The Pennsylvania State University

PROBLEMS AND PROGRESS IN HOME BUILDING

Better Building Report No 2

BUILDING RESEARCH CENTER

Engineering Experiment Department

JUNE, 1959

ENGINEERING RESEARCH BULLETIN B-77

College of Engineering and Architecture

University Park Pennsylvania

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The Pennsylvania State University

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Papers presented at the Small Builders School
at The Pennsylvania State University
March 5-6, 1959

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ACKNOWLEDGMENTS

On behalf of the Building Research Center and those it aims to serve, we accept the challenge of our sociologist friend, Dr. Coutu, and acknowledge with appreciation the help of our many associates in the College of Engineering and Architecture. We appreciate the generous assistance of J. Alvin Hawbaker, Regional Vice-President of the Pennsylvania Home Builders Association, who provided publicity and visual aids. And of course our plans could not have borne fruit without the cooperation of General Extension in making the arrangements necessary for the successful first meeting of the Small Builders School.

F. A. Joy
G. J. Stout

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WELCOME TO THE SMALL BUILDERS SCHOOL

Paul Ebaugh, Assistant Dean for Research
College of Engineering and Architecture

With funds appropriated by the Pennsylvania Legislature, the University has established a research program designed to aid the building industry within the Commonwealth. The work is centered in the College of Engineering and Architecture, but as you will promptly note, we are happy to draw upon the specialized knowledge available in other Colleges on campus. After an early planning stage under the supervision of Professor Frank Joy, our actual research got off to a flying start in 1958 with the addition to our staff of research associate Jerry Stout. Now the results are becoming available to you.

At present our budget is small, but we have asked the Legislature for an increase in funds for the next biennium. We have, of course, no way of telling what that budget will actually turn out to be. It is possible that we may be able to interest industries or industrial associations in sharing the sponsorship.

The results of this research program will be made public in a series of Better Building Reports. Their aim is to help the builder, in specific ways, to build a good product at a saving. The first of these -- Better Building Report No. 1, on the subject of "Slab-on-Ground Construction of Homes" -- is just off the press and is available in the hotel lobby.

The talks presented at our first Small Builders School will be published as Better Building Report No. 2. This will be sent without charge to all people registered here as soon as it can be printed. In the general case, we are forced to make a nominal charge for these reports in order to extend our research dollars a bit farther.

Other reports are planned for early publication. You will hear talks today and tomorrow that touch upon some of the subjects; for example, purchasing, scheduling, control of operations, and preassembly of components.

One feature of our overall program is the Small Builders School, which we plan to make an annual event. In this, we have a double aim: to pass on to you who attend some new ideas that you can take home and apply in your business, and to learn from you what problems are bothering you, what things need investigation. In the question periods and discussions, please don't hold back. If the experts don't have ready answers, your questions may be our best guides in planning future phases of our research. Please, then, let's make these sessions informal. If you have anything on your chest, now is the time to get it off!

I want to welcome you to the University, and to say that we sincerely hope you will benefit from the program we have arranged for you. By benefit, I don't mean culturally or esthetically, I mean through new ideas that, when put into practice in your business, will better satisfy your customers and will help to fatten your pocketbook.

BUILDING FOR HUMAN RELATIONS

Walter Coutu
Professor of Sociology

I have studied your two-day program carefully. The entire program is designed to help you; to help you cut costs, possibly to help you cut corners. There is nothing in the program to help the poor devils who have to buy your houses. I see that the committee has even corralled my friend Dean Williamson to tell you at seven o'clock tonight what more Penn State can do for you. Presumably Penn State can do nothing for its students, who will some day be your victims.

Two days are devoted to helping you; I have only thirty minutes to defend the American family.

PROBLEMS OF HUMAN RELATIONS

You gentlemen are interested in the stresses, strains, quality, and durability of materials. I am interested in the stresses, strains, quality and durability of people -- people who unfortunately have to live in your houses.

Every sociologist knows that the most difficult animal to live with is another human being. Man is the only animal of whom it can be said that one of his most difficult problems is how to live successfully with his closest friends, his relatives: husbands, wives, sons, daughters, fathers, mothers, sisters, brothers, and Lord help us -- sometimes in-laws, uncles, aunts, and cousins. I wonder if you ever wake up in the middle of the night and pray, "Lord, please send me a stranger." Why are human relations so difficult? We have plenty of evidence that successful human relations are difficult.

We have one of the highest divorce rates in the world. The average marriage in the United States has little more than a 50-50 chance of success. This is pure chance. Apparently the best way to kill a love affair is to get married, because you are then sentenced to live in a house. And you gentlemen build the houses.

Second, we have an increasing volume of juvenile delinquency, which is difficult to explain to other nations of the world, especially to the Communists. Does this mean that in our society youngsters do not consider family living fun and exciting?

Third, we have more cases of rape, assault and battery, and murder than any other country. We are a violent people.

Fourth, we have so many types of frustration that we lead the world in rates of nervous breakdown, neurotic wives, and what we please to call tired businessmen. ("Tired businessman" is merely a polite name for the neurotic husband. He is overwhelmed, not by his work, which he loves, but by the thought of what he is in for when he gets home.)

Fifth, we are witnessing what we call a population explosion -- the enormous increase in the birth rate since 1940, after 100 years of declining birth rates. This is as much a problem for you as it is for the sociologist. It means more true families. But do you really build houses for families? In a recent study I asked a large number of students how many children they expect to have. Girls said 5 or more; boys, 4 or more, despite the fact that, historically, college graduates have fewer children than others.

The sixth problem of family living today is the problem of discipline, the problem of incorrigible and rebellious children of all ages and both sexes. Is this because children somehow have changed, or is it because the houses that you build are not really built for families?

We have enough research in sociology to give an accurate account of the extent of these problems, but we are not quite sure about causes; and since I am not completely sure whom to blame, I thought it would be a good idea to blame you. For I am more and more convinced that these, and still other problems of human relations, are largely due to the space arrangements to which you people seem to be enslaved by tradition. Why don't you try something different -- if for no other reason than sheer adventure!

FRUSTRATING FUNCTIONAL FAILURES

Frustrated functions make frustrated people, and frustrated people frustrate other people, and it spreads throughout a community like a forest fire or a chain reaction. It is 7:30 on a spring morning. Mother wants to get an early start at housecleaning. The long parade of separate breakfasts is finished, so mother removes the curtains in the livingroom and gets on a chair to wash the upper part of a window that is stuck and cannot be pulled down. The chair tips and she falls, skinning her leg.

The "old man" runs in to see what happened, and in between some healthy cussing she yells at him to pull the top of the window down. He hammers and pulls and bangs with his hand, but nothing happens; so he grabs a mullion and pulls with all his weight. The mullion breaks and he cuts his hand. Frustrated and angry, he yells, "To hell with it!" and heads upstairs to the bathroom to get a Band-Aid.

He opens the medicine cabinet and out fall three bottles, a tube of toothpaste, and a box of face powder. One bottle breaks on the washstand, and the face powder and the broken glass cover the floor.

Getting madder by the minute, dad takes the other bottles and the face powder box just around the corner, and puts them in the linen closet in the hall.

Just then daughter, racing for school, rushes into the bathroom and closes the door. A scream is heard in the bathroom, and daughter rushes out, cussing dad because her shampoo bottle is broken, her face powder all over the floor, and she cut her toe on the broken glass, and it's all dad's fault. While she is dressing down her father, mother comes upstairs to get the antiseptic for her injured leg.

The general racket awakens little brother, who, discovering that he has dysentery, races past the angry mob and into the bathroom. There the three of them stand. Since they cannot get into the bathroom, they glare at each other and figure they may as well fight; whereupon mother lights into dad for cluttering up the linen closet with bottles, powder boxes, toothpaste tubes, and whatnot.

At this point the family dog starts upstairs to see what all the ruckus is about, and the cat follows up the stairs to see what the dog is up to. By this time the "old man" has had it. Fleeing down the badly lighted stairs, he stumbles over the dog, and the two of them roll down the stairs and land on the cat. The terrified cat makes a mightly leap and lands on the baby's crib. Now the family is really living! The baby is screaming, the dog is barking, the cat is hissing, the daughter is crying, and mother screams to the Lord to give her strength, while the old man, unable to take any more, races out of the house, starts his car at 40 miles an hour, and smashes into the neighbor's parked car.

Jones comes barging out of his house with shaving cream on his face, and he and the "old man" have a set-to, during which they bring up and settle some previous scores. Badly frustrated, Jones dashes back into his house to finish shaving, only to find that his daughter is now in the bathroom. Furious, he kicks the dog, the dog bites the cat, and the cat leaps into the baby's crib.

The "old man" races on to his office, furious with frustration, goes through a stop light, gets a ticket, and gives the cop a lecture. The cop is mad and bawls out the next motorist, who races to his office burning with resentment, fires his office boy, and snaps at his stenographer. She goes home mad and refuses to keep her date with her boyfriend; he gets mad, slaps his sister, kicks his dog, the dog bites the cat. . .

Within three hours this chain reaction has covered most of the town, and it all started from a stupid window in one of your houses. The best of the windows I have known get stuck now and then, and the top of the window is always hard to reach. There is also more heat loss at the top of the window, so why don't you eliminate it! Horizontal windows give more privacy, reveal more of the outdoors, give more light, save heat, require less expensive curtains and draperies, and are easier to paint and wash. But you continue to build vertical windows.

That was quite a scene inside and outside of the bathroom too, and I think it is not much exaggerated. If all of you were to sit down and figure out the worst possible place in the house to put the medicine cabinet, you would all come to the conclusion that the bathroom is the worst possible place, yet that is where you always put it. Even the cellar would be a better; at least you would have free access to it at all times. The bathroom is private when occupied, but the kitchen is not. Since I moved my drug department to a specially designed cabinet in the kitchen, I have not beaten my wife once.

And let us take a look at your beautiful but stupid bathrooms. This is really something! A bathroom is a highly functional unit, used for a large number of purposes: shower baths, tub baths, shaving, hand washing, face washing, make-up, normal elimination, enemas, bathing children, brushing teeth, combing hair, and many others. By tradition, most of these activities are private; therefore the room is traditionally private. If a person goes in for one purpose, all of the other facilities are immediately tied up. They may just as well not exist.

When dad's in there shaving, he closes the door; but mother wants to brush her teeth, little sister wants a tub bath, older sister wants to put on make-up, older brother wants to take a shower, and little brother has dysentery. So when dad comes out, he finds the whole family lined up, standing on one leg, wanting in. Not even architects could figure out a more stupid arrangement.

Then there is what goes by the name of "linen closet" in the hall. This space is usually not planned, it is merely a bit of waste space left over on the drawing board. I've seen so-called linen closets 3 feet deep and 2 feet wide, and every time you pulled out a sheet everything in front went on the floor, including the overflow from the medicine cabinet in the bathroom. Is it too much to ask that linen closets be planned instead of discovered?

This raises the question of closets and storage space generally. Every family is overwhelmed by labor saving devices and the endless gadgets of our civilization. Every room involves something that has to be stored at times, and everybody in the family has many things that need to be stored. Instead of using accidentally discovered left-over space, we ought to have intelligently planned closets and cabinets specifically designed for certain things: space for card tables, space for ceremonial equipment as for Christmas, space for games, guns, fishing tackle, golf clubs, skates, sleds, toys, umbrellas, extra light bulbs, candles and candlesticks, travel luggage, electric fans, cameras and photo supplies, vacuum cleaners, terrace and porch furniture, outdoor games, and dozens of other things (as the auctioneers say) too numerous to mention.

Then there is the ever-present problem of clothes: summer clothes, winter clothes, rain clothes, sports clothes, and work clothes, for every age and sex as well as for evening guests, week-end guests, and vacationing guests. Men get tired and neurotic, not from their work but from thinking about what they are in for when they get home. Dad comes home and goes to hang up his coat, but raincoats and overcoats are packed in so tightly he breaks a couple of hangers trying to wedge his coat in. With blood in his eye he gives a mighty push and gets one shoulder in, only to have a couple of hat boxes fall on his head. When he tries to push the lower part of his coat in, he gets into an argument with the vacuum cleaner.

A long series of small frustrations like this, small individually, build up cumulatively to dimensions that result in personality problems and difficult family relations. Sensible planning and a courageous disregard for tradition in space arrangements can make much happier people.

TRADITION VS. INTELLIGENCE

Tradition can be a tyrannical master, irrational, unreasonable, relentless, and powerful. I know you do not always have a free hand; if you build houses to sell, you like to play it safe. No builder wants to be a bankrupt hero. And frequently your hands are tied because people come to you and ask you to build the dream house they have dreamed up. You may depend upon it, they are bad dreams. The divorce rate and other social problems I have mentioned are convincing evidence that people do not know what they need, even though they may know what they want.

But the responsible builders in any society are something more than office boys who merely do what they are told or what they are paid for. A house is a work of art, but it is not like a painting that you can destroy if you don't like what you have done. Long after you are dead your house will remain -- a blessing or a curse to the community.

I know builders who excuse bad building practices by saying, "Well, I have to give people what they want." These builders are little men. What people want is frequently not what they need. You gentlemen are men of specialized knowledge and technical skill and professional judgment. But you grow timid and frightened and you lose the sense of your own importance. You tend to emphasize your role as salesman instead of your role as builder and consultant. In a very real sense you can be doctors of human relations.

In my work we often study ancient civilizations, and when, with pick and shovel, we dig up some old civilization to study what it was like, all that remains is what the builders built. The great symbols of every civilization are what its builders build. The role of salesman can be great, too, if you build what you believe in, and then sell with dedicated conviction. What kind of medical profession would we have, if the physician always gave people what they want! What kind of university would we have, if we always gave students what they want! We give them what we know they need, and we sell it with conviction!

With that invitation to greatness, let me now suggest some crazy ideas. Every bedroom I have ever seen looks like the annex to a furniture store. The furniture is bulky, ugly, and expensive. The rooms are usually too small for anything but sleep, but much larger than this function requires. I have never known either an architect or a builder who ever gave the slightest thought to this room as a place to sleep. The room is designed and built for only one purpose -- to store the ugly furniture. This is revealed by the fact that we even call it a bedroom, not a sleeping room.

We open a window at night to get fresh air, and in the morning it is so damn cold we leap out of bed, grab some clothes off a chair, and high-tail it to the hall or bathroom where we can dress without shaking our teeth out.

Let's you and I make an intelligent design right here and now; let's be real crazy. Let's build, on an outer wall, a small closetlike room just large enough to hold a built-in double bed, or if you wish to reduce frustration, two built-in single beds. They are built up from the floor so mom won't have to sweep under them. Since we sleep in the dark, we will have no windows, or at most a small high-up transomlike window for ventilation. At the end of this little room let's build an honest-to-God clothes closet.

The door from the sleeping room leads into a wonderful room with built-in drawers and cabinets, including a comfortable built-in writing desk and some built-in book cases. Here we will have comfortable chairs, good reading lamps, a chaise longue, and movable racks to hang our clothes on when we go to bed. And let's put a washstand in this room, with a cabinet for shaving supplies and make-up.

When we leap out of bed in the morning we merely step into this warm, comfortable, pleasant, private dressing room. Furthermore, for other times of the day here is a lovely quiet place to read, write letters, study, or sew -- and a place where dad or mother can escape the mad turmoil of civilization when they feel they're going nuts. Where can they escape to now? Oh sure, they can flee to the bedroom and sit on a straight chair between the end of the bed and the dresser and twiddle their thumbs. The need to be alone at times is an absolute essential in this Aspirin Age.

