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THE TECHNOLOGY AND MANAGEMENT OF MOBILE HOME PRODUCTION

by

Arthur D. Bernhardt*

The author presented a paper (1) to the First International Symposium on Low Cost Housing Problems Related to Urban Renewal and Development, on the present situation and future development of the mobile home industry, using this macro-analysis as a case study to demonstrate that the industrialization of the building industry is primarily an economic-political rather than a technological problem. This paper supplements that first one by examining one function--production--in greater detail, to show again that outstanding production efficiency as a result more of sophisticated management than of high technology.

A SYSTEMS APPROACH TO HOUSING PRODUCTION

Mobile home production represents a consistent systems approach to housing production. Management and technology of the production process have been designed to achieve the process objective--that is, the end product as defined by regulatory constraints, performance criteria, and market preferences--with the most efficient utilization possible of the basic resources of labor, materials and money. The efficiency of labor is optimized by developing the most efficient method of performing a specific operation (as opposed to improving traditional building operations), and by applying basic principles of mass production, including: division and specialization of labor, standardization and continuous repetition of operations, simultaneity and continuity of operations, mechanization and automation of operations (about 90% of heavy labor operations are automated), standardization of operation sequence and work flow, mechanization of material handling, provision of a controlled environment, and high-volume production yielding scale economies.

The efficiency of material utilization is achieved by standardized and interchangeable component and product designs which fully exploit the properties of materials, minimizing and even reutilizing scrap, resulting in operational, structural and mechanical details often completely different from those in traditional building. It is not tradition, but economics, which determines the types of materials used. In the past, mobile home production used aluminum and steel frame construction. Wood is now only being used because it is most economical at this time.

The efficiency of the utilization of financial resources is optimized by substantial cost reductions achieved through high-volume mass purchasing of raw materials and products (the largest mobile home manufacturer produces more than 40,000 mobile homes per year; even the smaller firms benefit from the volume generated by the industry leaders), by maximization of inventory turnover ratios, reliance on trade credit extended by suppliers, use of non-union un- or semi-skilled labor, highly cost-conscious design and control of production process and product, strict application of basic principles of industrial management, and by highly sophisticated management, scheduling, coordination, and control of the supply, production, marketing and distribution functions.

This systems approach largely explains the much greater efficiency of mobile home production as compared with the production processes employed by the other segments of the housing industry. The labor productivity in the industry is much higher; for the production of 1,000 square feet of net floor area, in place, exclusive of land and land development, the mobile home industry needs between 135 and 230 man-hours, the manufactured home industry needs 350 to 700, and the traditional residential building industry from 700 to 1000. This is reflected in the cost structure of mobile home manufacturing. Direct and indirect labor average 10% of F.O.B. price, and perhaps 20% of all firms even have a labor content of less than 8%. Comparable percentages for modular manufacturers are normally on the order of 14-17%. The industry is the only producer of low-cost housing today (on a first-cost basis), selling a completely finished and furnished dwelling unit at an average F.O.B. price of $5.00 to $6.00. Equally significant, during the last 15 years the per square foot costs have slightly declined, although the product has been much improved. What explains this outstanding performance--management or technology?

THE MANAGEMENT OF PRODUCTION

Production Management

Among the functions of planning, scheduling and controlling all production operations, the single most crucial management function--successfully mastered by the industry--is to synchronize production with sales, and to constantly and thoroughly monitor the market for changes which may affect effective demand, and thus production. Assuring a steady production flow and a reasonable capacity utilization of the plant is vital, because any slowdown raises overhead per production unit, quickly reducing profit and ultimately destroying capital. Since seasonality is a major problem in the industry, manufacturers successfully avoid negative effects of slowdowns by designing and setting up the entire production and marketing organization so that it can rapidly and effectively adapt and respond to market changes, which implies avoiding investment in highly automated facilities.

Manufacturers try to maintain steady employment to avoid layoffs of good men, and because seasonality makes this difficult, production planning and scheduling is even more carefully managed. If, on the other hand, sales exceed output, through constant production monitoring and operational time studies, the production management seeks to shift more operations from on-line to off-line, in order to minimize on-line labor which in turn reduces cycle time which in turn increases the output rate.

Quality control is most crucial in an industry in which about 60% of all firms use incentive systems for direct labor. The complex plant dynamic characteristics call for sophisticated monitoring and scheduling systems and equipment, involving substantial (and expensive) management requirements for quality control. Yet, this emphasis on quality control is another integral and crucial component of successfully employing the principle of mass-production in building.

Inventory Management

Maximization of the inventory turnover ratio is a key policy, as this ratio is a crucial determinant of the profit-investment ratio. Since mobile home manufacturers handle much larger quantities of materials than producers in the other segments of the housing industry, optimization of the inventory management functions becomes more important.

