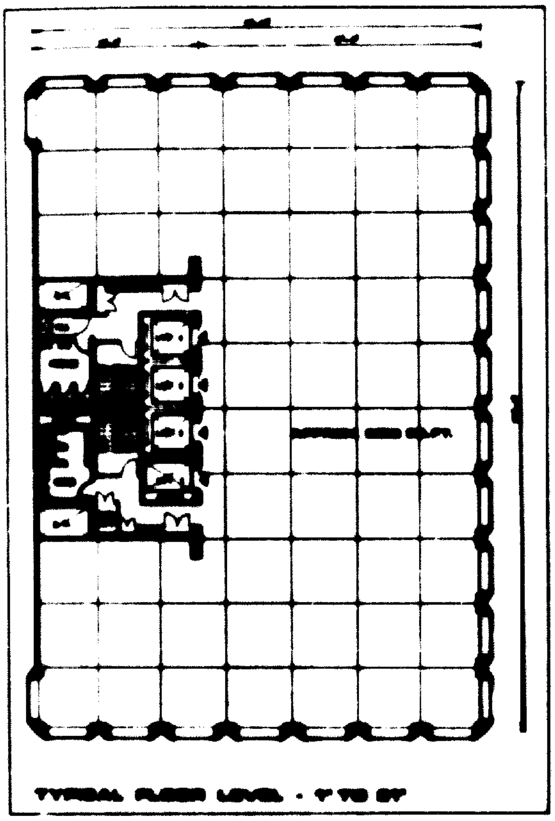

Figure 19

The only connections from floor to floor are via the service core and the peripheral columns which are cemented to each other, top and bottom, with epoxy resins (Figure 20). The live load capacity of the floors is 100 pounds per square foot increasing to as much as 200 pounds per square foot at the north-east and north-west areas. The column-free floor expanse provides maximum flexibility in office design and layout as movable FRP partitions can be placed at will to form the most advantageous space-use of the area.

Figure 20

Since the Sabemo buildings are extra light weight construction, the curtain walls, too, must also be light weight. Mr. Moratelli has revolutionized Australian conservative building by using colorful curtain walls (orange in North Sydney; bright blue in Perth) made of eleven foot squares of FRP with seven foot four inch square glazing centered in each (Figure 21). Although he would have preferred to

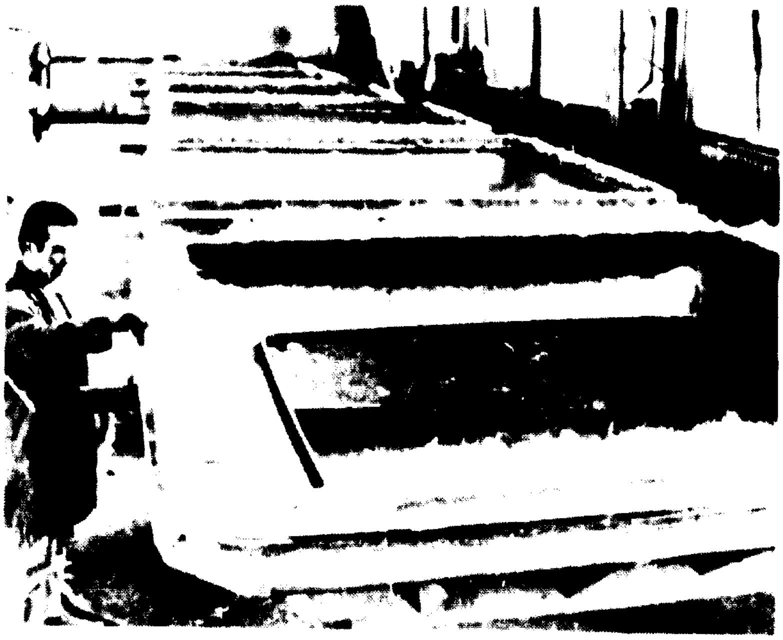

Figure 21

use acrylics, it was impossible to obtain such large sheets in his area. The glazing is double skin insulated reflective glass, allowing a 160° visual exterior span or projection. The effect is startling and provides maximum usage of FRP as high-rise curtain walls (Figure 22).

Figure 22

The lobby area is designed as an FRP tunnel approximately 66 feet in length and 22 feet wide with acrylic domes and recessed fluorescent light in the molded ceiling (Figure 23). Throughout the building, FRP lavatories are used wherein walls, bowls, pedestals and recessed mirrors and lighting take advantage of the strength and sanitary qualities of the reinforced polyesters. Structural elevator cabs and other refinements such as partition walls, lobby lights and planters, ducting and trim are also of FRP.

Another Sabemo building designed by Vittorio H. Moratelli is their corporate headquarters. This structure, built in 196[illegible], was constructed in concrete poured in FRP molds. On top of this 14 story structure, 190 feet above street level, is Australia's first all-plastics FRP-urethane sandwich dome used to house air conditioning machinery, plumbing and other utilities. Measuring 60 feet in diameter and 27 feet in height, this eight ton dome was built in 12 sections and erected on and attached to a concrete plinth in less than eight hours. Hoisted to the roof in sections, it was built to withstand winds up to 150 miles per hour. It is considered to be the largest dome of its kind in the Southern Hemisphere and is a landmark on the North Sydney horizon (Figure 24).

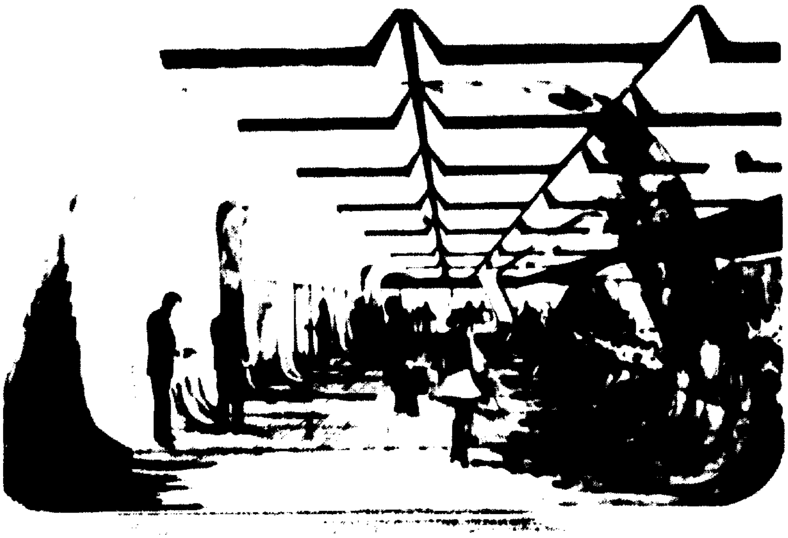

Figure 23
(see also Fig. 23a on page 46 of report)