All members of the family have a need to be alone. And all ages and sexes should have a place to be alone with their friends of their own age and sex. If we build the same kind of rooms for all the children, teen-age daughter can even entertain her boy friend in this kind of room with no embarrassing bed to forbid it. These rooms are not bedrooms, they are sitting rooms, visiting rooms, reading rooms, thinking rooms, peace and quiet rooms, with no moral implications whatever. And they are perfect in times of sickness; just bring in a day bed, and it will be almost fun to be sick.

If I had time, I could get critical. I should like to mention one more intelligent idea -- that is, one more crazy idea. In every society in the world, the institution that preserves the most heart-warming ceremonial, which provides the strongest and most enduring bonds of affection and security, which binds the family together forever, is that superb human creation -- the family meal. Its power and beauty have largely disappeared from our society, and it is partly your fault. What have you done with the dining room!

Oh, I know, space is expensive and you want airiness and free-flow throughout the house. Besides, you say, the dining room is used only once or twice a day... How many times a day do you use your church! How many times a day do you express your love for your father, your mother, your wife, your husband, your sons, your daughters, your friends? Why don't you do away with love? You don't use it many times a day. Why don't you do away with libraries, books, theaters, the arts, symphony orchestras, Christmas trees, cemeteries and the American flag! Some of the finest things in life are too precious to use many times a day.

Our appalling divorce rate, our family bickering, our undisciplined children, serve as tragic signs that we are losing the age-old art of family living, the only thing really worth living for. The mere fact that people permit you to do away with the dining room is evidence of their complete failure to understand the sociological nature of the family as an institution. The great value of the old-fashioned dining room is precisely that it was not used many times a day, but what wonderful times! This was a room set apart, almost sacred, a very intimate room in which the most powerful and the most beautiful of man's emotions could be expressed with confidence and security. It is not how often you use a thing that makes it good; it is how you use it.

At my age one begins to see the value of memories, and the most beautiful and heart-warming memories I have are of my childhood when my brothers and sisters, father, and mother were gathered round the dinner table in a room set apart just for us. The world could not enter here. This closed room was wonderfully just for us. Here we really belonged. This was really living.

If you walk home from work and pass the family church, just turning your head and looking at it does something for you. The family dining room is like a family chapel; just walking through it does something for you and for the family.

You build and sell houses for profit. I invite you to an adventure in greatness. Build and sell dining rooms for love!

THE SPACE AGE IN HOUSING

Gerald J. Stout
Research Associate, Building Research

The Germans call a carpenter a zimmerman, a man who builds rooms. Old-time carpenters were really room men, and a house was a collection of cubicles. Smaller houses might have but one or two rooms, centered around a fireplace, with a loft for sleeping. When stoves became popular, even the fireplace was eliminated, leaving only a chimney. There was no other heating system, and of course no wiring, plumbing, or built-ins, and some houses had not even a clothes closet.

You builders could still put up houses inexpensively if there was no more to them than early houses. No architect is needed to design a rectangular box with a roof. Land was cheap and building codes and union regulations were no problem. Likewise, water, sewer, and electric lines, pavements and landscaping affected builders almost not at all. The trouble is that buyers will no longer accept such houses!

The Industrial Revolution of the mid-nineteenth century increased the demand for houses but had little effect on methods of constructing them. Carpenters continued to saw boards and pound nails much as they had done in years past. The chief constituent of the average home was still the large amount of manual labor that went into it. There was little change in this situation up to World War II, when the cost of labor skyrocketed.

High labor costs are not the only factor that builders have had to face. A few years ago the cost of a building lot was about 10% of the entire selling price of house and land. A $5000 house would be located on a lot costing about $500. As recently as 25 years ago, some of the most desirable lots within cities could be bought for $300 to $400. Similar lots today would sell for at least ten times as much. Even as building costs have been inflated, land cost has increased so much that now it amounts to about 20% of the total selling price.

Still other factors which have contributed to building costs are appliances, equipment, and facilities. Complete plumbing, heating, and wiring systems are regularly expected. Not only that, but closets, chests of built-in drawers, and even tables and beds have been designed and used as sales features. Innovations such as household intercom systems, touch-plate switches, and loud speakers in every room also increase costs. But if enough builders display and advertise them, they will be demanded in new houses.

Appliances and utilities represent the largest increase of all in house building costs. The actual dollar increase is greater than that for the land. Utilities and appliances are attractive and convenient, and have come to be expected in the "completely equipped" house. Buyers do not realize just how much they add to the price. For example, consider a house of about 1000 square feet which sells with lot for $12,500. If we assume that the cost of the land is the usual 20%, this leaves $10,000 for the house. A breakdown of costs of extras might look something like this:

Architects, engineers, other fees (10%)	$1000
Utilities (20%)	
Heating, air conditioning, chimney, plumbing, sewer, wiring and fixtures, TV aerial	2000
Built-ins and appliances (15%)	
Water heater, disposal, dishwasher, laundry, surface and wall cooking units, refrigerator with freezing compartment, kitchen cabinets, and other built-ins	1500
Landscaping, walks and/or drives (5%)	500
	$5000

None of these items were included in the old carpenter-built square box. They now represent about half the cost of the completed house, exclusive of land. The builder is left with only $5000 or 40% of the total price with which to buy materials, build the foundation, do the carpenterwork, lay the floors, plaster and paint, install the roof, insulate the walls, and so on. But the materials he must buy for such a house may amount to over $3000.

It is not difficult to see the "fix" you builders are in. It takes very close figuring and expert shopping to be able to pay for labor at today's prices and still come out with a profit.

The only solution to the builder's dilemma seems to be that of cutting costs. Naturally, much of our research program is slanted in that direction. Prefabricators also are forcing small builders to cut corners. But it seems that there is another opportunity to help our building industry, and one which we should not overlook.

I believe we have failed to get across to customers the fact that they are getting more for their money than ever before. Education of potential customers seems to be one of the greatest needs. Comparing the amount of "house" one can get today with his take-home pay, we find that in 1959 buyers get considerably more than they did even at the bottom of Depression days of the 1930's. Workingmen's wages buy twice as much house today as they did a few years ago.

Yet building surveys show that the percentage of national income spent for housing has progressively declined. At the same time, the percent of income spent on liquor, automobiles, and other relative nonessentials has just as progressively increased. Even with all the conveniences and comforts of modern homes, people still are not paying, and they seem unwilling to pay, as much for housing as they formerly did. In many cases they are spending more just on their automobiles, all things considered, than for housing their families.

Writers in popular magazines have been critical of house builders. The Life series was interesting, but it seems unfair for editors and architects to pass all the blame on to someone else. No matter how efficient a builder may be, he has to face the problem that people who buy his houses are unwilling to pay prices comparable to what they pay for other things. The Life series pointed out that people are not getting the houses they should have, and that space, privacy, convenience, and durability are neglected. But those are precisely the items for which buyers seem unwilling to pay. Life pointed out that houses should have more partitions, wider hallways, and adequate storage space for better livability, as Dr. Coutu has just said. But what is the builder to do when people will not pay the little extra first cost to obtain those desirable items?

If people are unwilling to pay more for housing, the deficit must come out of the builder's 40% of the selling price. Costs of land, utilities, and appliances are more or less fixed. The only way a builder can meet the demand for lower selling price is to REDUCE SPACE. If selling prices could be increased just 10%, the additional money would permit builders to increase space by about 25%!

Part of the trouble comes from an overselling job on the part of advertisers or manufactures, but I believe that a large part of it comes from an underselling job on the part of builders and people like ourselves here at the University. We have done little or nothing to point out the incongruities of the situation. The national building-trade magazines emphasize that luxury features such as beautiful kitchens and various built-ins are what sell houses. The glitter is what attracts buyers, rather than the space they ought to have. Big builders have contributed to this situation by constantly emphasizing gadgetry while saying little or nothing about more important matters like good design, adequate space, and quality.

Buyers do not hesitate to tell builders precisely what they want in the way of appliances, gadgets, or built-ins. Every home magazine carries eye-catching advertisements advising them what to insist on in their new homes. But when it comes to a decision on the amount of space they need and how it should be arranged, buyers are likely to have very hazy ideas.

Development of a new concept of "net floor area" or "net living area" might help to convince people that by spending only a little more money they could have far more livable houses. The floor area generally occupied by furniture, cabinets, closets, utility areas, and hallways or passageways is not living area. This essential loss of living space may amount to as much as 500 square feet, and is nearly as great in a small house as in a larger one. The free area in a 1000-square-foot house may be only about 500 square feet. Still smaller houses have little more living area than a large house trailer.

Comparing a 1000-square-foot house with a 1500 size, after deducting nonusable space, the living space of the latter is about 1000 square feet or double that of the smaller house. Adding 500 square feet to the size of the house adds essentially no extra cost for utilities, appliances, and the like, so the selling price should be increased no more than $3000, or only about 25%. However, that would increase the net usable living area by as much as 100%.

SPACE, therefore, is the best commodity a builder has to sell. It also is the chief item on which he can hope to make his profit. SPACE is also what buyers need most but are least likely to get, according to critics of the industry. Then should we not, within the industry, make an all-out effort to sell SPACE? Should we go on letting gadgets and luxury touches take the richest cream off the builder's market, leaving him only skim milk from which to glean a profit?

STANDARDIZING HOUSE COMPONENTS

Melvin W. Isenberg
Associate Professor of Architectural Engineering

I would like to produce a formula which would reduce building costs without any sacrifice in quality. Unfortunately I cannot, at least not one which can guarantee such results. I can, however, outline some procedures that may ultimately prove to be beneficial.

We are all in complete agreement on the need to reduce building costs. Just how this can be accomplished will depend on many factors, such as individual experience, company organization, current economic trends, weather conditions, and a host of other considerations.

One reason for high construction costs is immediately apparent to those familiar with modern production methods. It is the use of extremely small components. This means the on-site assembly of thousands of small parts, which naturally boosts labor costs. This practice also gives nature a much more significant hand in establishing final costs, because there is so much to be done without controlled climatic conditions. Off-site production of larger components can minimize this lack of control at the site.

We want to reduce the cut, fit, and waste that inflate construction costs. To do this we must face up to that word so carefully avoided by so many people, the buying public as well as the custom builder -- <u>prefabrication</u>. Nothing in the term implies either an inferior product or a restriction of design flexibility. Every builder has used prefabricated products in his houses for years. Prefabricated components such as windows in frames, doors, mantels, and stairs are accepted by all. Prefabricated kitchen cabinets, built-in cupboards, wardrobes, and space dividers are used as normal procedure. Fire places and chimneys can be ordered from a catalog.

Why, then, should we hesitate to go one step further and use for floors, walls, ceilings, and roofs, prefabricated panels which can be assembled much more efficiently off the site than on?

Any partial prefabrication we may accept should lead immediately to a basic and all-important principle: all components need a common measure so that they may fit together with ease and eliminate all cutting and fitting on the site. For this reason, I shall from this point on imply that such components are "modular" components. This means simply that such a component is a standardized unit adaptable to coordinated design. It also emphasizes the need for a common unit of measurement, or a module. Later on, I shall develop this idea a step further with a discussion of modular measure. For the present, however, let us consider this matter of partial prefabrication.

OFF-SITE PREFABRICATION

There are a number of degress of off-site prefabrication, which might be classified as follows:

1. Traditionally preassembled units, such as windows, doors, mantels, stairs, cabinets; and the newer ones -- fireplaces, chimneys, etc.
2. Precut structural members requiring all assembly to be done on the site.
3. Completely prefabricated houses, for which the entire structure (if small) or large sections of the structure are assembled in a central plant, and transported to the site, and there connected and anchored in place.
4. Portions or smaller panels, adapted from standard framing practice, brought to the site for connecting together.
5. So-called stressed-skin panels, including structural sandwich construction, manufactured in a central plant and assembled on the site.

All of you are thoroughly familiar with the first class. The second class offers some definite advantages, and is in fact now being used by most builders, even though the precutting is done on rather than off the site. The third class is of interest to only a very small percentage of builders and therefore should not be dwelt upon here. The fourth and fifth classes are the ones which offer the greatest potential help to the small-scale builder.

Standard Framing Panels. Those panels which follow closely the standard framing practices with which we are all familiar are the ones that are most easily designed, manufactured, and understood. Platform framing, or some variation of that type, is generally used. We may use standard sizes of members, such as 2 x 4's for studs, and therefore the panels are easily and quickly mastered by carpenters familiar with standard practice. There is little difficulty in converting to panelized construction of this type, and it conforms to most code requirements.

The panel sizes are limited only to the extent that they may be handled and transported conveniently. A very common and convenient size is one which is 4 feet wide by 8 feet high, although any size based on 4-inch multiples could be used. The joining of adjacent panels requires attention. Details must be worked out so that panels may be nailed or otherwise fastened together with ease and with no waste of material.

Floors are usually of standard platform framing. Girders may be flush or dropped, and if dropped, the joists are tied together with splice plates. Preassembled roof trusses are usually included in this type of construction, with the lower chords fitting into slots cut in the upper plates of the wall panels or fastened by metal anchors.

One producer of wall panels of this type stocks a line of modular components which interlock with wood splines. There is an assortment of sizes to permit a high degree of design flexibility. All doors and windows are installed at the factory, completely glazed and weather-stripped. Prefabricated trusses using split-ring connectors are available in a limited range of spans with a single popular pitch.

If the volume of your work warrants it, you can preassemble your own panels off-site in controlled conditions and accomplish similar results. Even the assembly of panels on the platform floor and tilting them up in place will generally save you money. This may be done for exterior walls with framing members only, or with sheathing and insulation in place; and with interior partitions under roof, with one or both sides partially finished.

Stressed-Skin Panels. The fifth class of prefabricated components, again modular in sizing, is the stressed-skin panel, sometimes called "stressed cover." This consists of a frame with a continuous skin glued under pressure on each side of the frame. Pressure may be supplied by nailing or stapling only, but the use of clamps or presses will improve the glue bonds. Insulation is usually factory-installed in wall panels and field-installed in ceiling panels, where the skin is applied on one side only.

Because the loads on the panels are partly carried by the skins, the framing members can be lighter and fewer in number than in the standard framing type of panel. Strength and rigidity are both increased by this combination of frame and skin. Plywood glued with cold-setting casein or synthetic resin materials is generally used for the skins, but other sheet materials such as hardboard may be used. The joint is the most troublesome problem, frequently solved by using splines and a batten for weather protection.

The 1959 NAHB Research House at Knoxville uses stressed-skin panels throughout, with hardboard as the skin material. Exterior panels are 4 inches thick, and interior nonloadbearing partitions are 2 inches thick. All panels are 8 feet high and vary in width from 1 to 4 feet, making the system completely modular in planning and details. Steel splines join the panels and also support subassemblies such as shelves and cabinets. Exterior panels are prewired at the factory. On one section of kitchen wall the service panel and eight electrical outlets are premounted, to supply power to the major kitchen appliances and to the two bathroom waste disposers. Branches from this "electrical wiring tree" extend up into the attic and there terminate in two distribution boxes, each serving a particular area of the house. A remote-control low-voltage system is used, with prefabrication accomplished by the electrical contractor. The point to emphasize in connection with this house is the tremendous reduction of on-site labor, with consequent saving in cost and with no apparent sacrifice of either design appeal or the quality of construction.