Consciously using their purchasing power, manufacturers have shifted the burden of warehousing to the suppliers, often demanding one or even several precisely scheduled daily deliveries--thus in effect implementing a no-inventory policy. The average turnover of inventories is much higher for the mobile home manufacturers than for prefabbers or merchant builders. Accordingly, mobile home manufacturers often earn much more on their capital. Skyline Corp., for example, some years ago earned 49% on its capital by turning assets into sales 8 times and inventories into sales 62 times. Those are probably the best turnover ratios for the total shelter industry.

Individual operations are characterized by either one of the two alternative basic procurement approaches found in the industry. The "Indiana Approach" aims to minimize the need for in-plant

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manufacturing and to limit the operations to assembly, that is, to purchase as many as possible of the needed components and parts in as finished or pre-assembled a state as possible. This approach depends on the availability and proximity of suppliers and sub-assembly and component manufacturers, as is the case in the major geographical mobile home production centers, such as Elkhart, Indiana. This approach is indicated in regions with shortage or high cost of labor, or if the regional demand is too unstable or unpredictable to justify investment in raw material processing equipment. The "Michigan Approach" seeks to control as many as possible of the raw material processing or basic manufacturing operations. It is indicated in remote regions isolated from component manufacturers or if low-cost labor is available.

Production Organization

Basically, the spine of every mobile home production facility is the main assembly line, with anywhere from five to more than twenty assembly stations. Many factors determine the number of on-line stations, including the production volume, run size and model variations, the level of mechanization, the skill and material requirements, and the degree of capacity utilization. Basic manufacturing and sub-assembly operations take place on one or both sides of the main assembly line. The layout of the sub-assembly lines is typically perpendicular to the main line. On both main and sub-assembly lines, the mechanical, labor and material resources are stationary. The products travel through a series of stations in a programmed sequence, meeting at predetermined stations for sub- or final assembly. The main assembly line is a completely coupled line--all units move from one to the next station simultaneously. The production cycle time, that is the amount of time the unit stays in one station, ranges in efficient plants from 20 to 40 minutes. The feeding sub-assembly lines are normally linked to the main line by buffer stations (inventory) thus avoiding the need for complete synchronization of the flow rates of all sub-assembly lines with that of the main line.

There are two basic main assembly line arrangements-- the "side-by-side line" and the "end-by-end line". On the first, the units are placed with their longitudinal axis perpendicular to the production flow direction; on the latter this axis is in the flow direction. Sideway movement requires less plant length, is better suited for production of double-wides, allows more economical feeding from sub-assembly lines, and can better accommodate high production volumes. Combinations of both line types are often employed.

The material flow starts with the in-feed facilities--rail sidings or truck docks. Materials and pre-assembled and pre-finished components enter the production system at the beginnings of the sub-assembly lines, and completely finished dwelling units roll off at the end of the main line. For a given plant capacity, flow pattern, layout and size of the plant depend much on whether the Michigan or the Indiana Approach is used. The Michigan Approach must provide much more indoor and outdoor inventory and storage space, greater numbers of more intensive sub-assembly stations, and more direct and indirect employment than the Indiana Approach. Thus, the first approach may result in a 20 acre production complex with several buildings, whereas the Indiana Approach seldom requires more than one building. Layout and size are also substantially different if two or three different main lines are installed.

THE TECHNOLOGY OF PRODUCTION

Material Handling

Material handling is a much more crucial function in shelter manufacture than in most other mass production processes, simply because of the bulk and weight of the materials and final product involved. Indeed, the material handling functions--shipping of raw materials, unloading, storage, distribution of materials to line stations, material handling at the station, and handling and storage of the finished assembly--as decisively influence overall production efficiency as the production technology per se. Effective material handling can reduce waste, can improve the in-plant work flow patterns, can reduce costs by more optimal labor and space utilization, and can increase the effective production capacity. The mobile home industry has concentrated much effort into very successfully coping with the material handling problem. Mobile home operations are more characterized by careful material flow planning and effective strategic coordination of using fork lifts and trucks, conveyors, overhead cranes, hoists and pallets, than by the degree of production process automation.

Sub-Assembly Operations

The Metal Shop is of significance primarily in plants operating according to the Michigan Approach, processing basic metal products into components to be fed to other sub-assembly stations. The conversion of aluminum coiled stock into panels for siding and trimming employs a decoiling reel continuously feeding baked enamel finished or PVC-coated light-gauge plain aluminum sheet to a roll-former, forming it into a structurally effective design, and then to automatic equipment cutting, stacking and palletizing the panels. Coiled steel stock may be converted into panels for ductwork. "Indiana"-oriented manufacturers, however, normally purchase formed and finished siding panels, trims, and ductwork.

