

## PRODUCTION PROCESS OF MOBILE HOME CONSTRUCTION

Mobile homes are built in much the same manner as General Motors builds automobiles.

Some of the production principles involved are: adjacent work stations, work flow, division of labor, simultaneous operations, fixed operation sequence, similar interchangeable parts and components and standardized customer options.

Purchased products and raw materials are received in railcar and truckload quantities, routed through the off-line machining and sub-assembly departments and merged into the finished homes as they move along the final assembly line.

We shall first consider the off-line feeder departments and how they contribute to the total process.

The millshop converts raw lumber into the dimensioned piece parts required by the assembly departments. Examples of the machines and operations performed here include multiple or gang-rip saws, radial arm cross-cut saws, mortise and tenon machines, dado saws, sanders, planers, shapers and panel saws.

Much of the material from the mill flows on into the cabinet assembly department. Among the items built here are the kitchen cabinets, vanitory cabinets for the bathroom, chests, buffets, special dividers and all the drawers used throughout the mobile home. Another operation is the lamination of materials to form counter and sink tops. Passageway, hollow-core type doors are another item produced within this department.

The metal fabrication department converts coiled steel and aluminum into sized and formed panels, trim and roofing sections. The main process involved is called a metal line. The metal line begins with a decoiling reel, from which the continuous ribbon of metal is fed through an edger that forms a weatherproof joint where panels will be mated on through an automatic shear that cuts the ribbon to predetermined lengths and then to a stacking machine where the newly formed panels are palletized for mechanical transportation to the usage areas.

Another feeder department is the framing group. Here the sidewalls, endwalls, interior partitions, wood-roof assembly and truss rafters are manufactured. All of these units are completely pre-built before moving to the final assembly line. Sidewalls, as an example, are constructed on a horizontal jig which allows the assemblers to quickly and positively position the required structural members. Pre-cut studs, headers, top



and bottom rails are dropped into position and power-stapled to form a required frame. After the glue is applied, pre-cut panels are positioned and secured. These panels form the interior wall surfaces of the unit. Upon completion, the entire sidewall, as much as sixty feet in length, is moved into a storage area to await final assembly.

Smaller, off-line sections include heat duct fabrication and the construction of the plumbing assemblies which includes both the copper water supply system and the drain lines.

As in any modern manufacturing plant, constant effort is made to maximize the amount of off-line assemblies so as to allow shorter on-line cycle times.

The final assembly process starts in the welding shop where steel I-beams, structural crossmembers and the hitch are placed in a jig and welded together to form the steel frame. At this point, the frame is in an upside-down position. The frame is then moved to the next station where the running gear, tires, wheels, axles and springs, are attached and the unit is then turned over. From this point on through the assembly process the unit will move on its own wheels.

The unit is then moved into a paint room where the entire steel frame is spray painted.

Next, the steel frame is mated to the wood floor assembly. This wood floor assembly is jig-built using 2' x 6' floor joists, 16" on-center with 16-penny nails. Again, this assembly is built in an upside-down position. The complete heat duct assembly, fabricated off-line, is moved in and mated to the wood floor assembly. Fiberglass insulation is added and then covered with asphalt impregnated fibreboard panels which are power-stapled to the joists. A transfer mechanism then picks up the assembly, rotates it 180° and positions it to the steel frame.

Moving on down the line, the wood floor assembly is then lag-bolted to the steel frame. The water supply and drain assemblies are laid into the floor, and the plywood decking is applied and secured.

At the next station, the plywood deck is power sanded and then covered with carpeting and/or seamless resilient flooring. The crew loads all the required cabinets and interior partitions, distributing these to their approximate final locations.

The unit then moves into the next station where the four exterior walls are brought from storage, positioned and secured to the floor. As this is being done, other members of the crew set and begin to secure the interior partitions. Once the



exterior walls are positioned and as these are being secured, other men start stringing the rough electrical wiring and applying the fiberglass insulation.

Moving to the next station, the wood-roof assembly (built as a single, 60' x 12' unit, for example) is crane-carried from storage, positioned and secured to the sidewalls. Concurrent with this, the rough wiring is completed, the furnace is set and the cabinets are set and secured.

The unit then moves through stations where the pre-cut aluminum exterior siding is applied, the metal roof is unrolled and secured, the windows and exterior doors are mounted and the clearance and tail lights are secured. Inside the unit, the bath fixtures are installed, the cabinets and partitions are secured to the ceiling and the finish electrical installation is begun.