Closely akin to the normal stressed-skin panel for wall, floor, and ceiling, is the prefabricated plywood girder. One, two, or three layers of plywood are glued to a structural frame to develop a member of considerable strength and still permit incorporation within a 4-inch wall space.

Sandwich Panels. The structural sandwich is the same as the stressed-skin panel except that the core is a relatively weak and lightweight material instead of a frame of structural members. Facings must be of strong, dense, and relatively hard material, such as plywood, asbestos-cement board, steel, or aluminum sheets. The core serves the dual purpose of providing a support to prevent buckling of facing sheets, and complete insulation. Core materials that have been used successfully are fiberwood, foamed glass or plastic, and grillages of plastic-impregnated paper products.

There will soon be on the market a structural sandwich panel with a core of urethane foam, insulated and soundproofed. Such a panel will provide finished inside and outside walls to reduce on-site labor to a very minimum. It can be fabricated and installed quickly, and should prove to be a worthwhile cost reducer.

In general, the advantages of sandwich-type modular component panels are their lightness coupled with stiffness, and the ease with which major portions of a building can be transported and erected.

The 1959 NAHB Research House at South Bend uses sandwich panels consisting of a shop-bonded foamed polystyrene core with redwood batten exterior and a variety of interiors, such as plywood, Masonite, and gypsum. In a single working day a five-man crew erected all wall and roof panels, including all interior load-bearing walls and beams and all curtain walls. The roof of this house, as well as the one at Knoxville, consists of plywood panels on which are placed aluminum panels 48 inches wide, extending continuously from ridge to eaves. The aluminum is embossed with a special finish to reduce glare.

Preassembled Roof Trusses. Another type of component which may mean a definite cost saving to you, as well as a means of obtaining other advantages, is the preassembled roof truss. If it is shop-fabricated, it can result in as much reduction in cost as any other off-site pre-assembly. Even if the truss is assembled on the site, worthwhile savings are possible due to reduction in errors and the improved efficiency of working on a horizontal platform rather than from an uncertain perch up on the roof. Wherever the truss is assembled, a jig will serve as an easy and quick check on lengths, sizes, and cuts, thereby reducing errors and waste.

All of the roof trusses we are concerned with use standard framing members for upper and lower chords and for diagonals. Differences are noted only in the joint systems. The three common types of joints may be classified as those with (1) split-ring connectors, (2) glued plywood gusset plates, and (3) nailed scabs of wood or metal. There are variations and combinations of these types, and mechanical aids for fabrication. All are construction devices aimed at reducing costs without impairing quality.

The roof truss is easily adapted to post and beam construction and fits in well with modular panels. It is a simple matter to achieve full modular coordination with it. Another advantage is the fact that the entire interior is left free of obstructions. This permits the building to be quickly closed in, allows full use of components for partitions, provides conditions for tilt-up construction, and eliminates all load-bearing walls inside.

THE MODULAR METHOD

In order to reap the maximum benefits from the use of modular components, it is most important that such components be so designed and manufactured that they will permit efficient assembly on the job. That means assembly of similar as well as dissimilar units, some or all of which may be either mass-produced or site fabricated. In short, all components must follow the principles of the modular method: they must use a common unit of measurement, called a module.

We could find many historical examples of the use of modules for like component pieces of a building, such as the stone unit used in the Egyptian pyramids or the sun-baked brick unit used in Mesopotamian buildings. Any unit of measurement might do, but it is only when we settle upon a standard applicable to all materials that we can assemble those materials without waste.

The 4-Inch Module. Modular designing for a house begins with the planning stage. We start with some module in mind, a planning module. It should be considered a three-dimensional affair, and it gives us a design or planning grid. In plan, we see a pattern of squares or rectangles based on some convenient measure. For the modular method, this will be in all cases a multiple of 4 inches. That will permit the assembly of varied components, provided the components themselves are designed and manufactured on the same module, The walls, too, must follow a similar pattern if we are to use modular components.

Please bear in mind throughout this discussion that all the components in the house must be joined so that the materials plus the necessary joints will result in measurements that are multiples of 4 inches.

Comparing nonmodular with modular plans, we note the absence of fractions on the latter and the use of both arrows and dots on dimension lines, arrows terminating on a grid line and dots for between-grid locations. A large-scale detail will actually show the grid lines. A note of explanation relative to the modular system of dimensioning should appear on the cover sheet of the drawing set.

Modular materials will fit together when planned that way. Many materials and components are now available for modular planning; others still need to be converted. That conversion is bound to come as the demand is made upon the manufacturers. Ultimate savings will depend upon the extent to which all materials and larger construction components become truly modular in size.

Among presently available modular products are such materials as plywood, wallboard, plasterboard, insulation, and many masonry units. Concrete blocks and bricks are manufactured to fit the system. There are several varieties of modular brick to satisfy different aesthetic needs. Steel windows, aluminum windows and many cabinets are now modular. Further modular standardization is still needed for componenets such as wood windows, plumbing fixtures, resilient flooring, and ceramic tile. The simple sizing of sash in 4-inch increments does not make a modular window. Remember that the component, including the necessary joint and tolerance, must measure in 4-inch increments.

The mason has access to several aids for building by the modular method. There is a modular mason's line marked off in 4-inch increments, with a special mark on every sixth module. This enables the mason to lay the first course in mortar without the usual time-consuming dry layout. At least two different modular mason's rules are available for aid in vertical spacing of all common sizes of modular masonry.

Advantages of the Modular Method. Ample evidence supports the belief that the modular method will benefit the builder. After a brief orientation period, perhaps through the first modular job, most builders have agreed that the following benefits are possible.

(1) Estimating is made easier and faster, with fewer errors and more complete cross-checking. One contractor who normally spent two weeks on a take-off and had never before heard of the modular system, finished all quantity take-off in just three days for his first modular job.

(2) Layout in the field is faster and more easily checked. Fewer foremen are needed, or more workmen can be handled by one foreman.

(3) Elimination of fractions makes it easier for the workmen. Less time is wasted on the job, and production can increase.

(4) Waste is reduced. There is far less cuting and fitting on the job. Masonry savings of 5 to 10% are reported consistently.

(5) Workmanship improves throughout and becomes immediately evident in the final product.

SUMMARY

In this brief discussion of standardizing house components, I have outlined the possibilities of savings through the use of modular components, and I have indicated that the success of a component system depends on a complete modular method. The fundamentals of modular measure based on the 4-inch grid were explained, and the importance of good planning in 4-inch increments was stressed.

As a final reminder, let me repeat that the most promising solution we have today for paring down the high cost of construction is found in increased off-site fabrication according to the 4-inch modular system, which decreases the on-site assembly of the thousands of small pieces that go into the conventional house.

INSULATION OF WALLS, CEILINGS, AND FLOORS

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Suppose we had infrared vision that would let us see a wall as it looks to heat-energy approaching it to escape to the weather. The usual uninsulated wall would appear as a stockade of dark framing members, which offer considerable resistance to heat flow, separated by gray areas where heat flow encounters only the nominal resistance of plaster, sheathing, and siding. Glass areas would be big holes in the wall, resisting the heat very little. Such a picture would give the impression that an attempt to heat an uninsulated house would be like trying to heat the entire county. Too often, that is how the discouraged home owner feels as he struggles with excessive fuel bills.

Social changes of the past generation have, in effect, moved the need for insulation from the individual to the walls of his house. Industry and employers in general have provided more comfortable working conditions. We have less need for heavy clothing at work or in travel, and we expect to be at least as comfortable and unencumbered at home.

Unfortunately, the housing contractor, the buyer, and the buyer's friends never do have infrared vision. It is therefore somewhat difficult to get insulation into a house at the right time -- during assembly. At this time the buyer is financially sensitive, and he exerts every subtle pressure on the contractor to keep the total cost of construction as low as possible. When \$20,000 wants are being trimmed to fit \$15,000 financial assets, one of the items that gets clipped with monotonous regularity is insulation.

It is omitted from the walls first, and in extreme cases from the ceiling or roof, too. Hidden away in the walls, insulation does not have the intrinsic or popular appeal of decorative siding or shrubbery. And thus a decision is made in favor of visible items that require maintenance, and against this item that would pay dividends throughout the life of the house.

Just how much can be gained through the use of insulation may be judged to a great extent by the cost of the heat that is saved. Heating costs include cost of heating plant, cost of fuel, and cost of operation. When the heat requirement is reduced, the heating plant can be smaller, with less fuel consumption and lower operating cost.

One attempt to define the very minimum of insulation value necessary for a house is given in the Minimum Property Requirements of FHA. These MPR's are designed to avoid construction that is totally unsatisfactory, but they fall short of assuring construction that is completely satisfactory in so far as insulation value is concerned. They are a step in the right direction, but a short step, as their name implies.

SAVINGS FROM INSULATION

To go beyond a minimum value of insulation requires some analysis of the cost and effort involved and the resultant effects on property operation, maintenance, and value.

For a single-story house in northern Pennsylvania, enclosing 1200 square feet of floor area with basic construction having U values (the overall coefficient of heat transfer) for the walls of 0.25 and ceilings of 0.36, the heating plant must have a capacity of 105,000 Btu per hour. First cost of the plant would be approximately $400, and installation approximately $105. Yearly operation under a 6000 degree-day season, with oil at 15 cents, would be about $290.

If the same house were insulated at the time of construction to provide walls of 0.06 U value and a ceiling of 0.07, the heating plant could be reduced to 60,000 Btu per hour. First cost would drop to $320, and installation to $80. The yearly operating cost would be $160. This would provide savings of $105 in first cost and installation, and $130 annually in operating cost. If the installed cost of the insulation is $300, its cost will be amortized in two years, and the savings thereafter are dividends from the use of adequate insulation.

COMFORT FROM INSULATION

Dollar savings are not the only dividends to be expected from adequate insulation. A very marked increase in the comfort of the occupants of a house can be noted with adequate insulation. Wall and ceiling surface temperatures are much nearer to the air temperature, with reduced drafts and less radiation from the person to the walls. Although a heat balance can be achieved for a person and his surroundings by control of the air temperature, satisfactory comfort cannot be provided by the heating system alone.

Warmer insulated walls reduce the stress on the human system and provide a condition of comfort that is essential for the satisfaction of the home owner. He has made a financial outlay for a house he expects to operate as a home. It is his castle, but it must be more comfortable than any castle ever was. The insulation provides a difference that may seem small, but it bridges the gap between satisfaction and dissatisfaction.

DUST PATTERNS

Another corollary benefit derived from the more uniform wall temperature with insulation concerns dust patterns, which reflect even small differences in surface temperatures. The accumulation of dust is not understood completely, but there is considerable evidence that the colder areas collect dust faster. It is surmised that the minute differences in relative humidity account in part for increased dust over the colder areas. The water vapor in the air diffuses so rapidly that the moisture concentration is very uniform throughout an entire room. Flowing down over a cold wall, the air passes over areas of different temperatures, and the colder areas would create higher relative humidity.

Whatever the reason, dust is attracted to cold areas. In old construction with wood lath and plaster, every lath and stud can be seen in the dust pattern. The wood provided a small measure of insulation value, and the plaster surface was warmer over these areas. Consequently the lath shows light and the plaster key shows dark in the dust pattern. One thing which is not understood is why the corners remain clean.

With the modern tendency to use wall paint of uniform color across the wall, the use of insulation can delay the accumulation of dust on the surface until repainting is desired for a change of color or for some reason other than dust patterns.

THE BEST INSULATION

We frequently have requests for information on the best insulation. A laboratory such as ours should know which insulation is best. The question is similar to "Which is the best car?" Each one has its proponents, each has its good points, some have their weaknesses, many are sold on reputation or prestige. And so with insulation materials.

As a contractor, you may prefer to use a certain insulation because of the personality of the salesman rather than the color of his fibrous glass. Or proximity of manufacture may provide a price advantage. Ease of application, acceptance by workman, and vulnerability during erection and before covering are factors to be considered. Susceptibility to damage from other trades working on the insulated structure is a big factor.

The insulation can never work any better than the condition in which it is installed. Published figures of thermal conductivity or transmittance U values are laboratory values for insulation applied in a careful manner to realize its full benefit. Most insulation manufacturers make an honest effort to design their product for easy, effective installation. They must of necessity, however, stake their reputations on the care with which the contractor installs their product.

AIR CONDITIONING

As year-around air conditioning becomes more popular and in those areas where summer cooling is a sizable load, the use of insulation can be a considerable factor in reducing the first cost of the air conditioning system and the cost of operation.

To demonstrate the magnitude of these savings, the same 1200 square foot house without insulation would require a 3 ton system, which would cost $30 to operate each year. With proper insulation to provide U values of 0.06 for walls and 0.07 for the roof, the system would be reduced to a 1 ton system costing $10 per year to operate. Several hundred dollars would be saved in the first cost of the system and $20 a year in operating expense, which would pay for the house insulation.

At the northerly latitude of Pennsylvania, the benefits from the insulation in reducing air conditioning costs are not as spectacular as they are at more southerly latitudes.

FIRE PROTECTION

An important consideration in the choice of insulating materials is their combustibility. Fireproof or incombustible materials are preferred when other factors are equal. Insulation is usually installed out of sight within the wall, along with the electrical wiring, piping, and so forth. Incombustible materials will certainly not lend any support to a fire originating from any cause, and may even retard the progress of a fire where facing materials and frame are combustible.

Fire retardant treatment for combustible materials is recommended. Good insulation nearly always has a low density and a cellular or fibrous nature, which makes it susceptible to quick ignition and combustion. Although a contractor cannot foresee all possible situations, he does have a responsibility to use safe materials where there is a potential hazard to the life and property of the home owner.

REFLECTIVE INSULATION

An insulating material that is gaining in popularity and has very definite advantages under certain heat flow situations, is reflective foil. Used as foil sheets or as very thin foil on paper or paper board, it is always applied in conjunction with an air space. The bright aluminum surface reflects the radiant component of heat transferred across the air space; or when the heat is flowing from the foil surface, it prevents the radiation of thermal energy. During the summer heat flow condition, the most favorable situation is the ceiling position. Downward radiation is largely eliminated, and the air in the space tends to remain stagnant. With radiation and convection both reduced considerably, very little heat is transferred. In the ceiling position, one foil surface can have an effective resistance to summer heat equal to 2 inches or more of fibrous or mass insulation. Wall orientations are less favorable, but reflective insulations carefully placed are still quite effective.

Cheaper transportation and storage costs are a major advantage of foil insulation. Because of its light weight and low bulk, insulation for an entire house can be packed in a small space.

LIGHTWEIGHT AGGREGATES

The use of lightweight aggregates in plaster and concrete improves their insulating value, usually at the expense of their strength. As is true for all materials, as the density is lowered the insulation value improves and the strength decreases. The mixes to be used are a practical compromise to attain some insulation value while retaining adequate strength.

The primary advantages of lightweight aggregate plaster are the reduction in weight and the reduced effort required for lifting and handling. The increased insulation value is small and incidental, especially if other insulation is used in the wall.

CONDENSATION

No discussion of insulation would be complete without mention of the hazard of condensation. The physics of a house wall and the house environment is such that the addition of insulation creates an environment in which condensation can occur. This should not be charged against the insulation, for it is a result of the insulation's being effective in reducing the heat loss through the wall.