The Cutting Mill is an off-line operation again typical only for the Michigan Approach. Structural and non-structural members and other dimensioned pieces are automatically cut in the mill and fed to the floor, cabinet, wall and roof sub-assembly stations, and also to some on-line stations. Operations conforming to the Indiana Approach buy most or all of their lumber pre-cut.

The Welding Shop is a further operation found in "Michigan"-type plants. Here, massive steel chassis are fabricated in frame jigs. Before (or after) the chassis pass through the paint shop, the running gears are assembled, often with the chassis in an upside-down position. The assembly of the undercarriage may require only a total of 4 to 6 man-hours in direct labor. Under the Indiana Approach the finished chassis, with or without running gear assembly, is usually purchased.

The Ductwork, Plumbing and Electrical Sub-Assembly Stations, again typical only for the "Michigan"-type operations, manufacture ducts, plumbing trees and other sub-assemblies in jigs from pre-cut parts. Electrical sub-assemblies and wiring harnesses are pre-cut, stripped and assembled. In-floor sub-assemblies are fed to the floor sub-assembly stations; in-partition sub-assemblies are fed to the cabinet shop. Indiana Approach operations tend rather to purchase prefabricated sub-assemblies.

The Floor Sub-Assembly Stations manufacture the typically 12' x 60' floor sections in one piece. The frame structure and the insulation board are assembled into a single unit on a horizontal flooring jig. Aided by overhead monorail and crane, the floor section is then easily flipped over onto a second jig, where the in-floor mechanical equipment--heating and air-conditioning ducts, plumbing, including water supply and drain assemblies, and electrical wiring sub-assemblies--are installed between the joists. Finally, the plywood subflooring is installed, often by glue application and pneumatic screw or nailing machines. The finished floor section is then fed to the main line. This entire operation may not consume more than a total of 5 to 7 man-hours in direct labor.

The Cabinet Shop manufactures kitchen and bathroom cabinetry, built-in furniture and interior partitions. Often, partitions and cabinets are pre-assembled into larger complex sub-assemblies to reduce on-line operational time.

The Wall Sub-Assembly Stations fabricate the often 60-or-more-foot long exterior walls in one piece, on either vertical, A-frame or horizontal framing jigs. Fiberglass insulation is installed between the studs. To assemble one full-length wall may not require more than a total of 4 to 8 man-hours in direct labor. Automated wall fabricating equipment, though not yet extensively employed, can produce 800-1000 linear feet of wall per hour, eight to fourteen feet wide.

The Roof Sub-Assembly Stations may either use purchased trusses (Indiana Approach) or they may fabricate them (Michigan Approach), often on automated bow string truss machines. The

entire ceiling/roof sub-assembly, normally 12' x 60', is typically fabricated in one piece, on vertical, slanted or horizontal jigs, using automatic staplers. The completed roof assembly is lifted up by overhead crane and transferred to the main assembly line. One such roof-section (not including truss fabrication) can be assembled with a total direct labor input of 3 to 4 man-hours.

The Window and Door Sub-Assembly Stations and Drapery and Furnishing Shops, often fabricating these components from raw or half-finished materials, are of significance primarily in "Michigan"-type operations. Under the Indiana Approach all or most of these components are bought.

Main-Assembly Operations

The main assembly line starts with the chassis, complete with the running gear. The towing end is mounted on a temporary wheel, set onto a floor monorail, with the chassis hitched to the one ahead, which in turn is hitched to the one ahead of it. All units being thus pulled together, the individual unit advances through the various stations on its own wheels, with a job data card on the chassis hitch telling plant personnel the specifications of this particular unit. On side-by-side production lines, where the units are pulled in side saddle fashion, the chassis, without axles and wheels, is placed on dollies which are pulled along tracks in the floor. This keeps the floor of the units lower, making it easier for workmen to get in and out. Finished units are pulled over a pit where the running gear is installed.

From the floor sub-assembly area, assisted by monorail and bridge crane, one or two men can lift the entire finished floor section and carry it to the chassis waiting on the main line. The floor section is lowered onto the chassis, which is then lagbolted to the floor perimeters. Some factories choose not to complete the floor section in the sub-assembly area: while the floor section is still in an upside-down position on the jig, the chassis, upside-down, is lifted onto the floor system by crane, the two are mated and then, by overhead cranes or tilt jigs, the entire assembly is turned over 180°, the mechanical in-floor equipment is put into place and the sub-floor is installed. Resilient flooring or carpet goes down onto the plywood deck, applied in a single 12' or 14' wide sheet from continuous overhead rolls. Thus the entire 12' x 60' floor section is covered with the finished flooring before any partitions go into place, an efficient method of eliminating the fitting of floor coverings to individual room sizes.