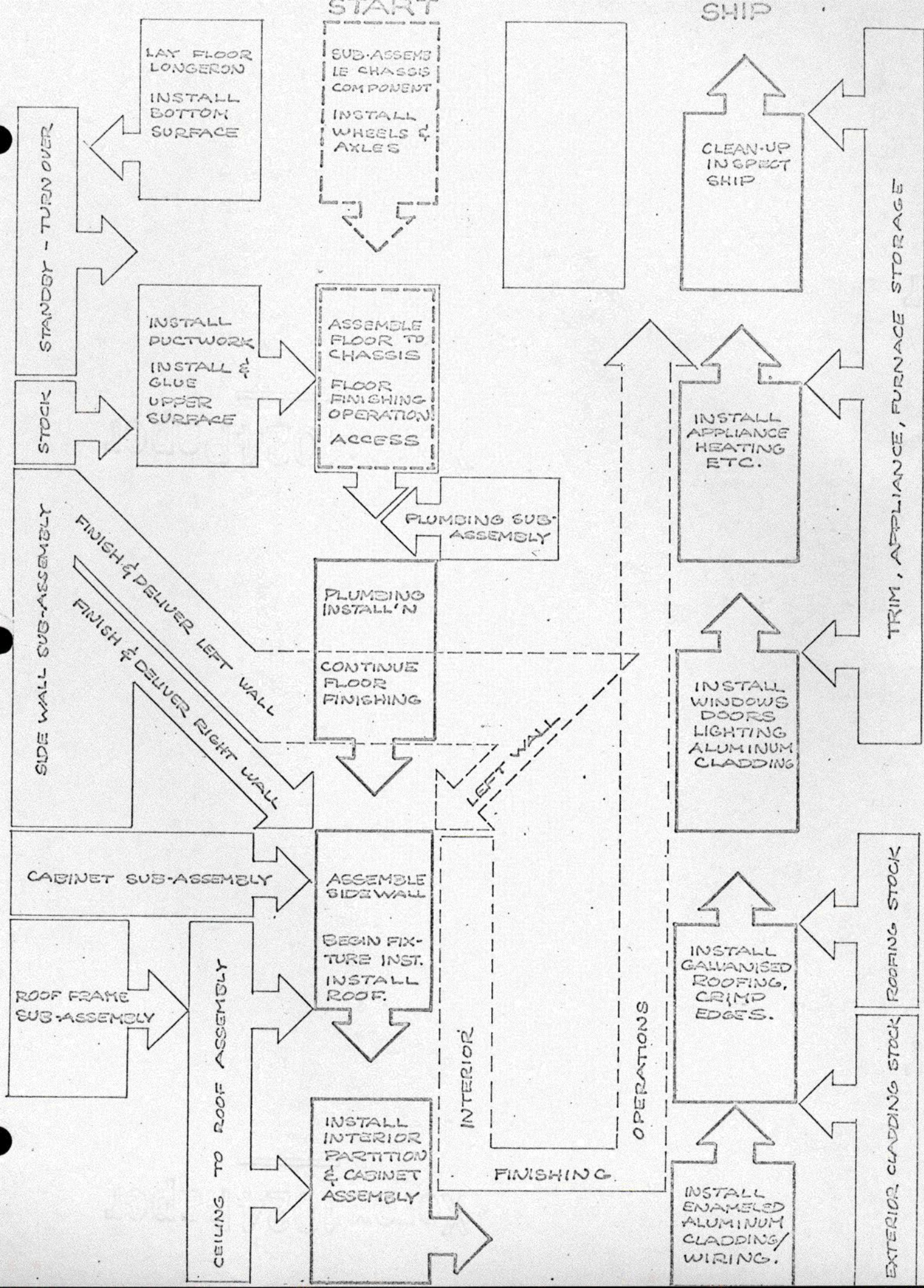
At the next station, molders apply all the interior wooden, plastic and chrome moldings. Electricians install the fuse box, switches, receptacles and light fixtures. Inspectors check the plumbing lines for leaks and the electrical system for possible shorts.

The unit then moves to the appliance bay where the range, refrigerator, washer and dryer are installed.

Finally, the unit passes into the last station for clean up, touch up, installation of furniture, draperies, curtains and pictures.

After a final inspection, the unit is moved to the dispatching area.