To benefit from the insulation, it is necessary to guard against the accumulation of condensed moisture. At this time we want to point out and emphasize that it is necessary to do this. The various techniques for avoiding condensation will be the subject of another paper.

SHOP FABRICATION

The economy of maximum use of shop labor in assembling building components applies equally well to insulated shop-assembled panels. Prefabrication also opens a field for putting insulation to work in a dual role. Certain types of insulation, such as boards, cellular cores, and foamed plastics, can serve as both the spacer and the shear resistant core of a sandwich panel.

Panels of this kind offer great promise of large, light, strong prefabricated components that will speed erection in the field. At the moment, joint techniques are a bit of a problem, but some day someone will make a break-through that will permit a quick, tight panel assembly in the field. Then the economical fabrication and assembly of a house will be a reality.

RECORD KEEPING AND SCHEDULING SAVES MONEY

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Planning and control of operations are probably as complex functions as any others performed by businessmen. In the past, and to a large extent today, these operations have been "guess-timates," based on inadequate past records and that nebulous thing we call experience. The truth, if we face it, is that we all feel inadequate at the time we are planning a job. We tend to excuse ourselves from the boring details by saying it is uneconomic to consider job details at the start when we can take care of them on a day-to-day basis as the job progresses. Yet these neglected details are often the root of materials shortages, wasted labor, excessive financing charges, high equipment costs, and poor customer relations, in addition to our own loss of sleep, increased nervousness, and loss of efficiency in performing our work.

THE BASIS OF GOOD PLANNING AND CONTROL

In order to do a good job of planning and control, it is necessary to keep adequate and accessible records. Fundamental records include:

1. Materials (purchasing records)
   - a. Suppliers
   - b. Cost per unit
   - c. Delivery time (lead time required)
   - d. Other services rendered by suppliers
2. Labor
   - a. Performance (standards)
   - b. Rates
   - c. Availability
   - d. Subcontractors
3. Construction equipment
   - a. Standards of performance
   - b. Costs
     - (1) Depreciation
     - (2) Operation
     - (3) Maintenance
   - c. Availability
   - d. New equipment
4. Burden charges
   - a. Project burden
     - (1) Supervision
     - (2) Field office
   - b. General burden

In addition to these basic records, you may desire special records on items which are troublesome, many times called "bottlenecks." Records of this type should be transitory in character. That is, they should be kept only as long as they are useful, and not for the sake of complicating your system.

Records must be current and easily used if they are to be serviceable. To keep them current requires that only worthwhile information is recorded. Miscellaneous data of doubtful character and little use only clutter your files and make it difficult to keep them current. The more information you must sort through to get the data you want, the less inclined you will be to use the information you have collected, and the probability of errors will be greater.

In general, you will be better satisfied with your system if you design it yourself rather than take someone else's system which may or may not fit your requirements. This constitutes one of "management's" primary jobs: analysis and constant revision of the control system.

THE WORK SCHEDULE -- A BASIC CONTROL TOOL

Records kept for records' sake may be of interest historically, but this is not an objective of management. Unless records are used, you are just carrying on a very expensive hobby. To apply accumulated data to future operations, you need a tool that will help you correlate all the information on a prospective or planned job. Such a tool is a work schedule.

Although most people fail or refuse to realize it, time is one of the primary elements of cost. Some wit has stated that time costs money, but it would be better to say that time is money. You can also say that time takes no holidays, it recognizes no strikes or bad weather. Like Old Man River, it just keeps rollin' along.

You do not control time, but you can utilize it to your best advantage. People have mentally translated data into time scales since the dawn of history. Travel is a good example of this. You say, "It takes me two and one-half hours to drive to Harrisburg." The Indians said, "It takes two moons to make pemmican."

Basically this is all we are doing when we set up a work schedule. With a given amount of equipment, a certain work crew, a given design, and certain conditions, it takes a given amount of time to excavate, set footings, pour foundations, set framing, place the roof, put on siding, install windows and doors, flooring, and finishing, and to perform the other elemental operations of building a house.

Figure 1 illustrates one design of a work schedule. We will call it the Plan and Progress Chart or PAP Chart. It is a complete picture of your plans before you start work. After you start the job, it shows you what you must do and when to do it so that the house will be completed on time. Planning is its major function; it also serves as a progress record. Both fit together to spell success. We'll take a look at planning first.

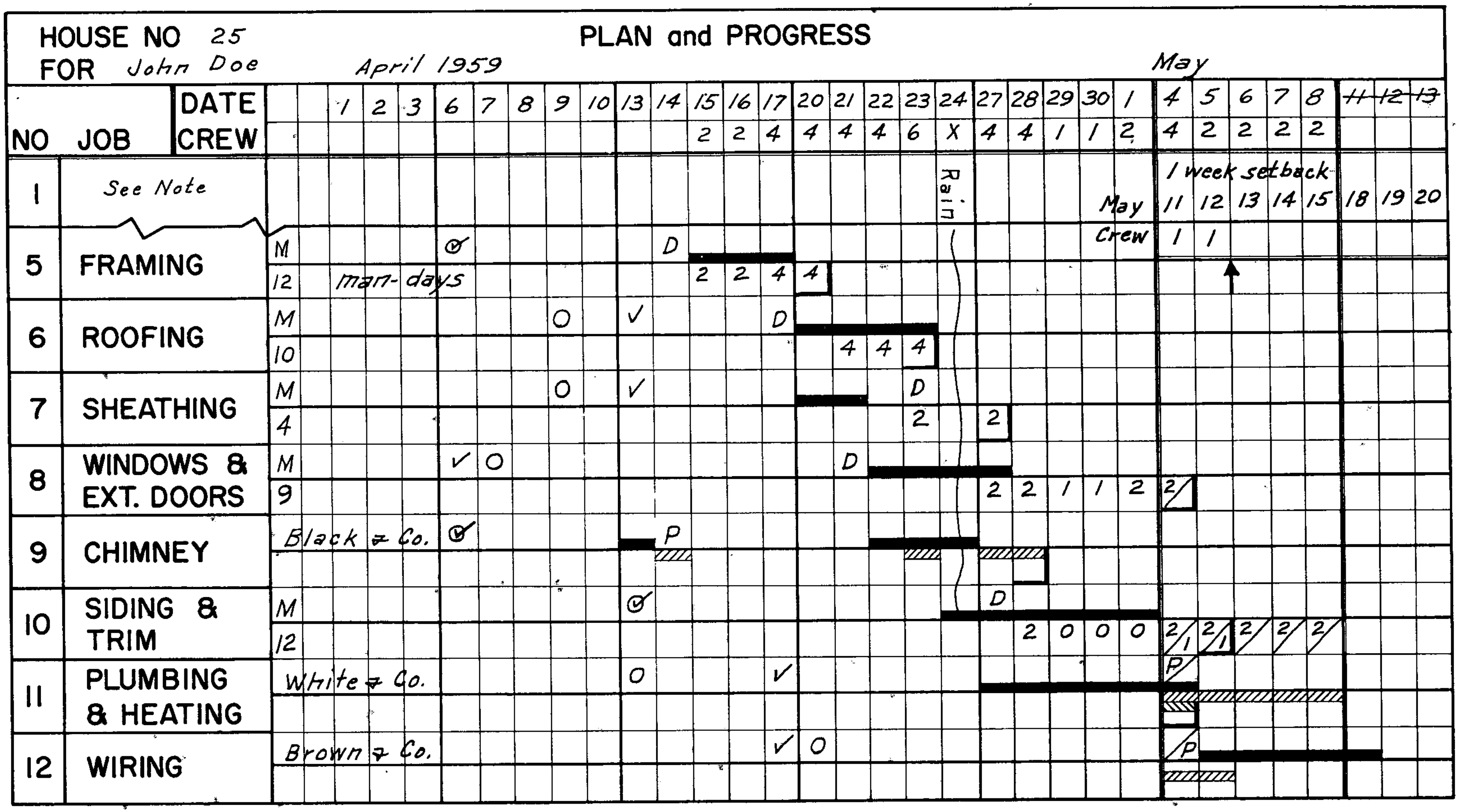
Figure 1 is only a small portion of the complete PAP Chart for house No. 25. At the left are listed the several jobs that must be done, in their natural order. The total number of jobs -- 10, 20, or 40 separate elements -- is for you to decide. Twenty is a good number to start with. Then on your next house you may want to split up a big element that is really done in stages. Printed PAP forms showing all these elements may be obtained later.

Across the top are the dates of working days, five per week. You might mark a cross, stick a red headed pin, or paste a gold star under the date you plan to start each job. Or you may mark a solid black bar extending from starting date to finishing date, as shown. Here is where your experience and judgment come in, choosing the number of days (and men) you want to put on each job. Better include 10% excess time for bad weather and other delays. Of course, you think in terms of man-days, which you may list opposite each job.

Some jobs have to follow others. The sequence of jobs on the foundation and floor is omitted from Fig. 1 to save room, but they will appear on your chart, which will probably be several times larger than Fig. 1. It may be on two sheets, or on both sides of heavy paper if more convenient.

With the basic idea of the PAP Chart, we will go on to details by referring to the notes under Fig. 1. Eight jobs are shown. Opposite each job is a heavy line across the page. Above this line are materials, M, and your plans. Plans include the scheduled work time shown by the work bar and the date to order materials. The "lead time" between order and delivery depends on the material, the source, and the market. You know from experience (sometimes painful) how much lead time you must allow in order to be sure you will have materials on time. Mark the chosen order date O. Later, when you actually place the order, you use a check mark (✓) or the supplier's initial to show what you did. When the material is delivered, mark the date D.

Below the line, you show labor (man-days) and progress by means of figures indicating the number of men at work each day, and when they started and finished the job. If Saturday work is done, record it in red below Friday's work force. These records will help when you plan your next house.



Symbols above line: M = materials, O = planned order date, ✓ = actual order date, D = delivered date; P = promised date of subcontractor, ▬ = planned work dates.

Symbols below line: Numbers under M = planned man-days, numbers under work bars = men on the job; ┘ = job completed, ▨ = subcontractor working.

Fig. 1. Plan and Progress Chart, small portion of complete chart. Arrow is "today," May 12, 5 P.M. A one-week setback is shown (see text). Note: Jobs 1 to 4 on foundation and floor are sequential and not shown.

Three jobs in Fig. 1 are done by subcontractors, whose names are shown. Order dates and planned work bar are determined from experience. If the subcontractor supplies material and labor, you won't need to separate them, but you will record his promised starting date, P. Below the line, you can show when he worked by a cross-hatched bar or merely a line. If you need to rent equipment, you may show it on your PAP Chart by a letter E at the proper date, or as a separate job like a subcontract.

In Fig. 1 we have planned several jobs to be concurrent, but we are careful about jobs that must be sequential and about manpower if we have a steady crew, not neglecting other houses we are building at the same time. Our total crew working on this house is shown at the top under each date. Notice that our chart is up-to-date through "today," May 12, 1959. Let's review some of these jobs.

Framing was estimated at 12 man-days and scheduled for April 15, with 4 men working 3 days. Lumber was ordered on April 6 as planned, and delivered on April 14. Work began on schedule, but the crew available was small and the job dragged over into Monday, April 20.

Roofers and roofing were ordered on April 13, 4 calendar days behind schedule, but fortunately all materials arrived in good time on April 17. However, the roof had to wait until the frame was completed. Then, with a forecast of rain, 4 men were put on the job and it was finished in 3 days.

The sheathing job was not so lucky. The boards, ordered 4 days late, did not arrive until April 23. Two men, brought in from another house, could not complete the job before the storm, but they finished on Monday, 6 calendar days behind schedule.

Unfortunately, delays like this have a way of wrecking "the best laid plans of mice or men." But one big value of the PAP Chart is that it calls your attention every day to what is going on and spurs you to correct it. If the job is behind schedule, you can take steps to bring it back on time or you can "live with it," adjusting the remaining schedule to the accepted delay but not allowing the "setback" to widen. This adjustment may be made in several different ways. You might make a new chart; or accepting a week's delay, you might draw a red line across the chart, marking it 7 as a reminder that every item below should have 7 days mentally added to its scheduled dates. Whatever you do, do it consistently so that you won't be more confused than helped by your corrections.

A convenient way is shown in Fig. 1 where a setback from May 4 to May 11 has been made merely by changing the dates. Don't rub out the old dates; just write in a new line below, starting May 11. On May 1, do your "double dating" for the week ahead. This is your new plan, and all your jobs fit into the new dates nicely. Notice that you now have 10 work days (May 4 to 15) within a one-week column of your chart, clearly marked by double lines. Within these lines, your new plans (solid work bars, order dates, etc.) all take the new dates. But your work force has the five old dates in which to catch up.

You want to record the work in both weeks, of course, and you can do this by dividing the usual daily space by a diagonal line, the upper half showing the first week's work and the lower half the second week's work. Thus, in Fig. 1, windows and exterior doors were finished on May 4. On the siding and trim job, two men worked every day of the first week and 1 man worked Monday and "today" (Tuesday, May 12), completing this job. The plumbing and heating job, after some shopping, was placed on April 17 with a promise for May 4. This work started May 4 and was completed on May 11, two cross-hatched bars being shown. The wiring job was promised on May 11 and is now in progress, ahead of the new schedule.

Try this PAP Chart on your next house. Make it simple the first time, but correct. After you get used to it, you can prepare a good chart in half a day and make the daily records in a matter of 10 minutes. It will be the best time you ever spent -- outside of this school, that is!

It must be emphasized that the chart is not the "control." What you do is control. The steering wheel on a car is a tool for driving; the control is how you use it. The chart is simply a tool that aids you.

OTHER PLANNING AIDS

There are additional aids for planning that have not been discussed here.* Some of them are:

1. Time value charts -- to provide the necessary data in a convenient form for rapid use in making up the Plan and Progress Chart.
2. Crew assignment charts -- for control of crew movements.
3. Equipment assignment charts -- for control of expensive and much-demanded equipment.
4. Exception reports.
5. Orders -- move, tool, work, equipment, inspection, rework.

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* It is expected that some of these aids will be the subject of Better Building Reports soon to be published.

CONCLUSION

Good scheduling pays dividends. It reduces costs, reduces idle worker and equipment time, makes provision for sufficient and satisfactory material, improves customer relations, reduces financing costs, and enables the builder to compensate for market conditions of supply. It also helps to improve his competitive position by increasing the accuracy of his estimates and by eliminating nonprofitable business.

There is another way -- the Fumble, Bumble, and Grumble Method -- but it is hard on the pocketbook and the disposition.

NEW DEVELOPMENTS IN PLUMBING

Melvin W. Isenberg
Associate Professor of Architectural Engineering

Someone has said that it took the plumbing industry about forty years to move the outhouse indoors -- and that was not accomplished to a significant degree until the early 1920's. Considerable progress was made in the twenties and thirties in establishing a norm for the bathroom and kitchen in the middle-class house. During this interval new-style fixtures were developed, and although building in general was at a standstill during the depression years, the plumbing areas of the house were being refined to a highly satisfactory stage of completeness. There was little further development until recent years because directly after World War II the housing boom moved so fast that no one had time to perfect changes of any sort.