At the next station, interior partitions, storage units, cabinetry, and plumbing fixtures and other major sub-assemblies are loaded onto the floor and their installation with pneumatic machines begins. Thus, the unit is being built from the inside out, in reverse of the site-built house--there is no need to enclose due to weather.

Twenty to forty minutes later, the unit moves to the exterior wall installation station. Overhead monorails lift the completed walls off the wall sub-assembly station, transfer them to the main line, and place them into position on the floor perimeter. In some factories, another advantage of overhead monorails is exploited. When the walls are approximately in place, vertically over the floor, the monorail holds the walls in place while being positioned, plumbed, and secured to the floor section. Then, the exterior walls are fastened to the interior walls.

As the unit moves to the next station, electricians and plumbers move through the unit. Rough electrical wiring is begun and electrical harnesses are installed. If, as many operations prefer, insulation has not been placed into the exterior walls during sub-assembly, insulation is installed at this station.

At the next station, a single man picks off the 12' x 60' completed ceiling/roof sub-assembly from the roof sub-assembly station by overhead hoist and transports it aloft to the main line, over the walled shell of the mobile home. The roof section is then lowered into place, positioned, and secured to the exterior walls. It is not until the roof is in place that the unit, hitherto looking unstable, straightens out, and a virtually one-piece structure results. The unit is engineered as an integrated rigid and torque-proof structure, with no redundancies in its structural components. Then, a roll of insulation from an overhead storage rack is delivered by overhead crane, unrolled over the entire roof area and secured.

Once the unit leaves the next station, the wiring harnesses have been installed, and most interior items are on board. The securing of the partitions and cabinets has been completed, as have been the water heater and furnace hook-ups. And the roof has been sheathed with an asphalt-impregnated insulating board. This station may also serve as a carry-over station for uncompleted work from the prior stations.

At the next station, the aluminum siding panels are installed, with power-driven leakproof screws. Windows are set here. Exterior doors are hung. Overhead trolley work platforms are used. The monorail delivers a roll of galvanized heavy gauge steel sheet or single-ply vinyl roofing onto the roof--the 12-foot wide one-piece roof sheet. The sheet is unrolled and secured. The steel may then be coated with aluminized roof coating.

The unit then moves to stations where interior and exterior operations continue, interior doors are hung and moldings are applied. All interior trim is completed. Air operated pneumatic fastening equipment is almost exclusively used. Final mechanical finishing will commence at this station, including final plumbing and heating system hookups and final electrical trim.

Appliances are loaded and installed at the appliance bay. From the original receiving area, refrigerators, ranges, ovens, washers, dryers and other appliances have moved by fork truck to the bay and are now fed by roller conveyors to the unit. Thus, there is no manual handling of appliances. Then, the exterior metal trim is completed.

At the last stations, furnishings, draperies and pictures are loaded and installed. The plumbing and gas lines and the electrical system are tested. The final clean-up is completed. After a final quality inspection, every 20 to 40 minutes, a completely finished and furnished dwelling unit leaves the assembly line ready for occupancy.