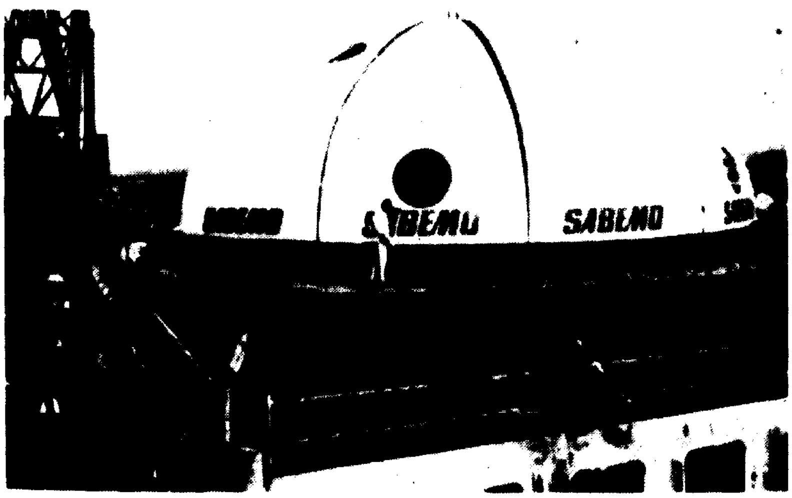

Figure 24

Dr. Jens G. Pohl, a faculty member of the School of Achitecture and Building of the University of New South Wales in Sydney, in 1967 conceived an unique high-rise building structure system based on multi-story air inflated towers. Although no full scale prototype has yet been built, a new ten story scale model was recently sponsored by and is currently displayed at the Sydney Building Information Centre Ltd.

The Pohl theory is based on an inflated flexible tube with sealed ends. Although the tube is non structural in its deflated state, it stands upright and becomes load bearing when supported by a column of air (Figure 25). The skin membrane may need to be reinforced, but the building itself can resist bending, buckling and torsion.

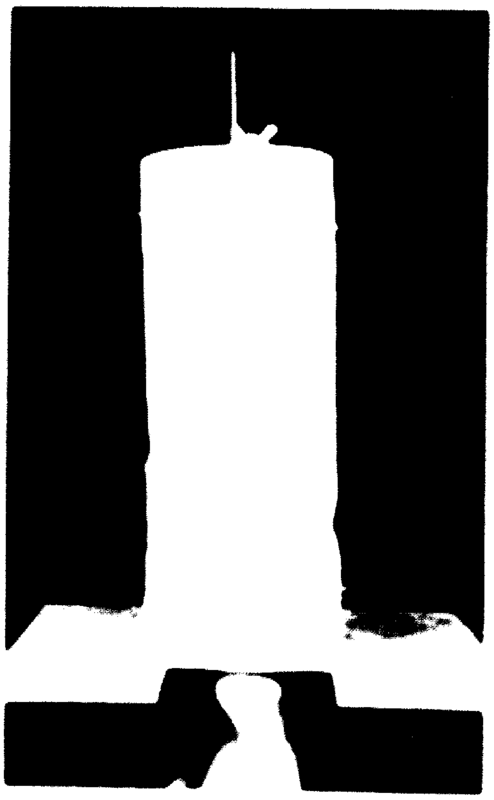

Figure 25

A series of circular floors are attached to the upper membrane by means of a bearing floor. As the column is inflated, these floors will be carried (attached and suspended by cables) upwards as the column grows (Figure 26). A rigid center shaft would provide elevators or stairs and access into the building proper would be through an airlock tunnel.

The risk of puncture is minimized by the strength of the plastics skin plus other standby equipment. Some tough films already exist including nylon scrim based laminates capable of yield strengths up to 1,000 pounds per inch, but these scrims preclude the clarity factors needed aesthetically and visually in the outer membrane.

Dr. Jens G. Pohl's concepts are challenging. The existence of air

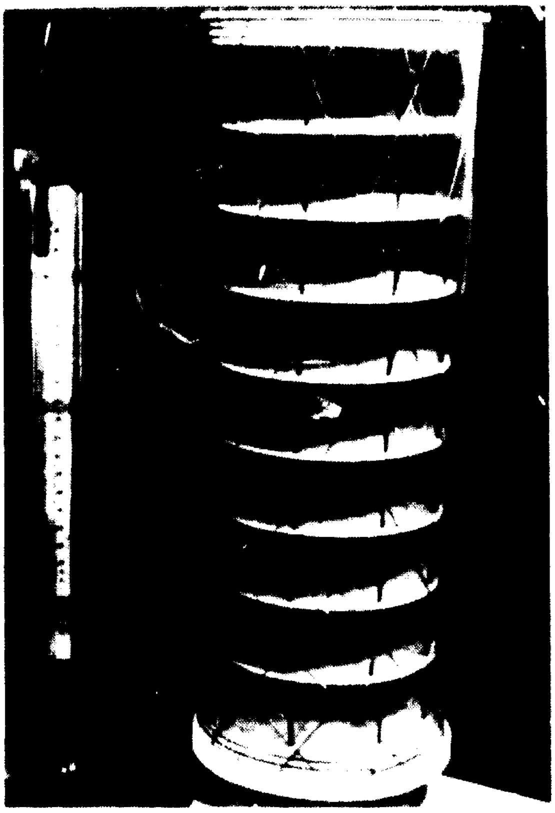

Figure 26

Figure 27

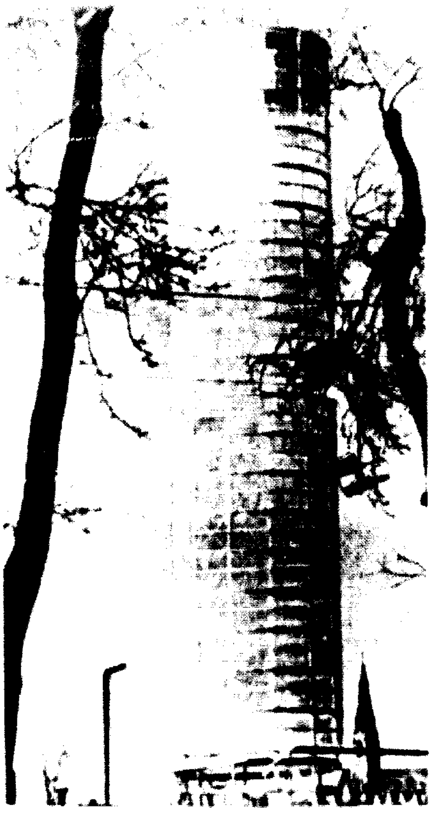

Figure 28

inflated buildings as storage buildings, exhibition halls, green houses and covers over tennis courts and athletic fields are commonplace. Dr. Pohl suggests greater and broader uses based on sound plastics, pneumatic and mechanical engineering principles and ranging from small two story bungalows (Figure 27) to full scale 14 story buildings (Figure 28).

Other plastics structures have been developed in Australia. Although their markets are small compared to those in many parts of the world, their need for low cost housing is amplified in two prime areas: in the [illegible] where their "[illegible]" are extremely expensive even for the affluent [illegible]; and in the "Great Out Back"....those regions being opened to mining, oil drilling and general expansion.

Transtar Villas Pty. Ltd. of South Australia won the 1969 Prince Phillip Design Award for their all-plastics unit (Figure 29). It is a one-piece molded shell sandwich composite of glass reinforced polyester skins over a rigid PVC foam core 2 inches thick. The outer skin has a specially applied film which serves both as a surface color layer and as an ultra violet stabilizing screen. The one piece shell construction includes ceiling, floor and walls. Ends, internal partitions and glazing are added later. The basic module unit is 24 feet long by 14 feet wide. The raw materials used are non-flame supporting and termite proof. The absense of seams and joints minimizes weathering and leaking problems.

