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INNOVATIVE HOUSING IN NORTH AMERICA

Alan Johnson

BUILDING RESEARCH ASSOCIATION OF NEW ZEALAND

PREFACE

The Building Research Association of New Zealand (BRANZ) publish this report by 1987 BRANZ Study Award winner, Alan Johnson, as part of its ongoing support for innovation in building. The views represented are not necessarily those of the Association.

This report is intended for building firms, manufacturers, local authorities, government, and other members of the community interested in the provision of affordable housing.

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ABSTRACT

BRANZ Study Award winner Alan Johnson toured North America to study the relevance of housing innovations there to both the building industry and the housing market in New Zealand.

INTRODUCTION

Over half of the two million or so houses built in the United States each year are built partially or entirely in a factory. Could this approach to house building be the reason that house construction prices in the U.S. are between a half and one third of what they are in New Zealand ? If there is some link between an industrialised approach to residential construction and lower housing prices what can the New Zealand housing industry gain from a similar approach here ?

These two questions led to a proposal to study innovative housing in North America as part of the BRANZ Study Award in 1987. The subsequent trip to North America took place between mid-March and late May 1988. This paper is a report of this trip as well as a discussion of the relevance of North America housing innovations to both the building industry and the housing market in New Zealand.

A variety of housing organisations were visited, principally in California, Oregon, Wisconsin and the north-eastern states. Visits were made to 14 private sector corporations, two research institutions, and several Government and industry organisations.

The author also took the opportunity presented by this trip to visit a variety of community/ non-profit organisations involved in housing provision in some way. While the information gained from these visits is not directly relevant to the area of work that BRANZ is involved in, this information may nevertheless be valuable in lowering housing costs in New Zealand. Unfortunately there is not sufficient room for a discussion of these visits within this paper but those individuals interested in this area may wish to contact the author directly.

This paper begins with an overview of the U.S. housing industry. This overview will seek to outline what can be perceived as an intense rivalry between the two totally distinct sectors of the industry; the manufactured housing sector and the conventional site builders. It is worthwhile here to also comment on the regional characteristics of the industry. Here climate, labour supply, the level of wealth and historical accident seem to play a part in determining the shape and form of the building industry in various parts of the United States. This brief industry survey will also consider the various markets each part of the industry is serving and consequently the shape of consumer demand and various constraints on this demand.

The second part of this paper deals specifically with reports on the various corporations and organisations visited. These reports vary in depth and detail partly because several of the organisations visited offered little that was appropriate to the New Zealand housing industry and partly because the level of cooperation and the information supplied varied enormously between organisations. These individual assessments, where possible, will consider the techniques and technologies adopted by the enterprise, the market it is producing for and the final cost as well as the structure of the enterprise.

This emphasis on markets, costs and institutional structures is seen to be an integral part of this study. Without reference to such factors it is difficult to decide the value or otherwise of a building technology and even more difficult to determine the relevance of such technology to New Zealand markets and conditions.

The conclusion of this report will outline the techniques and methods seen in use within the U.S. home building industry which may be of use here in New Zealand. A brief mention will also be made of the approaches which are not seen as relevant to the New Zealand scene and the reason for this view. Finally the conclusion considers the overall value of the trip and includes some recommendations for future action.

For the casual reader it may be worthwhile to begin by reading the conclusions and referring back to the bulk of the report for details of particular products or organisations that are of interest. There are ample references in the conclusion to allow this.

THE U.S. HOUSING INDUSTRY

The housing industry in the United States is divided very clearly into two sub-industries, notably the manufactured housing or mobile home builders and the more conventional site builders known colloquially as stick builders. To the casual observer there would appear few differences between the products produced by each sub-industry particularly at the margin between up-market manufactured homes and low priced site-built homes. Nonetheless the market is distinctly aware of the differences as reflected in the resale value of each product.

It is obvious that there is an intense rivalry between the two sectors of the industry. This rivalry often made it difficult to determine fact from fiction when asking participants in one sub-industry to comment on the benefits of their sector over the other.

Site or conventional builders would often refer to manufactured housing disparagingly as mobile homes and claim that they were not built to the same quality or standard as site-built homes. To illustrate their point they would refer to the appearance of mobile home parks around the country and suggest that whenever homes were damaged by floods or tornadoes they were inevitably manufactured or mobile homes.

In response, manufactured house builders point to the major cost savings possible with manufactured housing, to the improving quality or manufactured homes and to discriminatory land use planning which often relegated mobile home parks to second-rate and potentially dangerous sites. Moreover, manufactured housing advocates claim that the standards to which manufactured housing must comply are simply different and often more comprehensive than those applied to site built houses.

Regardless of the merits of these arguments it is an inescapable fact that manufactured houses are significantly cheaper than their site built equivalent. U.S. Department of Commerce figures for 1986 showed that the average size of a manufactured home was 1,110 sq ft (103 m^2) and cost $US20.18 per sq ft ($217 m^2) while for a site built home the average size was 1,825 sq.ft (169 m^2) at a cost of $US49.05 per sq.ft. ($527 m^2). Yet despite this wide and apparently growing price differential the manufactured housing industry's market share of new single family homes has declined steadily in recent years. This decline may be due in part to change in regional demand where states such as Texas which are large producers and consumers of manufactured homes have been hit by the recession in the oil industry. Additionally this reduction in market share may be partially a result of increased industrialisation in the site-built housing sector.

It is probably worthwhile to consider the characteristics of each of the sectors of the U.S. housing industry separately in order to gain a better appreciation of the differences between them.

Site-Built Housing Industry

The first impression of the site-built housing industry in the United States is one of an industry dominated by large corporations. Certainly by New Zealand standards the U.S. home building corporations are large. However, within the U.S. housing industry the market share of these corporations is minimal. In 1986 of the 1.805 million site-built houses built, 94,000 or just over 5 per cent were built by the biggest ten home builders. The 482 building companies with annual sales exceeding $US 15 million build 450,000 houses or 25 per cent of the total market. A 1987 survey of builders activities, undertaken by the National Association of Home Builders (NAHB), showed in fact that 67 per cent of all builders had fewer than 25 housing starts per year and that 97 per cent of building firms were privately owned. (as opposed to publicly listed corporations).

There is an adage within the U.S. building industry that all you need to be a builder is a pickup truck and a dog. Entry into the house building industry appears relatively easy as a result of the availability of merchant credit and the absence of a formal trade training system. Builders generally acquire their skills through O.J.T. (on the job training) and in many states where the economy is less buoyant (i.e., the Midwest and the South) building contractors are literally working for wages. The existence of low paid operators with minimal capital backing has a significant effect on larger corporations working in the area of industrialised housing.

Because of this ease of entry and the low margins inherent in new home construction in many states the number of active building organisations fluctuates dramatically. The National Association of Home Builders (NAHB) estimates that there are between 96,000 and 130,000 home building corporations or partnerships nationwide depending on the state of the industry. In addition the 1982 census reported that there was 125,000 self-employed building contractors in the United States.

It appears also that the bulk of house building activities takes place in suburban markets. Roughly two-thirds of builders are building in such markets while a further 25 per cent are active in central city areas. Such a distribution of home building effort can be explained by the deteriorating nature of many inner city residential areas and the continuing emphasis on suburban development.

In recent years in the site-build housing industry, there has been increased interest in industrialised approaches to house construction. While the range of industrialised techniques available in the U.S. is far greater than that available in New Zealand, on average it would appear that the typical U.S. building firm uses about the same level of technology as most New Zealand home builders. Such reluctance to use more advanced technologies may be the result of the large numbers of small firms in the industry and the comparatively low level of capital investment required in such operations.

The industrialised techniques available to U.S. builders range from virtual stock-in-trade products and equipment such as roof trusses and pneumatic nailers, through relatively simple technologies like floor trusses, open wall panels and foam sheathing to more advanced materials/components such as structural foam panels and laminated veneer lumber. (Many of the more relevant of these will be discussed in detail later).

As well as having a wide variety of innovative products at its disposal the site-built housing industry has developed a number of building systems each of which is well established within the industry and some of which have their own market niche. Such building systems include:

Modular Housing

Modular housing is the term given to a construction system where a house is prefabricated in whole sections usually in a factory environment. These sections are generally 3.6-4.2 metres wide and up to 20 metres in length and are usually completely finished inside though often sidings and roofs were left partially unfinished. Modular sections are transported to site and often lifted by crane on to completed foundations and married up with associated modules. Some firms offer two- and three-storied modular houses where modules are simply stacked on one another. In many respects modular house construction is similar to that of manufactured or mobile homes though in the former the quality of materials used and the standard of design and finish is superior.

Panelised Housing

Panelised houses come in several forms. Some are merely floor, wall and roof components fabricated in a factory transported to site and erected with the use of a crane. Such panels are sometimes left open (open panels) for fixing to adjacent panels and for regulatory inspection. Panels of this hybrid type can be 3.0 metres wide and up to 13 metres long depending on the transport available and the design. Often panels of this type are little more than elaborate pre-nailed frames with some form of sheathing attached.

More sophisticated panels involve the use of polystyrene or polyurethane foam. Some of these foam panels use timber or aluminium framing for strength and fixing. Others use a form of stress skin construction where the foam is sandwiched between sheets of plywood or a form of coarse particle board often known as waferboard. There appears to be an ongoing debate within this sector of the industry over the merits of polystyrene versus polyurethane foam and over the various methods available for the fixing of sheets to foam. Corporations producing foam panels appear to be concentrated in the north-eastern United States particularly in New England where the high thermal efficiency of this form of construction is a key selling point. Some panel systems can provide thermal resistance "R" values of 10 (m^2 C/W).

Component Housing

Component housing is virtually an extension of the pre-cut, pre-nail packages available in New Zealand. Components available range from pre-hung doors and roof trusses to floor trusses, truss frames including both roof and floor trusses, and a variety of composite wood beams and laminated veneer lumber.

Log Housing

Log homes are another version of factory-made housing available mainly throughout the snow belt states (i.e., the northern U.S.A.) The log homes available come in a variety of styles from hand-hewn round logs to precision-machined interlocking planks. Examples of the latter are already available in New Zealand from local companies and, more recently, North American franchisers.

A mixture of panelised and log housing is the timber-framed or post and beam building system. As the name suggests this system uses heavy timber (200 x 150 min) for posts, beams and rafters and often uses skilled handwork to make specialist joints and scarfs. To provide walls and roofing post and beam, builders use logs in their various forms or stress skin foam panels. Needless to say, due to the labour intensiveness of this style of building and the use of top quality timbers this method of construction is expensive.

For both conventional log homes and the post and beam hybrid the key selling point is their distinctive appearance and their use of natural materials. Because of this distinctive appearance the market for such houses is limited.

Dome and Alternative Housing

Dome housing in the U.S. extends beyond the geodesic dome structures that are occasionally built as homes in New Zealand. As well as the use of timber as a construction material, domes are also built from fibreglass and ferrocement and from reinforced concrete with an earth shelter. This area of the U.S. housing industry was not studied, largely because of the limited market that such housing would have in New Zealand.

Manufactured Housing Industry

The manufactured housing industry has evolved over the last 40 years from making aluminium trailer homes (a form of large caravan) to the manufacture of substantial factory built homes. The early products of the industry left much to be desired particularly in terms of aesthetic appeal and unformity of standards. These links with the trailer home business of the 1940s and 1950s have led to manufactured homes being called mobile homes, a term which the manufactured housing industry would be pleased to erase.

The term mobile home is in fact hardly appropriate to the modern day manufactured home. While a manufactured house is fabricated in a factory environment and often shipped hundreds of kilometres, once it is located on its eventual site is seldom if ever relocated - in fact it is generally immobile.

The manufactured housing industry has since the early 1980s produced between 240,000 and 300,000 houses each year though over this time the industry's share of the single family home market has declined steadily. There are approximately 130 firms producing manufactured homes in 320 plants throughout the United States though only a dozen of these are publicly listed corporations. The bulk of the industry is therefore made up of small-to-medium-sized privately owned companies most of which are owner-operated.

Trends

Sources within the industry itself acknowledge that by nature the industry has been rather incestuous and introspective. Many of the changes of ownership of plants and companies have taken place within the industry with few new entrants. This may be because of the specialised nature of the industry and its unique approach to management, production and distribution which appears to be a mixture of the styles of the auto industry and the home building industry.

For some time now the manufactured housing industry has been attempting to improve its image in an effort to shake off the negative images of 40-year old trailer homes. Efforts in this regard have been geared towards stressing the quality and affordability of manufactured homes in an attempt to have them seen as close substitutes for site-built housing. The work of the Manufactured Housing Institute (MHI), the American Planning Association (APA) and several of the larger corporations has been important in this effort. Pilot projects or model developments using manufactured homes in well-planned, good quality subdivisions, have sought to demonstrate that with sensitive treatment and flexible planning controls, housing of a standard and amenity similar to site-built housing can be achieved.

However, despite these efforts to improve its image, the competitive nature of the industry and the persisting problems of housing affordability for low income Americans have led some producers to reduce their bottom line on size and quality to increase their sales. Several manufacturers are now producing a "house" which is a cross between a trailer home and a manufactured home, a product known within the industry as a park model home.

The park model home is generally a single wide (i.e, a single 3.6-4.2 metre wide module) manufactured home up to 12 metres in length and often not built to the same standards as more conventional manufactured homes. Producers of park model homes may claim that this product is not seen as a substitute for other manufactured homes but merely as an up-market trailer home designed for siting within vacation parks (the NZ equivalent to a caravan park) or as a holiday home (the NZ bach or crib). In reality, park model homes are used as permanent accommodation in both these settings with local authorities turning a blind eye to the practice. To some within the industry the advent of the park model home is evidence that the industry is bound to repeat the mistakes of the past.

There are fears within the manufactured housing industry of an invasion by the Japanese home-building industry similar to that which brought about a decline of the U.S. Auto industry. The Japanese housing industry has over the past 20 years become very mechanised with extensive use of computers and robotics. While the industry there is highly industrialised and more capital intensive than the housing industry in either the United States or New Zealand, its replication outside of Japan may be limited because of the nature of local consumer demand (which often prefers custom-built homes) and because of the local resource base.

While it is doubtful that Japanese homebuilders will make significant inroads into the U.S. housing market in the near future it is highly likely that they are nevertheless interested in the largest housing market in the world. However, given the manufactured housing industry's declining market share (despite improvements in their cost advantage over site built homes) it would appear that at present the manufactured housing industry is not a particularly attractive area of investment. What appears to be the declining fortunes of the manufactured housing industry may not be the fault of the industry itself but rather the result of a decline in the real incomes of those groups who have the highest demand for manufactured housing. Federal Government assistance for these groups in an effort to reduce levels of homelessness is likely to have a positive impact on the output of the manufactured housing industry.

Production Techniques

The production of manufactured homes follows the same general form in most manufacturing plants though the extent of on-site fabrication of components may vary from plant to plant. In common with other forms of industrialised housing in the U.S., the manufactured housing industry has adopted a relatively low capital, labour-intensive approach to production which uses what may best be described as an intermediate level of technology. Thus extensive use is made of pneumatic nailers and power tools to assist in what is generally a labour-intensive process. Medium-sized computers are used to programme and schedule work for workers to carry out.

The labour-intensive nature of the industry may be due in part to the low wages paid to most production workers who are generally unskilled. Almost without exception, manufactured housing plants employ non-unionised labour and are often located in areas with low levels of employment opportunity. As a result it is possible to pay wages not much above minimum rates of $US 3.30 per hour. Some operators adopt bonus systems though it unlikely that many production workers in manufactured housing plants would earn more than $US10,000 per year before tax.

A typical manufactured housing plant would be 5000-6000 sq metres in area and employ 120-150 people including management and production supervisors. The capital cost of such a facility would be about $US 2 million exclusive of land costs and would be capable of building up to 1000 houses per year. At such a level of production annual sales would be $US15-20 million of which approximately 15% would be labour costs.

Manufactured housing plants can be quite integrated, undertaking the manufacture of most of the components in a house including cabinets, doors, ducting, trusses and chassis. Wage workers would undertake most of the sub-trades including the installation of all services (perhaps with the exception of electrical wiring) and all painting and finishing work including laying floor coverings.

Production begins with the welding together of a steel chassis made up of two RSJs with struts to which are attached a towing hitch and two axles.

Once on site these are detached for re-use and the chassis becomes the subfloor of the house normally anchored to the ground with bolts and concrete pads. On to each chassis a single wide of a house 3.6-4.2 metres in width is built. Houses are generally made up of one, two or three single wides with each single wide transported separately and married up to the others on site.

Timber floor joists are assembled into the floor framing on top of the chassis and attached to it by bolts. The floor framing generally comprises 150 x 50 joists at 400-450mm centres. All timber used in the framing is kiln dried. Prior to the fixing of flooring, subfloor services including heating ventilation is installed as is underfloor insulation which generally comprises fibreglass blankets. The floor comprises two layers of 15mm particle board glued and stapled to the floor joists. At this stage vinyl/lino floor coverings are laid in future entrance ways and service areas.

Following the completion of the floor, the unit moves down the assembly line where interior and exterior wall panels are attached. Wall panels are fabricated at the side of the assembly line in 3.6-4.8 metre lengths using 100 x 50 mm or 150 x 50 framing with drywall (paper-faced gypsum board) attached to one side. These panels are lifted onto the floor section with a simple hand operated gantry crane. Exterior walls are fixed to the floor frames with nail plates and the installation of electrical wiring and fibreglass insulation (R 1.2 or 1.8) follows.

At this stage roof framing is attached to the top plate with the use of nail plates. Roof framing may either be rafters (generally 150 x 50) or light scissor trusses at 350-400mm centres. The central spine of a manufactured house is a plywood box or I beam running down the ridge line, which supports all roof members. All manufactured homes have a relatively low-pitched roof so that they can comply with the maximum height restriction of 4.2 metres imposed on most freeways. Generally, too, in order to achieve a more spacious interior, cathedral or pitched ceilings are used in most manufactured homes. On top of the roof framing members 12 mm plywood is stapled, which in turn is overlaid with a bitumen rubberised building paper (roof felt). The roof cladding of fireglass or asphalt shingles is glued to this roof felt.

While the roofing is taking place other workers below are fixing the exterior cladding which may include one or two layers of sheathing. With two layers the sub-surface layer is generally made of 10 mm waferboard, a form of coarse particle board. The final exterior cladding may be a form of tempered hardboard either in a textured/grooved sheet or as weatherboard, an exterior plywood siding or PVC weatherboards. Following this, aluminium windows are installed and exterior painting commences.

Interior finishing work involves the plastering and painting of ceilings and sometimes walls, installation of cabinets, services and appliances, fixing of mouldings and trim hanging of doors and the laying of carpets. Generally this is undertaken by a series of specialised crews.

Once complete, a single wide is first sealed against the weather using plastic sheets and then stored in the yard until its companion wides are completed. Normally to avoid confusion over critical measurements, colour matching and trim matching, single wides are built consecutively on the assembly line. On completion of a complete house the component wides are shipped immediately to the dealer/distributor who has ordered the house. In general, shipping distances are less than 600 km from the factory to allow for delivery and return in one day.

Manufactured homes are generally finished to a level far in excess of that expected in New Zealand for houses in the same area of the market. Standard finish includes all carpets, drapes and appliances such as fridges and stoves. A great deal of attention is paid to the interior design of the house with the placement of windows and mirrors to create a feeling of spaciousness. Less attention is paid to the exterior appearance which can often be flat and uninteresting.

Siting and Planning

In the past, manufactured homes tended to be located on rented sites in a mobile home park. This arrangement where the individual owned the home but another person or a corporation owned the land was often unsatisfactory from the houseowner's position because it did little to protect their equity in the property. The long history of unscrupulous practices on the part of park owners has led to a strengthening of laws in favour of homeowners, to a move towards co-operative ownership of parks and a trend to more individual ownership of manufactured home sites.

In 1987 nearly 60 per cent of manufactured homes were located on individually-owned sites though there were still over 24,000 rental home parks in existence. Monthly rents in such parks typically average between $US80 and $US150 though in new parks in Southern California rents of over $US250 per month are common. In rapidly growing cities the purchase of vacant developed residential sites for the location of manufactured homes is difficult because most residential development is undertaken by or for site-builders.

In the past, too, manufactured home owners have suffered discrimination within the land use planning system. Manufactured housing has been, and is, seen as socially inferior housing, second-rate housing for second-rate people. This has led local authorities to use their land use zoning powers to exclude manufactured housing, particularly rental parks, from their jurisdiction. Alternatively, such land uses are relegated to the least attractive sites, further reinforcing the negative image of such housing. Sixteen states have now passed laws prohibiting discrimination against manufactured housing and this combined with the improving quality of this type of housing is leading to a softening of these long-held negative attitudes.

THE U.S. HOUSING MARKET

The U.S. housing market has several distinctive characteristics which are worthy of some brief discussion because they highlight the differences between the various sectors of the house building industry and explain in some way the development of some forms of industrialised housing.

Site-Built v Manufactured Housing

There is a very clear distinction between the market for site-built housing and that for manufactured housing. The site-built market itself is divided into a number of sub-markets, notably the single family market, the multi-family market (i.e, high and medium density housing) and the rental market. Many developers/builders tend to concentrate on one market alone and in part their choice of markets is determined by their capital backing, their attitude to risk and their time horizons.

The manufactured housing market, because it has in the past been seen as an inferior form of housing and perhaps because its product is consistently cheaper than that of the site-builder, is not seen within the market as being a close substitute for site-built housing. Ownership of a manufactured home particularly within a rental park is concentrated amongst the elderly and young low-medium income families. The elderly and retired often trade down in the housing market in order to realise some of the capital in their home and often to retire to a warmer climate such as that of Florida or Arizona.

Young families on the other hand typically see the ownership of a manufactured house as a step between renting and ownership of a site-built home. A problem arises here in that often manufactured house values, especially those in rental parks, fail to appreciate at the rate of inflation or more importantly at the rate of site-built housing. This often leaves such people trapped into manufactured housing ownership.

There doesn't, however, appear to be any particular concentration of manufactured homes in any one part of the country. This result may be explained by the wide range of reasons people buy manufactured houses in the first place. For instance people may buy a manufactured home for retirement, because site-built housing is too expensive, because of land prices or because of the difficult climate for site building.

Regional Variations

Climate, the local resource base and the underlying wealth of the region all contribute substantially to the nature of the housing market in the various parts of the United States. On a region by region basis the folowing factors are important in the various markets.

The Southwest

Southern California in particular has seen almost continous urban growth since the early 1950s. This growth in industry and housing continued almost unabated until the early 1980s, buoyed up by large tracts of undeveloped land, cheap energy and a warm sunny climate. By the 1980s Californians were becoming concerned about the growing level of taxation and in a voters referendum passed the now notorious Proposition 13 which limited the State Government's ability to increase taxes beyond the level of inflation.

This decision is now proving to be both shortsighted and retrograde because it limits both the State and Local Government's ability to deal with the growing problems of congestion, pollution and inadequate urban infrastructure caused by unabated urban growth. In an effort to raise additional finance to deal with these problems, authorities have turned to the use of development levies which, in turn, push up house prices by $US 8,000-13,000 per household unit.

Continuing congestion and pollution have led to further voter initiatives to limit growth by way of restrictive zoning. Both housing developers and local authority planners see such techniques as unworkable, iniquitous and as failing to address the underlying problems. Certainly such "growth initiatives" as they are called, will create a monopoly situation for the owners of suitably zoned land which, in turn, will lead to higher land and house prices.

Because of its relative affluence and long history of growth, the housing markets in the Southwest are buoyant and diverse. California is home for about one-third of the nation's 400 largest home builders though of course not all this building activity takes place within the Southwest. There is a large market for rental developments in this area since it possible to develop good quality accommodation at an affordable price. The manufactured housing market has declined in relative importance in recent times though in the rural and more isolated areas this is still the most important form of housing.

The Northwest

In many respects the Northwest U.S.A. is similar to New Zealand in terms of its climate and attitude to housing. This region has a wet temperate climate not unlike many parts of New Zealand and has an abundance of forests of a variety of species. The cities of the Northwest are smaller than those of California so there is less congestion and pollution and also less pressure for urban expansion.

Two factors appear to play a part in the form and construction of housing in the Northwest; the abundance of timber and the isolation of many communities. The abundance of timber has led to its extensive use in housing particularly up-market housing. The Northwest is home for two of the largest producers of log homes and there is an active export market to Japan for this form of housing.

The relative isolation of many communities and the often harsh climate in the mountainous areas have provided a ready market for modular housing. Such housing is most often produced in a yard rather than in a factory by small (i.e, less than 100 houses per year) firms. Modular homes are exported via barge to Alaska where because of reasons of geography and climate the building industry is very small.

The Northwest also has relatively high levels of manufactured housing occupation and Washington state is relatively important as a producer of manufactured homes.

The Midwest

Since the agricultural recession of the early 1980s the housing markets in the Middle West of the United States, have been somewhat depressed. Climate in the Midwest plays an important part in the design and construction of housing. Most houses here have below-ground basements which house central heating and ventilation equipment. Many new houses use heat exchangers within their ventilation systems as a form of energy conservation.

In general the building season is limited to six months of the year and for this reason amongst others there has in the past been extensive use made of panelised and modular housing. Basements and foundations are typically made of concrete which cannot be poured for half the year because of the permafrost. This has led to the development of timber basement foundations which allow year-round construction but which have been slow to catch on. To extend the construction season builders may construct several foundations during the summer and complete the house with the use of modular or panelised components during the colder months.

The industrialised builders of the Midwest are facing hard times as a result of the regional downturn. During the early 1970s several builders developed large production facilities (100,000 sq ft or more) which are now being significantly under-utilised. Some of these firms were initially active in the lower end of the market making several standardised models. However, in an effort to increase sales some firms have gone up market into larger more elaborate homes. Industrialised building techniques are not always suited to the construction of such homes because they have a lot of customised design attached to them which undermines the purpose of industrialisation. It would appear that in the Midwest's present economic climate industrialised builders are serving little economic purpose and seem to be struggling for survival in the hope of a future upturn in the local housing market.

The Northeast and Middle Atlantic States

The New England states have witnessed a reversal in their fortunes since the late 1970s as a result of a shift in the local manufacturing base to high tech industries. Here unemployment is well below the national average while new house prices are well above the national average. This has resulted in shortages of skilled labour and an absence of inwards migration on account of high housing costs. Similarly the Middle Atlantic states have experienced an economic resurgence on account of the weakening U.S. dollar and with this resurgence some skilled labour shortages. Low levels of unemployment and rising wages are leading to a mild recovery in the housing industry in this area.

Despite the strength of the economy in the Northeast, the housing market only accounts for 16% of the country's housing starts. This may be due in part to the slow growth in the region's population and the already well developed housing stock. These factors mean that there are less green fields development and greater emphasis placed on infill and rehab housing. Much of the new housing therefore tends to be up-market custom designed homes where the use of natural products and energy efficiency are important. As a result, panelised housing with timber frame construction is common. Factory based modular housing is common in the Middle Atlantic states principally to overcome skilled labour shortages and short construction seasons. Manufactured housing is relatively unimportant in the Northeast both in terms of production and occupation.

The South

While the South has nearly 40 per cent of the housing starts in the U.S., threequarters of these are on the Atlantic coast and the bulk of them in Florida. Florida in fact has the largest residential construction market in the country, made up primarily of retirement housing as people from the Middle West and Northeast migrate south on retirement. Often, too, manufactured housing ideally suits these people which has led to Florida becoming the leading state in terms of manufactured housing production.

The housing market in the remainder of the South is a lot less buoyant than that on the Atlantic coast. Texas has been hard hit by the oil recession of the mid 1980s which has led to a glut of existing homes on the market and to the collapse of several large savings and loans banks traditionally active in home mortgage markets. The poorest states in the U.S. are in the South and often the housing conditions in rural communities are little better than those of the Third World.

Standards and Regulations

A major criticism made of manufactured homes relates to the building codes under which they are built. Site-built housing, including all forms of industrialised building systems mentioned above are subject to local government building codes. There are some 3000 such codes within the United States though most are modelled on one of five nationally accepted model building codes.

This practice of course creates problems for any factory-based house builder who is likely to build homes in 10 or 20 cities or counties each with a different code. Problems of inspection are compounded by the virtual completion of houses or components before they leave the factory. These issues and the problem of inconsistency in quality and standard of manufactured homes led in 1974 to a set of Federal Government regulations to control the manufactured housing industry. These regulations known as the Manufactured Home Construction and Safety Standards are administered by the Department of Housing and Urban Development (HUD) and have become known as the HUD Code within the industry.

In essence the HUD Code is a performance-based code while local building codes are more prescriptive in nature. While most local codes are modelled on nationally accepted model codes, local quirks and bureaucratic attitudes mean that no two codes are identical. Often the larger cities and the more populous counties have their own building codes which sometimes reflect the interests of local pressure groups in the specification of materials to be used and in the employment of unionised or indentured labour. In general neither the modular housing or manufactured housing industries build in areas subject to such codes. On the other hand while the HUD code specifies a range of materials which can be used it is possible to have new materials approved for use subject to proof of their suitability and the relevant inspection and certification procedures.

In terms of inspection the manufactured housing industry claims that the HUD Code is superior to local building codes. It is claimed that site-built housing is not subject to the same quality controls as manufactured housing and that it is practically difficult to inspect every aspect of a site-built house. Moreover, because site-built housing is carried out in a less controlled environment it is held that the scope for faulty workmanship and defective materials is increased.

The manufactured housing industry has a three-tiered system of inspections under the HUD Code. Each manufactured housing plant must be registered with the relevant State authority under this Code. The HUD Code then requires each model being produced by that plant to be approved in terms of structural capacity, fire safety, material durability, standard of amenity and services. As well, the plant operators are required to have a quality assurance manual relating to each model produced which is approved by the inspection authority. The intention of this system is to ensure that the initial responsibility for quality control and code compliance lies with the manufacturer. The second tier of the inspection system involves third party inspectors from licenced inspection companies known as primary inspection agencies. Each manufacturer is responsible for hiring and paying for a primary inspection agency for both the preliminary approvals listed above and for the inspection of ongoing production. These agencies are subsequently responsible for certification of each manufactured home in accordance with the HUD Code. The third tier of the inspection system involves the inspection and licencing of the third party inspectors to ensure that they maintain standards and their independence. This third tier is the responsibility of a Federal Government agency.

The success or otherwise of the HUD Code system of approvals and inspections is difficult to determine partly because the effectiveness of the alternative codes and inspection systems is difficult to measure largely on account of their diversity and numbers.

Periodically HUD reports to the U.S. Congress on the manufactured housing programme and included in this report is information on product defects and consumer complaints. HUD estimates that complaints or defects are most likely to arise in a manufactured home within two years of manufacture. In the two year period 1982-83, the National Conference of States on Building Codes and Standards (NCSBCS) Washington DC, received 5,729 complaints listing some 13,078 defects in manufactured houses. This would represent approximately 1 per cent of all the manufactured houses produced during this period. The bulk of defects reported related to structural faults (57 per cent), principally roof and window leaks, problems with plumbing (15 per cent) and with the installation of the home on site (8 per cent). A common problem appears to be the presence of formaldehyde vapours from the reconstituted timber products used extensively in most manufactured homes.

Despite the apparent comprehensiveness of the three tier approval and monitoring system and its extensive use of third party inspection agencies there nevertheless appears to be significant scope for systematic design and production errors. During the study trip one large corporation producing manufactured homes was facing remedial work likely to cost $US 20 million as a result of incorrect manufacture of nearly 20,000 manufactured homes. While information on the exact fault was sketchy it appears that is related to the fixing of wall panels (which are in effect sheet braces) to the floor framing and roof members.

While systematic errors in the interpretation of and compliance with a building code are possible with any code this problem is likely to be more serious with manufactured housing because of the uniformity of design and construction details involved. For site-built housing such errors are more likely to be isolated.

A central question that must be answered before the HUD Code can be rejected as inferior to site-built building codes is the extent to which practices allowed under the HUD Code are insufficient or inadequate for the purpose for which they were intended. In many ways a key point in this matter is the level of over-design inherent in any building code which is generally justified in terms of an adequate safety factor.

From casual observation, some of the structural members used in the construction of manufactured houses appeared somewhat flimsy, particularly in the roof framing. However, on the other hand, the extensive use of plywood and various forms of particle board in the exterior cladding and roofing would suggest that overall the structural design standards were similar to those of NZS 3604. By comparison, site-built housing in the U.S. appears over-designed, at least by New Zealand standards. This issue will be raised in a later section dealing with the use of materials. The extent to which over-design and over-building is the result of the requirements of the building codes is not known, though there does appear to be an element of custom and consumer demand behind this practice.