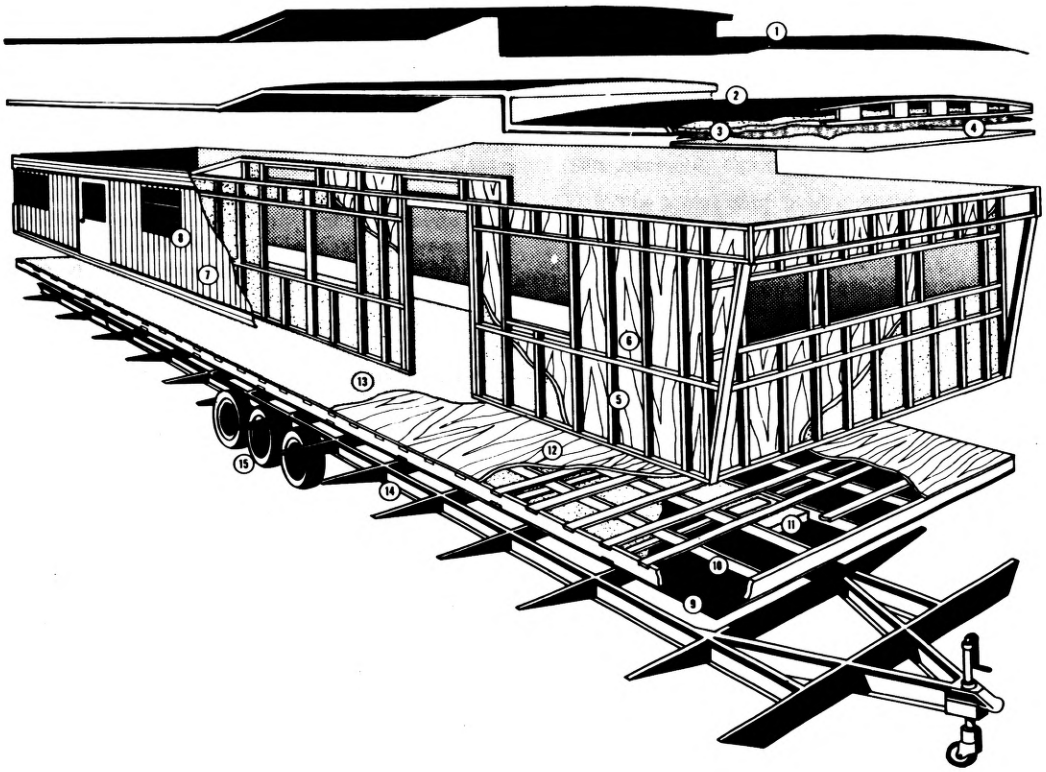
CONCLUSIONS

Two conclusions are apparent. First, the management and production capabilities of the industry can be used to produce modules as efficiently for fixed-site housing, even plug-in modules for medium- and high-rise mega-structures, since the industry has a long history of using aluminum and steel-frame construction. As discussed in the above-mentioned paper (1), of course, this first requires removal of a large number of economic, legal and political constraints, but it is well to remember that the nature of its present product is accidental--dictated to the industry by public regulation and other external factors.

The second conclusion is that, technologically, it is easy to produce mobile homes, or any other industrialized shelter, but that it requires highly sophisticated management to do it efficiently and profitably. Traditional on-site builders or building manufacturers can achieve the same efficiency, but they must to a much greater extent and more consistently apply basic industrial management principles, without need, however, to necessarily shift operations from site to factory. The quality of the organization and management of the entire process is a more important prerequisite for successful industrialization than the technological quality and the (off- or on-site) location of the production function.

REFERENCES

1. Bernhardt, Arthur D., Creating A Resource for Low Cost Urban Housing: Towards a Policy for Developing the Mobile Home Industry, in Proceedings of the International Symposium on Low Cost Housing Problems Related to Urban Renewal and Development, Oktay Ural, ed., Rolla, Mo., University of Missouri, 1970, pp. 91-94



ROOF CONSTRUCTION

1. One piece galvanized roof stretched over sides, caulked and screwed to insure overlay construction.
2. 1/2" insulation fiber-board installed over truss type roof rafters gives backing to roof, insulates, and deadens sound. Roof is also vented for circulation.
3. Heavy fiberglass blanket type insulation covers entire roof.
4. Blanket polyethylene plastic between 1/2" ceiling panels, rafters — excellent vapor barrier.

SIDEWALL CONSTRUCTION

5. 2" x 3" Spruce studs on 16' centers, double dadoed glued and screwed. Strapped to floor every 2'.
6. Natural wood interior wall panels — glued to wall frame with full thickness fiberglass insulation.
7. Aluminum exterior metal with prebaked-on enamel finish.
8. Extra large weather-tight, frost-free, 12' awning type windows used throughout the home.

FLOOR CONSTRUCTION

9. Asphalt fiber-board is installed under entire home with heavy-duty fiberglass blanket insulation for complete weather-proofing.
10. 6" Floor kiln dried joists are installed longitudinally to insure strong construction. 5/8" by 4" upper cross members on 16" centers are glued and screwed to joist.
11. Polished aluminum four-sided heat ducts are placed between the floor joists and deliver uniform heat throughout the mobile home.
12. 5/8" Flooring panels are glued and screwed to the cross members then sanded and cleaned for floor covering.
13. Carpet (100% Nylon) throughout entire coach, except in bathroom, kitchen, and dining room.

FRAME CONSTRUCTION

14. 10" I-Beam with built-in camber to insure level floors and separated by cross members on 4" centers.
15. Heavy-duty axles, leaf springs, wheels, and tires complete the running gear.

Fig. 1. Mobile Home: Structural Details (Broadline Homes Inc., Elkhart, Ind.)

