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# PREASSEMBLED
# BUILDING COMPONENTS

Proceedings of a program conducted
as part of the 1960 Fall Conferences
of the
N.R.C. Building Research Institute
Division of Engineering and Industrial Research



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The Building Research Institute gratefully acknowledges the contributions to building science made by the speakers at this conference.

Milton C. Coon, Jr.
Executive Director

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# Abstracts of Conference Papers

THE ARCHITECT'S VIEW OF PREASSEMBLED COMPONENTS
By Carl Koch, Carl Koch & Associates, Inc.

It is stated that prefabricated components used with daring and imagination by the architect can help significantly to achieve a better living environment by making possible truly integrated systems of house construction, combined with the economies possible through industrialized production. The slow progress in acceptance of components by architects is attributed to failure on the part of both manufacturer and architect to appreciate and understand the areas where discipline is necessary and imagination desirable. Two demands the architect should make of a rational prefabricated component system are stated as: 1) better value; 2) real integration of structure and equipment.

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THE HOME BUILDER'S VIEW OF PREASSEMBLED COMPONENTS
By Alan E. Brockbank, Continental Real Estate & Insurance Co.

The current reaction of the home-buying public against sameness and monotony in houses is noted as a factor in the acceptance of components for home building. A list of 17 principles for research, formulated by the Research Institute of the National Assn. of Home Builders is presented, and the implications of each of these are discussed in relation to the development of preassembled components. Areas for further study to promote the use of components by mass home builders are defined as: dimensional stability, reduction of weight, improved fasteners and connectors, reduction of the necessary skills, minimizing the effect of weather, reduction of the construction period, improved materials handling, and surfaces and coatings.

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THE CONTRACTOR'S VIEW OF PREASSEMBLED COMPONENTS
By Henry Norair, Norair Engineering Corp.

The progress of the use of preassembled components in the large building field is noted, beginning with trusses, interior walls and partitions, exterior wall panels, etc. Emergence of prestressed and precast concrete building elements first in Europe and now in the U. S. is discussed, and the problems of the contractor in dealing with preassembled units are enumerated. Use of prefabricated sections of piping and duct work, and preassembled wall sections composed of various materials are mentioned as posing jurisdictional labor problems for the contractor, as well as not meeting the requirements of some local building codes.

THE BUILDING OWNER AND OPERATOR'S VIEW OF PREASSEMBLED COMPONENTS
By Robert J. Short, Procter & Gamble Company

The prime consideration in the building owner and operator's view of preassembled components is their effect on the first cost of the building, and in this connection it is noted that components can help to save on the over-all cost of construction. Two development programs within the author's company are described, one aimed at more efficient construction procedures, and the other at more efficient design procedures. The The use of plot plan models, preliminary equipment arrangement models and production engineering models in the design of buildings, plus the use of a photographic technique to produce a true orthographic picture of a model as a replacement for conventional drawings are described as techniques for investigating situations suitable for preassembly.

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LABOR'S VIEW OF PREASSEMBLED COMPONENTS
By Andrew P. Murphy, Jr., Attorney

Basic labor-management problems of the home building industry are discussed. Six persistent, underlying problems are listed as: 1) the form of bargaining in various localities between builders, contractors and subcontractors; 2) the problem of piece work; 3) the introduction of new methods and new machinery or materials; 4) the shifting of work between construction site and off-site operations; 5) the allocation of the labor force between jobs; 6) the need for a central forum in which specific problems may be solved on a national level.

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THE BUILDING CODE OFFICIAL'S VIEW OF PREASSEMBLED COMPONENTS
By Paul E. Baseler, Building Officials Conference of America, Inc.

Six questions are posed that must be answered about preassembled components before the building official can make a proper judgment as to their acceptability. The rigidity of some specification-type codes is noted, but it is also pointed out that even where performance-type codes are in effect, acceptance of preassembled components involving more revolutionary types of materials is difficult. Much of the difficulty experienced by proponents of preassembled components is attributed to the fact that no serious consideration has been given to the effect of building regulations on those products until after they have been put into mass production. The author recommends that manufacturers of components work with the recognized national code organizations representing building officials to secure approval of their products before attempting to market them, particularly when the components involve the use of little known or insufficiently tested materials or techniques. The role of the municipal government, the building official, the developer, the industry and the builder are defined in terms of the steps necessary to bring to the public the advantages of industry research and development of preassembled components.

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INVESTIGATION OF COMPONENT CONSTRUCTION FOR RESIDENCES
By Albert G. H. Dietz, Massachusetts Institute of Technology

This paper is a brief general progress report of the building component study sponsored by the National Association of Home Builders at the Massachusetts Institute of Technology.

It is divided into two principal parts: 1) a brief account of the status of component construction; and 2) a brief exposition of the study of the geometry of components relative to house design. No hard-and-fast conclusions are drawn, because the study was still in progress at the time the paper was prepared.

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PREASSEMBLY OF COMPONENTS FOR MANUFACTURED HOMES
By Willard J. Worth, National Homes Corp.

This paper lists the areas of greatest progress in the preassembly of components for manufactured homes as: 1) trussed roof construction resulting in part from improved lumber grading rules; 2) prefinishing of components, including the more common materials, and most recently, the metallic and plastic-based materials for exterior use; 3) development of "blind connections" for interior materials to eliminate problems of exposed nails and connectors; 4) emergence of new adhesives for use in sandwich construction and new tools for their application. Areas suggested for future development and further research are: more 8' wide interior finish materials to avoid jointing problems; dimensional stability of such materials equivalent to presently available gypsum-based materials; further improvement of foamed plastic-cored sandwich panels. Panel size, as it relates to economical construction, transportation, and other factors that concern the home manufacturer is also discussed.

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ON-SITE PREASSEMBLY OF COMPONENTS FOR HOME BUILDING
By Robert F. Schmitt, Schmitt Homes

Working from the premise that the prime objective in the use of components is cost reduction, the author discusses the advantages of the preassembled roof truss as an example. He points out that while the initial cost of the component may be higher than the cost of materials for conventional construction, the saving to be effected in on-site erection can often offset this. The influence of mass-produced, repetitive houses as compared to individually built, differing floor plans on the economy of use of components is cited, and the importance of design as a factor in increasing the use of component systems is stressed.

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PREASSEMBLY OF COMPONENTS BY THE MATERIALS DEALER
By Michael W. Boeke, Davidson's Southport Lumber Co., Inc.

This paper discusses the advantages of the preassembled component system developed by the Lumber Dealers Research Council, and the benefits it has for the fabricating lumber dealer in terms of elimination of certain types of inventory, shrinkage problems, storage space, etc. Various means by which Lureco panels and other components permit a saving in house construction are also detailed, and a new hardboard interior partitioning system not yet on the market is described. Introduction of new aluminum components is also mentioned. The type of contribution that can be made by the individual lumber dealer to the development of a more efficient system is illustrated by examples of elements devised within the author's own organization and others. Methods of production and distribution of Lureco components are given.

PREASSEMBLY OF COMPONENTS BY A PRODUCT MANUFACTURER
By John S. Parkinson, Johns-Manville Research Center

Steps taken by the manufacturer of building materials to help reduce on-site labor in construction are described as: prefinishing of materials, provision of adhesives to supplant or supplement mechanical fasteners, development of sandwich panels. Need for information about the demand for larger sizes of materials is pointed out, in view of the attendant need for retooling in manufacturers' plants, revision of the transportation and delivery pattern, etc. The three stages in the development program leading to production of new prefabricated components by the manufacturer are stated as being: development of a component which will, in most respects, resemble materials of construction currently used; production of a more sophisticated type of component in which are included means for heating, lighting, plumbing services, etc.; and eventually, production of the fully industrialized house. Stating that the industry is currently in the first stage of this development program, the author enumerates the properties essential to the ideal component, pointing out areas where progress is still needed. The need for physical and structural testing of the component and the assembly system, as well as their coefficients of expansion and contraction with moisture and temperature is discussed.

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DIMENSIONAL RELATIONSHIPS OF PREASSEMBLED COMPONENTS
By Byron C. Bloomfield, Modular Building Standards Assn.

This paper discusses the principles used by manufacturers in sizing building products, and how architects and home builders plan their buildings to utilize these dimensional products. Modular design principles, and particularly modular jointing principles, are described as they apply to component construction. Permissible variables used by the manufacturer to develop his specific modular products are named and illustrated. Design of houses for component construction through use of modular principles, and the application of the planning grid to commercial structures are discussed. Typical uses of dimensional products by architects and designers are shown.

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PREASSEMBLED COMPONENTS IN A LARGE COMMERCIAL PROJECT
By Thomas J. Hodgson, The H. K. Ferguson Co.

Use of components in three entirely different types of projects forms the basis of this paper. The first, one in which the use of components would not ordinarily be required, is a livestock feed mill consisting of a warehouse, a 78' processing tower, storage silos, head houses and unloading facilities. Components used and method of their erection are detailed. The second example is the expansion of a steel mill, including installation of a 550-ton slabbing mill and construction of a new blast furnace. This mill was completely preassembled on special temporary foundations, and circumstances surrounding its construction and relocation are discussed. The author notes that preassembly made this one of the fastest erection operations on record. The third project is an example of combining an almost entirely preassembled component building with more conventional construction, in a 58,500 sq. ft. research laboratory. Use of hydraulic jacks in lift-slab construction is described. Advantages of the preassembled unit to architect, engineer and builder are pointed out, and the author also mentions the influence of the type of subcontract on stockpiling, handling on the job, actual construction and guarantee of the work.

A METAL BUILDING SYSTEM
By William J. Deegan, Jr., United States Steel Corp.

A modular steel building system utilizing tubular steel columns with open web or steel trusses, and/or hot rolled light beam sections and standard and long-span open web steel joists is described. Advantages of the system in terms of lighter weight, ease of erection, and adaptability to either one- or two-story buildings are detailed. Two types of preassembled commercial curtain wall units are described, as well as various materials and finishes to be used for 2-1/4" preassembled interior partitions. Labor skills necessary to accomplish the erection are noted, as are the most commonly employed design criteria. Instances of acceptance or rejection due to building code provisions are cited briefly.

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PREASSEMBLED ROOF STRUCTURES
By W. D. Page, Plywood Fabricator Service, Inc.

This paper discusses the use of plywood structural components in preassembled roof structures. The design, fabrication and application of box beams, flat stressed skin panels, solid type curved panels, sandwich type curved panels and ribbed type curved panels are described and illustrated. In addition, a patented structural roof panel developed in England, which is fabricated with plywood webs and lumber flanges, is discussed. Use of these plywood structural components in various different roof systems is considered from the standpoint that, while they may be used independently, they find their best application when utilized as a structural system involving two or more types of components.

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PREASSEMBLED COMPONENTS IN A CUSTOM HOUSE CONSTRUCTION SYSTEM
By F. Vaux Wilson, Homasote Company

It is stated that only approximately 20% of all houses built today come into the category of custom-built, with the other 80% being prebuilt for sale either by operative home builders or prefabricators. Preassembled components considered include floor, roof, wall, ceiling and gable units, with the current lack of large dimension sheet surfacing materials being cited as the greatest obstacle to progress with component construction in this field. Use of the 4" module in component construction, and some of the attendant problems, are discussed. Ten fundamental considerations in the development of satisfactory components for custom house construction are listed, and the primary considerations involved with the individual components under discussion are noted. Savings in dollars and man-hours made possible by the use of components in a small house are estimated, and a hypothetical total saving on a single house set at $1,111.

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THE MANUFACTURE AND DISTRIBUTION OF PREASSEMBLED COMPONENTS
By James L. Pease, Jr., Pease Woodwork Co.

Comparison is made between the original number and type of components manufactured for the typical prefabricated house in 1939, and the methods of distribution used, as contrasted with the present systems. Details of present-day components and their advantages are given for exterior wall panels, interior partitions, roof trusses, gables, exterior doors and windows, interior doors, etc. Mechanics of packing and shipping structural components are described. Some considerations entering into the development of new types of components are also discussed, and areas are pointed out where improvement in materials is necessary.

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THE MECHANICAL COMPONENTS OF THE FERRO HOUSE
By Gilbert McMurtrie, American Radiator & Standard Sanitary Corp.

This paper deals with a house built for the purpose of integrating the mechanical components with the structure in such a manner that flexibility, ease of installation at the site, and trade, code and builder acceptance could all be assured. It is a two-story house with three bathrooms. For heating, air conditioning, kitchen appliance-wall products and electrical service, currently available mass-produced preassembled units were used, and the paper discusses these only in terms of the consolidation of these services and products into a centralized location in the house plan. The three bathrooms and the necessary supply and drainage system, which are units of experimental design, are described fully, along with the method of installation. Implications of this experiment for future development of mechanical component systems are discussed, and the author cautions that a full study of code requirements is prerequisite to the final development of any such units.

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THE PREASSEMBLY OF ELECTRICAL SYSTEMS
By Richard W. Osborn, Osborn Electric Co.

The installation of a temperature control center and a motor control center are discussed in this report. The motor control center, consisting of feeder protection, branch circuit protection and motor disconnecting means, motor controller and motor over-current protection, is for the purposes of this discussion applied to a central air conditioning system having remotely located air handling units and a system capacity of approximately 300 tons. In the temperature control center each thermostat is equipped with a potentiometer to permit the operator to raise or lower the temperature in any particular zone directly from the center. It is noted that such an arrangement reduces field wiring to a minimum, allows 90% of the maintenance of the system to be accomplished at the centers, and changes in the sequence of operation can be easily and quickly accomplished. Typical centers are shown in photographs.

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PRINCIPLES FOR DEVELOPMENT OF MECHANICAL COMPONENTS FOR HOME BUILDING
By Ralph J. Johnson, Natl. Association of Home Builders

The advantages of the use of mechanical components by home builders are set forth as increased productivity, better scheduling of operations, minimal labor and material waste, ability to build during inclement weather, closer cost control and reduced overall costs. The author points out that the development of mechanical components has been very slow, despite the fact that the mechanical systems of the house account for about 1/3 of the cost of the house without land. Attention is called to the contribution that could be made by mechanical components toward reduction of the required space for such facilities. Seven assumptions are stated which, when applied to the development of mechanical components, would establish some necessary parameters for their design and fabrication. And, based on these assumptions, is developed a list of 12 principles to guide future activity in this field as it relates to home building.

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THE FUTURE OF PREASSEMBLED MECHANICAL COMPONENTS
By John C. Martin, General Motors Corp.

In suggesting a reasonable and practical limit to the size and complexity of preassembled mechanical components, the author questions whether any real cost advantage will accrue from factory production of these items as compared to site fabrication from today's more conventional components. To illustrate the point, a group of five rooms utilizing equipment presently on the market combined to serve as components is described and pictured, including cooking area, food preparation center, dining room, etc. The advantage of present-day components in facilitating unit-by-unit modernization of existing houses is also pointed out. It is stated that appliances and mechanical components cannot make the necessary technical advances by themselves, but must advance together with the progress of structural and other changes in buildings, and the products and services of related industries, including transportation, food processing and distribution, textiles, utilities, etc. Four criteria that a new component must meet are detailed. Potential development of electronic refrigeration is discussed in terms of these criteria.

# ATTITUDES ON PREASSEMBLED COMPONENTS

Session Chairman - W. H. Scheick
Managing Director
American Institute of Architects

# Introduction

By William H. Scheick,* Managing Director
American Institute of Architects

The matter of attitudes toward the use of preassembled components is one of extreme importance to the building industry in terms of new materials, new products, and new ways of building. Actually, we are talking about acceptance. This acceptance, of course, is vital to the sale of anything new. Many workers in building research have reached that crucial point where something is all finished in the laboratory, it looks good to them, and they think it should look good to everyone else but still, at that point, they haven't the slightest idea whether this item is going to be widely used in the building industry.

This is a difficult matter for our industry, because it's not like putting out a new refrigerator, a new TV set, or a new car. If the public likes these, they will sell. There are, however, a lot of people connected with the building industry who set up, whether they intend to or not, a kind of series of hurdles that each new building product has to cross before it is really accepted. Representing these hurdle setters, we have in this conference an architect, a home builder, a general contractor, a building owner, an attorney presenting labor's viewpoint, and a code official. Those of you in the building industry know that all of these fellow members of your industry can raise questions and will have to be given the correct answers. They must have it proved to them that the new product is going to work, that it will meet the claims made for it, not only from the standpoint of better results, or lower original cost and installation cost, but from the standpoint of the maintenance and operation of the building over a long period of time.

Therefore, it should be of great interest to have on record these papers addressing themselves to this very point of such attitudes and their relationship to the acceptance of new products, and particularly to the acceptance of preassembled components.

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*SCHEICK, WILLIAM H., Member, A.I.A., Building Research Institute, Forest Products Research Society; Bachelor's degree and M.S. in architecture, University of Illinois; formerly executive director of Building Research Institute and Building Research Advisory Board, and most recently vice president for research, Timber Engineering Co.

# The Architect's View of Preassembled Components

By Carl Koch,* Architect
Carl Koch & Associates, Inc.

The thoughtful architect is aware that mankind's physical environment and his buildings are visual indications of his hopes and beliefs. He is, therefore, vitally concerned both to sort out for himself a workable philosophy he can believe in, and then to be able to have some effect in implementing these buildings. Most architects today are keenly aware that the physical mess which is so large a part of our environment is inexcusable, and believe that they would be able to do a great deal to improve these conditions if given the opportunity.

At the same time, an increasing number of architects realize that our approach to architecture is at least partially responsible for our failure to be effective. Too many of us subconsciously, at least, blame the industrial process itself for the chaotic environment we live in, rather than laying the blame where it belongs on men who have still not learned how to control it for our best use.

One modern architect after another with whom I have discussed prefabrication and standardization have told me they don't like to accept smooth surfaces, rigid machine requirements, and endless duplication of identical parts and pieces. They insist on freedom. I have listened to them sympathetically and then, having looked at their buildings, I find myself struggling with a paradox. Each one of them has had to accept considerable discipline or his building becomes an Italian wedding cake.

Unity, beauty, coherence are all important aspects of good architectural design. All demand discipline—subjugating the parts to the whole, striving for clarity rather than exuberance, using the simple versus the complicated way to accomplish a purpose. Throughout history the greatest architecture has been subject to a fascinating combination of daring and discipline. The pyramids (4,000 years old) with all our technology would still be quite an engineering problem to construct.

In the Classic Period, architects designed and built beautiful buildings using identical elements over and over again, refining them over long periods of time. (Aegana and The Parthenon.) In the Middle Ages, the cathedrals, which expressed man's hopes and

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*KOCH, CARL, Architect; Member, American Institute of Architects, Boston Society of Architects, Building Research Institute; B.A. and M.A., Harvard College; Bacon Traveling Fellowship, 1938-39; lecturer at Mass. Institute of Technology.

aspirations better than ever before or since, derived breathtaking beauty from the necessity to use a single material—stone—subject to extreme limitations in a daring way. The process was one of very slow evolution, and the architect accepted the rigorous discipline necessary to build in this medium.

Today, many of us lack the imagination necessary to harness the industrialized process by accepting the disciplines it imposes. This statement sounds paradoxical, but I will try to explain. It is true we can do an almost limitless number of things with our new processes and new materials. We can simulate natural materials by various manufacturing processes. We can support buildings with air. We can do almost any job with a bewildering choice of methods and materials. We can, as one engineer has said, correct almost any design mistake with technology. Mr. Fitch, in a recent article in the AIA Journal, points this out with considerable bite ... "and then at the same time, a considerable school of modern architects subscribe wholeheartedly to the Miesian dictum 'less is more'." There is certainly discipline of a sort in our buildings, but it is not discipline combined with imagination.

It is understandable that with this fantastic choice, the bewildering multiplicity of interrelated techniques, that much of our building is chaotic and much of it stripped to the necessities.

I believe that prefabricated components plus daring and imagination can help very significantly in achieving a better living environment. By accepting or even encouraging the kind of discipline required to achieve efficient, economical and beautiful industrialized components, we can harness industry to achieve our aims of providing an attractive, civilized environment at a price which everyone in America can afford. I will leave it to others to discuss the size of the market, the profit to be derived, and I will ask you to assume with me that with really integrated systems of house construction, real economies can be achieved. I would like to discuss with you the results—what these communities of industrialized components will look like—whether they will be pleasant and satisfactory places in which to live.

In the first place, I think we should be working toward better components for both the single family detached house and the row, garden apartment, or town house. Since others have been talking almost exclusively about the former, I'd like to discuss the latter. The town house offers an easier way to integrate industrialized components into a unified, coherent, satisfactory whole. This is because the whole, the sum of the parts, is always more than the single house.

Since you always see, in a town or a city atmosphere, more than one dwelling at a time, the dwelling itself is only a component and must be thought of, designed and built in relation to its neighbors. This has always been true in the past of the more satisfactory communities.

The same kind of imagination and discipline I have spoken of in classic temples and medieval cathedrals has been used in relating beautiful groups of buildings on a more residential scale: Herculaneum, Delos, Cambridge, Nantucket, Greek Islands, Street of Knights, Chatham Village, Williamsburg, Bath.

There is nothing prefabricated-looking, boring or monotonous about any of the places I have just named. But they all have two of my prerequisites for beauty—imagination and discipline. What makes the Greek Islands so breathtakingly beautiful is the combination of surprise, and the simplicity, paucity if you will, of materials with which it is done. Whitewashed stone is the only material used. Each house is made the same way, of the same materials as its neighbor, changing only as the topography and the common access to each make it change, relating to its neighbor but maintaining its identity. Each house would fail to be complete by itself. The reasons which have made these places a satisfying, civilized environment can apply to an environment for our time built with prefabricated components.

I believe one of the reasons we haven't proceeded faster in the development of rationalized components is the failure on the part of both manufacturer and architect to appreciate and understand the area where discipline is necessary and imagination is desirable. Too many men in industry are developing new and better ways to synthesize natural products. Too few architects are attempting to learn the reasonable limitations of machine-made products.

We are all of us, both architects and manufacturers, as citizens and as family heads, increasingly concerned with the laying waste of our countryside with sporadic, unplanned present and future slums. We are equally concerned in stopping our cities from rotting, and rebuilding them with intelligence. There are two related but quite different design problems for architects and manufacturers here. In one case, the architect's client and partner is the manufacturer of housing components. In the other case, the architect must learn the discipline which governs the efficient manufacture of all the parts of a house. He must somehow, working with dozens of different manufacturers, help them each to define rationally the many, many separate parts and pieces which must interrelate effectively with each other to provide the complete living environment.

What should an intelligent architect demand of a rational prefabricated component system?

1) Better value. There are too many instances in which the architect can point to factory-produced products where all the savings obtained from machine production are eaten up in large overhead, selling and distribution costs, resulting in very little saving in terms of conventional, on-site construction.

2) Real integration of structure and equipment. The present reluctance of most product manufacturers to accept the responsibility for more than a single product makes it very difficult to assure the efficient working of the complete building. There is, so far, in the industry almost none of the interrelation of products so essential to real economy and efficiency. Almost all manufacturers are terribly anxious to be subcontractors, but absolutely refuse to be concerned with the complete product. If we built automobiles that way, everybody would be anxious to make wheels, bumpers, doors, brakes and headlights, but there would be nobody to assemble and market the complete automobile.

A designing architect has a right to ask Producer A, who is selling wall panels, whether he also has floor and roof panels to go with them and if not, whether he has worked out with Producer B the most effective combination of wall, floor and roof panels, since it would also be reasonable of him to expect that plumbing, electrical and heating services will be effectively integrated into producers A and B's walls, floors and roofs.

In other words, the discipline should go two ways. The architect is, I think, prepared to accept a standardized bathroom if he gets something in return. A bathroom which is more efficient and economical than the present mess of pipes and fixtures, better related to enclosing walls, lighting, ventilation and heating to solve some of his present problems with joints, maintenance, etc., will offset the lack of individuality permitted him in placing the fixtures, choosing the type of tiles and accessories. Once he accepts the discipline of completely integrated and interrelated housing components, the architect will, I believe, tackle with real enthusiasm the tremendous job of making an attractive, imaginative and unique living environment therefrom.

If our components are designed with daring and imagination, are intelligently subjected to the discipline necessary to produce them efficiently, beautifully and economically, and are put together with daring and imagination, we can perhaps be proud to say that our ideals are showing.

# The Home Builder's View of Preassembled Components

By Alan E. Brockbank,* President
Continental Real Estate and Insurance Co.

The home building industry has been working very hard to bring about a transition in the industry which would change home building from a handicraft to an industrialized operation. One of the ways that home building has progressed in recent years is in the use of larger pieces of material in an attempt to cover larger areas. Douglas fir plywood, sheet rock, masonite and many other large sheet materials have made this possible. It would appear from our experience with these large pieces that it would only be a short step to the use of components, but before we actually analyze the use of components, let's look at the forces that have been working on the home building industry.

In recent years, people have been buying houses built for sale rather than having houses built for them to their plans and specifications; however, in the most recent studies the small house in the large tract, duplicated many times in precisely the same way, is no longer acceptable to the public. The public has been demanding more custom features which could only be delivered to them at a reasonable price in a production operation which considered all of the newest techniques for mass production. In 1952 the Natl. Assn. of Home Builders analyzed the forces in the industry. They found a revolution taking place in the methods of construction and the design of houses. They also found that, if the industry was not careful, housing would be priced out of the market. The result of this was organization of the NAHB Research Institute. The objective of this Research Institute is to find ways of building better homes for less, or at least better homes for the same price. The purpose of this Research Institute is to look at the whole house, not just segments of it, and find ways to study the complete combination of materials, methods, etc., to produce the house in accordance with the NAHB objective. While we have been studying this subject, our market has been changing. We are constantly finding the following conditions to exist:

1) That there are more younger and older families in our population to be accommodated than there were before. The largest home buying segment of our economy in the middle age group has greatly diminished in depth.

*BROCKBANK, ALAN E., Natl. Chairman, Research Committee, Natl. Assn. of Home Builders; Member, Building Research Advisory Board, Building Research Institute, Building Standards Committee of Natl. Bureau of Standards; studied industrial engineering at University of Utah.

2) Through the process of urban sprawl we have reached out further and further until we may have passed the point where the public will continue to buy their houses on a basis of single family locations in scattered neighborhoods, because of cost and time in transportation.

3) In defining what a home is—a good house located in a good neighborhood with shopping, recreational, educational and religious facilities plus transportation available to transport people to industry for employment—we have found increasing obstacles from government to producing a good home according to this definition.

4) We have had a considerable rise in costs. The pressures on the actual cost of construction have not been nearly so great as the pressure from land cost and financing.

All these things have brought up the definition of 17 principles for research, which we have adopted for the use of our Research Institute, which are as follows:

1) Increase use of component parts.
2) Make greater use of modular dimensioning.
3) Combine function of material and equipment. (Formerly homes were built with 12 to 14 layers of exterior wall, while the new NAHB Research House in Kensington, Md., has 5 layers including 3 coats of paint.)
4) Develop interdependent structural systems.
5) Develop durable prefinished surfaces.
6) Improve sound control.
7) Improve dimensional stability.
8) Reduce total weight.
9) Improve fastenings and connectors to reduce the 1/4 million hand motions in nailing a house.
10) Reduce total amount of on-site labor (10¢ per min.) Price is the cost of the material in place, ready to use.
11) Reduce number of necessary skills.
12) Minimize effect of weather.
13) Reduce total construction time, now 15 to 45 working days, by 5 to 8 days.
14) Increase use of machinery and power tools—automation.
15) Improve material handling.
16) Increase construction process efficiency.
17) Develop new products.

You will note that the first item on this list is the increased use of component parts. We have spent most of our time in recent years studying these parts. Ten years ago I would have said that the use of components throughout the house would have been adopted by all builders before five years had passed. I did not realize fully all of the things that might happen with components, or I would not have made that prediction. Today I would say that if we are using component parts by 10 years from now throughout all of the houses in this country I will be greatly surprised.

My reason for this pessimistic view is that the savings that we expected to make by the mass production of components seem to be eaten up by the excessive cost of production and transportation. In many parts of this country builders have worked very diligently to componentize their homes, only to find when they finished that they did not produce a better house for less money. There are some notable exceptions to this rule.

One of the very surprising things that has happened in recent years is the migration of component journeymen from the small communities into the larger ones, leaving a vacuum in the small communities which cannot be filled by part-time help. These communities have thus had little construction completed beyond the absolute necessities to maintain the community itself. Our huge highway building program is often running near small communities, making fast transportation available, so industry is locating plants near these small communities, necessitating home, school, church and commercial development. In this situation the component construction of a house is an absolute necessity because of the lack of competent mechanics. This small-community problem has not escaped the attention of our lawmakers. Many laws have been conceived, though not passed, which would make financing in small communities much easier. The only ones which have actually become operative are the Voluntary Home Mortgage Credit Program and the direct lending by the Veterans Administration, but neither of these processes has accounted for much housing. Many of the problems which have made components uninteresting to the large home builder in large communities are identified in our research principles. Some that are very important for solution before they will be operative are these:

Dimensional Stability. With all the effort that has been put forth in recent years to make many of our panels and large pieces entirely stable, we are finding some of the most excessive instability that we have ever had.

Reduction of Weight. In this category, one of our chief problems is with codes. One would almost think codes were written on a basis that the heavier the material the better it would stand up in the house. All of us know that this is not true, yet we have made little progress in changing the codes so that a real reduction in weight would be possible.

Improved Fasteners and Connectors. We desperately need methods or devices for fastening materials together which are far better than those presently used. In many climates in this country glues could be used, but only during the summer season without an excessive period of time for total set at low temperatures. Many of the connecting devices are not entirely acceptable. A great amount of work needs to be done in this field.

Reduction of Skills. A reduction of the number of skills needed to build a house is important if components are going to be used. Actually, in many areas of the country, the requirements as to what work a particular craftsman may do are becoming narrower rather than wider, necessitating more skills on the job rather than less.

Minimizing the Effect of Weather. Our experience in our research houses has led us to believe that we have only begun to think about the effects of weather on the construction program, and this materially affects the use of components.

Reduction of Construction Period. The construction period must be reduced. Even in areas using components the construction period is far too long. I believe that, if we were to take an average of the United States, the construction period on a house would run something like 45 working days. Components should help us in reducing this 5 to 8 days which is the goal we really need to reach. However, many components as they are used today only increase the speed of part of the construction period. They make some contribution, but it is not sufficient yet to overcome all of the obstacles.

Improved Material Handling. One of the problems in the components field is that we really need a component which is larger than 4' x 8'. We should have components which are more like 8' x 20', but when we get into this field we find the material handling process very inadequate and needing extensive study and research.

Surfaces and Coatings. As I visualize the use of components in a house, it is infinitely important that we get pleasing surfaces, not necessarily designed to copy some other materials, but surfaces which are long-lasting and which can be coated with paint or other material which will stand up under all kinds of weather conditions for much greater periods of time.

One of the problems in supplying houses to the second- and third-time buyer is that he wants something exclusively his. This often means designing some segments of the house in brick, concrete, tile or rock. In this field, components seem to be entirely lost. The U. S. builders who studied the construction in Russia were very much impressed with the fact that all masonry production reached the building site in 4' x 4' or 4' x 8' panels, which were simply set in place by large cranes. I do not know that any study has been made yet that would indicate whether or not this idea is efficient and labor-saving. I do know that our builders also stated that workmanship was very poor, principally done by women who had only rudimentary knowledge of masonry. However, if we have our minds set on developing components to their fullest extent, we must consider how to develop the masonry concept in order to make houses more diversified and dissimilar. If these things can be accomplished, then my prediction concerning components, I believe, would be erroneous and we could soon use components to their fullest extent everywhere.

# The Contractor's View of Preassembled Components

By Henry Norair,* President
Norair Engineering Corp.

There have been very few basic changes in the methods of construction and materials used for the past 20 centuries. When man started to put the first mud hut up for himself, all he had to use were materials he had immediately around him such as stone, mud and branches from trees to make his first building. As time progressed this improved to where he started using brick, stones and mortar. Only in the last 75 years have we started to use steel and reinforced concrete, a basic change from the original concept.

When the use of concrete and steel became common, the construction of buildings took an entirely new spurt. Whereas in the past, buildings took anywhere from two to 20 years to build, they now can be built in about 1/10 that time. Despite the use of new materials and steel, the construction industry has lagged behind in its mode of erection. Still, one piece at a time is added from the foundation up to make the building, while in other industries automation and new machinery have been introduced for faster production, and the number of people required per product has been cut more than 75%. In the construction industry this has not been achieved. Still today, we must have elaborate forms to pour concrete and walls are built up by adding stones or bricks one by one, by hand, which isn't much advanced from methods being used centuries ago.

You are all acquainted with the first prefabricated trusses, both steel and wood. Then came prefabricated interior walls and partitions. We have at the present time prefabricated outside wall panels, which include whole metal sections with windows, insulation, etc. In other instances these sections are formed by precast concrete with steel or aluminum frames inclosing windows. During the war and immediately after, a trend was started to build houses by preassembled sections, such as floors and walls which had been completely fabricated with necessary piping, duct work, etc. incorporated into them. In the field, all that was necessary was to bolt or nail these sections together into a complete unit. Many of these sections were sent to England and other parts of Europe.

There is another method developing which is not as prevalent in this country as in Europe, which is prestressed and precast concrete building sections. It is quite a common practice in Europe that prestressed columns, beams and floor slabs are assembled in the field by welding them together. This is very rarely done yet in this country, although great efforts are being made in this direction.

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*NORAIR, HENRY, Member, American Society of Heating, Refrigerating & Air Conditioning Engineers, American Society of Sanitary Engineering; educated at University of Pennsylvania; started his own firm in 1935; deceased, April 1961.

We should be interested in what contractors, especially the general contractors, think about these methods. As you all know, there are two basic questions facing the contractor:

1) Is it possible to handle these preassembled sections economically in the field?

2) Is it possible to get competent labor and what is the attitude of labor toward these preassembled sections?

Every progressive and alert contractor wants to put up a building as quickly and economically as possible. I doubt that any contractor would object to using preassembled units. However, one of the problems which he must face is that these preassembled units should be very carefully planned and assembled so that:

1) They are easily handled.

2) After they are put in place, they fit perfectly.

3) Joints between these sections are made in such a way that they will be leakproof and water and airtight, and will stand the effects of time and temperature changes. One of the greatest difficulties today in preassembled outside wall sections has been that of keeping them weathertight as leaks develop due to expansion and contraction.

I am not going to express my personal opinions here regarding manufacturing practices. This is outside my field. I feel that some of the difficulties will be eliminated in time. Definitely, using prefabricated wall panels has speeded up construction of buildings.

The mechanical trades have for some time used prefabricated sections of piping and duct work, preassembled in the shops, and sent to the job to be put in place. There has been a very difficult hurdle in connection with these preassembled units which a contractor, especially a union contractor, must face, in the form of the jurisdictional claims made by different unions. Suppose you get a preassembled wall section composed of metal casing, asbestos or glass fiber insulation, steel or aluminum framework, and windows all in one; immediately you must contend with ironworkers, sheet metal workers, engineers, insulation workers, and glaziers. All of these trades claim these panels.

I have been a member of the National Labor Board for settling jurisdictional disputes between various trades. This is composed of eight representatives of contractors and eight of the unions, covering territorial jurisdiction of the United States, Mexico and Canada. I would say that 50% of all disputes arose from factory assembled units of one sort or another. Unfortunately, decisions rarely were given on the basis of logic. Almost always in making decisions, priority was given to local practices. Most probably, whichever local union was strong was the one favored.

I remember a case some years back where a quantity of prefabricated piping was delivered to a plant in Newark, N. J., and the unions refused to handle it. The piping was taken apart and reassembled again in the field. These types of issues are gradually being eliminated, but there is still a long way to go.

Speaking as a contractor, I am convinced that every progressive contractor would like to see more and more preassembled units used in buildings. It will take some time to overcome the resistance raised by labor unions and local building codes. In many places it is impossible to use prefabricated panels because local codes have such antiquated requirements that it would be expensive to use them. Only five years ago in Washington, D. C., if you used prefabricated steel outside wall sections, they required you to put in 8" fireproof masonry wall behind it up to the window elevation. This has just recently been partially eliminated. Why should you put an 8" masonry wall behind a fully insulated metal section? This, nobody knows, but still it was a requirement.

# The Building Owner and Operator's View of Preassembled Components

By R. J. Short,* Director, Engineering Exploration
Procter & Gamble Co.

An examination of preassembled components should, of course, consider the long-range effect on operation and maintenance as well as the effect on the first cost of the building. As we go over our experience, however, we find very little of real significance to talk about, pro or con, regarding effect on operation and maintenance. Easily the over-riding consideration from our point of view is the effect on first cost. I would like to point out the seriousness of this first-cost consideration to a company like our own, and to report some of our experience in struggling with the problem. Hopefully, this will make a case for a much more comprehensive attack on costs, with preassembly fitting into its proper place when it is the best answer.

Let me start by outlining some factors that we who pay the bill must think about.

1) To ours, like other growing companies, the cost to build is a major concern. We work feverishly to make a profit, about half of which now promptly goes for taxes. An important fraction of what is left then goes to the construction of new facilities, either for growth or product improvement. And, here is a fact that is sometimes overlooked: a dollar saved in our manufacturing cost only nets about a half-dollar in profit after taxes, but a dollar saved in our construction means a whole dollar, since we build with after-tax dollars. This suggests that cost reduction effort in construction should at least match such effort in manufacturing per dollar spent.

2) Of the many cost problems that must be faced, the bill for construction seems to go up faster than any other item on the ledger. The cost to build a given building, for example, has gone up 2-1/2 times in 25 years, while the cost to buy a 300-ampere electric welder has remained about the same. A comparison of the Engineering News-Record construction index with the cost index of other industries shows construction the winner, hands down, in rate of increase. We who pay the bill must ask, "Why should this be?"

3) From where we sit, the cost reduction tools that have worked so well to hold down manufacturing costs are not being used effectively by construction. For example, consider research, which is the long-range attack on costs. The average manufacturer is spending about 3% of sales in research to improve his performance.

*SHORT, R. J., Member, American Society of Mechanical Engineers, Building Research Institute, The Engineering Society of Cincinnati; graduate of U. S. Naval Academy; has been associated with his present firm for 21 years.

The construction industry is spending about only 1/2 or 1%, with 95% of even this small amount spent by the materials manufacturers. This leaves only a dribble devoted to the study of better ways to engineer and to construct.

From another angle, we are all familiar with how industrial engineering has developed cost reduction into a science for American manufacturers. For every two supervisors in our factory these days, we will average one staff assistant whose sole function is cost reduction (using industrial engineering approaches to better methods), and he is paying off about four to one. This, of course, is equally true with other manufacturers. This industrial engineer with his tools is just as available to construction as he is to manufacturing (in fact, one of the pioneers of industrial engineering was a construction engineer) but he is seldom, if ever, found saving money at the construction site. Both of these approaches, research and industrial engineering, are being exploited to the hilt by manufacturing industries, but are little used in construction.

4) Many will say, "Construction is different; these cost reduction methods are O.K. for manufacturing, but will not work in construction." We have tested this possibility and can report from several years of experience that these methods can be applied to construction and will achieve important reduction in cost.

Our construction load is small compared to many, but its cost is no less important to our position. For several years we have allocated time and money for two development programs aimed at reducing these construction costs. The first is to develop more efficient design procedures, and the second is to develop more efficient construction procedures, primarily by applying industrial engineering principles. Construction firms with whom we have worked have been enthusiastic supporters and contributors to this approach.

These programs have revolutionized our concept of how to design plants and how to build them efficiently. They are producing better plants. They are reducing to an important degree both construction time and cost and, (of interest to this discussion) they are quite naturally increasing preassembly applications.

Let me sketch very briefly some of this work, not to suggest that our company knows all the answers to construction, but to support the point that this approach which we do know something about will pay off in construction. The same approach in your hands might well have found better answers.

The program to improve design procedures started with the realization that modern multi-story processing plants had become too complicated to visualize properly with the old conventional drawings. We turned to models and photography as the answer.

We now make and use three types of models:

1) Plot plan models
2) Preliminary equipment arrangement models
3) Production engineering models.

Figure 1 shows a typical plot plan model. Such models are built to a small scale, usually about 1/8" = 1'. As can be seen, the equipment and buildings are simple shapes, since at this stage of a project the information on equipment details is scarce. These models are used to develop the best over-all yard layout for the new facility. Next, preliminary

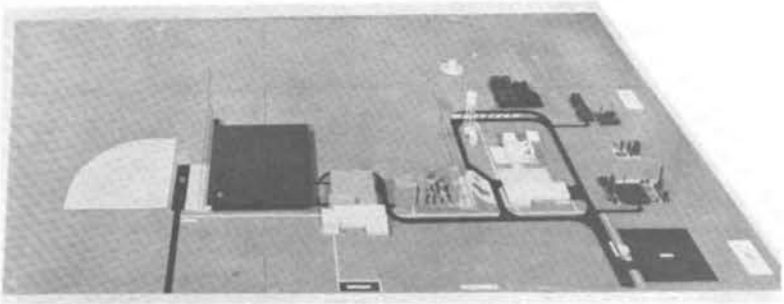

Figure 1

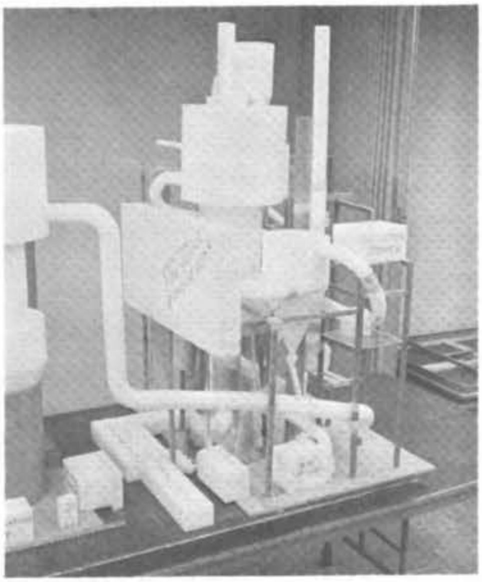

Figure 2

equipment arrangement models are made to a larger scale, usually about 3/8" or 1/2" to 1', but still with simple block and dowel replicas, because we still lack vendors' prints on many items. Such models are built to achieve the most economical equipment arrangement. Figure 2 shows how a model of this type is developed.

And finally, we build the so-called "Production Engineering Model," which is an accurate, true-scale development of the equipment, piping, conduit, chutes and ducts in complete detail. Figure 3 illustrates this type information on a conventional drawing—difficult to understand, even more difficult to refine and improve. Figure 4 shows the same type of information in model form. Its clarity invites the interest and contribution of managers and operators as well as the engineers. Such models are built to a scale of 3/4" = 1' and will include the following detail:

1) Piping and piping accessories
2) Structural members
3) Conduit
4) Chutes and ducts
5) Equipment, including instruments and safety
6) Building mechanicals such as lights, heating and ventilating.

All the conduits, chutes, ducts and piping are color-coded to indicate construction specifications and are then tagged with suitable identification tags, so that they can be referenced back to a pipe specification table and a conduit schedule. We usually locate the model in the design area where it can become the nucleus for the design effort.

Models built in this manner form the method now employed for transmitting design intent on piping, conduit, chutes and ducts to the field. As such, they replace the assembly drawings normally made for these elements. Figures 5, 6, and 7 show several models recently used in this manner.

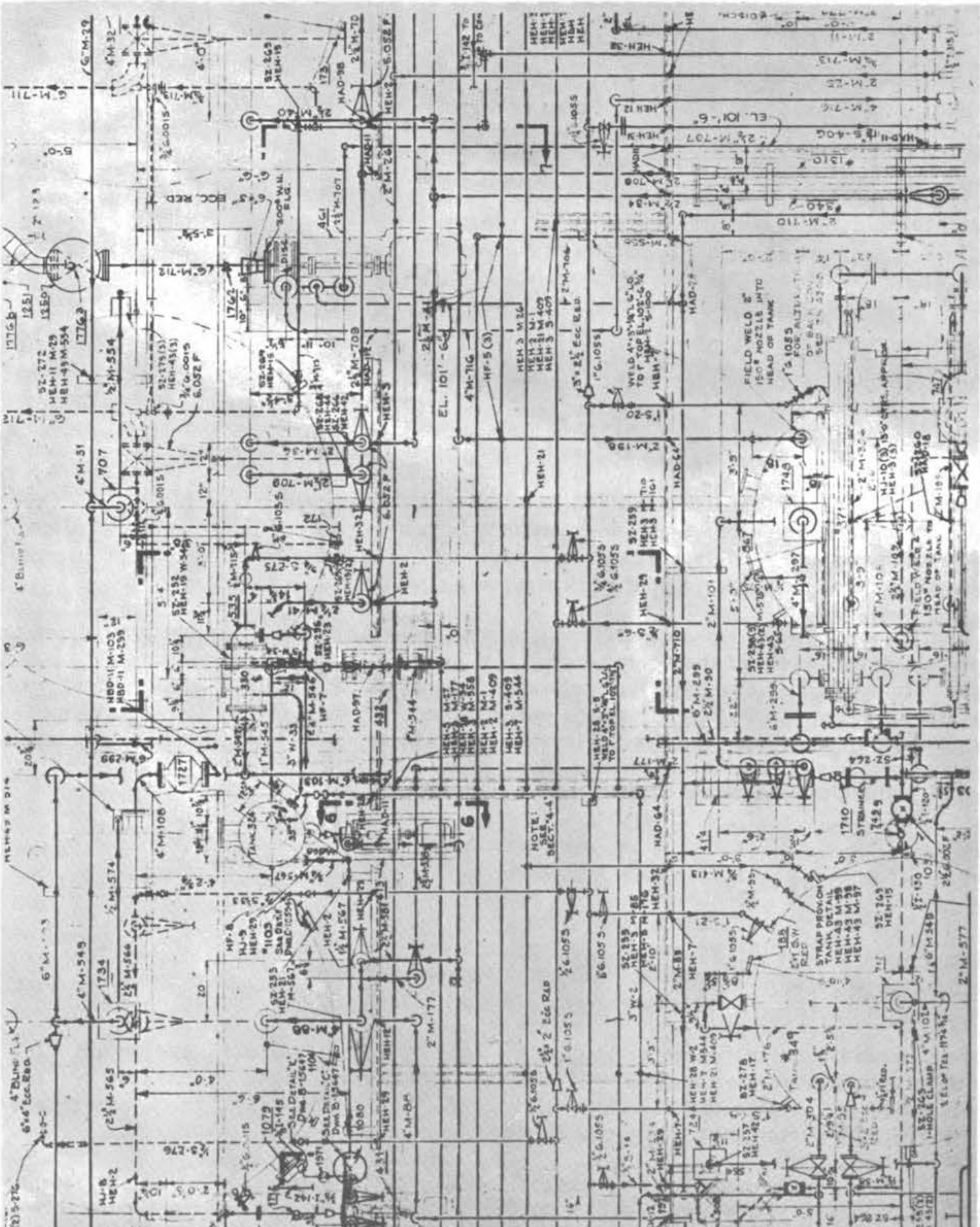

Figure 3

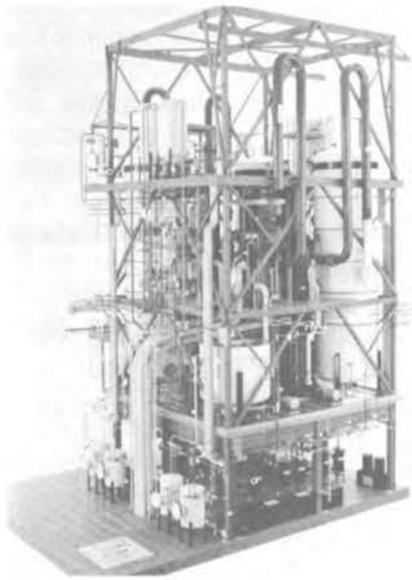

Figure 4

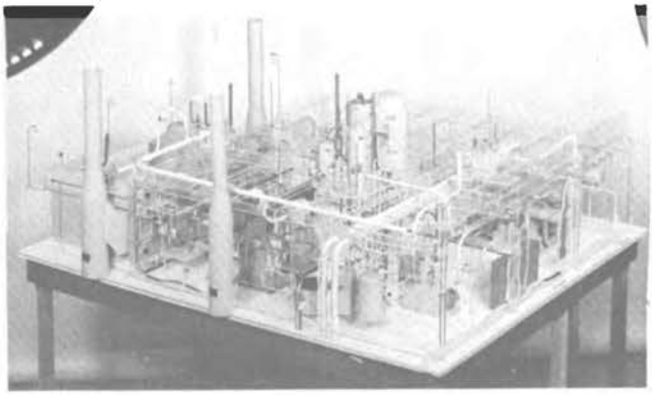

Fig. 5. Completed true-scale piping model with all phases such as electrical and mechanical shown.

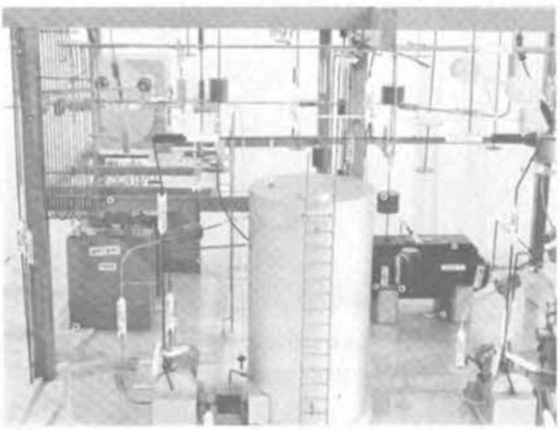

Fig. 6. Typical fine wire model of a process unit.