At this level of investigation there is no evidence to suggest that the HUD Code is better or worse than site-built building codes but merely different. Certainly questions must be raised over the effectiveness of the approval and inspection system used under the HUD Code particularly when costly systematic errors can arise. However, given the low level of complaints reaching State administration agencies (1 per cent) and the minor nature of the bulk of these complaints, it is reasonable to suggest that the HUD Code is serving the manufactured housing industry and its consumers well.

Distribution and Finance

The U.S. housing industry in general adopts a typically American style in the financing and distribution of industrialised housing, be it site-built or manufactured housing. As well there are interesting differences between the distribution and finance methods of the site-built industry vis-a-vis those of the manufactured housing industry. These methods will be studied briefly because they are instructive on the way the various products are used and because they offer some new ideas for distribution and finance of housing in New Zealand.

Manufactured Housing

Manufactured housing is unique in the housing industry for the way it markets its product and for the way purchase of that product is financed by the consumer.

Most large producers of manufactured homes supply a wholesale market and build specifically to order. Parallel to the production side of the business there exists a network of dealers, often called street dealers for the way they sell to buyers who come in off the street. These dealers are not generally franchised to any particular producer and are free to buy off a number of manufactured housing plants. However, it is recognised within the industry that the key element to growth and profits is marketing and sales, not production or technology. Consequently the larger corporations will often offer dealers incentives such as low interest finance for demonstration models or volume sales bonuses in an attempt to build up a strong distribution network.

Another form of distribution of manufactured homes is through rental home parks. In the past "closed parks" where prospective owner/tenants were obliged to purchase a manufactured home from the park owner were commonplace. The practice of closed parks is slowly being stamped out as consumer laws are strengthened in favour of home buyers. Smaller, owner/operated manufactured housing producers are more likely to sell direct to the public and to concentrate on a particular geographic area. At least one manufacturer produces a form of manufactured/modular home purely for his own use in motel and rental developments.

The manufactured housing industry appears to rely on quick turnover and to achieve this dealers are given 14 days free credit from the time the house is delivered and installed until they must pay for it. The efficiency of the financial markets in this area are such that longterm finance can generally be arranged and the transaction completed within this period. This quick turnover period, from raw materials to an occupied house in three to four weeks, gives the manufactured housing industry a distinct advantage over its site-built competition.

The long-term financing of a manufactured home can be achieved in one of two ways. If it is located in a rental park or on some other form of leased site the house will be financed by way of a longterm (i.e, up to 20 years) chattel mortgage similar to a hire purchase agreement in New Zealand. HUD offers those institutions prepared to lend on manufactured homes an insured loan scheme which generally covers 90 per cent of the value of the home. Alternatively, if the manufactured home and site are owned as one it is possible to obtain a normal real property mortgage as with traditional site-built homes.

Site-Built Housing

The long-term financing of site-built housing is, with a few exceptions, very similar to that in the home mortgage market in New Zealand. The exceptions are interesting and offer worthwhile models for New Zealand to follow but clearly fall outside the scope of this paper. There are two noticeable differences in the home mortgage markets between the U.S. and New Zealand. In the U.S. a home buyer would receive one mortgage from one institution not two or three from different institutions as in New Zealand. The second is the lower mortgage interest rates offered in the U.S. which, while making housing more affordable, also make housing development and purchase more interest-sensitive at the margin (a 1 per cent rise at an interest rate of 10 per cent has a greater significance than a 1 per cent rise at 20 per cent).

In many ways the distribution of industrialised housing has close similarities to the practice of sub-contracting which is popular within the site-built housing industry. In the U.S. home building industry 73 per cent of builders subcontract out 50 per cent or more (by value) of the construction work. Viewed from a site-builders position industrialised housing is simply a form of off-site subcontracting and it is perhaps the industry's preference for contracting out that has led to the growing importance of industrialised housing within the industry.

Modular housing is distributed via a variety of methods. Large modular home builders may manufacture 90 per cent complete units for sale to site-builders who may be franchised and who will be responsible for siting servicing and finishing the project as well as for bridging finance and sale. Alternatively, such modular manufacturers may sell units to a subsidiary development company which acts merely as a site builder as described above. Smaller modular home producers appear to be more vertically integrated often opting to undertake all fabrication, siting and servicing work with their own wage labour crews though normally they build for an identified customer. Most often such firms have their own sales force and are limited to one production facility, which itself may be quite comprehensive. There are geographic limitations to this approach caused by the return distances a siting crew can travel in a day.

Panelised and component housing is seldom sold to the retail market but normally to site-builders who are generally not franchised. Some panel and component builders offer builders a design service and are prepared to make customised panels or components. In essence they act very much like a truss or prenail manufacturer does in New Zealand.

Log home and timber-framed housing manufacturers may be active in both the retail and wholesale market. It is possible for a timber frame manufacturer to erect the frame of a house for a builder and perhaps to fit foam wall and ceiling panels which have been purchased from a panel manufacturer. Following this, seperate contractors may be responsible for roofing and the fitting of sidings and the builder himself completes the interior finishings.

It is difficult to generalise on the pattern of production and distribution in the industrialised housing sector mainly because of the diverse range of products produced by this sector. Often though the smaller companies attempt to undertake too many stages of the production/sales sequence no doubt in an effort to maximise profits. This often leads to centralisation of production facilities and to over-capitalisation for the market they can hope to serve.

It is probably fair to say that the larger public corporations see themselves less as home builders and more as an industrial organisation in the business of building houses. While such a distinction may appear somewhat trivial it does represent a subtle difference in attitude in the production and distribution of houses. As a result the larger corporations are more likely to specialise in one area of the business, say production, and allow site builders or developers to specialise in other particular parts of the home building process.

SITE VISITS

A total of 22 visits were made by the author to a wide variety of building corporations and other organisations associated with the building industry. Thirteen visits were made to private sector building firms of which three were with the manufactured housing industry, three were modular builders, four were panel manufacturers, one was a component manufacturer, one a post and beam builder and the last a log home builder.

Of the visits to industry-related groups, two were to research agencies, one to a government agency and three to specific industry/professional organisations. As well, a further three visits were paid to manufactured housing developments, two of which were in Southern California and the other in Indiana.

Organisations visited were spread throughout the United States in an attempt to gain an idea of the regional differences present in the U.S. housing industry. However, given the wide-ranging nature of this research and the large number of corporations/organisations active in the areas investigated, it is difficult to gain a comprehensive view of what is available in such a relatively short visit.

Nevertheless, as a result of the author's conversations with those working in the industry and from written information, it appears that those organisations visited represented a reasonable cross-section of the industrialised sector of the U.S. housing industry. Consequently it is fair to say that for the purposes of gaining a broad overview of what the U.S. housing industry had to offer the industry in New Zealand, the visits undertaken on this study trip were at least sufficient.

Manufactured Home Builders

Fleetwood Enterprises, Inc.

Fleetwood Enterprises is the largest producer of manufactured homes and for that matter single family homes in the U.S. In 1984 they produced 41,000 manufactured homes though partly as a result of the declining fortunes of the industry, output had dropped to 34,700 in 1987. Fleetwood is also a major producer of recreational vehicles and last year it manufactured 28,800 travel trailers (caravans) and 14,400 motor homes (camper vans). In 1987 the corporation had a turnover of $US 1.26 billion, assets of $US 482 million and a pre-tax profit of $US 73 million.

In 1986 Fleetwood had a 14.3 per cent share of the total manufactured home market, a share which has increased consistently during the 1980s and which exceeds the combined market share of its nearest two rivals, Redman and Champion. Fleetwood produces from 45 plants and is active in 24 states. The company's manufactured housing operations are organised on a regional basis so that it remains sensitive to regional market preferences and responsive to change. Currently the company's most lucrative market is in Florida though it is also attempting to open new markets in the Northeastern states.

Fleetwood plants are typically 6000-7000 sq metres in area and employ 120-150 people including plant management, technical and sales staff. Each plant is capable of turning out eight single wides per day and is estimated to work for 250 days per year, (i.e, approx 1000 houses per year per plant). Each plant is treated as an independent profit centre responsible for its own sales and profitability. Additional plants are established on the basis of a break-even analysis involving covering of fixed and variable costs at 25 per cent of its production capacity. At the time of the visit Fleetwood's factories were operating at only about 75-80 per cent capacity and there was a possibility of closing several plants, perhaps temporarily, to improve profitability.

With its size and its centralised purchasing system, Fleetwood has substantial purchasing power and maintains a rigorous internal cost control system. While Fleetwood is strictly in the business of producing manufactured homes for sale to the wholesale market it does have several subsidiary companies which supply timber and specialised components as part of its cost control strategy.

Fleetwood acknowledges that the keystone to its manufactured housing operation is its dealer network which consists of over 2,100 separate sales locations. While all dealers are independent and free to sell any company's product, Fleetwood secures its dealers' loyalty through a support system which includes training, sales aids and finance.

The technology of manufactured housing is seen to be of secondary importance to marketing and cost control. Fleetwood's production technology is typical of that of the manufactured housing industry which relies on a labour-intensive, specialist task approach to production. The Fleetwood plant visited was undertaking much of the fabrication of components such as doors and cabinets with the use of relatively unskilled labour and simple machinery. Fleetwood's preoccupation with cost control to some extent shows in its approach to finishing. For instance to avoid expensive and time consuming plastering, prefinished sheets of drywall (Gib-board) were glued and stapled to the interior walls and sheet joins were covered with matching cardboard battens. It is likely that such an approach is typical of the quality and price range of the manufactured homes that the plant visited was producing.

Of the 34,700 manufactured homes that Fleetwood produced in 1987 approximately 40 per cent were multi-section homes (i.e, more than one single wide). Fleetwood builds a wide range of manufactured homes with retail values between $US 10,000 and $US 47,000. The company, however, focuses primarily on the under - $US20,000 market.

The cost breakdown of a typical Fleetwood manufactured home illustrates the Corporation's attention to cost control and the wide differences in building material and labour costs between the U.S. and New Zealand. The following costs relate to a double wide, 104 m², three bedroom, two bathroom house located on its site and hooked up to all services. This model would be clad with "T 1-11 Masonite" sidings (a form of textured, grooved, tempered hardboard) and fibreglass roof shingles and includes all floor coverings and kitchen appliances (stove and fridge) though not an air conditioning unit or central heating furnace.

Cost Breakdown of Typical Fleetwood Manufactured Home

Materials	$US 1988
Chassis and running gear	1,100
Floor and framing	900
Plumbing and fixtures	450
Exterior Walls (excl. sidings)	500
Interior Walls	650
Sidings	600
Electrical and Fitting	300
Roof; framing and cladding	1,200
Exterior Doors and Windows	400
Appliances, carpets etc	1,600

Mouldings	250	
Shipping and close up	200	
Misc - paints, fasteners etc	500	
		9,300
Labour Allow 300 hours at $US 10 per hour		3,000
Plant Costs & Profits Allow		3,700
PRIME COST TO DEALER		16,000
Dealer's Margin Allow 30 per cent for transport, set-up, sales costs and dealer's profits		4,800
RETAIL PRICE EXCLUSIVE OF TAXES		20,800

Such a final price is consistent with the average per square foot cost cited by the MFI (Manufactured Housing Institute) of $US 20.18. Fleetwood claims that its savings are brought about through savings in labour costs, presumably from lower wage rates and the more efficient use of labour. A key to these savings, however, is volume and lengthy production runs with standardised models and designs. To achieve this and to allow for more efficient planning of production a vital component is the existence of a backlog of orders.

Fleetwood have undertaken technological support arrangements in Australia in an initiative to introduce manufactured housing there. It may be worthwhile to consider the Australian experience of manufactured housing if the assessment of its prospects here in New Zealand is to be undertaken.

National Prebuilt Manufacturing Company

National Prebuilt is a recent entrant into the manufactured housing industry and is a relatively small producer with one plant located in San Bernardino County, approximately 100 km east of downtown Los Angeles. Rather than attempt to compete with the larger manufacturers such as Fleetwood, National have chosen to carve out a market niche in the top end of the market. As a result National's manufactured houses are significantly more expensive than Fleetwood's - typically in the range of $US 24,000 to $US 52,000.

However, it appears that National has consciously attempted to build manufactured homes that are similar in appearance and finish to site-built homes. The appearance has been achieved through the use of more expensive sidings and windows, the use of triple wides arranged in an L or T shape and greater attention to exterior design such as the use of soffits, gable ends along long walls, recessed door entrances and bay windows. This attention to quality is carried inside with the use of textured ceilings and walls (rather than pre-finished drywall) better quality cabinets and appliances. An additional sales feature which National stresses is the use of 150 x 50 mm studs (instead of the 100 x 50 required in the HUD Code) which allows the fibreglass insulation to be increased from R 1.2 to R 1.8.

In terms of production the National Prebuilt plant was very similar to that of Fleetwood's in terms of size, layout and labour force. Minor differences were apparent in the house design, (i.e, rafters used instead of trusses) though these were not significant. At the time of the visit the plant was producing four houses per day though it was not clear whether this lower level of production (compared with Fleetwood) was due to the higher quality of the housing produced or to the fact that the factory was working well below capacity.

National supplied the wholesale market either via street dealers or through park dealers and their market was limited to Southern California, Arizona and parts of Utah. The margins to dealers appeared similar to those on Fleetwood homes where the prime cost to a dealer for a house retailing at $US 24,000 was $US 17,000.

Attached as Appendix 1 is a schematic diagram of a National Prebuilt manufactured home which is fairly representative of the design of double-wide manufactured homes.

Sebring Homes Corporation

Despite its name, Sebring Homes Corp. does not technically make homes but rather recreational vehicles (R.V.) Sebring is a small company located in northern Indiana about 150km west of Chicago where they have a small manufacturing facility which produces one unit per day.

Sebring manufactures a product known within the industry as a park model home. Park models are similar to single-wide manufactured homes in terms of construction and materials except that they are regulated by a different code and have to be less that 36 m^2 (400 sq ft). Consequently, park models are 3.6 metres wide and up to 10 metres in length and come in a variety of floor plans from one to three bedrooms.

The market for which Sebring caters is that of the holiday home and trailer home. There is continuing demand for houses or units to replace those nearing the end of their life in existing trailer home parks and it is this market especially which Sebring is serving. Sebring distributes its product through a network of 18 dealers in Illinois, Wisconsin, Ohio, Texas, Florida and more recently to the east coast, principally to New Jersey and Pennsylvania.

Despite its limited size the park model home does not cost much less than the average manufactured house. Sebring were supplying their dealers with the basic model at $US14,000 which is little more than the prime cost of 100 m^2 manufactured homes.

While park models are designed principally for trailer home parks and as holiday homes, there is nothing preventing them being occupied all year round. Often people prefer to live in a trailer home park environment because it may be remote or near a holiday resort and in general it is not possible because of site sizes to live in a manufactured home in such parks. It appears therefore that the decision to buy a park model rather than a manufactured home is governed not by price difference but as a result of siting convenience. Some of this convenience is achieved at the cost of a lower standard of development which ultimately reflects on the entire manufactured housing industry.

Attached as Appendix 2 is a pamphlet from Sebring which shows alternative floor plans available in their park models and gives a brief summary of their specifications.

Manufactured Housing Developments

The Highlands Mobile Home Estate

The Highlands Mobile Home Estate is a typical contemporary rental home park located in San Bernardino county 100 km east of central Los Angeles. The estate is a 14 hectare development which comprises 204 rental spaces for the siting of manufactured homes. Each space is between 400 and 450 m^2 in area and is completely serviced with power, telephone, sewerage disposal, and water supply. As well as the serviced lots all resident/tenants have the use of a clubhouse (a type of community centre) the pool and spa as well as a security service. Site development and servicing costs amounted to between $US 15-18,000 per site.

Site rentals varied between $US 250-260 per month and were accessed by way of a 10 year lease. Rents were reviewed annually and would escalate between 5 and 12 per cent depending on the rate of inflation. It was estimated that management and debt-servicing costs amounted to 75 per cent of total ingoings once the park was fully let. Consequently the development and operation of rental parks is proving to be lucrative at least in Southern California.

The company which owned and operated The Highlands Mobile Home Estate was itself owned by a group of central Los Angeles lawyers who also owned a variety of companies which developed, marketed and managed mobile home parks. At the time of the visit they had another 265 lot development on the market also in San Bernardino County. Over the next five years the parent company, known as Safety Investments, anticipated developing and leasing 3000 sites.

Custom Mobile Homes is a subsidiary of Safety Investments which undertakes the marketing and leasing operations of its parent company. As well as these operations Custom Mobile Homes also acts as a dealer for National Prebuilt and consequently most of the manufactured homes entering the park were National models generally in the range of $US25-45,000. With a 10 per cent deposit on a chattel mortgage over 20 years at 12 per cent interest rate a prospective buyer/tenant could expect to pay $US242 per month for the purchase of a $US25,000 home with a total monthly payment of $US500, which is comparable with rents in the area. Given that interest rates and ground rents are indexed to inflation the advantage of owning a manufactured home in such a park comes only when equity in the house is built up.

Greenhills Development, Yorba Linda

Yorba Linda is a recently developed suburb of Los Angeles located in Orange County some 50-60kms south-east of downtown Los Angeles. The area is predominantly a residential suburb made up of low and medium density housing, mainly site-built detached single family homes and townhouses. Housing prices in this area are moderate by Los Angeles standards and are generally in the range of $US 120-150,000 for a three bedroom home.

In an attempt at demonstrating how manufactured homes could be integrated into site-built housing, a traditional residential subdivision was developed using up-market manufactured homes. The Greenhills development is a result of the combined efforts of a specialist land developer and Fleetwood Enterprises and is made up of about 50 houses on an approximately 4 ha site.

In keeping with the surrounding development some effort has been made to attractively landscape the subdivision with specimen trees, grassed and landscaped pedestrian precincts and with masonry boundary walls bordering an adjacent principal road. In some ways the landscape treatment of the development was over-emphasised and exceeds the standard achieved in neighbouring developments.

Greenhills was a "spec" development and as a result all the houses included in the development are compatible visually in terms of colours, cladding materials and roof lines. Consequently there are only three or four different designs of homes available within the subdivision though this is hardly noticeable due to imaginative siting. To assist with this siting, site-built "accessories" such as garages (most often in front of the house) and pergolas are used on each house.

In terms of visual amenity the project looks identical to surrounding developments and so has succeeded in proving that manufactured housing can be effectively included in site-built developments. From the comments made by Fleetwood however, it appears that similar developments will not be undertaken in the future on account of the risks and associated returns involved. No doubt some cost savings could be achieved through less elaborate landscaping, through the factory fabrication of garages as well, or through the use of less expensive manufactured homes. However, given the market being catered for in this area such moves might have been counter-productive in terms of saleability.

HUD Demonstration Project, Elkhart County

Elkhart County is in northern Indiana about 150 kms east of Chicago. Indiana was one of the first centres of mobile home production and Elkhart itself is home to Skyline Corporation the fourth largest producer of manufactured housing in the U.S. The housing in and around Elkhart is a mixture of suburban residential and holiday homes built around the numerous small lakes in the area. As a result manufactured homes are a common form of housing here.

This development was a HUD affordable housing project which sought to demonstrate that housing costs could be reduced and standards maintained through the use of manufactured homes. Coachman Industries, another local manufactured-home builder, participated in the project with the production of a variety of model homes.

This project is different from that of Greenhill, Yorba Linda, in that the sections were larger, probably close to 1000 m^2 and the houses were of different styles and floor plans. The land developer had also taken care to preserve as much of the existing woodland as possible and some attention had been paid to landscaping the street berms etc.

Basically this development was a demonstration project which set up to display a number of models of manufactured homes and to prove that these could be sited so as to be indistinguishable from conventional site-built homes. This appearance of a site-built house was achieved in a number of ways including the construction of a facade out of brick, the use of a facade or fencing to visually link the house and garage and the use of the garage and a site-built entrance-way to make the front of the house more interesting. Some of the models used were single wides which made the alteration of appearance more difficult.

In terms of creating the appearance of a site-built house this project was both innovative and successful. However, the results with respect to affordability were not known, though one resident spoken to, claimed that they were significantly cheaper than the equivalent site-built house and without any appreciable drop in amenities or standards.

An example of the plans and appearance of one of these demonstration models is given in Appendix 3.

Modular Home Builders

Timberland Homes Inc.

Timberland Homes Inc is a medium-sized modular home builder with a plant at Auburn, a south-eastern suburb of Seattle. The company produces approximately 70 houses per year and began producing modular homes in the 1960s mainly for the Alaskan market. To date it has built over 900 homes in Alaska and a further 800 in the Pacific Northwest. At present the company has a construction staff of 30-35 who are employed on a labour-only contract basis as well as 10 salaried office staff.

As their name suggests, Timberland build their homes predominantly from timber including timber roof shakes (shingles) and timber sidings either as weatherboards or plywood sheet. Internally the houses are more or less standard and not distinguishable from conventionally-built homes. They carry a range of 40 standard designs though over 90 per cent of their work is custom-built.

Average square metre costs of Timberland's modular homes delivered and sited within a 50 mile radius are $US415 per m^2 including carpets, stove and dishwasher. They claim that on average this represents a saving of 5-8 per cent over site-built housing though this cost advantage is greater the further the site is from Seattle. Alaskan prices are significantly higher that this on account of more stringent building codes and the cost of shipping modules by barge.

Timberland claim that the advantages of modular construction include quicker construction times since work can be co-ordinated more effectively, because work is less prone to delays due to weather (despite the fact that they build in the open) and because foundations can proceed at the same time as framing work. Other advantages are better quality due to closer supervision and volume advantages that remote areas do not generally have.

A copy of Timberland's abridged standard specifications is attached as Appendix 4. Briefly, construction of most Timberland modular homes includes 300 x 50mm boundary joists with other floor joists being 150 x 50mm at 400mm centres. Exterior walls include 150 x 50mm framing (necessary to allow for sufficient insulation) and a triple 200 x 50 header (lintel) on top of the top plate supporting heavy duty half-trusses at 600 mm centres. Exterior walls and the roof framing are clad in 12 mm plywood which is glued and nailed to give the structure its shear strength.

Modules are generally 3.6-4.2 metres in width and up to 20 metres in length. These modules leave the plant 90-95 per cent complete with all sidings, interior and exterior finishing, all joinery and service fittings. They are jacked on to large trucks and either jacked or lifted off with a crane once on site.

Timberland stresses the quality of its product and largely this quality is achieved in terms of materials used and in the interior design and appointments. While construction costs may appear only reasonable by New Zealand's standards given the quality involved, they represent reasonable value in the U.S. housing market when compared with the average cost of a site-built house which is in excess of $US550 per m^2.

Nanticoke Sectional Homes

Nanticoke Sectional Homes is a medium sized modular home builder active in the Atlantic states. Nanticoke is a privately-owned firm which began back in the 1950s as a one man operation building prefabricated beach cottages. Since that time the firm has grown to an organisation which employs 400 people principally at its production facility at Greenwood, Delaware, which produces about 750 houses per year.

The plant itself has three production lines each employing about 110 people and producing up to two houses per day. At any one time there can be as many as 12 houses on the line as it takes up to 6 days to produce a house. Modules come complete inside and out with the exception of the sidings on the end walls which are fixed once the component modules are assembled. Other parts of the 30,000 m^2 plant undertake cabinet and door fabrication work to supply the three production lines.

Nanticoke employs non-unionised wage labour throughout its production from the floor assembly to the final siting. The company has its own cranes and trucks to transport and site the completed modules for a distance of up to 250 km. No dealers or franchisers are used and all houses are presold.

Two main design features separate Nanticoke's houses from many other modular homes. The first is the use of hinged roofs and soffits to enable higher pitched roofs and even for Cape Cod style homes to be built. Often rafters are double jointed and folded down into three components prior to shipping. The second feature is the multi-storied use of modules. This is achieved by building the lower module with ceiling framing while the upper unit has standard floor framing which rests on top of the ceiling joists below. Cladding materials include PVC sheet weatherboards and fibreglass roof shingles.

Nanticoke prefer to call their home sectional rather than modular because they believe the image of modular is too close to that of manufactured homes and that this acts as a barrier in some markets. In general though, except for the fact that Nanticoke's "sections" are 4.8m wide instead of the normal 3.6-4.2m, there is little to distinguish them from most other housing modules. Nanticoke's per square foot costs average about $US350 per m^2 including foundations and siting but excluding in-ground services and landscaping etc.

Ryland Modular Homes

Ryland Modular Homes is part of the Ryland Group Inc., currently the largest producer of site-built homes in the U.S. As well as its modular building activity Ryland is a nationwide site-builder trading under the name of Ryland Homes and in California through a subsidiary known as M.J. Brock. In 1987 the Ryland Group produced nearly 9,500 homes of which some 1858 were modular. For 1987 the company's turnover was $US848 million with a gross profit of $US136 million and assets of $US380 million.

Ryland's rise to the top of U.S. home builders has been brought about both by its own rapid growth (20 per cent pa. average in 1985-87) and the decline of its competitors. It appears that the output of 10,000 houses per year represents something of a critical mass for the large U.S. home building corporations; a level all corporations have so far found difficult to exceed or sustain. Ryland executives naturally wish to continue the company's growth record and to achieve this they have a corporate philosophy which manages the firm as an industrial concern rather than a building one. This stance is reflected in their specialist approach which limits the group's activities to home building and mortgage finance. Thus Ryland does not develop or speculate in land and most often they sell from large subdivisions that they have bought rather than to individual customers with their own section. Such a specialist approach constrasts noticeably with the smaller privately-owned firms which are more vertically integrated and active in a number of stages in the building/development process.

Ryland maintains a complex system of regional organisation to ensure that in each area it remains conscious of regional markets and changes in these. Consequently Ryland is not active in any one particular market but is well placed to move into a number of housing markets depending on demand and opportunity. Presently in many parts of the country Ryland's sales levels are remaining static though turnover and profits are rising as the company moves into more expensive "trade up" homes.

Rylands experience with modular housing dates back to 1982. Its modular operations have been focussed on the Northeastern states from North Carolina to Connecticut. Ryland produces modular homes entirely for the wholesale market, supplying approximately 150 builders in the Middle Atlantic region. None of these builders are franchised though Ryland does provide these and other prospective customer-builders with a comprehensive technical backup service. The company operates three manufacturing facilities, two in Maryland and one in Virginia. These plants produce a range of standardised models as well as customised designs.

A visit was made to one of Ryland Modular's production facilities in Maryland. This plant was some 11,000 m^2 in area and employed 125 people of which some 100 were production workers including six or seven production supervisors. The capital cost of the plant was about $US5 million with an additional $US2 million required for floating capital. The plant was capable of producing up to 800 houses per year for a 250-day working year.

Production of the modules appeared very similar to that of manufactured housing sections though without the sub-floor chassis. When compared with manufactured housing however, the quality of materials and the standard of the finish was superior. All wall and floor framing was assembled in pneumatically-operated jigs using kiln-dried timber and pneumatic nailers. Roof framing consisted of half-roof trusses, which were also fabricated in the factory and were supported by a central loadbearing wall. Both roof and walls were clad in waferboard and aluminium foil was wrapped around the exterior walls of all modules. All flooring and drywall (Gib-board) was glued and nailed to the relevant framing and all modules were largely finished inside before completion. A white or cream textured spray was used in many units partly to overcome problems of finishing interior walls and ceilings. As a rule, sidings and roof cladding were left off modular units and were the responsibility of the builder and his subcontractors to fix on site.

The building industry has significant problems with the labour supply in this region. This is caused partly by the high housing costs in the region and the reluctance of unskilled people to migrate to the Middle Atlantic states in search of work. These problems were well illustrated in the case of the plant which has ongoing problems of labour turnover (as high as 30 per cent per month), and of retaining even semi-skilled staff. The plant used non-unionised labour which was paid $US5-8 per hour with a generous performance-based bonus system which could almost double workers' annual income (if they stayed that long). Subcontract labour was used in the installation of services and sometimes drywalling (Gib-stopping), while third party inspectors were employed to undertake inspections according to the SBCC (Southern Building Code Conference) building codes.

Reports of saving possible with modular building and the sources of these savings appear to vary widely. This is probably to be expected in that no two building projects are the same and what is saving at one time and in one place may only be of marginal benefit elsewhere. Ryland claim that the modular system can reduce site time by 75 per cent though these savings have to be balanced against factory labour time which is about 300 hours per house. One report of a small builder using Ryland's modular homes claimed that savings of 12-17 per cent were possible. Another builder claimed that while "hard costs" were the same as for stick-built housing (in the vicinity of $US440-460 m^2) the time savings and thus the lower finance costs were the real source of savings.

Further advantages cited included the improved quality possible with houses built in a controlled environment and the ability of building/development companies to tap soft markets quickly or to extend their range of operations. This benefit is consistent with Ryland Modular Home's theme "Less Time Building, More Time for the Business of Building" which paraphases Ryland's specialist approach where the builder/developer acts more as a manager and entrepreneur while Ryland acts as an industrial producer.

In 1987 the average selling price (to the builder) of a Ryland modular home was $US 37,200. This final cost can be broken down roughly as follows.

	US$
Labour	5,600
Materials	20,500
Plant Overheads	7,400
Sales Expenses & Profit	3,700

To this must of couse be added the builder's costs of fixing sidings and roofing, foundations, landscaping, service hook-up and any site-built accessories such as porches garages and stairs.

Panelised House Builders

Wick Building Systems

The case of Wick Building Systems is illustrative both of the problems facing builders in the Midwest and of the risks involved in the industrialised approach to home building. Wick was started by a young engineer who began producing panelised farm buildings in a barn in southern Wisconsin in the mid 1960s. By the 1970s the business had grown to include both panelised and manufactured housing and by the late 1970s the company had 13 manufacturing plants producing over 3000 homes annually throughout the U.S. though still principally in the Midwest.

The agricultural recession which began in 1979 led to an 80 per cent drop in housing starts in the Midwest and to the collapse of many industrialised builders. Wick is one of several larger companies merely surviving in the depressed market in the hope that the fortunes of the building industry will improve in the long run. Today Wick has only one plant which is capable of producing 10 panelised houses per day but is turning out one per day at present.

Wick's panelised business was initially aimed at the bottom end of the market and to rural buyers who were locating homes on scattered lots. Today the company has moved up-market in an attempt at developing a more reliable and profitable market. They claim that in fact panelised housing of the form they are producing is better suited to up-market customised homes than is modular housing partly because the construction method is more flexible and partly because it does not have the negative market image of modular housing.

The Wick system basically comprises floor, wall and roof sections which are simply stick frames with sheathing, be it plywood, drywall or waferboard. Panels come in widths of up to 3 metres and lengths of up to 10 metres. A "wet module", which is a bathroom module (perhaps with the wet wall of the kitchen attached) is also constructed for each house. Sidings and windows are fixed in the exterior walls though doors and roof cladding are fixed on site.

Wick says that there are few savings in the panelised system in terms of labour or materials and that the principal area of saving is time which is important in an area where the effective construction season is from May to October.

Wausau Homes Inc.

Wausau Homes is another Middle West industrialised builder which is suffering from the downturn in the Midwestern economy. Its centralised plant located at Wausau 350 km northwest of Chicago is capable of producing 20 houses per day though at the time of the visit it was working substantially below capacity at about 5 houses per day. This plant was some 11,000 m^2 in area and employed a total of 350 staff including design and management personnel.

Wausau's plant has three production lines, two engaged in panel fabrication and the third in the building of modular houses. Elsewhere in the plant a number of ancillary tasks were undertaken including pre-hanging of doors and cabinet making.

Panels made by Wausau were very similar to those made by Wick Building Systems - simply sheet-clad timber frames. Frames varied in size but generally required lifting on site with the use of a crane. Floor panels were 3.6 x 2.4 metres and made of 250 x 50 mm kiln-dried joists at 400 mm centres on top of which was nailed 18 mm plywood sheeting. Wall panels consisted of 100 x 50 mm framing and drywall for internal walls and 150 x 50 mm framing with studs at 400 mm centres for external walls. Because Wausau stress the thermal efficiency of their homes, 25 mm thick polystyrene foam sheathing faced in aluminium foil is nailed to the outside of the frame and 135 mm fibreglass batts installed in the wall cavity, giving the wall panel a insulation rating of up to R 2.8. A variety of sidings are fixed at the factory and the vapour barrier is fixed on the warm (i.e, the inside) of the frame. The roof panel system consists of 150 x 50 mm rafters at 400 mm centres 2.4 metres wide and up to 4.7 metres long held together with 12mm plywood sheathing. The roof underlay and roof shingles are laid on site.

Acorn Structures Inc.

Acorn Structures Inc. is an up-market panelised home builder with a medium sized plant located in Concord, Massachusetts, some 25km northwest of Boston. The company was started in 1947 to serve a market for prefabricated affordable homes to house the returning soldiers and their young families. Today the company builds and markets direct to the public a range of architecturally-designed houses which use top quality materials and stress the importance of energy efficiency.