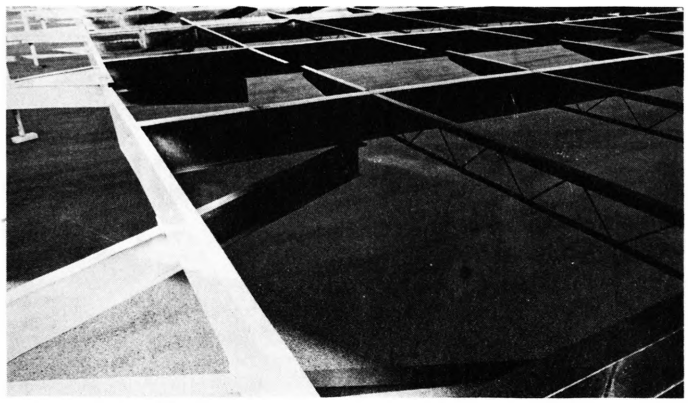


Fig. 2. Sub-Assembly Station: Chassis (Twin Lakes Manufacturing Co., Tampa, Fla.)

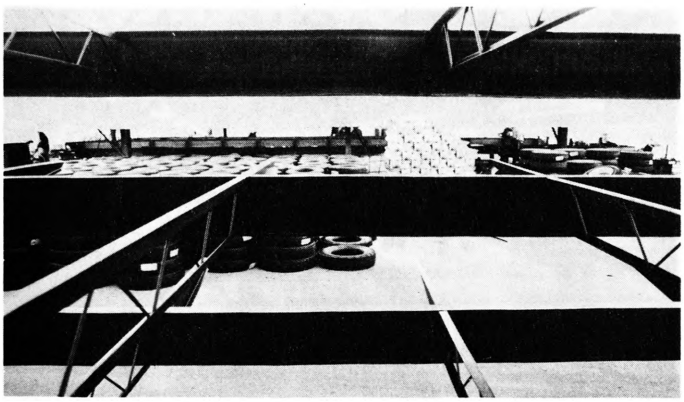


Fig. 3. Sub-Assembly Station: Running Gears (Twin Lakes Manufacturing Co., Tampa, Fla.)

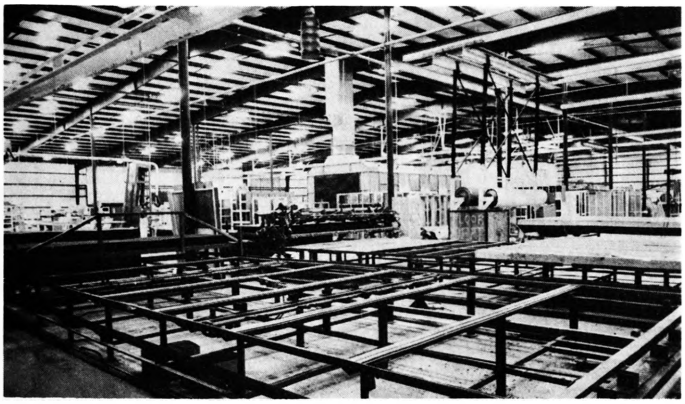


Fig. 4. Floor Sub-Assembly Station (Twin Lakes Manufacturing Co., Tampa, Fla.)

Fig. 5. Sub-Assembly Station: Cabinet Shop (Richardson Homes Corp., Elkhart, Ind.)

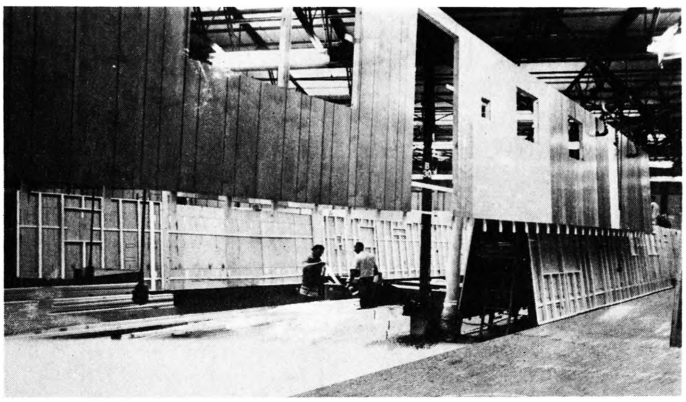


Fig. 6. Wall Sub-Assembly Station (Richardson Homes Corp., Elkhart, Ind.)

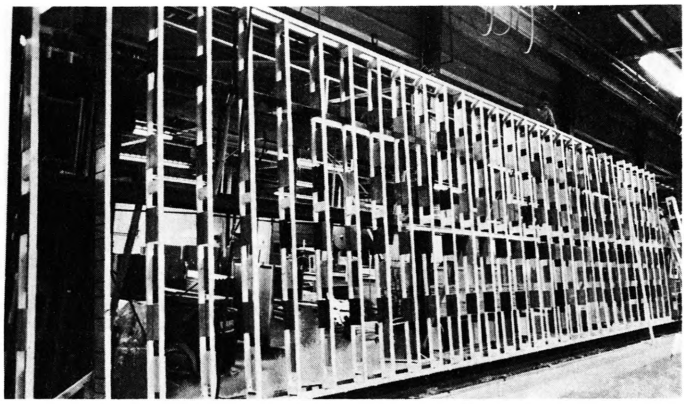


Fig. 7. Ceiling/Roof Sub-Assembly Station (Richardson Homes Corp., Elkhart, Ind.)