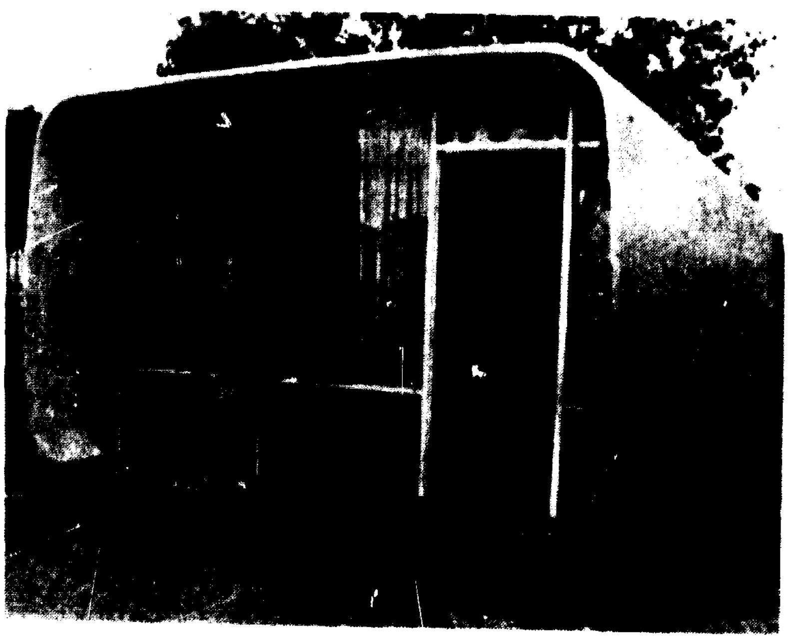

Figure 29

The basic design is a rounded oblong not unsimilar to the design developed by the Architectural Research Laboratory of the University of Michigan, Ann Arbor, Michigan in 1968 (Figure 30). Each of the Transtar units has integrally molded-in wiring and plumbing and is fully equiped and furnished. Their units can be used singly, in groups attached to each other on one level or stacked two or three high. The units are currently being sold for approximately $4950 Australian.

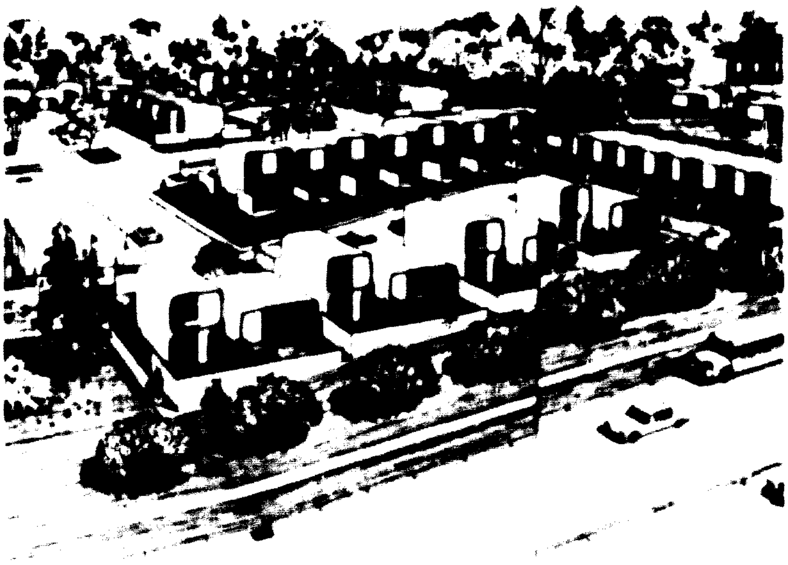

Figure 30

Figure 31

In 1965, the Housing Commission of Victoria initiated a research and development project aimed at the production of a villa which could be economically and efficiently produced within their State within a four to five year period.

Today, successful villas are being built (Figure 31). The external walls are 2 inches thick and consist of four feet by eight feet sandwiches of calcium silicate flexboard with one and five eighth inch cores of rigid polyurethane foamed in situ at two pound density. Steel edge columns are fabricated in place in the panel and increase resistance to fire as no oxygen can reach the enclosed core. Internal partitions are basically [illegible]-board. Such housing, although it uses limited amounts of plastic materials, show savings of from $250 to $1,[illegible] Australian.

Finally, three Sydney designers: Architect Reuben Lane, Designer John Anderson and Engineer John Johnson have designed a reinforced plastics house based on a two foot six inch module. Lightweight in construction, this dwelling has a central service unit from which shell-like wings radiate (Figure 32). The designers estimate that a 250 square foot module could be produced finished for approximately $2500 Australian...or about $10 per square foot Australian.

Figure 32

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WHAT IS LOW COST HOUSING?

Housing costs today are relative. The United Nations refers to low cost housing in developing countries in the standards of those regions in which housing is most desperately needed; i.e., East Africa, Central America and Indonesia. Because of the imbalance in currency values, many materials which Americans consider inexpensive are too expensive for developing or impoverished countries. The use of substantial amounts of inexpensive or no-cost native raw materials with small amounts of the expensive additives and/or binders provides the answer. Thus, where we consider systems using polyester-glass and urethane as potentially inexpensive housing according to our (American) standards, in many countries these systems are far too expensive to consider. However, were we to suggest the use of small amounts of polyesters as binders to native bagasse, sand or dirt, we begin to approach a system for low low-cost housing in the terms of that country's economy.

The fact that many ethnic designs indigenous to the lands are simple to reproduce makes such systems feasible. It is much less sophisticated to reproduce the teepee, hogan, yurt, long house, bure or hut than the more highly stylized ranch house or bungalow. Thus, in our own environments, low cost housing becomes an acute problem.

Low cost housing is often confused with poor design, but as we have discussed, it is apparent that with only a little sensitivity and planning, this need not be the case. Whatever its shape, however, low cost housing provides shelter for those who have no housing whatsoever. It provides sanitary and comfortable shelter for those who now live in poverty , ghetto, slum, waste lands or otherwise substandard conditions - and it can provide long lasting, more permanent, more convenient, maintenance free and less expensive dwellings for those who fall within the lower income brackets. Many of these people are forced to live in rented quarters - or with relatives - because they cannot afford to purchase the moderate or high priced housing which is available.

Low cost housing must not be confused with emergency housing or housing for low income families. The government, state or city usually provides low income housing as high-rise buildings which are controlled for low rents. One emergency housing system developed by the author has been described in the original 1969 survey.

WHAT HAS BEEN DONE

Several interesting current systems developed in the United States closely approach what can be considered as low cost housing. A recent nine company survey of modular construction in New York State indicated a wide range of costs. One system, however, was lower by 25% than the lowest of the other eight studied. This system indicated that on a limited profit basis, it is possible to build low cost housing (net) at $7.31 per square foot ready for occupancy. The company providing these fantastically low figures is associated with the Community Action Organization of Erie County, Inc., Buffalo, New York which was organized to provide low cost housing beyond ghetto conditions in Buffalo.

James A. Bryant, Jr., Deputy Executive Director, states," It is not that the need for shelter is a paramount world issue. The United Nations, along with every individual country in the world, is striving desperately to meet the exploding demands for adequate housing - and its concomitants: hospitals, clinics, schools, etc. The greatest obstacles to solving this problem are costs, financing and the availability of the necessary skills.