Acorn has a staff of 80 people (though only 10 of these are engaged in factory production) and produces approximately 250 houses per year. In line with their concern for quality the company employs several architects, interior designers and engineers to handle the customised design work they undertake. Site work is undertaken by independent builders who may either be dealer builders trained in Acorn's construction techniques or alternatively be a client-selected sub-contractor.

The building system used by Acorn comprises only wall panels with floor and roof framing being custom-built on site. Acorn has over 300 standardised wall panel designs and uses computerised engineering techniques to select panels from this range and to design custom panels once the architectural design is complete. Panels are up to 3.6 metres wide and up to 3.6 metres high depending on the rake of the roof etc. They are constructed of 100 x 50mm kiln-dried timber with a 12mm plywood sheathing.

Acorn stress two aspects of their homes in their marketing, namely energy efficiency and an "Architect Designed" appearance. Their emphasis on energy efficiency and the attention they pay to the thermal performance of each house they build has led Acorn to the claim that their homes will outperform 99 per cent of new homes in terms of energy efficiency.

Acorn's energy technology involves the three key components of an energy efficient house: conservation, heat collection and thermal storage. Conservation is naturally achieved by way of insulation which includes 90 mm thick fibreglass insulation in the wall cavity and a 25 mm foil-backed foam sheet fixed to the inside of the frame as well the use of extruded urethane foam in the solid foundation. Low emissivity glass is used in most Acorn homes to both retain and exclude heat. The use of insulation is economically assessed to ensure that it will yield a positive cash flow.

Heat collection is seen as both a good and a bad thing with attention being paid to the excessive heating up of houses due to solar gain during the warmer times of the year. Acorn has three basic techniques for heat collection, passive direct gain, passive isolated sunspace and active solar collection. Passive direct gain involves the use of windows on the sunny side of the house and the siting of the house to best achieve this. Passive isolated sunspace requires the building of a separate room (the sunspace) which has larger windows to achieve passive solar collection but can be closed off in times of heat loss or in times of excessive heat gain. Active solar collection uses solar collector panels to heat both water and air.

Thermal storage can be both active and passive in an Acorn house. Passive systems use thermal storage slabs which are either elevated (i.e, close to windows) for direct gain or remote gain in isolated sunspaces. Active systems involve the use of solar collection panels to heat water which is then stored in a thermal storage tank and circulated through a heat exchanger to warm air when required.

To New Zealanders, Acorn's attention to energy efficiency may seem excessive. However, with the use of the wide range of techniques in their repertory Acorn claims that they can lower energy costs by 90 per cent which in some North American climates can represent savings of as much as

$US2000 per year. Acorn does however admit that consumers today are less energy conscious than they were five years ago but claim that such an attitude can change overnight with a change in energy prices. For a more detailed discussion of Acorn's energy technology a copy of an Acorn pamphlet is included as Appendix 5.

The visual design aspects of Acorn's homes are their other key selling point. Acorn sees itself as neither a regular stick builder nor an architect but rather as cross between the two where they are more innovative than the average builder and more scientific than an architect. Nonetheless Acorn's houses are complicated to build. In order to reduce this complexity to a more manageable level Acorn have turned to their simple panel system, a comprehensive construction detail book to guide builders on site and to the computerised engineering techniques mentioned above.

Acorn homes are not cheap, they average out at approximately $US100 per square foot ($NZ1700/m^2) and by their own admission Acorn acknowledges that they are not competing with stick builders. Acorn had adopted a panelised building system not as a cost-saving measure but rather as a quality improving one. Several advantages of their panelised wall system were cited by Acorn including the advantages of a protected factory environment and the ability to supervise fabrication more closely and to use better quality materials since they are protected. A further advantage was seen in the quicker completion times.

The author's contact at Acorn had some interesting comments on the value of both the building and insulation codes. He felt that generally the insulation codes were weak and worked in favour of site builders as opposed to industrialised builders. Such a bias came about because the codes were deliberately evasive and had the practical effect of allowing site builders to build to a lower insulation standard. Similarly, he thought that the building codes were designed to protect the interests of site builders rather than those of the homebuyer. He felt that the codes reinforced the use of certain building techniques without regard for expense and that they also made innovation or non-standard building more difficult. He also claimed that there was little overbuilding inherent in the U.S. building codes.

Amos Winter Homes Inc.

Amos Winter Homes (AWH) produces a type of panel which is known locally as a stressed skin panel. These panels comprise a slab of polystyrene or polyurethane foam with sheets of plywood or particleboard bonded to each side. Such panels have both insulative and structural qualities.

There are about a dozen companies involved in the manufacture and use of foam-based stressed skin panels. Most of these firms are located in the northeastern United States where highly insulated homes are an important part of the local housing market.

This part of the industry has developed gradually over the last 20 years though there still appears to be an ongoing debate over the most appropriate materials and technology to use in the manufacture of stressed skin panels. This debate centres on two main points; polystyrene v polyurethane foam and the most appropriate method of bonding the foam to the particle board or plywood sheet.

Polystyrene has the advantage of being cheaper though it is more flammable and has a lower insulation performance than polyurethane. However, advocates of polystyrene point to the fact that polystyrene ignites at roughly the same temperature as wood (about 500 degrees C) and while burning both polystyrene and polyurethane react similarly.

Over the years costly errors have been made in the method of fixing the foam sheet to the adjacent plywood or particle board sheets. Many different types of glue were used initially and some of these did not perform well over a range of temperatures (typically panels are designed for a range of temperatures from -35 °C to 38 °C) or were difficult to apply satisfactorily in the factory. This led to delamination problems and to costly remedial work on site. One answer to this problem is that developed by Amos Winter Homes, where the foam is extruded as a sandwich between two sheets of particle board and bonds to the board in its molten state.

AWH (and its associated company, Winter Panel Corp.) is a small home builder with a 5000 m^2 plant in Brattleboro, Vermont, about 150 km northwest of Boston. The company employs about 30 people, 20 of whom are production workers producing nearly 100 houses a year. These houses are distributed through a regional network of contractors which extends down to northeast Pennsylvania and across to Michigan. Prior to 1985 the company produced just panels but has now moved into providing shell-only homes.

AWH produces both standardised budget homes and larger customised homes. Their houses are slightly more expensive than site-built homes of the same size, a difference they believe is more than compensated for by the improved energy efficiency of AWH houses. AWH sells its completed shell home to the retail market for $NZ 270-300 per m^2 which naturally includes insulation but does not include foundations, floor or internal partitions.

AWH produces a standardised panel which is 1.2 m wide and comes in lengths up to 8.5 metres. The panel with a trade name of "Structurewall" is produced by a machine which mixes the chemical components of polystyrene and extrudes it in its molten form between two sheets of "Oriented Strand Board" (OSB) a type of coarse particle board. This extrusion/forming machine was specifically designed by AWH's founder Amos Winter though several of their competitors appear to have similar technology.

Once formed, panels are taken to another workshop where they are cut and routed by a computerised saw and router. A 25mm rebate is routed along the edge of each panel in order to house a 100 x 50mm stud or spline which joins adjacent panels. Similar panels are used on the ceiling and walls though the ceiling panels need support every 2.4 metres of their length. Such support is achieved through laminated beams running parallel to the ridge line.

Though panels are normally less than 75 kg in weight they are generally lifted into place by mobile crane. This is partially due to the height at which they are used (often in excess of 8 m) and the steepness of most roof pitches. Once a panelised shell is completed it is wrapped in a vapour-proof barrier, walls are clad in timber or PVC sidings or plywood and roofs in timber, fibreglass or asphalt shingles. On the inside, drywall is nailed directly to the OSB facing of the panel.

A site visit was made to a AWH house under construction. This house was a large (300 m^2 plus) customised home with sloping ceiling and a steep roof pitch. This form of construction appeared well suited to such designs as it avoided much of the often difficult timber framing required.

A brief specification of the AWH panel product and a diagram showing the use of these panels is included as Appendix 6. As well, the author has a copy of an AWH construction guide (which is supplied to its contractors) for those who are interested in more detail.

Log and Timber Frame Builders

Lindal Cedar Homes Inc.

Lindal Cedar Homes is the world's largest manufacture of custom cedar homes and is the biggest operator in the U.S. precut house business. The company produces 850 to 1000 houses annually which it sells through its 300 strong builder/dealer network. One third of their homes are sold in northeastern U.S.A. though Lindal's single largest market is in the Canadian province of Ontario. Six to eight per cent of their sales are to Japan where timber homes are regarded as a status symbol.

Lindal caters almost entirely for the upper end of the market and supplies dealer/builders with a house kitset that does not include services or cabinets. As a result their homes are large and average 230-240 m^2 in area though they sell (to dealers) at approximately $US 30 per square foot ($NZ 510/m^2). At one time Lindal did experiment with lower cost modular houses but found that they were not as cost effective as originally anticipated, working out at 5-10 per cent less than stick built houses.

Two slightly different building systems are used by Lindal - one called Lindal and the other called the Justus system. Both systems use post and beam construction, oddly based on a 1.625 metre (5'4") modular grid. A copy of a Lindal specification which shows the construction details of these two systems is attached as Appendix 7.

Both the Lindal and Justus systems are similar to the solid timber homes offered by several New Zealand companies. The Lindal system is more or less standard stick frame construction with 50 x 50 horizontal battens nailed to the inside of exterior walls in order to provide an additional layer of fibreglass insulation. The Justus system uses 100mm thick T & G Cedar planks to make up non-loadbearing walls.

There appears to be little cost advantage in either of Lindal's building systems though the advantages to them come in improved insulation and the aesthetic appeal of wood. Though Lindal offers little for low-cost housing in New Zealand the importing of kitset Lindal homes or Lindal's hardwood flooring may be viable for up-market house builders.

Riverbend Timber Framing Inc

Riverbend Timber Framing is a small company engaged in the manufacture of braced timber frames. The company operates out of a 1000 m^2 workshop in southern Michigan where it employs about 30 people. Riverbend has experienced considerable growth since its beginnings as a two-person operation in the early 1980's. The company has figured consistently in the top 20 companies in Michigan in terms of growth, a feat it shares with such companies as Ford and General Motors.

Riverbend's approach to house building might be described as low tech and somewhat antiquated. Braced timber frames are basically a series of posts, beams and rafters making up the structure of a building with stress skin or foam panels being used to infill in the exterior walls and roof. This building system is not new but rather an updated version of building techniques used by early European settlers in the American northeast. Timber-framed houses have found a small though obviously healthy market amongst enthusiasts who are interested in hand-crafted houses and also in up-market housing where the heavyweight timbers are a status symbol.

Riverbend's braced timber frames are hand-crafted by a small team of semi-skilled workers. They use hand and power tools such as circular saws and angle grinders to carve and shape the mortice and tenon joints which are crucial in timber frame construction. Frame members are heavy and can be over 300 x 200 mm in cross-section and in Riverbend's case were made from Northern Red Oak.

Some houses are very large, sometimes over three stories in height and are erected by Riverbend's own staff who also infill the open frame with stress skin panels. Riverbend is not involved in the cladding or the interior finishing of the house which instead is handled by a general contractor. The cost of the timber frame is dependent on its complexity though is generally in the range of $US80 per square foot. The author's contact at Riverbend Timber Framing reported that the company was involved in exporting timber frames to Japan and was able to ship a house lot for about $US 3000. Included as Appendix 8 is a selection of Riverbend's literature which explains the timber frame system in more detail.

Component Manufacturers

Trus Joist Corporation

Trus Joist Corporation is a nationwide company which employs over 2600 people and has sales exceeding $ US 250 million. Since its humbler beginnings in Boise, Idaho, in 1960, the company has concentrated on the manufacture of building components and has experienced a 243 per cent increase in sales between 1982 and 1987. Trus Joist measures its success by sales per North American housing start - from this measure by 1987 Trus Joist was selling over $ US 50 of its product per housing start.

The Corporation is principally involved in the production and sale of structural components - namely lightweight trusses, laminated timber beams and composite joists. More recently Trus Joist have moved into the wooden window field as well. In the structural products area Trus Joist manufacture three products which go under the trade names of "Micro=Lam" "TJI Joist" and "TJL Truss".

Trus Joist claims that as virgin forests are being exhausted, timber millers are being forced to cut from second or even third generation forests. Often, they claim, the trees from these forests are smaller and of species such as Southern Yellow Pine (which is similar to Pinus radiata), which have inferior structural qualities. As these changes continue, sawn timber for use as beams or large lintels will become more scarce and relatively more expensive and it is this market to which the "Micro-Lam" range is aimed.

"Micro-Lam" is a form of laminated timber which is designed for use as beams and headers (lintels). It is made of thin timber veneers laminated so that the timber's grain runs parallel on each sheet (unlike plywood where the grain of alternate sheets are perpendicular) and each veneer forms the depth of the member rather than the width as with conventional laminated beams. "Micro-Lam" is produced in a width of 45 mm, depths of 130 mm to 450 mm and lengths of up to 9 metres for beams of 300-450 mm depth.

The "TJI Joist" is basically an "I" beam made of timber or "Micro-Lam" flanges and plywood or OSB(Oriented Strand Board) webs. The TJI comes in a variety of series from the TJI/25 which comes in depths of 240 mm and 295 mm and is designed as a replacement for 250 x 50 mm and 300 x 50 mm joists respectively, to the TJI/75 series which is able to span up to 12 metres as a floor joist and 13.8 metres as a rafter. The principle advantages of the "TJI Joist" are its versatility (it is available in lengths of up to 18 metres), its consistent quality and its light weight (a TJI/25 weighs approximately 3kg/metre) which allows for easier site use.

The "TJI Truss" is a truss system which uses timber for the top and bottom chords and light tubular steel for the webs. The "TJI Truss" comes in a variety of sizes and shapes and can be used in residential, light commercial or industrial construction. At the lower end of the range the "TJL Truss" has 100 x 50 mm top and bottom chords and is capable of spans of up to 11.4 metres in floors and 18 metres in roofs, though generally at 600 mm centres. The advantages of a timber and steel composite truss include its nailability and its light weight (it is claimed that two men can easily install a 12 metre truss).

The fact that Trus Joist's products are finding an expanding market in the face of static or declining numbers of new housing starts indicates that these products represent good value to the North American builder. Two independent contractors spoken to in Massachussetts who were using TJI joists claimed that they were worth the extra cost (over sawn timber) since there was no waste and because they were dimensionally accurate they were easier to install. The author's contact at Trus Joist claimed that the TJI/25 series of joists were roughly twice the cost of the equivalent sawn timber metre-for-metre and that they cost approximately $US 3.50 per metre to manufacture.

He, incidentally, is a New Zealander who trained as a civil engineer and has worked in the U.S. for the last 10 years or so. From his knowledge of the New Zealand building industry he believed that there was ample scope for the use of prefabricated "I" shaped joists in New Zealand adding that it was not necessary to use the "Micro-Lam" flanges used by Trus Joist in their product. He may be a worthwhile source of further information for anyone who is interested in developing this product in New Zealand.

Building Research Organisations

U.S. Department of Agriculture Forest Products Laboratory

The U.S. Department of Agriculture's Forest Products Laboratory at Madison, Wisconsin, undertakes research into a number of timber related areas including biochemical technology, wood products, timber processing and protection and paper products. The laboratory employs over 300 people of which 100 could be called research professionals such as scientists and engineers.

Initial contact was made with the Forest Products Laboratory (FPL) to learn more about the "Truss Frame" building system that they had developed in the late 1970s. The Wood Products Research Unit which was responsible for the development of this system is also active in a wide range of timber engineering work including the measurement of the structural qualities of woods and glues as well as the performance of structural components and systems.

The author's contact at the Forest Products Laboratory was one of the group of engineers who had developed the Truss Frame System (TFS) and who continued to maintain an interest in this system by encouraging its ongoing use as a practical building system. Since 1982 over two thousand houses in 31 states have been built using TFS. TFS has a public patent and as such is able to be used by anyone. Both the National Association of Home Builders and the Forest Products Laboratory are active in promoting the use of TFS.

As the name suggests, TFS comprises a series of truss frames spaced at 600 mm centres each of which forms a structural cross section of a house. The truss frame itself is made of a standard hip roof truss with a stud attached at each end. To the bottom of these studs is attached a girder floor truss about 400 mm deep. It is possible to have two-storied truss frames simply by adding a further pair of studs and another girder truss.

For single-storied truss frames the complete frame is assembled in a factory with studs being an integral part of both the roof and floor trusses. This does present some transport problems as an average single-storey truss frame is likely to be over 7 metres wide and perhaps 4 metres high. Nonetheless, a complete factory-built component is preferred since this is structurally superior to the use of so-called "field joints" on site as is required with two-storied or split-level houses.

Framing work for windows and doors is carried out on site once the truss frames have been erected. This is done by placing a temporary prop between the roof and floor truss and cutting out studs to fit lintels, sills and trimmers.

The Truss Frame System has several technical advantages including:

- Several rows of piles are avoided since the truss frame only requires support on the outside edges. As a result it is also possible to have open basement areas.

- At 600mm centres, nogging work can be reduced or avoided altogether through the use of underfloor and ceiling runners.

- Most truss frames have been designed to use 100 x 50 mm exclusively thus reducing waste and the need for heavier, more expensive timbers.

- Speed of erection. It is possible for a small team (of 3-4 people) to erect and enclose a house within a day (enclosing here refers to the practice of fixing OSB or low-grade plywood to the framing timbers before the fixing of wall and roof cladding).

Forest Products Laboratory claim that the TFS uses, on average, 30 per cent less framing timber than a conventional stick-built house which results in a 10 per cent overall saving in framing costs. However it is common practice within the U.S. building industry to run roof trusses at 600mm centres to avoid nogging to support the OSB or plywood undersheathing for the roof cladding. As a result, direct comparisons with conventionally built New Zealand houses are not strictly relevant.

At the time of the visit the author's contact at Forest Products Laboratory was engaged in the study of the composite strength effects of roof frames. He was load testing full-scale models of truss roof systems to gain some understanding of the effects adjacent trusses had on the loadbearing capabilities of an individual truss. He was surprised to learn that the New Zealand building industry often used trusses at 900-1200mm centres and thought some of the relevance of his work would be lost with such spacings.

The Forest Products Laboratory had also undertaken tests on the shear strength of horizontally fixed drywall (Gib Board). They found that sheets of drywall fixed horizontally had greater bracing strength than the same sheets fixed vertically and put this difference down to the strength of the paper along the taped edges.

As mentioned above, the Forest Products Laboratory is also involved in research into pulp and paper production. In the course of this research they have developed a high strength cardboard known as "FPL Spaceboard". As yet, Spaceboard's potential applications and its economic viability have still to be determined fully, though Forest Products Laboratory believe it to have potential use in residential construction as interior wall and ceiling panels.

Attached as Appendix 10 are copies of brief fact sheets on both Truss Framed System and FPL Spaceboard. Copies of a construction manual of TFS can be obtained from the National Association of Home Builders whose address is given in the Appendix also.

N.A.H.B. Research Foundation Inc.

The National Association of Home Builders Research Foundation is an independent non-profit subsidiary of the National Association of Home Builders. The Foundation has a research facility in suburban Maryland about 20 km east of Washington D.C. where it undertakes various building related research contracts for private corporations and Governmental bodies.

The Research Foundation has had a lengthy research interest in the reduction of housing costs and to this end it has made substantial contributions to the public/private sector initiative known as the Joint Venture for Affordable Housing. As well the Foundation is currently involved in the study of high-tech housing control systems, and the study of radon emissions which are becoming an increasing problem in North America and Japan.

One of the Foundation's earliest projects was a study "Optimal Value Engineering" (OVE) for the U.S. Government's Department of Housing and Urban Development (HUD). As a result of this study a book outlining cost-cutting building techniques entitled "Reducing Home Building Costs with OVE Design and Construction" was published by HUD and promoted by both HUD and NAHB.

OVE is basically a series of cost savings tips for stick builders and as such does not propose any major deviations from conventional building practice. It would probably be fair to say that most of the recommendations of OVE are similar or identical to existing New Zealand building practice. Thus the use of edge thickness slabs or the use of sheet sidings as bracing elements cannot be seen as particularly innovative in the New Zealand context. Although the recommendations of OVE are now over ten years old the fact that many of these recommendations are somewhat trivial or obvious suggests that the U.S. building industry may be less efficient than its New Zealand counterpart, at least in terms of material use.

Nevertheless there are several recommendations of OVE that have some small practical advantage for New Zealand home builders. Amongst these are:

- Using under-floor runners to keep floor joists square thus avoiding nogs. Such a practice is only possible however where the floor sheets are tongue-and-grooved so that sheet joins are effectively self-supporting. (see Appendix 11A for an illustration).

- Off-centre spliced floor joists can provide for up to a 40 per cent increase in joist stiffness. As a result smaller timbers can be used and less waste from long or short joists will occur. (see Appendix 11B for an illustration and explanation).

- The use of two stud (as opposed to three stud) corners with edge of the internal lining being supported by inexpensive metal clips, plywood cleats or a 75 x 25 mm timber strip (see Appendix 11C).

- Additional studs can also be avoided where an internal wall meets an external wall through the use of a mid-height block and the clips or cleats mentioned above. (see Appendix 11D for details).

- With a conventional roof frame with trusses and gable ends labour time can be reduced by the use of prefabricated gable ends which have their sidings attached prior to erection.

- To reduce the need for expensive wall coverings or a "paint quality" plaster finish, OVE recommends the use flat or semi-gloss off-white paint sprayed to ceilings walls and trim. This reduces the effects of stopping imperfections, increases the efficiency of the lighting, matches most furnishings and increases the apparent size of the room.

These recommendations were made with reference to the major U.S. building codes and may not be strictly applicable to New Zealand Standards. It is clear that further research work is required before such practices can be advocated in New Zealand.

Despite the apparent shortcomings of OVE from the New Zealand building industry's point of view the exercise does appear to have been of some practical use to U.S. builders.

The NAHB Research Foundation has been one of the key partners of the Joint Venture for Affordable Housing (JVAH). The JVAH was set up to consider ways in which housing costs could be reduced to a more affordable level. The findings of the JVAH help put the drive for lower construction costs into some perspective.

Staff at the NAHB Research Foundation who have worked with the JVAH claim that excessive housing costs come in five principal areas, namely:

- Inefficient or wasteful construction methods.
- Excessive and non-uniform building codes.
- High regulatory costs and planning delays (sometimes developers are faced with a 30-month approval process).
- Excessive land development standards.
- Low density zonings

The first two of these, inefficient methods and excessive standards, are responsible for approximately $US 500 extra cost presumably on an average American new house (of $US 90,000 value). On the other hand, the other three causes relating principally to planning and regulatory matters are likely to cost the average American new home buyer an additional $US 8,000.

The JVAH has as a result published numerous works on regulatory reforms and model land development standards with a view to reducing approval periods and land development costs.

The NAHB Research Foundation is also undertaking research into a high tech computer controlled house known as the "Smart House". The basic concept of the "Smart House" is a system of integrated circuitry which controls and coordinates most house operations and appliances. Each household appliance has its own silicon chip which indicates to a central computer the status of the appliance. As a result the central computer knows the exact energy requirements of the appliance, if it is operating safely and whether or not it is interfering with the use of other appliances, (i.e., a noisy appliance is turned off when the telephone rings). The "Smart House" requires special appliances which are already being developed in Japan and the overall concept should be on the market in the early 1990s.

Other Organisations

Several other public and private sector organisations were visited in the course of this study trip. Much of the information obtained from these organisations was of a general nature and has been incorporated in the first part of this report dealing with the structure of the U.S. housing industry. These organisations and the contact people are included in Appendix 13. Brief comments are made here on their contributions.

National Association of Home Builders

THE Building Systems Council is a sector group of the NAHB which represents the interests of builders involved in various forms of industrialised housing including panelised, modular and log homes. The Vice President of Technical Support at Ryland Modular Homes (John Slayter) is the current president of the Building Systems Council.

The author's contact at NAHB had definite opinions on the quality of manufactured homes and the HUD Code under which they were built. He felt that the cost advantage achieved by the Manufactured Housing Industry was at the expense of quality and that there was no one area of savings but rather a host of across-the-board savings brought about by high volume output and an assembly line mentality similar to that of the automobile industry. He also felt that modular builders tend to overbuild but that the biggest savings in this area of house building came in labour and finance not materials.

The NAHB has an active economic research unit which analyses and distributes economic information on housing-related matters. The author's contact there spent some time discussing the structure of the U.S. Home Building industry which by nature is dominated by small scale operators. He also explained the growing housing crises in the U.S. and the need for greater public expenditure on housing, particular by the Federal Government.

American Planning Association

The American Planning Association is a progressive organisation which caters for the professional interests of planners and local government politicians engaged in the planning process. The Association undertakes research work into a variety of housing-related areas including regulatory reform and the control of manufactured housing and associated land developments.

The author's contacts there believed that there was scope for savings from a streamlined planning approval process and that with sensitive design manufactured housing could become more accepted within the market place.

Manufactured Housing Institute

The Manufactured Housing Institute (MFI) is the equivalent of the NAHB for the manufactured housing industry though on a far smaller scale. The existence of the two and their attitude to each other does indicate the intense rivalry between the two sectors.

The author's contact at MFI discussed the current state of the manufactured housing industry but had some difficulty explaining the recent decline in the industry despite its continuing cost advantage over site-built houses. He felt that in the past the industry had been a closed shop and had in many ways tended to be counterproductive in terms of its image and marketability. He illustrated this point with the development of the park model which he felt was a retrograde step. Currently the MFI is engaged in improving the image of the manufactured home. It is also promoting the use of manufactured housing to Federal Government politicians as a way of solving the United States' burgeoning housing problem. A copy of an MFI fact sheet is included as Appendix 12.

Riverside County

Riverside County is a large expansive county adjacent to Los Angeles County and about 60 km east of central Los Angeles. Due to rapidly rising land costs in Los Angeles and Orange County, Riverside has experienced considerable urban growth dating back to the 1960s. Despite this a large part of the County remains unincorporated, that is outside a separate incorporated city authority, and within this unincorporated area manufactured houses make up 25 per cent of the existing homes.

Riverside County was approached in order to gain a local government view on a number of topical issues raised during the study trip. Included amongst these issues were:

- The regulation of mobile home parks.
- Calls for lower land development standards and a streamlined planning approval process.
- The use of affordable housing zones.
- The problems of urban growth and the use of development impact levies.

The U.S. local government system appears to be far more democratic than does the New Zealand system. Local voters in the U.S. have far greater say in the planning and administration of their cities and in California this is mainly achieved through voters' referendums. Such referendums are increasingly being used as a reaction to the consequences of continued growth: increased traffic congestion and pollution and rising infrastructure costs. It is basically political opposition from existing homeowners through these referendums which is preventing local authorities such as Riverside County from adopting a more positive attitude to developers' needs.

That is not to say that Riverside County is not receptive to the need for more affordable housing. In the early 1980s the County instituted an innovative affordable housing zone which gave developers density bonuses and other incentives to develop affordable housing. This initiative was apparently a success until the housing market picked up and developers and builders moved into more lucrative markets elsewhere.

California was one of the first states to pass inclusionary zoning laws which required all County and City authorities to accommodate manufactured housing and other low-income housing forms into their zoning ordinances. Riverside County as a result of this (and the popularity of manufactured housing) have developed flexible mobile home park zoning ordinances. As well, the County has gone to further trouble to protect mobile home park tenants from such practices as rent gouging through its "Mobile Home Rent Review Commission".

As a result of a voter initiative which restricts the Californian State Government's ability to raise taxes, local authorities are increasingly turning to development levies known as impact fees to meet the costs of providing urban infrastructure and community facilities such as schools. Such fees obviously have a detrimental effect on the drive for affordable housing. In the case of Riverside County such impact fees can add as much as $US 7000 to the cost of each housing unit a developer produces.

CONCLUSIONS

General Impressions

This study trip set out to investigate the reasons why American house construction costs were in some cases appreciably lower than those in New Zealand. Before the trip it was understood that the majority of new houses in the United States were built partially or entirely within a factory environment. It was suggested that there was a possible link between this level of industrialisation and lower relative house construction costs. Unfortunately this question has not been completely answered by this study trip.

Manufactured Housing

The achievements of the U.S. manufactured housing industry with its ability to produce modest through comfortable houses at around $US 20/ft^2 are impressive. Despite attempts to discover why the manufactured housing industry has such an advantage over the site-built housing industry no single reason could be found. Arguments that manufactured housing codes are inferior and give that industry a cost advantage are dubious. Suggestions that it is the manufactured housing industry's bulk buying power which gives them their advantage do not explain why large modular or panelised housing plants do not exhibit similar advantages.

Although unconfirmed it would appear that the manufactured housing industry's cost advantage comes about for three principal reasons, namely:

- The manufacture of a standardised product in volume with very little custom building.
- An aggressive attitude to cost control in the use of labour, materials and outside firms.
- A conscious attempt to minimise capital requirements in either high-tech plant or in inventory.

The experience of the U.S. manufactured housing industry is certainly worthy of further investigation if an attempt is to be made to reduce housing costs in New Zealand.

Industrialised Housing

In the U.S., the term industrialised housing is applied to such commonplace New Zealand practices as pre-nailed frames and pre-fabricated roof trusses. As such it would appear that many of the experiences of the industrialised housing sector of the site-built housing industry have little to offer the New Zealand home building industry.

From this investigation it appears that panelised, modular and other types of building systems have developed sometimes by historical accident, sometimes in response to shortages of skilled labour and sometimes to fill a particular market niche. While it is recognised that some industrialised approaches to house building do bring about savings in labour and finance costs they are also faced with higher capital costs and the need to maintain a high volume of production throughout the year to survive. Without a steady reliable market, industrialised housing has some difficulty competing with the small scale site-builder, at least at the lower end of the market.

The development of industrialised building in New Zealand would probably not be successful though for different reasons than those in the United States. Firstly, it is likely that the capital costs of an industrialised housing plant in New Zealand would be relatively higher than in the U.S.A. This is partly because of the higher cost structures of the New Zealand building industry and the higher cost of imported plant. These higher capital costs coupled with higher real interest rates require larger margins than an equivalent factory in the U.S. Secondly, any potential market for a New Zealand housing factory would be significantly smaller than that available to a North American plant.

Notwithstanding these comments, it is possible that the North American experience of various building systems may be helpful to New Zealand builders active in up-market housing. Acorn Structure's approach (see page 29) which combines high quality architectural design with production building techniques through CAD and a rather rudimentary open panel system may have some application in New Zealand. Similarly the Amos Winter Homes building system (see page 31) which uses stress skin panels with a polystyrene core may be worthwhile in colder parts of New Zealand. The products of both Lindal Cedar Homes (page 33) and Riverbend Timber Framing (page 34) may find some appeal to New Zealanders. However, given the quality raw materials used (i.e., cedar and oak), it would probably be more economic to import kitset homes directly.

Small Builders

The position of the small-scale site builder in the U.S. is somewhat different to that of the same builder in New Zealand. It appears relatively easier to enter the building industry in the U.S. partly because there is little trade or vocational training for builders there. In times of reduced demand or recession this often means that many small builders either leave the industry, perhaps temporarily, or are literally working for wages which in some parts of the U.S. can be very low. As well, small building firms and self-employed builders collectively dominate the new home building industry which is certainly not the situation in some parts of New Zealand.

Building Material Prices

One noticeable feature of North American building practice is the excessive use of structural building materials; at least by New Zealand standards. As mentioned elsewhere in this report it is commonplace for American homes to have wall studs at 450 mm centres or closer, for roof trusses to be run at 600 mm centres, for flooring to consist of two layers of 12 mm plywood or similar and for exterior walls and roofs to be sheathed in OSB (Oriented Strand Board) or plywood before a second layer of wall or roof cladding is attached. Such practices seem to be the results of custom,market preference and lower building skills though they are probably also related to the low cost of many building materials.

The following table makes a comparison of the costs of certain building materials in the United States and New Zealand. As shown in this table, building materials in the U.S. are on average less than half the cost of New Zealand building materials. Such a comparison is essential if we are to determine why American building costs are often much lower than those of New Zealand.