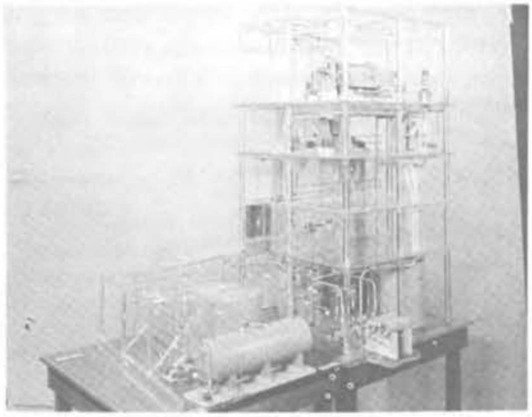

Fig. 7. Completed true-scale piping model with all phases such as electrical and mechanical shown.

The application of photography as an engineering tool has been an important parallel development. Figure 8 illustrates a floor plan photograph of a model that has been transposed onto a tracing to permit the addition of critical dimensions and notes for properly locating the equipment in the field. This procedure, of course, eliminates considerable drawing.

A photographic technique has been developed that will take a true orthographic picture of a model, eliminating the dimensional distortion which takes place in a conventional picture. This is illustrated in Figure 9. Such a picture can be enlarged and reproduced to match any required scale, metric or otherwise, and dimensions can be accurately scaled off the photograph. Another application is illustrated in Figures 10 and 11 which show photographs of existing equipment being used to indicate revisions. These photographs, again, are transposed onto tracing, permitting the engineer simply to add changes and notes. This procedure is much cheaper than conventional drawings and obviously

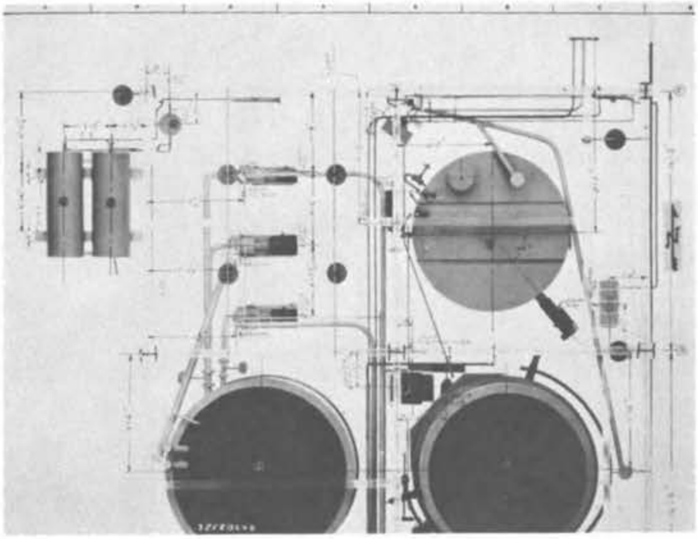

Fig. 8. A portion of a shadowless model photo-drawing.


Fig. 9. Comparison of model photographs taken with a conventional camera (bottom) and with a non-perspective (orthographic) device.

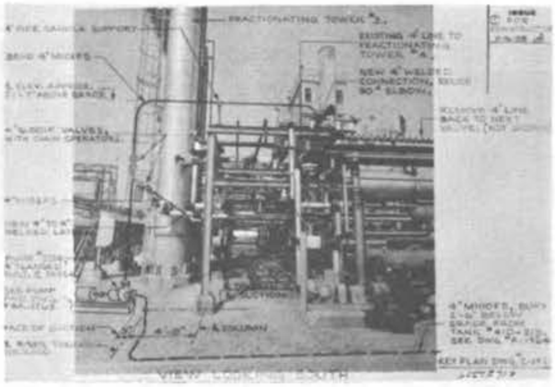

Fig. 10. Typical completed piping photo-drawing for a revision to an existing facility.

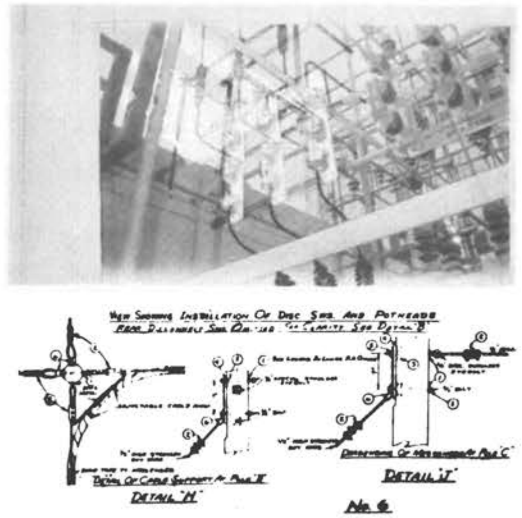

Fig. 11. Section of a completed electrical photo-drawing for a revision to an existing facility.

much clearer. The combination of modeling and photography is saving important time and money, and has become a standard engineering procedure.

Our second development program picks up at this stage, and has to do with the industrial engineering approach to the erection of the plant. This approach is built around a few simple assumptions stolen from manufacturing experiences. It is assumed:

1) That each small block of work deserves to be analyzed in detail as to how it can best be done.

2) That alternative methods should be searched out and priced out against the standard method.

3) That the cheapest method, when finally selected, should be spelled out in whatever way is most helpful to the foreman or supervisor who must do the job. It should help him schedule the work, allocate the right people, and line up the right equipment in advance.

This sounds like a lot of extra work, but as long as one dollar will get you four, we will buy it. It reveals cheaper methods (like preassemblies) as a routine day-by-day procedure, and actually puts them into effect. Most of the ideas usually come from the construction superintendent, his craft foreman, or often from the mechanics themselves, but the methods man is there to do the rounding-up of the ideas, the analyzing and planning.

And here is where preassembly comes back into focus. It will be considered on its merits for each situation. It may be right or it may be wrong, but if right, the details will be worked out and it will be applied.

To summarize the points we have tried to make:

1) Preassembly ideas will only achieve proper development as a part of an aggressive, over-all program of cost reduction.

2) There are well known and tested approaches to cost reduction that will save money on any construction operation.

3) We have no illusions that the details of our approach are best or even usable by others, but we are convinced that the principle of more intensified research and methods study will pay off for any firm or individual involved with construction.

# Labor's View of Preassembled Components

By Andrew P. Murphy, Jr.,* Attorney

This paper will discuss what I regard as some of the basic labor-management problems of the home building branch of the construction industry, particularly as they apply to component construction. There are two broad purposes to be accomplished. First, I want to suggest to you certain themes to be emphasized, and second, I wish to discuss a group of labor-management issues in this industry.

As to these themes, we should recognize at the outset that there are a growing number of signs that labor relations in the home building industry are coming of age. They are being formalized and are increasingly interrelated with the labor relations of other branches of this industry. A larger proportion of home construction, particularly in the larger cities, is conducted under organized conditions, more or less, and this makes it obvious that labor relations in housing are coming of age.

Second, in thinking of labor-management relations in this industry, we want to bear in mind that contractors have as many problems that affect labor relations between themselves as they have with the labor. In other words, the builders have problems with their subcontractors which affect labor relations. The builders who employ carpenters directly may have specialized problems when they employ carpentry subcontractors. These labor relations between the various contractor groups are frequently as influential and decisive in determining labor-management relations as the broad problem of the relations between the contractors and the unions.

The third point I want to emphasize is that construction in general, and housing as well, involves the constant building and rebuilding of organizations. The construction job requires the building of a specialized management organization for each job. No two of them may be identical. Construction management, be it in home building or elsewhere, to be successful must become expert in the building and unbuilding or rebuilding of organizations. This constant attention to organization and the relationships among people in these organizations becomes one of the key factors in construction, and very decisive with respect to construction costs. This is more true of home building than of other industries where, once an organization is built, it may remain relatively stable over a period of time.

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*MURPHY, ANDREW P., JR., Member, Federal Bar Assn.; B.A., Harvard College; L.L.B., Boston University; formerly associated with Natl. Assn. of Home Builders.

Finally, the fourth theme I want to enunciate is that I am anxious to put labor relations problems, as I see them in this industry, into some type of focus. Too frequently, the spectacular or the grotesque, the exterior symptoms, get the attention, whereas the underlying problems escape notice. If you ask most people what are the problems of the industry, you will probably turn up with a list. I have seen many such long lists of cost-inflating factors, featherbedding, etc. I am not saying these are not useful, but it seems to me these lists, on the whole, have diverted attention from what I am prepared to contend are the more fundamental and more basic problems of the industry.

Let's apply these ideas to a group of what I call labor-management relations issues in the industry.

The first of these is the relation of the home building branch of the industry to the rest of the construction industry. The home building industry cannot be looked at entirely in isolation from the rest. This relationship varies, of course, in terms of high construction and low construction, and since the industry's labor relations are only gradually coming of age, we have not yet fully jelled what is to be the relationship between labor relations in home building as compared with the rest of the construction industry.

Large sections of the home building industry were only organized in the post-war period, and bargaining arrangements in the unionized sectors are still in flux. It seems to me that we must recognize that the home building branch of the industry has a dilemma, and any way it tries to solve this dilemma is bound to have problems. One solution would be to say, "Well, let's have the home builders bargain separately with the unions and seek to set up their own contracts which recognize their distinctive problems," for there are some distinctive problems in the industry.

The difficulty with that approach is that when labor market conditions are tight, people wish to pay above scale to get workers. The separate negotiations frequently mean that the home builders, whose economic position may be different from the rest of the industry, may find bargaining alone a disadvantage sometimes.

The second alternative is to simply follow the leader, and that very frequently happens. You just take what somebody else agrees to. That, of course, has its difficulties because the economic conditions in home building may not be comparable to those of other industries, and the contract terms on a number of points such as apprenticeship, tools, stewards, etc., may not be directly applicable to construction. Also, following somebody else's lead, when you have substantial volumes of employment, can pose problems.

Finally, the third alternative is, of course, to embark upon a joint negotiations program. This, too, has its difficulties. Many of the existing associations are not too happy about newcomers joining the association. It is true that the addition of further associations to bargaining makes the bargaining more complex. The home building industry frequently has different problems, and existing associations may not wish to be bothered or may not be sympathetic with these problems in negotiation. The simple fact is that home builders frequently have divergent interests from other contractors. When business declines, they may be under greater competitive pressure. Organized home builders have not only nonunion competition, but also competition from self-employed builders and from do-it-yourself addicts, which aren't quite so significant to general contractors.

Whichever of these three alternatives the home building branch of the industry follows, has its promise; all three arrangements have, in fact, existed. The home builders may also choose to follow a different policy when business is good from that which they follow when business declines. Once you have tied your tail to somebody else's kite, it cannot be lightly abandoned. This is a very fundamental labor relations problem in the industry. If we face a decade or two of substantially high home building, the only stable long-run solution is essentially a joint type of bargaining arrangement with other contracting groups. My own personal conviction is that it must develop gradually in each locality.

There is one further complication to joint bargaining that also should be squarely put on the table. The subcontracting groups in the home building industry, particularly with respect to the carpentry trade, seem to raise very special problems. If the home builders wish to speak for those subcontracting groups, they must accord them some kind of representation in their association which, in many cases, they may not now have. The unions will say that the subcontractors are their true employers and the builders are not and may, therefore, prefer to split off the subcontracting groups and deal with them one by one, such as the roofing contractors or the framing group, or the flooring group, or the foundation form group, and other such groups of carpentry specialists.

The builders, if they desire to bargain jointly with other associations, have a very special obligation to handle the problem of the carpentry subcontractors' group with a good deal more care than it may have been handled in some localities.

The first basic problem is how shall the structure of bargaining in this industry be organized? The answer to that question is frequently more fundamental with respect to labor costs and productivity than many other issues that are commonly referred to.

The second basic issue in labor-management relations is the method of wage payment. It takes a certain amount of, perhaps, boldness, even to mention this. I am referring to the practices of piece work and lumping in this industry.

Despite the persistent opposition of unions, almost universal in this instance, and despite the formal opposition of most associations that I have knowledge of, it is correct, I think, to say that piece work and lumping in various forms persist in practice in this industry more widely than most people are willing to admit. An observer of what is transpiring in labor-management relations ought to see it as a symbol, ought to see it as the one-eighth of the iceberg above the surface, and ask himself, "Why does this practice exist? What is it about this industry that results in this practice breaking out despite the most vigorous methods applied in many localities?"

First of all, much of what has come to be called "lumping" is really a form of subcontracting. A crew of rough carpenters will elect, for a price, to put up the frame part of the house. What they are really doing is subcontracting from the builder the erecting of the frame. The real problem, therefore, in this respect, is a problem of subcontracting. My own conviction is that, in each locality, the builders sooner or later must come to a standardization of the degree of subcontracting, and I am speaking particularly of carpentry subcontracting.

By that I mean I am anxious that competition be preserved so that a builder can build a house himself from the foundation to the ceiling if he wishes to, or he should be privileged to subcontract it out. But it would be preferable, in my opinion, to subcontract it out by agreement in specified blocks: the foundation forms, or framing, or interior trim, or insulation, or roofing, or flooring, to a limited number of groups. Then we don't get into a situation where there are increasing degrees of subcontracting by finer and finer groups, who have very little standing as contractors and who cannot really deal with the union, and can have no labor policy.

Piece work, or lumping, and these terms should not necessarily be used interchangeably, is, first of all, a reflection of this problem of subcontracting. It is a reflection of the wide variation in experience and in the training of the work force. Some workers are extremely skilled, and others are not so skilled. Men in their 50's and 60's who have done interior trim for years and years, and who are put on a row of houses at a union scale, will finish the house long before the novices across the street, and they will do a vastly superior job to that of the novices, who may be getting officially the same rate of pay. That condition is productive of instability and leads, sooner or later, to the development of some kind of piece work or lumping arrangement to compensate for these differences in skill, experience and training.

This highlights the central importance of the problem of developing a labor force of more highly skilled classifications and experience in the home building field. Nonetheless, the piece work or lumping problem is a reflection of this disparity in training and experience.

Finally, the emergence and persistence of piece work or lumping grows out of supervision problems. Where jobs are isolated, and houses are isolated, it is frequently impracticable for a builder to exercise the kind of supervision, the kind of persistent direction of operations that is possible in a factory and, in these cases, piece work and lumping are frequently a form of supervision.

What emerges, what shows above the surface as a persistent tendency in many localities toward piece work and lumping, is a problem which is itself a reflection of at least three other major problems in the industry.

Another major labor-management problem has to do with the introduction of new materials, new methods and new machinery, and particularly the growing proportion of work operations performed off the site. Manufacturers, architects and others associated with the industry must be made more cognizant than they are now of the labor relations implications of their new ideas. It doesn't do to invent a new material and have it come to the job site, only to have it become a source of great friction. It doesn't do to have a piece of material developed in the shop and send it to the job site, only to be rejected on grounds that it doesn't conform with long-known rules and practices.

The wide ramifications of labor-management relations have been a lesson which modern mass-production industries have had to learn. There is not a company in the United States in the mass-production field that hasn't had to learn, for example, that you must be careful about the day you announce your profits and dividends. Many a company has been in the position of announcing its dividends and profits unwittingly in the midst of negotiations, when a wage settlement was almost ready. There are implications connected with dividend policy in the labor-management field. It is with respect to this area of new materials, for example, that in the mill products field, further larger components can be expected and be practically accepted.

If you study the history of the building trades unions, this observation will stand the test, that the national unions, on the whole, have had a more sensible policy, a more economically sound policy, with respect to this topic than many local unions. This does not arise out of any greater benevolence, but out of the obvious vantage point of a national union office. In particular, national unions have been able to see that such attempts to resist new machinery have, in the long run, been in vain; that resistance to particular types of materials has frequently resulted in nonunion operations which the national union subsequently has had to clean up. Such opposition has led to the creation of a group of contractors who have found those methods or those machines profitable, which in turn has led to the putting out of business, or the financial detriment, of those upon whom the unions sought to impose the rule.

With a number of these lessons before us, it is my observation that the national offices have been more sensible about this. This does not mean that they have been willing under any and all circumstances to intervene strongly, or even mildly, in individual localities on this problem, for they have their problems internally, as any organization does. But, if one seeks a solution to a problem of the introduction of new materials and new methods, the backing and cooperation of the national office of that union ought first to be sought, and the problem handled from the national level in the most serious of circumstances, with, of course, some prior work done on the local level. The opportunity for making headway on these problems, to reduce the time required between the appearance of a new method or idea and its eventual acceptance, may in many cases be assisted by seeking the cooperation of the national union offices.

The fourth major problem has already been discussed: the problem of labor supply and allocation.

First one might ask the home building industry in particular, and other branches of construction as well, whether as much attention is being paid to the training of a skilled work force in this industry as is customary in other modern industries. How much time and energy is devoted, and how carefully designed a program is presented in your community for the training of a work force? How do these expenditures compare with those which are made in other industries?

The highly competitive and small-scale operations of many builders make many of them content to draw on the labor pool. Therefore, the training of the work force in this industry has too frequently been allowed to fall into the hands of a few, particularly some larger operators who cannot escape the problem, and smaller operations simply draw upon, live off, the skills which have been created by other builders or by other branches of the industry. This is a very serious, long-run problem.

In the area of the allocation of the labor force, to the extent that we expect to live in a world of high levels of employment, we will be forced to allocate and make better use of the labor force we have. One wonders whether all is being done that can be done to classify and to allocate the home building labor force in various localities.

One problem of the allocation of the labor force in a locality where jobs are of a short duration is to be sure that the specialists we have go most quickly to the jobs which they are able to perform. We will raise productivity and lower costs in the allocation of our labor force if the specialists go to the jobs they are most able to do, rather than be compelled, by lack of work, by lack of information, to take jobs where their efficiencies are less pronounced.

The home building industry, with its jobs of short duration, and frequent loss of time between jobs, admits to the need for enormous improvement in the allocation of its labor force. This is an area which needs a great deal of work.

The whole construction industry has long needed a forum in which there may be more regular and systematic consultation between the national officers of the unions involved and the national representatives of the home building industry, not only for purposes of open and general discussion such as this, but also to arrive at a mechanism to solve particular problems, to handle specific issues that arise. One of the labor-management relations problems of this industry has been the establishment of a proper mechanism by which the problems of one side may be brought to the other, and an attempt made at the national level to work out specific solutions; an arrangement whereby problems which may not be handled locally may be raised to a national level for further action. In the last year, significant steps in this direction have been taken with the establishment of the Construction Industry Joint Conference.

To summarize, the persistent underlying labor-management problems of this industry are:

1) The form of bargaining in various localities, the arrangements for bargaining, not only with other groups of contractors but also with carpentry subcontractors in the home building branch of the industry.

2) The problem of piece work, which I see as a symptom of other problems.

3) The introduction of new methods and new machinery or materials.

4) The shifting of work between construction site and off-site operations.

5) The allocation of the labor force between jobs and specialities.

6) The need for some central forum in which specific problems may be tackled directly on a national level, which we hope to find in the Construction Industry Joint Conference.

# The Building Code Official's View of Preassembled Components

By Paul E. Baseler,* Executive Secretary
Building Officials Conference of America, Inc.

In the past fifteen years there have been great advances in the construction industry. Home building, for example, has advanced from a craft to an industry. The use of "panel wall" construction for other buildings has developed. There have been many changes in building techniques. In this process, men of vision have turned to the construction of units of buildings in a factory for assembly at the site, applying modern assembly-line techniques to an age-old industry that traditionally has been accepted as the handcraft cutting and assembly of small pieces.

But this has brought with it many problems:

1) How do these preassembled components compare with the conventional elements they replace?
2) How can they be fairly and adequately evaluated?
3) Can they be analyzed by accepted engineering formulae?
4) How do known criteria, applicable to conventional construction, apply to them?
5) Can visual inspection suffice for determination of quality?
6) How should these components be used?

These and many other questions are pertinent to the assurance that buildings in which preassembled components may be used will be safe and reasonably durable. It is the responsibility of building officials to determine the answers to these questions.

In the face of these advances in the construction industry, it has been charged that building codes hamper progress by preventing the free use of new materials or techniques and improved methods of using well known materials. To some extent this is true, especially in those communities where independent building codes are still in existence. Many of these codes contain rigid specifications of materials and prescribe the conditions and methods by which they are used. These codes also frequently include personal prejudices of members of the volunteer committees that produced them, or show the influence of local pressures and free advice from vested interests, but the extent of this has been grossly overemphasized.

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*BÁSELER, PAUL E., also serves as Code Coordinator and is BOCA representative on the Joint Committee on Building Codes.

The recognized building codes now made available to local communities by nonprofit service organizations make provision for the acceptance of these new developments. These codes state requirements in terms of performance rather than specification. But, even with these codes, there are a number of problems in the acceptance of preassembled components, especially when they employ the more revolutionary materials.

Some manufacturers of preassembled components have had difficulty with acceptance of their products. Much of this results from lack of understanding of the reasons for building regulations, and the functions and responsibilities of building officials. In general, building regulations are based on experience. When new materials or techniques are introduced, it is often necessary to evaluate their expected behavior by known criteria and control them by regulations designed for more conventional materials or methods, until experience with them shows that they may be evaluated or should be controlled by modified regulations. The effect of this may be to impose on these new materials or techniques unnecessarily restrictive regulations for a time.

It has generally been conceded that it is not the function of the building official to assure the best possible work, or raise the standards of construction, or establish the best practice; but rather to assure a construction that safeguards the public from the dangers incident to buildings. This was sufficient when buildings were built for a specific owner who had a measure of choice in the materials to be used. But, under present conditions, with completed buildings offered to buyers as finished products, government must look after the interest of the public to some extent by determining that the components of the building are of reasonable soundness and durability, especially when these components are completed away from the construction site.

Much of the difficulty encountered by the proponents of preassembled components has resulted from the manner in which they have sought approval of their products. Many of them have not given serious consideration to the effect of building regulations on those products until they have been put into mass production and their use has been questioned in the field. Often they have then obtained the approval of a local official, or obtained a permit for an experimental or "research" house, or a waiver of building code requirements for an individual project. Frequently, an attempt is made to use this local experience with one building in one community as the basis for obtaining permits for similar construction in other locations.

The experimental use of a product in one building does not prove its soundness and durability; nor does the permission of its use in one community under waiver of applicable regulations constitute acceptance of it. The use of products in this manner in buildings offered for sale to the public would result in the use of individual property for experimental purposes. If governments permitted this, the purchasers of such property would have justifiable basis for demanding government support in their quest for restitution in case of failure.

The investigation and certification of preassembled components, especially when composed of several constituent parts, extends beyond determining the physical characteristics of the completed product. It requires the determination of the quality and characteristics of the materials used in the completed assembly. It frequently necessitates a basic understanding of the processes of manufacture. It involves investigation of the adequacy of plant facilities and competency of responsible personnel. There must be assurance of continued and competent quality control.

There are also other factors that must be considered. There is a growing tendency to reduce the size and thickness of the constituent parts of preassembled components. Based on end use only, this may be justifiable; but end use is not the sole consideration. Factory assembled building components must withstand handling during assembly, loading and unloading, storage at the site and similar abuses, often under less than optimum conditions. These may introduce stresses in excess of, and sometimes directly opposite to, those to which the assembly is subjected when properly incorporated in the structure. If they weaken members or disturb joints, they may affect the integrity of the structure. The comparison of building construction to airplane or ship design is not valid. Components used in planes and ships are not subject to site delivery that may cause severe racking, or result in their storage on uneven supports that may twist or distort them.

The preassembly of mechanical equipment, plumbing systems, electrical distribution centers, heating and air conditioning units, is subject to similar questions. The suitability and durability of the constituent parts for the conditions to which they will be subjected; the adequacy of the design of the completed component; the competency of the plant personnel; the thoroughness of quality control to assure uniformity of production; the precautions against damage in transit, delivery and storage must be carefully controlled. Factory produced components complying with applicable requirements, with due consideration for these conditions, should be equally as acceptable as assemblies hand crafted at the site.

These characteristics of preassembled components cannot be determined by visual inspection of the completed components either in the manufacturer's plant or on the site. Detailed examination of much data is necessary. Few, if any, building departments are equipped or sufficiently staffed to make the necessary investigations. Obviously, therefore, it is desirable to have some central agency to which building officials in local communities may turn for information. This agency must be in a position to determine the soundness of preassembled components that may be constructed in one community, and to certify to officials in other communities that they are adequate for the conditions under which they are intended to be used. The recognized code organizations representing building officials have established workable procedures to provide this service, and the officials they represent have recognized the reports of these organizations.

Proponents of preassembled components could save much valuable time if they would work with these organizations to secure approval of their products before attempting to market them. When these components involve the use of little known materials or employ new engineering techniques, or when they are not similar to well known building components, frequently much could be gained if the developers would confer with the building officials' organizations before completing their research to determine the possible application of building regulations to the products. In the past, the building officials' organizations have generally learned of such products only after they have been put into mass production and distributed to local markets, and then usually after their use has been denied by some local official because he has no information about the product or its proper use.

The time to begin to think about the acceptance of a new product under building codes is during the development of it. After initial research, but before putting the product into production or tooling a plant for mass manufacturing of it, a central building code authority should be consulted to determine the possible application of code requirements to the product. It may be found that minor changes in design would result in a more universally acceptable product at little or no increase in cost.

Preassembled components involving a basic product may be developed by individual companies or by the combined effort of a number of companies through a representative industry trade association. Either way, the basic industry involved has an important place in the activity.

Industry standards for the basic product and the completed component are an important adjunct to any such development. Competent and effective methods of quality control and self-policing within the industry are also essential, but the industry cannot develop satisfactory standards or establish quality control until experience with the product has been gained. It may be necessary, therefore, to work with building code authorities to develop realistic interim regulations. Frequently, these will be specification requirements with certain limitations on the use of the products. As rapidly as standards can be developed and followed in the construction of the components, which can be depended upon to produce specific and consistent behavior, the specification limitations can be changed to performance requirements.

What, then, are the essential factors in bringing to the public the advantages of industry research and development through preassembled components? Who is involved?

1) Municipal Government's Part - The first essential is the enactment by local governments of building regulations that will produce the required safety without imposing unnecessary hardship. This means the repeal and discard of locally prepared, independent building codes that contain personal prejudices, influence of local pressures, or biased considerations based on free advice from vested interests. The second is provision of competent administrative and inspectional personnel, adequately compensated and free from political pressure.

2) Administrative Official's Part - Administrators should be progressive, willing to learn about new materials and techniques, and amenable to change. The building official must recognize that it is not his function to assure the best possible work, or raise the standards of construction, or establish the best practice; but rather to assure a construction that safeguards the public from the dangers incident to buildings by observing the laws that have been enacted for his and the public's guidance.

3) The Developer's Part - Developers of new products must recognize that building regulations are based on experience, and that until code officials have knowledge of new products and experience with their behavior, they may have to evaluate them by known criteria and control them by regulations designed for more conventional conditions. They should, therefore, plan for the use of their products under regulations from the very beginning of the development of the product. As development progresses—but before it is completed—the building officials' organization should be consulted. If possible, advance publicity should be given to the product, and the approval of a recognized central agency obtained before the product is marketed. Building officials should not be left to learn of the product only after it makes it appearance on construction sites under their jurisdictions.

4) The Industry's Part - The segment, or segments of the construction and building materials industries principally concerned with the development of components should strive to develop standards through the accepted standards-sponsoring agencies as quickly as possible. Both material standards and test standards

may be necessary. These will permit the identification of acceptable products and the proving of their behavior. In the absence of material specification and test standards, it may be advisable to develop specification code requirements establishing the basis for use of the products, until such time as satisfactory performance requirements can be written on the basis of accepted standards and the necessary experience. Industry should provide the code authorities with all possible assistance in developing such requirements.

5) The Builder's Part - Where local governments have not discarded individual regulations and adopted recognized codes, or when the developers have failed to apprise building officials of their products, or the industry has not developed standards or recommended code requirements, it may be necessary to secure local approval and waiver of limiting regulations for use of components. Such local waivers or special permits should never be used as criteria for acceptance of a product or approval of its use.

Although many preassembled components have been accepted under modern building codes, the universal acceptance of this type of construction can be expedited by these procedures. To accomplish this requires the combined efforts of all concerned.

# Open Forum Discussion

Moderator - William H. Scheick, Managing Director
American Institute of Architects

Panel Members - Messrs. Baseler, Brockbank, Koch, Murphy, Norair and Short

R. C. Fritz, McKinney Mfg. Co.: Please comment on accelerated tests of building products.

Mr. Baseler: I don't think that the building official is particularly concerned with accelerated tests, except as it may be necessary to have them in order to determine in advance the behavior of the product. This, of course, we recognize as a problem. The test methods that are used for the evaluation of building products are developed through standards-sponsoring organizations that are largely manned by industry. Building officials sit on many of the committees as a matter of education, but not to tell you how you must evaluate your product. However, if you do not evaluate it to show that it will produce the required performance, we can't accept it or we can't use the standard. Really, the question of the desirability of the development of accelerated tests is one for industry itself to solve, I believe, not for the building officials.

W. H. Smith, U. S. Plywood: What generic type of housing components offer the greatest possibility of savings in house construction—mechanical cores, roof components, wall components, floor components or foundation systems?

Mr. Brockbank: As far as meeting some of the 17 items that we listed as requirements for the development of a greater industry, we feel that some of the old and well tried materials are the best ones to start with and, of course, plywood is in that class and so are several other materials. However, I don't think there is one material that we can point out that can be used successfully in all of those places. Today, there is a great deal more work being done in wall components, especially exterior walls, and in roof trusses, and more work is going on in floors, roofs and interior partitions. We recently went back to all of the houses that we have built (there are four research houses) and discussed the things that the people who live in these houses found most satisfactory. Incidentally, all who have purchased or rented the houses did so with an understanding that the houses would be re-evaluated over a period of years. Without exception, they said the thing they liked most about the houses was the fact that we had surfaces on the inside that were easy to clean. Now, this was a rather surprising thing to us, and yet maybe it isn't so surprising when you think that the woman lives in the house most of the time, and that's the part she would appreciate the most. These occupants have put up with some rather unusual situations, in that we have tested the walls and in some cases made openings in them, in order to tell what was going on inside, but in every case they consider themselves to be sort of researchers on their own and, therefore, they are interested to find out what happens there, too.

Some of the materials that we expected to stand up very well have not done so, and we are replacing these and advising the manufacturer what to do in order to improve the product.

Mr. Scheick: I think you will agree with me, Mr. Brockbank, that at the builders' meeting we attended not long ago there was a good deal of emphasis placed on floors. This was pointed out as an area where almost everybody, so far, has been licked on components. I think it's safe to say that there is more progress on other components than on floors. Do you agree?

Mr. Brockbank: That's right—very much more. However, it's hard to prove, so far, that you can do much with roof components beyond the truss and still stay within the realm of possibility from the standpoint of price. Still, the roof seems to be the subject of a great deal of attention, while not nearly as much is being directed at the floor.

W. H. Lewis, University of Illinois: How do you receive competitive bids on your work if only models are used? Do you write specs for the contractor?

Mr. Short: We have placed a good many million dollars worth of work competitively, with the contractors taking their estimates from the models at the site. Yes, we do supplement the model with specifications. The models are color photographed and tagged for material specifications, for size, and that sort of thing, but there is a very considerable amount of supplementary specification that accompanies them. We have been told by many contractors, after they have broken through the ice and operated from a model rather than from drawings, that they consider the model a much clearer presentation of what is wanted. Therefore, they tell us that we are very likely getting a better price from them as a result of their use of the model as a source of information, rather than drawings. This can be understood from this standpoint: often when you are making a drawing you must necessarily put on an exact dimension for a piece of ductwork or a piece of piping and, as far the contractor knows, you really mean that you have to have it. The model gives him much more flexibility. All the model tells him is that you have to go from here to there, you have to be in line with this, you have to clear this particular duct, but it doesn't say that the vertical dimension has to be 9'-7/32". Therefore, he isn't required to be as absolutely exacting in his fabrication as he otherwise would, if he was using drawings.

Jos. B. Nelson, Carl M. Freeman Assoc.: Where can I find more information on orthographic photography and models as used by Procter & Gamble?

Mr. Short: As far as we know, we have the only orthographic camera that exists. This particular technique is one that was invented by a man in Boston (Mass.). We picked it up and developed it on through to this application. It is spelled out pretty well in a certain amount of our literature and if anybody is interested, we will be glad to tell them about it.

Unsigned question: What are the central agencies respected by local code officials to which a manufacturer can go to get "guidance" and "approval" of his product? Is there an agency that gives a respected seal of approval?

Mr. Baseler: There are three code authorities that maintain programs in this field. From the standpoint of their age in building regulations and in this field, they are: The International Conference of Building Officials, with headquarters in Los Angeles; The Southern Building Code Congress, with headquarters in Birmingham, Ala.; and The Building Officials Conference of America, with headquarters in Chicago. These agencies also recognize tests made by any independent laboratory that is equipped, properly manned, and otherwise qualified to make the kind of tests that are required.

Mr. Scheick: In your paper, you used the words "central agency." I don't think you meant one central agency, did you, for the whole country?

Mr. Baseler: No, not necessarily for the whole country. The time may come when we will be able to establish that. At the present time it is not practicable for a number of reasons.

William Lukacs, YMCA National Building Services Div.: Have there been any really binding agreements on multiple trade prefab components between plant and job site unions? What are future prospects for agreements?

Mr. Murphy: This is an area that has been much under discussion in the last several years but, to my knowledge, there has not yet been such an agreement. I would be hopeful, though, that we may see development along those lines within the next two or three years as components become more generally manufactured in the factory and used in the field.

G. Veconi, Cupples Prods. Corp.: Where does the responsibility lie for residential research, with the Government or with private industry? Why?

Mr. Brockbank: The Government has spent a lot of money in residential research in the past and I am not sure that it was spent wisely. My personal opinion is that, so far as the home building industry is concerned, home builders should put into a fund a small percentage of the cost or sale price of every single house they build, and that they should set up a laboratory of scientists of all disciplines. They should have two goals that they should seek to reach: one, to research basic information on housing, and the other one to do research on materials so that Mr. Baseler's organization would have some basic information available to it from a home builders' research organization that it couldn't get otherwise. The reason why I say that the home builders should do this is because almost every manufacturer has some kind of research laboratory, but his research is directed at making his products more salable and obtaining wider distribution of them. The real problem which faces the home building industry at this time is that no one is researching the total house, and until we research the total house, we are not going to make the break-throughs that we have to make in order to keep our product competitive. Therefore, I think it's the home builder's job and not the Government's.

R. H. Houck, Potlatch Forests, Inc.: Do you work with drawings and photographs together, or have you been able to complete projects using photos and models alone?

Mr. Short: We necessarily have a very considerable number of drawings. We haven't completely eliminated them, because we haven't been able, as yet, to replace drawings for the civil engineering, structural type work, where exacting dimensions are necessary. You can scale the model to a degree that will be accurate to within one field inch, but it doesn't replace all drawings by any means. We have only replaced drawings in the area of pipe, conduit, chutes and ducts. And, of course, we see as the greatest benefit of the model the clarity of the development of the plant we are trying to build, and the simplification and efficiency with which we can work out our assemblies.

S. K. Wald, Youngstown Kitchens Div.: Why not design construction systems around dimensional instability, which is normal and natural? With very few exceptions, materials do shrink, grow, twist, warp.

Mr. Koch: That's a very good and practical idea. Paul Wilson of Minnesota Mining was pointing out the other day that sloppy joints, if properly handled, are a very economical way of taking care of the situation, and it just happens that they have some new tapes that will take care of sloppy joints.

John S. Best, Dow Chemical Co.: Please enlarge on what you think is acceptable dimensional stability in building components or units.

Mr. Brockbank: I haven't reduced it to how many 1/32" a material can expand or contract, but I do realize that in order to make home building, and in fact, all building, practical, there has to be some limit. There has to be some shrinkage and expansion, but there must also be some limit on it. In some climates some materials would change dimensionally very little over a year's time or maybe over a hundred years' time, as long as the climate remains as it is. But there are other climates in which the material would change very markedly within one day and, therefore, there has to be some way of fastening those materials that will counterbalance that change, such as these crack fillers or these expansion fillers. This is a problem that we have to face up to quickly and have to make a decision on. My friend, Fritz Burns, used to build a prefabricated house in Los Angeles. He had a large plant there. He tried to cover the joint and not have it show at all, and he was having great trouble. An old architect came to see him one day and said, "Why don't you admit that there is a joint?" But Mr. Burns said, "I don't want to admit that." He put nearly a million dollars into this work, and then dismantled his prefabrication plant and went out of the prefabricating business, just at the time he should have been going into it. The fact of the matter is, we either have to admit there is a joint here, and provide some means of taking care of expansion and contraction, or we have to lick the dimensional stability problem or bring it down to a very narrow margin.

Walter Voss, Consultant: Many of you have heard it said that buildings move, creep, do everything. Too many people in the building industry don't know that buildings are doing these things. I find from my own experience that whereas the metal people can make a lot of fun of the way wood works with dimensional instability under excess moisture, the wood people can turn right around and say that metal does this thermally. This results from the properties that are in materials. I think what designers are saying is that if this is taken into account, then you can design anything.

William Lukacs, YMCA Natl. Building Service: The principal problem to the prior submission of new components is the manufacturer's reluctance to publicize a new device. How can he guard against plagiarism of his ideas?

Mr. Baseler: This is part of our responsibility. It is important that we consider in confidence anything that is revealed to us in confidence. If the manufacturer, the developer, is frank in his dealings with us in this respect, telling us this is advance information, we will treat it with that kind of respect. He is not going to the individual building official; he is going to a responsible organization, in that connection. By the time the product has reached the stage that the manufacturer can or is ready to apply for an approval of it, it will have reached the point that he is ready to put it into production. The development stage, then, is past, so that when information is distributed to our committee, (and that is the extent of its distribution until the approval is completed) it still can be treated with a measure of confidence, if necessary. It depends entirely on the manufacturer. He must, however, tell us in the beginning that this is the way he wishes it treated.

C. R. Humphries, Minnesota Mining & Mfg. Co.: Does not labor have to face the fact that many of the tradesmen will have to move to the factory as industrial workers, just as the carriage maker became the auto worker?

Mr. Murphy: I think that reflects my own view on the subject. It seems to me that the increased use of components is going to require higher skills of the building trades nature in the factory, and the building trades would do well to look towards training to provide those skills and trades for the factory. They should look toward deeper and more mutual cooperation between the field and the factory units.

Roger Halle, Architect: Would you comment on the standardization achievable with the 3'4" planning grid, which has been so widely adopted in England, especially in schools, but so little used here?

Mr. Koch: I haven't too much to say on that. Most of our building is in multiples or divisions of 16" because of 2" x 4" studs on 16" centers. I was interested to learn that a certain concrete floor slab manufacturer who uses a machine for making his slab which was developed in Germany, and for that reason the slab probably came out as 3'4", has been very successful in adapting his product to use very considerably in this country. I think 3'4" might be argued as being a more useful dimension than 4', but it's on a pretty theoretical plane as far as use in this country is concerned generally.

G. J. Schulte, Minnesota Mining & Mfg. Co.: What are the most important new applications for adhesives and sealants in houses? Do not many new adhesive applications offer the possibility for savings in labor to more than compensate for increased materials costs?

Mr. Brockbank: There is one important point that I failed to make in discussing this subject, that I think every manufacturer should be aware of, and that is that labor today is paid if you count overhead, fringe benefits, and everything else that goes into it, on the basis of 10¢ a minute. So, every time a person fails to do some work, it is costing money. Therefore, we propose that you consider the cost of your product not as a product, but as what it costs in the wall, or in the roof, or wherever the product is used. Therefore, it is possible, through some labor savings, to use a more expensive product and still have it cost less in the house or in the building, and do a better job. Some of the places where adhesives and sealants have been used are, of course, in putting together several pieces of material. For instance, one of the lumber companies uses low grade lumber in many places but, by putting it together with adhesives, it makes an excellent piece of material for walls, or floors, or anything else.

The place where we need some help now is in cutting down the number of layers of walls. We used to have 14 and I think we now have 5. We would like to get down to where, as far as the builder is concerned, it comes to him as one piece. This will require sealants and adhesives, but we do not yet have any way of putting materials together, especially if they involve wood, without the use of nails. We would like to get away from nails wherever it's possible. I am sure that your company can help us do this. Maybe they have already perfected the material, but it just costs too much as yet.

Al Schuszler, The H. K. Ferguson Co.: Do you try to make one model serve several projects? You tried to make one set of plans serve all four "Tide" towers and it didn't work!

Mr. Short: In those days we were operating a little differently than we are now. We certainly can't make one model build four different plans at the same time. I have duplicated models and, once you have gone through all the skulduggery of planning and developing—unless you want to build a model form—the cost of exact duplication is much less. The answer to that is, you've got to have a model. If you are going to build two things at the same time, you have to have a model of each one.

C. R. Humphries, Minnesota Mining & Mfg. Co.: Where can model components be obtained?

Mr. Short: There are two or three manufacturers around the country that make these models. I think there is an organization in Wilmington known as Industrial Models which makes and sells model components. We happen to make our own, simply because we have established certain scales that we consider best for our particular business, but models are readily available.

R. C. Schubert, Bureau of Yards & Docks: To what extent do codes in general permit the use of prestressed or post-tensioned precast concrete elements in building construction?

Mr. Baseler: To the extent that their stability has been proven. One of the biggest problems we have encountered in this is the question of fire resistance, because fire resistance is usually a requirement where concrete is used. That is to say that concrete is used in those structures where fire resistance is a requirement. As yet there has not been sufficient data developed in this field by actual testing, and this is the only way it can be developed for us to accept prestressed concrete on the same basis that we accept conventional concrete. The building codes that state the requirements in terms of performance do accept this kind of construction provided it has been or can be proven by accepted tests to meet the requirements required.

Charles I. Cassell, Veterans Administration: The U. S. Government through HHFA's extensive research activities produced a tremendous amount of competent information covering every aspect of home design, heating, insulation, construction and maintenance. This information was and is widely used by private agencies as well as government agencies. What more should be done, and why disparage such activity by government?

Mr. Brockbank: My personal opinion, and this is only personal, is that there was a lot of money spent for research by the Government that did not produce the kind of results that private industry could have produced if it had been spending the same amount of money. Therefore, I feel that we need more research on the part of private industry. I really believe that unless we get busy on research for the building industry in order to cut down the spiral in cost of production, we are going to have to put up with Government research, whether it produces the same amount of good as it would done by private industry or not. So, I really think we are over a barrel as far as this is concerned. We have not done the job on research that we should have done by this time, by any means.

Charles A. Nichol, Jones & Laughlin Steel Corp.: I noted recently that you have been retained by a steel company to design a multifamily type dwelling using as much steel as economically possible. Have you reached any conclusions yet concerning the future of: 1) rolled steel structural sections vs. sheet steel formed sections, and 2) steel vs. wood and other materials in the trend toward components?

Mr. Koch: We obviously had some preliminary ideas which we explored with the steel company, or we wouldn't have started, and nothing that we have done to date indicates that we aren't going to get somewhere jointly with this project. The word "possible" should be changed in the stating of the question to "practical." I think the steel people are very wise in making quite clear, in all the work we are doing together, that there is no need to look for the unsuitable or stretch the practicable limits of steel because there are so many practicable applications.

Ray Hanson, Stran—Steel Corp.: What suggestion do you have for coping with the code problem in the many large metropolitan areas which do not avail themselves of the large code bodies' tests and certifications?

Mr. Baseler: There is a growing tendency, even on the part of the larger communities, to recognize the advantages of the use of one of the available codes in preference to an independent code. Several of the larger cities in the U. S. can be stated as having already taken this step. We know of others in which it is under way. It is not going to be a rapid process and there are some of the large cities that will never take the step. One, in particular, has the idea that it will tell the rest of the world how everything ought to be done, but in Detroit, Los Angeles, St. Louis and in a number of the large cities, use of a model code has either already become an accomplished fact or it is under way.

# PRINCIPLES OF PREASSEMBLED COMPONENT CONSTRUCTION

Session Chairman - Rudard A. Jones
Research Professor of Architecture
Director, Small Homes Council-
Building Research Council
University of Illinois

# Investigation of Component Construction for Residences

By Albert G. H. Dietz,* Professor of Building Engineering
Department of Civil and Sanitary Engineering
Massachusetts Institute of Technology

Construction by means of a few relatively large components instead of many small pieces is a method of house building gaining popularity in many parts of the country. The obvious objective is to transfer much of the traditional cutting, fitting and assembly of the parts of the house from the field to the shop, and therefore to reduce costs and save time by taking advantage of fast, efficient shop methods, and by reducing the time spent in the field.

While the concept is reasonably clear, to attempt a precise definition of "component" as used in house building is not easy. The term means different things to different people, just as "prefabrication" means many things, depending on the point of view. Everyone agrees, though, that the term means precutting and bundling at the very least, and, to most components people, it means in addition shop assembly of the pieces into units that are relatively large and can be put together quickly in the field.

In practice, probably the most universally used component is the trussed rafter, made either with glue-nailed gussets, usually plywood, or with mechanical fasteners, among which the pronged metal plate is rapidly becoming pre-eminent. Gable ends are made at the same time. The trusses for a house may be shipped as a package to the site with sufficient roof sheathing to cover the job, and the sheathing may be precut.

Next in popularity is the wall panel. This may merely be precut and bundled; it may be assembled at the shop with or without sheathing attached; prefitted windows and doors may or may not be set in place in the shop; exterior finish may or may not be shop applied. In most instances interior finish is field-applied, but trials with shop-applied interior finish are being made by some component manufacturers.

Partition components rank next in popularity. Frequently these are merely precut and bundled, but in many instances they are shop assembled, with or without prefitted doors, but seldom with interior finish applied.

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*DIETZ, ALBERT G. H., Member, American Society for Testing Materials, American Society of Civil Engineers, American Assn. for the Advancement of Science, Building Research Advisory Board, Building Research Institute and others; A. B., Miami University; S. B., and Sc. D., Mass. Institute of Technology; author of many papers on building technology, engineering laminates and plastics in building.

Floors are much less frequently made as preassembled components but, if framed rather than slab floors are employed, they are usually precut and marked. Subflooring, if in sheet form such as plywood, may be precut.

Kitchen cabinets, wardrobes and similar pieces of millwork are often preassembled and either partially or completely prefinished. In many instances other items such as cornices and soffits at eaves and rakes are preassembled and partially prefinished, leaving only a field coat of paint to be applied. Plumbing trees may be partially preassembled. Components for kitchens, baths and utility spaces are usually planned to fit around equipment and appliances.

From the foregoing it may be seen that there is by no means any universal practice with respect to components. Some components manufacturers fabricate only to order, and produce custom-made parts to fit the individual house, usually making some revisions in dimensions to accommodate their jig-tables. Some builders fabricate only for their own use, and produce components tailored to fit their particular houses. Some manufacturers produce a set of standard components, not designed to fit any given house plan, but capable of being put together in a variety of configurations. A particular house plan has to be adapted to these standard components. Regular prefabricators, of course, preassemble the parts of their houses and ship them to the site for final assembly. Mobile home manufacturers commonly make subassemblies at various points in their shops and then put them together on the assembly line.

Just as there is no common pattern in the design and fabrication of components, so there is no one type of organization which manufactures them. Some builders have set up their own shops to produce components for themselves exclusively, or for sale to others as well. Other builders have entered into arrangements with local materials dealers or millwork companies to produce components. Some materials dealers have set up fabricating shops on their own and sell to builders, or they may build on their own account. In some instances regional materials distributors have set up shops to manufacture and distribute components in the region served by them. In at least one instance a large chemical company manufactures and distributes sandwich panels.

The present situation is evidently in a state of flux, unstable, and undergoing rapid evolution. Most of the systems of components are based on traditional construction methods and materials, partly because these have to date proven to be the least expensive, partly because the capital expenditures required to set up shop are relatively low, and partly because such components by and large conform fairly closely to building codes and are readily accepted. Here and there, however, components such as the sandwiches mentioned above are coming into the picture, others use the stressed-skin principle, and experimentation is going on with other ideas such as shells. It is to be expected that the present picture will change.

## Equipment and Appliances

Of considerable importance in any scheme of components is their relationship to equipment and appliances, including heating, air conditioning, plumbing, and electrical equipment. Indeed, one reason why the interior finish is often left off wall and partition components is the difficulty of incorporating wiring, piping, ducts and other lines, and making field connections. Careful planning is necessary to reduce such lines to a minimum and to run them in such places as attic spaces, above hung ceilings, and in baseboards.

The pieces of equipment and the appliances must be fitted into whatever system of components is devised. Here a problem is likely to arise, because equipment and appliances are not manufactured by the maker of the shell components, and two different systems of dimensioning may have to be reconciled. Few if any component builders are in a position to order equipment and appliances in such large numbers as to make it worthwhile for the manufacturer to produce special items to fit the builders' plans. Furthermore, tolerances in both components and items of equipment are such as to make exact fit unlikely. Filler strips or other means are needed to fill gaps, but by careful planning such gaps and the need for filler strips may be minimized.