We should recognize that new developments in plumbing, in the broader sense, include not only new fixtures and new materials but also a re-evaluation of the entire situation in the light of changing standards of living and the urge to whittle away at the constantly rising costs of building. Except for the introduction of new items, the plumbing problem is still simply one of getting the necessary water to the fixtures and removing wastes from those fixtures. This must be done in the simplest, most convenient way possible, consistent with comfort, health, and economy.

In this brief discussion, I should like to consider the following: (1) planning the plumbing facilities in the modern house, (2) economy in piping systems, (3) fixtures old and new, and (4) prefabrication and the use of modular components.

PLANNING THE FACILITIES

A single bathroom is no longer adequate even in the minimum-size house. The buying public wants the convenience of at least one and one-half baths, and if they can afford it, two or two and a half. It is perfectly obvious that standards have changed in the last few years, and it is extremely unlikely that we shall ever revert to the single-bath house. Some thought given to the layout, planning, and details of fixture placement will be fruitful in achieving a desirable and salable product, even within the limits of a very restricted building budget. There are some excellent suggestions in the "Bathroom Planning Manual" produced in 1957, at the request of the NAHB Research Institute, by the American Radiator and Standard Sanitary Corporation, which will supply a copy on request.

Consider, first, the simplest of all multibath arrangements -- the three-fixture unit, back to back. This is certainly the most economical, but it lacks imagination and privacy within the unit. Storage space is provided in shelf units and under lavatories. If the bathtub must be placed under a window, the window should be a high strip. Usually, one of the two adjacent bathrooms will serve the master bedroom, and the other will open to a hall. For a very slight additional cost, an extra lavatory may be installed in one of the bedrooms. This feature, small as it is, has a tremendous appeal to the house buyer.

Several variations of the two-bath arrangement are possible. You may provide square tubs, built-in lavatories, and extra storage space in unused corners. Additional appeal, from the standpoint of multi-use and privacy, can be procured by placing the water closet in a compartment of its own. The master bath may have a shower and the other bath a tub. Even if one bathroom must be an interior one, ventilation by fan is possible and acceptable today. More flexibility is possible when the tub is placed in its own compartment and is accessible from both bathrooms. For the more expensive houses, it is easy to give the master bath a luxury look by adding a second lavatory and a dressing area.

It is possible to cut costs with little sacrifice of convenience by using a one and three-quarters bath layout. In its simplest form, this means two separate two-fixture baths with a single tub-shower unit serving both. Built-in lavatories add a touch of luxury. A dressing area can be added if space permits. The use of twin lavatories serving the master bedroom will cost only a little more and will speed up morning traffic.

PIPING SYSTEM ECONOMIES

Another thing to consider in both planning and layout for plumbing is the relationship of the kitchen and laundry to the bathroom. Obviously, if it is possible to use back-to-back fixtures and common risers and stacks, very material savings will result. There is good reason for placing our modern laundry facilities right in the bathroom or adjacent to it, both for proximity to the major source of soiled clothes and for reducing piping costs.

The roughing-in of piping can be accomplished much more easily if there are no partition walls to worry about, no studs to cut through, no plates to get in the way. It is to everyone's advantage, therefore, to omit all interior partitions until the shell is finished, thereby permitting the plumber to rough in his lines without obstructions. This calls for the use of trusses rather than joists and rafters. The carpenter, too, should be happier if his wall framing is not weakened and if he is not compelled to patch up the destruction caused by the plumber.

The "wet wall" can serve a number of purposes. If it is a common wall between bathrooms, or between bath and kitchen or bath and laundry, all piping can be concentrated in that space. A preformed "plumbing tree" can be used to advantage and will save money. The wall can incorporate fixture hangers. Sound-absorbent material may be used in the space, or better yet, a double wall with no physical connection between studs will reduce noise transmission. The double wall would also eliminate cutting and notching of studs.

While on the subject of piping and fixture noises, we should consider the use of water-hammer arresters. The cheapest way to correct this situation is to use air chambers, or capped extensions of the water supply risers. Many patented devices are available, their chief virtues being that they require no maintenance and will operate continuously without need for replacing air. Under the sponsorship of the National Association of Plumbing Manufacturers, there has been in progress at the University of Iowa a research study to investigate noises in plumbing systems. This may well result in definite improvement of this common source of irritation in our homes.

There is little that is new in the field of piping materials. Copper is now accepted rather universally for drainage as well as supply lines. Thinner walls and smaller fittings make it possible to use a 2 x 4 stud wall instead of the usual 2 x 6 wall required to house the main stack.

Aluminum pipe offers many advantages. Plastic pipe has a tremendous future, but at present it is accepted by only a few plumbing codes. More definite proof of satisfactory service after long usage and weathering is demanded. Studies made about four years ago on many different kinds of plastic pipe showed no noticeable bad effects in relation to odor; taste, or structural change when exposed to weather and soil. The Knoxville NAHB Research House uses an all-plastic plumbing system which costs less to buy and less to install than conventional systems. Hot water lines made of an experimental "Propylon" are used with two pressure-temperature relief outlets to protect them against temperatures over 175 degrees. Plastic pipe is also used for drainage lines, both interior and exterior.

Simple stack venting is the cheapest method of arranging the drainage system for a bathroom. No backventing is required if the fixtures are properly related. We can even handle the kitchen sink on the same "tree." In a basementless house, the water closet must be connected downstream from the stack. If the sink has a disposal unit or if a dishwasher is used, such fixtures should be connected directly to a drain branch and backvented to avoid any possibility of contamination.

FIXTURES

Plumbing manufacturers have been putting forth considerable effort to improve existing fixtures, to enhance the appearance of the fixtures, and to develop new ones both to satisfy and to create demand. Architects and builders are reluctant to accept new products until they are thoroughly proved. One leading manufacturer had a new item fully developed for seventeen years before it was accepted and used. The public itself is sometimes responsible for the refusal to accept new or different ideas, the bidet being a good example.

Good taste today in the small and moderately priced house runs to simplicity in plumbing fixtures. If one wants elaborate, expensive fixtures and fittings, they are available. The cabinet or vanity-type lavatory is too well known to deserve any special mention at this time. Bathtubs are essentially unchanged, although there are now available two models of sunken tubs to provide easy entry and exit. Also on the market is a two-way tub designed to serve two adjacent bathrooms, with a curtain or translucent screen used on each side. A tub with raised bottom is available, and one could easily build up a conventional tub to facilitate cleaning and to keep all piping above floor level in basementless houses. Perhaps what we need is a tub mounted on a hydraulic lift so that we can enjoy all the benefits of a sunken tub, a flush one, and a raised one, depending upon our mood and physical condition. Prefabricated shower bases have already proved their worth and are widely accepted. Plastic fixtures are still in the experimental stage.

One of the newer developments in the fixture line is a wall-hung water closet for residential use. The advantage in sanitation and ease of cleaning is quite obvious. The three types available are the flush valve, the exposed flush tank, and the concealed flush tank. The flush valve is the noisiest and requires a large supply pipe and higher pressure. The concealed sweatproof tank will fit inside a 2 x 6 stud wall.

In the Knoxville Research House, a garbage-type grinder was installed under the water closet. This arrangement uses only 1 gallon of water per flush instead of 6, and permits the use of a plastic building drain only 2 inches in diameter.

A few new developments in kitchen sinks have made their appearance recently. Among them are a circular sink for easier cleaning, and a sink with the drain in one corner to permit a maple cutting board to fit over the sink. Through an opening in the cutting board, waste can be dropped down to the disposal unit.

PREFABRICATION AND MODULAR COMPONENTS

Over the years there have been repeated attempts at standardization and mass production of large components for the bathroom. None of these have been developed to any great extent, for a number of reasons, the most compelling of which are involved with plumbing and building codes and trade unions. In spite of a highly developed National Plumbing Code and other similar codes, there are still marked differences in local codes that prevent complete standardization. Regulations imposed by trade unions retard the full development of standardized components, but such unions are interested in health and safety. The National Association of Plumbing Contractors, for example, is "in favor of a plumbing code that will properly safeguard the health of the American public." Other factors which retard standardization are varying climatic conditions, differences in soil structure for sewage disposal, and greatly differing water pressures.

Efforts to mass-produce the bath unit can be traced back to the 1930's. In 1931 a patent was granted for a completely prefabricated bathroom, delivered to the site in one sealed unit for lifting into place. All plumbing connections were made on the outside of the unit so that no human being need step into the room prior to completion of the building and occupancy by the tenant. In the same year, a room consisting of complete vertical panels to be fastened together on the site was developed and patented. This assembly called for the work of a mason, a carpenter, and a plasterer, but no plumber. In 1934 a bathroom consisting of horizontal slices rather than vertical panels was patented. In 1938 appeared a complete "prefabricated bathroom" by R. Buckminster Fuller. This one was formed in two parts for easier transportation and handling. In a full-scale model which aroused much interest, all fixtures, including soap holders, were pressed out of copper sheeting. The bathtub was raised above the floor level.

The complete service core was another development that paralleled the mass-produced bathroom unit. One of the most successful of these cores, no longer manufactured, was the Ingersoll Utility Core. This unit incorporated not only the plumbing elements but the heating unit as well. Possibilities for research and development along this line are most promising.

Standardization is a logical development of simplification. We are certainly aiming toward simplification in construction, for the sake of economy as well as purity of design. We can do a great deal toward reducing costs when we eliminate cut, fit, and waste on the job. This will never take place, however, until a common measure or module is applied to all building components, small as well as large. Now in the planning stage are many large modular components for plumbing fixtures, cabinets, and so forth, all based on the standard 4-inch module. When these are available and used, together with such devices as prefabricated plumbing trees, there will be a decided saving in final cost of the house.

Perhaps the future will see striking mechanical changes in the bathroom, but for now we shall have to rely on modernization of a less spectacular sort. Plan well, use good taste in fixture and fitting, and take advantage of the best possible engineering to make your plumbing systems truly modern.

NEW TECHNIQUES OF FASTENING

Gerald J. Stout
Research Associate, Building Research

The term building implies assembling and fastening together pieces or components to form a structure. The overall cost of many assemblies can be reduced by using different materials and finding new ways of cutting and fitting. Improved methods of fastening offer further economies and greater strength.

For some purposes, we still have no good substitute for conventional nailing. For other purposes, nailing is not only wastefully time consuming but also provides relatively insecure attachment. When joints fail because the nails pull out rather than because the wood itself has failed, it is an indication that nailing has not formed a satisfactory joint.

NEW TYPES OF NAILS

Many builders figure that if they allow for wasted time of workmen, actual labor now costs about $5 per hour. One has only to check the time it takes to drive a pound of nails to determine their cost "in place." Even a slight improvement in design can effect time savings amounting to more than the purchase price of the nails.

Standard nails come in many sizes but they are all made of wire, and about the only way to secure greater holding power is to use more or larger nails. There is growing interest in new types of nails which, though they cost about twice as much to buy, have advantages that more than outweigh the extra cost. Because they are designed to hold better than standard nails, fewer are needed. They are also easier to drive.

These new types fall roughly into two general classes, the threaded and the annular, depending on the form of the shank. Annular nails have ribs or rings around the shank; threaded nails are so made that they turn as they are driven, with a kind of screw effect. There are many different designs and each has a specific use (Fig. 2). Some are made of aluminum for exterior work where rusting is objectionable. Others are made of tempered steel and may be driven into masonry.

Wherever nails are subjected to direct pull, the annular and threaded types perform much better than standard wire nails. Shear strength is improved less, but trussed rafters can be built using only nails to attach gussets.

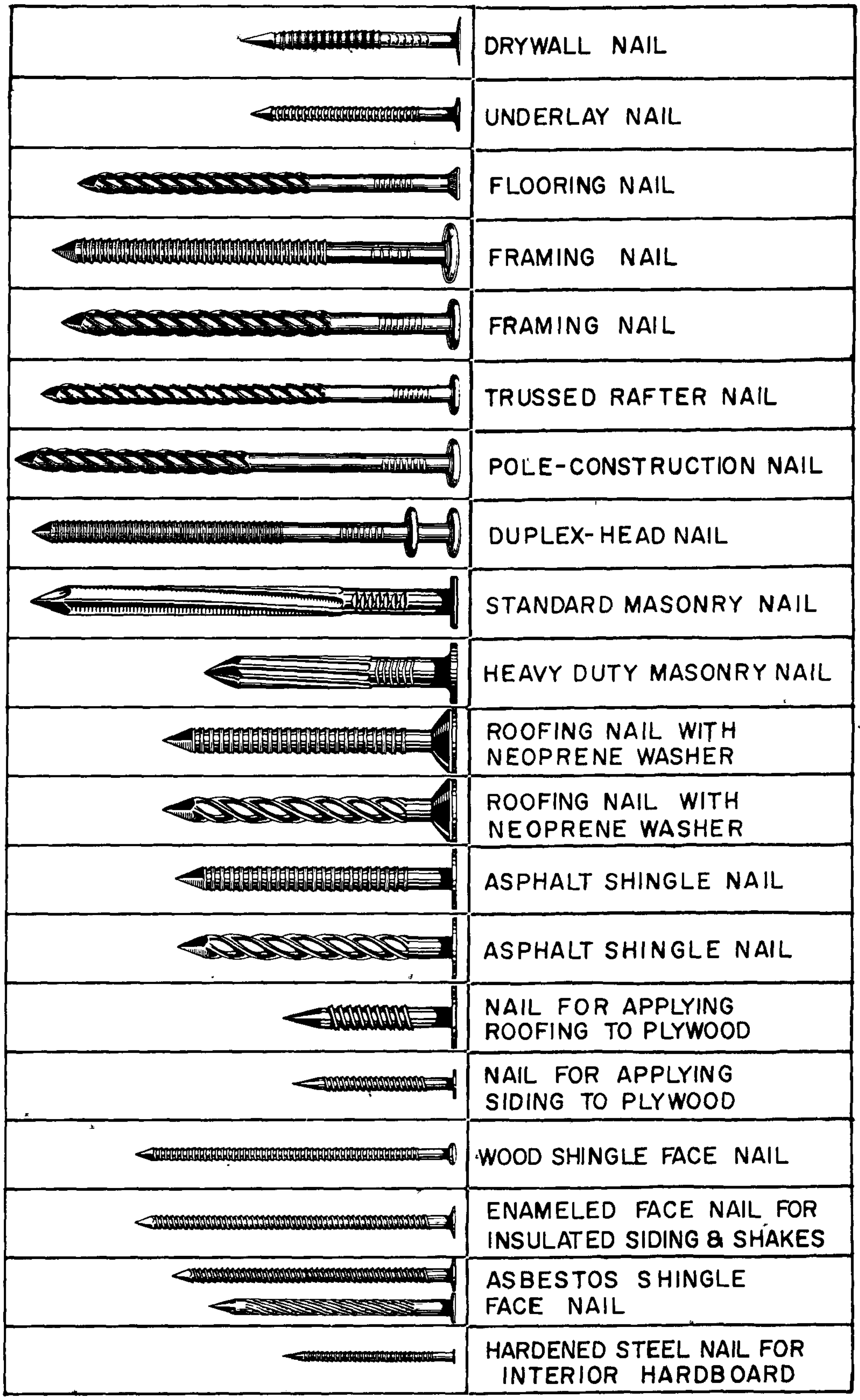

Fig. 2. Annular and threaded nails and their uses.

Dealers and builders may have some difficulty keeping on hand the right assortment of these special-purpose nails, but the advantages they offer are very great.