Comparison of U.S. and N.Z. Building Material Costs

Product		US Cost (in $NZ)*	NZ Cost (in $NZ)**	Ratio
Timber	100 x 50 mm B.T. No 1	1.10/m	2.60/m #	0.42
	150 x 50 mm B.T. No 1	1.90/m	4.85/m #	0.39
	200 x 50 mm B.T. No 1	2.60/m	6.60/m #	0.39
	300 x 50 mm B.T. No 1	5.80/m	9.80/m #	0.59
	100 x 100 mm H4 Tan	3.30/m	7.30/m #	0.45
Sheets	15 mm grooved ext plywood	20.00 ea	70.00 ea	0.29
(2.4 x 1.2)	12 mm Gib/Drywall	5.40 ea	14.00 ea	0.39
	10 mm Particle Board	10.80 ea	18.70 ea	0.58
	Ceiling Tiles	4.70/m²	8.90/m²	0.53
Plumbing Fittings	Toilet Pan/Cistern/Seat	108 set	270 set	0.40
	Bath	200 ea	400 ea	0.50
	Sink Faucett	55 ea	150 ea	0.37
	Bath Lining	125 set	200 approx	0.63
	P.V.C. Gutter 3 m length	7.70 ea	20.00 ea	0.39
Misc	Fibreglass Insulation R1.6	2.00/m²	5.40/m²	0.37
	Hollow Core Doors P.Q.	21.50 ea	45.85 ea	0.47
	Hollow Core Doors Veneer	29.25 ea	61.10 ea	0.48
	Entrance Lockset	13.80 ea	30.00 ea	0.46
	Wire Netting	1.20/m²	1.25/m²	0.96
	Nails Galv 30 mm F.H.	2.00/kg	5.00/kg	0.40
	P.V.C. Roofing 600 mm Cover	9.40/m	15.70/m	0.60

* U.S. prices are retail prices advertised in various weekend newspapers April-May 1988.

** N.Z. prices are retail prices from Placemakers price schedule 30/9/87 except prices marked by # which are retail prices from an Auckland timber yard, Nov 1988.

There are several possible explanations as to why New Zealand building material prices are higher than those of the U.S. Amongst these could be:

- New Zealand labour costs are higher. The U.S. Department of Labour reported in May 1988 that the average hourly wage in the manufacturing sector was $US 10/hr ($NZ 16.37/hr, March 1989).
- New Zealand labour is less productive. Labour productivity is a function of workers' effort, managerial ability and the level of capital investment.
- The U.S. has larger markets which allow greater economies of scale. Plant size rather than market size is the key factor in economies of scale.
- American raw materials are cheaper. Most North American forests are publicly owned (especially in Canada) and it was commented that the pricing of cut logs and cutting rights did not cover the replacement cost of these forests.
- The U.S. building materials market is more competitive than its New Zealand counterpart. There are often several large corporations competing in the same market (e.g., Louisiana-Pacific and Boise-Cascade in the sawn timber market). As well, the U.S. has anti-trust laws which prevent monopoly pricing practices.

A detailed discussion on the competitiveness or otherwise of the New Zealand building materials industry is clearly outside the scope of this report.

Relevant Lessons

The U.S. Manufactured Housing Industry

The experience of the U.S. manufactured housing industry cannot be ignored. It is possible that much can be learned from this industry in terms of producing a comfortable house at an affordable price.

Direct comparisons between the U.S. manufactured housing industry and New Zealand conditions are difficult to make and may be misleading. Nonetheless, an attempt is made here to compare the performance of manufactured housing industry with that of low cost New Zealand home builders.

Price Comparisons

Direct price comparisons are of limited use for two reasons. Firstly we are not comparing like with like; the products being compared are significantly different in terms of size and appointment. Secondly a comparison of prices via the current exchange rate (taken as $US 0.65 = $NZ 1.00) does not consider the spending power of the consumers in each country.

The U.S. manufactured housing industry can produce a 100 m² house with carpets and appliances including two bathrooms for approximately $US 21,000 ($NZ 34,300) sited, exclusive of land costs. By comparison low cost home builders in South Auckland are building 80 m^2 three bedroom, one bathroom homes with no floor coverings or heating appliances for approximately $NZ55,000. Clearly U.S. manufactured housing is significantly cheaper.

Cost Comparisons

As mentioned earlier, building material prices in New Zealand may be as much as twice that of similar materials in the United States. Similarly labour costs and profit rates may be higher in New Zealand than they are in the U.S. If these higher costs are placed in the cost structures of the U.S. manufactured housing industry the final price comparisons will be significantly different.

The question of labour costs and profit rates is a difficult one to resolve, particularly at the present time with falling real wages and profit rates in New Zealand's manufacturing sector. For convenience we shall take profit rates to be at the same level as those in the U.S. and consider only the impact of higher material and labour costs on the final price of a house.

<u>Typical Cost Breakdown of U.S. Manufactured Home</u>

(see page 19 et seq for details)

ITEM	$US	$NZ
Materials	9,300	14,300
Labour	3,000	4,600
Plant Costs & Profit	3,700	5,700
Dealer's Margin	4,800	7,400
TOTAL	20,800	32,000

Allow for 100 per cent higher N.Z. Building Material Costs

(see page 44 for details)

ITEM	$US	$NZ
Materials	18,600	28,600
Labour	3,000	4,600
Plant Costs & Profit	3,700	5,700
Dealer's Margin	4,800	7,400
TOTAL	30,100	46,300

Labour Comparisons

Manufactured housing and other forms of industrialised housing represent a substitution of labour with capital. Consequently one would expect that some labour savings will result for an industrialised approach to housing.

Therefore the key question is the extent of these labour savings compared with the higher capital costs incurred.

Such comparisons must be made if we are to fully assess the value of manufactured housing not only to the New Zealand building industry but to New Zealand housing in general. At this point it is worthwhile noting that more intense capital investment has occurred in most New Zealand industries over the past five years though this trend has not been followed in the house building industry.

Once again direct comparisons between the U.S. and New Zealand may be spurious and should be read with a degree of caution. For example, as mentioned previously, many manufactured housing plants undertake the fabrication of many of a house's component parts such as doors and cabinets. In New Zealand such work is generally undertaken by another firm and the inherent labour costs merely added on as material costs. Similarly, some labour in a manufactured housing plant is occupied in the organisation and storage of materials. In New Zealand this is often done off-site by the materials supplier and the labour costs added to the cost of materials.

Because of the imprecise boundary between labour and material costs the figures below should be seen as being more indicative than exact. These figures relate to an average house from a manufactured housing plant which is generally a three bedroom double wide home of about 100 m^2. The New Zealand example is a small (<100 m^2) three bedroom one storey home. Some allowance has been made for work carried out off-site by other firms and for the work required to finish the house to the same standard as the manufactured home.

Labour Requirements for a Typical U.S. Manufactured Home

A typical plant employs 120 to 150 people (including administration) for 250 eight hour working days per year. Such a plant would produce up to 1000 houses per year.

Therefore total in factory person hours per house	300 hours
Plus transport and siting, say	20 hours
TOTAL HOURS PER HOUSE	320 hours

Labour Requirements for a Typical Small NZ House

Prenail wall frames and trusses	10 hours
Carpenter	160 hours
Drainlayer	15 hours
Plumber	20 hours
Electrician	15 hours
Painter/Wallpaperer	50 hours
Gib Stopper	15 hours
Carpet & Lino Layer	10 hours
Cabinetmaker	25 hours
Design and Administration	50 hours
TOTAL HOURS PER HOUSE	370 hours

While these figures are only approximate they suggest that labour savings of 10-15 per cent are possible through an industrialised approach to housing similar to that of the U.S. manufactured housing industry. As well, the manufactured housing industry has a further advantage in that it mainly employs unskilled labour.

Comparison of Quality

Manufactured housing is often criticised for reducing housing standards. Most critics use the example of older mobile home parks to illustrate this point. However, over the last ten to fifteen years the quality of manufactured homes and mobile home parks has improved greatly and today they would rival most forms of low cost New Zealand housing in terms of quality and amenity. The achievement of good quality housing through the use of manufactured housing is dependent on sensitive design and siting of the housing units and thoughtful planning and landscaping of the sites.

Manufactured Housing in New Zealand

Several major problems stand in the way of the establishment of manufactured housing in New Zealand. The most significant of these is the problem of having a sufficiently large enough market to justify the capital investment required to establish a manufactured housing plant.

It appears that an average-sized plant would be capable of producing up to 1000 houses per year and would not be viable at less than 250 houses per year. These are large numbers for any local housing market in New Zealand unless an attempt is made to diversify the range of houses being built. Such diversification is somewhat counterproductive as it is likely to force up unit costs and diminish the advantages of industrialisation.

It is unlikely that a manufactured housing plant would be established as a purely private sector venture mainly because of the risk and limited market involved. Consequently some degree of public sector involvement is crucial even if it is only in the form of a guaranteed market for a certain level of output.

A second major problem is that of transport - given the standard of most New Zealand roads. In the United States, transport distances exceeding 600 km are common and are made relatively easy by an efficient inter-state freeway system. Roads in New Zealand (perhaps with the exception of State Highway 1) have lower design loads, tighter corners and steeper gradients than most U.S. roads, which presents a problem in terms of haul distances and load lengths.

Other less-imposing problems include likely resistance from the local site-built housing industry which often tends to guard its skills and market share closely and the problem of possible design monotony where manufactured houses are concentrated. The first problem is more a political one and may force the site building industry to look at ways of cutting their costs in response to a challenge from the manufactured housing sector. The second problem is already arising within low-cost site-built housing developments and can be relieved with sensitive siting and appropriate land subdivision and planning regulations as well as through mixed site-built/factory-built developments.

Manufactured housing has the potential to address growing housing needs in various parts of New Zealand. It has the capability to increase the capacity of the house building industry in areas of pronounced shortage such as South Auckland. It is worth noting that 250 houses per year (the minimum output of a manufactured housing plant) is less than half the number of state houses built in South Auckland each year and probably less than the output of two or three major companies building in that market.

Manufactured housing also has something to offer in areas with skill shortages or where remoteness is a key factor in high housing costs. Such features are present in both Northland and the East Coast where there is a critical shortage of housing. Clearly these areas with high levels of unemployment and the possibility of surplus industrial buildings in local provincial towns are ideal for the establishment of manufactured housing. However, such establishment is dependent upon some private/public sector partnership which will guarantee a ready market for the completed houses.

The Truss Frame System (See page 36)

The Truss Frame System (TFS) is worthwhile of further investigation also. The system offers a fresh way of looking at timber frame construction which may open up new possibilities in the design of other parts of a house's structure such as the floor or roof.

The fact that timber prices are relatively higher in New Zealand than in the U.S. combined with the 30 per cent savings in framing timber which TFS is said to bring about may result in higher costs savings in New Zealand than in the U.S. However, the closer spacing of roof trusses (i.e., 600 mm centres) that is required with TFS may counteract some of these savings.

It is likely that TFS will provide different levels of savings in different situations. An obvious area of saving is in the avoidance of internal foundation piles. In some situations where foundations have to be deep this may bring about greater savings than in others. TFS also has applications in pole platform type construction.

Optimum Value Engineering (See page 38 and Appendix 11)

Optimal Value Engineering (OVE) although presenting a wide range of building techniques which are common practice in New Zealand still offers the New Zealand home builder some useful hints.

In particular, off-centre spliced floor joists should be investigated further as it may well be possible to reduce the size of timbers used in floor joists. If spliced joists are viable it may also be possible for prenail plants to extend their range of work and begin splicing pre-cut floor joists with pressed truss plates.

Perhaps an important lesson can be learned from the OVE exercise in the U.S. This exercise was basically an initiative of the National Association of Home Builders (NAHB) and the US Department of Housing and Urban Development (HUD) in an attempt to encourage individual builders to think about more efficient building techniques and the aesthetics of design.

While by comparison the New Zealand house building industry is more efficient there may still be ways in which efficiency can be improved. Often innovations take place on site that go largely unnoticed because of the lack of communication. Such an exercise as OVE could possibly be undertaken and supported by organisations such as BRANZ or the Master Builder's Federation in an attempt to set up a "clearing house" for innovative ideas.

Joint Venture for Affordable Housing (See page 39)

The findings of the Joint Venture for Affordable Housing (JVAH) have important implications for New Zealand in the search for lower housing costs. As reported above the JVAH found that the bulk of potential savings came in the areas of higher residential densities, a more streamlined planning process and more flexible land development standards rather than in uniform building codes and more efficient building practices. It is interesting, however, that this finding does not explain the significant cost advantage that manufactured housing has over site-built housing.

Despite this shortcoming, the concept and the conclusions of JVAH have been imported both into Australia (known there also as JVAH) and New Zealand where it is known as the "New Zealand Housing Initiative" (NZHI).

NZHI appears to be an industry-backed attempt at lowering housing costs through less stringent land development standards and a more flexible planning system. The implication from this is that local authorities through their engineering and planning requirements are responsible, at least in part, for high housing costs.

There is without doubt a case to be made for the reduction in housing development costs through a reassessment of engineering standards and a more efficient planning process. The same case could also be made for a common interpretation of the numerous codes, regulations and bylaws which control the actual building process and which often add needlessly to housing costs. However, given the information above (see page 44) on the relative cost of building materials in the U.S. and New Zealand it is by no means apparent that regulatory costs are the biggest cause of high housing costs.

The New Zealand Housing Initiative should be applauded for its attempt at reducing housing costs in New Zealand. However, if the drive for lower housing costs is to be successful, all sources of cost should be examined rather than just the more convenient ones.

Trus Joist's Products (See page 34)

Trus Joist Corporation has a range of products which have found a growing market in the United States. Their approach to truss making which involves the use of steel webs and timber chords is worthwhile. This approach produces trusses with the same properties as timber trusses but with a greater potential to be mass-produced.

Trus Joist's "I Beam" floor joists in particular may have some potential, either manufactured in New Zealand or imported directly. By U.S. standards the I Beam is expensive when compared with sawn timber (roughly twice the cost) though in comparison with New Zealand costs it is more cost-competitive.

Final Conclusions

While it cannot be said that this study represents a comprehensive look at the U.S. home building industry, a wide range of building methods and a number of the most important organisations have been included. Overall it would be fair to say that the subsequent view gained of residential construction in the U.S. is representative of the industry and its practices.

In many ways this trip was a disappointment insofar as it failed to identify major areas of innovation in house building which could be useful to New Zealand. Most probably the major reason for this failure is the fact that the U.S. house building industry is no more innovative than its New Zealand counterpart. The fact that there are many large corporations active in the housing industry which by N.Z. standards produce large numbers of houses has not led a drive for innovation. This must in part be due to the dominance of small labour intensive operations in the U.S. industry.

It is often claimed that the New Zealand house building industry is not particularly innovative and the history of change in the industry would generally support this. The industry in New Zealand is in many ways the product of its environment, an environment of high materials prices, rigid consumer tastes and fluctuating demand. Such an environment has led to an industry which, while being efficient at what it does, is wary of change and justifiably cautious of excessive capital investment.

In the past the New Zealand housing industry has relied upon speculative profits for its survival. This reliance in turn has often led to wild changes in both housing demand and the fortunes of the industry. If the industry is to have a more stable future then it must rely more on productivity gains for improved profits than on the possibility of speculative windfalls. Unfortunately, improved productivity most often requires increased capital investment.

The innovations suggested here are only minor in terms of changing the way we build houses and their impact on final new house prices. Most often though, innovation is a gradual and sometimes haphazard process, which relies on the adaption of new ideas to solve particular problems. Hopefully, this study and report may have introduced some new ideas to the New Zealand house building industry which in time will lead to improvements,however minor, in the way we build houses.

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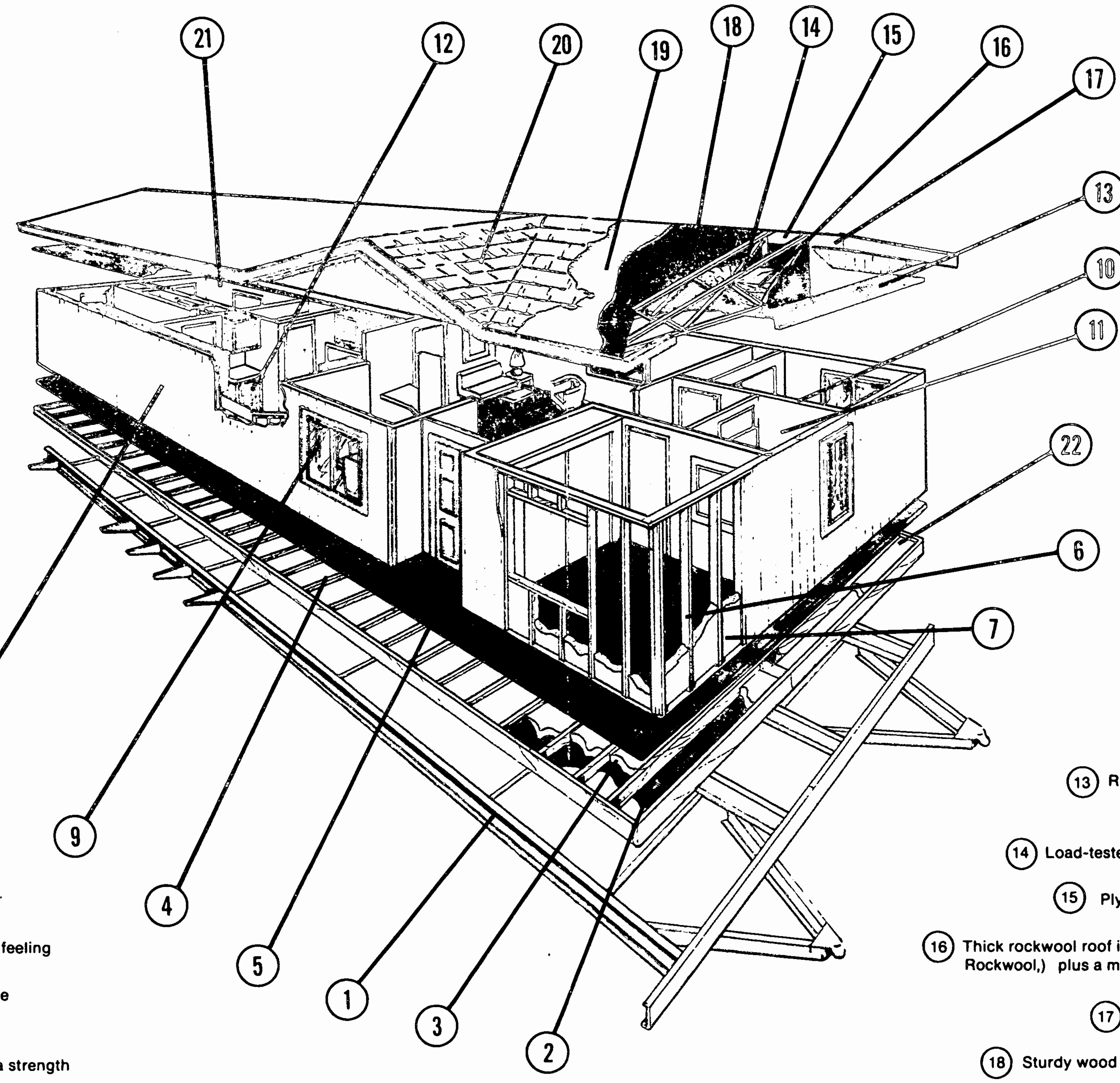
Appendix 1

NATIONAL PREBUILT MANUFACTURING COMPANY



✳ National Prebuilt reserves the right to change materials or specification at any time without notice or obligation. ✳

CONSTRUCTION SPECIFICATIONS

(1) Heavy duty steel "I" beam frames

(2) Rodent-proof bottom board

(3) Thick fiberglass insulation under entire floor

(4) Sturdy 2" x 6" transverse floor joist system for that extra-solid feeling

(5) Solid sub-floor water proofed in "Wet" areas. Fashionable carpeting or no wax linoleum.

(6) Solid 2" x 6" wood studs (TYP.) every 16" in exterior walls for extra strength

(7) Thick fiberglass insulation in all exterior walls with moisture-fighting vapor barrier

(8) Weather-resistant wood-type exterior siding

(9) House type brown frame sliding windows with removable screens

(10) Sturdy interior partitions between rooms with studs spaced 16" on center (TYP.)

(11) Fire-resistant and sound-deadening gypsum-drywall paneling throughout interior

(12) Fine-furniture cabinetry of superior design with base and center shelves. Name-brand appliances for extra reliability

(13) Residential fire-resistant and sound-deadening, sprayed and textured drywall ceiling

(14) Load-tested system of wood roof trusses/rafters every 16" for structural strength

(15) Plywood ridge beam

(16) Thick rockwool roof insulation, (some models have fiberglass insulation instead of the Rockwool,) plus a moisture fighting ceiling-area vapor barrier

(17) Front overhang eave with optional side eaves

(18) Sturdy wood sub-roof for secure shingle fastening

(19) Roofing underlayment between shingles and sub-roof for extra weather protection

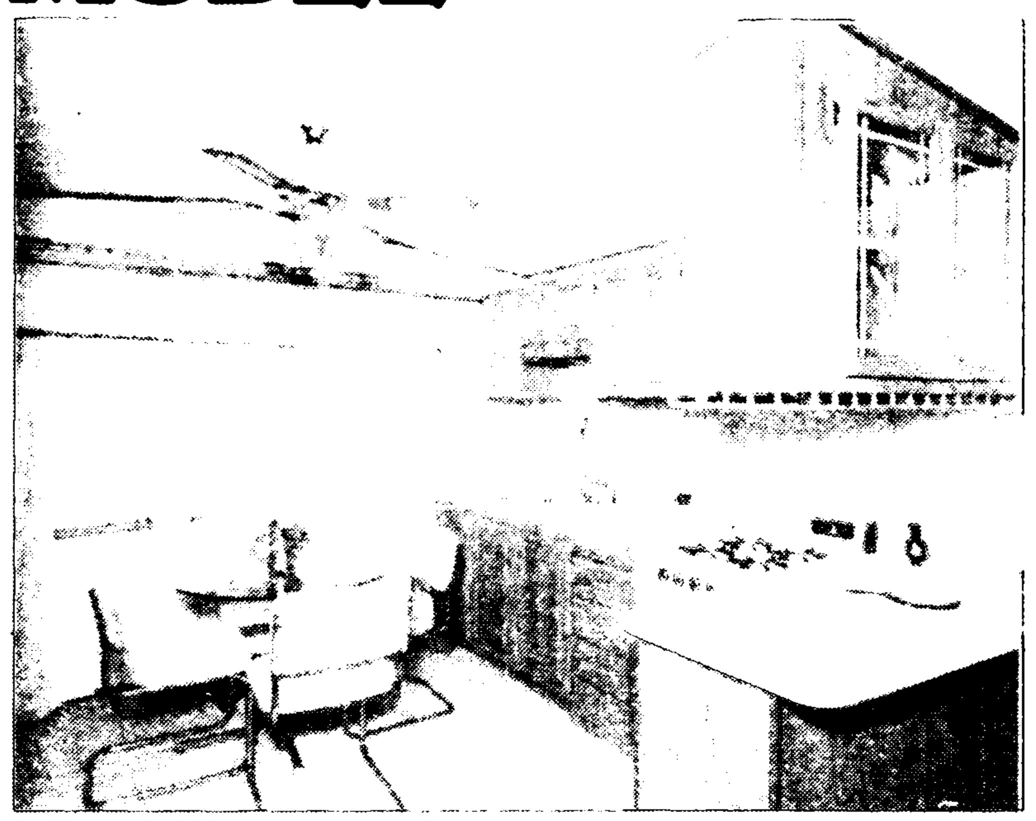
(20) Pitched residential shingled roof with optional dormer

(21) Copper wiring with convenient circuit breakers. Exterior GFI receptacle standard

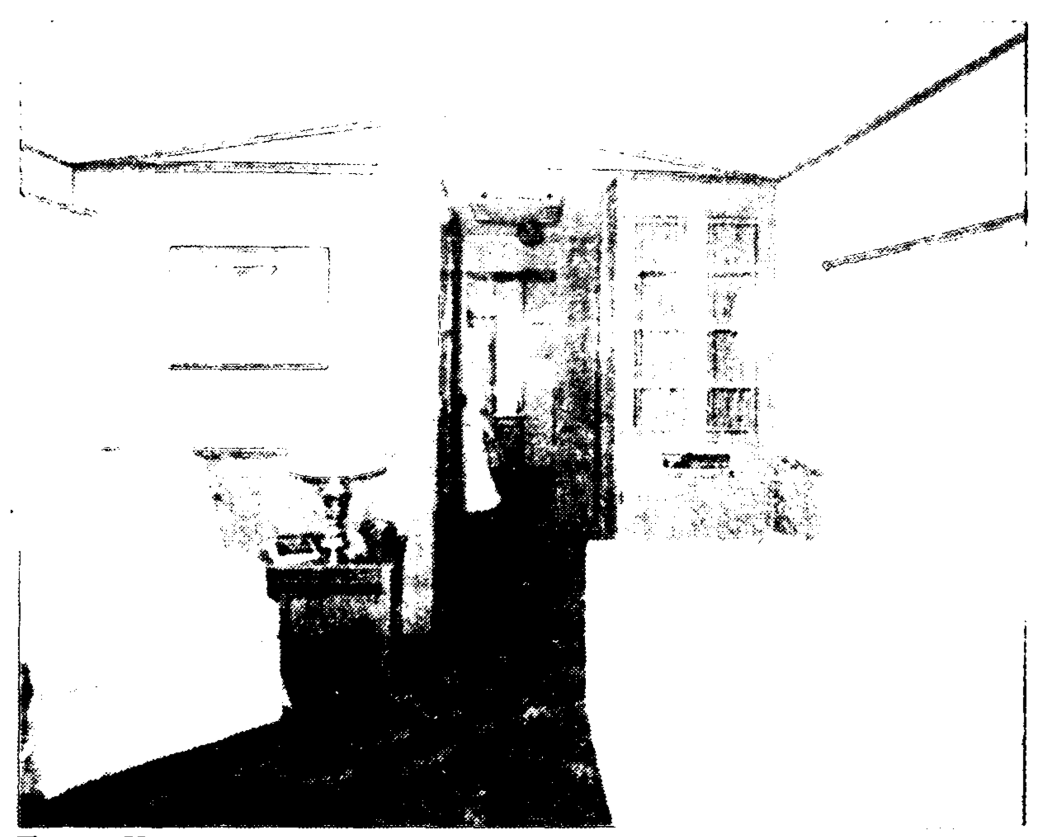
(22) Iron gas piping with shut off valves

Appendix 2

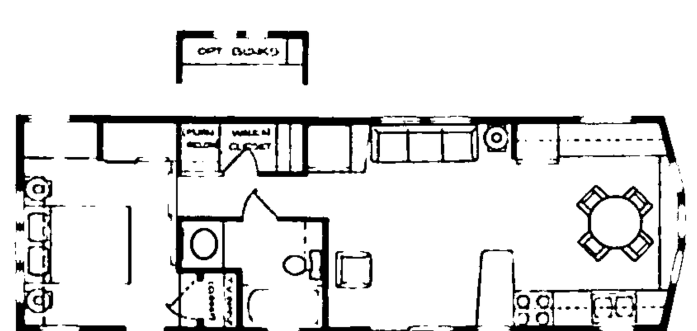
FRONT KITCHEN MODEL



Front Kitchen model features generous storage and plenty of counter space, plus the best in home-style fixtures and energy-efficient appliances.



Front Kitchen model has a comfortable living room midship featuring a cathedral ceiling, oak cabinetry, and wood trim moldings, plus plush carpeting and rich fabrics.

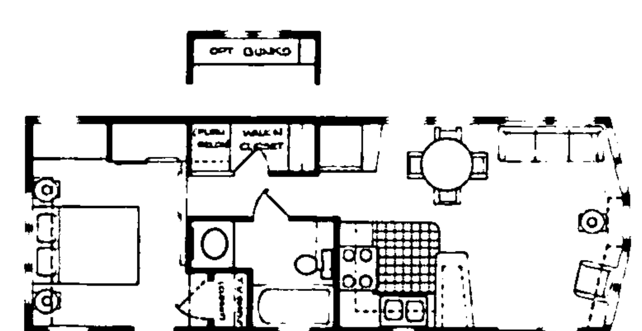


Side bath and rear bedroom complete the outstanding comfort and convenience of the Front Kitchen model.

SIDE BATH MODEL

Side Bath model features a stylish and spacious living room with cathedral ceiling, front window wall, oak-framed cabinets, carpeting, drapes and rich fabrics.

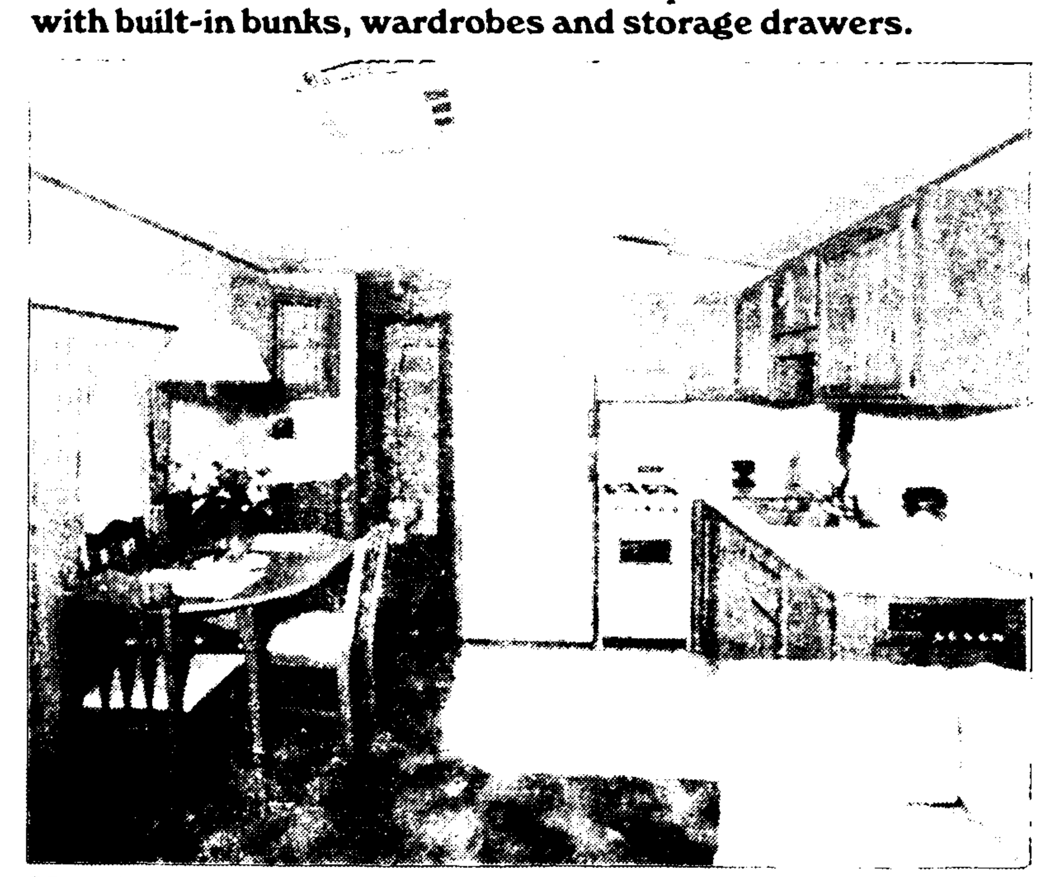
Spacious midship kitchen has smartly-styled oak cabinetry, wood parquet flooring, residential-grade sinks and faucet, and energy-efficient Sears appliances.



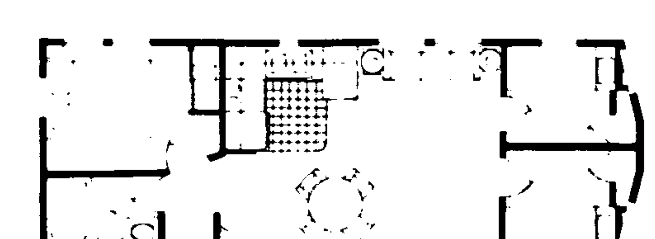
Side bath and rear bedroom are roomy with plenty of storage and beautiful decor.

FRONT BUNK HOUSE

Great idea for the kids, grandchildren or weekend guests! Front Bunk House model features unique forward bedroom with built-in bunks, wardrobes and storage drawers.