"It is news that a method has been developed for construction and overall techniques that breaks through the cost barrier, facilitates the financing, makes possible professional results with unskilled labor.

"The breakthrough to low cost was resolved by inventive acumen in the use of manmade materials of almost magical properties; mechanizing the production of material and the construction of the units to the point of saving weeks of time and labor, which can include engineering a portable. demountable producing plant that is set up on the project site.

"Throughout the construction plastics are used wherever possible. Modern technology has far advanced the functions of plastic for construction in many forms. Actual long-term usage has proven its durability and utility. Its lower cost is clear."

The ideas of James Bryant coupled with the genius and foresight of ex-investment specialist George Weinrott have made the Erie Project a success. At 77, George Weinrott is a vital, industrious, far seeing, idealistic and very successful builder who is working with James Bryant on a limited profit basis through his company, Urethane Systems, Inc. of Buffalo and New York City, New York. Their method uses non-flame supporting urethane foam coring sandwiched between Upsom Board (pressed paper), plywood or other standard skin materials; i.e., plaster board, wood panelling or melamine laminates.

First, the workmen prepare framing strips on which the skins are applied with air gun riveting and formaldehyde based adhesives. The frames are complete with door and window cut-outs which have also been appropriately framed. Floor and ceiling panels consist of plywood skins three eighths inches thick for bottom skins and one half inches thick for top ones. The hollow panel is 24 feet long, 12 feet wide and having a five inch thick cavity. One inch beams placed every six feet along the 24 foot span adds strength. The entire panel is then framed by two inch by four inch beams on all four sides. Throughout the units, all vertical walls are one quarter inch plywood or vinyl covered Upsom Board on the interior walls and one quarter inch Upsom Board on the exterior. Fire walls are constructed of one inch gypsum board skins.

One half inch diameter holes are drilled every six inches into the top edge of the panel. The panel is now placed in a steel platened hydraulic press and 14 foot probes feed a predetermined amount of 2.2 pound density foamed urethane into the cavities. Contained by the steel press, the panels are held flat and parallel against the foaming action of the expanding foam (six pounds per square inch) or 125 tons over the twelve foot by 24 foot panel). The pressure of the expanding foam locks it into a permanent bond with the panel skin. Curing takes 20 minutes and the completed panel is a load bearing structural component.

The four walls are fastened to the floor and ceiling at the appropriate positions using overlapping joints and are held together with resorcinal formaldehyde adhesives having holding strengths of 3,000 pounds per square inch. Silicone rubber roofing is applied in a horizontal position prior to roof placement.

After assembly, electric lines and plumbing are installed. Wiring is fed into raceways of PVC conduit. Heating is the baseboard type. Drain, waste and venting systems are PVC. All electrical attachments and any plumbing inside the cubicles are outside of the panels which provide easy access without disturbing the integrity of the urethane core.

Completed cubicles in the plant contain all appliances - washer, dryer, stove, refrigerator, kitchen cabinets, sinks, garbage disposal units, air conditioning, closets, wash bowls, toilets, tub and shower, tile, wall-to-wall carpeting, ceilings and interior partitions. All painting, wall papering and trim work is done in-plant. The unit is between 90% and 95% complete before it leaves for the construction site.

A typical dwelling consists of three completed cubicles for the first floor and three completed cubicles for the second floor - or a house with three bedrooms, living room, kitchen, dining area, utility room and one and one half baths -- covering a total area of 1,400 square feet.

The cubicles are now ready to leave the plant. At the site, land is graded. Foundations consist only of concrete piers which have been poured into 24 inch diameter paper sauna tubes set into the ground and rising 18 inches above grade. Anchor bolts are set into wet concrete. Metal pipe sleeves are placed over the anchor bolts as well as plumb and level sole plates. The floor sections have matching metal pipe sleeves so that they can be slid into appropriate locations. Nine piers are used for each house. Foundations are completed in one day.

The cubicles now leave the plant by truck and are lowered in place by boom cranes. After securing the first floor to the piers, points of contact for the second floor are covered with more resorcinal formaldehyde adhesive and the top cubicles are set in place. Total time: eight hours.

The house is now virtually completed. Exterior finishes are applied such as vinyl aluminum clapboard, aggregates in epoxy, glass reinforced polyesters, stucco or conventional coverings. Landscaping can be completed within several days. The house is livable as soon as the upper cubicles are in place and the service lines connected.

Overall cost statistics for this unit place 90% of the burden on raw materials and 10% on direct labor. A 1,400 square foot house takes 300 man hours of labor which includes both in-plant and on-site operations. Current operational plans call for 300 units (complete houses) per month per plant, working two shifts or 16 hours per day. At present, the $7.31 per square foot of completed house is increased to $8.00 but this includes landscaping. Limited profits, costs of land, land preparation,closing fees, mortgaging and sewers must be added.

The Erie Project homes in Buffalo are being built to sell for $10 per square foot. This includes $1,000 for land costs in the poorest area of the city. This cost also includes a "prefabricated" mortgage: the principal and 1% interest on a 40 year loan. Thus, a person can take over one of these units for $200 to $300 down and pay $69 per month plus taxes over the 40 year mortgage term. Closing costs and legal fees have become minimized or eliminated. Depending on how limited the profit structure becomes, the houses could sell for from $14,000 to $17,500 each depending on a fair profit, the locality and whether there were government subsidies available to supplement the differences between cost and selling price.

Plans for the extension of such projects to Florida and West Virginia are in effect. Additional plans include the setting up of manufacturing facilities at a given site to produce 2,000,000 square feet of homes - or approximately 12,500 units. The equipment would then be moved to a new site - and the factory converted to a recreation center, shopping mall or school. The English are currently studying the Erie Project and are contemplating the use of their basic units set into 24 story space frames where the cubicle serves as a box girder to strengthen the upper framework of the total high-rise structure.

All supplies, equipment, roofing and materials in these homes have been pretested to survive the 40 year life of the mortgage. George Weinrott believes that there is no use sacrificing basic costs since the reflection in the overall mortgage is negligible - and the maintenance-free house is most important.

The Erie Project homes are successful -- so successful, in fact, that several have been set afire by forces opposed to these revolutionary building tactics. Although code problems have not been totally resolved, public pressure - and pressure by radio, television and news media - are forcing Buffalo building officials to re-evaluate their position.

The Erie Community house components have passed innumerable tests. There are no leaks; the windows close with ease; the interiors "breathe". Loading tests on floor sections have convinced Buffalo officials that these sections are self-supporting and do not need more foundation piers. Heat tests were conducted on the urethane core with Upsom Board surfaces: a six foot by 12 foot sandwich with a seam running the 12 foot length was loaded with concrete blocks - 100 pounds per square foot and measured for deflection. The deflection was one inch. The panel was then placed in an autoclave under the same weighted conditions and heated by a propane gas burner to 600° to 700°F for 32 minutes. The panel deflected four inches, and the Upsom Board burned off, charing the urethane surface. After cooling, however, the panel returned to within three quarters of an inch deflection of its original flat plane. During the actual fire, previously mentioned, the Upsom Board burned off, charing the urethane, but not burning it.

Another project in low cost housing is underway by G-F-G Industries of West Babylon, New York, initiated by its President Jack Donohue. His house is also reminiscent of and not unsimilar to the units developed by the Architectural Research Laboratory of the University of Michigan in 1968 (Figure 30). Jack Donohue uses all-plastics and has designed inexpensive molds made of melamine laminated to plywood and set into a steel framework. His reinforced units are made in two sections which are later bolted together.