Many reasons are advanced for the use of components. A few of the most important may be examined.

1) Control - Builders who use components often emphasize that their major advantage lies in control of the operation from start to finish. Even if there is no cost reduction, and more than one builder says that direct cost reduction by components is minor, the element of control is a major factor. In the shop the most efficient flow of materials and the optimum use of labor can be obtained. Relatively few large pieces go to the field and there is little likelihood that anything will go astray. Sections are rapidly assembled and the uncertainties of weather are minimized. Pilferage and damage are greatly reduced.

2) Basis for House Package - While the components alone, e.g., roof trusses, wall panels, partitions, may not always provide a large cost saving, they make it possible to build up an attractive house package including all the other items such as roofing, flooring, finish of all kinds, cabinet work, and the other items that go into the house. These can be sent in one or more loads to the site in carefully coordinated packages, minimizing delivery costs and allowing for efficient handling. The whole package is attractive financially to both the dealer and the builder.

3) Shortened Construction Time - The house can be closed in fast, and finishing time considerably reduced. Among other things this reduces carrying charges and permits larger volume on a given capital.

4) Reduced Labor Cost - Shop labor rates are frequently less than field rates and, in any event, shop labor can be more efficient.

Small operators or operators building on several sites are likely to find components advantageous. Weather demanding quick enclosure is also a factor. (It is interesting to note that components seem to be used least where the weather is uniformly favorable for outdoor work.) Lack of skilled field labor is another factor.

There are problems associated with components. Shipping costs are higher than for more compact, unfabricated materials. Carrying charges and plant overhead are appreciable. To pay off, a plant must operate a high proportion of the time, which means a steady stream of orders. With components a major problem is that of joints and how to handle them in the field, particularly if finish is shop-applied. Foundations must be more precise than for custom building. The advantages of components are not always obvious and may be nonexistent in many cases. A careful study is necessary to determine in any given instance whether, and to what extent, to employ components.

## Geometry

A major question facing any manufacturer of components is what components to make. What should be the shape and size? What factors control the dimensions? Should there be a basic module? If so, what?

The question of a module repeatedly crops up. It has been faced in a variety of ways. One of the commonest is 4' because many sheet materials are made in 4' widths. The 4' x 8' sheet of plywood or wallboard sets the size for many panels. The wellknown LuReCo panel is essentially based on the 4' dimension. Many users of this dimension find it necessary to use submodules such as 2' or 16".

The Bemis 4" cube is another popular module employed by component manufacturers. It has a long history, has been adopted by a number of materials manufacturers, and is the subject of intensive study.

Many other modules are proposed. Among them are 3", used by a number of manufacturers of appliances; 1', used by a number of cabinet makers; and the three-series numbers combination suggested by Ehrenkrantz and studied at the British Building Research Station, as well as others. For use in Europe, a component system based on the meter has been developed. Incidentally, ten centimeters and four inches are nearly equal.

As long as all components are made by a single organization the module can be whatever that organization chooses, or there may be no module. Many in the housing field envision a time when a number of different manufacturers will provide components distributed through local or regional outlets. Such components will fit each other, and it will be possible to work out many house plans from them. If such a development is to occur it will be essential that all components conform to some module.

Closely allied to the question of the module is the choice of panel sizes. Today there is no uniform opinion. Some manufacturers adhere to 4'; some have two or three multiples or submultiples of 4'; some say that 12' or 16' is optimum; others would like simply to make all panels full wall lengths. Some look forward to the day when panels will be made continuously and merely cut off at whatever length is required, whether to a module or not.

In an attempt to gain some insight into the question of optimum component geometry, a study has been undertaken, as part of the project sponsored by the National Association of Home Builders, to obtain some conception of the dimensions of the parts of houses as actually used, and to determine what component sizes would best provide those dimensions.

Some 75 house plans were collected from architects, builders, and prefabricators throughout the country. Every effort was made to obtain as great a variety in plans as possible. These plans were analyzed by measuring the dimensions of wall sections, for example, from corner to window, across the window, to the next window, and so forth, noting the dimensions of solid wall portions, window portions, door portions, corners, and any other pertinent factors. The same was done for other parts of the house, such as partitions and floors.

## Computer Analysis

The individual values were punched on computer cards which were then sorted to obtain frequency distributions of the various dimensions. The values obtained were plotted on the graphs shown in Figures 1 through 5, included at the end of this paper. These curves show which dimensions most frequently occur, and they also give a frequency distribution for use in following portions of the analysis. The curves given here are for the entire group of 75 houses, but each house was itself separately analyzed for distribution of the various parts.

A program was written for the computer making it possible for the machine to try fitting various panel sizes to the distribution of dimensions achieved by the original measurements, and to determine from this how many panels of each size would be required to meet the entire distribution for all 75 houses. First of all, the dimensions for the various parts were grouped in terms of 4" increments, and various combinations of panels based upon 4" increments were tried against this distribution. This was thought to give the maximum flexibility that might be desired. Secondly, the dimensions were grouped around 1' increments and combinations of panel sizes to meet these 1' increments were tried.

Because small panels would cost more per square foot to construct than large panels, a cost bias was applied to the panel dimensions so that, for example, a higher cost was assumed for a panel 1' wide on a per square foot basis than for a panel 4' or 8' wide on a per square foot basis. The machine was instructed to use the least expensive combination of panels in fitting any set of curves. If such a bias had not been applied, the machine might quite properly have said that the most flexible arrangement was the one that used the largest number of small panels, but this, of course, would have been an uneconomic arrangement.

It became evident as this study progressed that various criteria might be used for determining optimum arrangement of components, and that different criteria would undoubtedly lead to different results. Discussions with the advisory group and with the various people consulted throughout the country indicated that probably the one most important criterion was cost. The best set of components in the world would not be employed unless those components would lead either to a better product at the same cost, or a lower cost for an equal product produced by traditional methods of construction. Cost was, therefore, taken as the primary criterion, but flexibility was incorporated to the greatest extent possible. Cost and flexibility appear to be the two principal objectives to be met by a feasible system of component construction.

Costs have not been easy to come by because they depend very largely on the basis on which they are calculated. In theory at least, it appeared probable that the per square foot cost of a small panel would be higher than that of a large panel, but that eventually a panel size would be reached in which such factors as transportation, erection, etc., would begin to become very high and, consequently, the costs per square foot again would begin to rise. Somewhere therefore, between the very short and the very long panel, would be an optimum range in which costs would be a minimum. A curve of that type could be approximated theoretically in a variety of ways, but a power curve of some kind such as a parabolic or an exponential curve would appear to be a logical one to fit this type of cost function.

Much more desirable, of course, is to use actual costs. In actuality, a smooth curve is probably not a correct approximation of costs because, with the available sizes of materials, there will undoubtedly be peaks and valleys in a cost function. If sheet stock can be used uncut as is, for example in 4', 8' and 12' intervals, there should be dips in a cost function at these points. In between, however, at, for example, 37", there should be rises in the cost function because of the labor and the waste of material involved in making a panel of that size. For the purposes of a first computer analysis, a simple curve was selected for a first approximation of the costs of the opaque wall sections. That curve rises steeply at the minimum increment of 4" and drops off to become a flat curve at 8'-0" and beyond. This curve is shown in Figure 6.

The computer analysis is not restricted to any type of curve, but can use costs of an irregular nature which cannot be approximated by any kind of curve. It merely applies the appropriate costs for any given panel size in making its analysis of the optimum arrangement of panels to meet any given distribution of sizes. Furthermore, the distribution of sizes does not have to approximate a true probability curve. It can be whatever the sizes are as taken from the original analysis of plans.

This smooth cost curve and the distribution of solid exterior wall sections shown in Figure 2 have been combined to provide an example of computer analysis, the results of which are given in Table I, included at the end of this paper. In this analysis, the wall sections were taken in 1' rather than 4" increments, and the dimensions shown in Figure 2 were re-grouped to the nearest 1' intervals.

In Table I the component sizes are listed on the left-hand side; for instance, 1-2-3 means that three components of 1'-0, 2'-0 and 3'-0 are being studied. In the next column are listed the relative total costs, that is, the relative cost of making all exterior wall panels with these three components; on the right are listed the number of each size required. By scanning the table of relative costs it is possible to determine the most economical system or to compare the relative costs of various systems.

If only three components are used, the system 1-4-6 is shown to be the most economical. When four components are used, the system 1-3-4-6 is the most economical. Note that these systems are the most economical only for the cost curve which has been assumed; if the cost function is different, the most economical component system will probably change also. Note also that the relative cost of the 1-3-4-6 system is lower than for the 1-4-6; this is because the same cost curve was used for both systems, whereas the actual cost per component of producing four different components will be higher than for three.

All of the calculations were done on an IBM 709 digital computer in less than 10 minutes. In view of these rapid calculations, it is possible to explore many different component systems which will be meaningful, if accurate cost data can be supplied to the computer.

The foregoing example seems to show a method by which computers can be employed to analyze a great many possible combinations of components in an effort to find an optimum. The optima found in this example are not strikingly better, cost-wise, than many others, showing that considerable variation in combinations is possible, under the conditions assumed in this example, without much variation in cost.

This study is a continuing one, so no hard-and-fast conclusions are drawn.

Associated in this research program are George Wadsworth, Professor of Mathematics; Lloyd Cutcliffe of the Department of Civil Engineering, Division of Building Engineering and Construction; and Allan Poms and George Szabo, Research Assistants in the same Division. A steering committee drawn from the National Association of Home Builders consists of Robert Fox, Chairman, D. S. Huber, Clayton Powell, Jesse Baker and Donald Decker. Milton Smithman, Richard Canavan, Ralph Johnson and John King of NAHB Headquarters have maintained contact with the project.

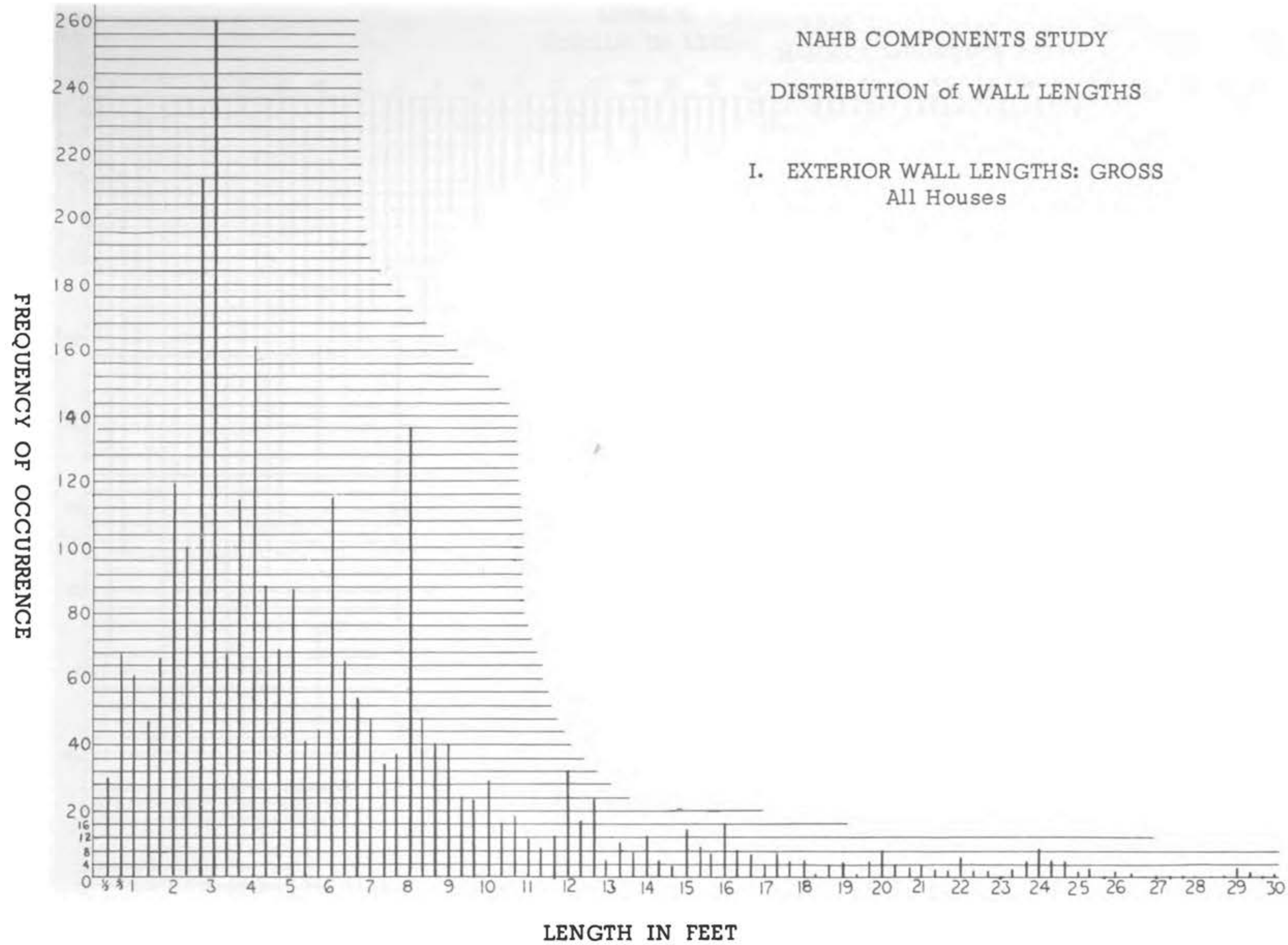

NAHB COMPONENTS STUDY
DISTRIBUTION of WALL LENGTHS
I. EXTERIOR WALL LENGTHS: GROSS
All Houses
FREQUENCY OF OCCURENCE
LENGTH IN FEET
0 4 8 12 16 20 40 60 80 100 120 140 160 180 200 220 240 260
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

Figure 1

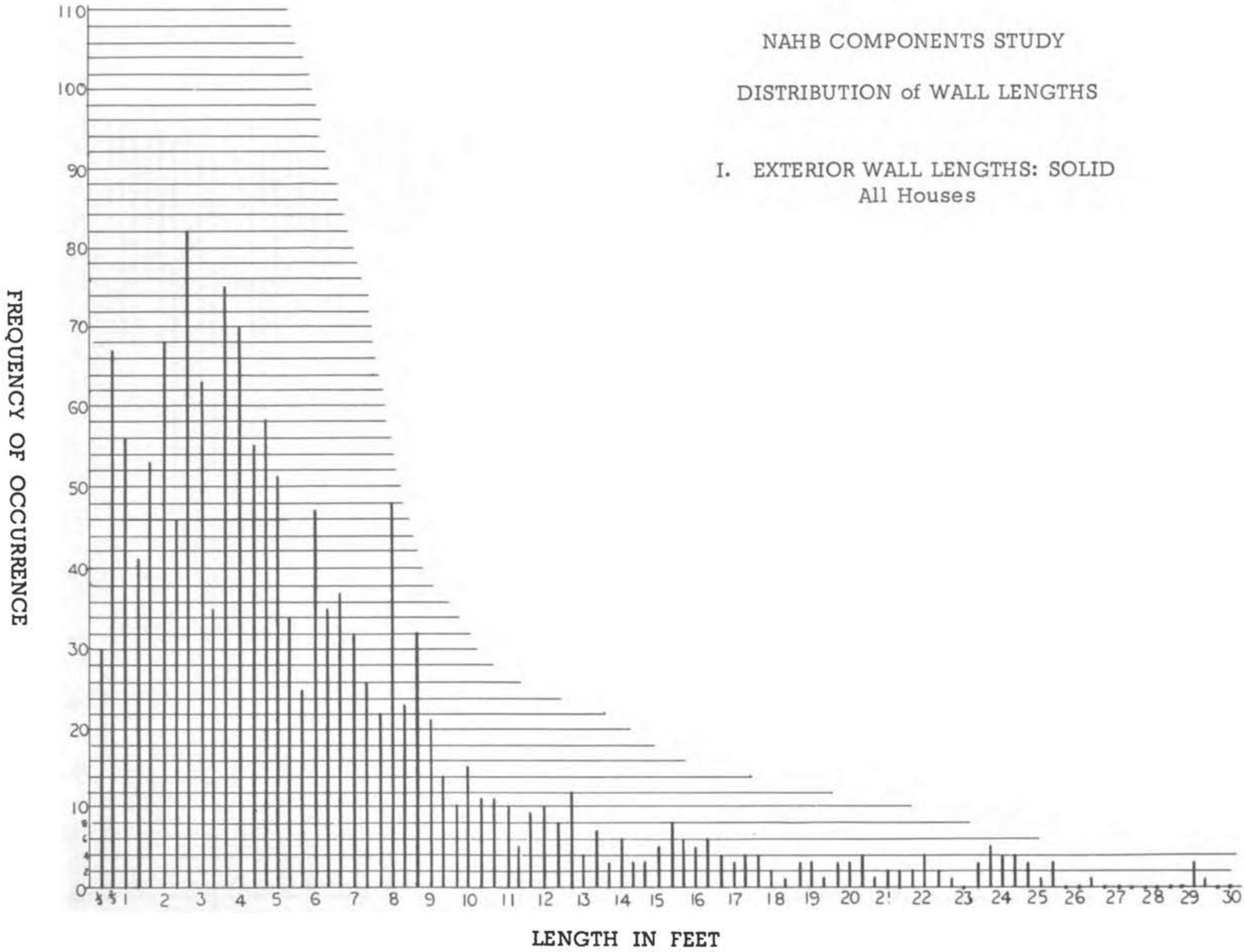

NAHB COMPONENTS STUDY
DISTRIBUTION of WALL LENGTHS
I. EXTERIOR WALL LENGTHS: SOLID
All Houses
FREQUENCY OF OCCURRENCE
0
10
20
30
40
50
60
70
80
90
100
110
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
LENGTH IN FEET

Figure 2

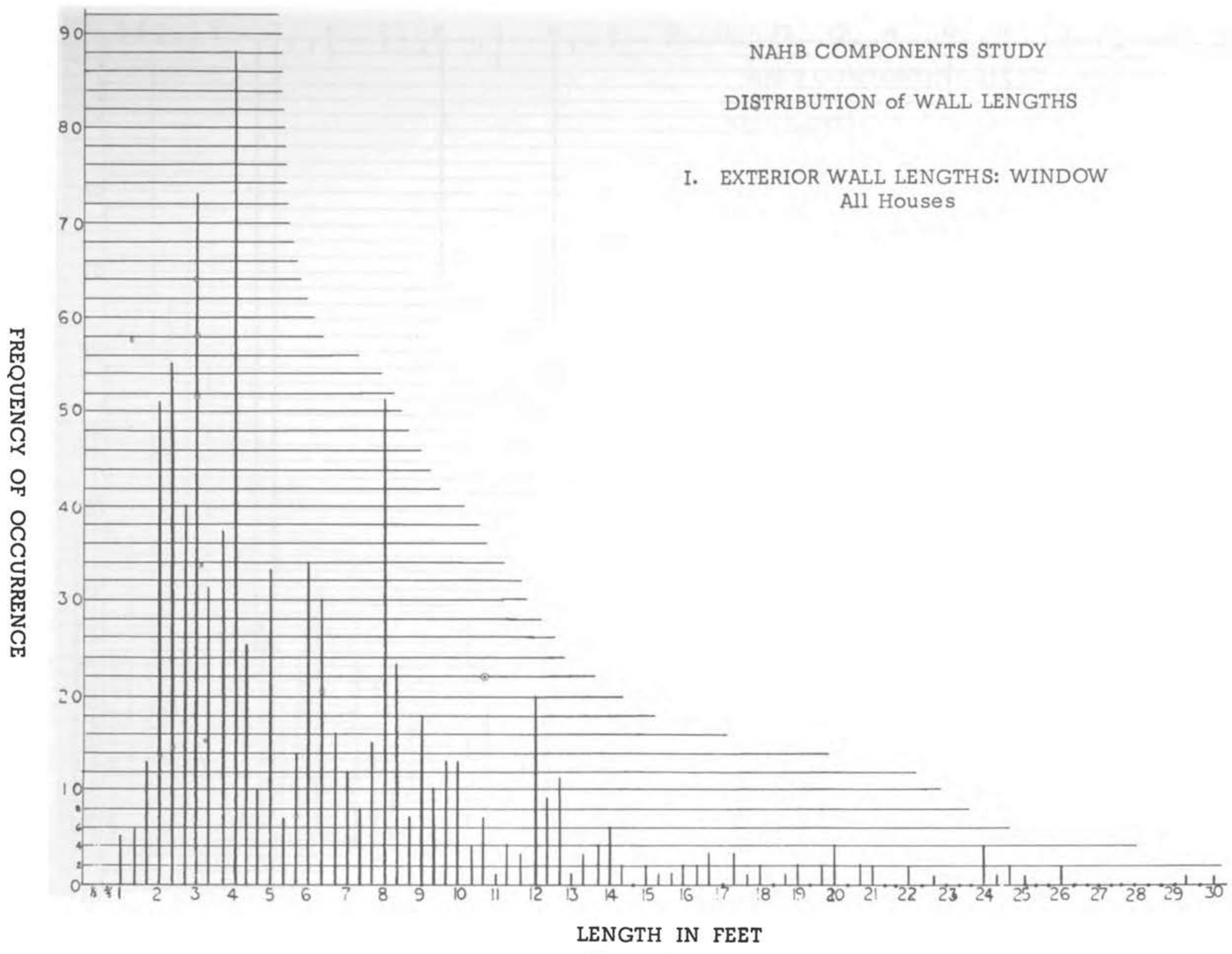

NAHB COMPONENTS STUDY
DISTRIBUTION of WALL LENGTHS
I. EXTERIOR WALL LENGTHS: WINDOW
All Houses
FREQUENCY OF OCCURRENCE
LENGTH IN FEET

Figure 3

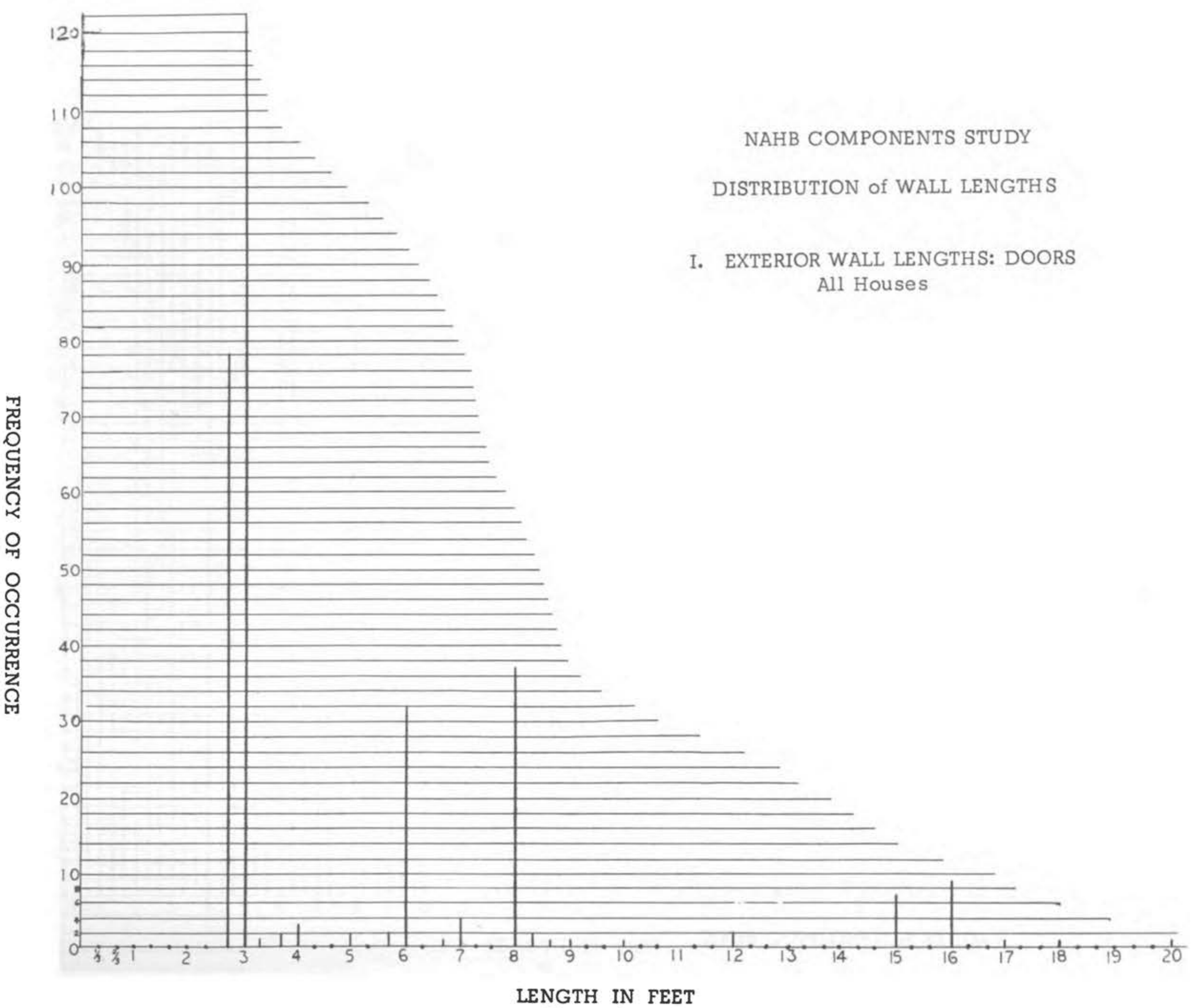
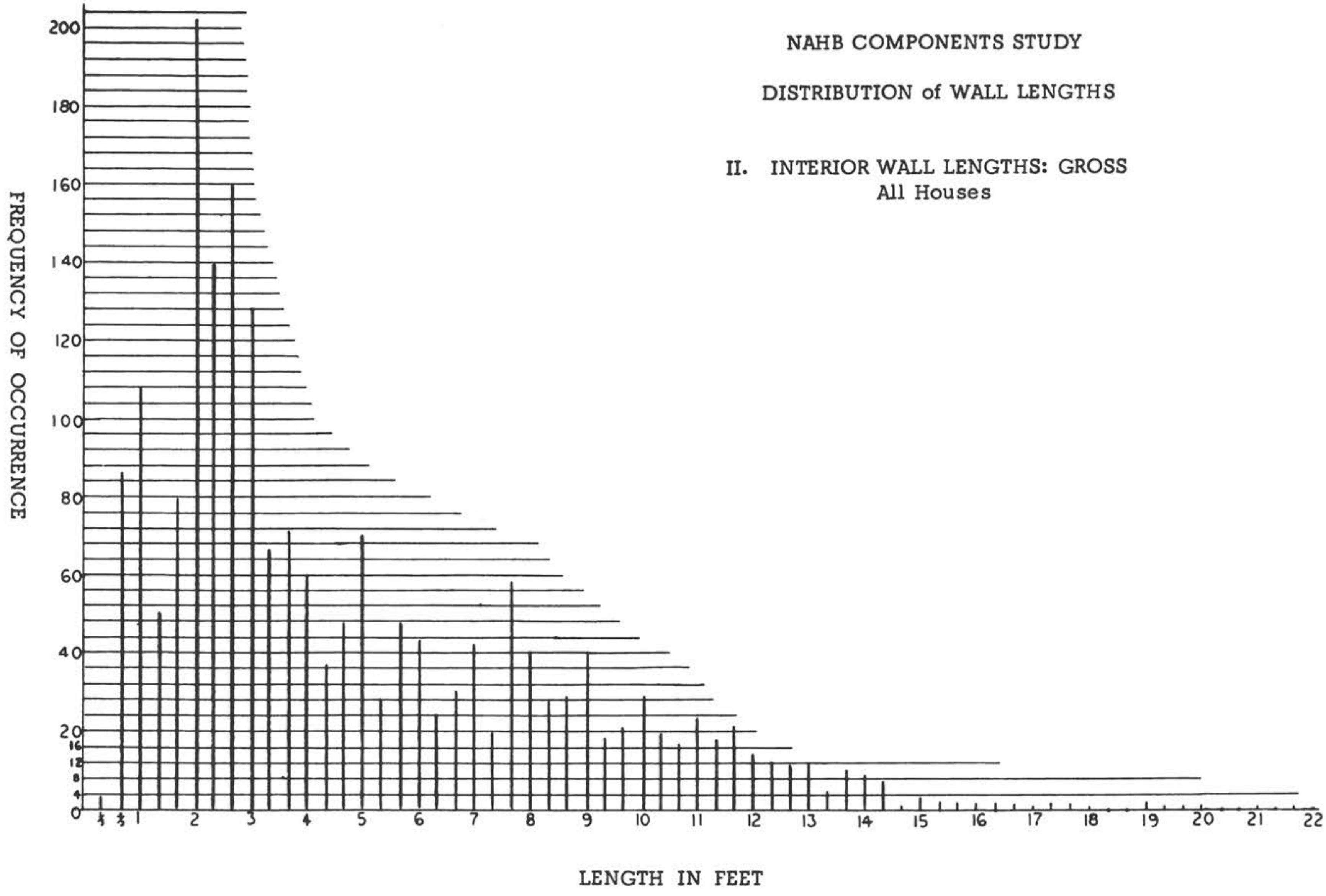

NAHB COMPONENTS STUDY
DISTRIBUTION of WALL LENGTHS
I. EXTERIOR WALL LENGTHS: DOORS
All Houses
FREQUENCY OF OCCURRENCE
0
10
20
30
40
50
60
70
80
90
100
110
120
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
LENGTH IN FEET

Figure 4



NAHB COMPONENTS STUDY
DISTRIBUTION of WALL LENGTHS
II. INTERIOR WALL LENGTHS: GROSS
All Houses
FREQUENCY OF OCCURENCE
0
4
8
12
16
20
40
60
80
100
120
140
160
180
200
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
LENGTH IN FEET


Figure 5

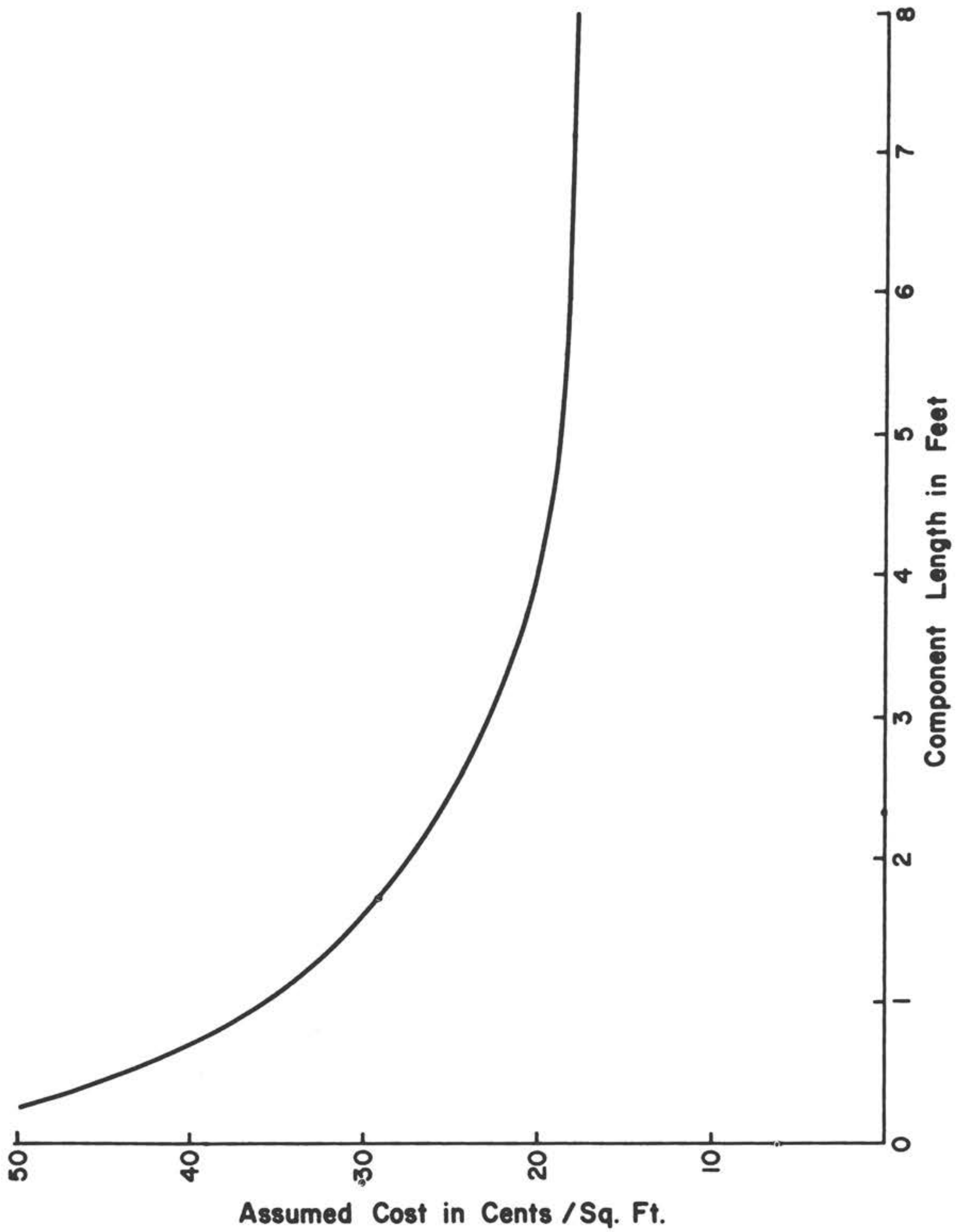

Assumed Cost in Cents / Sq. Ft.
50
40
30
20
10
0
1
2
3
4
5
6
7
8
Component Length in Feet

Figure 6

Table I

Most Efficient Component Sizes - Exterior Solid Walls

| Component Lengths (Ft.) | | | | Relative Total Cost | Number of Components Used | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | - | 2146 | 558 | 471 | 2458 | - |
| 1 | 2 | 4 | - | 1981 | 752 | 667 | 1697 | - |
| 1 | 2 | 5 | - | 1982 | 627 | 1221 | 1161 | - |
| 1 | 2 | 6 | - | 2012 | 752 | 1451 | 870 | - |
| 1 | 2 | 7 | - | 2042 | 704 | 1754 | 666 | - |
| 1 | 2 | 8 | - | 2081 | 752 | 1977 | 521 | - |
| 1 | 2 | 9 | - | 2146 | 698 | 2387 | 378 | - |
| 1 | 2 | 10 | - | 2192 | 752 | 2596 | 293 | - |
| 1 | 2 | 11 | - | 2217 | 738 | 2748 | 240 | - |
| 1 | 3 | 4 | - | 1949 | 758 | 672 | 1525 | - |
| 1 | 3 | 5 | - | 1958 | 1239 | 610 | 1161 | - |
| 1 | 3 | 6 | - | 1986 | 1500 | 718 | 870 | - |
| 1 | 3 | 7 | - | 1985 | 1395 | 939 | 666 | - |
| 1 | 3 | 8 | - | 1997 | 1373 | 1111 | 521 | - |
| 1 | 3 | 9 | - | 2051 | 1500 | 1324 | 378 | - |
| 1 | 3 | 10 | - | 2070 | 1462 | 1494 | 293 | - |
| 1 | 3 | 11 | - | 2088 | 1488 | 1582 | 240 | - |
| 1 | 4 | 5 | - | 1935 | 1361 | 787 | 873 | - |
| * 1 | 4 | 6 | - | 1932 | 1446 | 858 | 666 | - |
| 1 | 4 | 7 | - | 1978 | 1568 | 1375 | 258 | - |
| 1 | 4 | 8 | - | 2004 | 2086 | 655 | 521 | - |
| 1 | 4 | 9 | - | 2000 | 1877 | 1027 | 321 | - |
| 1 | 4 | 10 | - | 2012 | 1850 | 1251 | 202 | - |
| 1 | 4 | 11 | - | 2033 | 2074 | 1040 | 240 | - |
| 1 | 5 | 6 | - | 2044 | 2374 | 454 | 705 | - |
| 1 | 5 | 7 | - | 2323 | 4212 | 0 | 666 | - |
| 1 | 5 | 8 | - | 2028 | 2328 | 706 | 377 | - |
| 1 | 5 | 9 | - | 2095 | 2624 | 1025 | 125 | - |
| 1 | 5 | 10 | - | 2148 | 3069 | 575 | 293 | - |
| 1 | 5 | 11 | - | 2125 | 2877 | 766 | 197 | - |
| 1 | 6 | 7 | - | 2141 | 3095 | 311 | 559 | - |
| 1 | 6 | 8 | - | 2110 | 2942 | 426 | 422 | - |
| 1 | 6 | 9 | - | 2135 | 3069 | 522 | 297 | - |
| 1 | 6 | 11 | - | 2198 | 3393 | 798 | 63 | - |
| 1 | 2 | 3 | 4 | 1915 | 424 | 339 | 328 | 1697 |
| 1 | 2 | 3 | 5 | 1908 | 623 | 308 | 610 | 1161 |
| 1 | 2 | 3 | 6 | 1911 | 558 | 471 | 718 | 870 |
| 1 | 2 | 3 | 7 | 1915 | 525 | 435 | 939 | 666 |
| 1 | 2 | 3 | 8 | 1936 | 601 | 386 | 1111 | 521 |
| 1 | 2 | 3 | 9 | 1976 | 558 | 471 | 1324 | 378 |

Table I (Cont.)

| Component Lengths (Ft.) | | | | Relative Total Cost | Number of Components Used | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 4 | 5 | 1865 | 477 | 442 | 787 | 873 |
| 1 | 2 | 4 | 6 | 1876 | 752 | 347 | 858 | 666 |
| 1 | 2 | 4 | 7 | 1880 | 487 | 636 | 993 | 449 |
| 1 | 2 | 4 | 8 | 1898 | 752 | 667 | 655 | 521 |
| 1 | 2 | 4 | 9 | 1900 | 641 | 618 | 1027 | 321 |
| 1 | 2 | 5 | 6 | 1898 | 536 | 919 | 454 | 705 |
| 1 | 2 | 5 | 7 | 1889 | 600 | 836 | 654 | 476 |
| 1 | 2 | 5 | 8 | 1889 | 590 | 869 | 706 | 377 |
| 1 | 2 | 5 | 9 | 1927 | 544 | 1108 | 753 | 261 |
| 1 | 2 | 6 | 7 | 1945 | 655 | 1220 | 311 | 559 |
| 1 | 2 | 6 | 8 | 1935 | 752 | 1095 | 426 | 422 |
| 1 | 2 | 6 | 9 | 1944 | 681 | 1194 | 522 | 297 |
| 1 | 2 | 7 | 8 | 1986 | 628 | 1551 | 184 | 482 |
| 1 | 2 | 7 | 9 | 1985 | 700 | 1467 | 359 | 303 |
| 1 | 2 | 8 | 9 | 2046 | 674 | 1854 | 197 | 324 |
| 1 | 3 | 4 | 5 | 1855 | 631 | 275 | 882 | 778 |
| * 1 | 3 | 4 | 6 | 1854 | 818 | 268 | 682 | 754 |
| 1 | 3 | 4 | 7 | 1878 | 708 | 520 | 955 | 398 |
| 1 | 3 | 4 | 8 | 1871 | 846 | 584 | 527 | 521 |
| 1 | 3 | 4 | 9 | 1877 | 700 | 644 | 800 | 338 |
| 1 | 3 | 5 | 6 | 1866 | 823 | 552 | 559 | 600 |
| 1 | 3 | 5 | 7 | 1885 | 1109 | 380 | 723 | 430 |
| 1 | 3 | 5 | 8 | 1884 | 1128 | 440 | 586 | 437 |
| 1 | 3 | 5 | 9 | 1901 | 1038 | 550 | 897 | 189 |
| 1 | 3 | 6 | 7 | 1911 | 1131 | 684 | 399 | 471 |
| 1 | 3 | 6 | 8 | 1912 | 1288 | 556 | 405 | 436 |
| 1 | 3 | 6 | 9 | 1946 | 1500 | 523 | 522 | 297 |
| 1 | 3 | 7 | 8 | 1923 | 1106 | 897 | 251 | 415 |
| 1 | 3 | 7 | 9 | 1936 | 1131 | 925 | 513 | 153 |
| 1 | 4 | 5 | 6 | 1874 | 1133 | 518 | 589 | 454 |
| 1 | 4 | 5 | 7 | 1874 | 1145 | 561 | 642 | 325 |
| 1 | 4 | 5 | 8 | 1893 | 1361 | 350 | 725 | 311 |
| 1 | 4 | 5 | 9 | 1911 | 1361 | 609 | 677 | 188 |
| 1 | 4 | 6 | 7 | 1890 | 1248 | 801 | 436 | 258 |
| 1 | 4 | 6 | 8 | 1890 | 1446 | 405 | 488 | 360 |
| 1 | 4 | 6 | 9 | 1891 | 1302 | 738 | 458 | 208 |
| 1 | 4 | 7 | 8 | 1912 | 1568 | 558 | 254 | 412 |
| 1 | 4 | 7 | 9 | 1915 | 1438 | 871 | 238 | 254 |
| 1 | 4 | 8 | 9 | 1960 | 1823 | 655 | 258 | 263 |

Table I (Cont.)

| Component Lengths (Ft.) | | | | Relative Total Cost | Number of Components Used | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 6 | 7 | 1984 | 2065 | 358 | 420 | 357 |
| 1 | 5 | 6 | 8 | 1967 | 2000 | 350 | 402 | 339 |
| 1 | 5 | 6 | 9 | 1996 | 2142 | 363 | 542 | 185 |
| 1 | 5 | 7 | 8 | 1972 | 2038 | 492 | 256 | 323 |
| 1 | 5 | 7 | 9 | 1988 | 2087 | 605 | 387 | 117 |
| 1 | 5 | 8 | 9 | 2008 | 2215 | 682 | 252 | 137 |
| 1 | 6 | 7 | 8 | 2081 | 2781 | 252 | 243 | 360 |
| 1 | 6 | 7 | 9 | 2076 | 2745 | 252 | 342 | 247 |
| 1 | 6 | 8 | 9 | 2079 | 2766 | 381 | 246 | 206 |
| 1 | 7 | 8 | 9 | 2192 | 3483 | 184 | 235 | 247 |

* Systems shown to be the most economical.

# Preassembly of Components for Manufactured Homes

By Willard J. Worth,* Head
Research and Development, National Homes Corporation

No particular explanation or definition is necessary for the terms "preassembled components" or "manufactured homes," but I am, frankly, hard-pressed to define a single basic law, or principle, of prefabrication that I would not have to qualify at length, and then explain in detail the reasons for the numerous exceptions.

On second thought there may be, perhaps, such a basic law and if there is, I suspect the most valid law of preassembly is "interrelation," the influence of every element, from merchandising through transportation to land procurement, on every other element. In case this seems to be a vague and far-fetched law, let me illustrate briefly with a barely hypothetical chain of circumstances: A change in the mortgage situation, aggravated by increasing land and material costs, produces pressures to reduce lot frontage, which in turn emphasizes houses of shorter length and greater span. The necessity to transport longer trusses (and higher trusses) may in turn affect production methods and lead to such a decision as the field installation of prehung doors, rather than shop application, thereby balancing shipping space with a thinner wall panel.

However, there is actually little to be gained by attempting to trace our way through the maze of influences and interrelations (both logical and arbitrary) that may in fact change day-to-day decisions relating to fabrication and production types. Neither does it seem particularly rewarding to recite a list of idealized properties for new materials or new assemblies that in the end I would have to qualify with the statement, "In addition to the above properties it cannot cost more than a nickel a square foot."

Perhaps then, we can deal with the subject most effectively by reviewing the progress of the last five years, and by reaffirming or modifying what, in my opinion, are some of the basic ideas upon which the technical aspects of preassembly must be founded. Five years ago in a paper for the Building Research Institute 4th Annual Meeting, I mentioned some of the properties and precepts that appeared then to be necessary. In reviewing that list today, I find that there are some elements in which I believe definite progress has been made, others in which there has been little progress made, and still others which indicate that my remarks of five years ago were not valid.

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*WORTH, WILLARD J., Member, Building Research Advisory Board, Building Research Institute, Forest Products Research Society; B. S. in architectural engineering, University of Illinois; formerly research associate, Small Homes Council.

First, let us take those items of preassembly in which I feel there has been definite progress. Here I would list first the importance of the spread of trussed roof construction in all elements of the home building industry, but pre-eminently in the prefabricated house industry. This in turn has been based upon improved lumber grading rules, which have created the necessary grades to make trusses a feasible method of construction with widespread acceptance. I am sure it could be argued that further improvements and refinements are desirable, such as statistically assigned stress values for yard grade lumber, but I personally believe that there has already been significant progress in this field.

Second, I would mention the idea of prefinishing, which should be a basic part of any preassembly operation, and in which considerable progress has been made both in the more common materials and in the more recent metallic and plastic-based materials. Again it could be argued that there must be more progress, and that much of what has been accomplished to date has been confined to exterior products, such as siding, trim, and accessories, while there is an equal need to apply the same concept to interior materials. I would have to agree with this argument and reaffirm my belief that widespread use of prefinished interior materials will be the next major effort of materials suppliers, prefabricators and builders alike.

Third, I note that in my talk of five years ago, I emphasized the importance of blind connections of interior materials to the supporting structure, and reported our own efforts to perfect an all-glued connection system for attaching interior wallboard to framing. I must report now that those efforts of five years ago failed miserably, due to a combination of circumstances, and that we did not resume work on this project until a year ago. At the risk of being completely wrong twice in a row, I would like to say that our present efforts appear to be very close to success and that we believe we will be able to market such a system in the near future. The importance of such a development is, of course, that it solves one of several problems that hinder further progress in the area of interior prefinishing by eliminating exposed nails or other connectors and by completely eliminating the hazard of nail popping, which has hampered the use of many prefinished products.

As a fourth item, I think it would be fair to report some remarkable progress in the adhesive industry in producing products for the home building market. In many instances this progress has resulted in improved bonds as compared to those we were able to produce five years ago and, in several instances, these improvements have been coincidental with the use of adhesives that are more economical and more easily used than those of five years ago. And, today we are able to produce aluminum-clad doors and wall panels, which we were completely incapable of producing formerly. Some of this is undoubtedly due to a broader acceptance of adhesives by the home building industry and by our industries learning the more complex skills that are necessary.

To elaborate slightly on this point, National Homes Corporation would have rejected five years ago any adhesive system that involved techniques more complex than merely painting or rolling on the adhesive with a simple hand gun. Today we handle adhesives varying in consistency from thin liquids to heavy mastics and apply them by various techniques ranging from pneumatic flow guns through 100" wide roller coaters, which will simultaneously lay a thin film and a spaced bead of adhesive over an entire panel at an astonishing rate. In contrast, too, are the 1/100" wide nipper rollers which now provide the pressure that formerly we could achieve only with supplementary nails or staples. While this attitude is perhaps more extreme in our own instance, I do believe it is indicative of a general change in attitude of the home building industry toward adhesives as a means of connection.

Much more progress will certainly occur in this field and, as a wild guess, I might say that the glued-nailed truss, which is rapidly losing its market to a variety of barbed metal plate trusses, may again become an extremely attractive and economical construction with further advances in adhesive technology.

Now let me turn to those products and construction techniques that have not materialized since my previous BRI paper. The primary item, here again, relates to interior prefinishing. I speak of 8' wide interior finish materials, which have the inherent advantage of avoiding some of the jointing problems that still plague the conventional 4' x 8' materials. This is undoubtedly a recurrent theme in any discussion of the home building industry, but I still feel the need of such materials is a valid idea for preassembled houses, but I would point out that such a material must provide dimensional stability that has not been available, to my knowledge, to date, as well as providing structural and other properties that are commensurate with the presently available gypsum-based wallboard.

The last item I would like to mention concerns sandwich panel construction. Where I had previously believed that a wood-base product, such as honeycomb paper, would certainly be the favored core material of today, I feel that the situation in regard to the competitive position of sandwich panel construction has improved markedly and that the foamed plastic cores have made paper honeycomb a much less attractive product for this use.

While the addition of necessary insulation to a honeycomb core panel seems a difficult and costly operation to perform, the foams provide insulation much in excess of the minimum requirements without an economic penalty. Others will speak or have spoken on the current situation as regards foamed core panels for residential construction, so I will only add that I feel every progressive builder is watching these developments carefully in anticipation of producing or buying such panels at a price competitive to wood frame construction.

In closing, I would like to discuss panel size as it relates to preassembly. The prefabricator would, as a general proposition, prefer to handle the minimum number of pieces and the maximum size of piece that is practicable. This is the basic attraction of the foamed cores and the 8' wide building sheets that I have just mentioned. Weight, resistance to impact and damage during shipment, and field erection are all equally important factors in the choice of a construction method or a building product, and a final decision must inherently be a compromise, since some of these properties are mutually contradictory.