NAILING MACHINES

Automatic nailing machines for packing boxes have been popular for several years, but nailing equipment for house building has not. Two devices deserve attention. The power nailer for fastening down hardwood flooring is a great labor saver for that rather intricate operation. Another is a compressed air device that drives a large brad about 1 1/4 inches long. It will easily drive through the toughest hardwood and through a layer of light metal besides.

Small hand staplers, little larger than the usual desk type, are used extensively for installing insulation, fastening up bell and antenna wire, or putting up wire for electrical house heating before plastering. Heavier machines, generally called "tackers," that drive longer staples may be used to fasten wallboard, thin plywood, insulation board, and sheet aluminum, and to apply asphalt shingles. Tackers drive staples 1/2 to more than 1 inch long. They are usually operated by compressed air or by striking the driver with a mallet (Fig. 3). Wider use of adhesives for sheet materials should increase the popularity of tackers, because inconspicuous staples can be depended upon to hold panels in place until the adhesive has set.

SELF-TAPPING WOOD OR SHEET METAL SCREWS

The holding strength of screws is greater than that of nails, but the extra time required to drive screws increases the overall cost. The determining factor is the cost "in place." Improvements in the design of screws have made them more useful for builders.

A type of screw with a tapping point eliminates the separate operation of making a pilot hole. A simple mechanical driver will start and drive these screws in one operation, thus making this system of fastening more practical for installing devices and fixtures, as well as for applying plywood or other sheet materials to posts, beams, and rafters.

Self-tapping screws are obtainable in many sizes and types. The slotted-head type is the most difficult to drive with mechanical drivers. Builders should therefore consider the more efficient Phillips and hexagonal heads. These are widely used in automobiles because they are easier to drive and there is less likelihood of loosening.

Self-tapping screws may be quickly installed through light metals or roofing. For exterior work, screws with dichromate dip resist corrosion, or types made of aluminum or brass-plated steel may be employed.

BLIND RIVETING

For many kinds of sheet metal work, especially the installation of wall sheets or long spans of roofing, there is access to only one side of the sheet. A new pop-riveting device is an ingenious machine for such situations. It inserts rivets through holes in the metal and quickly and securely fastens them. The hand-operated type (Fig. 4) is generally used, but a semi-automatic type is available for extensive operations.

ADHESIVES

Glues and cements have been used mostly for attaching linoleum to table tops or floors or for setting asphalt tile, and as a "contact cement" for attaching plastic laminates. A great variety of adhesives is now available. Some have fantastic holding ability and many are moisture resistant. A new one is said to permit attaching linoleum to concrete slab floors. Cements have been developed for metal piping (such as aluminum, which cannot be readily threaded), and may be one answer to cheaper plumbing systems.

Good adhesives should be inexpensive, easily stored, and easily applied. They should set quickly enough but not too quickly, and should continue to hold properly under all normal conditions. Some adhesives are excellent except for high cost, which may be as much as 10 cents per square foot. This is a major consideration in the manufacture of stressed-skin or sandwich wall panels or roofs, which have two or more glue lines.

An important use of adhesives is in the construction of trussed rafters. Gusset plates may be held securely with glues, with a few nails to hold the plates in place till the glue has set. Choice of glue for this purpose is influenced by several conditions. Even if drying can be done indoors, it may be necessary to store completed rafters outside until they are put in place. Sometimes rafters must be built in cold weather, or in summer the hot sun on the roof may raise attic temperatures to 150° or higher. Rafter construction therefore requires adhesives that will stand severe treatment. Many glues good elsewhere are not suitable for rafters.

Common casein glue, obtainable nearly everywhere, is one of the least expensive adhesives and is satisfactory for rafters. Although it is not as strong as some others, it is better suited to rough lumber where joints cannot be made completely tight. Casein glue comes as dry powder and can be stored easily. Only water is added to prepare it for application, but once it has set it is waterproof.

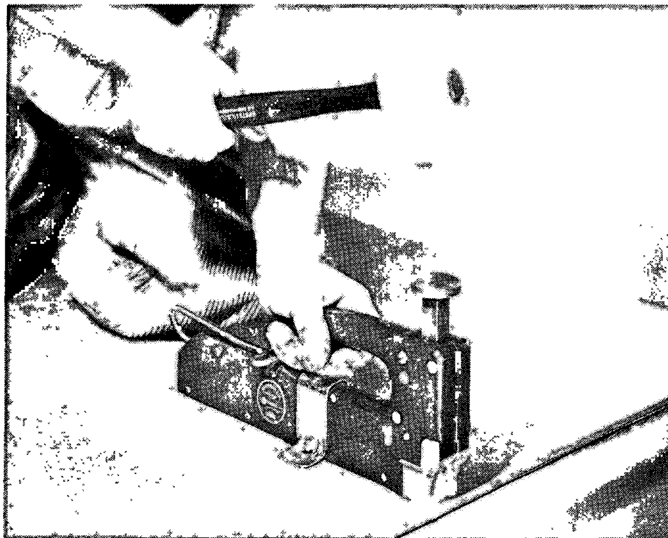

Fig. 3. Heavy duty staple tacker.

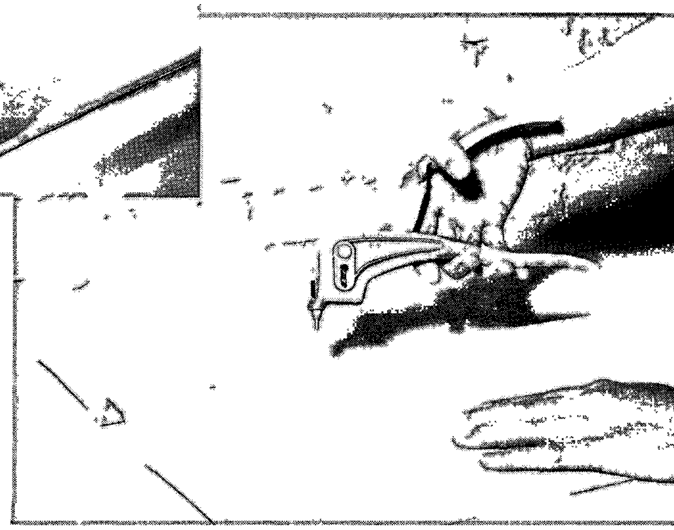

Fig. 4. Pop-riveting device loaded with rivet.

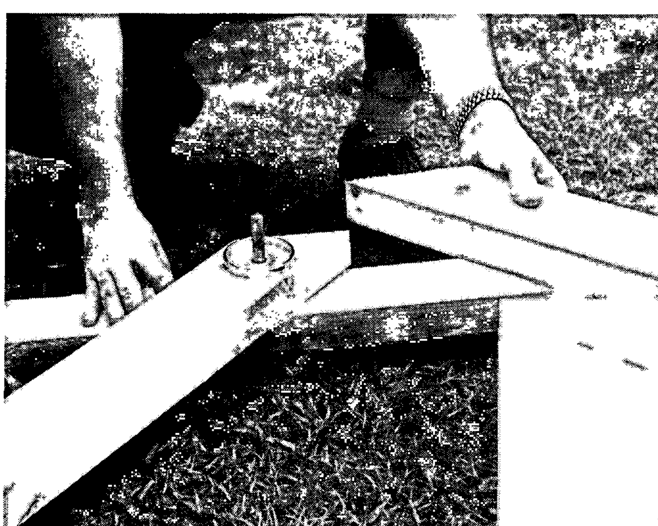

Fig. 5. Split-ring connector for rafter construction.

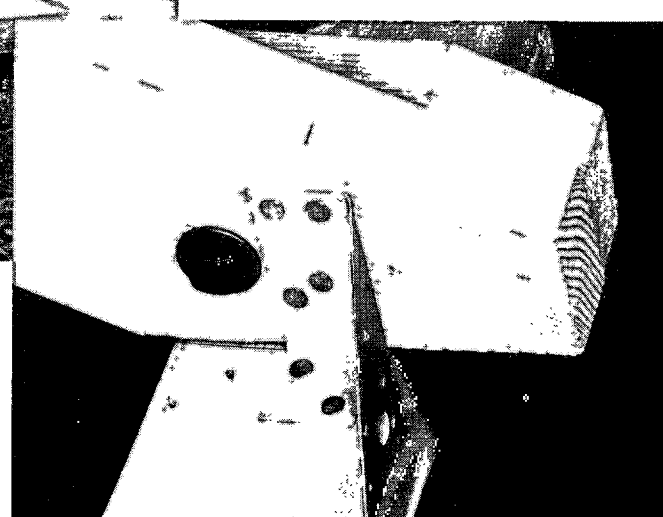

Fig. 6. Framing anchor fastens rafter to plate.

TIMBER CONNECTORS

Metal devices for holding wood framing members together have been known for several years. The surface type is best represented by the familiar grip plate. Another type is a concealed connector such as the split ring or toothed ring, used between timbers and usually depending on a bolt for attachment. Another is the framing anchor, which is a special kind of angle plate for reinforcing framing joints.

Many kinds of metal plates and metal gussets are on the market. They strengthen wood joints, particularly against a direct pull. Most of them are made of heavy steel and have special designs of teeth stamped into them. Merely held in place by nails, they make one nail do the work of several. These plates are an improvement over the established practice of toenailing. For most efficient installation, however, the plates should be applied by a power press. They are therefore more suitable for factory fabrication than for application at the building site. One of the chief advantages of metal plate fasteners is that rafters made with them may be stacked in small space, the thickest point being essentially the thickness of a single timber.

Other devices have been developed to give extra strength to timber joints. Toothed rings, spiked grids, and spiked shear plates are intended for use at joints that are fixed and permanently bolted. In order to embed the plates in the wood for maximum holding power, timbers should be drawn together with threaded rods of high strength steel or with small hand-operated hydraulic presses, after which ordinary bolts and washers are installed.

When rafters are to be fabricated and then shipped or hauled a distance, a different type connector is desirable. The split-ring type (Fig. 5) consists of a round smooth ring, double wedge-shaped in cross section, seated in a circular raceway cut into both members. A special drill cuts the raceway and drills the hole for the bolt in one operation. The advantage is that the whole rafter can be folded or taken apart for shipping and is easily assembled on the site.

Framing anchors (Fig. 6) consist of a piece of heavy-gage galvanized steel, bent into shape, with holes for nails. Anchors are most advantageous at joints between the plate and rafters and where studs attach to sills. Toenailing prevents sidewise movement, but anchors give more protection against uplift. Anchors are of several types, and the proper one should be selected for the purpose.

MOISTURE PROBLEMS AND VAPOR CONTROL

F. A. Joy
Professor of Engineering Research

Thirty years ago, your fathers would have called me crazy if I had warned them: "Look out for moisture in a frame house." The only moisture problems they knew resulted from rain and snow. We still have problems of keeping roofs tight and avoiding snow dams on low pitched roofs, but we also have to consider water vapor inside the house and how it behaves. Where does this water vapor come from? Why has it become a problem in modern houses? What harm does it do? What protection is needed? We'll consider each of these questions.

Water vapor is produced inside a home because people live there. Breathing produces vapor. Cooking, dish washing, bathing, laundry -- all produce vapor. Open gas flames produce vapor. Even the geranium at the window adds its bit. Studies indicate that the average family actually turns 3 gallons of water into vapor every day, more if there's a baby who needs frequent feeding and laundry. This vapor does no harm in the summer because the windows are open. The trouble comes in winter, and we call it condensation. But remember this: winter condensation is not the result of heating the house. There would be no condensation if nobody lived there.

Wrong notions about the cause of condensation are widely held. I visited a schoolroom on a cold day in January, in a big school with a central heating system. The windows were covered with frost, and the teacher said, "It's the gas heat." The school was heated by circulating hot water and the gas was burned elsewhere. The cause here was a crowded room and insufficient ventilation for the single-glass windows. Even teachers make mistakes.

Ventilation is one reason why our fathers were not troubled by condensation. Their houses were not tight. With loose windows and a fireplace, there was abundant air change to carry out the water vapor generated inside. In the small and tight modern house, the winter relative humidity (RH) may be 40% or even more.

At the opposite extreme, a drafty house occupied by adults away at work all day will have low RH, and supplementary humidification for the sake of furniture and carpets is desirable. Humidification may even be important, in rare cases, for people who have a respiratory illness.

Whether natural or artificial, 40% RH requires attention to the condensation problem.

CONDENSATION IN WALLS

Condensation on glass has been seen by everyone. Condensation also occurs inside of walls, though few have seen it. The cold outer skin -- the siding -- is the danger zone when insulating sheathing is used. And wet siding results in paint blisters. March is the month to see paint blisters, sometimes half a cup of water in one blister. People aren't looking at paint in March, so they rarely see them. In May the blisters are gone but the paint is loose and shabby. Some of the new types of paint resist blistering much better than older types.

Excessive condensation also produces swelling of wood siding. It may buckle, crack, or pull nails.

How does water vapor get into a frame wall that is plastered inside and has no cracks? We call it vapor diffusion, and we say that the wall is permeant to vapor. In the laboratory we measure the amount of vapor that will diffuse through all sorts of building materials, rating the materials in perms. The perm rating for vapor transmission compares with the C value or U value for heat transmission.

Ordinary gypsum lath with plaster rates about 20 perms. This wall finish, either bare or papered, will allow about 7 quarts of water (as vapor) to enter the walls (1000 square feet) of a typical small house in one day of zero weather. Glass fiber or mineral wool insulation and insulating sheathing also have high perm ratings. Since vapor wets nothing until it condenses, these porous wall elements rarely get wet in the Pennsylvania climate. Wood siding and paint resist vapor passage, and as a result, vapor condenses just as it does on cold window glass. (A more technical discussion of condensation in frame walls is available in Technical Paper No. 89, "Basic Concepts of Water Vapor Migration and their Application to Frame Walls" by F. A. Joy, College of Engineering and Architecture, The Pennsylvania State University.)

Shingles have cracks that permit vapor to escape with little condensation. Metal siding is usually vented for the same reason. Brick veneer may have a low permeance permitting condensation, which normally escapes through weep holes. In other wall structures similar principles apply.

To illustrate these principles, A of Fig. 7 shows the wall section of an unoccupied but heated house. Dots are used to suggest the concentration of water vapor, which is the same inside the house as outdoors. It is also the same in the wall cavity, which contains fibrous insulation. Vapor does not condense on the exterior of siding nor on its interior surface. This demonstrates that heat alone does not produce condensation. (It may be noted that a new house with new plaster provides, when first heated, a big supply of water vapor -- even more than an occupied house -- and the vapor concentration indoors is high until the plaster dries.)

In B of Fig. 7 the house is occupied. Vapor sources raise the concentration eightfold, and vapor enters the wall cavity through the plaster-gypsum finish. If the more resistant siding (the skin) were warm, the vapor concentration would quickly rise to equal that in the room. But the siding is cold, and concentration there is limited by vapor condensation. The vapor flow continues, with concentration or vapor pressure along its path dropping in proportion to the resistance of each element, as suggested in Fig. 7. But there is no condensation along the vapor path, which is everywhere warmer than the skin. This behavior can be explained in two simple statements:

1. Vapor diffuses from high to low concentration (or vapor pressure).
2. High vapor concentration plus a cold obstruction gives condensation.

CONTROL OF CONDENSATION IN WALLS

There are three principal ways to avoid condensation within walls:

1. Increase ventilation within the house.
2. Ventilate the cold side of the insulation.
3. Apply a vapor barrier on or near the warm side of the structure.