## SURVEY OF USED MOBILE HOMES

As a follow-up to tours of mobile home manufacturing plants, trips were made to mobile home parks in the New York area by the architects to observe the effects of use and weather on products which had been manufactured in plants similar to the ones observed.

This survey cannot be considered as a comprehensive study of the weathering process of mobile homes. The comments are based on inspection of about twenty used mobile homes from one to fifteen years old, representing about ten manufacturers. With such a small sampling, it would be impossible to reach any positive conclusions about the products of the mobile home industry in general.

However, since it is known that the competition within the industry has resulted in a product which varies only slightly from manufacturer to manufacturer, this report can serve as a valuable comment on what can be expected in applying existing mobile home technology to permanent housing.

### EXTERIOR

Siding: The baked enamel finish of the light gauge aluminum siding used by almost all manufacturers appears to be rather impervious to the effects of weather. Some chalking of the enamel was observed, but in general the finish retains its color well and the only maintenance necessary appears to be occasional washing.

The primary source of discoloring seems to be the fasteners used. Screws had been used in most cases, although some models were only stapled. The screws rust and stain the siding frequently.

Due to its flimsiness, the siding offers little resistance to impact. Dents, especially around areas of heavy use (doors and corners), were frequently observed. In the few cases where an overlapping corner beading had been provided, it had ripped loose in several places.

The siding seems to offer an adequate weather seal. Some of the more expensive models had seams and corners caulked, but in most cases a simple overlap had been used. No examples of leakage were observed in either case.

A few older models built about 1957 had been provided with a painted steel skin which has proven to be unsatisfactory. The paint had blistered and peeled and the steel had rusted. This siding required frequent repainting and in one case had been replaced with an aluminum skin.



Roofing: The roofing material used uniformly by the mobile home industry is a galvanized steel sheeting. This material requires an application every two to three years of a liquid known as Kool-Seal in order to maintain a weather seal. When this maintenance is performed, the roofing seems to be satisfactorily weatherproof.

However, several examples of leakage were observed as evidenced by stains on interior walls and ceiling materials. Most of these signs were in units which appeared to have been poorly maintained, but some also appeared in units which had been Kool-Sealed.

Windows: Small aluminum frame awning or jalousie windows are used regularly in mobile homes. They are usually screwed in place, although staples are used in some cases.

Very few examples of inoperative windows were observed, even in units which had obviously received severe abuse. This can probably be accounted for by the fact that the mobile home windows are minimal in size and therefore, the working parts of the frame have to support and move very small areas of glass.

Sub-Frames: The light steel fish-bone frame which supports the box of the mobile home seems to be standard, although a few examples were observed where open-web steel joists replaced the normal channel-section cross members and outriggers.

Rust appeared frequently on the frames observed, and the asphalt impregnated board used on the underside of floors was often warped from moisture. One unit had been provided with a galvanized sheet metal covering for the frame.

#### INTERIOR

Floors: The flooring material, which is applied to the floor frame before walls are put in place, is either a sheet linoleum or tiles varying in size from 8" x 8" to 12" x 12". Carpeting is frequently provided to living room areas.

In almost all models inspected which were more than two years old, the floors were in unsatisfactory condition. The materials used had not been able to withstand the heavy traffic and high concentration of furniture. The linoleum and tile sections, particularly bathrooms and kitchens, were badly worn through, scratched and torn. The tile was frequently lifting and curling apparently due to inferior adhesives or workmanship and not because of use. Areas around entrance doors were in particularly bad condition.



A few cases were noted where the floor-mounted heat gratings had been kicked loose.

Walls: Prefinished plywood and composition materials with imitation wood finishes, generally about 1/8" thick, are used for most interior wall surfaces. In bathrooms and kitchens, cardboard or composition materials covered with a vinyl veneer are frequently used. The inside walls of cabinets and closets are usually cardboard which is sometimes spray painted. These materials are stapled and glued to the wood studs. Seams are usually butted but sometimes receive batten strips; corners are lapped and in the more expensive models receive a beading.

In units where the owners had obviously taken care of the interior and had maintained the weather seal of the roof, the walls were in reasonable condition. But several of the trailers observed had been subjected to heavy abuse and neglect, and the walls of these units had simply given way. Surfaces were scratched and marred. Holes appeared in the paneling and the panels had pulled away from the studs. Corner beadings had been knocked off and the edges of the panelling chipped and torn. In several units even the inside walls of closets had been pulled apart and holes had been knocked through.