In the manufacture of preassembled components, given sufficient economic incentive, the prefabricated home industry is capable of making the necessary capital investment to economically handle large quantities of materials in sizes requiring special equipment. Transportation will, of course, place a top limit on the size and weight of panels that may be handled, but I do not see in the immediate future any developments that suggest any elaborate or special equipment for the handling of new types of construction on the building site. In the time that I have spent at National Homes Corporation, I have seen the prefabricated house progress from a single story, through the split-level, through the "English basement type," to the two-story house that we produce today, with only minor concessions to the problem of panel handling on the job site. Since we would expect that future constructions would be lighter rather than heavier, on a square-foot basis, we would not expect a reduction in panel size to be necessary for purposes of field erection.

I have tried to touch on the areas of progress and the areas for future work that have made, and will further increase, the importance of preassembly as a factor in the residential building industry. I think we should be much encouraged by the progress of the last five years and I look forward eagerly to the removal of the remaining obstacles between the building industry and greater technological progress.

# On-Site Preassembly of Components for Home Building

By Robert F. Schmitt,* President
Schmitt Homes

In order to discuss my subject adequately I would like to take the liberty of expanding it to include those components which the builder is instrumental in having made. This would then include builder-manufactured components, even though they might be made in an off-site activity, which would not necessarily be made for general distribution. The important things here are the fact that the builder initiated the production of the component, and his reasons for doing so. Hereinafter the use of "on-site preassembly" will presume this expansion of the term.

Basically, the use of components, and consequently their preassembly by the builder, is based on one simple objective—reduced costs. A generalization on the comparative efficiencies derived from the use of specific components is of questionable value because, in most cases, the contribution to the basic objective that any given component achieves is indirect. This is to say that the component is most frequently not an objective in itself but a relationship to a system. It can be frequently found that the component may, in direct comparison with its conventionally built counterpart, be more expensive, but when examined in terms of its relation to the over-all system, will represent a substantial saving.

A very good example of this is the roof truss. (Incidentally, a few years ago this component was usually of necessity an on-site preassembly but, as its value is becoming more widely understood, it is rapidly becoming a standard stock building product.) The truss on a direct cost comparison with a conventional roof will frequently, depending on labor rates, come off second. However, the truss is basically necessary to achieve a large number of major cost savings in the over-all production technique. They are:

1) Design freedom based on the clear span interior and on deeper houses. (A truss is practical up to 36'; conventional framing 28' with a center bearing wall.)

2) Less exterior wall to achieve a given square foot enclosure. The deep truss allows the structure to approach a square which has the minimum perimeter for area enclosed.

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*SCHMITT, ROBERT F., Member, Technical Studies Advisory Committee of Building Research Advisory Board; Building Research Institute; B. S. in industrial engineering, Ohio State University; actively engaged in home building since 1941.

3) Rapid enclosure, thereby minimizing exposure to bad weather.

4) Elimination of craft skill necessary to cut rafters and build roofs.

5) Standardization and simplification of purchasing of materials and stock control.

6) Production techniques dependent on the interior clear span such as:

   a) Installation of finished floors prior to interior partitions.

   b) Finishing of ceiling and interior walls prior to installation of partitions. With the use of taped joints on gypsum wallboard the butt joints, and frequently the longitudinal joints, can be positioned so as to be covered by a partition, thereby reducing the taping labor and material by as much as 25%.

   c) The use of economical interior partition systems, since no bearing load is necessary on any interior walls.

In this foregoing example lies the key principle in the use of components. It emphasizes that a component is not an end in itself, nor is its most important cost relationship a direct one. Another good example of this principle is a prefabricated plumbing drainage unit. With copper tubing it is possible to assemble the entire system in one assembly with accurate location of the fixtures. This can then be installed as a unit with resulting elimination of delay for plumbing rough-in. Cast iron, on the other hand, is less expensive but, because of weight and difficulty of achieving accuracy, cast iron is less subject to prefabrication. Therefore the indirect gains are lost and consequently the total cost of component copper systems is by far the least expensive.

A principal factor in the extent of the use of on-site preassembled components is the type of building operation. These operations range from highly repetitive mass-produced homes to individually designed custom-built homes. There is greater or lesser application for on-site components to this full range. The nature of the components, however, changes with the type of operation. Preassembly suggests a repetitive operation. Where the entire house is repetitive, the extent and nature of preassembly has its greatest potential. However, in houses that are different in floor plan and appearance, there still appears a significant number of standard parts. For example, doorways and windows in vastly varying houses can be reduced to a limited number of standard units which then make them subject to prefabrication into wall sections independent of the main structure.

Also, standard trusses can be used with an almost unlimited number of floor plans, both in arrangement and size.

In varying houses the plumbing often varies in fixture relationship which prevents preassembly of total units, but it is still possible to preassemble subassemblies which are standard to any plumbing unit.

A significant factor in the use of on-site preassembly is the beneficial effect it has on design. The designer tends to discipline himself much more, so as to gain the advantage of components. For example, in developing widely varied plans, it is possible to design as many different size bathrooms and fixture spacing as there are plans. The same is true of foundation size and resulting roof depth. These variations are arbitrary and usually are not based on reason, but normal lack of continuity in the absence of any reason for continuity. However, where the designer is component-minded, he can in these widely varied plans standardize certain elements which then make them unidentifiable with the plan and subject to mass production with all its accompanying benefits. This design discipline has its benefits in areas not subject to preassembly.

A word as to quality of preassembled units. The effect on and the control of quality is greatly enhanced by preassembly. Usually, fastening can be achieved in a much better fashion. The repetition of preassembly induces a degree of expertness. The job almost always requires less skill, which in turn is an indirect quality factor. The work is done under more favorable conditions, which contribute to quality.

In conclusion, on-site preassembly is a product of variable design and the over-all system employed by a builder. Systems vary according to climate, soil conditions and labor rates. Therefore, on-site preassembly will attain greater or lesser importance depending on these factors. It is these factors that tend to preserve on-site preassembly as compared to widespread manufacturing of components. Frequently components produced for a wide area of use are not, therefore, reflective of a specific condition, and end up being of limited value for all.

# Preassembly of Components by the Materials Dealer

By Michael W. Boeke,* Sales Manager
Davidson's Southport Lumber Company, Inc.

Let's go back for a moment to a day in the dark past before the existence of radio sets as we know them today. We are dealers in radio parts. We carry an inventory of headphones, tuner chassis, crystals and all the other parts necessary for the completion of a radio set. We sell to individuals who, with guidance or a "plan" from us, assemble these parts into radios. To upset this idyll, along comes a manufacturer who not only assembles the parts into a completed unit but also sells direct to our customers, leaving us out in the cold.

Although the parallel is not exact, this is approximately the position in which the retail lumber dealer found himself shortly after World War II. The dealers' private preserve had been boldly invaded by the "pre-fabber," and been found vulnerable. There were two factors that saved the dealers: the tremendous size of the housing industry and its resistance to revolutionary change; and a group of determined, aggressive lumber dealers who formed the Lumber Dealers Research Council in 1948.

The LDRC had as its main objective the building of a defense against these invaders. Its guiding principle was survival, and its major weapon was the LuReCo panel system, born about 1954. It will be our purpose here to review the LuReCo system, specifically in terms of development, production and distribution.

## Development

Advances in the field of LuReCo components have followed four routes:

1) Specific research programs by the University of Illinois supported by grants from the LDRC.

2) Research conducted by independent manufacturers.

3) Research by trade associations like the Douglas Fir Plywood Assn.

4) The dealers' own improvisations.

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*BOEKE, MICHAEL W., Member, Natl. Assn. of Home Builders, Construction League of Indianapolis; B.A., DePauw University; formerly associated with Forest Products Div., Olin Mathieson Chemical Corp. Southport Lumber Co. is a member of Lumber Dealers Research Council.

The most notable over-all contributions have come from the University of Illinois' Small Homes Council. First, they took the original LDRC idea and drew up the LuReCo panel system. Then, as technology advanced, additional LDRC grants supported new research which was outlined in two major reports: "Tests on Exterior Wall Sections,"(1)* and "Re-evaluation of Preassembled Wall-panel Framing System."(2)

In the latter report, the development of greatest significance to the LuReCo dealer and builder is outlined: the glue-nail header. From the outset of the LuReCo system, the most consistent complaint of builders was the trouble from twisting and extra labor required to put in place the ponderous double 2" x 6" continuous header with its long lag screws, used to tie the wall panels and header together. In its 1958 report, the Small Homes Council proposed a plywood glue-nail header utilizing one vertical and two horizontal 2" x 4" members with a plywood skin that would bridge the 4' top of each window or door panel. A single 2" x 4" top plate then would be used to tie the panels together.

This header was subsequently submitted to the Federal Housing Administration and accepted(3) for use in February 1960. To the fabricating dealer, it offers these advantages:

1) Headers can be made up in slack periods and easily stored until needed.
2) The new system saves 7-1/2 board feet of lumber per 4' panel over the old system.
3) Eliminates need for special length stud required by old system.
4) Eliminates need for 2" x 4" inventory.
5) Eliminates need for lag screw inventory.

To the contractor, it offers these additional advantages:

1) Eliminates wasted material. Old style header was needed only over window and door openings, but it continued over solid wall panels as well.

2) Eliminates additional time for lifting, adjusting and fastening continuous headers on the job, estimated by various contractors at three to eight man-hours per house.

3) Eliminates potential problems from shrinkage across width of 2" x 6" on old header.

The material saving, expressed in terms of retail sales dollars at 1960 selling price is:

Window & Door Panels, Studs 16" o.c.

Eliminate:

| | |
|---|---|
| 4 lin. ft. of cont. hdr. @ .45 per l.f. | 1.80 |
| 1 Lag screw & washer @.20 | .20 |
| 1 Pc. 1/2" insul. board 12" x 48" @ .085 | .34 |
| | $2.34 |

* Numbers in parentheses refer to list of references at end of paper.

Add to:

| | |
|---|---|
| 1 Pc. 1/2" plywood 12" x 48" @.135 | .54 |
| 1 Pc. 2" x 4" const. 8-3/4" @.08 per lin. ft. | .06 |
| 1 Pc. 2" x 4" const. 48" @.139 | .42 |
| Est. Glue | .05 |
| | $1.07 |
| Savings - | $1.27 |

48v - Panel, Studs 16" o.c.

Eliminate:

| | |
|---|---|
| 4 lin. ft. cont. hdr. @.45 per l.f. | 1.80 |
| 1 Lag screw & washer @.20 | .20 |
| | $2.00 |

Add to:

| | |
|---|---|
| 1 pc 2" x 4" const. 48" from lineal @.139 | .42 |
| Savings | $1.58 |

The reception to this header among our own contractors has been enthusiastic; it has wiped out one of the major obstacles in our sales approach to volume builders, to whom every minute of extra labor is important. We feel it has done more than any other development to put the LuReCo system in competition with the other major prefabricating systems.

Another important revision resulting from the SHC report of 1958 was the conversion from an inside module to an outside module on the width dimension; i.e., the minor dimension of the house, parallel to the floor joists and trusses became a multiple of 4' plus 8". The original system called for special 2" x 4" corner posts so that both dimensions had a plus 8".

Under the new plan, the panels on the exterior walls parallel to the trusses have an extra stud added to the corner panel (Fig. 1) to provide nailing surface for the inside wall covering. Even with this added stud, the elimination of the corner post results in a saving of 5-1/2 board feet per corner. In addition, these savings result to the builder:

1) On a 28' house, two 14' floor joists will span where the old 28'8" required one 14' and one 16' member. (A similar waste is also eliminated in any other span.)

2) A similar saving results in the bottom chord of the truss.

3) Standard 4' x 8' subfloor panels work out perfectly across the width of the house with no waste.

4) The extra on-site labor of nailing in the corner post is eliminated.

These modifications in the original system accomplish three things: they simplify construction, save labor and save materials.

The contribution of manufacturers to the growth of the LuReCo system has also been substantial and continuing. Probably the most noteworthy results are seen in windows.

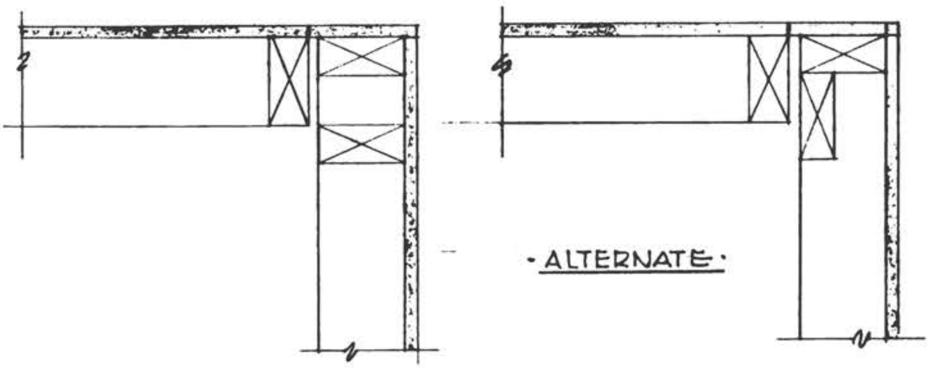


Figure 1

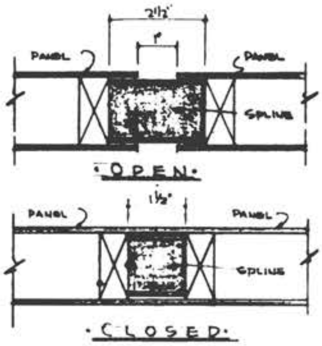


Figure 2

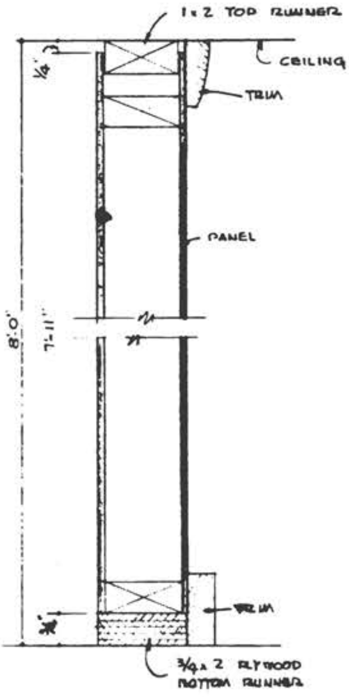


Figure 3

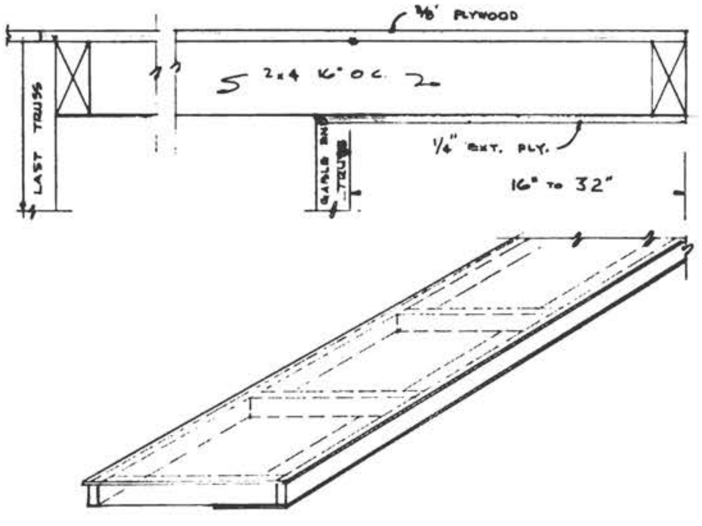


Figure 4

Several manufacturers have assisted the LuReCo dealer by adding to or altering their lines to include sizes which fit the 4' wall panel without additional cripples or blocking.

In addition to providing a LuReCo-size window, one manufacturer has provided further assistance in the form of a unit which includes not only the window itself, but the entire 4' wall panel in which the window is mounted. This unit marks the first appearance of an entire major component marketed by a manufacturer to the dealer, a trend which undoubtedly will be duplicated by other manufacturers.

Special sizes of insulation blankets have also been developed for the LuReCo system by some manufacturers.

Another project which is attracting much interest is a new hardboard interior partitioning system. Our firm was one of about five LuReCo dealers around the country who worked with the manufacturer on trial houses early in 1960. The model in which we used the system sold readily and drew a very pleased reception from the buyer. The partitions are 2' x 8' panels, faced both sides with a wood-grained hardboard skin separated by 1" x 2" wood stiffening members. The joint (Fig. 2) is a spline, a 2" thick member with matching wood-grained hardboard skins and a plastic foam center. The spline may be cut short to create a butt joint on the panels, or left longer for an open, reverse batten joint. The panels are secured to floor and ceiling by means of a pair of runners (Fig. 3). All closet and passage doors match the wall panels and are full length, ceiling height, thus eliminating headers. It has been estimated by one of the participating dealers that this panel offers a potential saving of $1.30 per lineal foot over conventional partition walls.

Although this system is not yet on the market, it seems to offer great promise by virtue of its durability, speed of installation and the fact that its 2" net thickness is a substantial space saver in comparison with the standard 4" wall. Just within the year 1960, one of the aluminum companies has jumped into the LuReCo program with the fervor of a zealot. In addition to the window program mentioned earlier, this company has made available to dealers an extensive line of LuReCo homes utilizing aluminum products. They have backed up the introduction of this line with an elaborate national publicity and advertising campaign, its apparent aim being to enable the LuReCo dealer to compete with the successful aluminum program launched by several home manufacturers.

Through their own sales channels, this company has attempted to interest the regular lumber dealer in LuReCo and, through LuReCo, in the use of its aluminum products. They have added to their line a 4' x 8' board-and-batten type aluminum siding with a different color on each side of the panel, thus minimizing the size of inventory needed.

Next among those groups contributing to the development of the LuReCo system are the trade associations, and particularly the Douglas Fir Plywood Association. DFPA research work on glue-nail headers for LuReCo led to the establishment of Plywood Fabricating Service, a DFPA affiliate devoted to engineering plywood components and licensing and policing fabricators of plywood components.

A joint DFPA-LuReCo project last year was the Champaign, Illinois, experimental house utilizing glue-nail beams, stressed skin panels and a new floor system (Fig. 4). This floor system, which employs a preassembled 4' x 8' floor panel of plywood and 2" x 4" x 4' joists, promises to break into still another area of construction which has resisted panelization up to now. The major supporting members for the floor panels may be either plywood box beams or larger lumber joist members 4' on center. In the first application of this system, a 2000 sq. ft. floor was laid in less than six man hours.

Finally, as far as development of LuReCo is concerned, comes the dealer himself. His contributions have, for the most part, supplemented the LuReCo system. In many cases they have been the type dictated by local conditions,[5] but because of their nearness to the point of actual use, they frequently have been realistic, down-to-earth solutions. As an example, consider for a moment several developments resulting from our own operation in Southport. All of these particular components resulted from necessity—the necessity of saving our business. The interesting thing is that, as a result of better utilization of materials, the use of shorts, and more efficient use of labor, these components frequently sell for less or no more than the pieces they replace. (See Tables I through VI at end of paper.) They include:

1) A thin, flat oak sill which eliminates the necessity for cutting the subfloor and joists to accommodate the thick standard sill.

2) An 8' or 16' soffit panel made of 1/4" exterior plywood with short 1" x 2" stiffeners on the back side. This panel slips into a routed gutter board and nails into a 2" x 2" nailer on the studs.

3) A preassembled rafter system (for the builder who objects to trusses) to supplement our truss. The rafters are precut, tied together with a collar beam and full-length ceiling joist, and held apart for the ridge beam by means of a spacer block. (See Table II.)

4) A door unit system which is significant enough to bear further elaboration. (See Table VI.)

Although our door unit was not devised specifically for LuReCo, it fits ideally into the LuReCo plan and is definitely a component of some consequence. It differs from most door units in one important respect: it is sold installed.

As soon as a house is framed in, a salesman measures each opening, numbers it and enters all information pertaining to it on an order form. When the order reaches our door unit department, a unit is manufactured specifically for each opening and the corresponding number is placed on the jamb. The unit features a one-piece jamb rather than the weaker split-jamb arrangement. When the unit leaves our shop, the door is hung in the assembled frame, and it is bored for the lockset. The trim is all precut and mitered, and all locksets are packaged for easy handling. The installer delivers and installs a job at a time, shimming each unit conventionally, casing it out on the job, and installing the hardware. When he leaves, all that remains before finishing is filling the nail holes and touch-sanding.

Any type of unit is available, from passage and by-passing to by-folding or pocket, with any combination of specie in doors, jambs and trim. A three-man crew can deliver and install three house jobs per day, and more than 10,000 of these units have been installed by our crew in the past two years. An additional feature of note to the builder is a warranty program under which we rehang and refinish the door if it should warp or otherwise prove deficient under the terms of the manufacturer's guarantee.

Somewhat tangential, but nonetheless an interesting component contribution, is the fact that we have for some time been furnishing floor packages and stairways to several large builders in our area, who buy house packages from a very large out-of-town home manufacturer. They turned to us first for precut floor packages because of our nearness and the ease of getting supplemental materials when necessary. This precut package grew (we have furnished well over 100 in the past year) until recently we designed and produced a panelized floor package (See Fig. 5 and Table IV) for a new two-story house recently introduced by this manufacturer. This package features a 4' wide panel which runs the width of the house, and each panel is composed of floor joists, end blocking and 2" x 4" blocking to support the plywood subfloor joint.

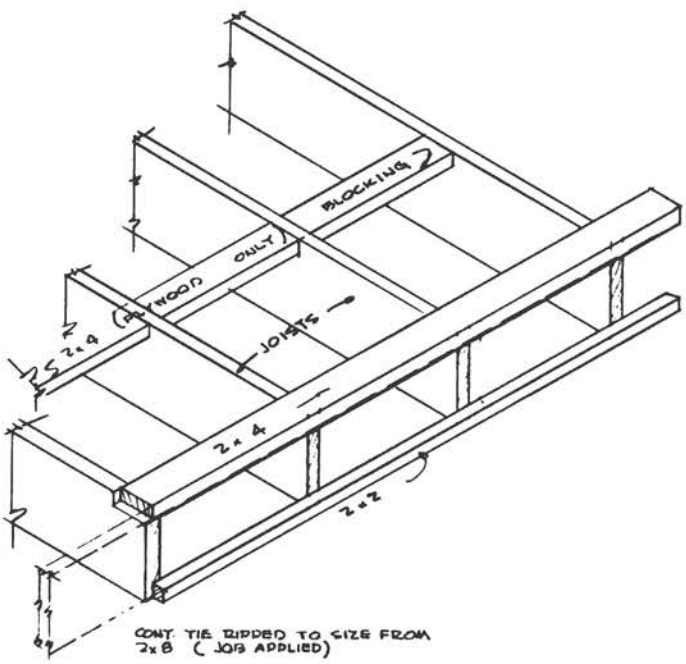


Figure 5

The stairway resulted a year ago from the introduction of a tri-level model. In cooperation with the builder we worked out a prebuilt stairway that he simply nailed in place as he assembled the house. Since then, we have jointly worked out a stairway for the two-story model as well. (See Table V.) These components are also available to our LuReCo builders.

Another dealer innovation of interest was the diagonal truss arrangement for an L-shaped house which Carl Scholz of Vandalia, Ohio, worked out in 1958. The trusses ran at a 45° angle to the walls, creating a hip roof and eliminating the need for additional framing where the two roofs intersected.

There are undoubtedly hundreds of other noteworthy contributions to the LuReCo system made by the individual dealers, but the number of developments listed here attest to the vitality of the system and the important position it occupies in the future of components. Some of the lessons of the present reaffirm the wisdom of the men who conceived the LuReCo panel. In the competitive market of 1960, the prefab builder has put heavy pressure on the fabricator to produce individuality and flexibility, frequently in terms of a model designed for that builder exclusively. To do this means abandoning the economy of repeated production of like models, and coming closer to custom fabrication.

With the manufacture of the big panels most fabricators endorse, the result was a new set-up for practically every house coming off their lines.

In contrast, the versatile 4' panel permits almost unlimited variation, and the stockpiling of panels without concern for their early obsolescence. There are rumors that one of the larger home fabricators has under serious study a small-panel system similar to LuReCo as the answer to this demand for individuality.

Production

The production of LuReCo components has been almost entirely a local problem. The lack of a central engineering service has been called the major weakness of the organization by many dealers. Except for basic instructions on construction of a wall panel jig, the LuReCo dealer, in most cases, has been left to develop his own production and material flow layout. To illustrate, here are a few of our own production elements, partially or completely developed by us:

1) Panel jig table with a pop-out feature (a lever arrangement for easy removal of the completed panel) and a special stop for window panels to hold the panel up from the floor of the jig table so that the window unit may protrude the necessary 1/2" or more through the panel.

2) A hydraulically operated truss jig which holds all truss members firmly in position while the plates are nailed in place, and then flips the truss over and releases it. (Most of the larger operators are using one of the various metal plate connectors for their trusses.)

3) A system of portable rollers feeding the truss into a motor-driven roller press (not developed by us), which presses the plates into the joint like a giant washing machine wringer. (Technically, trusses were not part of the original LuReCo system since, at its inception, it was a wall panel system only. However, almost all LuReCo dealers manufacture a truss of one variety or another.)

Several dealers have advanced to the stage of air-driven stapling equipment for the application of sheathing board and securing of the truss plates: the use of manually driven nailing machines is fairly common. Some manufacturers are experimenting with the development of spike-driving machines to be used in assembling the dimensional members of the wall panel, but as yet a proven operational machine is not known to be on the market.

Considerable advancement in the efficiency of LuReCo production is to be expected in the years ahead. Many dealers have reached an output that ranks them well up among the leaders in prefabricated housing. Such growth is sure to bring continuing improvement in production facilities and equipment, and further mechanization.

It is significant to note that in the period from 1954 to 1959, more than 100,000 LuReCo homes were built, and 1960 is expected to yield 30,000.

Distribution

Until very recently, the distribution pattern of LuReCo components was a very simple one: dealer to builder, or dealer to consumer in some few do-it-yourself cases. The volume LuReCo dealer now discourages sales to do-it-yourselfers because the amount of job-site supervision demanded by most such individuals is prohibitive in a volume operation.

However, this pattern is changing somewhat as a result of a recent move by the LDRC to create a more up-to-date distribution arrangement. The three categories set up by the LDRC are:

1) Manufacturing distributor, who sells to -
   a) Dealers only.

2) Manufacturing dealer, who sells to -
   a) Dealers for resale.
   b) Builders.
   c) Direct to consumer.

3) Dealer, who sells to -
   a) Builder.
   b) Direct to consumer.

This change encouraged the entry of wholesalers and jobbers into LuReCo manufacture as manufacturing distributors, who would sell components to lumber dealers either as their main and only line or as a supplement to a line of other building products. It also encouraged the larger LuReCo dealer to sell components to other smaller, possibly outlying, dealers as a manufacturing dealer.

The aim of this new policy is to make LuReCo components available to an even wider range of lumber dealers, especially those small enough so that a manufacturing operation of their own would not be economically practical. This aim is consistent with the purpose of the LRDC: to provide ammunition for the competitive war to every lumber dealer regardless of size.

In summary, these are the strengths of the LuReCo system and the reasons why the lumber dealer should handle components:

1) Components make sense for the lumber dealer. Our own surveys show that a LuReCo sale produces a larger dollar sale per house, and produces more profit because of:

   a) Fewer deliveries.
   b) Fewer pick-ups of material to be returned.
   c) Better average mark-up.
   d) Faster job pay-off.

   And yet, this same sale results in a saving to the builder because of:

   a) Less material waste.
   b) Less on-site labor.
   c) Faster turnover of capital.

2) The LDRC is good for LuReCo because it acts as a central coordinater, communicater, and disseminater of new ideas to the many member-dealers. It also acts as an agency for continued research.

3) The 4' x 8' panel is an asset today, although it may not be some time in the future, because:

   a) It is versatile, flexible and easily adaptable to the dealer's conventional plans.
   b) It is easy to handle—two men can erect a LuReCo house.
   c) It ties in with stock sizes sold conventionally.

4) The lumber dealer is in an advantageous position to make package house sales because of his proximity to the market. With freight such a big factor, components are a local commodity. The lumber dealer already knows the builders and has established sales channels which give him an advantage over his out-of-town home manufacturing rival. The lumber dealer is close to local officials and should find it easier to work out code problems relating to components.

5) The tremendous size of the retail lumber industry is an advantage to LuReCo. If we assume that the home manufacturing group accounts for somewhere between 10 and 20% of the homes being built, that means that lumber dealers are still accounting for from 80 to 90%. Manufacturers of building materials, realizing this fact, are becoming increasingly willing to aid their best customers in the development of new materials and ideas that will permit the dealer to lead the home construction parade. There are literally hundreds to thousands of possible LuReCo manufacturers and, if each were to reach his full potential, this would be a combination capable of dwarfing present home manufacturing capacity.

Components are a means of survival to the lumber dealer, and a means of greater growth. The only ingredient needed is a more universal recognition by the lumber dealer that the field of components is one to which he should direct his attention if he intends to remain a part of the volume housing market.

Table I

Retail Selling Price of LuReCo Wall Panels vs.
Material Only for Equivalent 40'8" Conventional Wall

**LuReCo**

2 - 48v - WB panels (1R & 1L). *
2 - Aluminum sliding window units in 48v panel.
1 - Aluminum sliding window unit in 8' panel.
1 - Panel frame for 3/0 x 6/8 ext door w/3/0 x 6/8 x 1-3/4" flush birch HC door.
3 - 48v panels.
3 pcs 2" x 4" - 14' Std & Btr S4S (top-plate).
2 pcs 2" x 6" - 7'8" ditto (wall lead).
2 pcs 2" x 4" - 14 3/8" ditto (wall lead blocking).
2 lbs 12d common nails.

Retail Price - $225.94

* 4' x 8' - 1/2" insulation applied to all panels; studs 16" o.c.

**Conventional On-Site**

40'8" Exterior frame wall with 1/2" insulation, windows and doors.
120 ft lin 2" x 4" const. fir S4S - plates.
44 pcs 2" x 4" - 7'8" ditto - precut studs.
1 pc 2" x 6" - 8' ditto - headers.
2 pcs 2" x 6" - 10' ditto - headers.
2 pcs 2" x 10" - 8' ditto - headers.
2 pcs 4' x 8' - 1/2" fir plywood - sheathing and corner braces.
6 pcs 4' x 8' - 1/2" insulation ditto.
1 Aluminum strip window, center fixed, 2 vent sliders, no screens or stm sash.
2 Aluminum single vent sliders.
1 OS Dr Fra 3'/0" x 6'/8" - 1-3/4 rab 4-11/16" MM csg - oak sill.
1 Ext. Dr 3'/0" x 6'/8" x 1-3/4" flush birch HC.
1-1/2 Pr 4" x 4" hinges.
1 Lock set.
6 lbs 16d common nails.
6 lbs 8d common nails.
3 lbs 1-1/2 Galv Rfg nails.

Retail Price - $230.34

Table II

Retail Selling Prices of Framing Systems For
Gable Roof on a 26' x 40'8" House

**Trusses**

21 - 26' span trusses, 4/12 pitch, 24" overhang.

Retail Price - $307.65

**Prebuilt Rafters**

31 - 26' span, 4/12 pitch, 24" overhang (2" x 6" rafters, 2" x 6" ceiling joist) prebuilt roof frame.

Retail Price - $403.03

**Conventional On-Site**

Ceiling joist and rafters for 26' x 40'8" house, 4/12 pitch, 24" overhang.
60 pcs 2" x 6" - 14' const.
62 pcs 2" x 6" - 16' ditto.
15 pcs 1" x 6" - 12' ditto.
42 ft lin 2" x 8" ditto.
50 lb 16d & 8d common nails.

Retail Price - $282.63

Table III

Retail Selling Prices of Interior Partitioning (164 Lin Ft of 2' x 4' wall)
Prebuilt vs. Conventional On-Site Construction

| Prebuilt | | | Conventional On-Site | |
|---|---|---|---|---|
| 1 | Built-up A panel | 11' - 8 3/4" | 492 | Ft Lin 2" x 4" const. Fir S4S. |
| 1 | Built-up B panel | 12' - 4 3/4" | 180 | pcs 2" x 4" - 7'8-5/8" ditto. |
| 1 | Built-up C panel | 2' - 0" | 78 | Ft lin 2" x 4" ditto. |
| 3 | Built-up D panel | 2' - 0" | 40 | lb 8d & 16d common nails. |
| 1 | Built-up E panel | 9' - 4-3/4" | | |
| 1 | Built-up F panel | 12' - 9-3/4" | Retail Price - $189.22 | |
| 1 | Built-up G panel | 4' - 4" | | |
| 1 | Built-up H panel | 5' - 3-1/4" | | |
| 2 | Built-up I panel | 7' - 8-1/8" | | |
| 1 | Built-up J panel | 11' - 3-5/8" | | |
| 1 | Built-up K panel | 8' - 7-5/8" | | |
| 1 | Built-up L panel | 3' - 9" | | |
| 1 | Built-up M panel | 1' - 10" | | |
| 1 | Built-up N panel | 5' - 5-1/8" | | |
| 1 | Built-up O panel | 9' - 4-3/8" | | |
| 1 | Built-up P panel | 12' - 11-5/8" | | |
| 1 | Built-up Q panel | 8' - 5-1/8" | | |
| 1 | Built-up R panel | 8' - 5-1/8" | | |
| 1 | Built-up S panel | (deleted in actual construction) | | |
| 1 | Built-up T panel | 12' - 9-3/8" | | |
| 1 | Built-up U panel | 12' - 9-3/8" | | |

Retail Price = $191.42

Table IV

Retail Selling Price of Prebuilt Floor System for
Two-Story House vs. Materials Only for Conventional Floor

| Prebuilt | | Conventional On-Site | |
|---|---|---|---|
| 25 | pcs 2" x 8" - 24'4-11/16" Const. | 25 | pcs 2" x 8" - 12' Const Fir S4S |
| 1 | pc 2" x 8" - 11'11-5/8" Const. | 25 | pcs 2" x 8" - 14 const Fir S4S |
| 1 | pc 2" x 8" - 11'0-3/4" Const. | 8 | pcs 2" x 8" - 6 const Fir S4S |
| 2 | pcs 2" x 8" - 14'0" Const. | 82 | pcs 1" x 3" #2 Fir S4S precut bridging |
| 2 | pcs 2" x 8" - 11'2-3/8" Const. | | |
| 2 | pcs 2" x 8" - 3'7-1/8" Const. | 224 | ft lin 2" x 4" const Fir S4S |
| 2 | pcs 2" x 8" - 16'4" Const. | 112 | ft lin 1" x 4" #2 Fir S4S |
| 2 | pcs 2" x 8" - 14'4" Const. | 24 | Sheets 4' x 8' x 5/8" Fir Plywood |
| 2 | pcs 2" x 8" - 2'6-3/8" Const. | 4 | 4" x 8" joist hangers |
| 2 | pcs 2" x 2" - 2'6-3/8" Const. | | |
| 4 | pcs 2" x 8" - 3'9-3/4" Const. | Retail Price - $309.41 | |
| 1 | pc 2" x 8" - 1'2-3/4" Const. | | |
| 46 | pcs 1" x 3" precut bridging. | | |
| 168 | pcs 2" x 4" - 14'-3/8" Const. | | |
| 112 | ft lin 1" x 4" #2 Fir S4S. | | |
| 22 | pcs 4' x 8' x 5/8" Fir Plywood. | | |
| 4 | 4" x 8" joint hangers. | | |

Retail Price - $385.84

Table V

Retail Selling Price of Prebuilt Stairway for Two-Story House vs. Materials Only for Conventional Stairway

Prebuilt

| | |
|---|---|
| 2 | pcs 5'/4" x 10" net 14'/0" clr pp. |
| 13 | pcs 1-1/8" x 8'-1/8" net - 36" clr. Red Oak S4S. |
| 13 | pcs 1-1/8" x 10-1/2" net - 36" oak treads. |
| 1 | pc 3/4" x 5'-1/2" - 48" clr Red Oak. |
| 40 | ft lin 3/4" x 3/4" oak cove mld. |
| 1 | pt sealer. |
| 1 | lb misc nails. |
| 1/2 | pt glue. |
| 2 | hrs machine time. |
| 7 | hrs bench labor. |

Retail Price - $121.33

Conventional On-Site

| | |
|---|---|
| 3 | pcs 2" x 10" - 14' const Fir S4S. |
| 2 | pcs 1" x 12" - 14 clr WP S4S 1 edge beveled. |
| 13 | pcs 5'/4" x 8'-1/8" net 3' clr Red Oak S4S. |
| 12 | pcs 5'/4" x 10'-1/2" net 3' nosed oak treads. |
| 1 | pc 5'/4" x 7'-1/2" - 3' nosed oak landing tread. |
| 1 | pc 1-1/4" x 5'-1/2" - 6' clr Red Oak S4S. |
| 13 | pcs 3/4" x 3/4" - 3' oak cove mld. |

Retail Price - $100.33

Table VI

Retail Selling Price of Installed Door Unit vs. Materials only for Conventional Door

Door Unit

2'6" x 6'8" unit with 1-3/8" flush birch door.
4-11/16" WPP jamb with stop, WPP Streamline casing, lockset, two 3-1/2" round corner butt hinges.

Installed Retail Price - $29.95

Conventional On-Site

| | |
|---|---|
| 2'6" x 6'8" - 1-3/8" flush birch door. | 10.45 |
| 4-11/16" WPP jamb with stop | 5.20 |
| 2 sets WPP streamline casing | 4.20 |
| 1 lockset | 3.50 |
| 1 pair 3-1/2" round corner butt hinges. | .95 |
| shims, nails & glue. | .45 |
| Retail Price - | $24.75 |

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# Preassembly of Components by a Product Manufacturer

By John S. Parkinson,* Director of General Research and
New Business Development, Johns-Manville Research Center

## Introduction

The largest part of the building research dollar is spent by the manufacturer of building materials. It is of the greatest importance, therefore, for the building materials manufacturer to be able to judge future trends in the building industry correctly. For this reason, the building manufacturers have been close and interested observers of the gradual evolution of building technology since the end of the last war.

We have made it our business to talk to builders in all parts of the country and to consult with the representatives of the Home Manufacturers Association and of the National Association of Home Builders. We have questioned our distributors and our dealers as to the buying habits and construction practices of their customers. We have also worked closely with the design engineers of the prefabricators. Everywhere we turn, we are told that building costs are too high and that ways must be found to reduce the cost of on-site labor. Currently, we are told by people who ought to know that the home builder today runs the risk of pricing himself out of the market.

We listen with interest to the proponents of off-site prefabrication. As operators of manufacturing plants, it seems reasonable to us that continuous assembly of standardized components in a completely equipped plant and by specifically trained personnel cannot fail to produce a more economical building unit. We also listen with interest and some excitement to the proponents of the industrialized house. Technically, we can conceive, without too much trouble, of an assembly line which would turn out complete houses or at least manageable sections of houses fully equipped with electrical, heating and plumbing services, and perhaps even with built-in appliances. None of these possibilities seems beyond the bounds of realization from the manufacturing or technical standpoint.

However, as we turn to the market, we realize that our progress must of necessity take place in a series of steps, graduated to the mechanics of the distribution and delivery system and adjusted to the ideas and tastes of our ultimate customers. Historically, our primary emphasis has been on the development of formulations and processes which

*PARKINSON, JOHN S., Fellow, Acoustical Society of America; Member, Society of Chemical Industry; Member of Board of Governors, Building Research Institute; educated at University of Wisconsin, Columbia University and George Washington University.

would permit us to turn out large quantities of materials at a minimum cost. I believe no one can deny that, over the past 50 years, tremendous strides have been made in the fabrication of all sorts of building boards, blocks and sheets, from either natural or synthetic materials, designed to serve the needs of the building industry. These materials have been designed for cutting, fitting, and fastening or adhering in place by workmen on the job. Moreover, they have been designed in sizes which would either cut readily or which could be applied without cutting.

Since the universally accepted method of framing has been wood studs, joists and rafters, our constant concern has been to design materials which would fasten to and supplement the wood framework of the residence. One of the first steps in reducing on-site labor consisted of prefinishing our materials. Today, these materials arrive at the job site in a wide variety of colors, textures, finishes and patterns.

Another step in reducing on-site labor was to provide adhesives which could be used efficiently on the job either to take the place of or to supplement mechanical fasteners. As a result, the builder today has a commendable variety of adhesives available for this purpose.

The next step obviously was the assembly of materials into a composite unit which would perform several functions. One of the earliest of these sandwich panels was a product made by facing wood fiber board with asbestos-cement facing sheets. This has been used in various types of industrial and commercial building walls for more than 25 years. Composite panels have also been used for 20 years or more in interior partitions. These panels provide both the finished surface for each face and also the necessary rigidity and structural stiffness, and sound insulation.

From time to time, pressure is brought on the building materials manufacturer to make larger sheets or sections. Equipment is available today to make wood fiber boards and sheets up to 12' wide in almost any length that can be handled, in the plants of a number of manufacturers. Most of the other building materials, however, are limited in size to a 4' width by the design of the machines on which they are produced. The manufacturer would, in general, welcome an opportunity to sell his material in larger pieces or sections as being a more efficient procedure, provided he was sure what sizes and what combinations of materials were needed.

Our company has 21 plants producing building materials. It is obvious that to change over the equipment in these plants to larger sizes or different thicknesses, or to adapt it to laminating or assembly operations, would require a tremendous investment. A number of problems arise immediately. Is the material in question too heavy to be handled in large sheets? Is it too fragile? Can it be handled in large sheets? These, and a variety of other questions, must be satisfactorily resolved before a basic change in manufacturing procedure can be adopted. Another question is where the preassembly is going to take place. If the place is the manufacturer's plant where he already has equipment, facilities, and manpower, the fabrication problem is simpler, but the delivery problem may become insurmountable. Unless the manufacturer is so fortunately situated as to have a large number of plants uniformly distributed through his market, it may prove that local assembly plants to serve individual market areas will be a more acceptable long-range solution. In such a case, the type of material to be produced may well be different, if only because of the necessity for multiple handling.

A second major technical problem is that the materials manufactured for prefabrication into components must fit into a pre-established system. Furthermore, this system must provide reasonable variety and flexibility in order to serve the individual desires of the builder, the architect, and the ultimate consumer. As a further complication, the desires of our customers vary considerably from one geographical area to another. A basic material suitable for prefabrication into an acceptable component system in New England may not be at all acceptable in California or in Florida.

## The Development Program

After we have studied the ideas and technical requirements of our customers, and after we have reviewed the possibilities and limitations of our materials and processes, certain general conclusions begin to emerge. Perhaps the most important conclusion is that no one type of material can be made to serve the over-all purpose. There is a temptation for the metals manufacturer to stress the use of metals in the house, or for the plastics manufacturer to stress the use of plastics, or for the asbestos-cement manufacturer to stress the use of asbestos-cement. As a matter of fact, our company undertook to design houses of asbestos-cement shortly before the last war, and did, in fact, erect quite a number.

There is, of course, no single ideal building material. The house of the future will use a wide variety of materials, and our problem is to find the materials that best serve a specific function in the house. Our second basic assumption is that the market is not ready for a standardized system of components of uniform size, appearance, and construction, even in limited areas. Therefore, any component system, to be acceptable, must be subject to modification in design at the desire of the architect or owner, and should be capable of modification on the site by the workmen with readily available on-site tools.

It appears, therefore, that a plan for the development of prefabricated components should probably have three separate stages:

> Stage One would be the development of a component which will, in most respects, resemble the materials of construction currently used. Preferably, it should be such that it can be cut with hand saws or power saws, and fastened, if necessary, with conventional nails or screws. If adhesive fastening on the job is required, it should accept currently available adhesives which can be applied by the ordinary skilled carpenter. It will probably have to be limited to a 4' width if the materials employed are not to be unduly restricted. It should be light enough that it can be set in place by two men without the necessity for elaborate power lifting equipment. It should be so designed that the interior and exterior finishes can be of a familiar type. In other words, this component system should be sufficiently retiring in nature so that when the house is finished, the casual observer may not even know that it was built from prefabricated sections.
>
> Stage Two will probably call for a more sophisticated type of panel. We may assume, for this panel, that thinner sections can be used than in Stage One because, by this time, door and window frames, and plumbing, waste, and vent pipes will have been reduced in size to accommodate the thinner panel. Being a thinner panel, it will have to have a more sophisticated stiffening system, which may well be molded or otherwise fabricated into the facing material at the time of manufacture. By the same token, the fastening or assembly system can probably also be expected to be more

sophisticated as more complex shapes are produced. By this time, it is also reasonable to suppose that materials will be produced in larger sizes, so that this thin, stiff panel will still be produceable in large sections. It is quite conceivable that this more sophisticated panel may also be produced in shapes other than flat in order to provide greater stiffness and greater span. By the time we have reached Stage Two, it is reasonable to suppose that some of the obstacles which now make prefabrication of plumbing and electrical services difficult will have been overcome. The planning of this more sophisticated component should, therefore, include means for heating, lighting, and electrical and plumbing services.

Stage Three we can conceive as the long-heralded industrialized house. This will obviously require the collaboration of several manufacturers, because services of various types will have to be introduced at the time of manufacture. Very probably, by this time, our knowledge of materials and processes will permit us to create large, lightweight sections which can be rapidly job-assembled into a variety of useful and interesting shapes and designs. Since the desire of the average home owner for additional facilities in his home increases year by year, we may also assume that the industrialized house will have to provide a degree of environmental control and a variety of living conveniences which today we probably cannot even conceive.

## The Design of a Preassembled Component for Stage One

While we are studying the technological developments which will permit us to achieve Stages Two and Three, we must at the same time direct our energies toward the job of providing the component which we concurrently produce for Stage One. What are the changes in the physical properties of our materials which we must provide in order to meet the requirements of this first relatively primitive component system? First, materials which are to be preassembled into some sort of a prefabricated unit will be more susceptible to damage in shipment, in handling and in erection.

Preassembled units are likely to be heavier, more awkward to handle, and more susceptible to impact damage. This means that the materials selected for such preassembly will have to be more tough, more durable, and more resistant to mechanical impact. If they are to be handled by local fabrication plants away from the point of original manufacture, they should be capable of being worked and assembled with relatively simple mechanical tools or power equipment, and should be such that mechanical assembly is straightforward. Let us take two simple examples. Lumber in its various forms is ideal for preassembly purposes because it can be readily changed in shape, nailed, fastened or glued. A material like glass tends to fall at the opposite extreme as being inherently subject to impact damage and difficult to work, fasten or adhere. The manufacturer inevitably turns to those raw materials and those finished products which are most conveniently worked and shipped.

Preassembly often implies prefinishing of the structural unit, even though this may mean no more than a prime coat of paint. It, therefore, becomes more important that the material used for the surfaces be smooth, hard, and easily paintable. By the same token, patching or touching up must be readily possible because of the inevitability of some damage during shipping and erection. Finally, any prefabricated system implies some practical method of field assembly and some means of sealing or protecting the joints which will occur. The selection of the materials used for preassembly, therefore, involves consideration of these field assembly factors as well.

For example, the coefficient of expansion and contraction of the materials should be as low as possible. If a combination of materials, such as a sandwich panel, is the choice of the component in question, changes in temperature or moisture content should not produce bowing or warping. If adhesives are to be used for erection or for making joints, the suitability of the surfaces or edges for receiving the adhesive bond becomes a vital consideration, as does the interlaminar strength of the material bonded. Finally, the adhesives or caulking compounds themselves become essential elements in the materials list.

If a reasonable degree of flexibility is to be maintained in the design of the preassembled unit, it will probably be necessary to cut or fit the unit on the job under certain circumstances. It, therefore, becomes desirable to make a unit which is uniform in cross-section throughout its area, or else so designed that it can be reworked on the job to achieve the same effect. For example, a factory finish which cannot be readily reproduced in the field presents a technical hazard. A panel design which employs edge framing may impose undue rigidity upon the ultimate design.

## The Testing and Evaluation of a Component System

There are two types of evaluation which the manufacturer must apply to a component system; the first is technical evaluation and the second is market evaluation. In the laboratory, the component must be subjected to a variety of physical and structural tests. For example, if it is an exterior wall panel, which is probably the first logical choice for a component development, it must be tested for structural strength in column loading, for flexural strength to provide wind resistance, and for racking strength. All these tests should be made on a series of panels assembled in the fashion which is proposed on the job. In other words, the assembly system must be tested along with the component itself.

In addition to structural tests, the panel and the system must be examined to determine their coefficients of expansion and contraction with moisture and with temperature. It may be noted parenthetically that this coefficient should certainly not be more than that of wood and ought to be appreciably less, if possible. It should also be noted that if the panel is made up of several materials glued or fastened together, it should be symmetrical in construction if possible; or if not, provision should be made to take care of the varying stresses which occur on the two sides of the panel.

The panel and the system should also be tested for sound transmission, heat transmission, and vapor transmission. In the latter case, both the interior and the exterior surfaces should be checked for permeability with the joints treated and finished in a manner typical of the final construction.

We have found, in our own laboratory tests, that the most difficult part of this evaluation is to predict the performance of the panel assembly. For example, it is possible to seal the joint by caulking with either an elastic sealing compound or a strong rigid compound. In our own case, in order to evaluate the various caulking adhesives proposed, we constructed a rigid angle-iron frame within which two panels could be mounted with a typical joint between. The outside edges of the panels were rigidly secured to the angle-iron frame. The whole structure was then cycled between 10% and 90% humidity until evidences of failure were observed. An entire run of test wall was then built by typical field construction procedure and the total expansion and contraction in length, width and thickness was observed, as well as any tendency for local cracking or distortion.