The first method is our fathers' way, though they did not plan it. Ventilation is the most practical way to get rid of vapor produced in the house, but ventilation in excess of the real needs of the family wastes heat. Actually, the minimum need for ventilation is based on control of odors, for which incidental ventilation or infiltration is generally adequate.

In zero weather, ventilation at the rate of 40 cubic feet per minute will remove the vapor equivalent of 3 gallons of water in one day, holding the average relative humidity down to 40%, but peaks of vapor production may require three times this rate. This is not assured by infiltration in a modern small home, and a kitchen exhaust fan controlled by a humidistat is recommended when more than three people occupy the house. A fireplace or other assured vent is desirable. Without such a vent, forcing fresh air into the house is not advisable because the outgoing damp air is likely to deposit harmful condensation in cold crevices. An exhaust fan is safer.

The second control method requires furring out the siding, and it is very effective. The gap between sheathing and siding should be 1/4 to 3/8 inch. It must be open at top and bottom, with screens to prevent insect entrance. We have tested this method on our test house, and the paint coat is still virtually perfect after 10 years.

The third method, generally used and often misused, is to apply a vapor barrier. Commonly the barrier is a sheet of paper with an asphalt coating, or a lamination of asphalt between two sheets to give it a 1 perm rating, a value that is adequate for typical frame wall construction. A 1 perm barrier well applied will reduce vapor entrance to 5% of the unrestricted flow through a plaster-gypsum finish. This small amount can usually escape through cracks on the cold side as fast as it enters. Thus the wall is safe from condensation. The vapor barrier sheet must not be colder than 45° F, to avoid condensation on itself. Placing the barrier close to the interior finish or on the interior side of insulation keeps the barrier warm.

Insulation blankets are usually made with a vapor barrier sheet on the warm side and a high permeance back-up or "breather" sheet on the cold side. Sometimes one or both are reflective. If the sheet on the cold side is aluminum foil, it should be perforated to permit easy escape of vapor. The blanket "ears" or tabs are formed to fit into a 16-inch stud space, with an air cavity on each side of the blanket. Each air space has insulating value if the air is relatively "dead" and tightly contained. The ears should be stapled to the interior face of studs as shown in A of Fig. 8. The barrier sheet must also be carried up over the face of the top plate and down over the face of the sole plate. When the gypsum is applied, it clamps the barrier against the framing to give a seal that is virtually airtight. Such tightness is very important for blankets placed in the middle of a wall cavity.

When a blanket is wrongly installed with a crevice between barrier and framing at the top and another crevice at the bottom, as shown in D of Fig. 8, there is a chimney action of the warm air on one side of the blanket and a downdraft of the cold air on the other side. Connected at the top and bottom, these air movements are continuous; the vapor is carried around the barrier and deposited as condensation on the cold side, rendering the barrier useless. At the same time, heat is transferred around the blanket, which may easily lose half of its insulating value. The crack size determines the rate of air flow and heat loss, but a very small air flow nullifies the barrier function. This is the reason why ears should not be stapled to the sides of studs, as shown in B of Fig. 8, unless a wood lath is added to clamp them tightly. This extra job is considered impractical.

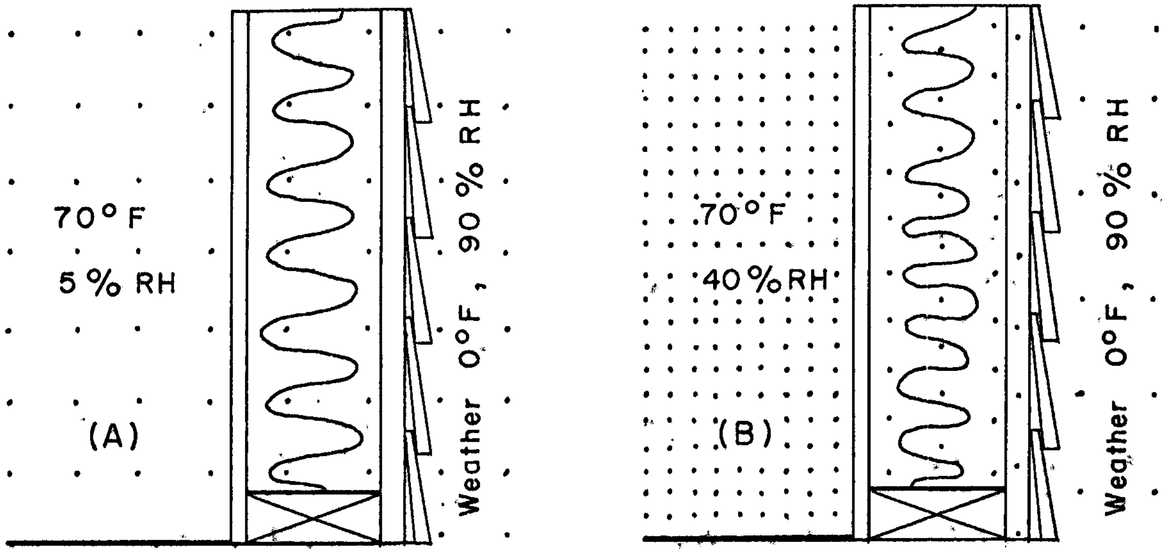

Fig. 7. Vapor diffusion in wall sections of (A) an unoccupied house and (B) an occupied house, without vapor barrier. Dots indicate vapor concentration.

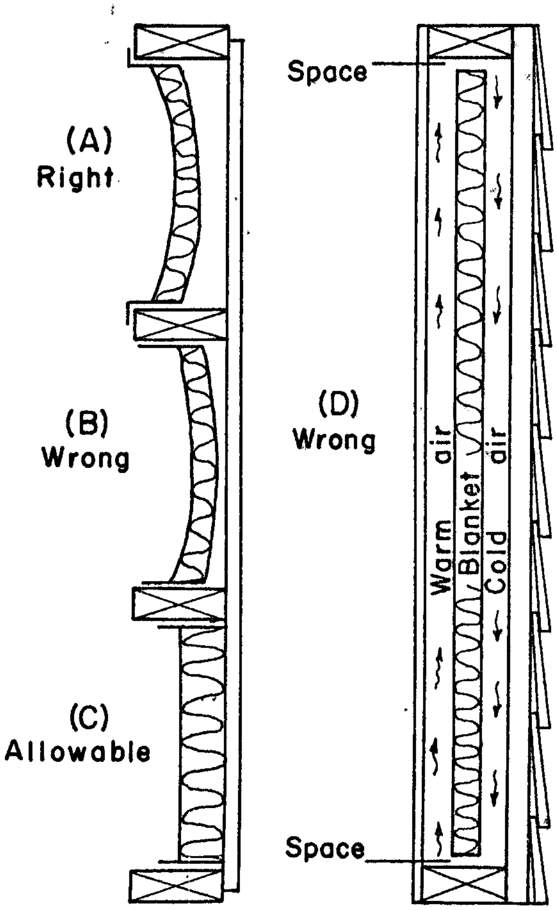

Fig. 8. Blanket attachment.

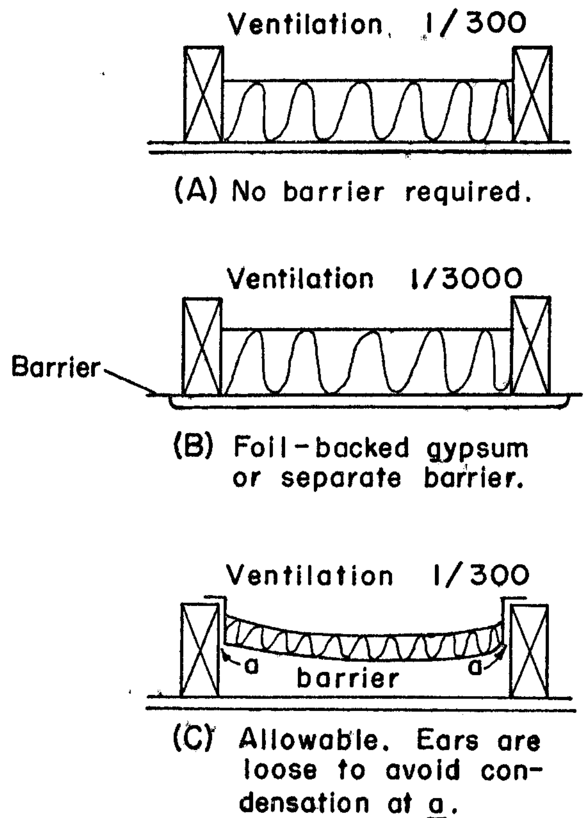

Fig. 9. Insulation above ceiling.

The attachment shown in C of Fig. 8 is allowable if the blanket or batt is 2 inches or more in thickness so that the vapor barrier temperature is above 45° F. Eliminating the cold cavity avoids air rotation, and minor crevices under the ears may be tolerated. Batts that fill the wall cavity generally require a separate vapor barrier. Walls of new houses to be filled with blown insulation should be built with a barrier in place, but old houses that are drafty rarely need such protection.

A dependable vapor barrier is provided by aluminum foil on the back of gypsum lath. Cracks between laths permit vapor diffusion in proportion to the area uncovered, but air circulation through the crack (the villain in B of Fig. 8) is stopped by the plaster coat. Another good vapor barrier is a large separate sheet installed at the last moment before the gypsum, thus avoiding injury. Present information indicates that polyethylene will be durable in this service. Since it can be obtained in large sheets that are easily installed, its cost is likely to be offset by labor saved in placing the insulation.

It is doubtful that the vapor barrier in walls is properly applied on more than one job out of ten. The fact that complaints are not more serious is believed due to the lucky assistance of other vapor control methods, such as ventilation (which protected father's house so well) and cracks on the exterior such as shingles provide. Valuable assistance also is rendered by paint as the interior finish. Varnish, oil, and rubber-base paints are all helpful, but water paint has little resistance to vapor.

In trouble, one sometimes has to resort to paint as the principal or only vapor barrier, but reliance on paint in new construction involves some hazards and is not generally recommended.

CONDENSATION IN ATTICS AND ROOFS

Above the occupied space, condensation presents other problems. Unless the attic is ventilated, vapor entering through the ceiling condenses on the cold roof boards. When the condensation is heavy frost, a change to warmer weather suddenly releases water that drops back onto the ceiling and may produce stains. In an extreme case the roof boards, retaining water in warmer weather, may rot and fail.

Under a pitched roof it is usual to insulate the ceiling and ventilate the attic, utilizing control method No. 2 as described for walls. With abundant attic ventilation, a vapor barrier in the ceiling is not ordinarily required. Attic openings properly placed, with a total net area equal to 1/300 of the ceiling area (A of Fig. 9), are considered adequate in Pennsylvania.

Under a flat roof with low crawl space, ventilation is less dependable and a vapor barrier in the ceiling is usually recommended.

When ventilation above the insulation is not adequate, the vapor barrier is most important and the problem of good application is evident. Blankets or batts as used in walls are entirely satisfactory if they are placed before the ceiling gypsum, with their ears or tabs stapled to the bottom of ceiling joists. A blanket placed higher, with tabs attached to the sides of joists, cannot provide a good vapor seal without hold-down laths which involve much labor. A more practical method uses foil-backed gypsum or a separate barrier sheet, as shown in B of Fig. 9.

When the attic is high enough for workmen, the insulation may be placed after the gypsum ceiling is applied. A blanket with integral vapor barrier may be dropped between the joists; the barrier, resting on gypsum, is partly effective because air motion is limited. Attachment of the blanket to the top of ceiling joists, leaving a cavity below, presents a hazard of condensation on the cold ears of the blanket if they are tight enough to stop vapor flow. Loose ears and attic ventilation are recommended if this position of the blanket is chosen (C of Fig. 9). The top sheet should be a breather, not a barrier.

Finished rooms in an attic often require insulation between the roof joists. A vapor barrier is usually needed, and ventilation between the insulation and roof boards should be provided by an assured path from openings under eaves to a vent at the ridge or at gables above collar beams.

A special situation is a roof slab made of insulating board 2 or 3 inches thick, which serves as the ceiling, the roof deck, and the insulation in one unit. As there is no attic, the cold side of the insulation cannot be ventilated. For the Pennsylvania climate, a vapor barrier as good as 1/2 perm is incorporated within the slab. When a slab of this kind is used for a flat roof with built-up roofing, vapor that enters cannot escape to the outside and is trapped until summer, when it must return by the same path. Fortunately, the summer temperature of the roof is high in this latitude and provides the necessary drying before another condensation season occurs.

CONDENSATION UNDER FLOORS

Floors over cold, well-ventilated crawl spaces should be insulated for comfort. A vapor barrier on the warm (top) side of this insulation is not required in normal floor construction since there is no cold outer skin to be protected. A vapor barrier on the cold (bottom) side is improper and might condense vapor if colder than 45° F. Insulating sheathing without vapor barrier, nailed to the bottom face of floor joists, is a good choice. So also is perforated aluminum foil.

If a blanket with integral vapor barrier is to be used, place the barrier up. If this is impossible, it may be placed down with the ears loosely attached to permit vapor escape. Heat loss due to such crevices is small since the heat flow is downward and the air above is warm and quiet.

When there is only a little ventilation, the crawl space is warmer and vapor rises from the damp soil. This is a hazard to the sills, which are cold. Moisture-laden air may also enter walls, the rooms above, or even the attic if there is any passage permitting upward air drafts. To guard against these results, the ground should be covered with a good vapor barrier resistant to rot. Heavy roll roofing or a polyethylene sheet is recommended. Joints should be closed but need not be sealed.

A crawl space used for warm air distribution or return is of course not ventilated and requires a ground cover. The vapor concentration is the same as in the living space, and if this is high, special problems are involved. For heat economy, the masonry foundation requires insulation, which may contact the masonry only if it has (1) good resistance to rot and (2) vapor resistance within itself or provided by a vapor barrier on its warm side.

An alternative treatment which leaves a gap (1 inch or more wide) between insulating board and masonry requires no vapor barrier. Vapor passing through the board condenses on the cold masonry and runs down into the soil under the ground cover, which is turned up a few inches on the warm side of the board. (In some cases this may be a good way to get rid of excess moisture without unwanted ventilation.) Insulating boards so located may rest on a few bricks topped with polyethylene to keep them dry. In either construction, safety of the boards from termites may require consideration.

Cold sills and sill plates should be protected from vapor and from condensate on the cold masonry by a good barrier or a bituminous coating on three sides, not including the weather side. The outer ends of floor joists are kept above condensation temperature by the sill and finish, totaling at least 2 inches thick. Such crawl spaces should be open to ventilation in summer.

Moisture under a slab on ground is a balance between liquid water supply from surface or deep sources and vapor diffusion, diffusion being mostly toward the cold perimeter in winter. Insulation is required around the perimeter, and only certain types, properly placed, are expected to stay dry for the life of the house. A vapor barrier under the slab and enclosing its edges is recommended. Details are presented in Better Building Report No. 1, "Slab-on-Ground Construction for Homes."

SUMMARY

In summary, these facts are emphasized:

(1) Water vapor in a house is produced by people living there, and it must escape somewhere.

(2) Ventilation of the house removes vapor and is necessary. Houses exceptionally tight or crowded need more than incidental ventilation.

(3) Condensation occurs under the vapor-resistant outer skin of the structure if it is cold.