Since the halves of his structures are identical, he can use one set of molds, then use his completed halves interchangeably. His first mold is a female in which the outer skin is layed-up. A polyester gel coat is sprayed for color, then backed up with .050 inches of non-flame supporting glass fiber reinforced polyester. The interior skin is made similarly, but by using a male mold which provides a gel coated interior panel. Both reinforced skins are left on their molds. The interior mold is then set inside the exterior mold so that the inside shell is held three and a half inches from the outside shell. Conduits for wiring and pipes for plumbing are place appropriately in this cavity. Next, non-flame supporting polyurethane foam is foamed-in-place between these two skins forming a sandwich four inches thick with pipes and conduits locked in place. The molds are then removed.

Two such units are bolted together - one opposite the other - to create a hollow box with a slightly curved floor and ceiling. A floor is placed in the structure. The space beneath the floor is used to hide additional wiring, plumbing or other unsightly necessities. A prefabricated, glass reinforced polyester water closet is attached to the open rear together with a utility room. This closes the back end of the unit. The front end is mullioned to accommodate a glazed door and full half span picture window.

Each unit is 16 feet wide by 22 feet long and nine feet high at the median point. Kitchen, baseboard or wall type electric heaters, internal partitions and aesthetic interior considerations such as carpeting,wall paper, wood veneer panelling, cupboards and closets are all added after the sections have been bolted together. Mr. Donohue states that a unit can be electrically heated for $68 per year.

His completed unit is trucked to a site where it is bolted to six concrete piers. It needs no foundation.

Should more than one of these 352 square foot units be desired, they can be made without duplicating kitchens or baths, then attached in tandem, or alternating patterns. They can also be stacked. The G-F-G units are planned to sell for approximately $10 per square foot installed, but exclusive of land or land preparation. Code problems still preclude the use of this house in most areas.

In summarizing and evaluating these first two low cost housing systems, the Erie Project used plastics as plastics to their best advantage although there is a disappointing lack of them as skins in the basic panels.Some of their bathroom furniture (tubs and sinks) were often imported English acrylics. The G-F-G house is entirely plastics in construction, though they have used other materials in the interiors and furnishings. The basic difference between these two projects is purpose. In order to mend a broken community, houses are needed and to fabricate enough houses to make a community, production methods - however cumbersome they may seem - are needed. The Erie Project is based on a philosophy to answer a human need. The G-F-G house has been designed primarily as a vacation home, which can also serve as a low cost dwelling. It is really a single unit to be carried away like other merchandise. G-F-G is not so much concerned with housing as it is with lowering the cost of the structure. Both projects are established and dedicated, however, and it is only a matter of time and experience until the missing ingredients are fulfilled.

The Wisconsin Department of Natural Resources' new Bureau of Commercial Recreation made a survey aimed at better housing in which they refer to the "Plastics Module" consisting of "interconnected lightweight tubes designed to be constructed of precast sections of self-skinning urethane. The tubes are transported within the 12 by sixty foot limits for conventional highway movement and are connected at the site.

Continuous shading visors fold down from the roof once the units are in place. The basic module (Figures 33 and 34) includes living room, kitchen, bath and one bedroom. An additional two bedroom unit is added as required. Earth berms and terraced steps connect the structure to the landscape".

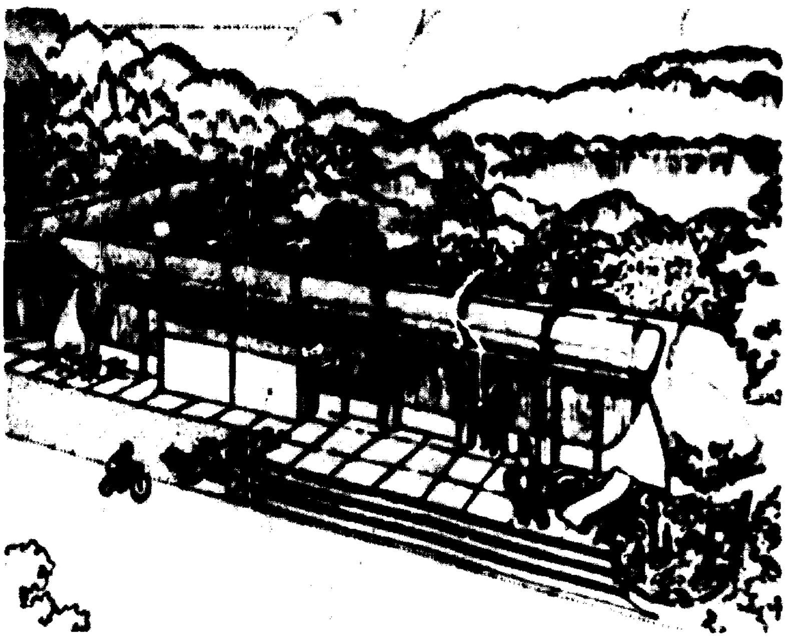

Figure 33

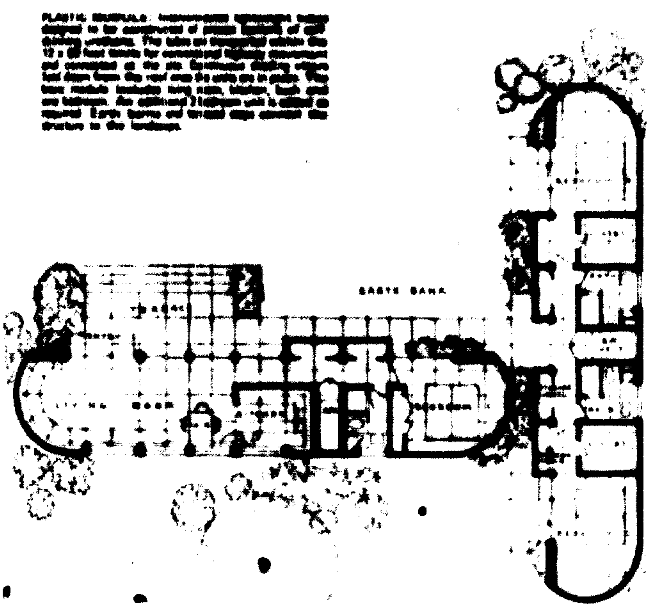

Figure 34

There are also many isolated forms of low cost housing using plastics, including free-form caves made by spraying urethane foam and/or glass re-inforced polyesters over burlap tents and stretched nylon. There are also foam filled vinyl bag environments. I have preferred to omit these from inclusion in this report in preference to a more conservative but realistic approach to the present problems.

Plastics materials provide freedom in design and concept. Who says that a window or door must be square or oblong? Why are we conditioned work in modules of two inches by four inches, four feet by eight feet, five feet by ten feet and so on? Because these are the modules, standards and preconceived units prescribed by the senior material producers. Most persons have difficulty in really thinking plastics and in using them to their fullest advantage.