In this same test wall, openings were provided for conventional prehung doors and windows. Any difficulties in installation were observed and corrected, and the performance of the doors and windows was also observed during the weathering cycles to make sure that there was no binding or sticking.

At the same time, the proposed method of construction and erection was discussed with selected builders and architects, and with the people responsible for code approval. As might be expected, a number of helpful suggestions were received and were incorporated in the proposed panel system. It is our belief that only by a constant interchange of this type of information with the research and development engineers can a practical system be evolved.

In summary, the building materials manufacturer would like to play his appropriate role in the development of preassembled components. Much of the technical data necessary to design and build these components is already at hand, and the techniques for evaluation of new materials and assemblies are certainly available. The principal need is accurate guidance as to the probable market requirements. Our company is making certain market trials in the hope of determining what sort of system is likely to receive the best acceptance. We do not know yet what our appropriate place is in the over-all picture, but we are sure that we can make a constructive contribution. Group discussions of this type can certainly accomplish much toward crystallizing the market requirements and thereby establish the manufacturer's research objectives more clearly.

# Dimensional Relationships of Preassembled Components

By Byron C. Bloomfield,* Executive Director
Modular Building Standards Association

This paper has been prepared to aid the architect or designer to understand the principles used by manufacturers in sizing building products, and to aid producers in gaining insight into how architects and home builders plan their buildings to utilize dimensional products.

Architects today must select materials and components for their buildings from among 20,000 to 30,000 choices, not counting variations in size, color or finish. Likewise, producers manufacturing only one, or a few, specific products comprise the dominant group from which products are made available to the building industry. Building product items from this group of producers reflect a creditable measure of economic value because of greatly refined efficiencies in production techniques and distribution methods. If products from these producers can be installed in an orderly, predetermined manner with a minimum of cutting and fitting which, in turn, reduces the total installed cost to a minimum, one of the principal objectives of building technology has been achieved.

Based upon this premise, the building industry adopted a basic module to be used in sizing all dimensional building products and materials. Consensus was achieved in 1945 after several years of deliberations and published in the form of American Standard A62.1. The basic module of 4" was therein adopted with the principles of sizing identified in Figure 1 as repeating elements and isolated components. Adoption of the base module paved the way for increased efficiencies when products from many different manufacturers were combined in one building. Simply stated, cutting could be minimized and waste reduced accordingly. Also, installation time could be reduced.

Adoption of the base module also opened the door for feasible introduction of the "component" or "panel" concept. First attempts at panelized construction were usually initiated because of design motivation, rather than economic justification on the basis of reduced installed costs. Genuine motivation for component construction is generated, however, when the analysis of a completed building project reveals it has fulfilled all design requirements, yet has cost less than if the same requirements had been satisfied by traditional construction methods.

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*BLOOMFIELD, BYRON C., Member, American Institute of Architects, Building Research Institute, Construction Specifications Institute; B. S. in architectural engineering, Iowa State University, B. S. in civil engineering (same); M. S. in building engineering and construction, Massachusetts Institute of Technology; formerly associated with Dept. of Education and Research, AIA.

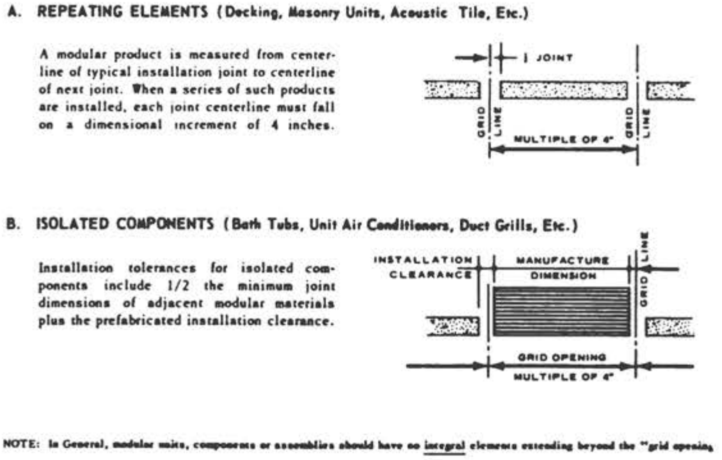


Fig. 1. Modular building product dimensional characteristics

## Modular Design Principles

Optimum conditions for planning buildings for construction from components are established when it is recognized that industry can most efficiently manufacture products with definite dimensional characteristics. Planning for use of such materials must be based on the jointing and installation characteristics of components and equipment.

Figure 2 illustrates the modular jointing principle. Three drawings are shown illustrating the principle of joining two different modular materials. Material A would be a material or component produced in any multiple of 4" with sufficient manufactured tolerance and joint clearance to enable installation without cutting. The same is true of material B. Different modular materials will ordinarily have different joint thickness requirements, but they all have the common characteristic that one-half the manufactured joint tolerance at either end is sufficient clearance for installation.

The lower sketch indicates the method of joining two dissimilar modular materials or components. Material A could be a door frame assembly, and material B could be masonry or, material A could be a window assembly and material B could be an exterior panel with a third material, C, being a door unit. This same methodology applies to all parts of the structure and indicates the principle of planning for modular materials such as bathroom fixtures, wall tile, flooring, ceiling tile, structural framing, sheet materials, electrical control boxes, plumbing, etc. The number of combinations is endless.

## Sizing Building Products

Knowing that architects are planning on the basis of joint-centerline characteristics in multiples of 4", the manufacturer develops his specific products in accordance with the permissible variables shown in Figure 3. This illustration was developed by Prof. Stanley R. Kent of the University of Toronto, Department of Architecture. He is also in charge of the Canadian Modular Program of the National Research Council of Canada. The conditions shown are for the purpose of establishing the "manufacture dimension" of building products. To the architect, the variables normally become a matter of specification with only the grid dimensions identified on the working drawings.

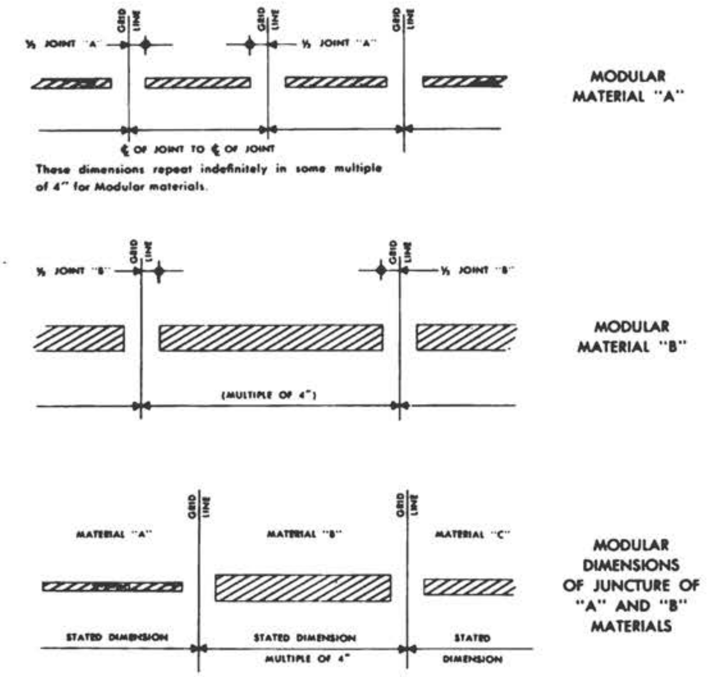


Fig. 2. Joining of two different modular materials.

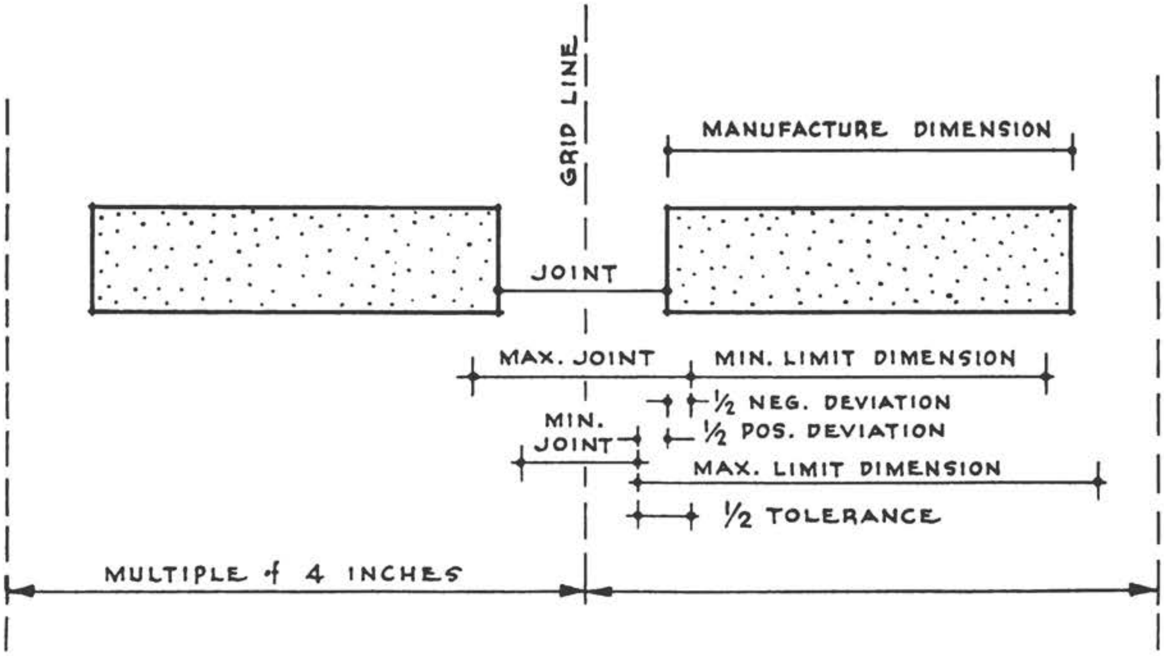


Fig. 3. Note drafting convention designating dimensions to the grid line with an arrowhead and to the off-grid point with a dot.

## Planning For Components

The floor plan of the 1958 NAHB Research House (Fig. 4) illustrates a fairly typical approach to planning for relatively large components. A 4' planning grid was used to establish exterior and roof panel locations. Interior partitions and equipment were then developed on the basis of 4" flexibility afforded by the basic module. In housing, the 4' planning module was originally used because of the large number of sheet materials available in that size at the time of the housing industries' first panelization efforts.

We will probably now see additional sizes of sheet materials produced. Most logical would be 5' widths which could also be cut into 2' and 3' sections, giving economic multiples for completed panels of 2', 3', 4', and 5' widths. At the present time, 4' sheet materials efficiently yield 16", 24" and 32", as well as 12" multiples, and can provide additional multiples of 4" increments when needed. Practically all manufactured homes are presently fabricated on a 4" module basis.

Home builders fabricating their own components are often concerned with what they term the "inside module" or "outside module." Both alternatives possess certain advantages and disadvantages which must be weighed by the designer. Use of the exterior module generally simplifies sheathing, roof truss or panel spacing, and may simplify flooring assemblies, whereas using the interior planning module leaves the interior space free to incorporate modular partitions and equipment more readily.

The use of planning grids for commercial structures is generally handled in a different manner by architects. They first work out the plan requirements and establish the planning module best suited to the specific needs of the building. For an office building, this might be 6'-4", 5'-0", 4'-8", or any other multiple of 4". The grid is not necessarily a square, as in the Time-Life Building, which used a 4'-0" x 4'-4" planning module. An apparent deviation from the 4" increment was used by Skidmore, Owings and Merrill in their Inland Steel and Reynolds Aluminum Buildings—both using a 5'-2" planning module generated by using 2" parting strips between every 5'-0" increment, thus accommodating modular materials between the strips.

## Ranges of Preferred Sizes

The concept of ranges of preferred sizes for panels and components has been pursued with varying degrees of intensity throughout the world. In effect, we do have definite ranges of preferred product sizes in existance in the United States right now. The sizes for stock production are determined by a natural selection process resulting from marketability studies. Marketability, in turn, is based on the preferences of users such as home builders, architects, or designers.

## Complete Component Systems

Most manufacturers contemplating expansion of their production lines to include additional building elements usually recognize the inherent difficulties of trying to produce every building item more efficiently than any competitive producer, or developing a system that does not appear "stereotyped" in appearance, does not inhibit the designer in his resolution of functional requirements, and is compatible with a variety of choices of mechanical and electrical equipment. Quite often these considerations are sufficient to justify the manufacturer's decision to restrict his production to only those building items in which he has already developed unique production skills and techniques. This may mean that some producers will concentrate solely on panel fabrication, incorporating the products of other manufacturers wherever possible. In so doing, these fabricators are almost certain to produce their panels in sizes compatible with the wide spectrum of materials already demonstrated to have market appeal.

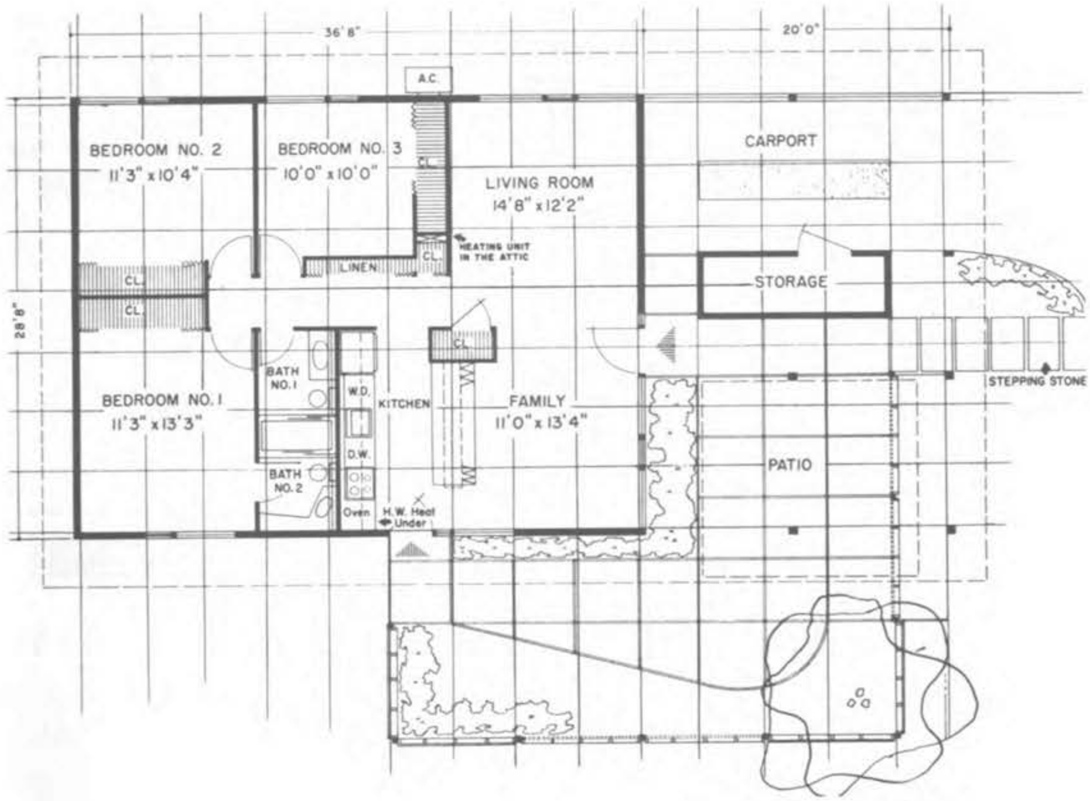


Figure 4

The panel fabricator has two principal conditions to resolve because of dimensional considerations which occur in wall panels. Modular panels need not be a multiple of 4" in thickness. When turning corners on either exterior or interior panels, the thickness becomes a major consideration. If the product is to be used as a complete system, the manufacturer must supply components to resolve these two conditions.

Exterior panels require study of the structural elements, particularly columns. Figure 5 shows various solutions to the column intersection problem. The first two alternatives allow the panels to by-pass the structure, with the panels outside of the columns. The two center examples involve dimensional considerations of the column itself and require study of the jointing conditions. The last two examples allow the panels to by-pass the structure on the inside.

Of all of the variables reflected in the manner in which different architects use materials and components, Figure 6 is probably the most typical of the manner in which dimensional products are used by architects. It shows a portion of the working drawings of a school project by Smith, Tarapata and McMahon of Detroit, and includes two types of windows and a door. The number of producers involved in this installation could be as many as a dozen, or only one. If one manufacturer supplied the combined unit, he would be concerned

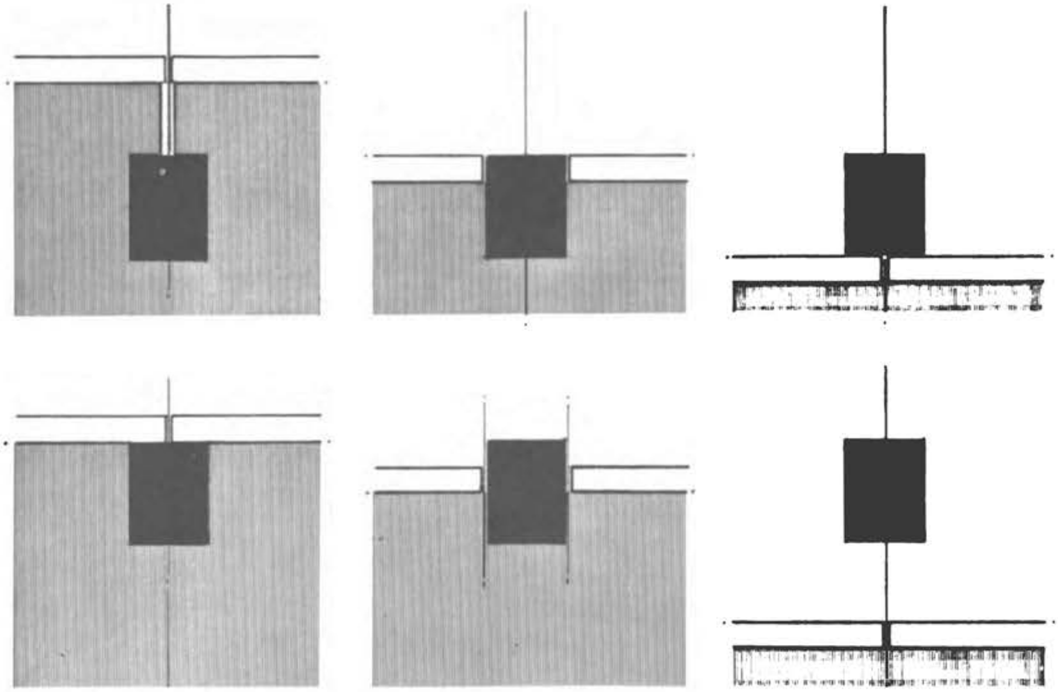

Figure 5

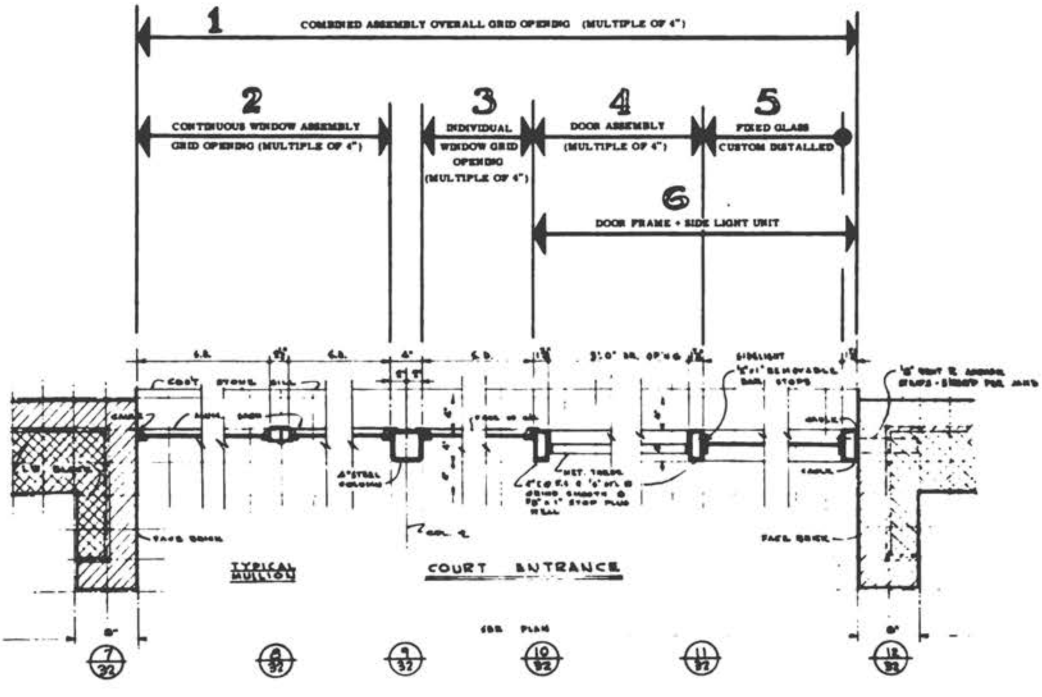


Figure 6

with the over-all modular "grid opening" of the entire assembly. If he supplied only one item such as the door, he would be concerned only with the grid dimensions of his particular unit.

To quote a statement credited to Richard Pollman during the planning of this conference, "It's not the blanks that give us the trouble—it's the holes!" Therefore, if the manufacturers of "holes" will concentrate on marketing them in modular sizes, and the manufacturers of "blanks" will continue to simplify their production, we may be assured that architects and home builders will be planning their buildings on "imaginary" grid reference planes, with the result that buildings will continue to be better and better, and cost less and less.

# Open Forum Discussion

Moderator - Rudard A. Jones, Research Prof. of Architecture and Director
Small Homes Council - Building Research Council
University of Illinois

Panel Members - Messrs. Bloomfield, Boeke, Dietz, Parkinson, Schmitt, Worth

C. R. Humphries, Minnesota Mining & Mfg. Co.: Can copies of the occurrence curves and the cost-minimizing plot be obtained? How may a copy of the report on your project be obtained?

Mr. Dietz: At the moment, the report is still in very rough form. I have provided a few extra copies of this paper to the BRI headquarters and more of them could be made available. The final report on the project will go to the NAHB presumably at its annual meeting in January 1961. I suppose the NAHB will have plans to make it available.

E. Tarnell, Roger Williams, Inc.: Can you elaborate on the type materials used for the facings and core of the panels you discussed?

John McIntosh, Neal-Blun Co.: What was the makeup, material-wise, of the panels in your test house: interior, insulation, exterior?

Mr. Parkinson: I deliberately avoided describing the material directly. This is an experimental material which we do not have on the market, but which was developed partly with this application in mind, to give it greater strength and durability. It's a synthetic wood fiberboard product. Beyond that, I am not free to talk about it.

N. B. Broder, Standard Building Products: Assuming great advances in adhesive research and production, please give your thinking regarding relative production costs (time, labor, material) between your present method of truss production and what you can foresee in the return of the glue-nail process, with particular emphasis on drying time and handling.

Mr. Worth: Unless the present requirement of the 24-hour hold period for glue-nail trusses is overcome, there is no future, in my opinion, for the glue-nailed truss in the prefabricated house industry. With this 24-hour hold period, we would have a perpetual inventory ranging anywhere from 2000 to 5000 trusses on hand at all times. These are large, bulky and expensive assemblies.

I didn't mean to imply that it was the glue-nailed truss that was going to come back, but rather the all-glued truss. I think the next improvement has to be in the elimination of mechanical fasteners completely, and this elimination is contingent upon the necessary adhesives that will operate in the jig in a time somewhere in the range of 2 to 3 minutes. With the wide variety of truss types that must be built today, it is not economically feasible to provide multiple jigs for each truss type. Therefore, this means a rapid turnover, rapid jig time, and all of these become problems that the adhesive has to solve if it is to recover that market.

John Shope, National Lumber Mfrs. Assn.: Do component manufacturers prefer 16" or 24" stud spacing? Why?

Mr. Schmitt: I am not a component manufacturer in an authoritative sense. My experience is purely personal. I think there is no structural reason for a 16" center. I happen to use a 16" center in my exterior walls for one reason only, and that is that, with the sheathing that I use, (3/8" plywood) there are some siding materials that will show a waviness if I don't use a 16" center. Structurally, I don't think anyone really feels that we need spacing any closer than 24".

Mr. Boeke: Since I am a sales manager, naturally I like to see 16" on centers, but I would agree with Mr. Schmitt that from a competitive standpoint 24" on centers makes lots more sense.

John Odegaard, Kingsberry Homes Corp.: How can the on-site damage problem be licked when prefinished interior surfaces are used?

Mr. Worth: We feel that the necessary resistance has to be available in the substrate material and the finish system itself. We do not feel under any circumstances that it is economically feasible to pad, protect or overlay the finish system to protect it during the transit. We shipped, for many years, a typical wood-base product with the prime coat on only. We attempted to do this with a completely prefinished wood-base product, but we found that the limiting factor was minor damage such as marring and abrasion, not actual major breakage. We also found when we began to promote the metal system that the finish available was of a sufficiently high quality after being baked so that minor abrasions and scuffing were not the problem. You either suffered no damage at all, or you suffered major damage that required replacement of the entire sheet.

Mr. Jones: I would like to call your attention to one of the statements that Mr. Parkinson made in his discussion about the desirability of repairability of some of these surfaces, so that they could be handled in the field. Would you elaborate a little bit more on that, Mr. Parkinson?

Mr. Parkinson: What I was saying is probably fairly obvious. I would agree with Mr. Worth that the problem you run into is usually minor scuffing or damage. Our thinking would be that, for instance, on an interior panel the prime coat could be applied, but you would want to put on the finish coat on the job. Unless you have an extremely hard or durable material, there is likely to be some serious gouging. It was our conclusion, largely on a theoretical basis, that if possible we ought to come up with a material which could be repaired even though the gouging might be fairly serious. Perhaps we are being a little idealistic about this. I think, however, that fundamentally this is probably a sound conclusion.

Al Lalonde, O'Connor Homes, Inc.: To what extent are you presently using component building methods in your own operation?

Mr. Schmitt: I am using trusses, window and door panels and gable ends. I am using whole wall sections in more repetitive houses, and plumbing components involving water systems, drainage systems and gas piping systems. Of course, there are many things we've been using for years that we don't presently call components, but which are in reality components, such as windows and doors or door assemblies, prehung doors, kitchen cabinets, etc. There is an application of the term "component" that I like to use which is not a physical thing, but rather a design component. I like to define a component as an organized, repetitive system of thinking that applies to some part of the over-all product. Sometimes this is equally important, both in a direct and indirect sense, to a physical component.

Walter H. Lewis, University of Illinois: Are you satisfied with the "visual environment" resulting today from houses built with components? If you are not satisfied, how do you believe houses built with components in the future can improve the visual environment?

Mr. Worth: Let's start by saying that I don't think there is any doubt that variety of appearance and individual taste, to some degree, are mutually contradictory with mass building. The problem today, I think, is not whether the house is built with components or whether it is built conventionally, piece by piece. It's a question of whether or not it is part of a mass-built project. Our own efforts to control this thing wax and wane according to the market conditions. An analogy is often drawn between the automobile industry and the home building industry in which proponents say if the automobile industry can dictate to you, the consumer, the style of the automobile that you must buy, then why can't the home building industry dictate to the consumer the style, architectural appearance and color of the home he buys. I think there is a fallacy here, and it's simply one of supply and demand. You have no choice in the automobile industry; if you want your automobile to look like a 1932 Essex, you have it custom-built at tremendous cost, or you don't get it at all. On the other hand, if you want your house to look like a log cabin, there are thousands of builders across the country, including at the moment ourselves, who would be delighted to build it for you. I think that this is the basic thing—taste is still being exercised in home buying. For the minimum house, for shelter alone, the consumer is willing to overlook to some degree his own personal preferences, in order to get floor space at minimum cost.

Mr. Jones: This is really a tough question. I might say that I think in some respects educators can take the blame here, because I feel that we have to educate the people to have proper taste. I want especially to emphasize the point that I don't think this problem of the appearance of a development is related to whether the houses are built with a component system, a prefab system, or constructed individually. The appearance can be good or bad, with any of these systems.

Mr. Schmitt: I don't think there is any relationship between the use of components and the appearance of homes. In the old days, before the word "prefabrication" of component buildings was known, there were more sins committed against the appearance of a house than today. What has happened today, coincidentally with prefabricated and mass-produced homes, has been the advent of mass housing in large developments. The failure hasn't been in the house or in the use of components, but in the design of the house, and more important, in the design of the total picture—the subdivision. It's entirely possible to build identical houses and, with subtle attention to subdivision appearance, to landscape it. The really economical factors, color, texture, combined with very superficial change, completely obliterate the look-alike appearance that I think was in this man's mind when he asked the question. I know it's possible to build a whole street of identical houses and get utter amazement from people when they are told that each of these houses is from an identical plan. We are associating two things that are not at all related.

Arthur Tisch, Independent Nail & Packing Co.: What progress has been made to produce and erect a LuReCo panel with both interior and exterior skins shop applied?

Mr. Boeke: To my knowledge, there hasn't been too much done in that field. I know, in our own case, we have not gone to the extent of an interior finish application. A good bit of that stems from the experience of our builders in comparing the package we provide without the interior finish applied to those of home manufacturers who do provide an interior finish on the panel. The main thing our builders are interested in is the total over-all cost; not whether they have more on-site labor or less, but whether the total cost is less. A good many of our builders maintain that they can apply the interior finish, and finish it out as economically over-all, as they can by buying the package with those elements included. To my knowledge, there hasn't been too much progress in that field by most LuReCo dealers.

H. B. Aiks, Owens-Corning Fiberglas Co.: Please comment on the technological advances required to achieve widespread acceptance of foam cored panels in residential construction.

Mr. Worth: In line with Mr. Baseler's comment on how building codes influence a new product, I am sure that this is one of the places to start. I feel what is really going to be necessary is a long-range program of public education conducted both at the consumer level and at the level of the building officials. I don't see any insurmountable problems in the plastic foam panels but, nevertheless, really widespread acceptance will have to come about through education. The public itself has to be educated to the desirability of these features. The public generally, according to the builder's outlook, has very little interest in the "nuts and bolts" of house building. The consumer rarely knows, after he has bought the house, whether he has No. 1 lumber for studs or No. 3. This is unfortunate, I believe, because it tends to exaggerate those parts of the house that are apparent and play down those parts that are hidden. This applies to sandwich panels, too, inasmuch as the sandwich construction is to a large degree hidden from the consumer. Therefore, I think he has to be educated, made aware of this advantage and, to some degree, even presold on this material as an economical way to build houses, not just as a construction novelty.

C. R. Humphries, Minnesota Mining & Mfg. Co.: The discussion of principles has not included increased fire resistance or fireproofness of homes. Is this a factor in considering selection of materials and procedures?

Mr. Jones: I know that this is of great concern to those who are working with new materials, such as foam sandwich panels, etc. On the other hand, I think that I am safe in saying that most building codes do not specify any given fire resistance ratings for any parts of the house. We rely more upon other specifications, such as exits, etc., to take care of this as far as the individual house is concerned. I think there is a lot of room for the question, and a lot of room for some better answers here.

Mr. Parkinson: Looking at it from the perfectly cold-blooded standpoint of market evaluation, the fireproofness of the materials used is not particularly critical, as far as we can tell, in the minds of the builders or the customers. I think I should add, though, that wood in its various forms is a better fireproofing material than it is often given credit for being. Wood does burn, but it does not ignite quickly and does not flash off the way some materials do. Our feeling has been, right along, that where possible we should come up with materials that were fireproof, or at least no less fireproof than wood structures.

Mr. Jones: In other words, we still use the standard conventional frame construction more or less as the base point in this design field. I have the feeling that this is the case in general. Mr. Worth, do you get into this at all?

Mr. Worth: Only to a certain degree. As a personal opinion, it appears to me that flame spread should be the most important criteria in new building products, rather than fire separation. In a single-story frame house, insurance statistics seem to indicate that fire separation is not an important feature, because people do not live with all the doors in the house closed and, in addition to that, the heating and other systems form a means of transferring fire throughout the house. What seems to be more important is isolating the fire initially, with a low flame spread rating.

Mr. Jones: Mr. Dietz, I'd like for you to comment on this, if you would.

Mr. Dietz: I believe the factor of flame spread is too often overlooked. This can be a much more important factor than the question of having material that will isolate the flame. Certainly, fire statistics seem to indicate that a great many fatalities are caused merely because the flames spread so fast throughout the house that people can't get out. The damage is done long before there is any particular structural damage to the house itself.

Mr. Jones: This is certainly true. Fire tests conducted by the Division of Building Research, NRC of Canada, in their houses along the St. Lawrence Seaway certainly illustrated that. The problem in most residential construction is to be able to get out of the house in time.

Mr. Parkinson: When we are talking component construction, we have a new factor to consider. The materials themselves, and their finishes, may be acceptable, but the method of assembly should also be examined from the standpoint of fire resistance. We are used to building houses held together with steel and entirely impervious, at least for a while, to the effect of a fire, but if we are going to depend on glues and adhesives, we should take a good, hard look at what flames, or even high temperatures, will do to them and how fast their performance will deteriorate.

Bernard Kohn, Architect, Balsa Ecuador Lumber Corp.: Much of the discussion deals with component systems copying or following traditional designs. Could we not carefully research the possibility of completely different forms arising from the existence of component and preassembly principles, instead of slavishly trying to adapt to tradition? Could not BRI and its members establish a body of architects, builders and engineers with the view of designing wholly new structures based on the components and their possibilities? This would serve as a focus to the industry—a rallying point which would lead to a modular coordination of different manufactured products.

Mr. Jones: There have been some studies done, particularly one at M.I.T., I believe, on a plastic house which departs completely from traditional forms. I would go back to our basic problem here being very much what Mr. Worth pointed out in connection with the foam sandwich, and that is the 400-odd building codes in the country. It's an almost insurmountable project to start out with a completely free, unlimited, design type of operation. I think this possibly could be done by someone from BRI, but then I think we would also immediately get into the problem of whose material we were going to use, etc. This would be difficult, but it is a very challenging thing. If someone should come along and say, "You have no limitations—we want to provide mass housing at very reduced costs. What can you do?" This, of course, would mean that most of us would have to stop and think quite seriously, because we are tied so much to our tradition. I can remember when National Homes, in the early stages, had a completely glued operation with 2" x 3" studs. I think you fought that battle until you got tired, didn't you, Mr. Worth, and came back to the 2" x 4"?

Mr. Worth: We did indeed fight the battle for many years and, in my own opinion, we were over the hump, so to speak, as far as acceptance of the system by building codes and the public in general. The one group that we had not been able to convince, because we had not directed our major efforts towards them, was the conventional builder. These are our customers, and in any expansion of our dealer organization we must draw from the ranks of the conventional builders. Here, we ran into a large group of people whom it was very difficult to convince because of their own experience and traditions, and also because of the lack of time and personnel on our part to carry this argument to every single builder in the country who might be a potential customer of ours. I really don't think that idea was killed by building codes. I actually believe that we were over the hump on that completely.

Mr. Dietz: Speaking from a theoretical standpoint, I agree that it might be highly desirable to stand back and take a brand new, fresh look at what could be done with design, utilizing components to their ultimate with many materials. I am convinced that new forms, new structural shapes, would be much more economical than what we do today with the flat surfaces that we use. There is no question whatsoever; it has been demonstrated that with shell construction that you can get tremendous strength, long spans with very thin structures, for example. And, with some of the new materials, you don't need great thickness, anyhow, from the insulating standpoint. I believe that the other factors, such as were brought out here, which would severely limit that sort of thing—building codes, public acceptance, all of these things—would make it a very difficult project to put across. I must say, again from a theoretical standpoint, that I think it is intriguing. I would like to see it done.

R. S. Cook, Virginia Metal Products, Inc.: Do you think a satisfactory line of homes could be designed using only vertical-patterned and plain-surfaced panels for the opaque areas, that is, without having any horizontal-patterned siding or panels?

Mr. Worth: Within an individual home, yes; within a subdivision, no. This relates back, to some degree, to the question that Mr. Lewis asked, and maybe I answered that too facetiously. It is necessary that variety be offered to the home buyer. Among our own builders, and among other conventional builders, I've heard the constant comment that the vertical-patterned materials are the most economical and the most popular because of the ease of making the joints between individual panels. However, there is no question that we and every other builder should, whether we wish to or not, offer horizontal-patterned materials in contrast with the vertical pattern, and here the jointing problem becomes much more difficult. Some of the economies are necessarily lost in the process of switching to a horizontal-patterned material.

# STRUCTURAL COMPONENT CASE STUDIES

Session Chairman - John M. King
Director, Research Services
National Association of Home Builders

# Preassembled Components in a Large Commercial Project

By Thomas J. Hodgson,* Director, Laboratory Division
The H. K. Ferguson Company

The use of preassembled components in the field of commercial and industrial design and building has paralleled very closely the economic and scientific progress of our country.

During the period from the end of World War I to the mid-30's the use of basic preassembled components was mainly confined to industrial work. This was the period of the standard industrial building. As shown by Figure 1, an example of this type was the butterfly monitor building with 50' x 20' bays, steel frame, steel sash, wood deck, and masonry sill walls. The design work consisted of locating the building on the site and arranging the standard bays to fit the required area. Construction consisted of pouring footings and slab, erection of the fabricated structural steel, steel sash, roof deck and masonry sill walls. Construction time was approximately 60 days after steel delivery and the cost was around $2.00 per sq. ft. The drawbacks of these standard buildings were poor lighting and ventilation, and fixed bay sizes. There have been very few, if any, buildings of this type built in the past 20 years. They were eliminated through the development of more advanced preassembled components including long span joists, combined roof heating and ventilating units, and fluorescent lighting. Time study and flow-of-material patterns also hastened the end of standardized buildings. Design layouts dictated the building to accommodate the process and equipment, rather than the equipment to fit the building.

Today's commercial and industrial buildings are designed as the requirements dictate, whether they are shopping centers, office buildings, industrial plants or nuclear reactors. To do this and still stay within reasonable economic limits, in terms of time and money, it is necessary to take advantage of every preassembled component that can logically be incorporated in the structure.

As examples of this approach, I have selected three entirely different types of projects for review. The first of these will show the use of basic preassembled components in a structure which would not normally be considered one in which these components would be required or used.

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*HODGSON, THOMAS J., B. S. in architecture, University of Michigan; Registered Architect in 13 States; has been with his present company since 1937. Aloysius Schuszler, Chief, Specifications Division, H. K. Ferguson Co., made the oral presentation on the Conference program, and served as panel member for the discussion.

Figure 1

Figure 2

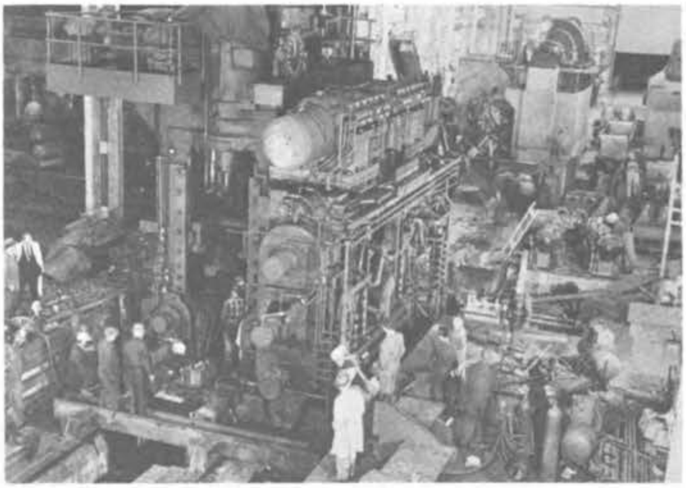


Figure 3

The project, as shown in Figure 2, is a livestock feed mill located in Iowa. The structure consists of a warehouse, a 78' high processing tower, storage silos, head houses and unloading facilities. The work was started in September and the plant was in operation the following May. In order to meet the completion date, it was necessary to have the structure ready in time to receive and set the equipment. Consequently, the work was planned to be continued through the winter.

The warehouse was constructed of steel rigid frame with precast reinforced concrete walls and a corrugated metal and plastic panel roof deck. The precast panels were cast while the foundations were being poured and were erected as soon as the steel frame was up.

The concrete tower was built by the slip-form method. The work was continuous and completed in 4-1/2 days. Preassembled tanks, conveyor bridges and all-metal head houses were used wherever possible.

Although temperatures reached -28° for a three-week period, the progress of the work was not halted. Preassembled components were the key to the successful and rapid execution of the project.

Engineering ingenuity and gigantic size of preassembled components is demonstrated by the second project selected for study. This project was the expansion of a steel mill in Canada. Two of the items of work of particular interest were the installation of a new 550-ton slabbing mill (Fig. 3) in place of an existing mill and the construction of a new blast furnace.

Six months of exact planning and preparation were required before the actual installation of the new mill began. This mill was completely preassembled on special temporary foundations 54' away from the point of its eventual installation in the exact spot occupied by the old mill. Also prefabricated was a giant "cage" completely equipped with reinforcing steel, principal anchor bolts and ventilation ducts, that was to serve as a form for the new foundation. Thousands of feet of piping and electrical conduit were installed ready for immediate hookup.

With all preparations completed, the old mill was shut down, dismantled and removed in 12 hours. The old foundations were blasted out and the new form "cage" lowered into place. Quick-setting cement was used in the concrete, with samples being taken at regular intervals. On the morning of the 7th day it was ready to support the new mill.

From the point of preassembly, the new mill was moved on polished rails by a hydraulic jack to the new foundation. The big push required 23 hours to cover the 54'. Due to precise engineering the mill was only .0017" out of alignment when it was set in place on the afternoon of the 8th day of operations. The alignment was corrected easily with jacks to make the mill ready for final hookup and trial run during the next three days. On the 12th day, the first ingot was put through the mill.

The construction of the blast furnace was an example of the use of preassembled components on an enormous scale. The furnace is 235' high and 22' in diameter. In addition to the furnace, three 110' high by 25' diameter stoves, a 73' by 24' diameter dust catcher and a 90' high by 16' diameter gas cooler were required for the facility.

Preassembly made this one of the fastest erection operations on record. Using this method, instead of following the customary practice of assembling the furnace stoves in an upright position plate by plate, short circular sections were formed of hand-welded plates in a jig. These short sections, rotated in a horizontal position on a special power-driven roller bed, were then joined into long sections by automatic welding machines. The almost complete unit was raised by cranes and set into position. Some of these preassembled stove sections weighed as much as 187,000 lbs. (Fig. 4) The project required 3,000,000 lbs. of structural steel and miscellaneous iron, 6,000,000 lbs. of steel plate, 10,000 lin. ft. of piping, and 60,000' of conduit.

The third project was selected to show an example of combining an almost entirely preassembled component building with more conventional construction, with the whole still presenting a unified appearance.

This project is a research and development laboratory with 58,500 sq. ft. of floor space. The laboratory consists of a central two-story structure housing the administrative functions, and a central core for services with a research wing on the left and a test and development wing on the right. (Fig. 5)

With the exception of the administrative wing, the general construction of the project consists of reinforced concrete foundations and floors, steel frame, insulated steel deck, brick and concrete block exterior walls with aluminum sash, and steel hollow metal doors. The two wings have a pitched roof with cantilevered overhang serving as a sunshade and covered walk. The soffit is covered with corrugated aluminum sheets, and a door is provided as an exit from each laboratory.

Wherever possible in this wing, preassembled units were used. Metal pan acoustical ceilings in the corridors, hollow metal doors, and frames and metal partitions for the lab offices were specified on the basis of economy and construction speed, as well as low maintenance cost and durability.

Throughout the central service core in back of the administrative section the same components were used. The roof of this section is flat with long span bar joists, supported by a structural steel frame. Other preassembled components were folding fabric room dividers, rolling steel curtains and overhead doors.

The wing on the right houses engine test cells, shops, service areas and shop offices. The construction is similar to that of the research wing.

The two-story administrative section houses general offices, library, conference rooms and similar facilities. The lower level is used for executive parking with a stair to the upper floors. The stair tower provides access for visitors directly up to the lobby.

With the exception of the foundations, the masonry backing for the stair tower and certain interior partitions, this structure is constructed of preassembled components. The floors and roof are lift-slab construction. (Fig. 6) After the foundations were poured 18 pipe columns were erected and the four slabs were formed and poured. The bottom slab remained in place and served as a base for pouring the other three slabs. (Later we added asphalt paving on top of this slab to provide slopes to drains.) In these slabs were incorporated conduit, pipe sleeves, inserts, openings, a cutback for the stair towers, and of course the lifting collars at the columns.

A hydraulic jack was mounted on each column, all jacks being controlled from a central console. The lifting operation of the 280-ton slabs proceeded smoothly, the roof slab

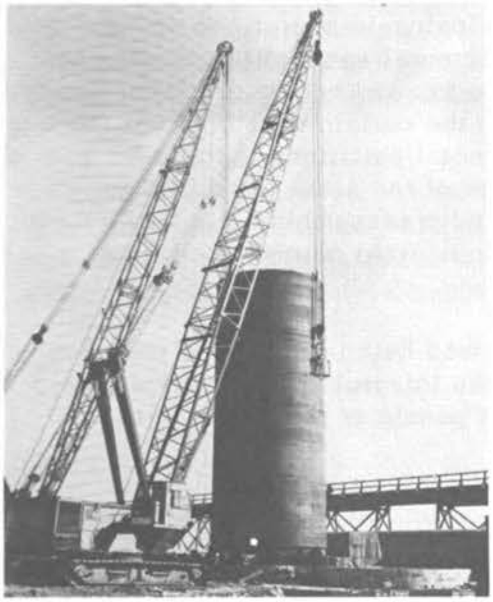
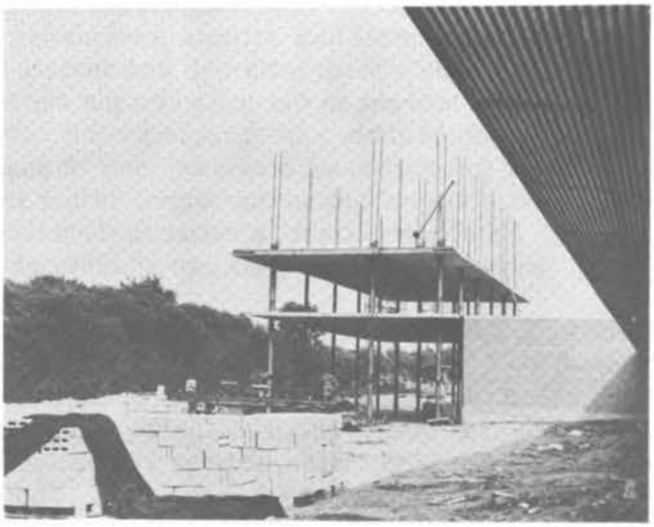


Figure 4

Figure 5

Figure 6



being raised into position and welded at the columns, then the first and second floor slabs raised and welded. With the slabs in position, closing-in operations proceeded rapidly. Aluminum frame curtain walls were used with integral sash units and insulated porcelain enamel panels. Connections were made at the top and bottom of slabs, the curtain wall being entirely free from the columns. With the curtain wall in place, air conditioning ducts and lighting fixtures were hung and metal partitions installed. The work of these trades was simplified by the flat underside of the slabs providing an unbroken working surface. Metal acoustical ceilings and preassembled steel stairs with aluminum railings completed the work with the exception of final painting and floor coverings.

The stair tower was constructed while the interior work was being done. The entrance unit, spandrels and sash frames were preassembled as an integral unit. The stair tower itself was constructed of masonry covered with 2" thick panels of precast granite, a deep red in color.

A 2" expansion joint was provided between the central section in back of the administrative wing and the lift slab structure.

In this project every effort was made to incorporate preassembled units. A general list of the quantities used is as follows: The lift slab required 50 tons of reinforcing steel and 425 yards of concrete. There were 16 tons of long span joists, 3200 sq. ft. of aluminum sash, 50,700 sq. ft. of metal deck, 5400 sq. ft. of curtain wall, and 170 hollow metal doors and frames.

From practically every angle, the preassembled unit offers advantages to the architect, engineer and builder. The architect, through his judgment and experience with the product, knows that it will conform with his design requirements, will perform as the owner rightly expects in terms of service and low maintenance, and will enable the builder to submit an accurate cost of the unit as part of the over-all cost. The engineer, through accurate design data, can select purely structural components to satisfy his load requirement, thus saving much design and drafting time. The builder is benefited by knowing the exact preassembled unit required, and is able not only to estimate his cost accurately, but the relation of installation time to his construction schedule.

The type of subcontract for preassembled components has a definite influence on stock-piling, handling on the job, actual construction and guarantee of the work. A subcontract to furnish and install has definite advantages over the subcontract to furnish material or components only. With a furnish and install subcontract, the material is fabricated in the shop and brought to the job when the material is needed. This avoids stockpiling for any length of time. Erection is by the subcontractor's own forces with less chance of labor or jurisdictional disputes, and is guaranteed after erection, the responsibility resting with the subcontractor alone, rather than with the vendor and the general contractor. This subcontract is particularly advantageous for such items of work as curtain walls, metal roof deck, metal pan acoustical ceilings and interior metal partitions.