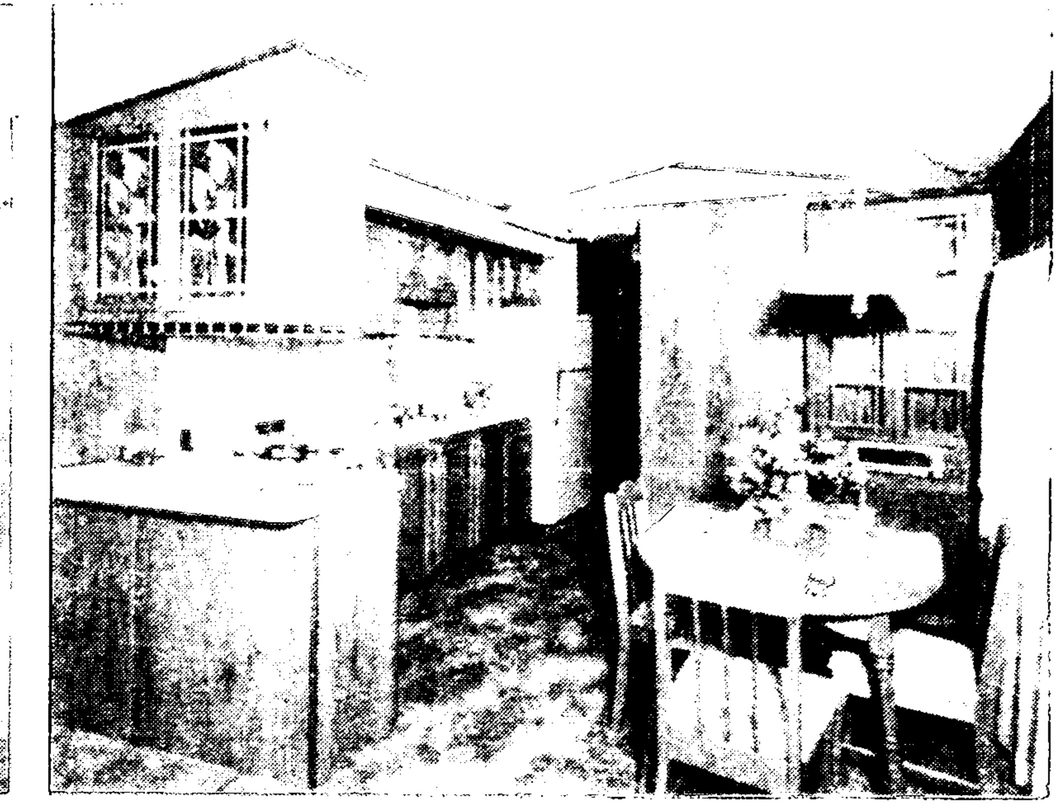


Midship kitchen is ideal for meal preparation and easy upkeep. Oak cabinet door and drawer fronts provide a rich look and plenty of storage.

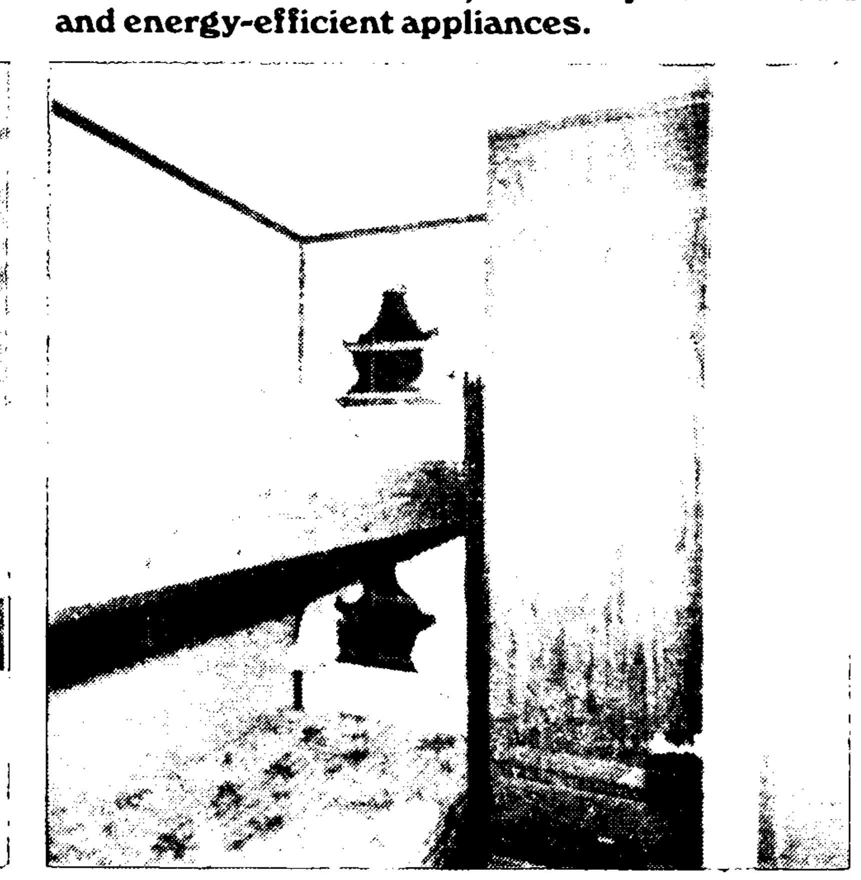


Large rear bath and comfortable rear bedroom complete the convenience and livability of the Front Bunk House model.

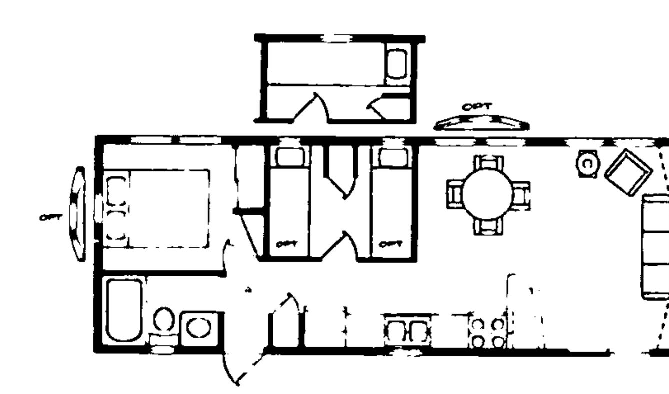
REAR BATH MODEL



Spacious side kitchen of Rear Bath model features oak cabinet doors and drawer fronts, home-style stainless steel sink, and energy-efficient appliances.



Optional second bedroom adds two bunk beds, storage drawers, and closet plus lamps, windows, and drapes.



STANDARD FEATURES

Foundation:
- ☐ 2" x 8" Steel Beam Frame
- ☐ Detachable Front Hitch
- ☐ Hurricane Straps
- ☐ Aluminum Underbelly
- ☐ 2" x 4" Floor Joists
- ☐ R-11 Floor Insulation
- ☐ Tyvek Air Barrier
- ☐ 5/8" Plywood Floor Deck
- ☐ Floor Glued & Screwed
- ☐ Quality Carpet/Pad

Sidewalls:
- ☐ 2" x 3" Studs/16" Ctrs.
- ☐ 2" x 6" Top Rails
- ☐ R-11 Wall Insulation
- ☐ Tyvek Air Barrier
- ☐ Vapor Barrier
- ☐ Vinyl Siding with 50-Year Warranty*

Roof:
- ☐ Certified Rafters/16" Ctrs.
- ☐ Fiberglass Shingles
- ☐ R-19 Roof Insulation
- ☐ Tyvek Air Barrier
- ☐ Pre-Wired for Roof Air
- ☐ Pre-Wired for Ceiling Fans
- ☐ Three Roof Vents
- ☐ Gutters

Windows:
- ☐ Five-Panel (ea. 24" x 58") Front Bay
- ☐ Patio Door/Lined Drapes
- ☐ 5' x 24½" Bath Window (Side Bath model only)

Service:
- ☐ 50-Amp Electric
- ☐ 17-Gal. Water Heater
- ☐ 40,000 BTU Furnace
- ☐ Floor Heat Ducts
- ☐ Three Outside Lights
- ☐ Outside Recept

Living Room:
- ☐ Cathedral Ceiling
- ☐ Deluxe Sofa Bed
- ☐ Swivel Rocker
- ☐ End Table/Lamp
- ☐ Solid Oak Cabinet Door Frames w/Glass Inserts
- ☐ China Cabinet
- ☐ Overhead Cabinets
- ☐ Wood Trim Molding
- ☐ AM/FM/Cassette Stereo
- ☐ 4 Speakers
- ☐ Full-Length Drapes/Sheers

Bathroom:
- ☐ One-Piece Fiberglass Tub & Shower
- ☐ Sliding Glass Shower Door
- ☐ Shower Grab Handle
- ☐ Large Lavatory
- ☐ Decorator Faucet
- ☐ Residential Ceramic Toilet
- ☐ Corner Medicine Cabinet
- ☐ Vanity Mirrors
- ☐ Linen Cabinet
- ☐ Towel Bar/Tissue Holder
- ☐ Exhaust Fan/Light

Kitchen/Dinette:
- ☐ Solid Oak Raised-Front Cabinet Doors & Drawer Fronts
- ☐ Self-Edged Countertops
- ☐ Cutting Board
- ☐ 24" Deluxe Range
- ☐ Range Hood/Light/Fan
- ☐ 16 cu. ft. 2-Door Frost-Free Refrigerator**
- ☐ Stainless Steel Sink
- ☐ Single Lever Faucet
- ☐ Parquet Flooring
- ☐ Wood Trim Molding
- ☐ Deluxe Dinette Table
- ☐ Two Dinette Chairs
- ☐ Swag Lamp

Bedroom:
- ☐ Full-Size Bed
- ☐ Quilted Bedspread
- ☐ Matching Drapes/Sheers
- ☐ Two Night Stands/Lamps
- ☐ 5-Drawer Dresser
- ☐ Wardrobe w/Sliding Mirrored Doors, Shelves & Drawers
- ☐ Cabinet w/TV Shelf

* See dealer for warranty details and limitations.
** Sears energy-efficient appliances.

OPTIONAL EQUIPMENT

- ☐ 43" Dinette Bay Window
- ☐ 58" Dinette Bay Window
- ☐ 43" Rear Bay Window
- ☐ Thermopane Patio Door w/Lined Drapes
- ☐ Tinted Windows
- ☐ 13,500 BTU Roof Air
- ☐ Roof Air Heat Strip
- ☐ Prep for Central Air
- ☐ 2½ Ton Central Air
- ☐ Storm Windows
- ☐ Foam-Core Insulation
- ☐ Total Electric Package – Base Board Heat, Electric Range & Dual 50-Amp Service
- ☐ Extra Outside Light/Switch
- ☐ Extra Outside Recepts
- ☐ 50' 50-Amp Cord
- ☐ Door Chimes
- ☐ Garbage Disposal
- ☐ 10-Gal. Gas/Electric Water Heater
- ☐ Stacked Washer/Dryer
- ☐ Plumbing for Washer
- ☐ Marine Toilet w/Holding Tank(s)
- ☐ Lo-Back Swivel Rocker
- ☐ Deluxe Hi-Back Rocker
- ☐ Hi-Back/Lo-Back Rocker
- ☐ Wall-Hugger Recliner
- ☐ Deluxe Queen-Size Sofa
- ☐ Extra End Table/Lamp
- ☐ Coffee Table
- ☐ Glass End Table
- ☐ Rattan Furniture Package – Sofa, Chair & End Table
- ☐ Two Counter-High Stools
- ☐ Glass Dinette Table/Chairs
- ☐ Glass Swag Lamp
- ☐ Wainscot/Living Room
- ☐ Carpet Upgrade
- ☐ Pleated Shades
- ☐ Mini Blinds
- ☐ Twin Beds***
- ☐ Sealy Queen-Size Bed***
- ☐ Elkhart Bedding Queen-Size Bed w/6-Leg Frame***
- ☐ Extra Night Stand/Lamp
- ☐ Deluxe Electric Range
- ☐ 24" Gas Range
- ☐ 30" Gas Range
- ☐ 17 cu. ft. 2-Door Frost-Free Refrigerator**
- ☐ Built-in Ice Maker**
- ☐ Spacesaver Microwave**
- ☐ Porcelain Kitchen Sink
- ☐ Indirect Kitchen Lighting
- ☐ Deluxe Ceiling Fan
- ☐ Light Kit for Fan
- ☐ TV Jacks Front/Rear
- ☐ Phone Jacks/Rear
- ☐ Wiring for 4 Speakers
- ☐ Hallway Closet Mirror
- ☐ Overhead Cabinet/Rear Bdrm.
- ☐ Pulsating Shower Head
- ☐ Oak Medicine Cabinet w/Light Bar
- ☐ Porcelain Lavatory Sink
- ☐ Decor Paneling
- ☐ Skylight
- ☐ Second Bedroom****

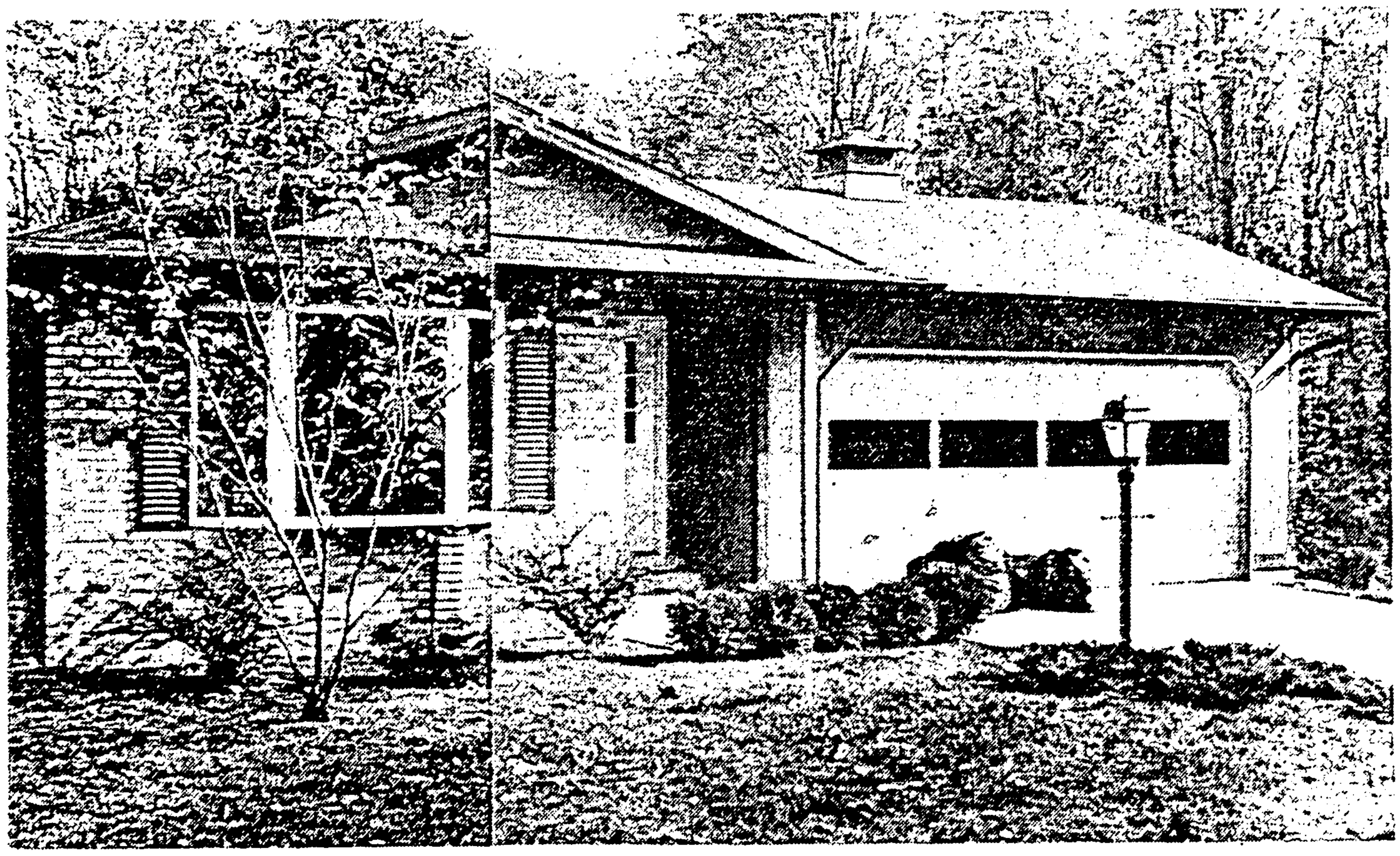
*** Quilted bedspreads with matching or co-ordinated drapes and sheers.
**** Second Bedroom in Side Bath models includes built-in bunk beds, storage drawers below, quilted bedspreads, co-ordinated drapes, two windows, bifold door, & walk-in closet. In Rear Bath model, the Second Bedroom includes built-in bunkbeds with quilted bedspreads, co-ordinated drapes, two windows, two reading lights, storage drawers below bed, house-type bedroom door, 18" closet with two drawers below.

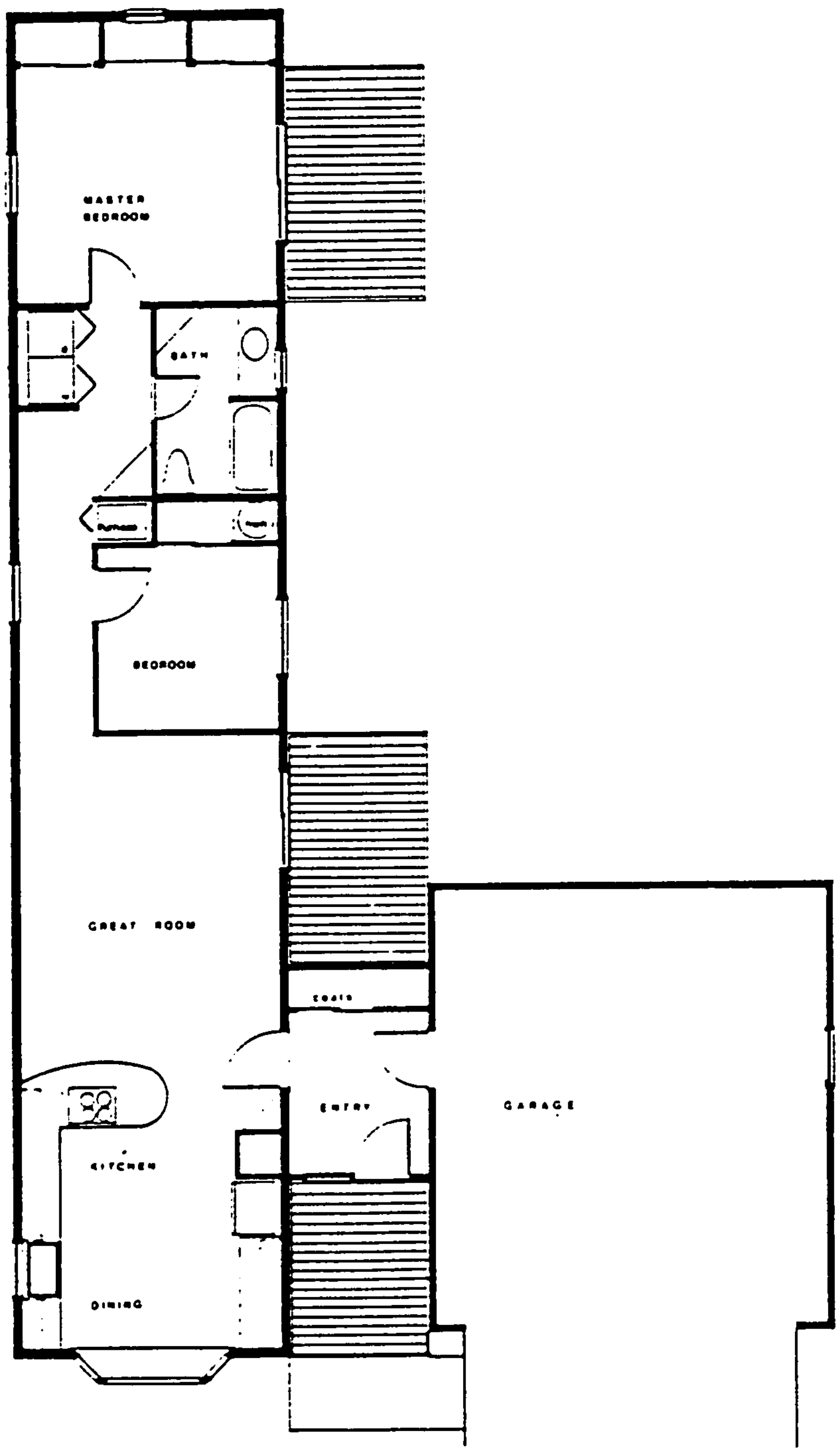
All product specifications contained within this brochure are based on the best possible information available at the time of publication. Due to continued product improvement and occasional changes in vendors, Sebring reserves the right to change specifications and/or standard features without notice or obligation. Product shown in some photographs may include optional equipment that is available at extra cost. Consult your Sebring dealer for details at the time of ordering.

SEBRING HOMES CORP.
51788 State Road 19 North/Elkhart, IN 46514
(219) 262-0151

PRINTED IN U.S.A.

Appendix 3





The appearance of this single-section "modular" unit has been enhanced by a site-built front gable, entryway, and panelized garage. A minimum unit-width requirement, however, can prohibit this attractive unit and others like it. (HUD affordable housing project, Elkhart County, Indiana)

Appendix 4

Timberland Homes®

SPECIFICATIONS

Exceeds 1988 State Energy Codes

FLOOR STRUCTURE
Kiln dried double 2x10 hem-fir #2 and better rim joist, glued and nailed. 2x6 KD hem-fir #2 and better skidplate. 2x10 hem-fir #2 and better floor joists, 16" o.c., ¾" T&G plywood subfloor, glued and nailed (combination subfloor/underlayment grade).

WALL FRAMING
2x6 kiln dried studs, 16" o.c., stud grade (non-bearing 2x4 walls 24" o.c.). 2x6 top plate and still plate, KD hem-fir standard and better. Continuous built-up header, triple 2x8 KD hem-fir #2 and better with ½" plywood shear, glued and nailed. Marriage line shear wall, 2x4 stud grade flat, ⅜ plywood, glued and nailed (engineered system). ⅝" rough sawn T-1-11 siding with 4" or 8" grooves, glued and nailed to framing. Heavy body stain.

ROOF SYSTEM
Engineered trusses installed 24" o.c. (55 lb. per sq. ft. total loading). 4/12 pitch with 24" overhang at eave and rake. ½" CDX plywood (Group 1) roof sheathing with ½" T-1-11 plywood at exposed eave and rake. 215 lb. Class 'A' (UL rated) fire and wind resistant three tab fiberglass, hand nailed seal tab shingles, 20 year warranty (roofing Manufacturer). For Southeast and Central Alaska 4' icing sheet at eaves is included.

EXTERIOR TRIM
Select grade 2x6 cedar fascia & rake, cedar corner boards and window trim. Window accents as shown on plans. Heavy body stain.

EXTERIOR DOORS
Metal clad with insulating thermally improved core (R-15.15), compression weatherstripping, dead bolt key lock. Bronze anodized aluminum thermally improved sliding glass door with tempered insulating glass per plan. Central Alaska premium dual glazed wood frame sliding glass door.

WINDOWS
Bronze anodized thermally improved aluminum sliding windows with dual glazed insulating glass and screens. Windows for Central Alaska: Premium dual glazed wood frame casement windows with screens as manufactured by Peachtree Windows.

INSULATION
Exterior walls R-19 (5½" batt), ceilings R-38 (11" batt), floors R-19 (5½" batt), floor insulation for Alaska R-30 (9½" batt). NOTE: floor insulation not included in basement models.

VENTING
Range hood and bathroom ceiling fans vented to exterior. Dryer vent kit consisting of through the wall coupler and wall cap with draft stop.

FLOOR FINISH
Designer carpet over ½" high density rebond pad in living room, dining room, hall and bedrooms. Cushioned vinyl over ½" plywood underlayment in kitchen, baths, and utility room.

INTERIOR WALL FINISH
Gypsum drywall throughout: ⅝" ceiling and ½" walls. All sheetrock is sealed before finishing. Acoustic finish on the ceiling and stipple on all walls. Flat latex paint in living room, dining room, hall and bedrooms. Semi-gloss enamel in kitchen, baths, and utility room.

CABINETS AND VANITY
We offer 2 different styles of cabinets crafted by Western Cabinet & Millwork:
CONCORD: The clean contemporary look of European style cabinetry. Ultra-sleek, easy to clean laminate finish. Solid oak continuous pulls.
WINSLOW: The perfect blend of beauty and practicality. Classic styled doors with oak-grained panels deeply recessed in sculptured hardwood frames. Available in several rich oak tones.

All of our cabinets feature: water resistant, wipe clean melamine laminate interiors with space savings adjustable shelves. Drawers are mounted on rugged side rails and guides with ball bearing rollers for trouble free strength and durability. A removable solid alder cutting board with slotted cutlery rack is built in and concealed behind a drawer front. Tip out storage in front of sink.

INTERIOR TRIM AND DOORS
Prefinished wood window liners, casing, prehung doors, wardrobe bi-pass and bi-fold doors per plans, baseboard throughout. Your choice of Cottage Birch, Sand Oak, or Autumn Oak to compliment your cabinets.

COUNTERTOPS
Formica with custom beveled oak backsplash and self-edge stained to match cabinets.

APPLIANCES
30" built-in Whirlpool black front range with oven, clock, timer, and oven door window. Range hood with light and two speed fan vented to exterior. Built-in Whirlpool black front power wash 4 cycle dishwasher.

HEATING
Electric forced air heating system with wall mounted thermostats in each room. Bathroom ceiling mount heater. Oil or gas furnaces or heat pumps optional. Heating for Alaska: Forced air oil or gas fired. Insulated duct work shipped loose for on site installation.

ELECTRICAL
200 amp. service panel with main disconnect. Copper wire throughout, except range, dryer circuit and through mast to panel. Includes smoke detector, front doorbell, exterior lights and ceiling lights in kitchen, baths, utility room, hall, entry and dining room. Dining room chandelier has dimmer control. Switched outlets in living room, family and bedrooms. G.F.I. (ground fault interrupter) circuit for outlets in baths and exterior weatherproof duplex outlet. Specific Alaska code requirements are included in Alaska pricing.

PLUMBING
Copper water lines (hot and cold), PVC and ABS waste and venting lines (supply and waste lines stubbed to joist space). Front and rear frost-free hose bibs. Glass lined, quick recovery 52 gallon electric hot water tank. Clothes washer rough-in with controls and drain. Specific Alaska code requirements are included in Alaska pricing.

PLUMBING FIXTURES
Vitreous china toilet, enameled steel basin. One piece fiberglass tub and shower per plan. Double stainless steel sink in kitchen. Single lever mixing valve faucets. For Central Alaska mixing valves on toilets are included.

BATH ACCESSORIES
Oak towel bar (1 per bath), paper holder, vanity mirror, curtain rod for tub, built-in glass door for shower. Recessed medicine cabinet where possible.

WARRANTY
One year manufacturer's written warranty. Specific items such as appliances, etc. are covered by the warranty of the respective manufacturer. Ten year structural warranty is standard for all Washington homes.

SHIPPING
Washington: Delivered and set within 50 miles of production facility. Alaska: Freight prepaid to Seattle dock. Packaged for shipment with polyethylene and plywood sheathing.

Appendix 5

A C O R N

ENERGY CONSERVING DESIGN IN ACORN HOUSES

Acorn Country House Model, Morristown, New Jersey

Systematic Design — The Big Picture

A home is a system. At its most fundamental level, the purpose of this system is to interact with the outdoor environment for the protection of the occupants. In order to create a system to perform this function, we must begin by understanding the context in which it will operate; in other words: the site. With this knowledge, we can take advantage of local opportunities to provide elegant solutions to the challenge of energy conserving design.

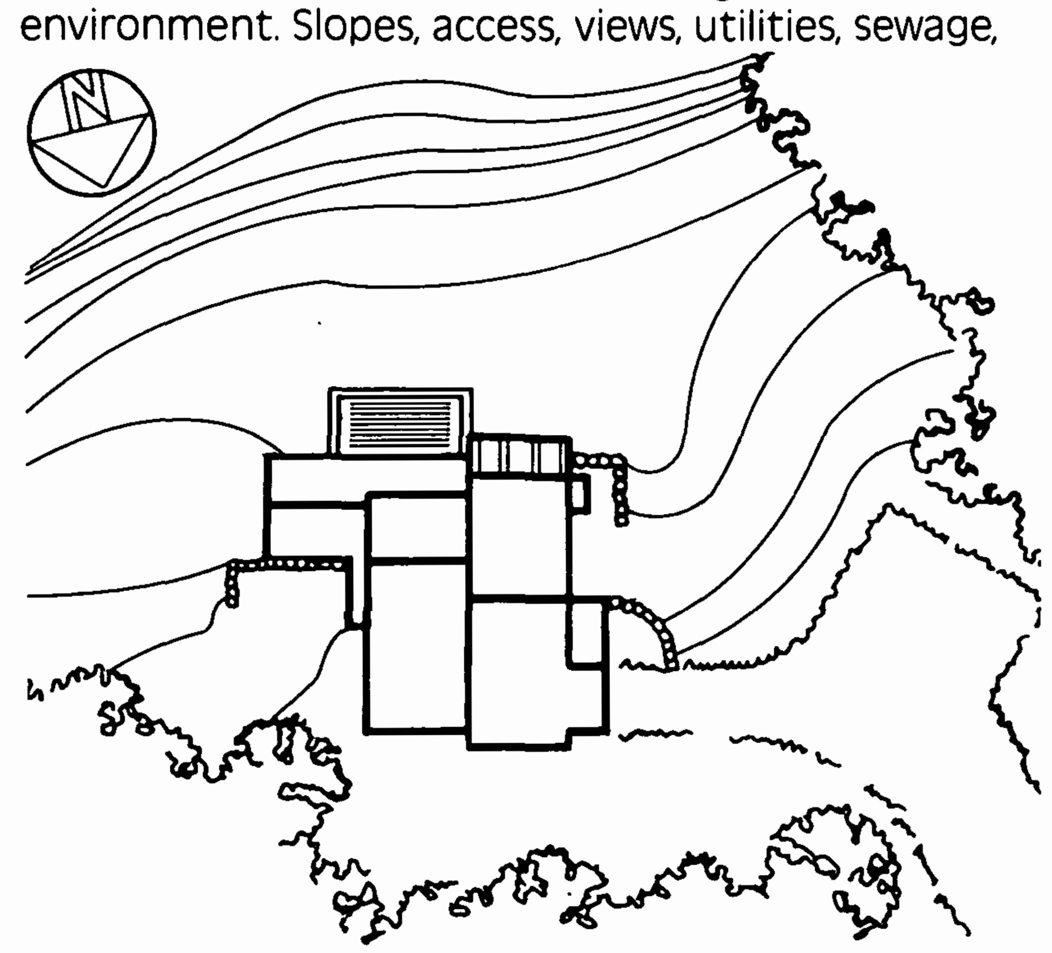
Most of the mechanical systems of a house are intimately connected to the outdoors. Heating and cooling are clearly responses to adverse conditions outdoors. So is ventilation to provide fresh air, control drafts, and control humidity. There are more subtle relationships as well. Visual comfort is strongly affected by sunlight—either pleasantly in a well-lit room or unpleasantly as glare. Most Acorn home owners also desire a high degree of connectedness to the outdoors: views, skylights, sunspaces, decks, and outdoor spaces are all part of good design.

Integrating all these design components to form a system that performs efficiently with minimum energy input requires an understanding of the larger context. To the maximum extent possible, the exterior environment should provide cooling, warmth, light, and beauty. A house is more than an elaborate defense against hostile elements; a well-designed house cooperates with its setting in architecture, energy, and comfort.

Design Approach—Start With The Land

In terms of energy, the climate is the major factor in determining the proper balance among key design elements. There are 14 significantly different climates in the U.S. In addition, many sites within each zone have microclimates very different from the overall climate.

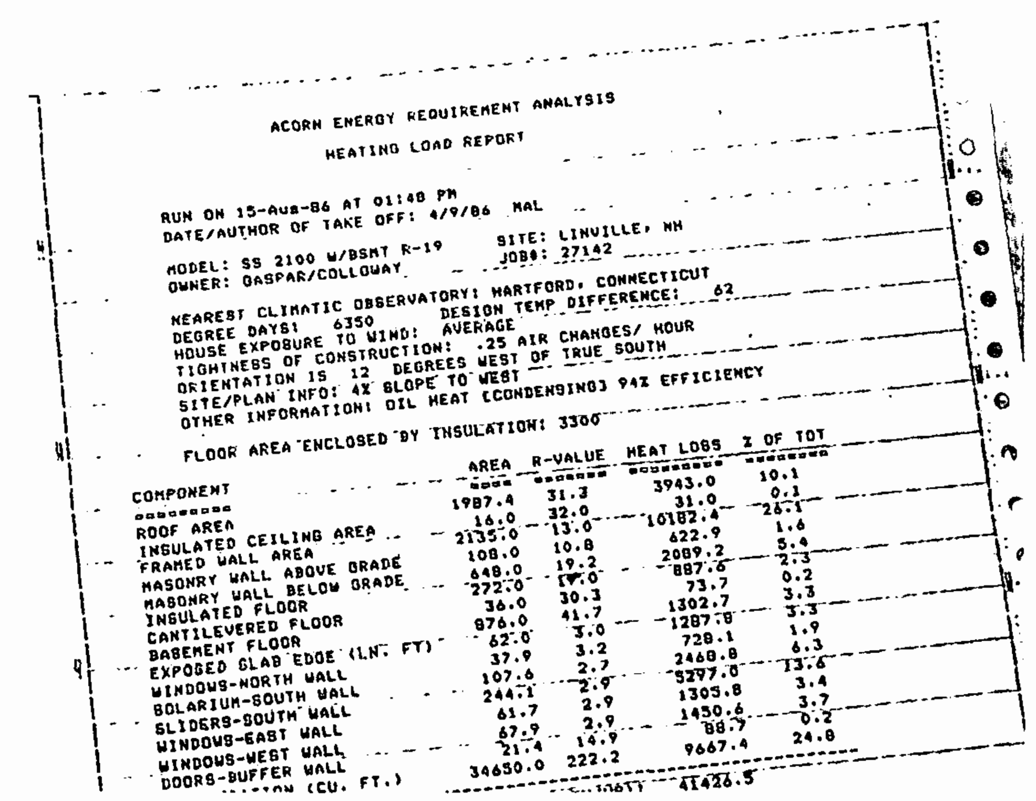
Siting a house is a matter of fitting it into the environment. Slopes, access, views, utilities, sewage, drainage, and soils must all be considered. Thought should be given to energy considerations, light, the local microclimate, landscaping, and trees. These all have a direct effect on the comfort and health of the occupants.