WHAT CAN BE DONE

We, as consultants, have our own research facilities in which to experiment with new materials, methods, processes and ideas. We have been concerned with low cost and emergency housing for over 16 years. We work with architects, industrial designers and artists as well as with engineers and chemists. After many years of concentrated effort in the direction of low cost housing, we have developed a system for attractive low cost housing which is realistic, practical and reproducable NOW. Called the "Win-Mar Modular Plastics System for Low Cost Housing", it has been engineered and architected by our firm, Armand G. Winfield Inc., in association with architect and designer Anthony Marchese of Brooklyn, New York. The system, in order to insure low cost, utilizes over 95% plastics materials, all of which are readily available, and special processes for total automation which we have developed.

The "Win-Mar" system is based on two basic modules- left and right. The basic unit is 30 feet in length, 10 feet in width and ranges from eight feet six inches to 12 feet six inches in height. These latter dimensions are controlled by the folded roof design: 12 feet six inches represents the highest peak of the folded plates while eight feet six inches represents the lowest dip of any of the folded roof plates. With a set of basic molds, certain sections can be blocked off to create partial modules. Thus, with maximum blocking, six additional module sets can be produced providing a multiplicity of sections and numberless combinations of housing configurations can be utilized for planning either a single dwelling or a community.

The modules are constructed from non-flame supporting glass reinforced polyester skins .100 inches thick on either side of a non-flame supporting two inch thick two pound rigid polyurethane foam core for all walls. The roof is similar construction except for three inches of core. The floors are .150 inch FRP skins over a corrugated lower skin and separated by two to four inches of urethane core (Figure 35).

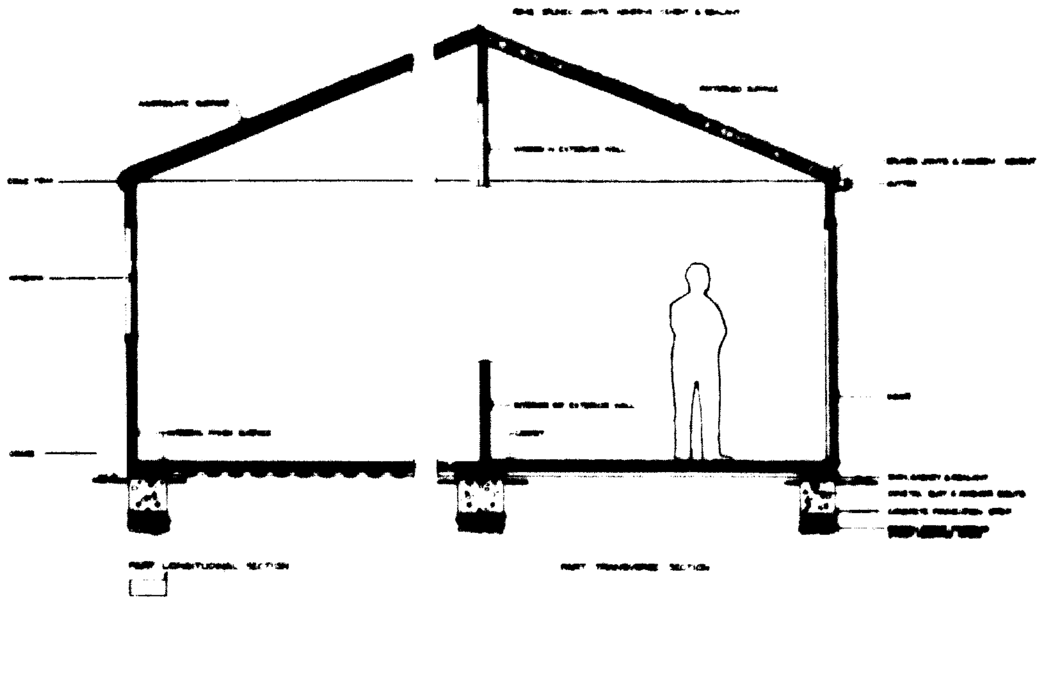

Figure 35

The costs of raw material for these modules are based on a glass to resin ratio of approximately 60:40 for spray-up techniques. Current United States costs for glass fibers range from $.28 to $.36 per pound. An average figure of $.32 per pound will be used. Polyester resins in large volumes can be purchased for as low as $.15 per pound, but with the addition of catalysts, color, flame retardents and other additives, a figure of $.20 per pound will be used. Two pound rigid polyurethane foam can be figured at $.50 per pound. The cost per square foot of the wall laminate will, therefore, be figured at approximately $.33 per square foot for raw materials. The raw material cost for the ceiling panel laminate will be approximately $.38 per square foot and the raw material cost for the floors will cost approximately $.55 per square foot.

In a basic module, there is 300 square feet of floor area, 340 square feet of roof and 546 square feet of outside walls. The total raw material costs for these laminate areas would be $474.38. Since the basic module is 300 square feet, the $474.38 figure must be divided by 300 to provide a raw material cost per square foot of completed house. This figure is $1.58 per square foot. Since the module, however, is open on one face so that it can be used in association with other modules, this figure might be misinterpreted. If, therefore, the module were to be treated as a complete 300 square foot house, an additional wall would have to be added increasing the raw material cost by $.60 per square foot or to $2.18 per square foot of finished house in that particular configuration. Deductions for door and window apertures have not been made; neither have provisions been made for internal partitions.

Since exact figures cannot be finalized until all design factors are clarified in accordance with location and/or ethnic considerations, we can only use the raw material cost of approximately $1.60 per square foot of completed dwelling. On terms of United States economics, to cover direct labor, overhead, machine and tooling amortization, plumbing, heating, wiring, water closet, kitchen, land preparation and a reasonable profit - preferably on a limited profit basis - the raw material figure of $1.60 per square foot would be multiplied by four. This final figure of $6.40 per square foot of completed house, less land costs, is considerably lower that others noted. This house is strong and has an anticipated life expectancy of at least 40 years.

Still on United States standards, a dwelling having 1,200 square feet of surface area could be sold, exclusive of land, for approximately $7,680. A 1,400 square foot home could be purchased for approximately $8,960 and a 1,600 square foot unit could cost approximately $10,240.

We are currently working on methods to reduce the raw material costs without sacrificing speed in production or changing the basic aesthetics by substituting expensive raw materials with low-cost or no-cost native products, by-products or natural resources in order to change the economics from low-cost to low-low-cost housing for such areas. In discussions currently underway with several republics in various parts of the world, the native labor rates, being so much lower proportionately to the American labor market, will reduce the overall costs of our units even farther.

The "Win-Mar" system is designed to provide the individual with freedom in his choice of house design without sacrificing cost. A series of blocks patterened after the actual module(s) are given to the prospective householder - or community planner. These blocks (Figures 36 and 37) can be arranged to form a pleasing and utilitarian structure. Mr. Marchese has also designed a series of typical units from a selected number of combinations (Figures 38 and 39) to show floor plans of such choices. Even row type housing has been included (Figures 40 and 41).