Fig. 8. Sub-Assembly Area: Appliance Bay (Richardson Homes Corp., Elkhart, Ind.)

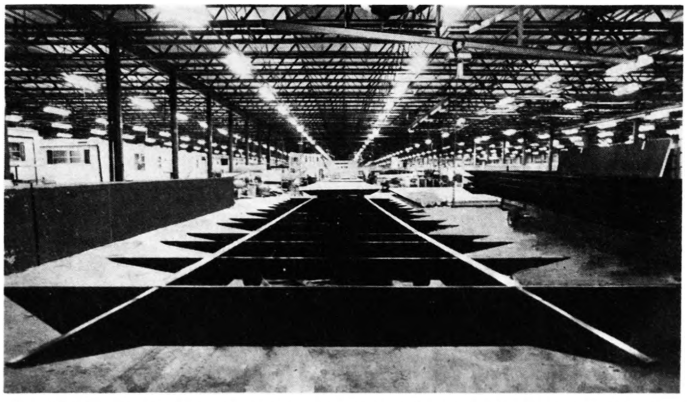


Fig. 9. Main Assembly Line (End-by-End Type): Chassis on First Station (Richardson Homes Corp., Elkhart, Ind.)

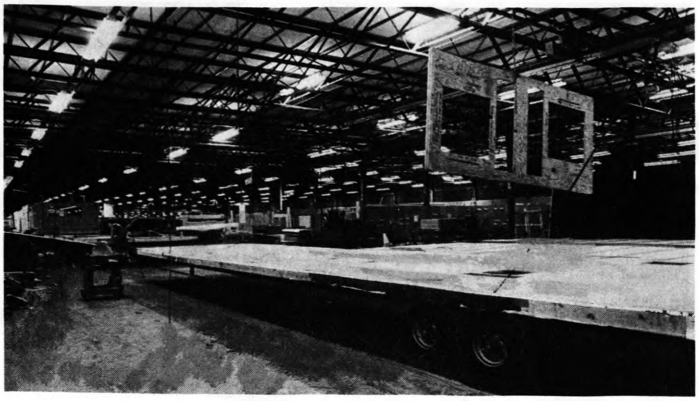


Fig. 10. Main Assembly Line (End-by-End Type): Floor Section Installation (Richardson Homes Corp., Elkhart, Ind.)

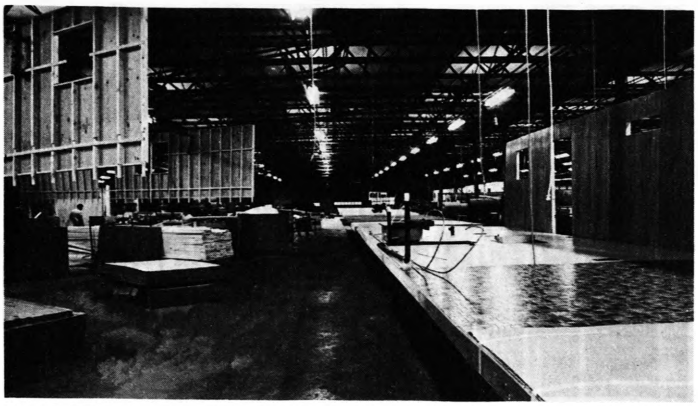


Fig. 11. Main Assembly Line (End-by-End Type): Plumbing Fixture and Cabinetry Installation (Richardson Homes Corp., Elkhart, Ind.)

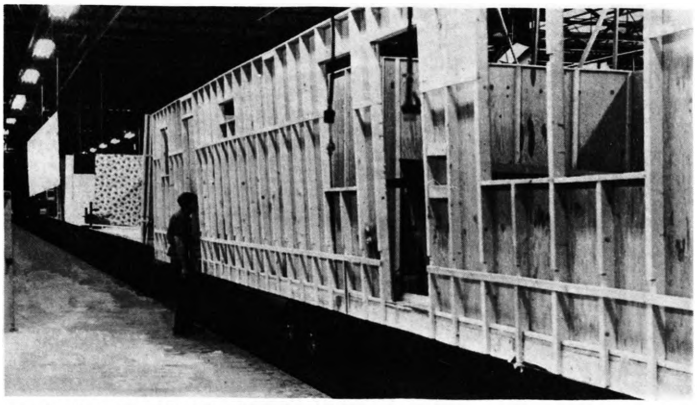


Fig. 12. Main Assembly Line (End-by-End Type): Wall Section Installation (Richardson Homes Corp., Elkhart, Ind.)