Siting the house is fitting it into the environment.

What If It Doesn't Face South?

Your needs and your site define the appropriate design response to climate. A beautiful view usually dictates the primary orientation of windows but often is not ideally located for collecting solar energy. Yet there are many ways to capture that northwest view and also capture solar energy. A house that is efficient will have minimal energy requirements regardless of orientation. Some good ideas: point a corner of the house toward the view and wrap the corner with glass to see a wider expanse; use the gable end to capture the sun or the view; frame the view with picture windows rather than floor-to-ceiling glass; use a trellis over west-facing glass (which causes the most overheating in summer) to shade, cool, and prevent glare. There are a host of other possibilities that will be suggested as your house design takes shape.



ACORN ENERGY REQUIREMENT ANALYSIS
HEATING LOAD REPORT

RUN ON 15-Aug-86 AT 01:48 PM
DATE/AUTHOR OF TAKE OFF: 4/9/86 MAL
MODEL: SS 2100 W/BSMT R-19 SITE: LINVILLE, NH
OWNER: GASPAR/COLLOWAY JOB#: 27142
NEAREST CLIMATIC OBSERVATORY: HARTFORD, CONNECTICUT
DEGREE DAYS: 6350 DESIGN TEMP DIFFERENCE: 62
HOUSE EXPOSURE TO WIND: AVERAGE
TIGHTNESS OF CONSTRUCTION: .25 AIR CHANGES/ HOUR
ORIENTATION IS 12 DEGREES WEST OF TRUE SOUTH
SITE/PLAN INFO: 4% SLOPE TO WEST
OTHER INFORMATION: OIL HEAT (CONDENSING) 94% EFFICIENCY
FLOOR AREA ENCLOSED BY INSULATION: 3300

COMPONENT	AREA	R-VALUE	HEAT LOSS	% OF TOT
ROOF AREA	1987.4	31.3	3943.0	10.1
INSULATED CEILING AREA	16.0	32.0	31.0	0.1
FRAMED WALL AREA	2135.0	13.0	10182.4	26.1
MASONRY WALL ABOVE GRADE	108.0	10.8	622.9	1.6
MASONRY WALL BELOW GRADE	648.0	19.2	2089.2	5.4
INSULATED FLOOR	272.0	17.0	887.6	2.3
CANTILEVERED FLOOR	36.0	30.3	73.7	0.2
BASEMENT FLOOR	876.0	41.7	1302.7	3.3
EXPOSED SLAB EDGE (LN. FT)	62.0	3.0	1287.8	3.3
WINDOWS-NORTH WALL	37.9	3.2	728.1	1.9
SOLARIUM-SOUTH WALL	107.6	2.7	2468.8	6.3
SLIDERS-SOUTH WALL	244.1	2.9	5297.0	13.6
WINDOWS-EAST WALL	61.7	2.9	1305.8	3.4
WINDOWS-WEST WALL	67.9	2.9	1450.6	3.7
DOORS-BUFFER WALL	21.4	14.9	88.7	0.2
...TION (CU. FT.)	34650.0	222.2	9667.4	24.8
			41426.5	

Thermal performance analysis is done for each house.

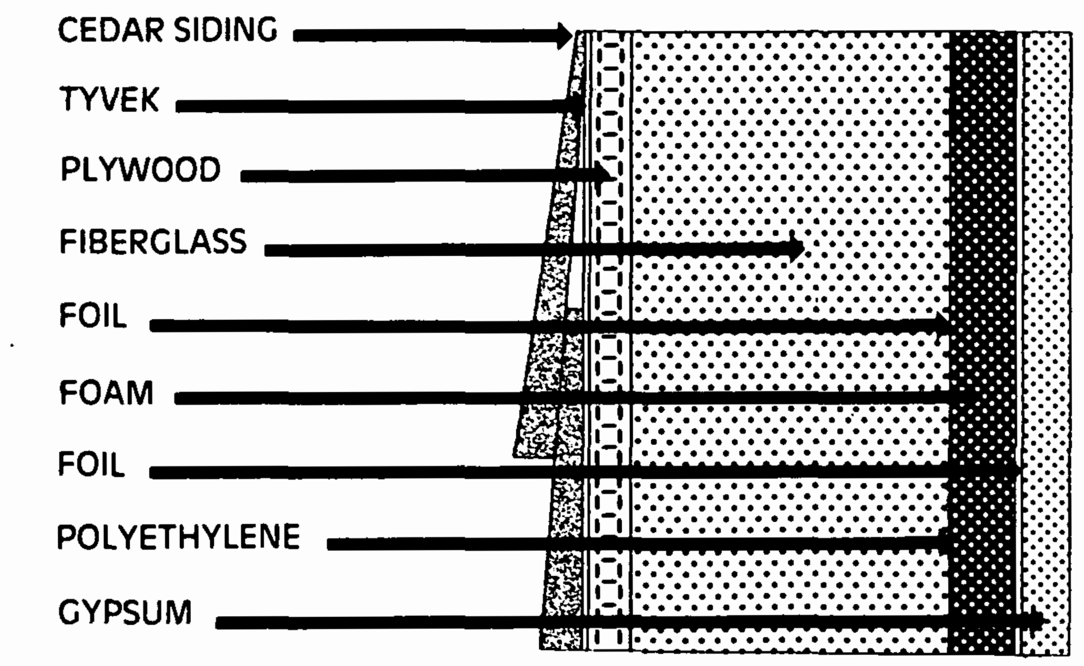
Positive Cash Flow

Each house undergoes thermal performance analysis to compute the effects of each building component on energy use for both heating and cooling in your climate. We predict the performance of the design and analyze the effects of changes. At your request we'll provide an annual performance analysis and an estimate of solar performance and fuel requirements.

Our energy research staff will help choose the most cost-effective balance of energy techniques and tailor them to your site and climate. Our analysis covers the entire life cycle of your energy investment allowing us to include initial costs, maintenance, and energy costs as well as the tax benefits of choosing different options. The goal is maximum comfort at minimum overall cost.

Techniques

To meet this goal we use a full palette of techniques to adapt the design to the climate. At Acorn we have a wealth of available options that fall into four basic categories: 1. heat retention; 2. heat exclusion; 3. heat collection; and 4. heat rejection. As we shall see, each has its place in the system.



Redundant layers in the wall prevent wind infiltration.

Conservation

Conservation of energy is the cornerstone of any approach to high performance. Techniques include *heat retention* when it's cold—using insulation, infiltration control, high performance low-E glazing, and a wide variety of other superinsulation techniques. At the same time our approach to insulation is balanced with economics. We analyze the building to see where heat is lost and then add insulation where it is economically justified. The amount of insulation is also balanced: it makes no sense to have three feet of insulation in the attic if the wind blows right through the house.

Heat exclusion is the first line of protection when it's hot outside. We can examine the site and modify the designs and landscape to avoid high cooling loads. The use of design to reduce overheating is called passive cooling—an important part of planning in warm and moderate climates. Examples are shading, overhangs, trellises, wingwalls, natural ventilation, radiant reflective heat barriers, and trees and plants for shading and cooling.

Heat Collection

The highest level of design adaptation to the site is the use of solar energy to defray fuel costs and enhance thermal and visual comfort. Acorn has experimented with a variety of solar techniques but three in particular have moved into the mainstream of Acorn designs.

Direct gain brings sun directly into the living space.

Passive Direct Gain

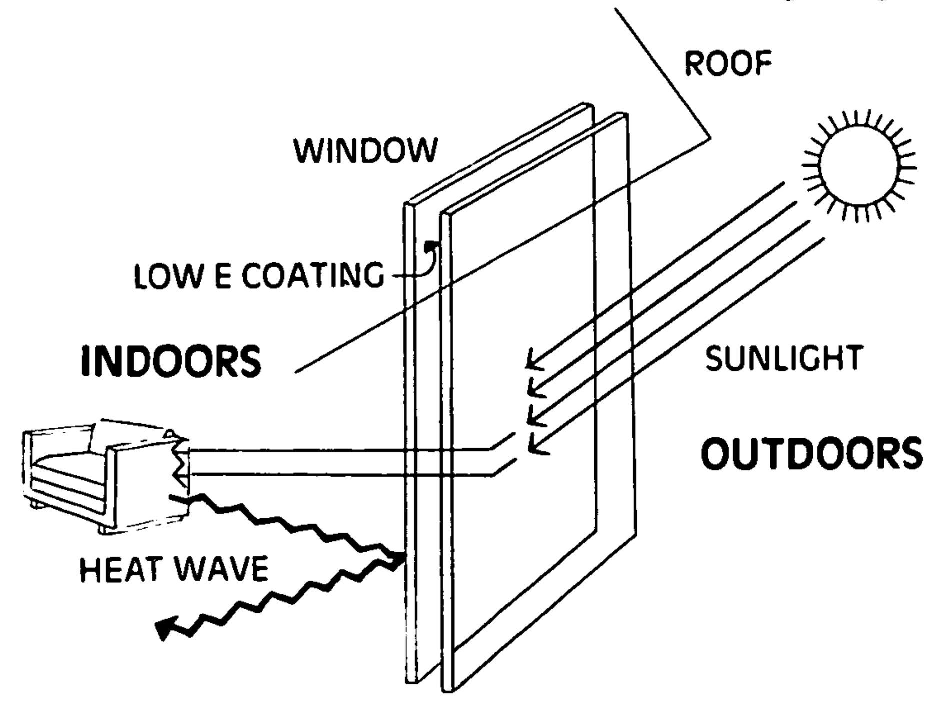
The most popular solar technique is passive direct gain. At its simplest level this is simply adding more glass to the south side of the house. But this simple approach is limited to small areas of south glass and small solar contributions. More glass can be added but attention must be paid to couple the extra glass with thermal storage to avoid wasting the collected energy, overheating the house, and actually increasing fuel bills. Acorn's thermal analysis calculates the benefits of more glass and signals the need for added thermal storage.

The use of low-emissivity glass on Acorn houses also helps to use extra direct gain solar more effectively. Low-E glass lets the sun's heat and light in but traps the heat once it's inside the house. It actually helps prevent overheating by reducing the amount of solar energy transmitted in; this effect is more than compensated for by its heat-retention qualities. The net benefit is economically well justified and adds significantly to comfort.

The best part of direct gain passive solar is that, in addition to economy, there are benefits in light, warmth, views, openness, and comfort.

Passive Isolated Sunspace

For those who want maximum passive solar performance, or whose climates are unforgiving to large areas of glass because they are too hot or too cold and cloudy, Acorn offers the isolated gain sunspace. This space is a separate room—generally but not always on the south—in which to collect and enjoy the sun's heat when available. It can be opened to the house when it's sunny, or the collected heat can be transferred automatically. At night or when it's cold and cloudy, the space is closed off and acts as a buffer for the warm main living spaces. In hot weather the isolated sunspace is directly ventilated and closed off from the house to prevent overheating. Such sunspaces offer a wonderful environment for plants and a sunny spot for breakfast or entertaining—a focal point for a unique lifestyle.

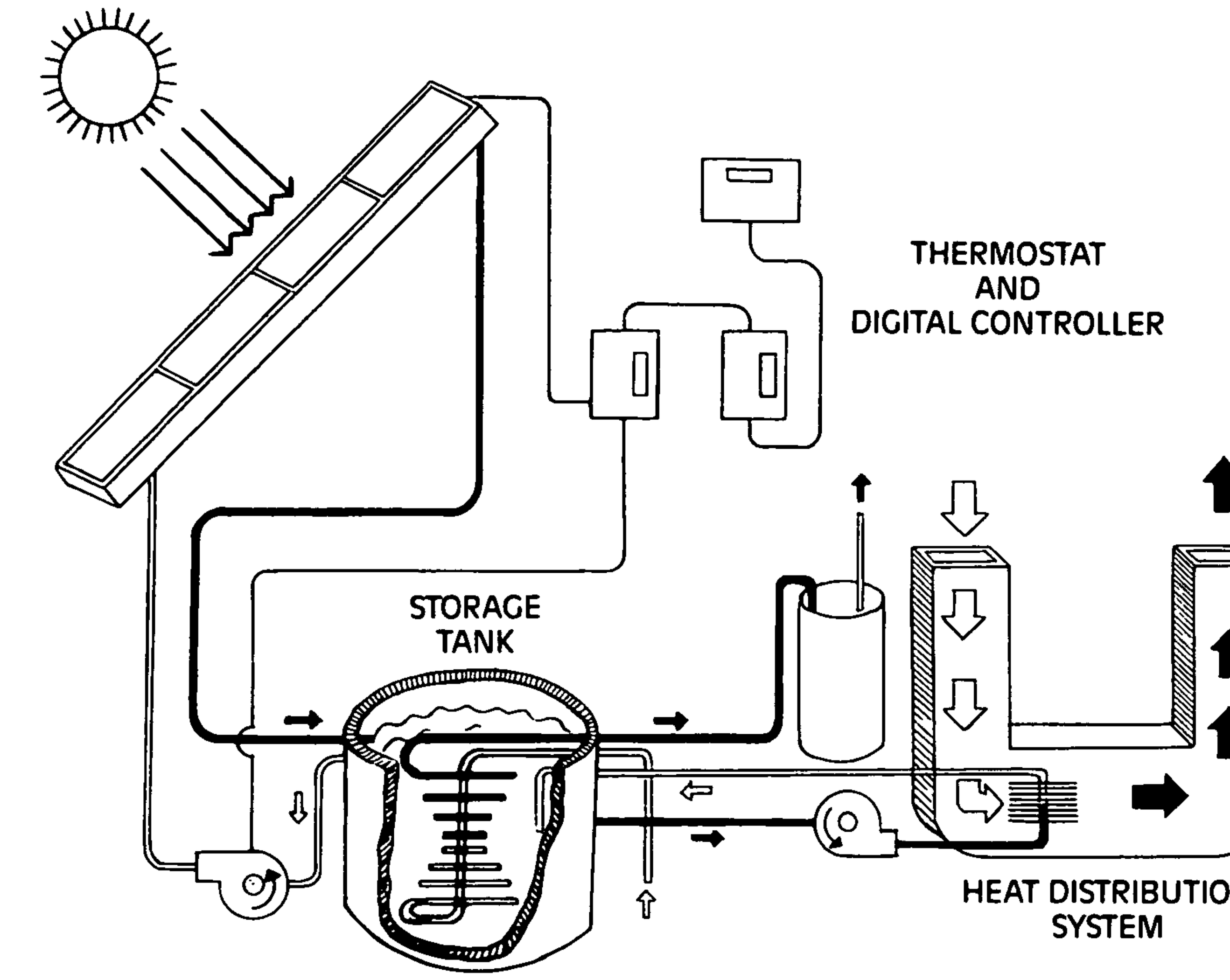


How Low E glass works in winter.

Isolated gain sunspace is closed off from the house.

Active Solar

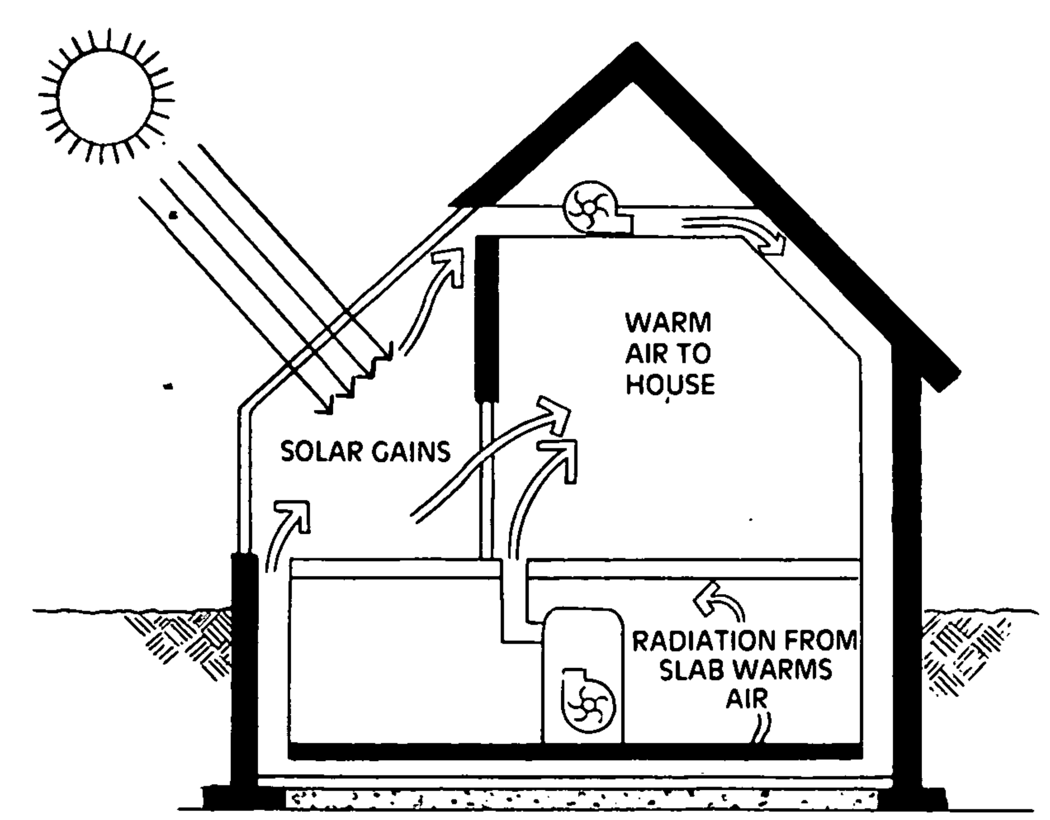
The third option is the active solar collection system. Acorn's Sunwave system has proved in over 12 years of production to be a dependable producer of energy. Two basic systems are available—one produces domestic hot water only and the other produces space heat *and* hot water. Recent technological advances have led to the development of a new high-performance collector introduced in 1986. The Sunwave system is simple in concept and in operation. It is controlled by a thermostat no different from the ones you're used to, and requires very little attention or maintenance. Many customers enjoy watching the temperature in the storage tank rise and fall as millions of solar BTUs are collected and delivered to the house. In most U.S. climates, the standard Sunwave system will provide over 50 million BTU per year—equivalent to over 500 gallons of oil.



Sunwave active solar space heat system.

Thermal Storage

Acorn offers a variety of thermal storage options to meet design, system, and climate needs. Thermal storage is crucial to improved solar performance for both active and passive systems. The wide range of choices allows greater flexibility in design—yet all systems are as simple and economical as possible. Storage systems include efficient calculation and use of the intrinsic thermal mass of the house, thermal storage slab and the new elevated storage slab for direct gain, the remote storage slab for isolated gain sunspaces, and a variety of tank sizes from 300 to 2000 gallons for different active systems. We have a system that integrates perfectly with any house design.

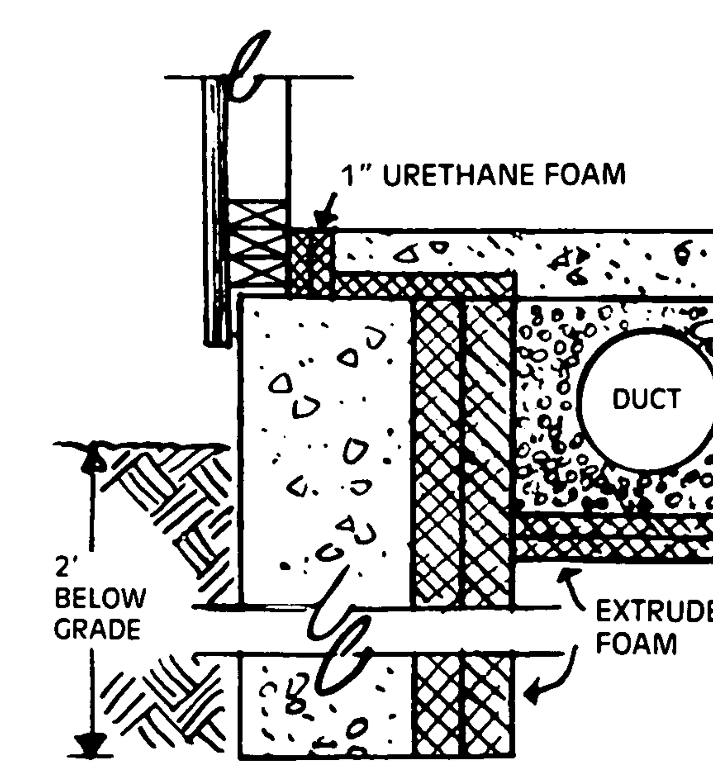


Energy flows from an isolated sunspace.

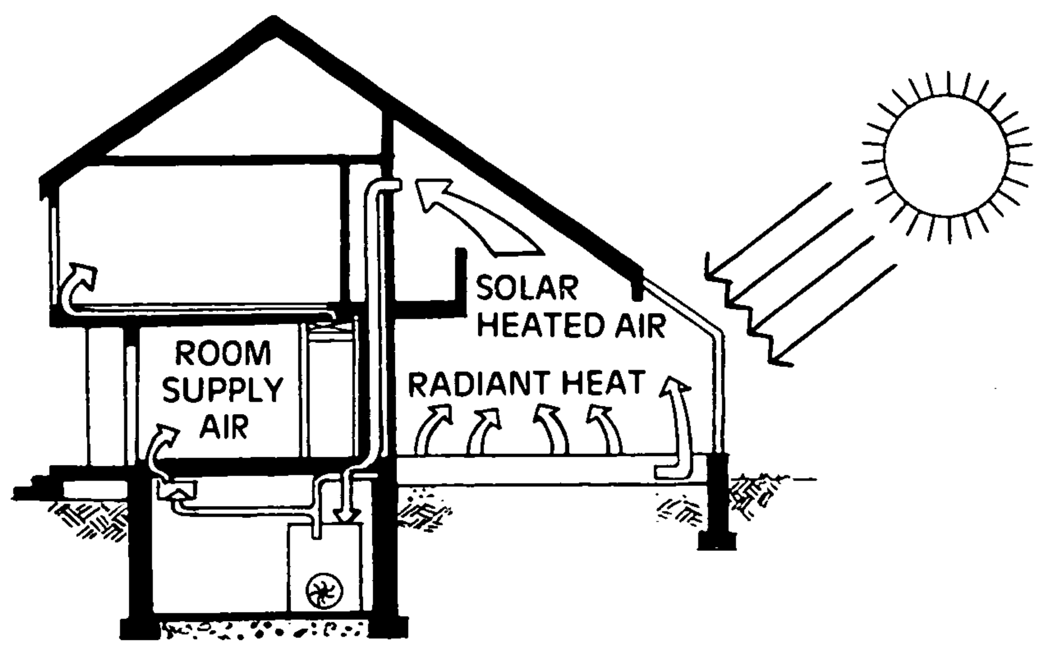
The Indoor Environment: Comfort And Health

At Acorn we care about the quality of life inside our houses. We have been pioneers in the monitoring and testing of indoor air quality, selection of safe materials and auxiliary equipment, and residential ventilation.

Today there are as many concerns about indoor air quality as there are for a clean outdoor environment. Acorn selects and specifies materials with careful consideration for their potential impact on the indoor environment. We avoid materials that may present a long-term risk to health and rely as much as possible on those that have proved safe over the years.



Acorn's research led to slab insulation details that set new standards for efficiency.



Energy flows with direct gain passive.

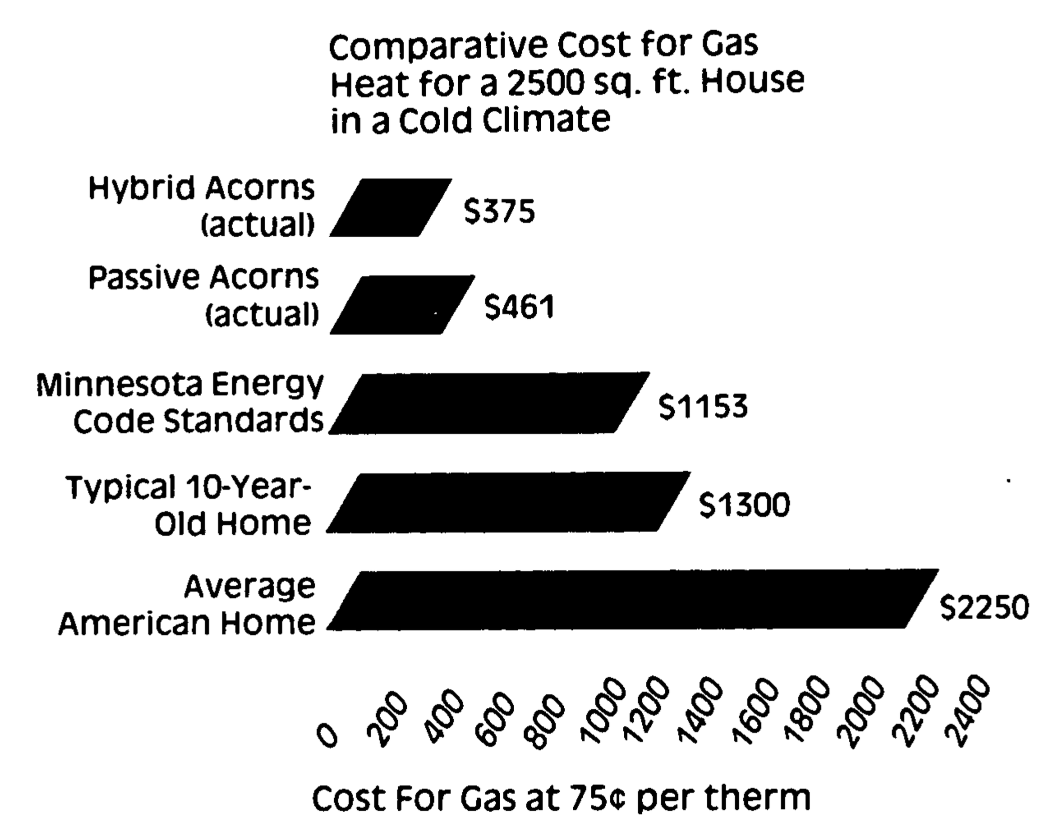
Are Houses Too Tight These Days?

Tightness is one very important key to energy efficiency. It's also the only way to eliminate drafts and take control of the indoor environment. To the casual observer, the concerns about indoor pollution seem to be at odds with this approach to conservation. And yet, while building a drafty house is certain to result in high energy bills, it is no assurance of fresh air. Since this approach relies on wind and random air leakage, pollutants can build up during calm weather and leakiness can create an upward suction (the chimney effect) that can draw more radon into the basement, cause moisture problems in the roof, and cause backdrafting in combustion equipment. The best houses built today and in the future will be built as tightly as possible and deliberately ventilated. A thoughtful approach to designing a ventilation system, exhausting the pollutants at their source using an air-to-air heat exchanger to save energy, results in a cleaner indoor environment that is within your control.

Research

Acorn is at the forefront of research in building performance, energy efficient design, and indoor air quality. Acorn has measured performance data on real houses. We know where energy goes in buildings, what works, and why. We have the advantage of thousands of built houses to form an incomparable data base on actual performance. Thorough analysis, an active research program, and a commitment to the integration of technology and design have made Acorn a recognized national leader in building and energy research.

Independent testing confirms the high performance of Acorn designs. The Acorn house is not only energy efficient but also sensitive to site, views, micro-climate, indoor and outdoor environment, health, comfort, and functionality.



Acorn Annapolis 4300 Model, Annapolis, Maryland

Questions About Acorn and Energy

♦ = This symbol denotes availability of a detailed Acorn Technical Bulletin devoted to the subject. Contact your Acorn representative for a complete list or to request a specific bulletin.

How energy efficient are Acorn houses?

Acorn houses outperform 99% of today's new houses. See technical bulletins #2, 3, 4, 6, and 24 for actual data and performance reports. ♦ 2, 3, 4, 6, 24

What if my lot doesn't slope to the south or my view is to the west or north?

As mentioned earlier, there are a host of options. Get to know your site, see technical bulletins for more ideas, and talk to your Acorn representative about appropriate changes to your plans. ♦ 23, 25

Are all Acorns solar houses?

No; although all Acorns are energy efficient, some site conditions don't lend themselves to either passive or active solar collection. In most cases, at least some passive solar features are included.

How does passive solar work? Isn't overheating a problem?

Passive solar uses the design of the building to collect, store and distribute heat. A well-designed passive solar building will overheat less than a conventional building where little attention is paid to reducing cooling loads. ♦ 13

Does active solar really work?

For over 12 years Acorn's Sunwave active systems have proved to be reliable producers of large amounts of energy. In technical bulletin #2 home owners' own performance reports tell just how hard these systems work. ♦ 2

How much money can I save?

Energy costs in an Acorn house can be up to 90% lower than conventional houses of similar size. ♦ 2, 24

Why is Acorn's redundant barrier wall system better than a 2x6 wall?

There are two good reasons. A 2x6 wall has wood studs that make a continuous thermal bridge from inside to out. This reduces the effectiveness of the wall as a system to less than R-19 and produces cold spots at each stud. Acorn's system covers all the studs with a continuous layer of insulating foam—preventing thermal short circuits. The second benefit of the redundant system is reduced infiltration. The exterior layer of Tyvek, sealed internal polyethylene vapor barrier, and foil faces on the foam provide three overlapping layers of wind protection.

How long has Acorn been manufacturing active systems? Passive systems?

Acorn began manufacturing its Sunwave active solar heating systems in 1975. The idea of using the house itself as a solar collector began soon after that, with the first Solar Cape in 1977.

Does Acorn build superinsulated houses?

Yes. The best features of superinsulating technology have been incorporated into our standards. The insulating levels for each house are chosen with regard to climate, design feasibility, and economic benefit. ♦ 14

What happens if it's cloudy?

The active system can store energy for one or more cloudy days depending on how cold it is outside. Passive designs generally store energy into the night of a sunny day. In any case, there is always a backup system capable of keeping the house comfortable. ♦ 6

Which is better, solar or superinsulation?

The best houses use a combination of both technologies. The ideal mix depends on climate, since each system saves energy in a different way. Superinsulation minimizes dependence on the sun; solar provides light, openness, and connection to the outdoors. ♦ 14

Does solar make sense in my climate?

No doubt. Although the best type of system varies with the climate, solar can provide significant amounts of energy economically anywhere in the lower 48 states. We don't encourage reliance on solar for Alaskan winters, however.

Doesn't passive solar just mean lots of glass on the south side?

Too often, that's all it means; but there is much more to a good passive solar design. Thought must be given to heat storage, distribution, overheating, thermal mass, window insulation, and a variety of other concerns. Overglazing can be a real problem; too much glass will lose more energy than it gains and cause serious overheating. ♦ 13

What is low-E glass?

Low emissivity glass has a thin coating on one surface that reflects heat. Although light passes through the coating, heat is trapped inside. This effectively increases the insulating value of the glass.

What will it cost to heat or cool my house?

We can give you an estimate based on a standard house thats similar to the one you want. Once your house has completed preliminary design, a more specific estimate can be made based on the design, climate, and site. ♦ 2, 24

Why does Acorn use interior foundation insulation instead of exterior?

More insulation can be put on the inside economically, without the problems of protecting the exterior insulation from insects, moisture, and deterioration. There is little thermal advantage to putting the basement walls inside the insulation.

Why does Acorn recommend forced warm air heating?

Forced warm air is by far the most flexible system. There are many functions that only this type of system can perform: cooling, distribution of solar heat, air cleaning, dehumidifying, ventilating, and destratifying.

What about overhangs for shade in summer?

Many Acorn designs have wide overhangs; others can add them. Overhangs aren't always the best shading solution, however. Trellises (particularly on the west side), exterior shade screens, and trees are often better. Overhangs on the south side are very often too deep—shading in spring when you want the sun to shine in.

What about shading sloped glass?

Acorn's seasonal exterior shades can reduce solar heat gain by 75%. Trees and vines can be a beautiful and effective solar solution as well.

ACORN STRUCTURES, INC., BOX 250, CONCORD, MASSACHUSETTS 01742 (617) 369-4111

Appendix 6

WINTER PANEL CORP.