In bathrooms where moisture is a constant problem and in other areas in units that had leaked, wall panels were badly warped and stained.

The wall surfacing is one area where the downgrading of materials used in mobile home construction is particularly evident. Some units observed had been built in the middle and late '50s when mobile homes were still constructed much like travel trailers. Moulded plywood with birchwood veneers was used extensively. Corners were rounded, solid batten strips covered seams, and rubber mouldings were used to fill inside corners. Many of these units had gone through several owners, and the wall surfaces were still in excellent condition.

Ceilings: The major problem with ceilings that were observed was warping due to roof leakage. The composition panels, which are fastened to the roof trusses by rosette screws and stapled batten strips, were frequently bowed and badly stained.

Doors: A variety of door types was observed. The more expensive models frequently had hollow core doors. Cheaper units used composition board about 1" thick with wood or imitation wood veneers; in one case this type of door was reinforced with wood ribs applied to the surface.



The doors themselves seemed to withstand use quite well, but the hardware used with them often appeared to be completely inadequate. Sliding fixtures are used extensively and several examples were seen where the door was off the track or inoperable and the track itself was pulling away from the frame. Hinges used on the heavier doors were too small for the weight of the door and they were often working loose from the door and from the frame. In one instance, the stop for a heavy hollow core door was a thin strip of wood which had been stapled to the frame; it was pulling loose.

Built-in Cabinets and Closets: Cabinet work is another area of the mobile home which demonstrates the marked decline in the quality of workmanship and materials in recent years. Whereas the older models used heavy plywood for cabinet doors and drawers, the newer models use left over wallboard for the sides and bottoms of drawers and composition board or thin plywood for drawer fronts and cabinet doors. In one unit, the composition board drawer fronts had been badly warped and chipped.

The hardware used in the older units was of good quality, and continuous piano hinges were used extensively. The newer models use inexpensive hinges and fasteners which were frequently observed to be loose and inoperative. Slides for drawers appeared only in the most expensive models.

Bathroom Fixtures and Plumbing: The fixtures installed in the units inspected were standard items of generally accepted quality. A few examples of chipped and rusting bathtubs were observed.

The major fault was that seams especially around the bathtub, were not well sealed, and leaks had caused rusting of the fixtures and warping of the wall and floor materials.

In some units where the kitchen was placed at the front of the trailer, the pipe which runs across the living room floor at the wall base had apparently leaked causing the metal casing to corrode.



THE APPLICATION OF MOBILE HOME MANUFACTURING TECHNOLOGY  
TO LOW INCOME HOUSING AT RESTON

Introduction

At the present time, one of every five single family (non-farm) housing starts is a mobile home, and 75% of all new single family homes valued at less than \$12,500 are mobile homes. Well over 200,000 mobile homes were shipped by manufacturers in 1966 with estimated retail sales exceeding one billion dollars. Mobile home prices range from \$3,000 to \$19,000, and the current average price for a mobile home ten feet to twelve feet wide by fifty-five feet long is \$5600, or about \$10.00 per square foot, depending upon the furnishings and equipment. By comparison, the average price of site-built homes is about \$14.00 per square foot unfurnished. New mobile homes are sold fully equipped with major appliances, furniture, draperies, lamps and carpeting included in the purchase price. Mobile home purchasers are most frequently young married couples and retired persons. The mobile home buyer has a socio-economic profile which is typical of the middle income families of this country, and some are in the lower income group.

The mobile home industry has demonstrated to the housing industry as a whole a number of significant innovations. The most important contribution it has made has been to demonstrate how to build housing units at a low cost. Low income families must have a total house package that meets their budget needs. The mobile home industry has demonstrated that a 680 square foot house can be sold at a retail price of about \$6,000, which gives it an average per square foot retail price of \$8.80. Compared to conventional housing, not only is the cost per square foot low, but the total house package is low.

The mobile home can be so inexpensively priced primarily because of the following reasons:

1. The mobile home is engineered as a complete housing unit with every effort made to minimize cost. The best possible combination of materials is used.
2. Because mobile homes are manufactured under controlled factory conditions, there is efficiency in utilization of materials not found in conventional home building. There is a minimal amount of scrap and wastage.