Fig. 13. Main Assembly Line (End-by-End Type): Roof Section Installation (Richardson Homes Corp., Elkhart, Ind.)

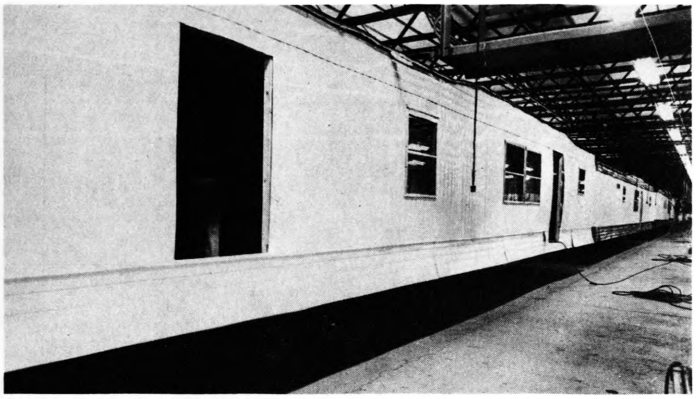


Fig. 14. Main Assembly Line (End-by-End Type): Siding Installation (Richardson Homes Corp., Elkhart, Ind.)

Fig. 15. Main Assembly Line (End-by-End Type): Window/Door Installation (Richardson Homes Corp., Elkhart, Ind.)

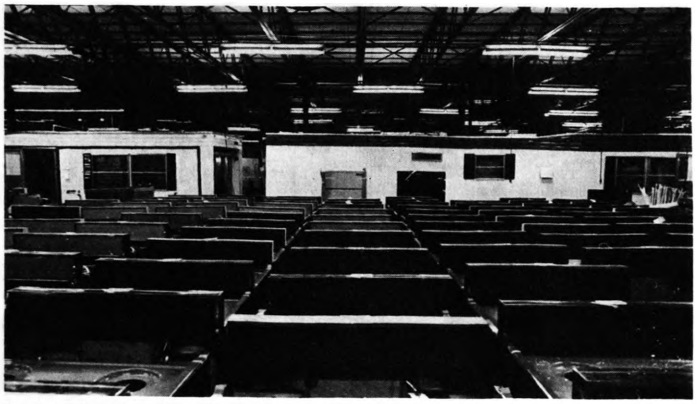


Fig. 16. Main Assembly Line (End-by-End Type): Appliance Feeding (Richardson Homes Corp., Elkhart, Ind.)

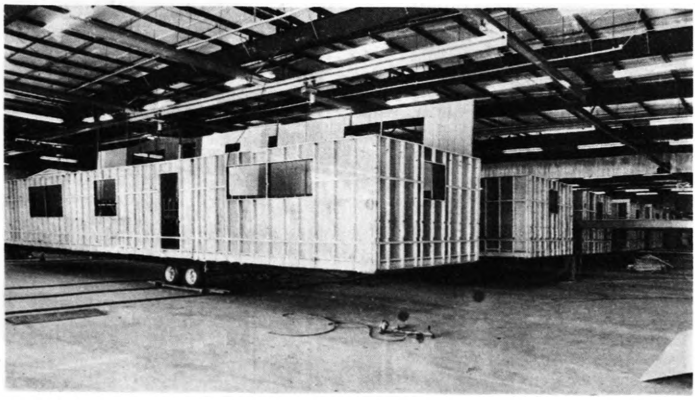


Fig. 17. Main Assembly Line (Side-by-Side Type): Production Sequences (Richardson Home Corp., Elkhart, Ind.)

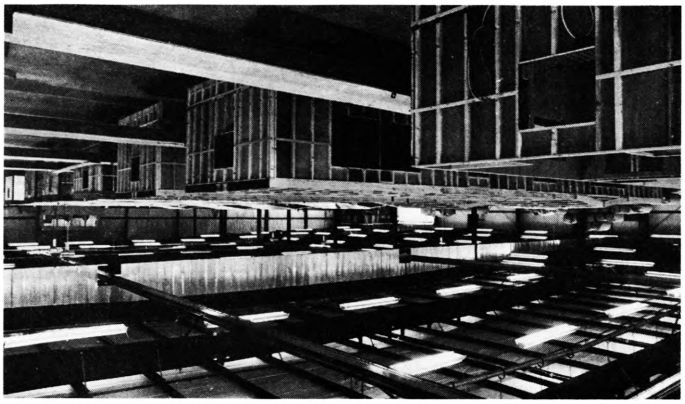


Fig. 18. Main Assembly Line (Side-by-Side Type): Production Sequence (Richardson Homes Corp., Elkhart, Ind.)