STRUCTUREWALL™

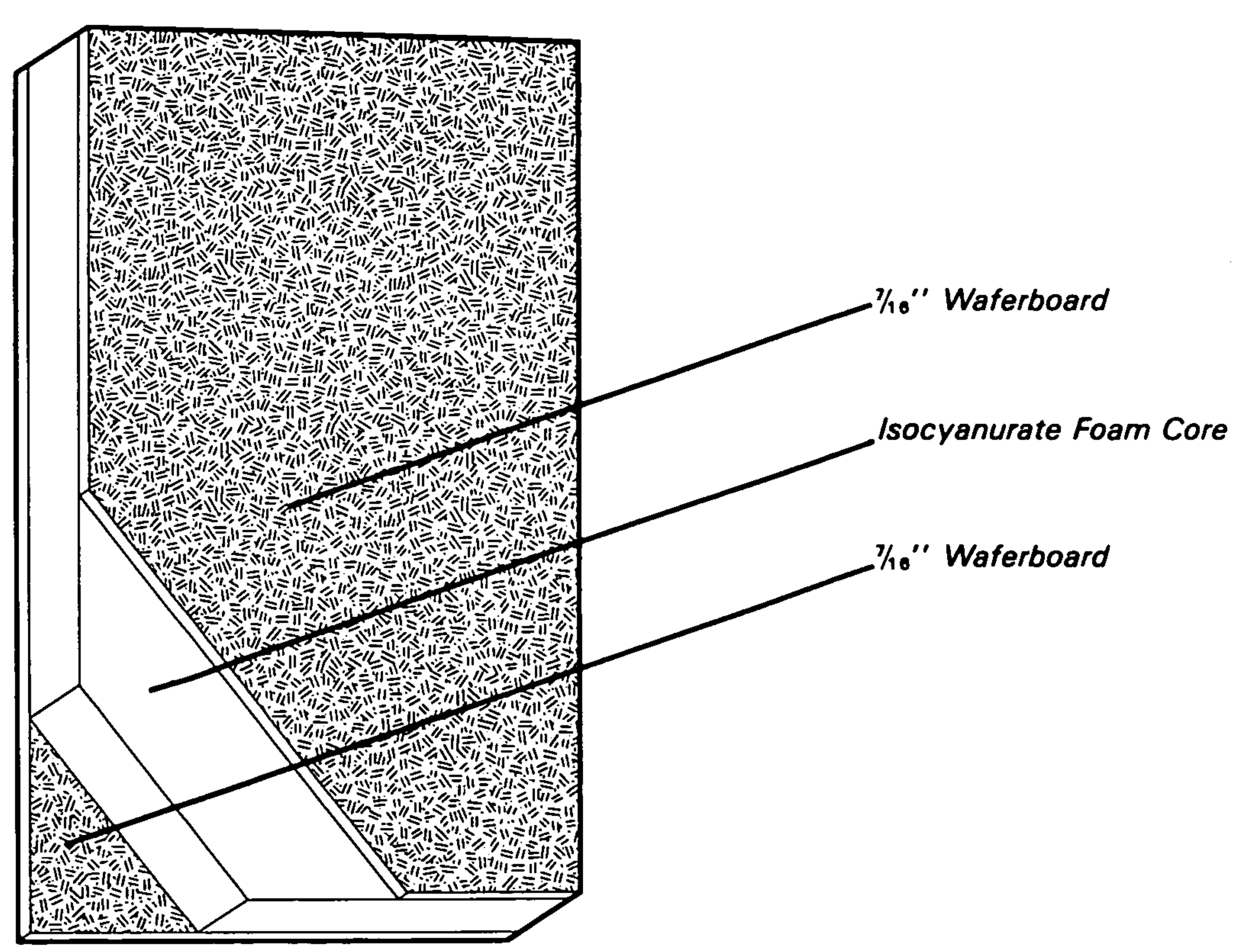
TECHNICAL INFORMATION

Product Data | **No. S-1.1**

General Description

Structurewall™, manufactured by Winter Panel Corporation, is a structural-grade stresskin panel for use in panelized home construction. The panel provides more than three times the strength of a standard 2x4 wall system. It achieves this remarkable strength through its laminated construction, with two skins of 7/16" oriented strand board or oriented waferboard (a structural grade of waferboard) surrounding a core of high-density isocyanurate insulation.

Structurewall™ is manufactured in a continuous lamination process in which the foam directly bonds to the skins, providing the highest strength bond possible. The high-density isocyanurate insulation (an advanced formulation of urethane) provides very high insulation levels (R-26 for the 4 9/16"-thick panel) and excellent fire safety characteristics. Structurewall™ panels insulate as well as 9" of fiberglass or 6" or 1-lb density expanded polystyrene (EPS), yet at an overall thickness of only 4 9/16".



Applications

Structurewall™ panels provide an alternative to conventional studwall and rafter framing systems in residential and light commercial buildings, offering superior strength, thermal performance, and ease of installation. Four foot wide panels, joined by inset splines, produce an extremely strong wall or roof system. Upper floor walls are stabilized by truss-joist floor deck systems. Roof loads are carried by ridge and purlin laminated beams and the intersecting wall plate or floor platform. 2x4 splines are typically used for wall joints, sill or floor deck attachment and corner intersections. Dual 1x3 splines are recommended for panel joints in roofs.

Structurewall™ panels may also be used in enclosing timber-frame houses where extra strength or a cabinet nail base is required. These panels are frequently used in kitchens and bathrooms, while Curtainwall panels (with drywall on the interior) are used to enclose the rest of the timber frame.

Dimensions and Physical Properties

Outer Skin 7/16" Oriented strand board (OSB) or oriented waferboard, a high-quality, exterior-rated, wood composite board.

Inner Skin (identical to outer skin).

Insulation Core Polyisocyanurate, a 2-lb/ft^3 density, Class I, closed-cell foam. The foam insulation contains no formaldehyde or formaldehyde-related chemicals.

Adhesion An extremely strong and durable bond between foam and skins is provided by the continuous lamination manufacturing process with injected foam expanding against the two skins under pressure.

DIMENSIONS AND WEIGHT:

Overall Thickness	4 9/16"
Thickness Tolerance	± 1/16"
Width	48"
Width Tolerance	+0" -1/8"
Standard Lengths (ft)	8, 9, 10, 12, 14, 16, 20, 24, 28
Length Tolerance	+0" -1/8"
Weight	3.75 lb/ft^2

STRUCTURAL PROPERTIES OF FOAM:

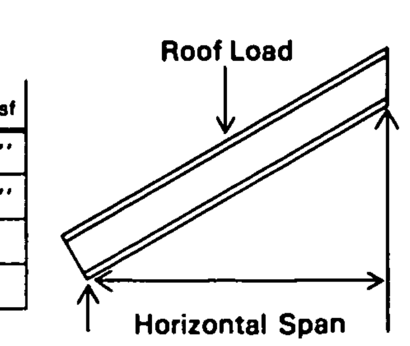
Compressive Strength	23.7 psi (ASTM C-365)[1]
Shear Strength	11.9 psi (ASTM C-273)[1]
Tensile Adhesion	16 psi (ASTM C-297)[2]
Flexural Modulus	760 psi (ASTM C-393)[2]
Shear Modulus	750 psi (ASTM C-273)[2]

1. Source: Pittsburgh Testing Laboratory
2. Source: Mobay Chemical Corp.

STRUCTURAL DESIGN GUIDELINES (PANELS)

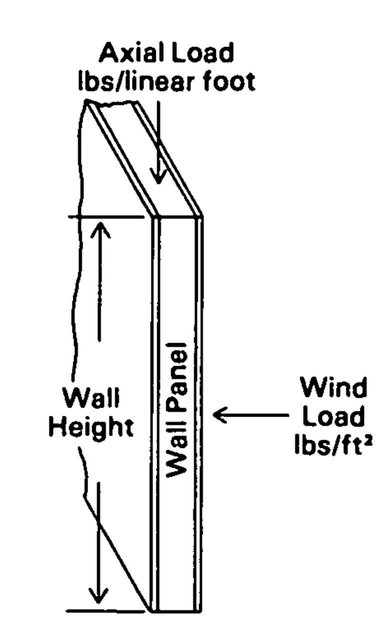
ROOF SPAN TABLE (FT/IN) - HORIZONTAL LOAD

DEFLECTION LIMITS	UNIFORM LOAD (LIVE LOAD PLUS DEAD LOAD) 20 psf	30 psf	40 psf	50 psf	60 psf	70 psf	80 psf
L/180	12'4"	10'3"	9'0"	8'0"	7'3"	6'7"	6'1"
L/240	11'0"	9'2"	7'10"	6'10"	6'2"	5'7"	5'2"
L/360	9'0"	7'4"	6'3"	5'4"	4'9"	4'3"	
L/480	7'9"	6'2"	5'2"	4'5"			



WALL LOAD TABLE
(ALLOWABLE AXIAL LOADS (plf)

WALL HEIGHT	WIND LOAD 13 psf	16 psf	20 psf	23 psf	25 psf
4'	7800	7700	7600	7525	7475
5'	7525	7400	7225	7100	7025
6'	7150	6975	6725	6575	6475
7'	6675	6450	6150	5575*	5150*
8'	6150	5500*	4525*	3800*	3325*
9'	4875*	4050*	2950*	2125*	1575*
10'	3600*	2675*	1450*	550*	
11'	2425*	1400*	75*		
12'	1325*	225*			
13'	325*				
14'					



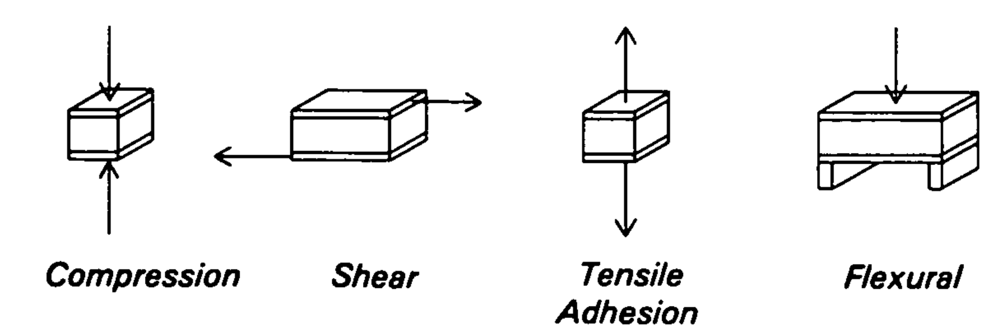
*Loads limited by L/240 deflection.
Other loads limited by combined stress analysis.

THERMAL PERFORMANCE:

Conductivity of Foam (k value) (aged 6 months)	.13-.15 [Btu-in/ft^{2}hr°F]
Minimum R-Value of Panel (aged 6 months)	26 [Ft^{2}hr°F/Btu]
WATER VAPOR PERMEABILITY	less than 1 perm.
WATER ABSORPTION	2.4% (ASTM C-209)

FIRE SAFETY:

Finish Rating	½" drywall facing required to meet standard 15-minute finish rating.
Foam Fire Rating	Class I
Smoke Developed	300 (ASTM E-84)
Flame Spread	23 (ASTM E-84)
Structural Integrity in Fire Conditions	Isocyanurate foam is a "thermoset" plastic. It retains its structural integrity until completely consumed by fire. Melting does not occur.
Toxicity of Combustion Products	Dangerous gases may be given off in a fire. Combustion products are **are similar to those produced by burning wood.**



WARRANTY AND CODE COMPLIANCE:

Winter Panel Structurewall™ Panels come with a full ten-year warranty covering defects in materials and workmanship. For complete warranty information, contact the company. Structurewall™ panels have been thoroughly tested for structural properties, R-value, fire safety and durability by independent testing laboratories. Test results are available upon request.

Code Compliance:

Meets Massachusetts Building Code Requirements
Rhode Island Building Code Standards Committee
(see Report #83-150)

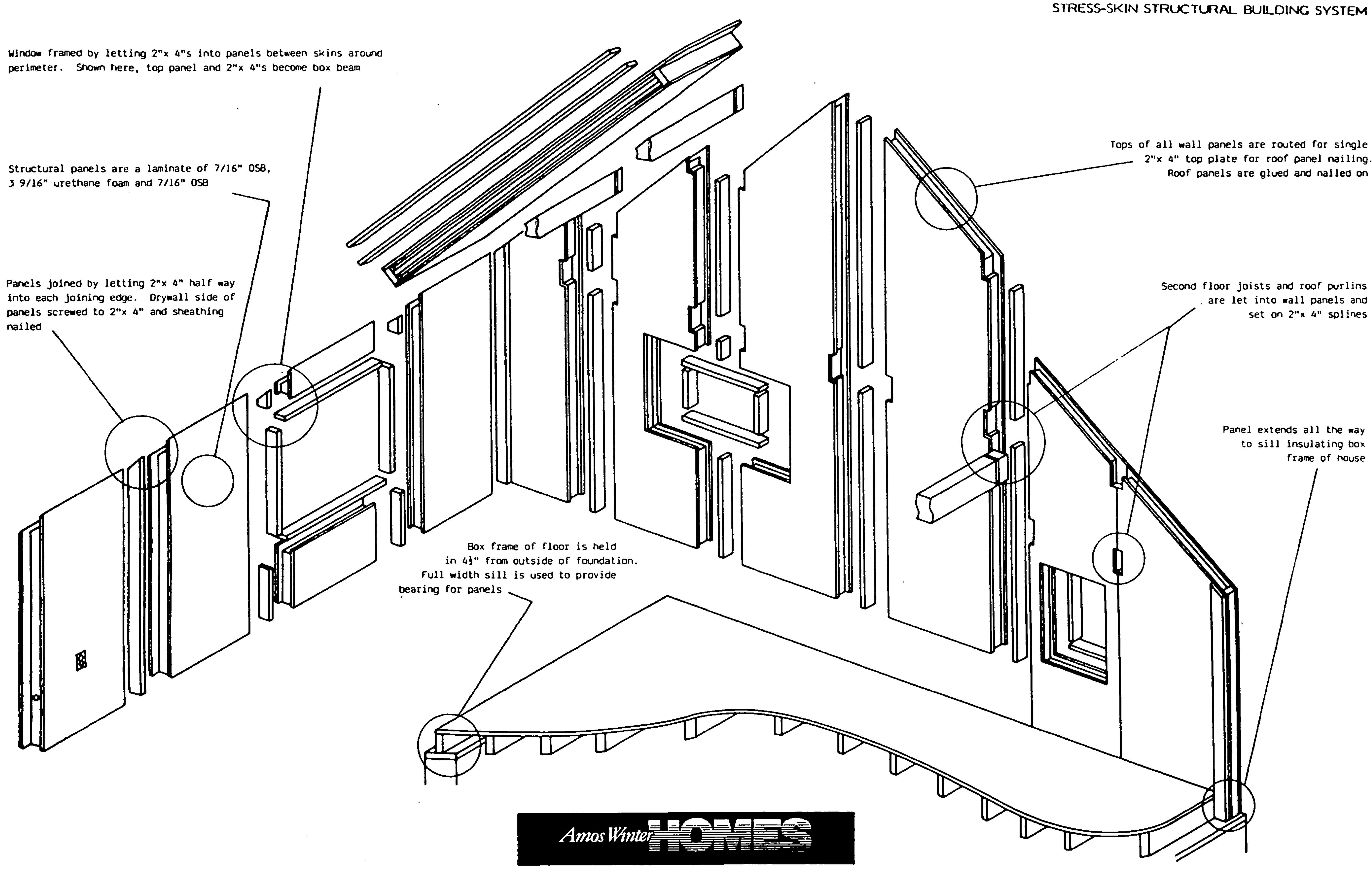
FOR MORE INFORMATION:

For additional information on Winter Panel stresskin products and applications, contact the company:

WINTER PANEL CORP.

Winter Panel Corp.
RR 5, Box 168B
Brattleboro, VT 05301
(802) 254-3435

STRESS-SKIN STRUCTURAL BUILDING SYSTEM



Amos Winter HOMES

DESIGN • COMFORT • VALUE

RR5 Box 168B, Glen Orne Drive, Brattleboro, VT 05301

Appendix 7

Lindal and Justus differences

The major differences between the Lindal frame specification and the Justus solid wood specification are found in the wall and roof.

Lindal

Beautiful kiln dried, select grade Western red cedar from our own sawmill clads every Lindal and Justus home. In the Lindal specification the wall is frame construction which is also known as double wall, or cavity, construction. The outer wall is lined with one-inch thick, resawn cedar planks that are tongued & grooved for a tight fit. The inner wall is drywall. The whole wall system, described in the following section, is very energy efficient with high R values.

A complementary cavity roof system tops this frame specification. Packed with fiberglass batt insulation, the roof system is extremely energy effective and earns a top R value rating. Drywall lines the interior.

Justus

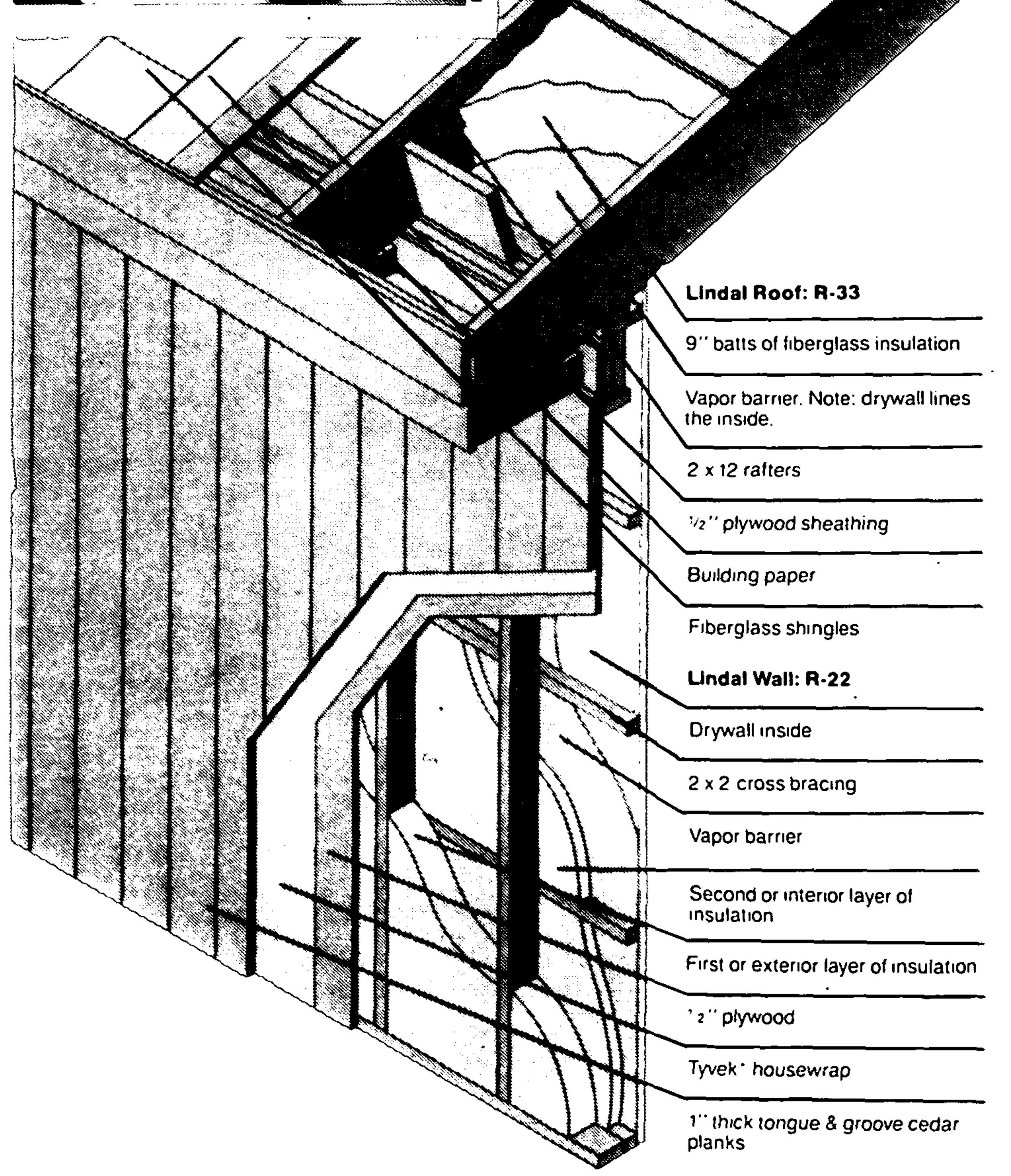
The Justus solid wood specification is for people who love cedar. Solid wood construction evolved from early log construction, but improved on it in many ways. Most obviously, the Justus wall is not made of ill-fitting round logs. Instead, the walls are made of four-inch thick, finely finished, solid cedar timbers, which are edged with double tongues and grooves, to lock together for a zero tolerance fit. For intersecting walls, the dovetail, the optimum woodworking joint, is used to prevent movement and slippage. This sophisticated version of log construction bypasses the energy and settling problems of typical log homes and pioneers a new standard in strong, solid wood construction. Energy is locked inside and air infiltration is stopped. The fit is so tight that no caulking is required between the timbers—yet, because the timbers are factory precut for each individual home, construction is both fast and easy. And that can translate into significantly lower labor costs.

All our cedar is *kiln dried* in an exhaustive process. Contrast this with the wood of many other manufacturers who frequently use green material, resulting in shrinking, twisting and warping. No straps, cables, tie rods or bolts are required to hold the Justus home together, unlike the homes of many log home manufacturers.

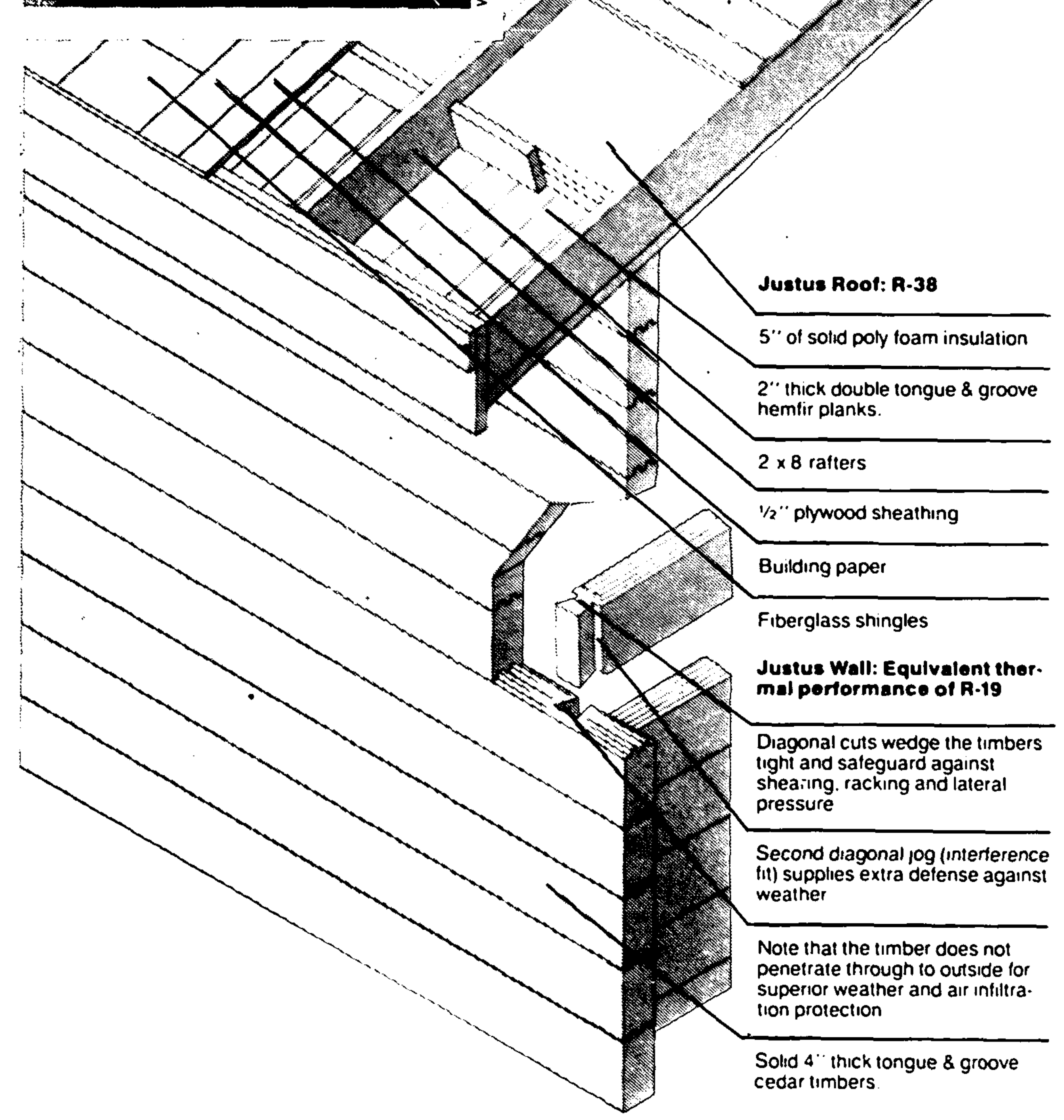
All this cedar also makes a Justus home heavy—actually many times heavier than a conventional house. And that heavy mass really pays off in energy storage. The thermal mass created by the four-inch thick cedar timbers provides the equivalent thermal performance of R values used in more conventional housing. More on thermal mass in the following section.

A solid cedar home needs a solid plank roof, so the Justus home comes standard with a two-inch thick, double tongued & grooved plank roof, insulated with solid foam insulation for excellent energy efficiency and a high R value rating. Naturally, if you prefer, you can substitute the Lindal cavity roof and, vice versa, the Justus solid plank roof on the Lindal.

Lindal: Double wall, frame construction. Outside, the exterior siding usually runs vertically. Inside, partitions are drywall with cedar panelling an option.



Justus: Single wall, solid wood construction. The outside walls are constructed of solid, four-inch thick cedar timbers positioned horizontally. Inside, partitions are drywall with cedar timbers an option.



Appendix 8

RIVERBEND TIMBER FRAMING, INC., is a small business located in Blissfield, Michigan (20 miles NW of Toledo, Ohio; 35 miles SW of Ann Arbor, Michigan) that is dedicated to the design, development and construction of timber framed homes and small commercial buildings. Timber framing is combined with the modern technology of stress-skin panels to create a weather-tight, super-insulated shell that not only will be easily heated and cooled, but will also radiate the natural beauty of wood throughout the hundreds of years such a structure can reasonably be expected to last.

The Craft of Timber Framing

Timber framing is a type of post and beam construction that is distinguished by use of wooden joinery (mortise and tenon, dovetails, scarf joints, etc.) to join large wooden timbers to create the structural skeleton of a building. These joints are secured by hardwood pegs called trunnels or "tree nails." There are no nails, bolts or joist hangers in a true timber frame.

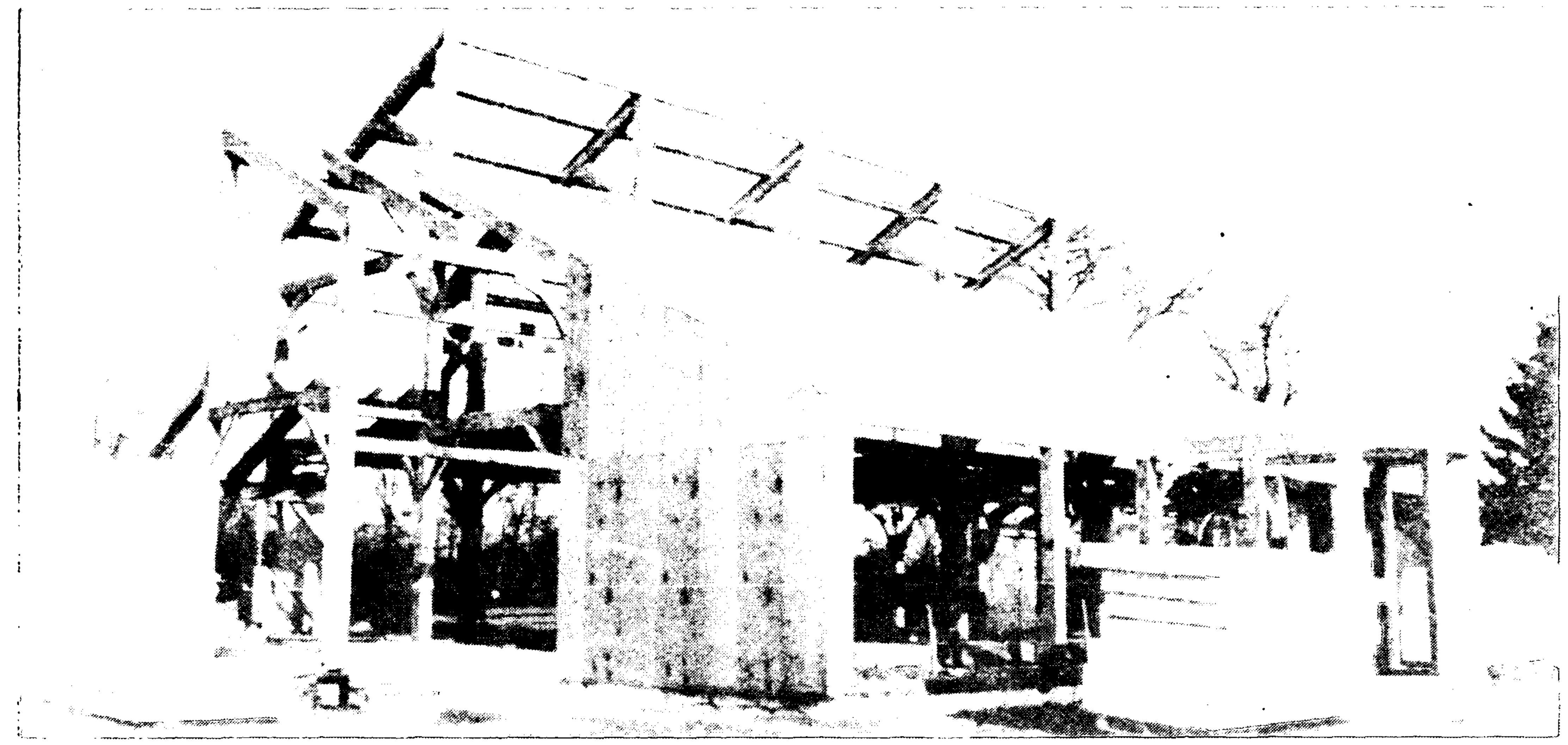
Timber framing will be immediately recognized as the building method used by American colonists and farmers to build the often-copied architecture of their time. It is also nearly universal in application. Historically, timber framing has been the construction method used by ancient builders to create the elegant traditional buildings of Japan, venerable English Tudor style, formal German buildings, very ornate sacred buildings, and rustic Alpine houses, many of which remain sound after several hundred years of use.

Timber framing is a disciplined craft, and the level of execution of this craft determines the durability of the resulting structure. The fact that some old buildings are stately creations and other are tumbling wrecks suggests that a high quality timber frame is the sum of painstaking execution of joinery, thoughtful engineering and careful enclosure.

As a result of changing demands made of modern housing, people are once again realizing the value of a timber frame. Far from merely being the resurrection of a nostalgic relic, the current revival of timber framing represents an opportunity for modern builders to respond to the need for practical, energy efficient buildings. Riverbend timber frames typically combine such sensible characteristics as structural strength, design flexibility, super-insulation, passive solar design and the natural warmth of wood to make beautiful, durable, and energy-efficient homes.

Beginning in New England in the early 1970's, the current revival of timber framing has steadily gained momentum and this unique approach to modern housing requirements is now available to home builders in the Mid-West.

Stress-Skin Panels and Energy Efficiency



Stress-skin panel wrap the frame in a continuous blanket of insulation.