Guided by a series of available colors and textures, the prospective owner or inhabitant can choose roof color and style(slate,tile,grass),

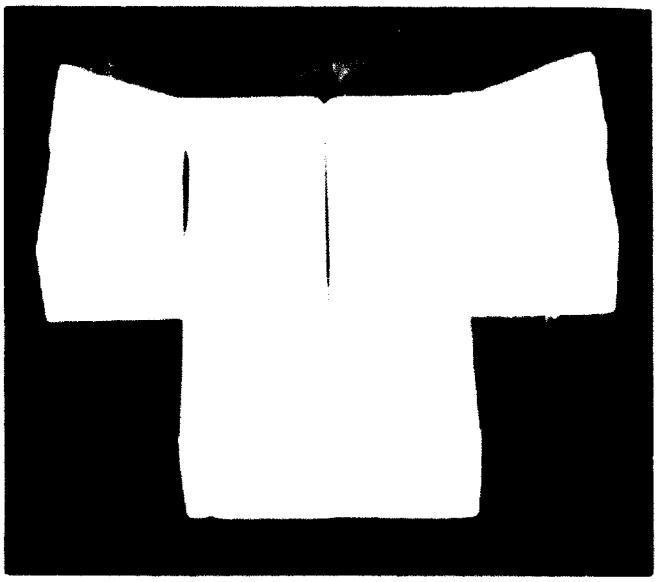

Figure 36

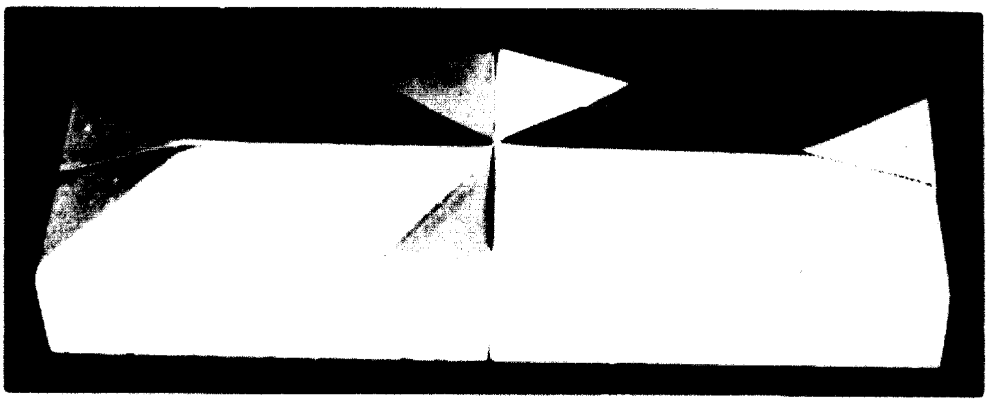

Figure 37

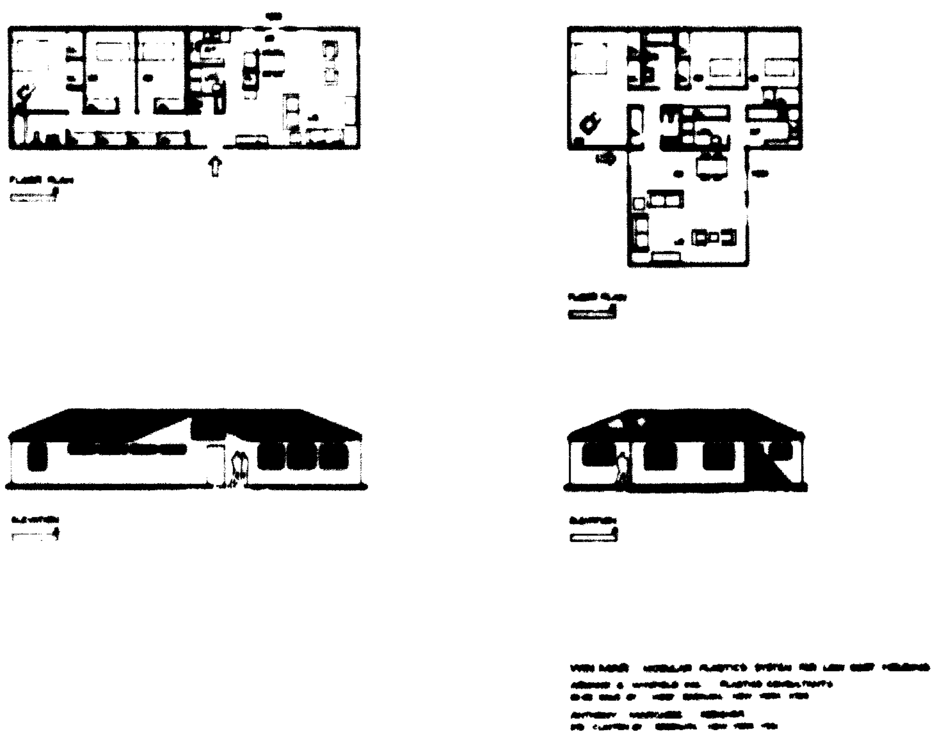

Figure 38

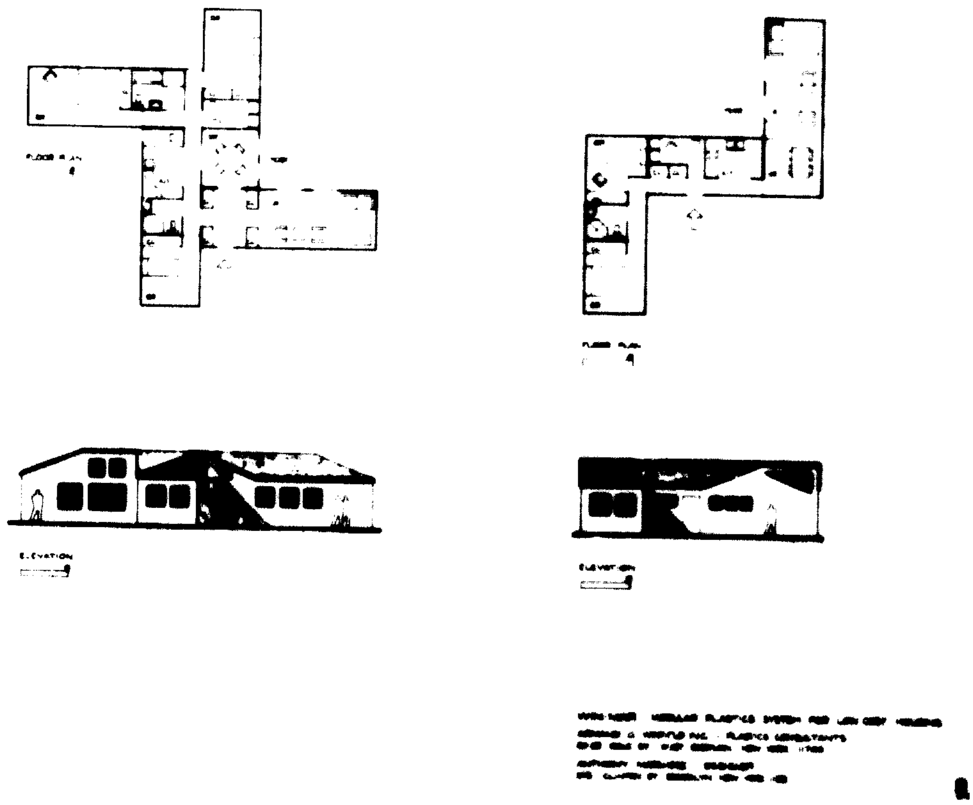

Figure 39

interior color scheme, exterior color and texture - and in many cases he would be able to choose internal partition arrangements.

Completed units would rest directly on the ground in some localities or on longitudinal foundation strips (Figure 35) in others.

The economics for the "Win-Mar" system are based on the manufacturing technology developed for this project.