Very little, if any, difficulty has been experienced with the quality of the preassembled components used in the buildings which I have described. Selection of the components was based on actual experience as to quality and performance; in the case of components not previously specified, samples were examined, actual installations inspected and standards reviewed. This critical evaluation is of extreme importance in the case of substitutions requested by the builders. Too often in the rush of business, approval of substitution is given without thorough review, with resulting grief to the architect or engineer, builder and owner. To insure a successful job the careful and thorough checking of shop drawings of components is of extreme importance. Nothing is more disheartening than to have a well designed and built piece of work arrive at the job, only to find that it does not fit.

The combination of careful selection of preassembled components (with regard to use, code compliance, economy and maintenance) with proper subcontracting, checking of shop drawings and installation will insure a satisfied client, whether the job is a residence or a commercial complex, built in Maine or California.

# A Metal Building System

By William J. Deegan, Jr.* Chief Engineer - Modular Construction
American Bridge Division, United States Steel Corp.

The development of an all-metal building system is a natural consequence of the increasing scarcity of skilled labor for conventional construction and a practical effort to augment this labor force with modern production methods and tools. Shop production permits optimum use of labor and materials to produce building components of a maximum practical size. This use of larger building segments minimizes field labor and greatly speeds the final completion of normal buildings. The use of steel products in the production of components for a building system meets a majority of the performance standards required of building materials and completed structures.

There is nothing new in this concept; for many years there have been a number of standard all-steel buildings available for use as mill buildings, warehouses, and similar industrial and commercial applications. Generally, these buildings have not possessed the flexibility, quality, or architectural attractiveness required for their use as buildings for more sensitive occupancy.

Many manufacturers produce metal building components which can be used as portions of a metal building system. Few, however, produce all of the parts essential to an integrated design. The selection of these diversified parts by a designer and their use in a project pose a coordination problem which makes it difficult for him to realize the effectiveness of the components or the efficiency of a well-conceived system. Each part must be adapted to its associated components at the expense of speed, performance and/or money, and frequently with the loss of any advantage the metal components may have had over conventional construction.

Since the behavior of an all-metal building is so different from that of a building composed of conventional materials, complete integration of the design and the parts is most essential to its successful performance. The effect of wind and roof loadings, expansion and contraction of the frame and wall systems, vapor penetration of the exterior walls and condensation, heat losses and gains, acoustical properties, and compatibility of materials are all problems substantially different than those experienced in the more conventional buildings.

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*DEEGAN, WILLIAM J., JR. Educated at University of Wisconsin, University of Florida; formerly executive vice president, Structo Schools Corp.; Member, Building Research Institute.

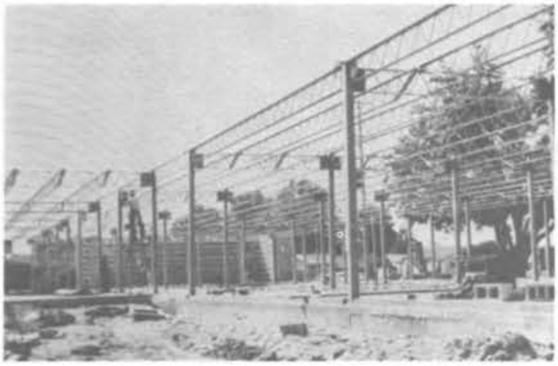

Figure 1

Figure 2

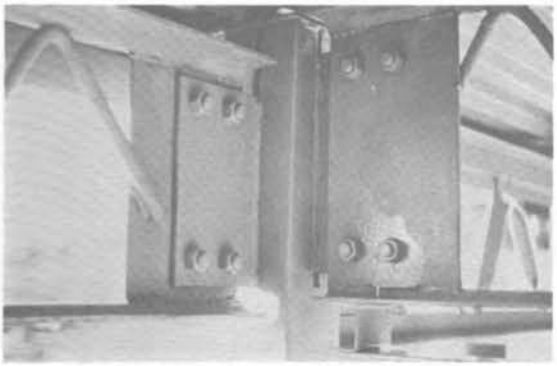

Figure 3

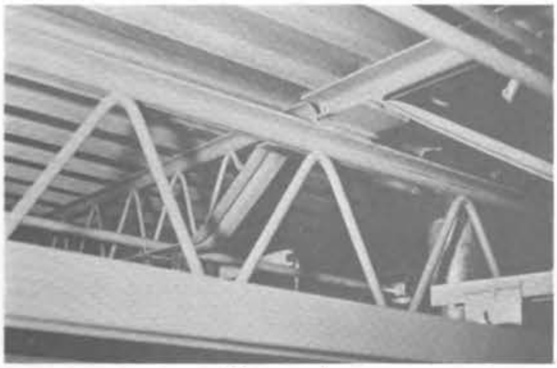

Figure 4

Our organization, in the development of its modular steel building system, has attempted to include all of the major preassembled components necessary to complete integrated structures of many types other than individual housing units. These components have been inter-related in such a manner that the performance of one is compatible with the performance of another, with dissimilar materials when used, and with the building as a whole.

Our modular building system utilizes tubular steel columns with open web or steel trusses, and/or hot rolled light beam sections and standard and longspan open web steel joists. These are assembled to produce an extremely lightweight steel framework similar to that shown in Figure 1.

When used to its maximum advantage, this framing system is most economical in its usage of steel. Structural frames have been designed for single-story buildings (Fig. 2) weighing much less than 4 lbs. per sq. ft. of building area. It is highly desirable, for greatest economy and effectiveness, that these frames be laid out on a uniform module employing the maximum percentage of standard parts. Deviation from the uniform module and pattern in itself can quickly increase the cost of the framing system from 5 to 10% or more. The use of custom or nonstandard parts will likewise increase the framing cost needlessly. The structural frame is quickly and easily erected by locally recruited ironworkers, since the frame is assembled with standard bolt connections and joists are attached to the girders or trusses by field welding (Fig. 3). To this framework is applied a light gauge steel roof deck suitable for various types of roofing finish (Fig. 4).

The structural frame is encased with a preassembled exterior wall panel system which has no mechanical attachment to the frame. The panels are held in position by a head retainer channel and a lower edge retainer shoe, and the joints are usually of the batten type employing neoprene gaskets to insure weather tightness and the flexibility to accommodate expansion and contraction. Figure 7 illustrates the technique.

The panels carry only the lateral wind loads (Fig. 8), and both they and the framing system are free to react and behave independently as loads and temperature affect the several parts.

The preassembled commercial curtain wall units are of two basic types. The first is a 4' x 11'8" mechanically fastened panel 2-5/8" thick composed of two steel face sheets riveted to a rolled steel channel frame and filled with semirigid batt type insulation. The second may be 1-1/2", 2", or 2-1/2" thick and composed of two steel face sheets assembled into a sandwich panel with a polyurethane foamed-in-place plastic core. Either panel may have exterior face sheets of porcelain enameled steel and interior face sheets of porcelain enameled, baked enameled, vinyl coated or prime painted steel. The plastic core sandwich panel may have face sheets of flat, ribbed, fluted or otherwise preformed steel (Fig. 9) with porcelainized, galvanized or painted coatings, or they may be thin gauge, rigidized stainless steel.

This curtain wall panel in place has a "U" value of not more than .168. Interchangeable panels may contain hot rolled steel sash, stainless steel sash or aluminum sash to meet fenestration requirements (Fig. 10), or may contain single or double door facilities with wood, hollow metal or polyurethane foam filled doors, including necessary and appropriate matching hardware.

The interior areas are divided by permanent or movable 2-1/4" preassembled commercial partition units (Fig. 11). These also may be of two types, one having steel face sheets mechanically attached to a rolled steel channel frame

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11

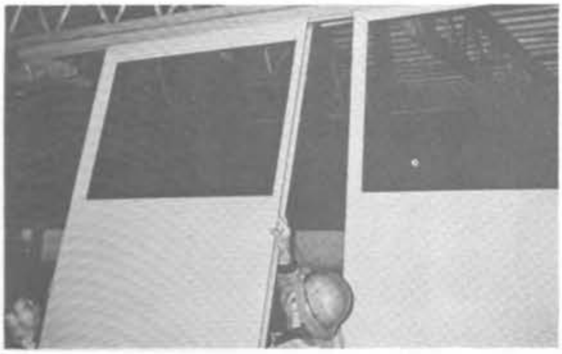

Figure 12

and the panel filled with semi-rigid batt type insulation, and the other being a full sandwich panel of two steel face sheets and a polyurethane foamed-in-place plastic core or a paper honeycomb core. Any of these partition units may have steel faces of porcelain enamel, baked enamel, vinyl coated or prime painted steel. The mechanically assembled panel has an average sound attenuation of 48.6 decibels, while others have attenuation values determined by the thickness and density of the foam cores or by the thickness and/or filling of the honeycomb. The interior panels may be of flush joint or batten joint types and may be mounted between the floor and the structural system, or between the floor and a selected ceiling system. Interchangeable door units, louvered or vented special panels, partial height or partially glazed partition panels are available, as well as the usual solid panels (Figs. 12 and 13).

Where both interior and exterior panels occur on a job, they are usually erected by a composite crew of ironworkers and carpenters. If interior panels alone occur, they are usually erected by carpenters. Erection requires only the normal skills of these trades, since all of the components are piece-marked, pre-punched, and go together in accordance with simple erection drawings. The fastenings are simple, accessible, and generally hidden when the project is complete. Where blind fastenings are excessively expensive, alternative methods of mounting are employed. Both interior and exterior wall panel systems will accommodate the usual tolerances which may be expected in the construction of concrete foundations and slabs, in the erection of structural steel, and in the placing of masonry walls. Unless panel wall systems have this tolerance and flexibility, the use of standard building units is unnecessarily restricted and modification costs are high.

This modular steel building system may be employed in single story or multistory structures (Fig. 14) and is sufficiently flexible to permit the designer maximum latitude for architectural expression, if he becomes familiar with the production limitations on the materials used and if he applies imagination and understanding to the use of materials compatible with the metal building components. Many architects have successfully used conventional building materials in conjunction with the usual components of the metal building system.

The reverse has not always been so true. Designers have done this new architectural concept its greatest injustice when they have pitted a partial metal building system and some of its components against a conventional building design. Prudence, judgment and, above all, a sense of fairness must be employed in a design which desires to mix these new, industrialized components with conventional materials to produce a desired architectural objective. Details, adapters, trim techniques and materials have been developed and used successfully to join the conventional materials to the metal building system.

The design criteria most commonly employed by architects and engineers using the steel building system provide for a 20 lb. per sq. ft. wind load and either a 30 lb. or 40 lb. live roof load (Fig. 15). Buildings have been readily designed to meet the various hurricane codes, seismic codes and special roof-loading codes of specific areas. With a steel framing system weighing less than 4 lbs. per sq. ft., as compared with many designs weighing 12 to 14 lbs. per sq. ft., and a wall system weighing 6 lbs. or less per sq. ft. as compared with a conventional wall of equal performance weighing 80 to 100 lbs. per sq. ft., designers may greatly reduce foundation sizes and costs. These light buildings may be used successfully in many areas where conventional materials are too heavy for the bearing available.

Very little stock-piling of fabricated parts is required for the metal building system,


Figure 13


Figure 14


Figure 15


Figure 16

Figure 17

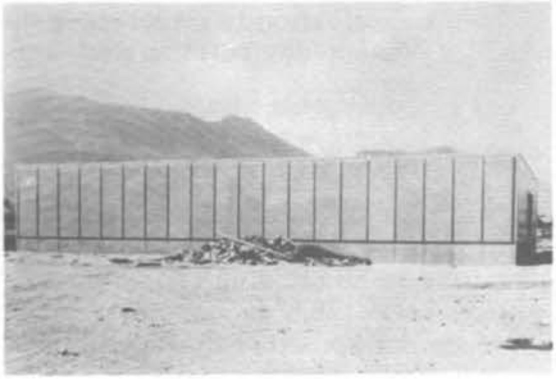

Figure 18

Figure 19

Figure 20

except for tubular column material, sash, doors, hardware and mounting accessories. The standard joists, hot rolled sections, roof deck, steel sheet stock and similar components are conventional, are obtainable from many sources, and are usually in inventory or production at any given time. Because of the natural variation in finishes, color treatments, venting, etc., it is not practical to stock-pile completed exterior wall panels or interior partition units. In lieu thereof, an inventory of standard size materials, together with tools, jigs and fixtures to produce the required units in standard sizes, shapes and colors, is essential to expedite delivery and keep costs at a minimum. Preassembly of these materials into completed components for a specific job can be quickly done if the design utilizes these standard parts, in standard sizes with standard finishes. Delay and higher costs immediately occur when any deviation from standard that requires custom production interrupts manufacturing schedules.

Our experience indicates that architects and engineers can readily design the normal building to utilize the modular preassembled components without serious compromise of architectural intent (Fig. 16). Unfortunately, some designers do not utilize modular dimensioning to any great degree, nor do they understand the reasons for the size selections for many of the major components. The special items which they include in their designs require production as handmade items, with abnormal demands on engineering and production time, with much higher costs, and slower and more expensive erection. All too often, the details are not carefully thought out and we have seen designs which could not be erected. It has been our experience that custom production will cost from 50 to 100% more than the standard preassembled components system.

General contractors and subcontractors find modular construction to be advantageous, even though the component costs may be approximately that of conventional materials.

The speed and simplicity of erection, the integration of the components, and the high quality and uniformity of larger, shop-produced components make for a better completed building. After a first experience with a modular steel building, the contractor and the subtrades find that they can handle the work with ease and a minimum of conflict. Other than a few early questions concerning jurisdiction, no serious problems have been encountered with labor.

Building codes have not posed insurmountable problems, except in a few large cities where the entire metal building system is prohibited or must be so compromised as to make it impractical. The majority of the component materials are well known, and their behavior can be very easily calculated and evaluated. Standard tests have been run by recognized authorities which confirm the predicted performance of the materials when used in composite. Wherever the results of these tests have been presented to state or local code authorities, and the proper explanation of their application is made, acceptance of the system has been forthcoming. We do not consider present-day building codes to be a serious deterrent to a well-designed metal building system.

We have encountered peculiar interpretations of national codes or obsolete local codes which have required the modification of the metal building system to some degree. Typical are code provisions in some areas which require that the steel columns be filled with concrete; in others the building may be required to have a fire-rated ceiling system. In some areas both are required, even though the structure is an isolated one-story building. In some areas metal interior partitions are not acceptable as corridor walls for schools, hospitals, and similar occupancies; yet they are permitted in many other areas.

Typical buildings such as those shown in Figures 17-20, including an office and sanitary building in Ohio, a foam insulated warehouse in Utah, a power plant in Pennsylvania, and a doctor's office also in Pennsylvania, have been erected around the country. These buildings have performed well. They have remained weathertight through all weather extremes in climates varying from northern New England to southern Texas. Owners, architects and engineers have repeated designs and orders. Some of the buildings have been enlarged. Application has been made to buildings varying in size from approximately 1,000 sq. ft. to 1/4 million sq. ft. Experience would indicate that the high quality metal buildings are not economical for very small structures. The exact break-even point varies with the type of structure, and seems to fall between 5,000 sq. ft. and 12,000 sq. ft. The advantages increase as the size increases, as long as special items do not become too numerous. The maintenance in the buildings proper is very low and is expected to remain low during the normal life expectancy of the building. Damage from vandalism, accidents or disaster can be readily repaired at reasonable cost. Alterations, additions and rearrangements can be easily accomplished, since the system contemplates flexibility in both construction and use of the buildings.

# Preassembled Roof Structures

By W. D. Page,* Executive Vice President
Plywood Fabricator Service, Inc.

Plywood structural components are not new, they were developed in the early days of World War II. Their structural design and their long-term performance have been well established. However, until recent years their use has been quite restricted, chiefly because sources of manufacture were limited. As a result of a market survey about three years ago, the plywood industry decided that the time was right to introduce these units into the mass-construction market. Since they do not lend themselves to site fabrication, the big problem was to attract private capital to set up factories to produce them. Once this had been accomplished, the industry felt certain services would have to be provided for these new fabricating firms. This eventually involved the establishing of a subsidiary of the plywood industry's trade association, the Douglas Fir Plywood Association. This subsidiary was named Plywood Fabricator Service, Inc., and the services it provides consist of:

1) Quality control, involving both plant inspection and laboratory testing on a continuing basis.

2) Industrial engineering advisory service.

3) Structural engineering advisory service.

4) Research and development.

5) Sales promotion.

## PLYWOOD STRUCTURAL COMPONENTS DEFINED

In our circles, we use the word "component" in a more restricted sense than it is generally used. In order to eliminate confusion, we say, "plywood structural component." By this we mean a construction component assembly involving plywood in combination with other materials, wherein the various elements of the assembly have been connected together in such a way that the entire assembly functions as a single unit. In other words, a rafter no longer functions only as a rafter, and the deck no longer functions only as a deck, but each contributes to the other and the entire assembly functions as one piece of material. Such a component demands a strong, rigid and durable bond

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*PAGE, W. D., B. S. and M. S. in forestry, University of Washington, formerly associated with Douglas Fir Plywood Assn., of which his present organization is an affiliate.

between the various individual elements in the assembly, and this usually means a structural glue line. This is why the quality control part of our service is so important.

The goal of achievement is greater efficiency of materials. By analyzing the way stresses operate in a beam or panel, we can put material where it is needed and, where it is not needed, we can leave it out. The deck and ceiling can become the flanges of an "I" beam and thereby reduce the size of the rafter which functions as the web of the beam.

When greater efficiency of materials is accomplished the result is lower material cost and an extremely high strength-weight ratio.

## TYPES OF PLYWOOD STRUCTURAL COMPONENTS

### Box Beams

Box beams (Fig. 1) are hollow structural members composed of a structurally efficient arrangement of plywood and lumber elements. The principle of having material where it is needed and leaving it out where it isn't is well illustrated here. In addition, the materials themselves are used to best advantage. Solid lumber is used for the flanges because it is stronger axially, hence able to withstand great axial forces, while the plywood is used as web material because of its considerably higher shear properties.

Box beams usually consist of two or more vertical plywood webs glued to lumber flanges which are separated at intervals along the beam's length by vertical spacers. These spacers function as stiffeners to prevent web buckling and distribute concentrated loads.

Design - Box beams are statically determinate and can be designed according to accepted engineering formulae. Four considerations must be made:

1) Determine required cross-section for lumber flanges. The lumber flanges are so stressed that the top one is in compression and the bottom one is in tension. Since the working stress for wood in compression is less than in tension, the design of the top flange will always control in a symmetrical section. Usually, fabricating problems tend to make symmetrical sections desirable, although otherwise, it would be possible to reduce the size of the bottom flange over the top one.

2) Determine total web thickness. Although the plywood webs carry a portion of the bending moment, they are primarily stressed in horizontal shear. Individual plywood panel thickness is not important as long as the total required thickness is achieved. Additional webs can be placed in the areas where shear is largest, normally from the reaction points to the quarter points.

3) Determine flange-web connection area. Moderate shear stresses in the flange-web connection must be resisted. When these joints are glued, it is the rolling shear stress in the plywood that determines the required contact area.

4) Determine deflection. Ordinarily beam deflection is calculated by conventional formulae with normal allowables—1/360 of span for floors and 1/240 for roofs.

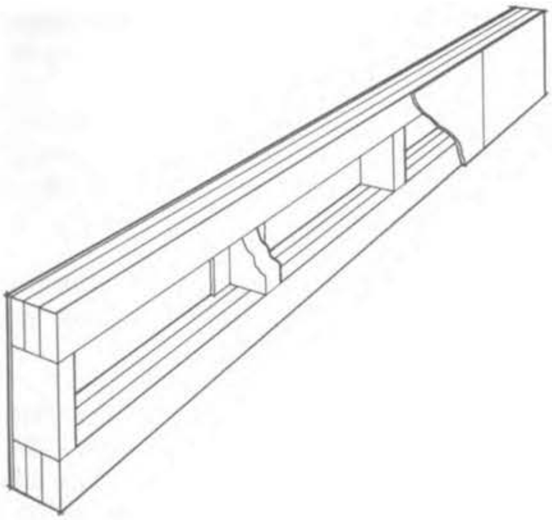

Fig. 1. Box beam.

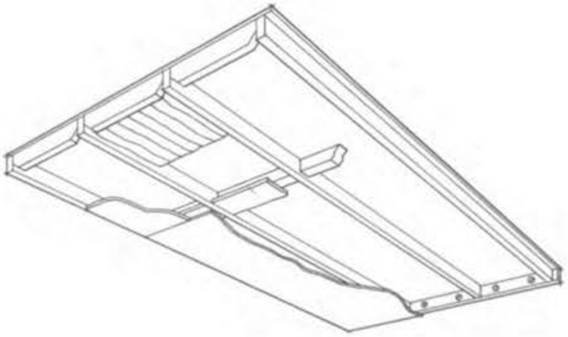

Fig. 2. Flat stressed skin panel.

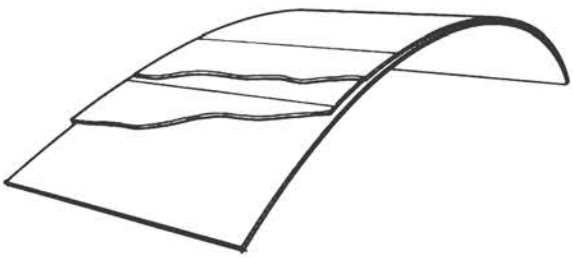

Fig. 3. Solid type curved panel.

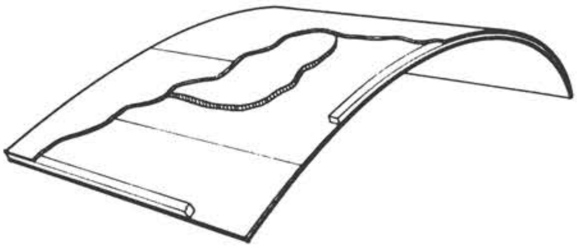

Fig. 4. Sandwich type curved panel.

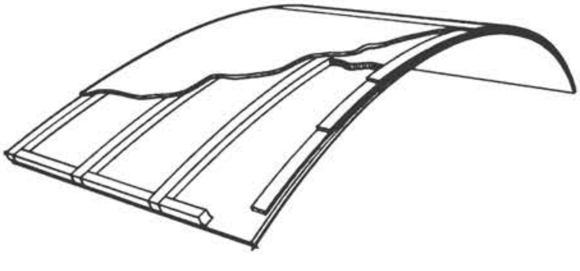

Fig. 5. Ribbed type curved panels.

Fabrication - Because gluing is involved, box beams must be fabricated under close control. This usually eliminates fabrication in other than factory conditions.

When flange cross-sections require lumber greater than 2" nominal in least dimension, the flange must be laminated out of 2" nominal or less in thickness; when flanges are laminated, pressure must be achieved by mechanical means such as clamps or press. Nail-gluing is not a satisfactory way to laminate two pieces of lumber together.

Plywood webs can be laminated to previously assembled flanges using nail-gluing techniques, but pressure by means of a press or clamps is more efficient. The latter method is also used to make beams in a one-step operation.

Ordinarily lumber for flanges must be scarfed to full length. In the case of the plywood, standard lengths can be used with either butt joints or scarf joints in the webs. Where butt joints occur they must be adequately backed up with a glued plywood splice plate.

Applications and Recommendations - Box beams may be used in spans up to 100' or more. They lend themselves to considerable design flexibility, and are used in residential, commercial, school, and industrial buildings.

Stressed Skin Panels

Stressed skin panels are structural coverings for floors, walls or roofs. Longitudinal framing members serve as stringers and to these are bonded a top and bottom skin (stressed skin panels may be designed with only a top skin) in such a way that the entire assembly functions as a single unit. The skins, then, become the flanges for a series of small "I" beams ("T" beam in the case of a one-sided panel) again making for high efficiency in the use of materials.

Stressed skin panels may also be of sandwich construction utilizing paper honeycomb, expanded polystyrene, expanded polyurethane, or other materials for the core between the two plywood skins (Figs. 2-5).

Design - The principle of stressed skin panel design is the same as for beam design. Actually, the stressed skin panel can be considered as a box beam laid flat, with certain modifications. With this analogy, the stresses carried by the flange of a box beam (i. e., the tensions and compression) are now carried by the top and bottom skins of the stressed skin panel. The shear carried by the web of the box beam is carried by the stringers or core of the stressed skin panel. There is one discrepancy in this analogy. The vertical lumber members, or stiffeners, of a box beam serve a definite structural purpose. Whereas, the horizontal lumber members between the stringers of a stressed skin panel act only as headers at the ends of the panel, or if the fabrication technique used requires blocking. If the panel is 8' long or less, or if scarf jointed plywood is used, there is generally no need for these horizontal lumber members except, possibly, at the ends for connection purposes, or in a panel with exceptionally thin and deep stringers that need lateral support.

As in the box beam, the connection between the plywood skin and the stringers must be analyzed. For rolling shear stresses, however, deflection normally controls the design.

The plywood skins of stressed skin panels must be adequate to resist the secondary bending stresses from loads applied between stringers. In addition, the skins tend to buckle under excessive loads. As this occurs, less of the skin (flange of the "I" or "T" section) is effective. This factor is considered in selecting a stringer spacing. Also, the allowable bending stresses are reduced to a minimum of two-thirds the ordinary value.

Fabrication - Stressed skin panels can be fabricated either by nail-gluing or pressure-gluing. However, nail-gluing is not efficient and frequently creates serious appearance problems. They lend themselves quite readily to easy fabrication by press or clamps.

Many fabricators use hot presses which have heated platens. These are usually single-opening, and will turn out a panel every six or eight minutes.

A very practical way of pressure-gluing stressed skin panels by the cold press method is by means of the so-called chain-clamp press. It is possible to get 15 to 25 panels in a single lay-up, depending on the assembly time of the glue, after which pressure is applied by using an impact wrench to tighten the nut on the bolt running through the flange of the top beam.

In installation, it is common to join adjacent panels by means of a tongue and groove joint formed by recessing the edges of the skin on one outside stringer and lapping the edges on the other outside stringer. A shiplap joint and other variations are also possibilities.

The interiors of stressed skin panels should be ventilated. Insulation, conduit, heating ducts, and other items can be incorporated into the panels at the time of fabrication.

Advantages and Applications - The big advantage of stressed skin panels, apart from efficient use of materials, is that the framing, deck, and finished ceiling all go up in one operation. On-site labor is therefore reduced to a minimum.

Stressed skin panels are practical for spans ranging from 8' to 24'. Lumber stringers must be full length or scarfed to full length, which limits the span to available lumber lengths. Plywood skins can be scarfed, or butt joints with proper splice plates may be utilized. The panels may be used in almost any type of construction including residential, commercial, light industrial, institutional, and farm.

Curved Plywood Panels

Curved stressed skin panels are excellent for roof structures because their arching action permits the spanning of great distances with relatively thin cross-sections. These units have made a real contribution by bringing the aesthetic appeal of the arch within the economic reach of the architect.

Three different panels are available: the ribbed panel, the solid core panel, and the sandwich panel. They can be designed for use with or without tie rods. A fourth possibility is a curved section designed as a thin shell vault. In this case, the beam action is built into the curved section, thereby eliminating the supporting beams ordinarily required.

Design - There are two approaches to the design of the curved panel. One is to consider the curved panel as a highly cambered flat panel and the design procedure is, of course, the same as for a flat panel. Provision for horizontal movement under load must be provided at the bearings, otherwise a horizontal force will develop. This approach generally results in a relatively thicker panel than that required using the second approach—the two-hinged arch.

Tie rods, struts, buttresses or other means must be provided to resist the lateral thrust developed in a two-hinged arch design, and these panels tend to be relatively thinner.

There are seven logical steps to be taken in the design of a two-hinged arch, as follows:

1) Assume a trial section and calculate its dead load and properties.
2) Calculate all reactions for the various loading conditions.
3) By statics, calculate the moments at intervals for the loading conditions.
4) By inspecting (plotting) the results of Step 3, the point of maximum moment can be determined.
5) Calculate the direct stress and shear at the point of maximum moment.
6) Calculate the maximum unit stresses in the panel at the point of maximum moment. These stresses are:

   a) Flexural stresses in the skin.
   b) Shear stresses in the core.
   c) Radial stresses between the skin and core or framing.

7) Calculate maximum deflection for the various conditions of loading.

It is also possible to design the roof as a thin shell vault. In this case it must be analyzed also as a beam and the procedure is somewhat complicated, due to the shape of the section and the flexural stresses developed because of the curvature.

Fabrication - The fabrication of curved panels is not nearly as complicated as it might seem. They may be cold-pressed in a chain-clamp press simply by inserting a male form into the press, although only one panel (two or three at the most, if very thin) can be pressed at a time.

A curved panel hot press utilizing heating strips in the rib area is also used by some fabricators.

Advantages and Applications - Curved panels find their chief advantage in the architectural design possibility they offer. Their major uses are for various types of roofs where the curved shape is desirable, and they are used for school, commercial, industrial, and residential buildings. Spans up to 32' or more are quite possible, but in actual design they seldom exceed 24'.

There is also a patented structural panel developed in England (Fig. 6), and available only to fabricators licensed by PFS. It is a parallel arrangement of "troughs" fabricated with plywood webs and lumber flanges. They function as slope-webbed box beams, and are designed as such. This component is available in five standard sections which should meet most job requirements. However, the box beam design method can be used to design other than standard sections.

Design - Its design is identical to that of a box beam. The complicating factors are the determination of the section properties, due to the unusual shape of the lumber flanges, and the fact that the webs are sloping. The net result is more arithmatic.

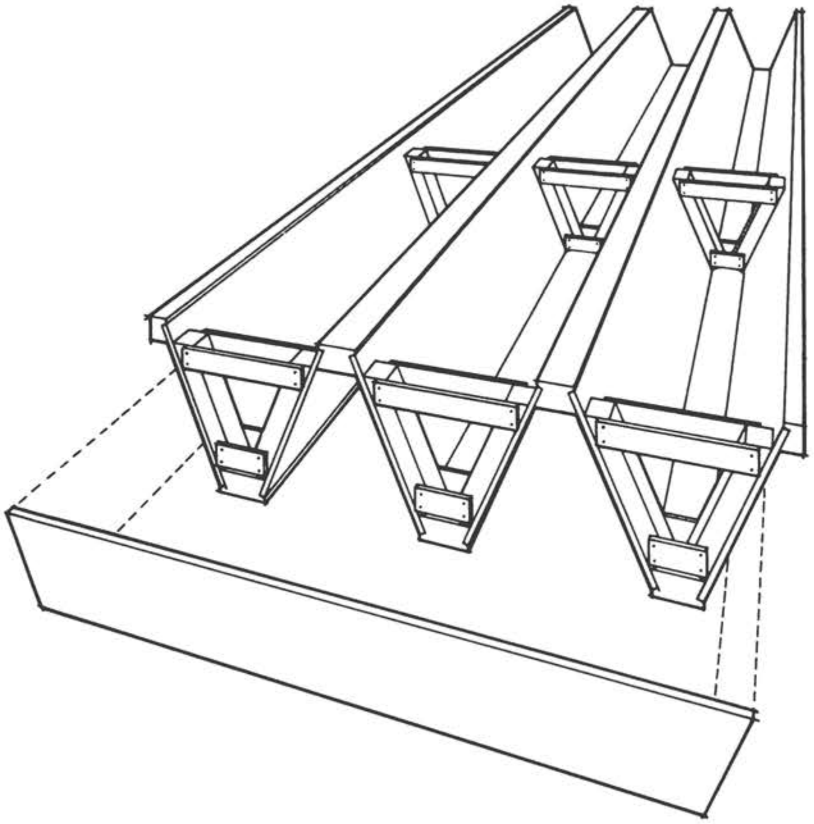

Figure 6

Fabrication - This component can be fabricated either by nail-gluing or pressure-gluing, with pressure-gluing being most desirable from an efficiency as well as an appearance standpoint. This product is new to our fabricators, but most are now equipped to, or are planning to fabricate by hot-press, pressure-gluing.

Advantages and Applications - It is outstanding for its high strength-weight ratio and its unusual architectural design possibilities. It can be effectively used on spans up to 50', but its most advantageous use is for spans ranging from 28' to 40'.

## PLYWOOD COMPONENT ROOF SYSTEMS

In roof systems, these plywood structural components may be completely independent of each other, but they find their best application when utilized as a structural system involving two or more types of components. In other words, box beams may be used in combination with stressed skin panels, curved panels, etc. to form a roof system, for example. Considerable flexibility in spacings and spans is available, and a wide variety of architectural effects can be achieved easily. Figures 7 through 10 show a variety of applications.

### Flat Roofs

The most simple and economical system, when a flat roof is satisfactory, would include box beams and flat stressed skin panels. For clear spans in excess of 40' a beam spacing of 8' on center with 4' x 8' stressed skin panels is desirable from an economic standpoint; 16' and 20' beam spacings with appropriate panel sizes work well for spans under 40'. When roof insulation requirements are not high, a good combination would be beams spaced 4' on center with regular 3/4" plywood fastened directly to the beams.

Fig. 7. Stressed skin panels used in a cathedral ceiling

Fig. 8. Box beam - stressed skin panel roof system

Fig. 9. Glued folded plate roof

Fig. 10. Curved plywood panels form canopy

Folded Plate Roofs

Plywood folded plate roofs may be conventionally framed, but a considerable number of them are built with glued components. Although they are designed the same way, from a fabrication standpoint they fall into two classes:

1) A pseudo folded plate, where box beams are the main supports and the individual folds are designed as stressed skin panels.

2) A true folded plate, where the folds themselves are designed as giant box beams thereby eliminating large valley beams.

Delta Structures

The delta structure uses several components in its assembly. Rigid bents composed of two tapered box beams form the predominant delta shape. Additional tapered box beams cantilever from each side of this bent, partially balancing the moments that would otherwise be quite large. Stressed skin panels, curved panels or folded plate can be used as covering over the bents.

Delta structure should be economical enough for utility buildings and yet has the design potential to be considered for churches, schools, and other structures with high design requirements.

Curved Panels with Box Beams

Another interesting combination is the use of box beams and curved panels as a component roof system. Although each of these components may be used without the other, they make a very effective team when used together.

## CONCLUSION

Although the PFS program is only a little over a year old, tremendous strides have been made in getting fabricators established, and in gaining acceptance among users and specifiers, as well as among inspecting and insuring agencies. Architects and engineers have been particularly enthusiastic, and code acceptance has been no problem to date. We feel that the plywood structural component has a great future and that the PFS program will be instrumental in bringing that future to reality.

# Preassembled Components in a Custom House Construction System

By F. Vaux Wilson, Jr. ,* Vice President
Homasote Company

Accurate figures do not seem to be available to determine exactly what is happening in the housing market, but as a basis let us assume that approximately 60% of the houses are built by operative builders using standard plans developed by them, 10% as alterations of those plans—modified to suit customers who come into the picture before the house is too far along—and 10% as stock models of prefabricators. One might then say that, to all intents and purposes, 80% of our housing today is prebuilt. Thus, the custom-built market has probably been reduced to 20% of the total, if our assumptions are anywhere near correct. It is this market to which we will devote our attention and we will try to see how preassembled components can be tailored to it in such a way as to effect substantial savings.

Our discussion is confined to those components that make up the basic structural elements of the house, and will not include such components as prefit door and window units, kitchen cabinets and accessories of that nature. We will deal solely with floor, roof, wall, ceiling and gable components (Fig. 1).

It might be well to consider at this point why, suddenly, there should be so much attention paid to components. Practically every trade journal discusses components frequently and all kinds of people are trying to get into the components business without really knowing how, or what components to build, what materials to use, and whether or not sufficient savings will be effected to justify their investment.

Probably the biggest problem facing builders today is the shortage of skilled labor. Without going into the reasons for this situation, suffice it to say that many builders are taking a long and sustained look at ways and means to avoid as much site labor as possible. The more the site labor can be reduced the better the builder's control over the quality, speed and cost of the final product. Most builders recognize that a quality product will create a sustained demand for itself. They also recognize that speed is of utmost importance, as it means more houses per year, per crew. And, of course, lower costs improve the competitive situation and enlarge the group of possible purchasers.

*WILSON, F. VAUX, Jr., Member, Building Research Institute, Research Committee of Natl. Assn. of Home Builders; educated at Lehigh and Columbia Universities; formerly associated with A. C. Horn Co., and with systems division of Remington Rand.

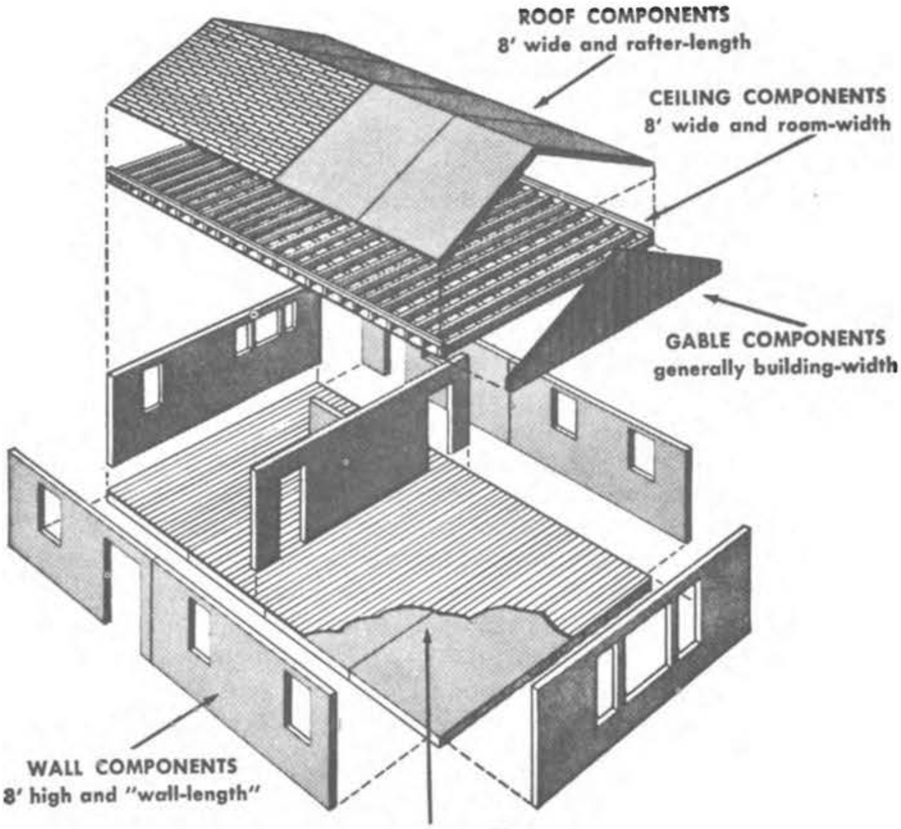


Figure 1

As the number of skilled workers declines, and it is rumored that more than 50% of our skilled carpenters are over 50 years of age, it becomes obvious that there is a great need for the development of standardized methods to handle the construction of the basic parts of the structure, and a further need to make these operations simple enough and automatic enough for unskilled hands. Also, it is vital that these operations be performed in an area not subject to extremes of climate.

However, the problem is by no means confined to labor. Probably the greatest drawback to economically sound components is the lack of big-sheet surfacing materials. For sheathing and interior wall and ceiling surfaces, 4' width materials are not adequate to handle the problems involved. There are too many joints to take care of, too many nails to drive (at least twice as many as with big-sheet material), too many components to erect and fasten together, too much doubling of members and too much loss of strength in the ultimate structure. As an example of savings in time, it takes four men only 44 man-seconds longer to put a component 14' long into place than it would take two men to put a component 4' long into place. This is a saving of 18 labor hours in the placement of the exterior wall components for a 1000 sq. ft. house.

Another field which needs immediate research by the manufacturers is the preassembly of prefinished strip flooring or block flooring in panels, say, 2' wide and reaching from wall to wall. Some work has already been done on this by fabricating the panels in a jig with the prefinished flooring face down, placing plywood on top of the flooring, and stapling them together. Efforts in this direction, so far, have produced panels which are fairly good, but more study is needed on the proper conditioning of the flooring before its use, to prevent buckling or excessive shrinkage. Where the components for floors are produced with the joists, subflooring and finished flooring applied, a satisfactory covering for the finished flooring, that may be applied in the fabricating plant and then sealed when the components are installed, is another area for research and an important one, as it is highly essential that the flooring be laid before the components go to the site.

To refresh your memory, it might be well to state that the components currently manufactured consist mainly of roof trusses and exterior wall panels with only the sheathing applied. These, in the main, are 4' wide. The rest of the framing for the house may or may not be precut.

There seems to be a general impression among those in the building trades, and in the distribution system serving them, that components, per se, would stultify the range of choice of design and hamper the freedom of imaginative and creative thinking so much desired by the architectural profession. When one considers that, normally, a component is thought of as a panel 4' wide, the reason for such thinking is apparent. But, as previously mentioned, the 4' panel has come into being mainly because of the prevailing size of sheet material. Anyone who works with a 4' module soon finds that exceptions have to be made. For example, it is not possible to enclose a 16" square chimney with 4' panels if you have to keep within 2" of the chimney. This forces the breaking of the module, which is like breaking a company policy—once it is broken, you literally have no policy.

Of course, this problem was overcome by the research work instituted and paid for by Mr. Albert Farwell Bemis, which brought into being the 4" cubical module. Only two sides of the cube have been generally used, the height side not having been employed to any great degree. Actually, the discovery that was made was that the walls and partitions of a house, normally representing a greater area than any of the other components, were the determining factors of the size of the modular unit. For example, in frame construction with the usual 2" x 4" stud wall, the actual dimension of the stud is 3-5/8". Centering the wood frame between two 4" modular lines leaves a distance between the studs and the modular lines of 3/16" on either side, or a total of 3/8". Thus, any modular wall unit running into the corner of a building would be in modular dimensions minus 3/16", and if the wall component runs from corner to corner of the building, the length would be in modular dimensions minus 3/8". Intermediate components, not reaching to the exterior walls, would be in exact modular dimensions. In the actual production of the units, the fractional dimensions do not show up. For example, in cutting plates for wall components, or joists or rafters, the stops on the saw bench are so made that they automatically compensate for the fractional differences; and the same applies to the guides used for cutting sheet material. As a matter of fact, many thousands of war-time houses, which were constructed with 2" x 3" studs, used the 3" module in exactly the same way as the 4" with complete success.

Normally, it is not necessary to take the wall-surfacing material into consideration, except for cutting it. Then, its relationship to the modular line is taken as the basis for cutting. With the 4" module, the architect simply draws all his walls and partitions 4" wide and spaces them apart in multiples of 4". This actually speeds up the drawing of plans, and makes checking of them fast, simple and accurate. The take-off, for estimating purposes, is also a lot simpler. It should be pointed out that when the 4" module is used it is never necessary to change the over-all length or width of a building more than 2", which is negligible. In frame construction 1/16" is the smallest dimension normally used, but this means that it is necessary to deal with as many as 192 dimensions to the foot.

With the 4" module, there are only three dimensions to the foot. This makes possible all kinds of tables that help to speed things up and to eliminate mistakes. For example, the use of modular lintel lengths for windows and doors permits the instantaneous determination from one small table of all the surrounding framing, for any size of rough opening. Fabrication mistakes are very rare because, if there is a mistake, it will always be 4" and that is seeable! If the sheet material covering a component is short, or over, it will be 4" and is immediately discernible. Experience has shown that the Bemis 4" module is probably the greatest cost-cutter ever devised. It is flexible enough so that design is not hampered; it is big enough so that mistakes are caught immediately; but, most important of all, it provides a positive control occurring every 4" throughout the length and width of the structure.

Not everyone can develop satisfactory components. To do so requires a great deal of experience in the shop as well as in the field. While a house might not seem to be too complicated a structure, one large housing operation, moving at the rate of 60 houses per day, required 95 different crews to handle the various operations in the field alone.

A few fundamentals that might be taken into consideration are:

1) The components should be of as similar a nature as possible from the standpoint of framing, so that workmen can be shifted from one component to another without having to acquire a lot of special know-how.

2) Fastening and attachment methods should be standardized as much as possible, so that workmen do not have to be taught how to use a wide variety of tools.

3) Economy in lumber lengths should be carefully determined, and study given to minimizing the amount of cutting.

4) Size of components should be as large as practicable to eliminate as much doubling of members as possible, and as many fastenings as possible.

5) Components should be designed with the minimum of depth so as to take up as little truck space as necessary; a very valid reason for not shop-installing windows and doors in wall components because of sill extensions.

6) Weight is also an important consideration if mechanical equipment is not available at the site. (Today's manpower will not lift the weights it would 20 years ago.)

7) All sheet material possible should be applied in the shop. This includes sub- and finished flooring, wall and roof sheathing and interior wall and ceiling finish; the larger the sheet material the better. Panels up to 8' x 14' appear to produce the least waste. Large sizes like this eliminate 22 wall and ceiling joints in every 1000 sq. ft. of surface covered, as compared with 4' widths. The material must be tough enough for safe handling, and of high weather-resisting qualities.

8) Every effort should be made to do the electric wiring in the shop. One man can wire up to four houses per day.

9) Wherever possible, all cutting for plumbing lines should be done in the shop. On large jobs, the plumbing can be completely preassembled, and even tested against leakage through the various lines.

10) Once components are erected, the only work left should be the running of the baseboard, installation of kitchen cabinets, closet shelving and hook strips, floor covering, roofing, heating, plumbing, tiling, installation of hardware and decorating. In other words, about three weeks work.

Let us consider some of the fundamentals of the components themselves, such as:

1) Floor components work out well with the subflooring and finished flooring applied, and this method has been thoroughly tested in thousands of houses.

2) Wall components should be of room size, and in some cases longer. The drywall material must be applied to both sides of the wall in the shop and should be glued as well as stapled.

3) Ceiling components should be 8' wide and room depth. All joists should be strapped to provide a better surface for the drywall, permit the electric wiring to be pulled across the ceiling under them, and let out any water that might accumulate if it should storm before the roof is on.

4) Roof components should be up to 8' in width, and rafter length.

5) Gable components work better if built in single units, and should be so designed that the studs may be square-cut instead of having to be cut to the roof pitch. This helps to use up short lengths.

Why should all five components be fabricated? The answer is that by so doing sufficient savings can be made to open up markets which have currently been lost because of constantly rising prices. A saving of $25 to $50 per house is important to an operative builder who is filling a tract with several hundred houses, but we are thinking of custom-built houses, and at the same time trying to reach into all price markets. What we are looking for is at least $1000 reduction in the cost of a small house, without taking the reduction out of the materials or skimping on the construction. We feel the quality should definitely be kept up to the finest construction standards. Therefore, the saving must be obtained from the reduction of the hours required at the site, speeding up the operation and reducing the overhead.

Analyzing a small, three-bedroom house of 1040 sq. ft., we find that it requires 227 labor hours to produce the components and 65 hours to erect them, a total of 292 hours. If the same work were performed at the site it would require 496 hours. The saving is 204 hours. Doing the work at the site, and using a crew of four, without components, it would require 15-1/2 working days. As the erection requires two days, this means a saving of 13-1/2 days. Assuming a field rate of $3 per hour, components save $612. The delivered price of the components being $3326, the elimination of the contractor's overhead on this part of the operation amounts to $499, making the total saving $1111. This is substantial, because it means at least $111 reduction in the down payment, which should permit an additional 10% to 15% lower income group to purchase. The use of trusses and exterior wall panels, without interior finish, would save only about 36 hours of site labor. The detailing of any architectural plan averages about 5/8 of 1% of the sales price of the house, exclusive of land cost.

The fabrication and merchandising of components should be confined to our present distribution channels for custom-built houses. This will produce a highly integrated industry operation. Our building material wholesalers present an excellent set-up for fabricating, as they legitimately purchase at the lowest levels and their overhead is generally one-half that of the lumber dealer. In this way, the operation can be decentralized with distributors operating in a 100 mile radius of their plants. This permits a truck to go to the site, unload and return the same day.

As the lumber dealers have the collateral materials to go with the components, and currently are buying the pieces from the wholesaler, it seems logical for the dealer to sell the components. In most distributors' trading areas a group of 200 lumber dealers could be enlisted to sell the components and, if they sold components for five houses apiece each year, the distributor would find himself with a $3 million dollar business. The program would also permit the participation of local architects, lending institutions, contractors and subcontractors.

With the Bemis 4" module and the five major components produced by the building material wholesaler and sold through the local lumber dealers, any style or price of home, any size, may be produced faster, better and more economically than by conventional methods. Best of all, the home owner can get what he wants at a quality and speed not possible in any other way.

# The Manufacture and Distribution of Preassembled Components

By James L. Pease, Jr.,* Treasurer
Pease Woodwork Company

Our company has been manufacturing and distributing manufactured homes and the components for use therein since 1939. Before that time, our business was primarily the distribution of millwork and other building materials by mail throughout the Middle West. We entered the manufactured home field in order to increase the proportion of materials and labor that we could furnish for each home we sold. Thus, we were able to increase our volume per sale and to furnish more parts of the house at less cost through the economies afforded by shop labor, factory equipment and engineered use of materials.