3. Mobile home manufacturers are able to utilize volume buying to keep their costs down. This is true even of the small manufacturer who benefits from the volume created by the larger manufacturers.
4. Since the mobile home is manufactured in the factory under controlled conditions, the efficiency of labor is optimized. This is typical of most manufacturing assembly line techniques.
5. Because mobile home manufacturing is an industrial process and the work elements have been simplified through the application of industrial engineering, unskilled labor can be used. Labor costs run less than \$2.50 per hour in the mobile home factory.
6. The intense competition between many large and small manufacturers producing the same commodity helps control prices.

The above elements of engineering-design, efficient use of materials, mass procurement, efficiency of labor, low cost of labor and competition all contribute to lowering the cost of the mobile home. The relationship of material, labor and overhead to factory price is shown in Exhibit A. The factory price of producing a mobile home using materials comparable to a conventional home is about \$7.00 per square foot. Some comparative prices are given in Exhibit B.

People will compromise on the use of conventional materials if a suitable alternative is available at low cost. The mobile home, an elongated box, demonstrates the compromise people will make. Although the interiors of mobile homes look much like conventional homes, there are contrasts, particularly in the use of imitation wood interior wall surfaces. These surfaces have proven to be low cost and are very practical since they do not mar, scratch or show dirt easily.

The mobile home industry has also demonstrated a new way of community living through its system of mobile home parks. In these parks, the home is owned by the occupant, but the space and surrounding area is owned and maintained by the park management. This provides the homeowner with the security that comes from a closed area, the lack of responsibility for maintaining the common area, and common recreational and service facilities such as a swimming pool, recreational hall and laundry facility. These latter amenities are important ingredients in making life more pleasant when budgets are limited.



During the last few years, a sectionalized housing industry has developed which uses the principle of joining two mobile homes together to create a house. The concept of using mobile home size units as building blocks is fast developing.

Although mobile homes are providing good low cost housing, the mere fact they are mobile homes means they are limited in the communities in which they may be placed because of their appearance. People in more expensive conventional housing developments do not want "trailer parks" located nearby. They are also limited in mortgage financing because of their portable characteristic. However, it would appear that a number of principles can be borrowed from the mobile home industry and combined with conventional housing principles so as to provide a package that will become a good looking, low cost housing unit.

#### Low Cost Housing at Reston

It is first necessary to select the basic building materials which best meet the needs of the future occupants. Functional characteristics involve using some of the interior materials found in the typical mobile home such as pre-finished wall surfaces, mobile home type windows and mobile home type built-in closets and furniture. Safety and health characteristics involve adherence to conventional code requirements such as fire protection in the case of multi-family units.

After the proper selection of materials, the mobile home manufacturing techniques will be applied to putting these materials together into blocks or modules. These building blocks will be factory built and shipped to the site. The transportable width of twelve feet allows an acceptable room size unit to be delivered.

Once the building blocks are brought to site, they will be arranged in the most practical way to maximize the density so as to keep the total housing costs low, including the cost of developed land. They may be grouped in clusters or large complexes. The most practical and aesthetical combination for Reston has yet to be selected.

The building blocks will be put together in such a way that the future occupant cannot differentiate the completed structure from one built by conventional on-site construction techniques.

The concept of common grounds and common recreational and service facilities is now manifest at Reston. Perhaps the



housing blocks can be sold in much the same manner as Reston's townhouses with a fee to cover use of the common areas and facilities which are maintained by the project management. It is necessary to protect the common areas so the image and value of the total housing complex is maintained.

#### Limitations

The first limitation in the use of mobile home technology is the need to use different materials for a multi-family structure versus a mobile home, a requirement that comes from the need to meet the fire codes. The selection of proper materials and the combination of these materials is in process.

In designing the building blocks and the multi-family structure supporting them, it is important that the design, both exterior and interior, be acceptable to the people who will be living in them. Setting the right balance between cost, design and materials is being analyzed.

Another limitation to the use of mobile home technology is the rigidity in design caused by factory produced units of a standard width and length. It will require considerable skill in floor plan and manufacturing design to get a compromise that is acceptable. It is desirable to have as many types of room arrangements as possible at a good price.

#### Conclusion

It is apparent the mobile home manufacturers offer some tangible assets as partners in this enterprise. They are familiar with the technology, and there are several hundred potential factories all over the United States which can immediately qualify as contractors for the low cost units (see following map for distribution of mobile home manufacturing plants).

Before a final decision is made, the opportunity to participate in Reston's demonstration is being given to the mobile home manufacturer, the sectionalized house manufacturer and the building material supplier to determine which best fits the program and can best supply the end product.