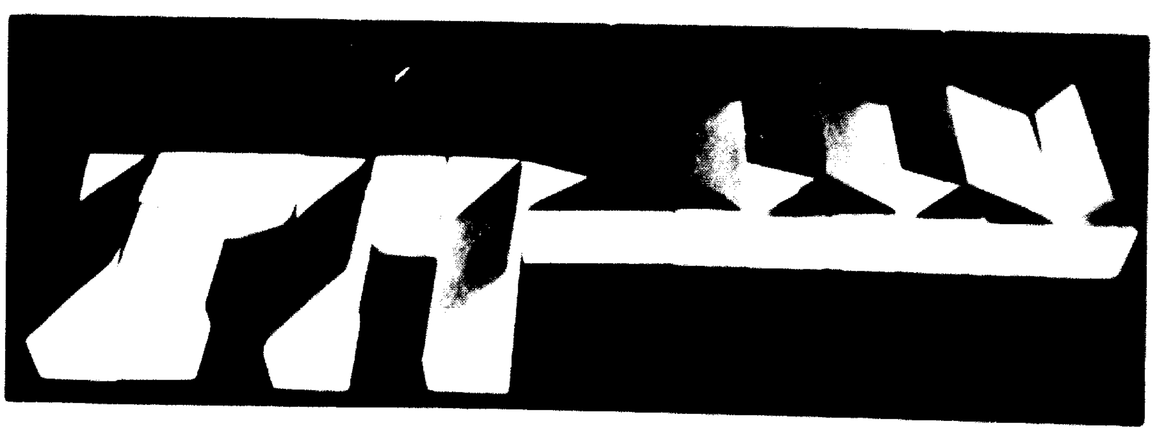

Figure 40

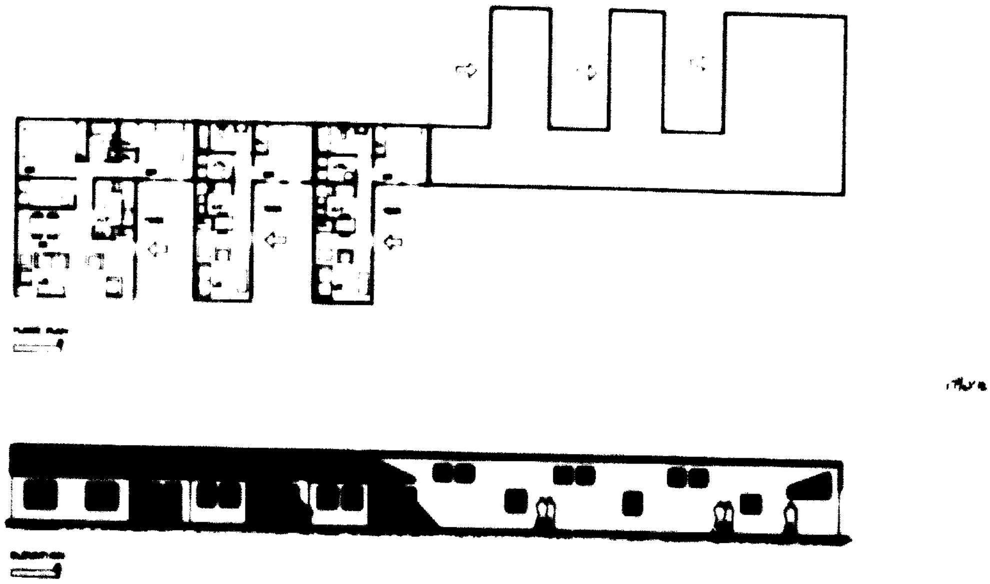

Figure 41

CONCLUSIONS RE LOW-COST HOUSING

With our tremendous technologies in man-made plastics materials as well as high speed sophisticated processes, we firmly believe that housing answers lie in low-cost communities, not in low-cost single dwellings. Our efforts to find answers in this decade will provide new generations with tools to achieve what they now seem to be seeking; i.e., new systems for living -- even for survival.

At present, we are convinced that low-cost housing can only become a reality if:

1) Companies - or countries - are willing to work on limited profits, but on large volumes of production

2) Mortgages and closing costs can also be "pre-fabricated" and financed at reasonable rates of interest over long term loans

3) Labor will limit itself to realistic wage demands and not resist new material usage

4) Municipalities will work to update building codes to allow for these dwellings

5) Governments will make commitments to back low-cost housing

6) The innovators, business adventurers and the dreamers will pool their resources and make the systems work

and

7) If the public - in all parts of the world - will exert its force to demand the type of low-cost housing that can be available to them.

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Figures 12 and 13	Courtesy of the New York Sunday News, New York, New York
Figure 16	Courtesy of Winzen Research, Inc., Minneapolis, Minnesota
Figures 17, 18, 19, 20, 21, 22, 23, 23a and 24	Courtesy of Sabemo Pty. Limited, 221 Miller Street, North Sydney
Figures 25, 26, 27 and 28	Courtesy of Dr. Jens G. Pohl, University of New South Wales, Sydney, N.S.W.
Figures 29 and 32	Courtesy of *RPRD Fiberglass Journal*, Sydney, N.S.W.
Figure 30	Courtesy of *Progressive Architecture*, Stamford, Connecticut

Figure 31	Courtesy of the Housing Commission, Victoria, Melbourne, Victoria
Figures 33 and 34	Courtesy of Taliesin Associated Architects of the Frank Lloyd Wright Foundation, Madison, Wisconsin
Figures 35, 38, 39 and 41	Drawn by Anthony Marchese
Figures 36, 37 and 40	Courtesy of Armand G. Winfield Inc. 80-82 Dale Street, West Babylon, New York.

Paper Respectfully Submitted,

Armand G. Winfield

August 27, 1971

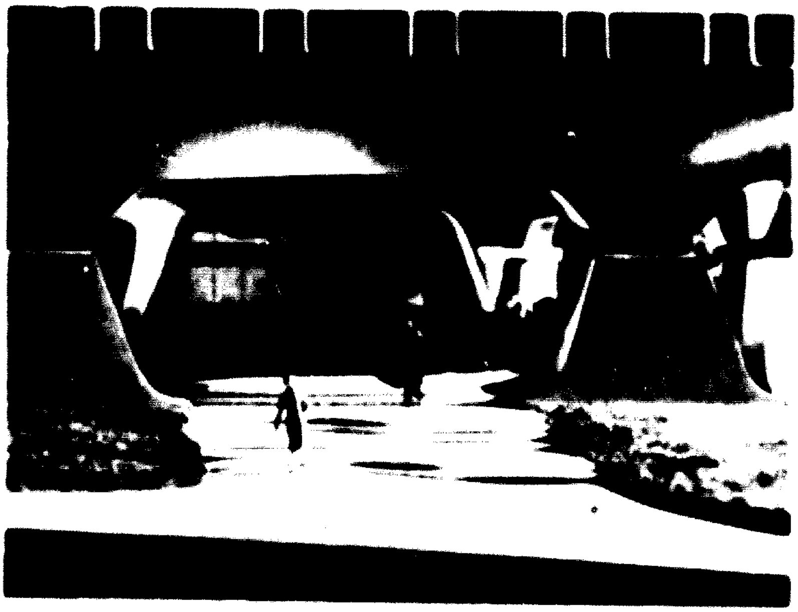

Figure 23a

(see pages 16 and 17 for reference)

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