Originally, the manufactured home we produced consisted of these preassembled components:

1) Exterior wall panels were room size or larger, made of 2" x 4" studs, 16" o.c., with 5/16" plywood sheathing, building paper and furring strips for conventional sidings applied on the outside, and 1/4" fir plywood, wallboard grade, applied on the inside. These inside skins were made from horizontal 4' x 8' sheets of plywood, side- and end-joined into room-size panels by means of a 4" gusset on the back fastened with urea resin glue in a hot press. The panel joints were made by a male and female spline arrangement. The interior surfaces were factory primed to provide a sealer for the wallpaper that was later field applied. We did not recommend field painting of interior surfaces because of the grain raise and checking problem, nor did we prefinish the panels because of the handling problem. Since the only exterior sidings offered were bevel siding, cedar shakes or brick veneer, these were left for field application and finishing because of the joint problem.

2) Floor panels were 4' wide by room length and factory assembled with 25/32" x 3-1/4" prefinished oak flooring over paper, 5/16" sheathing and 2" x 3" sleepers, 16" o.c. These were then field nailed to the joists which were supplied precut and covered with a protective paper to preserve the finish during construction.

3) Interior partitions were fabricated in room-size panels much like exterior walls, except that both skins were primed 1/4" fir wallboard.

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*PEASE, JAMES L., JR., Vice President, Home Manufacturers Assn.; A. B., University of Cincinnati; M. B. A., Harvard Graduate School of Business Administration.

4) Ceiling panels were fabricated of the same side- and edge-joined, primed 1/4" fir plywood panels nailed and glued to 1" x 3" ribs. These were then leveled and field nailed to the ceiling joist. In some cases "field joints" were necessary in ceiling panels because of the 8' least dimension allowable for truck shipment. (Usually these field joints, nailed and glued using casein glue, were well made. However, some poor joints were made when care was not exercised in the field.)

5) Gables and dormers were also shop fabricated in three sections, without interior finish, as most homes were sold with an unfinished second floor.

The only other "components" supplied were those common to our sash and door business, window units and kitchen cabinets. The roof was precut, and interior and exterior doors were prefit but not hinged. No mechanical components of any kind were furnished; heating and plumbing were done conventionally as was wiring which had to be "fished" through the walls.

This original house, which was a 30' x 24', 1-1/2-story model with living room, kitchen, bath and two bedrooms on the first floor and unfinished second floor, sold for $1,380.00. Through 1947, this was competitive with conventionally built homes using lath and plaster or gypsum wallboard interior finish. It met all FHA and most code requirements. Within the limitation that interior surfaces had to be wallpapered and changes in floor plan required other panels which we were seldom willing to produce and therefore had to be field produced, it was well accepted by the home-buying public. However, the problem of grain raise showing through the wallpaper occasionally existed. This was usually taken care of by the field application of wall felt which was then repapered or painted.

This system of plywood components met its demise in 1950, chiefly because the price of 1/4" plywood reached $100 per 1000 sq. ft., while gypsum board and lath and plaster remained much less expensive, and because the home buyer demanded much more flexibility than it was possible to offer with these room-size panels.

In 1949 we brought out a line of 4' modular exterior wall components composed of 2" x 4" studs 16" o.c., with 5/16" plywood sheathing. This was soon abandoned in favor of our present system of 1" modular panels because it, too, lacked flexibility. Panels were seldom interchangeable between house plans, and the resulting factory-production complications made the 4' modular panels uneconomical. Also, when the location of windows and doors was determined by the 4' module, the resulting elevation often was either of poor design or did not correctly fit the floor plan.

Our present system of producing manufactured homes includes the following components:

1) Exterior wall sections are composed of 2" x 4" studs, 16" o.c., with 5/16" CD (exterior glue) plywood applied in the shop. The upper top plate is sent loose for field application to tie the panels together. End joints between panels are made by lapping the plywood over a stud of the adjoining panel. Sections are produced on a 1" module with window and door openings (also on a 1" module) separate from blank panels. This, of course, allows almost complete flexibility. "Opening" panels are offered for four sizes of wood sliders, 14 sizes of wood double hung windows, nine sizes of wood awning and fixed sash, six sizes of aluminum sliding windows, three sizes of aluminum single hung windows, and 15 sizes of aluminum awning windows. In addition, we have four exterior swinging door panels with 43 designs of doors, five aluminum sliding door

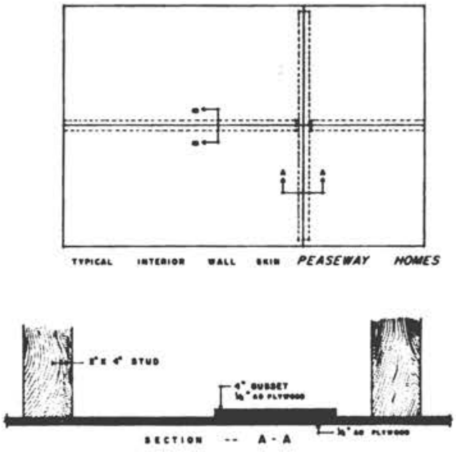


Fig. 1. Interior wall skin

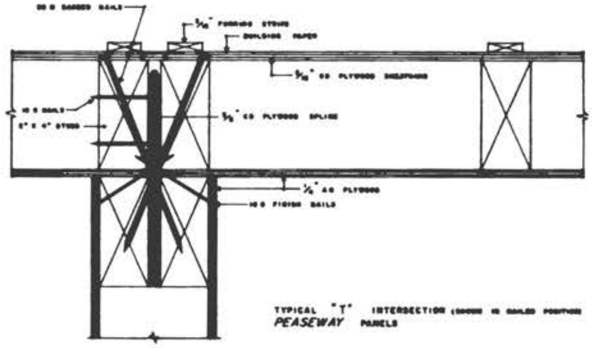


Fig. 2. "T" intersection nailed in place

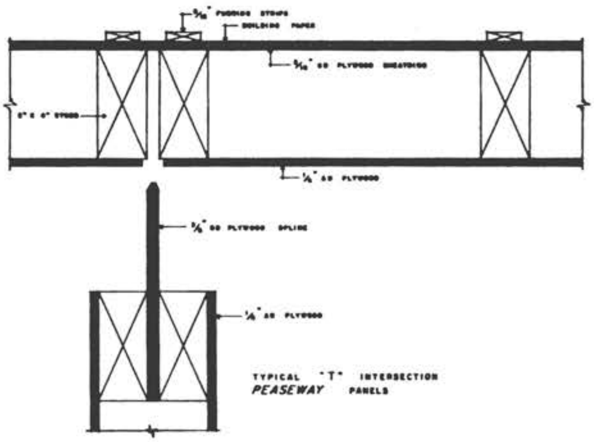


Fig. 3. Typical "T" intersection

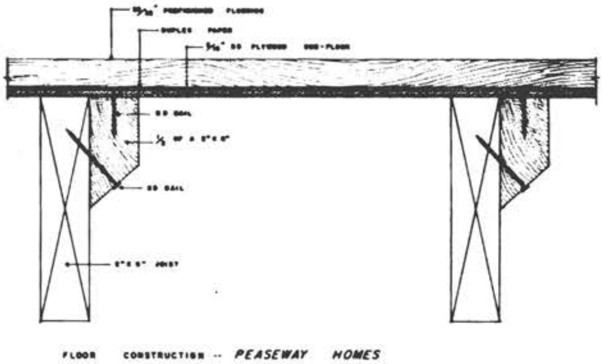


Fig. 4. Floor construction

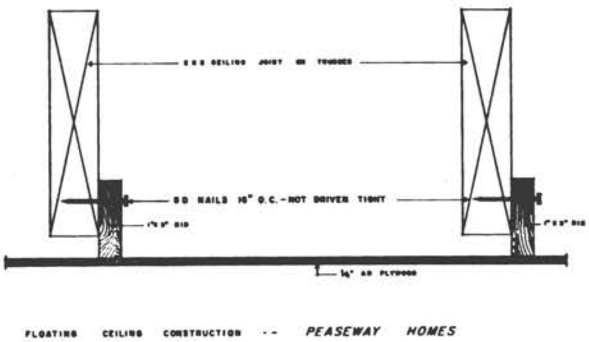


Fig. 5. Floating ceiling construction

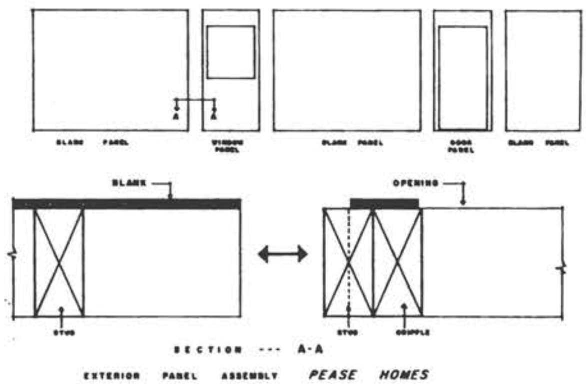


Fig. 6. Exterior panel assembly

panels and three garage door panels. This range of panels places virtually no limit on architectural design. Plywood sheathing is used in preference to slightly less expensive (per square foot) fiberboard, as it costs less in place because:

a) Fewer nails or staples are required.
b) It has greater resistance to damage in shipping and handling.
c) Butt joints in horizontal sidings can be made at any point, not just over studs.
d) No special fasteners are required for field application of sidings.

Interior finish and insulation (if required) are field installed.

2) Interior partitions are framed of studs 16" o.c. with single framing around openings (except a few load-bearing partitions which have double framing). Interior gypsum board or plaster skins are field installed.

3) Roof trusses are fabricated from 1500 f 2 x 4's with metal toothed plate connectors. The chief advantage of these metal plates over plywood gussets or ring connectors is less shipping bulk (trusses are only 1-3/4" thick instead of 2-1/4" to 2-5/8"). Roof trusses are produced in three pitches, two overhang lengths and nine spans from 16' to 34'. Hip trusses, 2/12, are also produced for most spans.

4) Gables are framed with siding and gable cornice applied. A 3/8" plastic-faced plywood or 3/4" rabbeted siding are the most economical facing materials, since sheathing can be eliminated.

5) Exterior doors and windows are completely assembled into units exclusive of interior trim, but not installed in panels, again because of the shipping problem. Screens, storm sash, combination doors and windows are factory installed in the window and door units to save packaging and factory shipping errors.

6) For homes with basements, box girders, basement stairs and stairwell assemblies are factory assembled but joist, bridging and subfloor are precut. We have not used stressed skin floor panels because they cost more and the installation of heat ducts presents a problem, even though they do offer the advantage of quicker installation.

7) Interior door units are furnished completely machined and with hardware applied, but not assembled because the packaging and shipping costs exceed field assembly time.

The structural components for our homes are shipped horizontally on flat bed trucks. This method of loading allows material to be loaded on the truck more compactly and results in lower shipping costs. One-way specialized carriers are used, since the scheduling problems with commercial carriers are insurmountable. It is more important to have the truck on the job at a specified time than it is to reduce the shipping costs a few dollars by using carriers with two-way hauls.

Our present system of preassembled components, being "conventional" in design, meets FHA-VA requirements and 99% of all building codes. The panels are of such size that they can be handled manually by two or three men and can be assembled quickly (a house usually is under roof in one day) by relatively unskilled labor.

Due to the wide range of sizes, which yields flexibility, most of the components are manufactured to order. Inventories are maintained in the form of raw material, cut parts and subassemblies, rather than finished goods.

As previously mentioned, the 1" module allows almost complete design flexibility and simplified and speedy on-site erection. The ability to pre-establish field assembly schedules, effect savings in man hours, and also reduces construction financing requirements because of the shorter building cycle. All factory components bear the union label so that, even in those areas where union labor is used in the field, no problems arise.

Quality control from the home owner's and mortage lender's standpoint is an important ingredient. Being large manufacturers with a substantial investment, we must provide the necessary inspection and be responsible for the performance of the components, providing they are properly used. This proper use of components is the responsibility of the field erector, but we, as manufacturer or distributor, must educate the field men and inspect their efforts.

Factory produced sandwich panels utilizing foamed-in-place polystyrene are being test produced and marketed by our company. However, serious problems are anticipated because of the lack of inexpensive stabilized interior and exterior skin materials. The moisture and temperature differences between exterior and interior faces, in view of the high insulating and vapor barrier characteristics of the polystyrene, seem to create buckling and warping problems with plywood, gypsum board and aluminum skins. Also, the lack of availability of large sheet sizes of most of these materials offsets the advantage that large, lightweight joint-free components can be produced.

Since the making of field joints is the most expensive part of any complete component system, we believe that all panels should be made as large as possible, i.e. wall panels 8' high by lengths of at least 12'. Eventually, as shipping techniques are developed, even these components will be shop assembled into larger sections of the building—perhaps even the entire structure. The development of economical interior and exterior skin materials in large sheet sizes will make possible real breakthroughs in the development of these practical components. Until they are available, we will be stymied in doing the job that is possible in the factory.

We have distributed these preassembled components as a part of a complete house package to builders who, in turn, have provided the land and field work, and have sold the finished product and arranged financing for the buyer. In recent years it has become necessary for us (and most other home manufacturers) to supply not only the integrated package of components, but also, as part of this distribution process, such services as land acquisition, financing and planning, construction and permanent financing, decoration and architectural advice, construction, technical and cost advice, code and FHA approval, advertising, sales promotion and training, and such other assistance as is necessary to assure the builder that his residential building operations will be profitable. (A home manufacturer today is not just a producer of components, but more important is a distributor specializing in merchandising and selling an integrated, complete package of components and who is even willing to hold the builder's hand if necessary.)

Without providing these services, the product (as we know it today) is hardly saleable to the builder in view of the competition from local fabricators and on-site fabrication techniques. Also, as more and more manufacturers enter the field on a sound basis, the area in which our product is distributed will be reduced because of freight costs.

Only the advent of the more economical, larger and further finished components that require relatively large amounts of capital to produce will remove this highly competitive (and in many cases, unprofitable) influence from the distribution picture. Even so, I'm afraid that the product may be secondary to the services (financing, promotion, etc.) that must be available to the customer to whom we expect to distribute our product.

# Summary and Conclusions

By John M. King,* Director of Research Services
National Association of Home Builders

The emphasis which the preceding papers have placed on the importance of certain criteria, and particularly on the methods and details employed to gain certain objectives, has varied to an extent. It is apparent, however, that all agree on the merits of the use of preassembled structural components. If we were allowed to apply only one principle or objective to the use of preassembled structural components, I believe it would be the more efficient use of labor and materials. The key word is "preassembled."

At the risk of repetition, I will summarize briefly some of the major advantages of preassembly or factory fabrication.

1) Preassembly lowers site construction time and the impedance of the construction schedule by adverse weather conditions. This will aid in leveling out the seasonal nature of construction and provide year-round employment for a greater portion of our labor force.

2) The use of power cutting, fastening, handling and finishing equipment in the shop will reduce the time necessary to produce components. Greater automation of the fabrication process will provide, in some areas, one answer to labor shortages and high wage rates.

3) With specialized equipment and a controlled environment, it is possible to use materials and techniques that cannot be used at the building site. For example, many adhesives require application and curing within prescribed ranges of temperature and humidity. Components can also be prefinished to a greater extent with special shop equipment.

4) With centralized facilities, the manufacturer or fabricator is afforded better control of the quality of his products. Building tolerances may be reduced with consequent structural economies, less waste, and over-all improved quality of the finished assembly.

5) As the volume of component construction increases, the fabricator is in a position to pass on savings resulting from volume buying of materials and an ability to

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*KING, JOHN M., Member, American Society for Testing Materials; B. S. in architecture, University of Illinois; formerly associated with National Homes Corp. NAHB is a member of BRI.

operate with smaller unit profits. He may also be in a better position to finance expensive equipment, additions and improvements.

6) Aside from the obvious benefit of more efficient use of labor and materials, a greater degree of preassembly will reduce the over-all construction time and provide corollary economy. Today in home building, for example, it is not uncommon for builders to have 20- or 30-day construction schedules. Shorter schedules will provide significant savings in construction financing and other expenses related to the builder's overhead.

It is interesting to note the emphasis that has been placed on technological progress; the development of new products, equipment and methods. Manufacturers of building products have shifted their development programs into high gear and are now producing products designed specifically for component systems. Architects and engineers have become enthusiastic advocates of preassembly. Builders and contractors have shown a willingness to accept new disciplines in their operations, and the buyer or user of our buildings is beginning to accept innovations in architectural designing, planning, materials and equipment. While we have made progress over the past decade, we have only recently come to recognize the tremendous potential that lies ahead. Having recognized this potential, we often find that our efforts are frustrated by the lack of a comprehensive building science, a lack of standards and criteria, a lack of an up-to-date performance code, a lack of the cooperation of labor, and a lack of public understanding. These are all problem areas that must be attacked from all sides.

Let's consider for a minute the question of codes and standards. Building codes, like death and taxes, are certainly here to stay and we can be thankful that we have them, since they afford us protection that would be difficult to achieve in any other way. I think we can adopt the premise that most building officials have a sincere desire to be fair and make honest decisions. Their decisions must be based on the evidence that is presented to them, in comparison with the regulations and standards that they have at their disposal. They need both the facts and the standards.

To take advantage of new techniques and materials development, we need new criteria and standards. We are too impatient to wait 10, 20 or 30 years for the results of experience. What is our status today? We investigate function, performance, primarily through mathematical computation and testing. We are progressing in our knowledge of engineering analyses, and in the area of test methods for materials and (to a lesser extent) combinations of materials. We are fast developing criteria for judging the performance of materials, but again, we are lagging in the ability to judge adequately the performance of combinations of materials in building components or elements. We appear to be ahead in our criteria for judging mechanical systems, but woefully lacking in criteria for the building structure. We speak of standards, but our standards are usually not standardized. We do not have agreement on such vital factors as magnitude and duration of loading, safety factors as applied to materials in complete structures, structural durability, and other criteria which would enable us to design with greater structural efficiency.

Building product manufacturers have naturally been concerned primarily with the acceptance of their individual products, usually composed of one, or at most a few basic materials. The architects, engineers and builders who concern themselves with industrial, commercial and other large building types are usually in a better position to gain acceptance of new techniques and materials for one-of-a-kind building. At the present, the home builder's position is somewhat nebulous.

I would like to believe that each participant in this Conference will return to his company or organization and begin an active campaign for performance building codes, and new and better standards and criteria. Collectively, you have the power to carry on a significant movement in the direction of these objectives. You have the strong incentive of expanded market and increased profits.

There are a number of ways to speed progress:

1) Join and actively participate in the work of standards-setting groups such as American Society for Testing Materials, American Standards Assn. and Modular Building Standards Assn.

2) Strengthen and expand the effectiveness of the standards activities of your industry associations.

3) Work in your local communities to establish national and state model building codes.

4) Cooperate with other manufacturers, architects, engineers and builders in gaining acceptance of new building components.

5) Attempt to bring about a better understanding by labor of our objectives.

6) Develop advertising and promotion programs designed to lessen apathy and encourage action.

7) Enlist the cooperation of your distributors, dealers and suppliers.

There is reason to hope for more rapid progress. This progress can and will be achieved by a coordinated effort of all elements of the building industry.

# Open Forum Discussion

Moderator - John M. King, Director, Research Services
Natl. Assn. of Home Builders

Panel Members - Messrs. Deegan, Page, Pease, Schuszler and Wilson

Tom Mitchell, American Cyanamid: What is the desirability and status of preapplied, finished, weatherable coatings for preassembled roof components in both residential and nonresidential building?

Mr. King: There is a considerable amount of work being done by the various manufacturers of those products in cooperation with organizations like ourselves and, in our case, there are actually test jobs being put up at the present time. It looks very promising that these coatings will be a major factor in the immediate future.

H. A. Segalas, Procter & Gamble Co.: What was the cost per square foot of the laboratory building you discussed?

Mr. Schuszler: I didn't figure it out, but the guaranteed maximum was $2,216,000 and there was an arrangement whereby any saving effected under that guaranteed maximum would be divided 40% to us and 60% to the owner. It is my recollection that we managed to save about a quarter of a million dollars by, shall I say, effective and efficient methods. The owner finally felt that we were getting too much of a cut. In the beginning they were counting pennies and saving everywhere, but later on, when they saw how much we were making on the savings, they said, "Spend more money." At all events, it ran to $2,216,000 for about 64,000 sq. ft. of building plus a lot of land and road work, a drum storage building, a gas meter building, a cooling tower, etc. The building itself came to about $1-1/2 million; that's the estimate the owner put on it. I estimated $1,400,000, so that comes to about $20 a sq. ft.

Arthur Tisch, Independent Nail & Packing Co.: Could you give us a cost per square foot for the elementary school in Pennsylvania? Where can we obtain more details on your school building experiences?

C. R. Humphries, Minnesota Mining & Mfg. Co.: Can you give some idea of the final costs per sq. ft. for some of the building types—for example, schools, small hospitals?

Don Brown, Reynolds Metals Co.: What do typical panels cost per sq. ft.?

Mr. Deegan: In answer to all three questions the cost per sq. ft. of a school building varies materially, depending upon the standards under which it is built, and depending upon the facilities that have gone into the building as a component part of the cost. The building recently built in Pennsylvania was a composite project, including the standard heating, ventilating and lighting required in Pennsylvania. The building cost just under $15 a sq. ft. complete. That doesn't tell you anything, I am sure. We have had schools built under different State codes running from as low as $12.50 a sq. ft. to as high as $18 a sq. ft. Again, the variables are so great that it is difficult to give any real cost measurement on the metal curtain wall phase of the project. We have printed technical information for designers, and structural design criteria information for structural engineers, readily available to anybody upon application. Specific information concerning proposed buildings can also be obtained.

John R. Bemis, Acorn Structures, Inc.: Would you explain the reasons why your system is not economical for small (less than 5000 sq. ft.) buildings?

Mr. Deegan: I think the reason why our particular system has not been economical for very small buildings is the fact that about the smallest size steel tube column which we use is perhaps bigger than will be necessary for these little buildings. Our joists again fall in the same category, and little buildings have such a high percentage of metal wall to gross floor area that the higher cost of that unit becomes impractical. It would be much easier to do the same job with more conventional material. We find some of the smaller buildings with a very high perimeter ratio to floor area, which again puts our relatively high cost exterior wall in a disproportionate position in the building as a whole. Actually, a porcelain paneled exterior wall, with or without a window or door, is bound to have a certain basic cost which is higher than that same type of wall built out of conventional material. When that becomes disproportionate to floor area, it then becomes impractical in our opinion. Also, some of the small buildings have a far higher percentage of partitioning than such bigger buildings as schools and office structures.

S. I. Daigle, Unistrut Corp.: How do the ceiling joints look with the 1/4" AD plywood panels? What is the reason for not nailing ceiling sleepers all the way into ceiling beams?

Mr. Pease: The ceiling joint looks the same as any sidewall joint. It is just a butt joint of plywood, much resembling the taped gypsum board joint with which perhaps we are more familiar. We did not, at that time, believe in making the joints apparent. As far as nailing ceiling sleepers is concerned, I think that probably is a little bit of architectural license in making up the drawings. They generally were nailed tight against the joist. The space was allowed so that if the joists were warped or twisted, there would still be a flat ceiling down below.

Arthur Tisch, Independent Nail & Packing Co.: Has your experience shown that roof panel construction and the systems you described are more economical than trussed rafter construction?

Mr. Page: That depends on a lot of factors, including the efficiency of the production line for the stressed skin panels. We have at the present time, I believe, three tract housing operations going on where fabricators are supplying stressed skin panels to builders at costs comparative with conventional roofs. In other cases, that doesn't prove to be true. For stressed skin panels to compete strictly on the basis of cost requires a very high volume, a very efficient fabrication operation. In some cases they do; in some cases they don't.

Mr. King: What about commercial buildings? What has been your experience there?

Mr. Page: Based on actual bid, with a conventionally built motel that was identical to the component motel I mentioned, $70 per room was saved by going to stressed skin panel construction. Again, to make cost comparisons, you have to take two specific situations and compare them. If the plywood structural components are in the right bracket, they compete, and more than compete, with other ways of doing the same job. In some cases, they don't.

Mr. King: As the use of preassembled components increases, will the requirements for skilled site labor, both in quantity and quality, increase or decrease?

Mr. Schuszler: I am only an architect and specification writer. I don't have much connection with our construction division, so I don't think I am competent to answer that. Our construction people who erect the things our company designs are more familiar with labor conditions than I.

Mr. King: Mr. Pease, how about you tackling that?

Mr. Pease: Well, certainly the more fabrication we can do in the shop the lower it will make the on-site requirements for skilled labor. There is no question but that we have to develop these components to the point where they can be put up, not even by semi-skilled, but rather by unskilled labor. We must make them so simple that they just can't go wrong. I think that's the current trend. We could develop panels, etc., that would require more highly skilled labor, but most of our efforts are directed the other way at this time.

A. J. Steiner, Underwriters Laboratories: Have any standard tests been conducted to determine performance under fire exposure conditions, i.e., stability of foam insulated panel due to flame and pressures created by the foam; stability of glue line in varied structural members?

Mr. Page: For many years there has been a standard test for delamination of plywood glue lines under fire. As far as the components are concerned, there are tests being conducted at the present time on the over-all performance of the components in fire, and the performance of the glue line is one of the things that is being observed in the test. With a properly made glue line and the proper kind of glues, delamination under fire is not a problem.

Mr. King: How about entire panel components, for example, the stressed skin panels? Have you undertaken any work in that area?

Mr. Page: The tests being conducted at the present time are being made on box beams. The problem would be the same as far as the glue line is concerned. They are being tested under loads.

Mr. Deegan: At the present time we have not completed any so-called qualified tests on the behavior of the foam-filled panel. We have done some for our own use in our own plants, and at the present time are still mechanically attaching the back face to the front face, until we know a little more about the behavior of a foamed panel under fire conditions. We have not submitted a foam-filled panel for a fire test as yet.

John McIntosh, Neal-Blun Co.: Have you found it practical to sell through retail dealers or have sales been primarily direct to builders?

Mr. Pease: We have not sold through retail lumber dealers. In effect, we are retail lumber dealers ourselves. Most of our sales have been to the builder, although maybe 20% over the years have been made directly to the home owner.

Albert Lalonde, O'Connor Homes, Inc.: Would you please expand on your statement to the effect that the services, such as land planning, financial assistance, etc., will become as important as the product itself?

Mr. Pease: I wish I didn't have to expand on that, because it is what we consider a necessary evil in our business, but the competitive situation in the manufactured home field, and I believe in the broader concept of the components field, has made it necessary that the builder get financial assistance. Therefore, in order to be competitive, you have to furnish the same services. It again goes along with the package concept—we are furnishing a complete building service rather than just individual components. When we started 30 years ago, we were furnishing only the raw materials from which the builder fabricated the house himself. Then we got into the actual fabrication of some of that raw material, and now we just carry it one step further to furnishing those other services that are just as important. In fact, today it is more important to the building operation to provide such services as land planning and acquisition. Land represents a fourth to a third of the cost of any home. Financing represents, in many cases, as much as 10% of the cost of the home. So these other phases are just as important as the structural and mechanical side of the house.

William Lukacs, YMCA Nat'l Council: You used a lift slab on a small building with only 2 or 3 slabs. Is this system economically feasible? What would be a minimum size worthwhile job in sq. ft. floor area?

Mr. Schuszler: That's a very good question and I put that question to our construction people at the time. It was their opinion that with a slab of that size, about 50' x 120', it wasn't economically advantageous to build that way. They said that the system of lift slab construction is much more effective in the larger project, but for a small one like this, they didn't think it was worth it.

C. B. Monk, Structural Clay Products Research Foundation: Do you feel that the mixing of skeleton framing, conventional modes of framing, with panel components disguises the inherent economies of a potential, totally-integrated structural component system? Is this mixing holding back rapid progress in the field?

Mr. Page: I am not sure that I am qualified to answer that. We have not had that question raised in any of our work thus far. It's a matter of another subcontractor being on the job. There is a problem of coordination, such as when the job is ready for the roof, the fabricator comes in with the roof system. I don't know whether that's a good answer or not.

R. F. Below, Republic Steel: What is density of urethane core in your metal panels? Is foam placed in assembled panels with both skins in place?

Mr. Deegan: Actually, the panels are foamed in place with both skins in place, so that the foam becomes the adhesive for holding the two faces in position. We are using about a 2 lbs. per cu. ft. density foam in our normal panels.

B. B. Christensen, Alcan International: How much is included in the 4 lb. per sq. ft. weight figure you indicated?

Mr. Deegan: When I said our building weighed about 4 lbs. per sq. ft., that included the column system, the girders and the joists, but not the roof deck. Actually, those structural framing systems which were most efficiently designed to utilize the standard materials weighed as little as 3.2 lbs. per sq. ft.

G. Cross, Insulite Div., Minn. & Ontario Paper Co.: Please elaborate on the reasons for using blanket insulation in some panels, as opposed to foam plastic in others.

Mr. Deegan: Originally all the panels had blanket type insulation in them; the glass fiber is separated from the exterior face sheet by a stainless steel spacer so that the panel can breathe. We, and I expect other manufacturers of metal panels, who have had trouble with humidity, vapor penetration of the panel and the frost accretion which occurred, were very careful to preserve the ability of the panel to breathe under all conditions and that type of insulation lent itself to those processes the most easily. With the advent of foams, we are not worried about this problem. However, at the present time, because foam is still quite new to us, it still has not completely supplanted the other type of panel.

Stanley Panitz, Panitz Bros.: What effect do you think the growing use of preassembled components will have on the prefab housing industry?

Mr. Pease: We look at it this way—that they are all joining us. We were talking about components and making components as long as 30 years ago. Today, everybody else is recognizing the thing we've been trying to sell for the last 20 or 30 years. There are still many different systems, and the approaches are slightly different. The approach that the NAHB has taken is somewhat different than our approach, but basically we are trying to accomplish the same objective which is, through better engineering and factory methods, through closer control of quality in the factory, to give people a greater value in the home they buy.

Mr. King: Can you envision any system of construction for houses that would enable the fabricator to inventory a substantial stock of structural components, such as walls, floors, ceilings, panels, etc.?

Mr. Pease: This can be done and is done by many of the people in the prefabricating field. The question becomes one of variation in inventory, and whether it is worth while to carry a large inventory of varied materials. There is one rather large company in our field that still makes only one house. We used to make only one house also. In those days, in the winter time, we would make as many as 200 houses and hold them in stock to be shipped out in the spring and summer, but architectural requirements today call for such variety and flexibility that we almost have to make each house to order.

G. J. Schulte, Minnesota Mining & Mfg. Co.: How are the joints sealed in folded plate roofs made with plywood panels? Are better joint sealants needed? Are better paints and coatings needed for plywood exposed to weather?

Mr. Page: On the first question, conventional methods of flashing and roofing are used generally at the present time. However, there is a need for better joint treatments—paints, sealants and coatings of various kinds—and we are certainly following all the progress in that area with considerable interest. We look forward to much better methods of making those joints in the near future.

P. B. Welldon, Hercules Powder Co.: Would you please comment further on the coatings systems for the steel panels you described? What are the advantages and disadvantages of each?

Mr. Deegan: Generally speaking, our exterior panel is Class A porcelain; that is our prime basic finish coating for the outside. The industrial building which I illustrated, the mill head building, was an experiment in single-coat porcelain finish on corrugated steel. The porcelain which we used is called low temperature porcelain, fired somewhat below 1400°F, 1350°F preferably, so that it is reasonably free from the extreme brittleness of the high-fired porcelain. The single-coat porcelain is a high-fired porcelain, and it has a tendency to be slightly brittle under impact. The interior finishes may be porcelain, again Class A, where required for toilet rooms, laboratories, etc., or a good grade of baked enamel finish which is quite commonly used in schools, hospitals and office buildings. We are using a great deal of the new vinyl coated steel, which has texture and color quite suitable for architectural application, a material which is very highly abrasive resistant. It has many other excellent characteristics. It can be washed and cleaned, it does not stain, and is relatively low-cost when purchased in quantities. In order for us to use it successfully, it has been necessary to pick about 6 or 7 most acceptable colors, those appropriate for the type of buildings toward which we are directing our efforts, and to buy the material in maximum quantities to get the advantage of a lower price for long roll. We also use some of the rigidized stainless steels, some of them porcelain coated, for architectural treatment and for special applications. Most of our emphasis is on selection of finishes which will be reasonably free from maintenance problems, and which will cut down the cost of operation of the buildings after their completion.

Mr. King: What factors do you gentlemen feel will help bring about public acceptance of new structural shapes for commercial, industrial, and residential building types?

Mr. Schuszler: Well, my guess is that if we produce finer materials and products of this nature people will accept them.

Mr. Pease: I think there are two factors here. One is what the designers want—what they are trying to achieve. Knowing this, we can produce almost any shape they need. The only question then becomes one of economics. As some of these developments, the stressed skin panels, for instance, and the curved roof panels, become more economical than current systems, they will stand a better chance for acceptance.

Mr. King: You put it on the basis of economics?

Mr. Pease: No, I think it's dependent on both design and economics. We are making a geodesic dome which is sufficiently economical, but it doesn't have the general public's acceptance because of the design. It is a matter of time. In housing, particularly, people are ready for changes, but these changes don't happen overnight as they do in automobiles, appliances and things of that sort. It takes somewhat longer.

Mr. Deegan: I think I agree with Mr. Pease. Our biggest single problem seems to stem from the unwillingness of a number of people to use the so-called standard parts as much as possible. The tendency seems to be the other way on the part of many designers, who call for just enough difference so that the particular panels won't be exactly like those used in a building which was built in a nearby town. We are just experiencing a case of that kind now where a design calls for a change of exterior panel face dimensions from 11'-8" to 12'-2", a very simple and relatively minor change. However, we have to wait six months until we can get the sheet stock rolled again in sufficient quantity to make these panels, because we are equipped to handle only up to 12' sizes. An architect may decide that he doesn't want a window 3'-7" wide, but he wants it 3'-7-1/2" wide, or he wants a door which may be 3'-6" instead of 3'-8", and these dimensions are not available in standard sizes. We have 47 standard colors of porcelain, and yet we find buyers who can't find a suitable color out of the 47. If they would realize the advantages inherent in being able to produce in quantity certain standard size components with standard materials and standard finishes, they could reap great economic advantages. Then, using their ingenuity, they could apply the other products, the other materials, in conjunction with the standardized parts to get the variation which is architecturally desired.

R. A. McGarry, Housing & Home Finance Agency: Is drywall construction being received by the public as well as plastered wall construction? Why has not the prefab industry stressed drywall construction as being equal to the plastered, or wet wall, construction?

Mr. Pease: I can't speak for the national picture, but in the Middle West that is exactly what we have done. Every home manufacturer uses some form of drywall construction, and we find that the demand for plastered walls is decreasing every year. There are still a few cases where plaster is desired, again because of the fact that Mrs. Home Buyer wants her house just like her mother's house, but the acceptance of drywall is rising. I would say it is used in 80 to 90% of the homes built in Ohio, Indiana and Illinois today.

# MECHANICAL COMPONENT CASE STUDIES

Session Chairman - Richard B. Pollman
Designer-Consultant

# The Mechanical Components of the Ferro House

By Gilbert McMurtrie,* Chief Engineer, Plumbing Design
Research Department, American Radiator & Standard Sanitary Corp.

The Ferro Research House is located in Northfield Center, a suburban community southeast of Cleveland, Ohio. The Ferro Corporation with the architect, Carl Koch & Associates, incorporated modular or unitized construction in planning the basic house design. Ferro, with its team of participants, set out to apply mass production techniques to various elements comprising the mechanical components in order that a dwelling might be erected more speedily and more economically than present-day housing.

The primary objectives of the Ferro House mechanical component design search was to provide an opportunity of integrating the mechanical components with the house in such a manner that flexibility, ease of installation at the building site, trade, code and builder acceptance could be accomplished.

Many of the mechanical components of the house are strict prototypes, and require further development and refinements before installation costs, performance evaluation, or dimensional standards can be determined.

Originally the house was to be a 1-1/2-story dwelling with a single bath on the first floor, however it grew into a full two-story house with three bathrooms. The change of plan to include additional bathrooms afforded the opportunity of experience with multiple installations in a single residence, but it also presented an additional challenge by complicating the drainage and venting problems.

For the heating, air conditioning, kitchen appliance wall products and electrical service, currently available mass-produced preassembled units were used. For the purposes of this paper the case study of the Ferro House will deal with these units only in regard to consolidation of these services and products to a centralized location in the house plan. The products themselves are current production models.

In contrast, the three bathrooms and the necessary supply and drainage system employ units of experimental design. The objective of this approach is "units" instead of "pieces" as a deviation from current bathroom product design and installation methods. This unit or component approach offers the opportunity to consider preassembled elements delivered

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*McMURTRIE, GILBERT, Member American Society of Sanitary Engineering; B.A., Carnegie Institute of Technology. American-Standard is a member of Building Research Institute.

to the house site and a reduction in the number of trips involved in the trade operation at the site. The bathroom plumbing products used in the house are current fixtures modified for integration with the unit or component method of installation, and experimental prototype fixtures were specifically designed for this purpose or installation.

The mechanical components for the integrated plumbing, heating, air conditioning and electrical utilities for the house, including three bathrooms, a second floor laundry, and the kitchen appliance wall, originate in a compact center located on the first floor of the house.

Limited penetration of the concrete slab is achieved by bringing all plumbing service supply and drainage to a single opening or pit in the slab, at which point the service and drainage connections are made between the house service and the plumbing or appliance components. A pipe chase extending into the bathroom enclosure contains the preassembled service and drainage for the components and serves as the vertical connection for the upper floor bathrooms and laundry. This supply vent and drainage pipe chase, being independent from the partition walls, presents an opportunity to use a lightweight 2" partition in place of the conventional 6" to 8" "wet wall." In essence, this concept permits the installation of a three-fixture, "L" plan bathroom made up of preassembled components independent of the perimeter partition walls of the bathroom area. (Fig. 1)

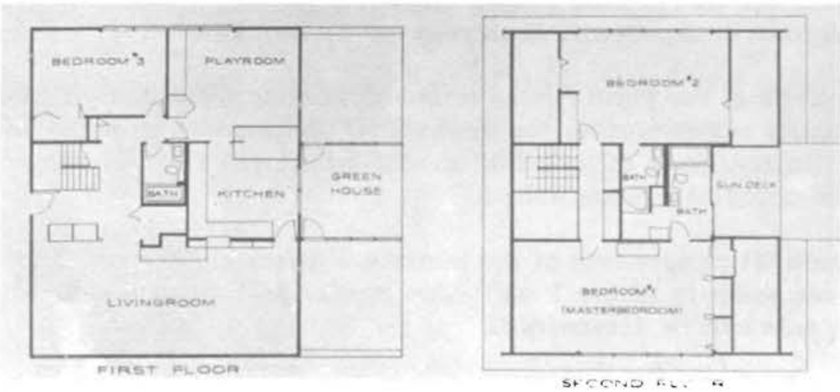


Fig. 1. House plan showing location of mechanical center and bathrooms.

The bathrooms are evidence of the flexibility of size and location for this type of component approach. Although the basic arrangement of the various unitized fixtures is identical, the visual appearance of each bathroom is quite different.

The component treatment of the three-fixture ensemble is divided into two separate units:

1) A lavatory-water closet-cabinet component with accessory wall and lighting. (Figs. 2 and 3)
2) A bathing and showering component with tub, enclosure walls and pipe chase. (Figs. 4 and 5)

The floor-to-ceiling treatment of the complete "L" assembly of two components provides a rigid assembly with self-contained, finished wall surfaces for a major portion of the bathroom perimeter.

Fig. 2. Preassembled lavatory, wall-hung water closet and cabinet component.

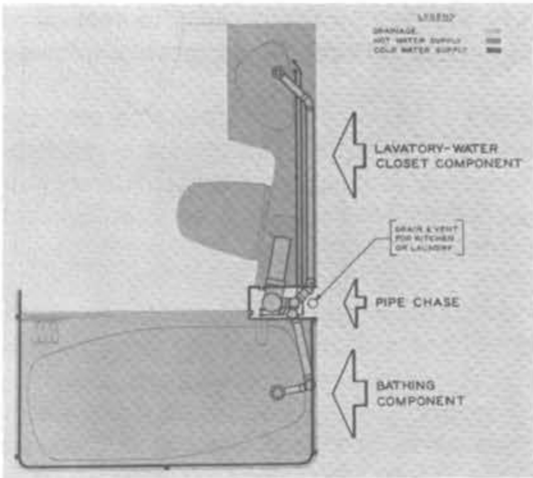


Fig. 3. Preassembled supply and drainage installed within cabinet structure.

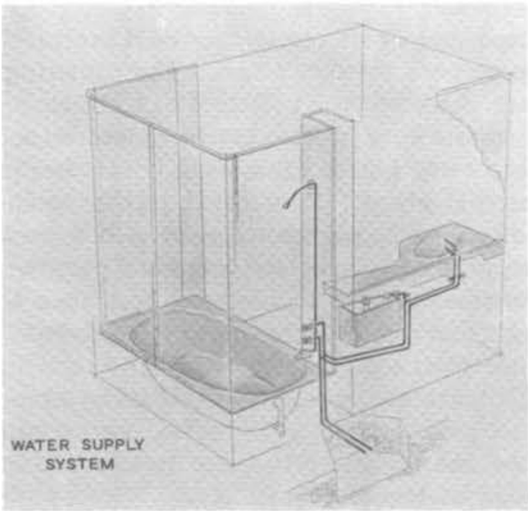


Fig. 4. Tub and walls to be added to lavatory-water closet component.

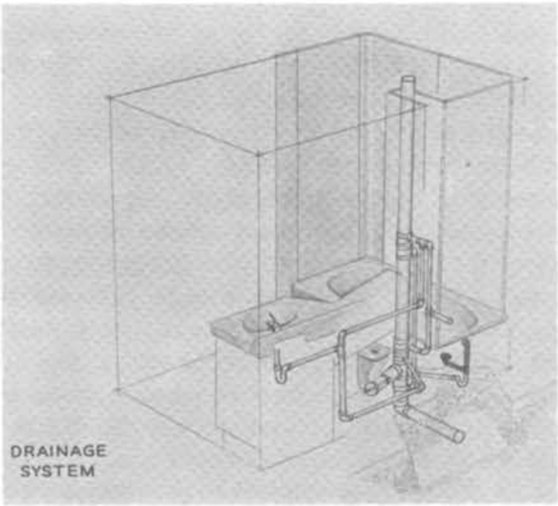


Fig. 5. Supply and drainage for tub-shower component.

Another feature of the unitized approach, and an effort to provide improved installation practice and performance, is the consideration of mechanically joining the bathing unit, tub or shower to the surrounding enclosure walls and pipe chase. This provides a more permanent bond between the walls and the fixture than found in present-day installation methods.

This house is a reasonably comprehensive application of the mechanical component approach with its 1-1/2 floors, three baths, and steel framing erected on a concrete slab. The resultant mechanical components employed in this house are not limited to the Ferro House design or type of construction. Other construction materials, such as wood framing, inclusion of a basement, as well as a variety of architectural styles and plans would be readily adaptable to the use of this same basic component approach.

One of the primary advantages to participation in this mechanical component experiment was the opportunity to conduct a realistic feasibility study on the use of mechanical components simultaneously with the installation and operational problems of providing a house which will be in daily use, and not limited entirely to engineering appraisal and laboratory study.

The development and construction schedules for this house were clearly outlined to participants and included the provision for installing the rough plumbing and other mechanical component connections prior to the installation of the fixtures and finished wall components of the various service centers. Due to variation in the completion dates for various parts of this house, it developed that the mechanical components, including the fixtures, were ready for installation in advance of other elements. Work was permitted to progress and the plumbing, heating and air conditioning services were installed within a skeleton framework of steel columns, resulting in nearly complete bathrooms with all fixtures installed and operational prior to the erection of partition walls, a roof, or any of the rest of the house except the minimum required to support the second-floor bathrooms. This is possibly an accidental exposure of some of the merits of the preassembled component design as applied to on-the-site installation.

A significant design factor in any mechanical component development for residential construction is the code situation. The Ferro House was no exception. The planning of the services and equipment for this house had been done within the limits of the code governing the State of Ohio. However, the final location of the house was determined at a point in Summit County, Ohio. Summit County code authorities were contacted with a request to approve the plumbing supply and drainage plans. The flexibility or latitude of the basic design permitted the required minor changes to be made, making it acceptable. During discussions with plumbing inspectors, the regional code requirements became evident. As an example, due to a lower design temperature for construction in this area, large venting was required to offset the effects of frost reducing or choking the vent stack. The materials to be used for the supply and drainage system were also thoroughly reviewed by code authorities and agreed upon. Despite the success of securing approvals rapidly in this rather stringent code district, it is evident that the potential variations to be found in other areas require a very serious code design study in order to provide the most universally accepted components in a minimum of model variations.

The mechanical component center and adjacent lines to kitchens and laundry are made up of preassembled conventional or standard copper fittings. This was necessary to accomplish the installation within the allowable time for completion. This represents an experimental phase approach with the realization that future studies and development are required to determine whether or not any or all of these subassemblies can be developed into a unitized product with sufficient flexibility to meet a variety of installation and code conditions. This is the key to the future success of the mechanical component method. Flexibility of planning, variable code acceptance, servicability, and improved methods of installation at the building site are all basic requirements for the proper application of the mechanical component concept.

The prototypes developed for the mechanical component areas have served the purpose of providing a basis for continued development with more specific objectives and targets arrived at through the experiences with this installation. Continued search for means of providing flexibility for dimensional tolerances built into a mechanical component is a worthwhile objective to bring about the acceptance of the mechanical component in residential construction.

Professional architectural evaluation to date on the Ferro House has indicated that this endeavor represents a reasonably successful and interesting proposed solution as a beginning point for the component system in residential development. The lessons learned from the Ferro House, and those still to be learned from the study of this development, should result in clearer direction for the future steps required to make the mechanical component a reality in the home building field.

# The Preassembly of Electrical Systems

By Richard W. Osborn,* President
Osborn Electric Company

In the past 25 years we have witnessed a transition from on-the-job assembly of units to factory-fabricated units. These preassemblies take many forms, including:

1) Unit substations
2) Switchboards
3) Panelboards
4) Busducts
5) Motor control centers
6) Terminal boards
7) Wiring harnesses
8) Prewired equipment, air conditioning units, steam generators, boilers, etc.
9) Load centers
10) Temperature control centers

For the purpose of this discussion, I will combine an installation of a temperature control center and a motor control center.

The motor control center (Fig. 1) will consist of feeder protection, branch circuit protection and motor disconnecting means; motor controller and motor over-current protection. These items will apply to each motor. The number of motors is not important, as it could be any number. However, for the purpose of our discussion, we will apply this motor control center to a central air conditioning system having remotely located air handling units and a system capacity of approximately 300 tons. Such a system would normally require cooling tower motors, compressors, pump motors, fan motors, valve motors, damper motors, filter motors and solenoid. In the way of safety devices, there will be pressure switches, oil failure switches, high temperature limit thermostats, low temperature limit thermostats, smoke detectors and vacuum limit switches.

All of this equipment needs to be electrically interlocked to provide a desired sequence operation. In addition, circuitry needs to be designed, so that equipment failure will provide failure in a safe direction. Also to be considered is the programming of the

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*OSBORN, RICHARD W., Member, Natl. Fire Protection Assn. and Chairman, Code and Standards Committee, Natl. Electrical Contractors Assn.; Chairman, St. Louis County (Mo.) Building Commission.

Fig. 1. Typical motor control center.

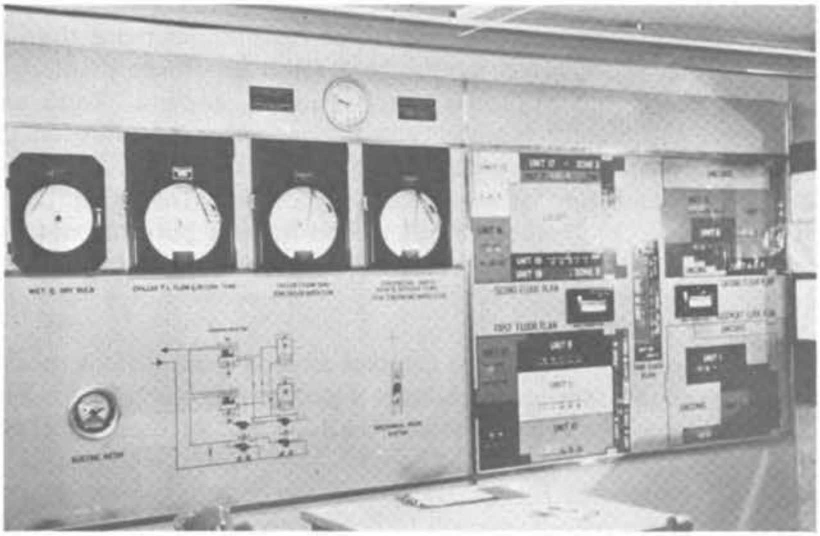

Fig. 2. Typical main temperature control center.