(4) Ventilation under the skin (on the cold side of insulation) is one way of preventing condensation.

(5) A vapor barrier limits vapor entrance into a structure to a safe value. The barrier must be placed where it is warm to avoid condensation on itself.

(6) Movement of warm air can carry much water vapor to a cold condensing surface.

(7) Vapor barriers lose their effectiveness when crevices allow air currents to bypass the barrier.

HEATING SYSTEMS FOR RESIDENCES

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The purpose of a heating system is to keep the occupants of a residence comfortable during cold weather. In this latitude every residential building must have some kind of a heating system.

This is an elementary discussion of heating systems for residences. At the outset, it should be made clear that a well-designed heating system will not alone provide all the comfort desired if the structure is not properly insulated and sufficiently well constructed to exclude infiltration air around windows and doors or through walls. Therefore, it is assumed that the envelope of the structure has been well designed and constructed.

It has been customary to classify heating systems according to the heating medium that carries the energy to the space to be made habitable. On this basis there are four systems now in use, with certain variations of each. They are (1) hot air, (2) hot water, (3) steam, and (4) electric. This discussion will deal principally with the first three.

HOT AIR HEATING SYSTEMS

Hot air systems have been used extensively, primarily because they are less expensive to install than either hot water or steam. When properly designed and installed, they will heat a residence well and provide a high degree of comfort. In these systems the furnace heats air, which is then circulated either by gravity or by a fan to the various rooms. The addition of moisture to the air should be carefully controlled; otherwise, condensation may occur and cause damage.

Hot air systems offers several advantages. (1) The cost of initial installation is relatively low. (2) They are adaptable to air conditioning. (3) Humidity can be supplied and controlled from a central source. Most houses of low occupancy are too dry in the heating season, and supplementary humidification is desirable. (4) They are adaptable to radiant heating. (5) They provide air motion. (6) Ventilation can be controlled. (7) Air can be filtered.

There are also disadvantages. (1) Heat exchange from the combustion chamber to the heating medium (air) is not as efficient as it is to water. (2) Gravity air circulation systems are not very satisfactory. (3) Noise produced by the fan and air distribution system may be bothersome. (4) Owing to the small heat-storage capacity of air and to periodic operation, a sensation of coldness may be experienced when the thermostat is not calling for heat (cold 74).

In slab-on-ground construction it is important to counteract the edge heat loss of the perimeter of the slab. This is done by insulating the edge of the slab. In many cases this is not sufficient to adequately avoid cold floors around the outer edges. Perimeter ducts for distribution of the hot air provide an excellent means of increasing comfort. This is, in effect, radiant heating by making what would be a cold portion of the floor the warm panel. Perimeter distribution also puts the warm air at places where it counteracts downdrafts from the heat losses through the outer walls and window glass.

The new baseboard hot air diffusers, which are placed under windows and portions of the outer walls, not only provide excellent distribution but produce a certain degree of baseboard radiant heating. The whole floor of a residence can be heated by distributing hot air under it in a network of ducts and discharging the warm air along the outer walls. This makes a comfort-producing radiant system, and gives the added advantages of ventilating with air motion and counteracting discomfort from cold walls.

It is possible to design a hot air system with the hot air introduced in the ceiling and cold air returned under the windows. This type of distribution system is well adapted to both air conditioning and heating.

A hot air system provides excellent versatility in design and is a good system when properly handled.

HOT WATER HEATING SYSTEMS

These heating systems have been used extensively and are considered the de luxe type for residences. They are readily adaptable to both new and older homes. With the mechanical equipment now available, such as new boilers, pumps, controls, heat exchangers, and copper tubing and fittings, hot water heating can be easily installed and efficiently operated. On the other hand, it is the most expensive heating to install.

The advantages of hot water systems are: (1) they provide uniform heating throughout the space, (2) they are responsive to control requirements, (3) they are good for radiant heating, (4) they provide some air motion by natural circulation, (5) there is no "cold 74," (6) heat exchange in the boiler is efficient, (7) they present no noise problems, and (8) water temperatures can be varied to meet desired capacities.

The disadvantages are: (1) hot water systems are expensive to install, (2) they are not too adaptable to air conditioning, and (3) they depend to a large degree on infiltration to provide ventilation.

The series-loop arrangement, using baseboard units of low heat capacity and a circulator or circulators, is an excellent system and provides the ultimate in comfort. It can be broken up into any desired number of zones, with separate controls on each. The principal advantages of this arrangement are that it is responsive, gives radiant heat along with convective heating, and maintains a low temperature gradient from floor to ceiling. The room units occupy very little floor area and are located so that they counteract downdrafts from windows and walls. Some units are attractively designed and will blend nicely into the decor of the house.

Room units are now on the market that have fans to force air over the heat exchangers. These units are adaptable to individual room control. They can also be used for air conditioning with chilled water circulating through the system. The fans on these units sometimes produce a noise level that is a nuisance.

Single-pipe hot water systems have been developed and can be installed around the perimeter of the house for as little as $350 for furnace and piping. In this arrangement, the heat exchanger is a plain 3/4-inch pipe without fins; the heating medium is water, which may be carried at 220° F. This simple system can be attractive in low cost housing.

PANEL HEATING

Panel heating systems, or "radiant" as they are popularly known, are introduced here because hot water is the principal medium of energy distribution used. This type of system has been used successfully for many years in England and on the Continent. In panel heating, a surface (floor, ceiling, wall, an added surface, or some combination of these areas) is warmed to such a temperature as to supply the heat losses from the room and raise the mean radiant temperature to the desired level for comfort.

The principal mechanism of heat transfer is radiation, particularly in overhead arrangements, but convective transfer is an important factor in floor installations and to a lesser degree in wall panels. A word of caution: radiant systems can produce considerable discomfort if they are not properly designed and operated.

There are some things to guard against in panel heating. When it is used in the floor, the surface temperature should not exceed

80° F. Human beings become uncomfortable when their feet are too warm. The structure in which the piping is installed should have a minimum of mass or weight. Otherwise, the system will not be responsive to changing weather conditions. Floor installations with limited temperatures (not to exceed 80° F) oftentimes will not provide sufficient heating area to compensate for the heat loss from a room, particularly if there are large glass areas. In addition, carpeting serves as an insulating layer. It is therefore necessary to have an auxiliary heating surface. Wall areas under windows are generally selected for this purpose. If the piping is installed overhead to make the ceiling the heating panel, which is a very effective application, an auxiliary ventilating system or fan should be used to avoid stagnation of the air. A feeling of "stuffiness" in a house is usually caused by lack of air circulation.

The temperature of a space heated with panel heating is called the mean radiant temperature (MRT). It is not practical to maintain this temperature at a value much different from the air temperature shown on a thermometer. Claims are often erroneously made that the air temperature with radiant heating can be under 70° F and still be comfortable. Small temperature gradients from floor to ceiling in radiant systems provide greater comfort in the living zones.

STEAM HEATING

Steam heating in residences is obsolete. It is rarely installed in a home nowadays. It lacks flexibility, and the auxiliary components, such as air vents and traps, require too much servicing. Steam systems are also likely to be noisy.

THE FURNACE AND THE BOILER

Three fossil fuels -- coal, gas, and oil -- are generally available in all parts of Pennsylvania. The least costly of these is coal, particularly bituminous. The liquid or gaseous fuels are more easily handled and burned under controlled conditions. On the other hand, recent developments in stokers and magazine feed devices have made the handling of solid fuels easier in residential heating systems.

The approximate efficiences of fuel utilization for home heating are as follows:

1. Coal
   a. Hand fired, 40%
   b. Stoker, 60%
2. Gas, 70%
3. Fuel oil, 70%

It is interesting to note the advances made in recent years by the boiler and furnace manufacturers. The Btu output per pound weight of metal furnace has increased tremendously. As a result, heating units are much smaller and easier to install than formerly. Furthermore, the new units are more efficient. Induced draft oil-fired boilers and other fuel oil combustion devices now being introduced promise to further improve the efficiency and cleanliness of fuel utilization.

THE HEAT PUMP

This discussion would not be complete without mention of the heat pump. Although little use has been made of the heat pump in this area, it is believed that with increased demand for air conditioning, this device will receive more attention. The heat source can be weather air or the ground; or if there is a good stream nearby, water will serve the purpose.

A feature of the heat pump is that its coefficient of performance may be as high as 3 to 1 on the energy supplied. Other features include its reversibility for air conditioning, as well as the cleanliness and accessibility of electric energy. The principal disadvantages of the system are high initial cost and high maintenance costs. Future developments are expected to overcome these handicaps.

For the time being, the cost of electric energy for the heat pump may be equivalent to the cost of gas or fuel oil in houses that are equally well insulated. With the continued rise in the cost of these fuels and the downward trend of power rates, the heat pump will become more competitive.

HEAT EXCHANGERS

Space heat exchangers are now of the finned convective type, with low heat capacity. A limited percentage of the heat transfer from these is by radiation. The old cast iron radiator is no longer used for several reasons. First, the excessive weight of metal is costly, not only initially but also to install. Second, the unit was not particularly efficient because of the lack of responsiveness. The new lightweight heat exchangers overcome these disadvantages.

SUMMARY

Installed costs for hot air and hot water heating systems (including the chimney) for houses of 1000 to 1200 square feet are: hot air, $600 to $1000; hot water, $1200 to $1500; 1-pipe hot water, $500 to $700.

Rising costs of fossil fuels and less rapidly rising, or gradually declining, electrical energy costs will probably cause a marked change in the kind of heating system installed within the next few years. In the meantime, coal, oil, and gas will continue to be used in systems the costs of which are much the same for the different kinds of fuel.

New developments in combustion, auxiliary equipment, and controls will keep fossil fuels competitive for several years. One of these is catalytic combustion. It promises, when released, to offer material improvements in residential heating. Other developments utilizing induced draft, oil atomization, and new controls will keep the fossil fuels in a competitive position for a long time.

Builders should again be reminded that heating systems can go only so far in providing comfort. Insulation, efficient construction practices, and good design must be used to produce a structure that can be heated properly and economically.

ELECTRIC HOUSE HEATING

Fred Nicholas
Associate Professor of Engineering Research

Electric house heating is rapidly gaining acceptance and popularity. Trends in the residential building market indicate that this method of heating is on the threshold of tremendous expansion. It was first employed in the low cost power areas of the Tennessee Valley and the Pacific Northwest. The Tennessee Valley Authority estimates that more than 95% of the new homes constructed in that area during the past five years have been equipped with electric heat.

TYPES OF ELECTRIC HEATING

Resistance heating and the heat pump are the two general means of electric heating. A heat pump is a self-contained refrigerating unit that cools a house in summer and by reversal heats it in winter. Resistance heating equipment includes baseboard units, central furnace units, floor units, wall heaters, glass or ceramic radiant panels, and heating cable. All resistance units convert electric energy directly to heat. Some units operate at red heat, while others scarcely reach 150° F.

SELECTION OF A HEATING SYSTEM

The major factors that should be considered in selecting a heating system for a residence are:

(1) Availability of Fuel. A heating system should obviously not be planned for a fuel that is not available or is difficult to obtain in the area where the home is located.

(2) Fuel Costs. Cost of the fuel today should be considered, and also what its cost will be during the life expectancy of the home.

(3) Initial Cost of the Heating System. This factor always deserves consideration, but small dollar differences are not important when spread over a period of years.

(4) Maintenance of the Heating System. It is always desirable to prepare an estimate of the anticipated cost of maintenance in order to obtain a more accurate picture of total operating costs.

WHY CHOOSE ELECTRIC HEATING?

The increasing acceptance of electric heating for homes indicates consumer recognition of its manifest advantages:

1. It is fully automatic, with individual room temperature control.
2. It requires practically no space. Boiler rooms, chimneys, pipe and duct chases, and fuel storage facilities are eliminated.
3. Electric resistance heating systems using low or medium temperature elements cost very little to maintain. Thermostats -- several instead of one in a fuel system -- are the weakest spots. Heat pump maintenance costs may be comparable to those of fuel-fired systems. But as in other refrigerating equipment, bad breakdowns are expensive.
4. Resistance heating is safe, clean, and noiseless.
5. It is practically 100% efficient in converting electrical energy into heat. Heat pumps may have an effective performance as high as 300%!

Consumer acceptance of electricity for space heating implies that operational costs are reasonable and acceptable in many areas. With the lower electric heating rates now available in Pennsylvania, the resistance heating cost for a house that is insulated as specified for electric heat averages 30 to 50% more than the cost of conventional fuels in typical houses with less insulation as they are normally built.

INSULATION REQUIREMENTS

The heating system has to replace the heat that is lost through the walls, floors, roofs, windows, and doors, and by infiltration through cracks around windows, doors, and structural joints. Insulation and weatherproofing reduce transmission and infiltration losses. Storm doors and windows or their equivalent are also generally recommended. When the construction job is well done, the cost of both energy and heating equipment will be less and the home will be more comfortable in winter and in summer.

Minimum insulation requirements for electrically heated homes are:

1. Floors: 2 to 3 inches of mineral wool or equivalent above unheated basements, and 3 to 4 inches under floors exposed to outside air temperatures.
2. Side walls: 3 5/8 inches of mineral wool or equivalent.
3. Ceilings: 4 to 6 inches of mineral wool or equivalent.
4. Concrete slab on ground: 2 to 3 inches of perimeter insulation against the inside of the foundation, extending down to a depth of 2 feet or running horizontally from the foundation 2 feet

under the slab. (Note: Better Building Report No. 1 specifies 1 to 2 inches of perimeter insulation for a fuel-heated home.) In addition, a suitable waterproof membrane should be placed over the gravel before the slab is poured.

5. Windows and doors: All windows and doors should be weather-stripped and properly calked, and should have double-pane glass or equivalent.

CALCULATION OF HEATING REQUIREMENTS

The procedure for calculating the kilowatt capacity required to heat a house electrically is identical with the method employed for a conventional fuel-fired system. The first step is to estimate the Btu losses per hour and then convert these values to kilowatts. This can readily be accomplished by dividing the Btu/hour heat load by 3413, which is the number of Btu in 1 kilowatt-hour.

To estimate annual kilowatt-hour consumption, the National Electrical Manufacturers Association suggests the use of the formula

$$F = \frac{HL \times DD \times C}{TD}$$

where F = estimate of annual kilowatt-hour consumption for heating
HL = heat loss of the house in kilowatts at design temperature = Btu/hour divided by 3413
DD = average annual degree-days for the location
C = factor with a suggested value of 18.5
TD = temperature difference between inside and outside design temperatures, in degrees F

This formula is an easy and satisfactory means of estimating the annual cost of electrically heating a home. Actual experience in similar houses is also a good basis.

FUTURE OF ELECTRIC HEATING

The trends in house construction, coupled with fuel costs expected in the future, indicate that electricity for house heating is assured of a larger share of the home heating market. Some optimistic authorities believe that within 20 years, electrically heated homes will comprise 75 to 90% of the new housing starts.

SLAB-ON-GROUND AND GRADE-BEAM CONSTRUCTION

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Professor of Architecture

This subject, discussed at the Small Builders School by Professor Hallock, is presented here only by title. It is fully reported in Better Building Report No. 1, "Slab-on-Ground Construction for Homes" (Engineering Research Bulleting B-76, College of Engineering and Architecture, The Pennsylvania State University).

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