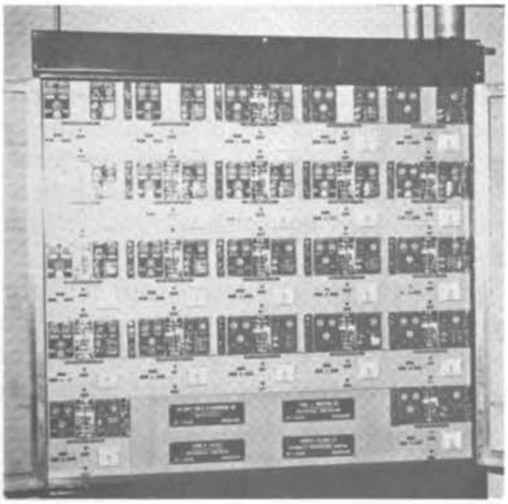

Fig. 3. Typical electronic main temperature control center.

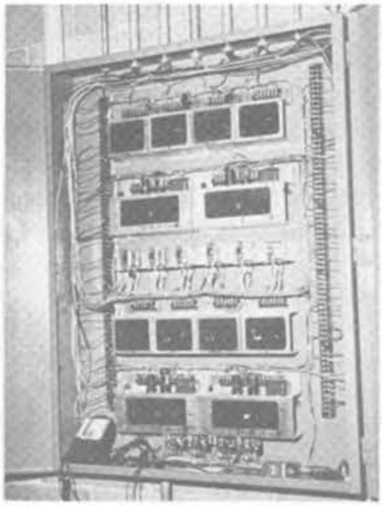

Fig. 4. Typical subtemperature control panel.

various pieces of equipment, some of which will be normally in a standby position. Alternate use of this equipment is desirable.

All of the above indicates a rather complex control problem. As a field installation, it would certainly end up being unsightly, due to the various pieces of equipment required, the network, the conduit and the wiring materials. Fortunately, we have at our command two items of preassembled equipment, which simplify considerably such an installation. We will consider first the temperature control center. (Figs. 2 and 3)

For an installation of this size, we would have a lucite panel in the front of a steel cabinet, which would be painted to indicate graphically all equipment in the entire system. The panel would be approximately 90" high by 12' wide by 30" deep. All motors would be capable of manual, automatic or off positions from this center. There would be such a switch for each motor in the entire system, with the exception of the damper motors, valve motors and filter motors.

There would be a pilot light indicating motor on or off and, if more than one speed, a pilot light for each speed. The panel would be drilled for these pilot lights and switches at the point where the motor or equipment is graphically shown. Each temperature zone would have a constant indicating, remote type thermometer mounted on this same panel, located graphically, to indicate present temperature of that zone. All remotely located thermostats, humidistats and similar equipment would be wired directly back to the temperature control center. Each thermostat would have a potentiometer that would permit the operator to raise or lower the temperature in that particular zone from the temperature control center.

In addition to the above, the temperature control center would have recording thermometers to permit the recording of the temperature from a particular zone when necessary. There would be a trouble bell or other type of signal to indicate failure of critical equipment.

All motors would be connected to motor disconnecting means adjacent to the motor itself, and from this point the motor circuit would continue to its own particular unit on the motor control center. The motor control center would be located in a room which is dry and reasonably free of dust, where temperatures are somewhat constant. All remote control equipment of the motor control circuit must be located in the temperature control center, necessitating control cables between the two points.

Field wiring then reduces itself to simple circuits back to the motor control center or the temperature control center. Interlocking of the entire system is accomplished at the factory, in the motor control circuit or in the damper control. (Fig. 4) Ninety percent of the maintenance required for the system can be accomplished at either of these two points. Maintenance should be low, due to the ideally located equipment.

The cost of equipment is not reduced, and the cost of field labor is turned into factory labor. Factory fabrication is somewhat more efficient and provides for pretesting. This aids considerably in the closing days of the project completion. The appearance of the equipment is usually quite attractive. The construction is substantial and the structure in general is a result of considerable engineering.

The biggest single problem is the moving in and setting up of this type of equipment, which requires large openings, due to its considerable size. However, once set in place, field wiring becomes routine. If, for some reason, a change in the sequence of operation is desired, it can be readily accomplished in the terminal control board at one or both of the two preassembled pieces (motor control center and temperature control center).

Manufacturers have simplified the construction of motor control centers to the point where the assembly of a custom unit is a matter only of removing from the shelf almost all items. Temperature control centers are still in the custom-built category, as far as the graphic front is concerned. However, the other components are so-called shelf items. Labor for such an installation is highly skilled; in some cases it reaches the stage, especially at the system calibration point, requiring a technician. Such a system, once installed and operating correctly, is practically trouble free. The operation of such a large system from a single point is no small achievement. This type of installation is becoming more and more the rule, and less the exception.

# Principles for Development of Mechanical Components for Home Building

By Ralph J. Johnson,* Director, Research & Technology Division
National Association of Home Builders

There has been more change in the character of the home building process in the past decade than during the past 2000 years. An understanding of at least the highlights of this new process is fundamental to productive development of new products or components.

Character of the Home Building Industry

Prior to World War II, 80 to 90% of new homes were built for a known buyer on a "sold" basis. The builder literally assembled thousands of unrelated pieces by measuring, cutting and fitting on the site. Under adverse conditions of productivity, he adjusted all of these unrelated items over a period of six months to a year, so that they would fit and make a house. Today, perhaps 80 or 90%of new homes are designed and produced on a "for sale" basis to an unknown buyer at a predetermined price. Typically, the house is built in a few weeks after the foundation has been laid. This very brief statement highlights a fundamental change which, although evolutionary in appearance, is revolutionary in character. Indeed, home building is well on its way to having evolved from a craft to an industry.

Economic Realities

Greatly oversimplified, it may be stated that in recent years the median price of the house offered for sale has been tending to rise faster than the median family income. It is obvious that this divergence cannot long continue without impairing the market. Unlike anything else an American buys, there is a direct relationship imposed by the mortgage banking fraternity between income and price of house which the purchaser is allowed to buy, if he wishes to use mortgage financing. Under these circumstances, the price of the house has a more critical relationship to its total market potential than any other product offered for sale in America.

Furthermore, it is unfortunate but true that a segment of the working population is financially unable to buy a new home. They have been priced out of the market by skyrocketing costs of land, land development, the rising costs of labor, materials and

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*JOHNSON, RALPH J., Member, American Society for Testing Materials, American Standards Assn., Building Research Advisory Board, Building Research Institute; B. S. in civil engineering, University of Illinois; M. S. in engineering, Harvard University; formerly housing chief for Public Health Service.

financing, and requirements of governmental bodies of many types. The NAHB Research Institute is attacking these conditions by research aimed at improving the quality and reducing the cost of new homes in all price brackets. Component construction is one method of furthering this objective.

Component Construction

Much has been and is to be said about components. Consequently it is important to examine the "why" of components in home building. Some components which apparently cost more money than conventional materials or methods are being used by builders today. How can this possibly be so? Basically, components are wanted and used by home builders because they make it possible to increase productivity, schedule operations, minimize labor and material waste, build during more inclement weather, control and know cost and, in sum total, to reduce cost.

In the research and technical operations of NAHB, there has recently been activated a Components Committee. In the early deliberations of this group of builders, who are now making and using components in their own building operations, one fact about components has evolved: namely, components are a means to an end. That end, basically, is control—that is, control of production, of schedule, of materials, of labor, of cost, and even of money.

Components, as we use the term, simply means parts made off-site, which are modular, fit with each other, serve multiple functions, and inherently make design flexibility possible. This definition is selected to exclude such items as 4' x 8' sheets of a building material, or individual bathroom fixtures which might be called components.

Before proceeding further, it is necessary to make a fundamental assumption: namely, that the development of a mechanical component or a system of interchangeable mechanical components will make a contribution to the value which the home buyer receives in his new home. I firmly believe this is true. It has been demonstrated to be true with respect to structural components, and no reason that I know of exists which would mitigate against the ultimate truth of this assumption as regards mechanical components.

It is inherent in this statement, you will notice, that the buyer is provided with better value. In the fiercely competitive home building industry, material and construction savings are and must be passed on to the buyer. Of course, a corollary part of this is that the buyer will receive a house which serves his needs equally well or better (especially in terms of value) than that which he is able to purchase now.

Mechanical Components

There has been great interest and progress in the development of structural components, but the mechanical systems of the house account for approximately 1/5 - 1/3 of the cost of the house without land (depending on the house and which elements of the total house are included). These have virtually been overlooked.

It is difficult to define mechanical components. However, in our terminology, mechanical components are considered to be those items which will perform the functions of all the mechanical systems of the house. For the purpose of this discussion, these systems are divided into two types, those outside the house, and those inside. The units outside the house are those related to the supply and use of energy and water, and sewage disposal. These are highly important items. However, in this paper, comments will be limited to mechanical systems inside the house.

The mechanical systems inside the house are those described by the words plumbing, electrical, heating, cooling, and kitchen and mechanical appliances.

Plumbing is considered to be the lines distributing and collecting water, used water and other waste, and air, plus the fixtures, which include the tub, shower, water closet, lavatory, kitchen sink, and clothes washing and drying facilities or connections for these latter two items.

The electrical system is considered to be the entrance requirements which are the main and subpanels and control or regulatory mechanisms, and all or part of the distribution system which includes both the high power requirements for heating, cooling or cooking, and the low power requirements for lighting and incidental energy consumption.

The thermal system is considered to be the heating and/or cooling unit, with all or part of its distribution system, and the hot water heating unit.

The kitchen and mechanical appliances include at least some nonrefrigerated food and household accessories storage units, along with the kitchen work surface and sink which is also referred to under plumbing. Optional components include range and oven, either separately or combined, food refrigeration, dishwasher, garbage grinder, and trash burner or incinerator.

Mechanical Component Functions

We have now identified a general common terminology. What about the functions of these systems? Whatever mechanical components are to be produced and used, the needs of the home owner must be kept paramount. The mechanical component should perform the functions of today's units equally as well, but preferably better and more efficiently than those presently in use. As far as the consumer is concerned, there are several prime recurring items: first, better reliability of performance of mechanical-electrical units; second, easier access for on-site maintenance of these units; and third, easier cleaning by the householder, not only of the unit but the space around it.

General Principles

The Research Institute has identified some general principles to guide our own research work in the next decade. These principles, interestingly enough, serve also to define future construction and technical trends in home building. Briefly, they include:

1) Reduce on-site labor
2) Increase use of component parts
3) Reduce required on-site skill
4) Increase the use of multiple function items
5) Increase the use of modular dimensioning and construction
6) Reduce the total weight
7) Reduce the total construction time
8) Increase the prefinishing of materials and products
9) Improve structural connections and fasteners, including the use of glues and adhesives

10) Reduce or minimize the effects of weather on the construction process
11) Improve materials handling at the site
12) Improve the use of tools and equipment.

All of these principles are applicable to the development of mechanical components. Any research and development effort aimed at producing marketable mechanical components should comply with most of them. More importantly, unless there are very compelling reasons, it should not violate any of these principles.

Some of these general principles are particularly related to the development of mechanical components: i.e., the reduction of on-site labor; the reduction of required on-site skill; the use of modularly dimensioned elements; reduction of the total weight; and reduction of the total construction time. Any mechanical component that makes a contribution to these principles within reasonable costs, and with functional performance equal to or better than today's elements, may confidently be expected to have a broad market.

There is, in addition, one other general principle which is particularly applicable to mechanical components, namely, reduction of the required space. Floor space in a house is worth $10 to $15 a sq. ft. A 2' x 2' area for a hot water heater is, thus, worth about $50. Must it consume that much living area? Home builders would like to think this is not necessarily so.

Assumptions

Mechanical components and systems are by far the most complicated, involved and interrelated components which are needed for a house. It follows that specific principles governing their development are, by far, the most difficult to state. It would be relatively simple to make a statement of principles and functions on an idealistic or utopian basis. For example, one could say that the mechanical components shall perform all the required functions, be installed in no time, with no skill; occupy no space; have no weight; and cost no dollars, as well as fit all house designs. This is, of course, absurd, but it does suggest some practical limiting assumptions, as follows:

1) Assume a house design discipline. In the foreseeable future, it appears not to be practical to proceed with the development of a mechanical component core or system that would fit all house designs. A mental multiplication of simple variations like door positions, number of fixtures and elements, lefts and rights, sizes, numbers of baths, bath and kitchen positions, etc., equals more than 1000 different units without any consideration for color, texture or style variation. A practical design assumption that would be, with limited modifications, applicable to at least one-third of today's new houses, or approximately 400,000 houses annually now and twice that many in 10 years, would be to assume that the kitchen, bath, heating and hot water unit are backed up. A left and right of this in one bath, one and one-half, and two-bath models would require only six slightly different units. This is not stated to discourage any corporation which has sufficient time, money and interest from pursuing the concept of the ultimate plug-in mechanical components to be located anywhere in any kind of house. Rather, it is stated to reduce the problem to a practical and manageable form.

2) Assume a dimensional discipline. The industry is rapidly adopting modular dimensioning. For practical purposes, this means that outside dimensions of

houses occur in increments of 2', and inside wall elements occur in increments of 1', although as the industry progresses, a larger module will probably become adopted. Wall thicknesses generally should be limited to even increments of 1", but this need not upset the modular system. For example, if 2, 3 or 5" thick walls are used, space can be "borrowed" from or "added" to adjacent rooms without damage to the design or modular concept. In short, the mechanical component or system must fit the modular discipline.

3) Assume that the critical exterior dimensions of the mechanical core unit are limited in one dimension to a maximum of 8 or 10" (or maximum land shipment dimension in 1' increments) and that the other dimension is to be held to not less than 1' increments. In short, design the unit, if it is to be a single unit, to be shipped on its own removable wheels or trailer truck. It is not possible in a brief paper, to set forth all dimensional criteria, but again I can sum up by saying, it must be modularly dimensioned.

4) Assume that the mechanical component can weigh enough to require mechanical equipment for placing it on the site.

5) Assume that the mechanical component will not have to support any roof or ceiling load, but do not rule out consideration of a two-story unit for a two-story house. (The first and biggest market for a large volume of these units is the one-story house.)

6) Assume that it is possible to have either a "wiring harness" or surface distribution of electrical energy for lighting and low power requirements in parts of the house other than the mechanical component portion.

7) If the mechanical component contains its own ceiling, assume that the clear height from top of subfloor or slab to bottom of rough ceiling framing is 8'1-1/2" and that a minus tolerance of 3/4" may be present. If the mechanical component does not have its own ceiling, then this dimension must be reduced another 3/4", i.e., to 8'0", to allow for construction tolerances).

Certainly other limiting assumptions will be necessary as research and development progresses. The NAHB Research Institute stands ready to confer with any manufacturer to assist in corroborating the technical and marketing feasibility of such assumptions.

Mechanical Component Principles

With the above assumptions in mind, the following principles can serve as guides for development of mechanical components:

1) Development thinking should start with new concepts of fixtures and devices and their relationship to their related parts of the structure, based on their required functions rather than, for example, on modifying to some degree an existing water closet or a bathtub.

2) Provide an integrated, preplumbed, prewired single unit component, which at a minimum contains the "bathroom," heating unit, hot water heating unit, kitchen sink supply and drainage lines, as well as other plumbing lines in the house, the electrical entrance and control mechanisms, plug-in connections for lighting

and low energy circuits, all high energy wiring, and preferably, an installed kitchen sink and one wall of cabinetry. This concept allows the mechanical unit to be installed independently of performance of the other trades or work crews. It should be possible to install it on the site with one connection each to water supply, drain line, gas or oil line, electrical entrance cable, supply and return hot air (or equivalent) and with plug-in connections for lighting or "low power" circuits. If vent lines are used, the unit should be designed to avoid the need for poking holes in the roof.

3) As an alternative to Number 2 above, provide a system of interchangeable mechanical components of "plug-in" or "add-on" type to be used in conjunction with a basic preassembled core element incorporating the objectives set forth in Item 2 to the degree feasible.

4) The total mechanical component unit should be factory assembled, including the application of interior finishes, especially if they are to be superimposed on a substrate. In the alternative case of the system of interchangeable mechanical components, it is assumed that they will be related in part, at least, to wall and floor surfaces, and that they will be partially preassembled and finished.

5) Provide as much design flexibility as possible without harassing the developers of the unit, in the beginning, with the problem of the multiplicity of outside finishes. For example, if the element is to be placed on an outside wall of the house, the practical value to be gained by the use of the mechanical component more than off-sets any secondary site application work needed to apply the outside finish on the unit. The same principle is applicable to the outer faces of the mechanical unit exposed on the inside of the house.

6) Reduce the floor area required for such items as the furnace and hot water heater to the minimum but do not reduce, for example, free floor area in the bathroom below current practice, unless the ingenuity of the designer is such that he can provide equal function in lesser space.

7) Design the component to be self-supporting, assuming that it rests upon a structural floor. For example, do not design the walls so that they need to be reinforced on the site with 2 x 4's.

8) Provide a unit which is a "one call" installation, which can be set and connected in two hours or less, leaving the remaining six hours to close in the structure around it--a currently feasible and obtainable objective.

9) Provide a design with all plumbing lines and wires above the floor or slab surface. (This principle imposes certain limitations which may be undesirable or unnecessary if the mechanical component is designed to be integrated with a particular floor or roof system.) If it is good enough in its entire concept and does not unduly limit design, such integration with other elements like floor or ceiling is acceptable, and automatically voids this principle.

10) Provide for ease of repair and maintenance of mechanical units in place, or for "slip-in" substitution of a new subcomponent for one which is nonoperable.

11) Provide for simple removal and replacement of individual units that are readily subject to obsolescence due to technological progress, in the case of either the single mechanical component or the interchangeable mechanical component system.

12) Provide an entire design which is far easier for the housewife to clean and maintain than currently is possible with individual pieces. Specifically, the new mechanical component should eliminate the nondustable and noncleanable joints, cracks, and inaccessible deep, narrow spaces. This immediately suggests such things as, for example, a bathtub which is continuous with the walls and floors, a wall-supported and integrated "water closet equivalent," and many more items. (Incidentally, there is no real need to continue to think of a "water type" water closet and, as a matter of fact, there are many advantages to eliminating it.)

## Codes

So far, no mention has been made of the related problems of codes and labor practices. It would be folly to say they do not exist. We must believe that they can be solved, for without this belief there could be no progress and we would be locked forever in the status quo. By way of encouragement, I would like to re-emphasize that the NAHB Research Institute and building code department, as well as its labor, legislative and other departments, will cooperate to the fullest extent possible with any group or corporation that will devote adequate resources to the development of a mechanical component. Reducing the total cost of the mechanical systems is a high priority NAHB objective.

## Historical Review

The task of making a marketable mechanical component is complex to say the least, but some progress toward this goal has already been recorded. Patent drawings were submitted in 1931 for a sectionalized bath. A two-section bath in 1938 was produced; a modified bath-kitchen utility core in 1948. Henry Dreyfus designed a two-piece bath in 1957. In Sweden and Russia, they are using prebuilt cast concrete utility "heart" units containing bathroom, kitchen and heating units. In 1960, one particular home builder was building and using a mechanical core unit designed for his houses, containing bathroom, furnace, hot water heater and one kitchen wall. The challenge is great, but I am confident that the imagination and creative genius of American industry can meet it.

In conclusion, it should be emphasized that it is exceedingly difficult even to touch upon the highlights of this complicated problem in so brief a paper. In effect, one must set forth an integrated summation of all his knowledge and experience. Anything less is not adequate for the subject. Certainly, it will take the integrated summation of knowledge and experience of many people to bring a good mechanical core component to market. Its solution will tax the full ingenuity of American enterprise, but the rewards for success will be measured in markets of hundreds of millions of dollars annually.

# The Future of Preassembled Mechanical Components

By John C. Martin,* Asst. Chief Engineer, Non-refrigerated Products
Frigidaire Div., General Motors Corp.

Preceding papers have given a more than adequate treatment of the technical aspects of component construction--past, present and future. To say the least, the future appears to be promising. There are, however, certain aspects of this future which seem to warrant a thoughtful reappraisal.

First, there is the implication that the continued progress of component construction is dependent upon further integration of the building structure with preassembled mechanical components. Second, it is implied that progress in the mechanical component field is related directly to a further increase in the size and complexity of the preassembled package. I do not believe either of these implications is correct.

Underlying all of this is my concern that the thinking being developed in the total field of component construction, but perhaps more specifically in the area of mechanical components, is too much product-, builder- and factory-oriented, and not enough people-oriented.

It is not possible at this time to conduct a complete reappraisal of the component concept. Perhaps, though, in discussing the future of preassembled mechanical components (or for brevity, PMC's) I can pose a few questions from which you can develop your own conclusions.

In a paper delivered at the BRI 6th Annual Meeting in 1957 on the mechanical and electronic appliance components of the future, I dealt chiefly with the potentials of individual appliances in terms of what we called the "function-center" concept. From the technical standpoint, this forecast of future developments has changed little. While progress has been made, commercial reality is still a long way off for such things as the video phones, meal programmers, ultrasonic washers, fog showers, pneumatic beds, and self-guidance controls for automobiles which were discussed in my 1957 forecast. That there is nothing drastically new in the crystal ball may be disappointing to you, but if it's any consolation, remember that there really isn't anything new in our present space age planning that Buck Rogers didn't anticipate 25 years ago. Yet, it is much more exciting now because it is becoming real.

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*MARTIN, JOHN C., Member, American Society of Mechanical Engineers, American Society of Heating, Refrigerating & Air Conditioning Engineers and others; B.A., Wittenberg University, B.S. in mechanical engineering and B.S. in business and engineering administration, Mass. Institute of Technology.

It is with this desire for realism that I would like to approach the future. Realistically, I am convinced that the socio-economic and technical factors involved weigh heavily in favor of some reasonable maximum limit on the size and complexity of PMC's. Why, then, is there an interest in creating super PMC's, such as complete preassembled kitchens or utility cores?

For one thing, we hear much about the reduction in the cost of on-site labor, and other economies which may accrue to the builder through the use of super PMC's, which should then result in a better value for the home buyer.

I will not go into the complicated situation of labor rates and capital requirements except to say that I believe there is a definite question whether there will emerge in the next decade any real cost advantage in factory production of super PMC's as contrasted with site fabrication from the more conventional PMC's now on the market. One of the blessings of the free enterprise system is its facility ultimately to award success to that which provides the optimum economy. Today's packaged, self-contained appliances, air conditioners, and communications systems, to mention only a few, are the result of this phenomenon.

Then, there are often mentioned the use and functional advantages that would accrue to the home owner from larger preassemblies of mechanical components. Actually, it is difficult to validate any use-value advantages by combining several appliances into a single preassembly. This can be particularly questioned in terms of the desired work habits or plan arrangements preferred by the home owner.

Here we come face to face with the human side of the matter, often neglected in "Cloud 13 adventures." The crucial question is, will super PMC's provide the home owner with any real benefits not also possible with products in production today? This is the acid test, for unless real benefits accrue to the ultimate customer, no product will enjoy continued success in the market place. For those who believe that the mission of architecture is to direct the masses to live in conformity with some arbitrary "better life," the super PMC is a potent tool for regimenting the design of family dwellings. Yet, to me, there is increasing evidence that this is not what the American family wants. With a few interruptions, the American family has over the years expressed a rather consistent preference for individuality in home design. One recent survey indicated a willingness among women in communities across the country to spend upwards of $1,000 extra for a new home if it possessed sufficient individuality. In contrast with super PMC's, the variety of appliance and utility components available today offers almost a maximum potential for individual architectural design.

To illustrate how creative and practical this approach can be, Figures 1-3 show a thought-provoking development by the Frigidaire Styling Staff. This five-room collection, called "Ideas for Living," is not intended as a complete home plan, architecturally designed in every detail. Rather, it is intended to stimulate creativity in translation into the design of one's own home. To make these ideas truly practical, all equipment used is now on the market. The application of other features is limited only by the range of imagination. "Suggestions for Relaxed Living" is the theme of the leisure room, (Fig. 1) complete with the modern version of the walk-in fireplace. In it we see the skillful use of materials to amplify the mood of relaxation. The bold grain of the natural woods, the colorful rough weave of the rug, the polished raised stone of the hearth, the adobe wall, the stained glass windows, and the court beyond, all uniquely combine to create the desired mood.

Figure 1

Figure 2

Figure 3

The kitchen area (Fig. 2) has a studio atmosphere, yet with the practical purpose of the homemaker's "control center" for her many activities. On the wall to the right is a mobile grill between two unique storage units. Behind large counterbalanced pantograph doors, shown open, are storage shelves. To the left is the refrigeration center, partially built into the wall. Behind the "chef" is the range, mounted on a slim pedestal rising out of a floor planter.

Behind the range is a storage wall. Three large pantry units pivot out, exposing an entire wall of shelves. Note that with this storage and that shown on either side of the grill, we have eliminated completely the look of the conventional wall cabinets and, at the same time, made maximum use of the important knee-to-shoulder-height storage area.

The use of floor planters, together with the random slate floor, gives a new, alive feeling to the whole kitchen area. The food preparation center includes chopping block; sink with detergent, soap and hand lotion dispensers; and a Lazy Susan tray for sorting and preparing foods for storage or serving. A dishwasher beneath opens toward the sink for convenient loading. At the extreme right, near the outside entrance, is the laundry center.

The careful selection of materials, lighting, and a departure from conventional shapes, combine to create a sense of leisure, even in a busy kitchen.

In the dining room (Fig. 3), there is a successful blending of the formal with a sense of at-homeness. Walnut and leather, with candlelight simulated from the molded fixture above, offer an elegant contrast with adjacent areas. The buffet features its own cooking and warming unit which folds back into the panel when not in use.

The floors of the entrance-ways for this display were made of end-grain wood block, a very practical material generally associated with factory use, but subtly sandblasted to give individual character in this application.

So far, our thoughts have centered on new construction; yet, over any reasonable period of time, new construction represents only a very small portion of our total housing inventory. The dream of replacing an existing house with a new house on the same site has many desirable aspects, but is not practical in the foreseeable future for many technical, economic and political reasons. Thus, the problem of modernization will be with us for some time to come, and in this as well as new home construction, the individual mechanical components, as we have them today, offer several pointed advantages over the concept of the super PMC. With the appliances or PMC's available today, the home owner, five or 10 years, or any time after buying a new home, can carry out a unit-by-unit modernization of his appliances, extending such a replacement program over a time period of his own choosing. He can thus minimize his budget problems, and at the same time be assured that each appliance which he buys will be the latest and best design possible. On the other hand, picture the problem of replacing, as a package, a preassembled kitchen or unitized utility core. Perhaps certain elements included in the new package may be no better than the ones in the old package, but they must still be included in the replacement price. There is nothing gradual about such a project. It is a "package" deal. Over the life of a house structure, the owner of a super PMC-type house may have to be content with a higher average obsolescence for his in-use appliances than would the owner of a home with today's separate appliances, plumbing, and electrical fixtures.

What all this means to me is that the next 10 years at least will see no technical revolution in preassembled mechanical components, although we will undoubtedly see further use of the function-center approach, using site assembly of individual appliance components. But the combining of these existing mechanical components into larger packages at the factory appears to be neither practical nor desirable.

It has been said that, "At every crossway on the road that leads to the future, each progressive spirit is opposed by a thousand men who appoint themselves to guard the past." This may seem to be the situation as I present it, when viewed through the eyes of a battered and bruised crusader. Actually though, this is an illusion. The thousand men who seemingly oppose you are actually moving along with you, but at a slower pace. It is like being in a perpetual traffic jam on the super freeways. You have to flow with the traffic, perhaps gaining ground now and then, but, if not impossible, it is certainly impractical and downright dangerous to try to speed or race ahead. This is true in any consumer-controlled technical field. The technical advances which we seek are possible only when many related elements of our total economy have also made substantial advances. Appliances or mechanical components cannot make these advances alone. They must advance together with the structural and other elements of the building, and the products and services of related industries, including among others transportation, food processing and distribution, textiles, utilities, etc.

Our General Manager has used the story of a hypothetical new product effectively to clarify the picture of the complexity of the forces, both technical and nontechnical, which affect the future of any new development. Inadvertently, news of the development of a multi-widget preassembly has leaked out, and the building industry is excited, even though it's only one laboratory model that works only sporadically and with a dozen engineers in constant attendance, and it cost almost a million dollars.

When will it be announced? We are told it will be shown publicly at the Builders' Show next January. Come January, there it is, still full of bugs; still prohibited by 9 out of 10 building codes; but it is announced. Now comes the question, "When can you get into mass production and begin to sell the mass market?"

There are a thousand factors to be considered at this point, but they all divide into the same two categories as the original question, those factors concerned with the mass production of the product and those concerned with the mass selling of the product. Much has already been said about the technical production aspects of preassembled components, and this need not be repeated except to say that, in this day and age, anything you can afford is possible in mass production.

It is the area of mass consumption that I believe has been neglected in debating the merits of such new product concepts as the multi-widget preassembly. At this point there are four questions which I would like to pose to you as a test for the multi-widget product, or any other product, to determine its probable success or failure in the mass consumer market.

First, consider what the new product supplants. Does it represent sufficient improvement over the old method? Does it offer an added benefit to the user? Looked at realistically, how much is it actually worth to the budget-conscious buyer? What we are really asking, you see, is a question that many people failed to ask in their excitement over the new multi-widget, namely: "Is there really a need and/or desire for this product right now?"

The second area to question is that of application and installation of the new product. Does it require special equipment, special wiring, or special building construction? Is it the right size to fit into the home? Is it flexible or does it require precision construction? Is it easily transported to the site, and on the site?

The third area to question has to do with reliability and simplicity. It is harmful to rapid acceptance of a product to put it on the market before reasonable reliability is assured. Also, the new product must not appear to be complicated and invite service problems, or get too far beyond the knowledge of today's service force. When service is required, it must be easily accessible and/or replaceable.

Question four is: "Does this new product depend on another industry's developments?" The availability of frozen foods in the stores boosted food freezer sales. New textiles affect new washer and dryer acceptance. Color television sets had to wait for sufficient telecasts in color. As an example, the meal programmer to prepare whole meals automatically and on schedule, which I described in 1957, if put on the market today in a practical form and at an acceptable price, would have hard sledding for 10 years or longer, until all the other factors necessary to its successful and practical application and operation had completed their proper evolution.

Sometimes a product gets involved in a fifth area. It finds itself in a position where vast socio-economic changes actually have to take place before there is mass acceptance.

The perspective of history is sometimes shocking for the people who insist on knowing how soon a development will become a successful reality in the market place. The dishwasher offers a good example of this. Washing dishes by hand three times a day is one of those basic household chores that women have always disliked. There never was any question about the need for a dishwashing machine. Believe it or not, the first dishwashing machine was patented 110 years ago, and one was placed "on the market" 74 years ago. By 1920, there were more than 25 dishwashers on the market, but the dishwasher still failed to meet many of our test criteria. It was not until after World War II that the product was right, and there were financial, sociological, and psychological factors working in the dishwasher's favor. Yet, even today, 93% of American homemakers still do not know the joys of using this wonderful appliance.

To carry the story a step further, five years ago we first demonstrated the ultrasonic dishwasher in our Kitchen of Tomorrow. It was not a mock-up; it really worked. And people began to ask, "When will it be on the market?"

Let us test this new development against our criteria for a successful product. While it did do the job, we know the machine was not too reliable. And I won't even tell you what it cost us to build and how much mechanical paraphernalia the engineers had hidden backstage to make it work. Looked at realistically in these terms, a mass-produced ultrasonic dishwasher for home use may be a long way down the road.

The history of the electric refrigerator reads something like that of the dishwasher. Certainly the product was needed, yet only 10,000 were sold by all manufacturers during the first five years. Of course, this was quite an achievement when you compare it with the modern-day acceptance of the electronic oven. In its first five years, only about 3,000 have been sold for use in homes. However, if you will go back and submit the electronic oven to the test questions for a successful product you will begin to see why there still has been no market breakthrough.

So-called electronic refrigeration is attracting a great deal of attention right now. This involves application of the thermoelectric principle which would eliminate the conventional compressor system used in today's refrigerators. There have been "showings" of thermoelectric refrigerators, and some recent government research projects in this area have focused attention on this principle. Just this past year, we have made a remarkable stride in our thermoelectric work, but all of this news is misleading if it causes you to think that tomorrow the homemaker will have something drastically new in her kitchen.

The first model of a thermoelectric refrigerator will probably fail to pass many of the tests for a successfully marketable product. Not the least of these tests is the one which questions the dollar value of the improvement of the new over the old it replaces. After all, both the new and the old have the same temperatures inside.

To summarize in the form of a challenge what I believe all this should mean to you as leaders in the building industry:

1) In planning for progress, remember that the house is a consumer product and the proper perspective of time is a consumable concept needing periodic if not perpetual renovation and modernization.

2) Examine the motives for wanting to make changes in a product or design concept. Be certain to aim first for increased benefits to the consumer, and then to the builder and manufacturer.

3) These consumer benefits must be appraised from the standpoint of long-term satisfaction as well as immediate appeal, if the new product or concept is to have continued success.

4) Give heed in planning and design to the trend toward increased individuality in consumer desires, and increased awareness of values other than price.

5) If you subscribe to my forecast that the super PMC concept will not materialize commercially in the next few decades, then a more realistic way must be found to provide increased benefits to the consumer with the tools at hand. I believe substantial advances can be made in the component concept of structural assembly with the proper use of the PMC's now on the market.

Perhaps I have strayed too far afield from the technical aspects of preassembled mechanical components, but I sincerely believe an understanding of the principles of industrial progress can be a valuable guide to future technical developments in home building. Long-term research in residential building and related industries is a must if our progress is to continue. Yet, I am convinced that the next decade will be primarily a period of reducing known programs to commercial reality and developing their mass acceptance.

And, while all possible approaches to the PMC concept must continue to be explored, I cannot avoid the conclusion that there are many, many American homes being built today that will not provide to their future owners the full benefits of construction concepts and products, including the PMC's that are commercially available now, and for which a mass appeal has been demonstrated.

Equally important to the future health of the building industry is the problem of providing on a practical basis the benefits of modern construction, PMC's and other products, to the owners of the millions of existing American homes. Rising to these challenges is far more important to the strength of our nation over the next decade than any other endeavor of the building industry.

# Summary and Conclusions

By Richard B. Pollman,* Designer-Consultant

The interest which this Conference has demonstrated in the preassembly of various building components, and the problems and the needs of the industry which have been spelled out, have been most instructive to all of us, and should enable us to outline the framework for future research and development of these new building components. All BRI can do is to provide an open forum for discussion between those parties most interested and capable of resolving the building problems which are common to all of us.

What we should do now is go back to our own companies and give these problems consideration. Through contacts made at this meeting, many of us have found people who share our problems and our needs. In the interest of further progress we should not hesitate to contact either the authors of these papers or any other members of BRI to ask for their help and their suggestions, or to tell them what we know that might solve some of their problems.

Thought should also be given to what BRI can do as the next step in the field of preassembled components--what phases of this matter should be discussed in further detail, and which areas may have been omitted that you feel are important. Any suggestions you would like to make should be sent to Mr. Short of Procter & Gamble, who is heading a committee with the objective of appraising the conference and making recommendations to BRI for future planning.

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*POLLMAN, RICHARD B., Member, Building Research Institute, Home Manufacturers Assn.; B. S. in architecture, University of Michigan; formerly engaged in building component development for Reynolds Metals Co., Dupont, Koppers Co., etc.

# Open Forum Discussion

Moderator - Richard B. Pollman, Designer-Consultant

Panel Members - Messrs. Johnson, Martin, McMurtrie and Osborn

Wm. A. Stewart, University of Florida: How is P-trap space achieved?

Mr. McMurtrie: I assume that the reference to the P-trap in this case is the floor drain from the tub unit. This installation, using as we stated a conventional product modified, requires that this space be provided in the slot. As I mentioned, the services were brought in at a pit; the P-trap was located in the same pit.

Mr. Stewart: How are joints made between panel and fixture elements?

Mr. McMurtrie: The joints between the fixture on the wall panels, assuming we understand these panels are porcelainized steel, are made by a mechanical joint drilled through the product and the flange of the wall unit (we are referring now to the bath), and are brought down to a final seal between the top of the product and the flange of the wall panel. I might mention that this is one of the areas of additional technical development that bears a great deal of thought and, in order to accomplish this and to determine how much movement we might have or how much support we needed to have for these walls, it is probably overdesigned in this application. I think future work would indicate to us how far this has to go. These joints, by the way, are also additionally calked with a mastic calking compound in the color of the walls, merely for finish.

Mr. Stewart: What are the principal code difficulties?

Mr. McMurtrie: The code difficulties are not unique in this component approach as we encountered them in the Ferro House. There is no difference in the code problems for this house than there is in the acceptance of any other house. It depends on the requirements in your particular locality. Our experience with the code authorities in Summit County was very good, and there is no single area we could put our finger on that was unusual or where any abnormal code problem was encountered. It is basically a component that employs a reasonably normal application. There is nothing unique about the piping system nor the drainage system. It is merely the application of a pattern acceptable in the majority of areas that require special treatment, such as code districts that have special design requirements. The entire system is possibly adaptable to almost any area we know of today.

Mr. Pollman: In the interest of continuing this for a few minutes, I would like to try to conduct a two- or three-minute TV debate between Mr. Johnson and Mr. Martin. I would like to ask Mr. Johnson how he could justify his position and viewpoint on this program, and then I would like Mr. Martin to justify his position and viewpoint in light of what Mr. Johnson may say.

Mr. Johnson: I think that Mr. Martin is one of the outstandingly competent people in the field, and I assume that his corporation had a look at what he said. My only difficulty in trying to comment on this is that I don't know whether he is trying to discourage his competitors from beating him to the punch, or whether he is trying to justify his position. This is impossible, of course, to ascertain. I don't mean to imply that he is presenting essentially a fallacy here. It is just a part of the realities of the economics of a capitalistic system which I dearly like.

Mr. Martin: Actually, the principles that Mr. Johnson set forth would be an excellent guide for anyone, including ourselves, who wanted to undertake the development of large mechanical components. I am referring here to appliances and air conditioning and other products available today, and this idea of putting them all together in one great assembly. That is really where I drew the line. For anyone who is interested in research on the large components (and I certainly didn't intend to discourage anyone from researching that) I think Mr. Johnson's statement of principles is one of the best that you could use as a guide. What I was trying to point out, though, were some of the realities of industrial product development, some of the problems facing suppliers to the building industry in tackling some of the things suggested. We have been through this several times, and we have accumulated experience in what the problems are and what deters one from marketing such products.

It was said earlier, I believe by Carl Koch, that America was possibly going to leap from barbarism to decadence without having touched civilization. I believe that we are in about the same position in mechanical components. The NAHB would like to have us leap over there, and I wish we could, but I think there are steps in between that are logical, systematic, economically justifiable, that will get us over there in due course of time. What I was attempting to set forth was the way of getting there, not from barbarism to decadence, but by passing through this civilized area, step by step, and not attempting to leapfrog. In industrial product development, leapfrogging has proved fatal, and I certainly wouldn't want to recommend that.

Mr. Johnson: Mr. Martin is opposing what he calls PMC, the single unit. Actually, the fabricator and home manufacturer today are making and using one, doing it because of its dollar advantage, unquestionably. On the other hand, I think I mentioned two alternative approaches to this. One is the system of plug-in components, the hook-them-on-quick type, that could be built around a central core unit. All Mr. Martin has to do is take the wheels off a couple of his appliances and redesign a connection in the core unit, and he is in business. This is an interim approach, or it actually may be in the long run a more advantageous one. This requires a great deal of study, research and understanding, including marketing research. I am highly in favor of such a unit. It could be put together in two hours, and I don't think that this is really impossible at all. I recall in the first work on the NAHB Austin (Texas) Air

Conditioned Village, some six or seven years ago, the on-site labor for the electricians for connecting one unit was about $250, and shortly thereafter one of the manufacturers had one all pre-wired which, all by itself, reduced this cost to about $28.

Robert Holtz, B. F. Goodrich Co.: The use of prefinished wall panels creates a problem for wire distribution. What is being done to integrate electrical distribution wiring with panel construction in home building?

Mr. Osborn: Actually, nothing is really being done except that we do have surface wiring systems that could do the work. Personally, I think they are unsightly, but there is no accounting for taste. Some people want all the colors. Perhaps surface wiring is preferred by some people, but it is rather expensive. A surface wiring job in a residence will cost considerably more than a conventionally wired house rendering the same service. So far as I know, there isn't anything being done. We do run into some code problems in the support of outlet boxes, and things of that sort. If you provide for these supports in all the places the home owner might want outlets, then your costs go up initially.

Where you insist on having finished walls, I don't think they are going to have any prefabricated wiring except for that installed by the rope method, and this is rather expensive. The surface wiring is the other answer. We used surface wiring in a house where the wire was surface-mounted and then was covered with molding. This wasn't unsightly and it worked out pretty well, but that was a case where there was time to put the architectural treatment on the molding.

Mr. Johnson: I assume from his remarks that Mr. Osborn is more acquainted with the large building type of construction than home building. There is quite a lot going on in the matter of surface wiring, with very substantial improvement and considerable change going on right now in the home building field. In our own work, we've managed to bring the cost of the item itself down 75%. The unsightly metallic units are still available but are very costly to install. As for the materials themselves, they are so expensive that for practical purposes they offset the advantage of the component part which has both skins applied before it reaches the site. When I say 75% reduction, I mean just that. There are at least three corporations we know of that are working on this. A man was in my office this morning talking about what might be a workable solution. Further than that, I know we are not far from remote-operated light fixtures, that is, sonic actuated. This is about a $9 unit which is pretty close to the cost of an extra switch. There has been a lot of progress on this score by the plastics manufacturers also. Most of these envision a simple Underwriters Laboratory type of approved wiring and outlet system with an extruded plastic cover which does a combination of things. I think the next step involves the electric heat manufacturers. There is a possibility of developing a combination of that surface distribution system with an electrical heating unit, either on the surface or in the panel, or in the component part, and then you can start building up multiple functions. One of the general principles that I mentioned was that if you start to deal with a large enough dollar volume, other things become possible.

Mr. Osborn: There seems to be a difference of opinion as to what we are talking about. As I pointed out earlier, the problem is not the wiring in itself; the problem is licensing. We have at least ten different systems at our disposal that are currently produced. The plastic type outlet is not new, we have used it for some 20 years now. I am talking about what we can do to wire a house, once you deliver it. There is no problem about what we could do with a house at the factory; that only means bringing a licensed electrician to our factory to wire it. There is no trick to prefabricating wiring. You can wire a house almost completely within six to eight man hours after it hits the site. We've done that. But it was my understanding that we were discussing what we can do to a house now, under the present conditions. The only thing I can come up with is what I've said; wiring must be done after it gets there. If a house is going to a community where licensing is not required, of course you can completely prewire it, including the application of all the finished parts except the fixtures, which might break easily. In some cases we install those ahead of time, too. There is no problem to it if you can overcome the licensing requirements, and it can be done much more economically than it can in the field.

Thomas E. Werkema, Dow Chemical Co.: On the basis of reaction to date, do you think the component developed for the Ferro house (or one very similar to it) can be marketed?

Mr. McMurtrie: The reaction to date has been rather sporadic and it's certainly not sufficiently far along to base any marketing plans or calculate any market acceptance on this information. It's going to be some little time before that will be a reality.

W. H. Lewis, University of Illinois: You referred to positive future improvement in the area of plumbing through tests. Would you expand on this?

Mr. Johnson: We have preliminary hydraulic data which indicate that substantial savings in the venting system of simplified and engineered plumbing systems are possible. When enough such data are put together, we will do something about it. It will require about two years of very careful, authenticated laboratory data. Incidentally, I think this is the core of all the code problems. We have had a considerable amount of success in the code field. We have been working with competent people, the model code bodies, BOCA, Southern and International, and a lot of progress is being made in that area. If I were they, I would be supersensitive to all the comment about codes, but they are thick-skinned enough so they seem to stand up under it. I think that the basis of our code problems is our fault. It's ignorance; we're stupid. We go to a plumbing or electrical or building code body and say, "We think that this ought to be accepted." And they say, "We don't think so." So we are only matching opinions. One corporation has recently been marketing a stressed skin component panel that has no studs in it. That's a little bit worse than a 24" stud spacing, but they are having remarkable acceptance. As a matter of fact, over 150 communities where they have never even sold one, and probably don't intend to for some time in the future, are writing in and asking to get the information. They would like to accept it. This is almost an unbelievable reaction. The word has gone around that they have really complete, scientific engineering data covering fully those things which are necessary. When we reach this stage I'm sure we won't have nearly as many problems with codes as we have presently, or think we have.

# Conference Roundup

By William H. Scheick, Managing Director
American Institute of Architects

I believe I have never attended a BRI conference with more real meat in it, and with a more mature attitude taken by the part of the people who presented the papers, than this one. The optimism expressed in their thinking is very different from such a conference ten years ago. And, remember, many of these men, home builders particularly, are men who must find time for this activity in between beating their brains out on problems of land cost, codes, financing, and all that sort of thing. Yet, they are still hopefully keeping at the job of making the house, itself, better and more easily available to more people.

Carl Koch made a very profound statement in which he used three words: civilization, discipline and imagination. He is talking about the state of civilization we live in today, and is asking, in fact, why we don't do what has been done by designers down through history--use the best methods available for building that this civilization offers to lead us toward the goals of industrialization.

The papers devoted to attitudes toward the use of preassembled components really set up certain hurdles that must be surmounted, and yet they took a cool-headed attitude toward these, named certain problems, and suggested how they might be overcome with procedures which are available to us. The group of papers on principles of fabrication all seem to agree that we are at a very unsophisticated stage in the development of components, but Mr. Brockbank, Mr. Worth, Mr. Parkinson and Mr. Johnson all spelled out objectives and very definite requirements, which are the things that research people must have to make a start. These were not narrow, binding requirements, but broad statements that do not cramp imagination. Generally speaking, these authors shared the optimistic view that competitive research will move this industry forward to more sophisticated components, and finally, to the completely industrialized house.

Other papers dealt with the application of some of these principles to nonresidential construction, and I am quite convinced that we have fewer problems of consumer acceptance in nonresidential construction than in residential. Thus, we may see more rapid progress there.

This Conference brought out some good examples of component development, primarily related to steel and wood, respectively. The discussion of mechanical components was interesting, because it was presented by people who have been industrialized for quite some time. Mr. Martin, representing a marketing-wise industry, pointed out some real hurdles and check points in the rush toward total industrialization.

Let's take a look at what all this means to those who are ambitious for progress in the component field. We found out during the course of the Conference that there are many different kinds of people ambitious in this field. We have the builder himself, the lumber dealer or materials dealer, the manufacturer of building materials, and the dealer-fabricator, all going into this field and moving ahead.

George Cline Smith of the W. F. Dodge Corporation has predicted that the decade of the 60's will result in a total of $950 billion worth of construction. While this figure includes highways and heavy construction, it is still a good 40% more than the past decade. He has also cautioned manufacturers that the market competition is going to be terrific.

Another group meeting recently agreed that there will be thousands of fabricators of the kinds I mentioned who will want to get into the component field, but many of them will fail as research leaves behind the inefficient. The do-it-yourself craze will probably very soon be as obsolete as the hammer-and-saw tradesmen, when it comes to building houses. One comment was made in this meeting that seems very reasonable to me, and that was that the home builder himself, as we know him today, will prefer to be, and be most successful by being, just a home seller. The fabricating industry will supply this man with easy-to-erect houses that he will be good at selling. Just what that fabricating industry will consist of is an interesting question.

So, for those who would succeed, I think our experts are trying to tell us that design and engineering concepts must be complete, using the advanced techniques and plan illustrations that were described, for the more complicated structures. The architects will probably hire model makers, not draftsmen, for this work. The designer must understand the disciplines and the problems of this system, and the behavior of materials, since he will often be using several systems together.

Each component concept must be tied to an over-all comprehension of the complete house or building, and of all the materials and components other than the manufacturer's own component, with which it is to be used. If you are designing, you must also have that concept. The cost analyses are mandatory, and again they must be made on the basis of a complete structure, in terms of man-hour savings, overhead savings, transportation costs, etc. It is encouraging to some people producing more expensive materials that you may find out you can use more costly materials because you can show a net saving in the entire process. But first, you must fully comprehend shop processes, investments, tools, and the different labor attitudes involved. Then you must think about getting your shop-produced items onto the site where they are handled or erected by people from different labor trades, and probably with very ordinary skills.

Certainly, the contractor, Mr. Norair, made it very clear that extensive testing is necessary, and Mr. Parkinson gave a good description of how his organization is accomplishing that. It is necessary to guarantee the performance of a component, always remembering that a failure which causes a builder trouble can be a serious setback, and would be almost a fatal setback to a fabricator.

Finally, it would seem that you must keep yourself informed and abreast of developments in your field and by your competitors, if you don't want to be one of the many expected casualties in this business of component fabrication. This means you must keep abreast of the building market itself. If you are doing research, you must keep in mind the question of lead time. In one industry that is interested now in such things as fabrication, the feeling is that more-or-less conventional construction is preferable. Such an attitude is all right provided they also ask themselves about the longer view and whether someone else is stealing some lead time from them; has them down one, two, or three years, because they are not taking the long view at the same time.

So, we can conclude that competition will be of the essence in the field of preassembled components. Still, we are all in the same boat, and therefore the sharing of ideas will be beneficial to all. The Building Research Institute provides a good means to continue doing that.

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