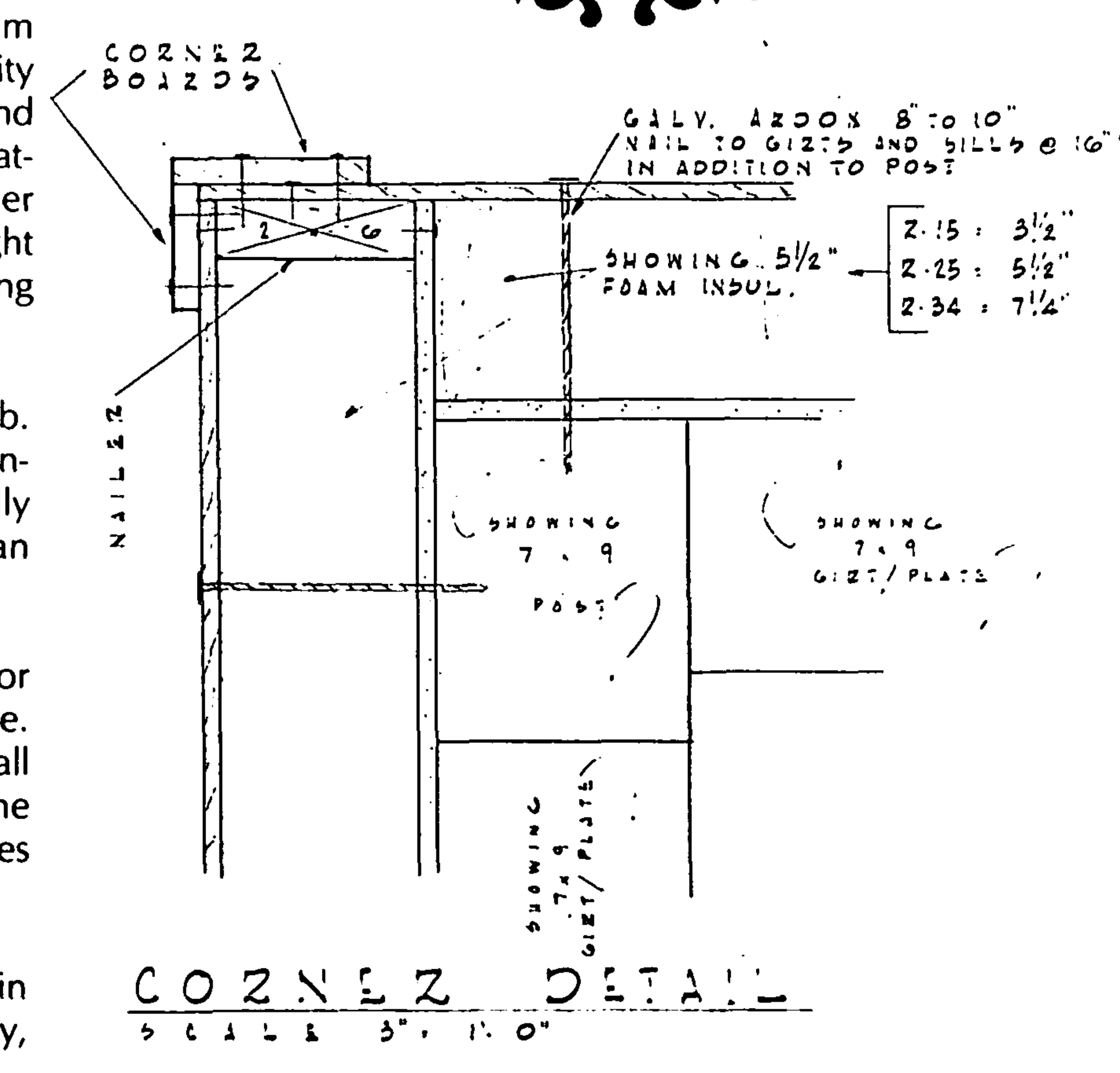
The recent combination of stress-skin panels with timber frame construction solves previous enclosure problems and establishes timber framing as an outstandingly energy-efficient building medium. We find that by using these insulating panels made of interior and exterior sheating material laminated to a rigid foam core, we can enclose, insulate and install drywall in one lap around the house (walls and roof) in a fraction of the time and with a better insulating blanket than that offered by any other method. We believe that stress-skin panels give a timber framed building the ease of enclosure and energy efficiency that matches or exceeds the performance of any other style of building.

These panels perform like an I-beam, the sheathing materials resisting the forces of tension and compression, and the foam acting as the web. They have the inherent structural integrity required to span the eight, nine or ten feet between sills and connecting girts, or girts and collar ties and rafters. When attached to the outside of the frame, splined or locked together and sealed with site applied foam, the panels create a tight blanket of insulation that is uninterrupted by structural framing members.

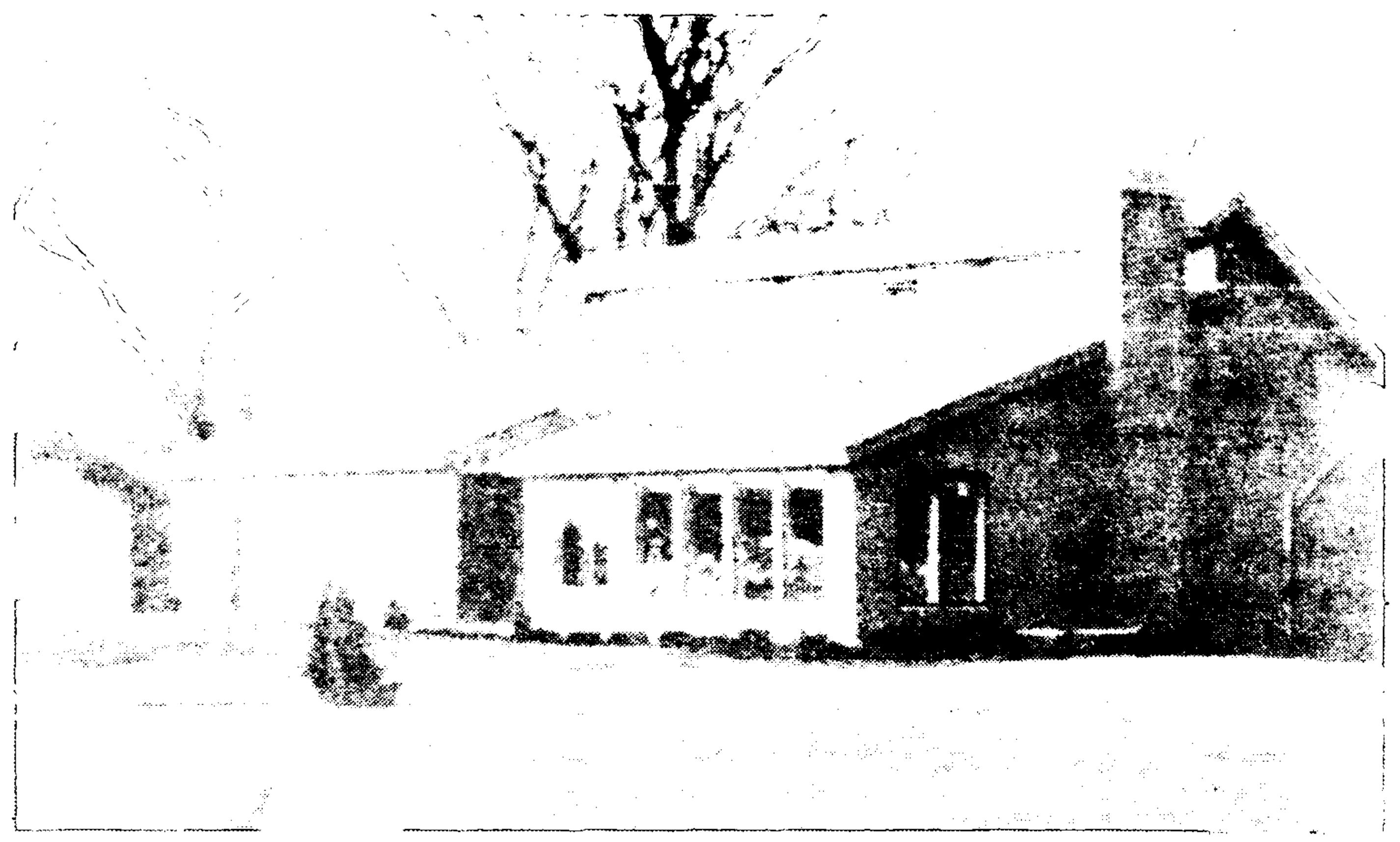
Riverbend's panels are custom manufactured for each job. This gives the flexibility to vary sheathing materials and insulating values to suit particular circumstances. We typically use R-25 wall panels and R-35 roof panels for our Michigan climate.

The labor saved by installing drywall, insulation and exterior sheathing in one operation makes this method very attractive. In addition the continuous mass of foam within the wall eliminates the problem of air infiltration around studs, and the low permeability of the foam greatly reduces if not eliminates the problems of moisture condensation within walls.

Stress-skin enclosure combined with timber framing results in a structure that meets the requirements for natural beauty, durability and energy-efficiency in our homes. Because of the large bays created by the post and beam structure, areas of passive solar glazing are possible without complicating the structure of the frame. With no need for load-bearing interior walls (all loads are carried by posts), an open floor plan conducive to distribution of radiant or solar-gained heat is practical. Since a typical oak frame for a two thousand square foot house weighs thirty thousand pounds, and since the frame is kept entirely within the insulating blanket, thermal mass for heat storage is built right into a timber framed home. This thermal mass will qualify for solar tax credits in some states.

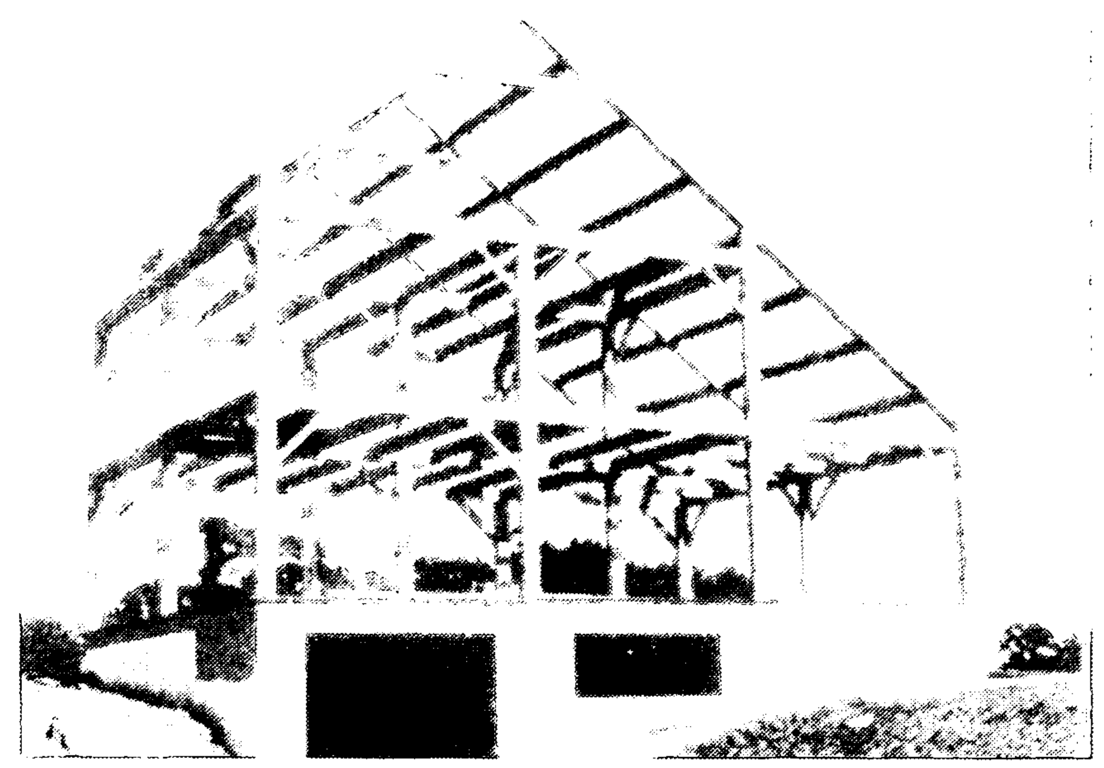


Design Flexibility, Durability, and Conservation



Timber framing is a suitable building method for many architectural styles.

1984 American Wood Council
"Design For Better Living Award"



Timber frame construction is a suitable building method for many architectural styles from Colonial reproductions to the most contemporary designs. The massive wooden framework is exposed to living areas creating beautiful and dramatic effects in each room. Beamed ceilings are naturally incorporated in a timber framed design.

The timber frame itself provides a sound structural base from which a wide variety of interior spaces can be created. Open floor plans and great rooms with cathedraled ceilings are typical design elements. Other spaces can be created with conventionally built interior partitions or simply suggested by post and furnishing placement. Since the entire frame is wrapped by the insulating blanket, the space normally lost to attics can be readily incorporated into lofts, playrooms or heated storage.

There is a timber framed temple in Japan that has been in use for over one thousand years. Many European timber framed buildings are over seven hundred years old. Timber frames from America's Colonial period are youngsters—merely three hundred fifty years old. Wood is a very durable building material. Kept in an environment of relatively low humidity, free of condensation and radical temperature extremes, wood will last indefinitely and although modern construction methods and materials should help preserve today's timber frames even longer than their ancestors, the traditional joinery of historic timber frames is an unsurpassed method of creating durable structures. Precisely crafted, tight fitting joints are the key to a long-lived building.

The durability of a structure should be of prime importance to a homeowner. The true cost of any building is determined by the initial cost, plus the costs of operating and maintaining it over its entire life. Of significant importance to a timber frame owner is the assurance that their structure will last indefinitely. Their investment is protected by the enduring soundness of their frame. Savings in heating and cooling costs should continue to provide additional financial paybacks for many generations.

It should also be considered that timber frame construction makes very economical use of a precious resource—wood. Although wood is a renewable resource, proper management practices are only beginning to be put into place. Conservation may be the best management practice. Timber structures normally use less raw material than stud framed structures and far less than log structures. There is also further economy in the milling phase — there is not nearly so much saw dust made sawing timbers as there is sawing two by fours. All of this is in addition to the conservation inherent in the exceptionally long life-span of a timber framed structure.

Owner-Builder Involvement

The past few years have seen a dramatic increase in the numbers of owner-builders. These people, whether for financial, philosophical or personal reasons, are choosing to devote their time, energy and skills to the construction of their own homes. A timber framed home offers several unique opportunities to an owner-builder for reducing the amount of time to complete the project as well as to ease budget drain.

Once a frame is erected on its foundation, stress-skin panels enable an owner-builder to apply drywall, insulation and exterior sheathing in a fraction of the time required by conventional methods. Elimination of load-bearing walls can greatly simplify interior finish. Also, given the open floor plan typical of many timber frames, the frame can provide both structure and finishwork, again reducing the construction and labor requirement. A final advantage to the owner-builder offered by the combination of timber frames and stress-skin panels is that the structural qualities of the stress-skins allow window and door units to be installed any time during (or after) the construction process as time and budget allow. Such flexibility is invaluable to an owner-builder.

Riverbend has on many occasions been able to supply an owner-builder with a "closed-shell" package — a precut timber frame (to be raised by the owner with assistance from one of our craftsmen), stress-skin closure material and doors and windows. Owners can choose from our standard design packages or can choose to have an entire custom package developed by our design staff.

The speed with which such a "closed-shell" package can be erected benefits an owner-builder in several ways. In five to ten days of on-site work, the frame can be raised and made weather-tight. Not only is the interior protected from the elements, but the site is made less inviting to thieves and vandals that are occasionally found around construction sites.

Speedy construction can also prove to be financially beneficial. Quite simply, the less time spent in construction, the fewer interest payments made on a construction loan. A quicker completion date means that a builder can retire the more expensive loan in favor of a normally lower cost mortgage, resulting in a significant savings.

Many exterior finishes are used on timber frames.

Riverbend Workshops and Seminars

In a country whose history is rich in owner-builder tradition, it is unfortunate that present day owner-builders should be faced with such obstacles as a lack of information and opportunity for practical experience. However, as more people are choosing to become personally involved in the design and construction of their homes, it is clear that building professionals need to become more flexible and willing to share their knowledge. Since 1980, Riverbend has conducted courses designed to instruct participants in the skills of timber framing and in the principles of owner-builder contracting.

Riverbends timber framing courses are conducted by members of our professional staff—designers, engineers, craftsmen and licensed builders. The students are young and old, male and female, from all parts of the country and all walks of life whose common interest is the creation of efficient and beautiful buildings. Many are owner-builders preparing for the construction of their own homes. Others attend simply out of curiosity about this inspiring craft. No prior building experience is required. The only prerequisites are a desire to learn the skills of timber framing and a willingness to share a few days with others in pursuit of a common goal. The feeling of community that develops during the workshops is one that remains with the participants and the instructors long after the projects are completed.

All instruction in our courses takes place on an actual building site. We have found this to be an ideal situation for integrating classroom teaching with hands-on experience. This arrangement also allows us to offer our classes in many parts of the country.

Recently we've been able to expand our workshop curriculum to include courses instructing participants in the techniques of stress-skin panel enclosure and masonry heater construction. We hope to continue this expansion of our owner-builder program.

Ask for our current workshop and seminar brochure for more information.

ENGINEERING: PIECES of the FRAME

BASIC TIMBER FRAME ENGINEERING

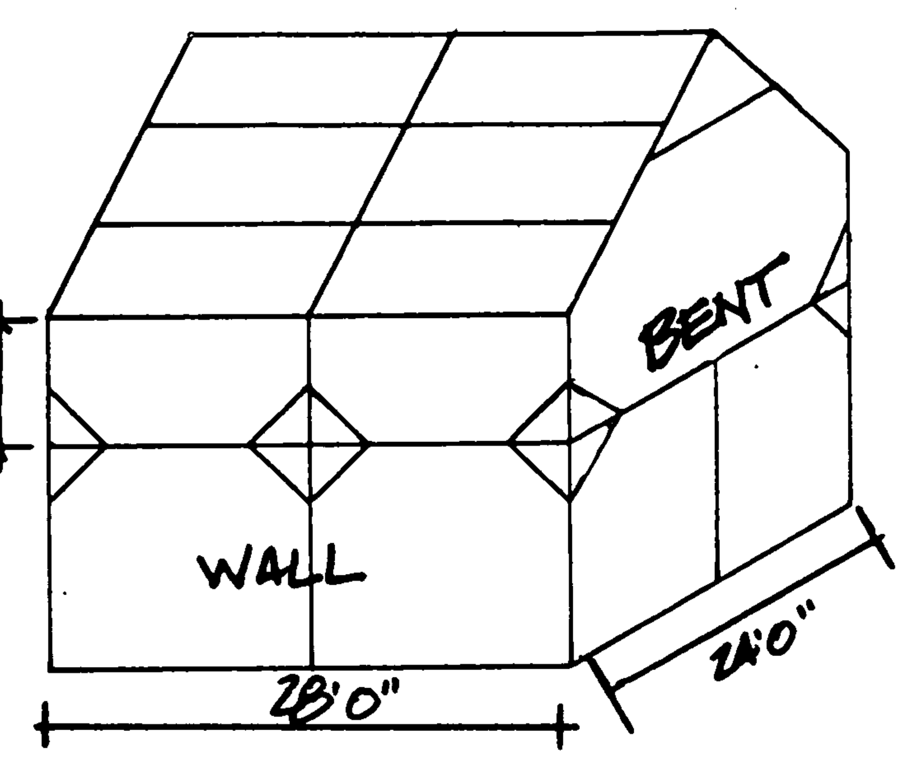
Gravity and wind apply the forces buildings must withstand. Understanding the effects of these forces is the key to designing a durable timber frame. Analyzing a 24'x 28'tall-posted Cape frame will help clarify what happens to the pieces of the frame under load.

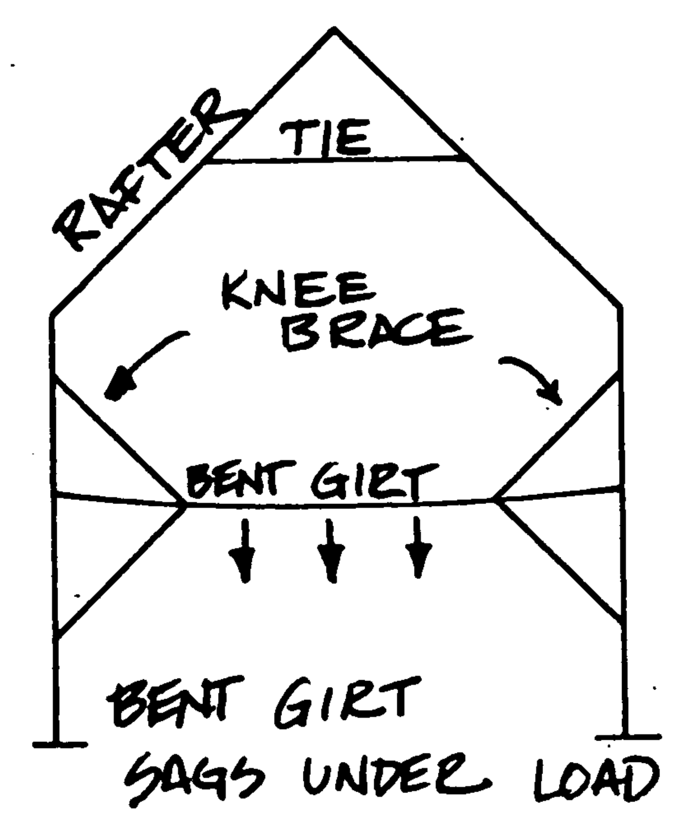
Bent Members

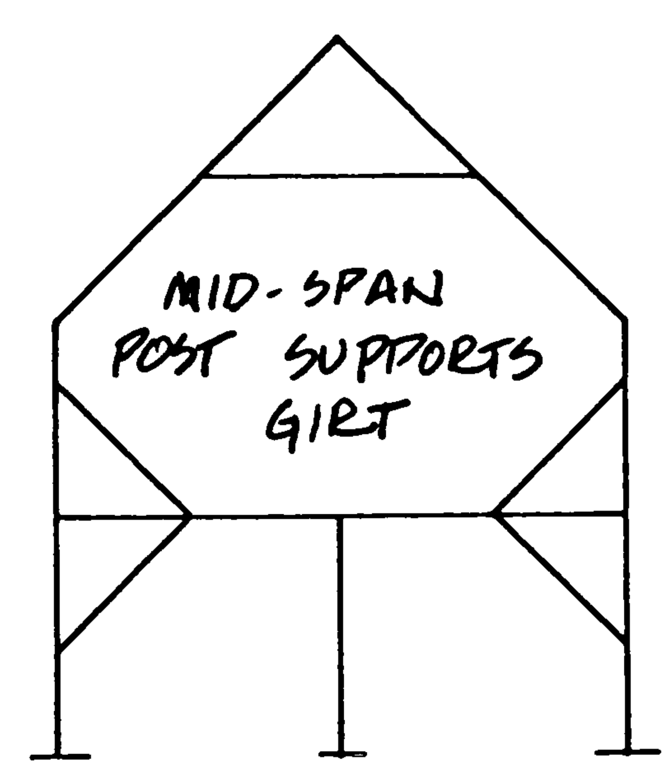
Design considerations for posts: The job of the post is to transfer the loads of the building to the foundation or footers. We know that wood is extremely strong in compression perpendicular to the grain. Therefor, in almost all cases, posts are designed to accomodate incoming joints. If it is big enough to handle the joints, it will be big enough to carry the load.

Design considerations for the bent girt: We know that when a beam is loaded, it must withstand the forces or fiber stress, bending, and horizontal shear. We also must work within practical limits of our material.

Lets assume that the girt in the middle bent of our frame connects the two exterior posts without intermediate support--effectively a twenty-four foot clear span. Assuming a uniform combined load of 50psf this beam must carry 16,800 pounds. The maximum allowable deflection for this span is 0.75." An oak beam 7" wide and 20" deep would perform to these standards. But, since 7x20's are hard to come by, we must reduce the span of the beam to meet our performance standards(don't worry about where these numbers come from. That topic is yet to come).







PIECES of the FRAME

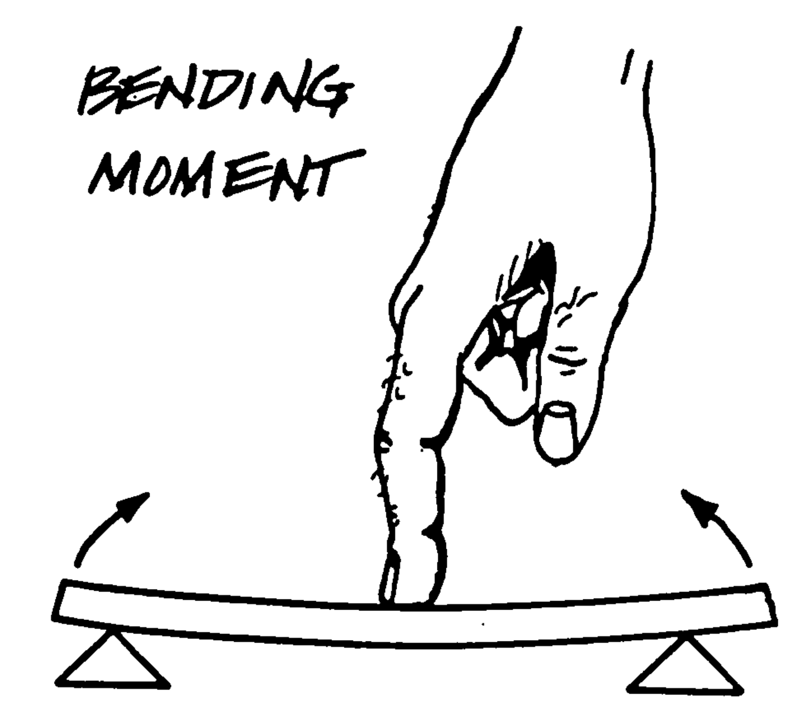
By supporting the beam with a post at midspan, the design load is reduced to 8,400 lbs., the maximun allowable deflection is 3/8," and a 7"x 9" will do the job(typically Riverbend would use a 7x11 in this case to counteract the effects of cutting the notches for the floor joists).

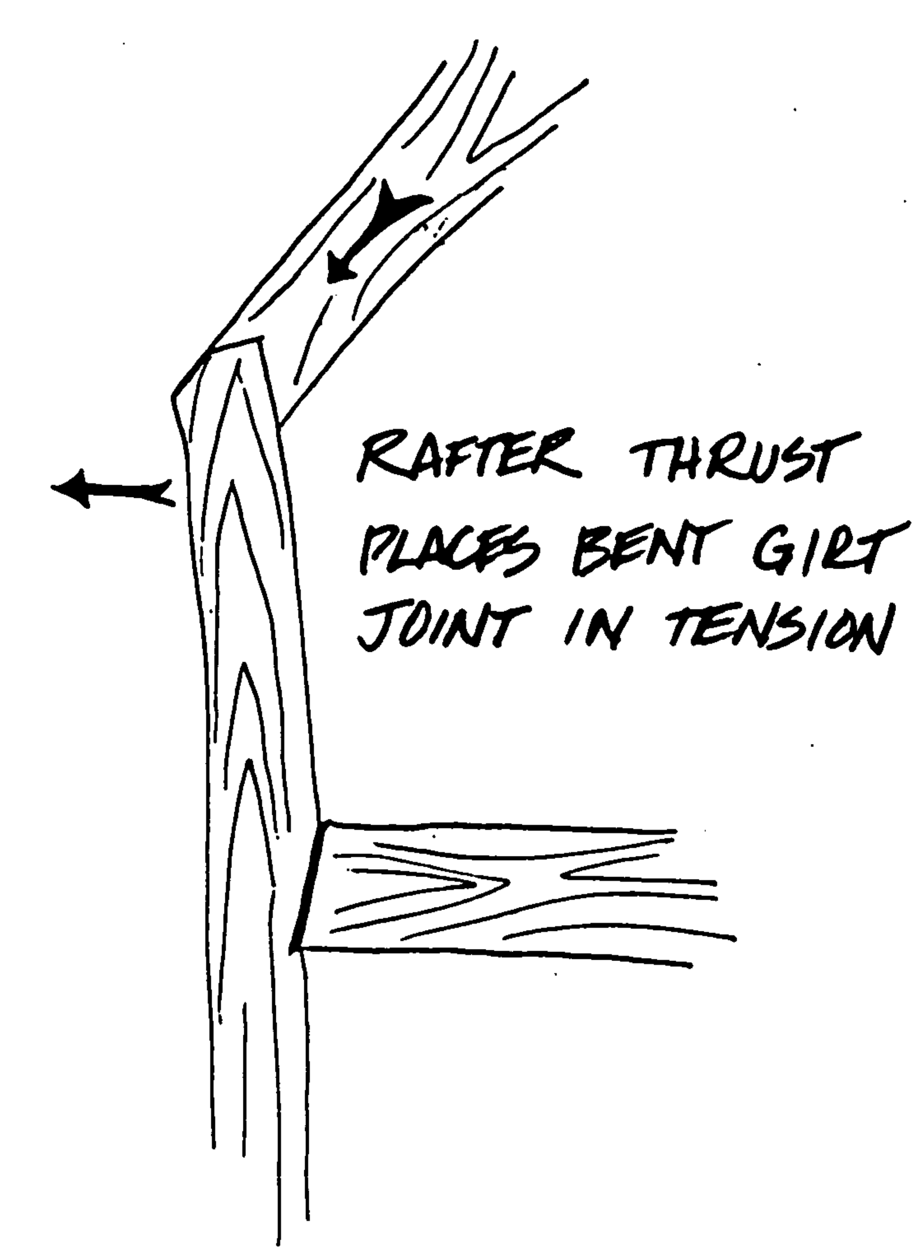
We must also consider the forces acting upon the joints at the end of the beam. Imagine supporting a 1/4" diameter, 12" long stick at its ends. Push down at the center of the stick with your finger. The ends react to the downward force by rotating upward and toward the middle. This is the same force acting on joints at the end of the bent girt. And in the case of most pegged, mortise and tenon joints, this withdrawing force must be resisted primarily by the pegs--the weakest part of the joint. So the stiffness of the beam(its resistance to bending) again becomes an important consideration.

Refer to "Mortise and Tenon Design" for additional design considerations for the bent girt joints.

Design considerations for the rafters: Rafters must react to the effects of bending in much the same way as the girt.* However they transfer their loads to the posts with an outward thrust that has a long-ranging effect. The lower the roof pitch, the greater the thrust.

The thrust of the rafters causes the posts to bend outward, which in turn puts the girt to post joint in tension(everything is trying to tear this joint apart!). In a tall-posted cape, this effect is increased because the post projects four feet or so above the girt--how much more can you move with a four foot





lever? Therefore the design of roof systems largely revolves around arresting this thrust.

Role of the collar tie: The tie collar is a horizontal piece that connects rafter pairs. It helps reduce thrust in two ways.

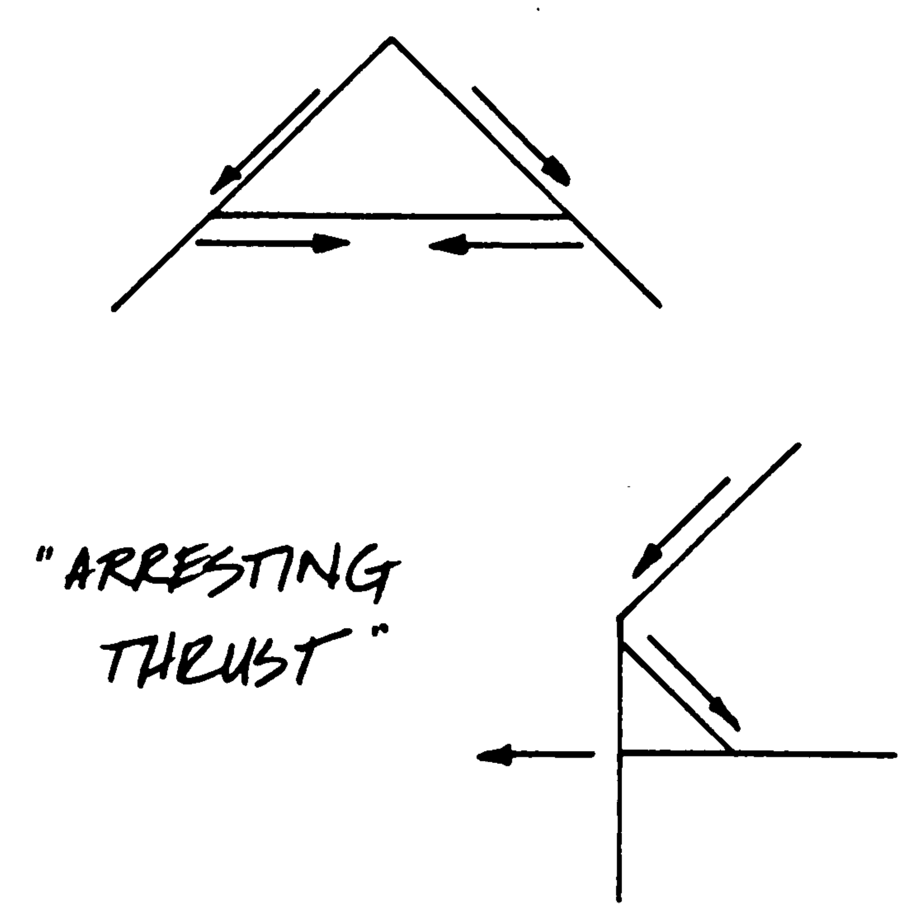
First, it mechanically restrains the thrust of the rafters. Second, it divides the span of the rafter into smaller spans, each with less potential for sag or deflection.

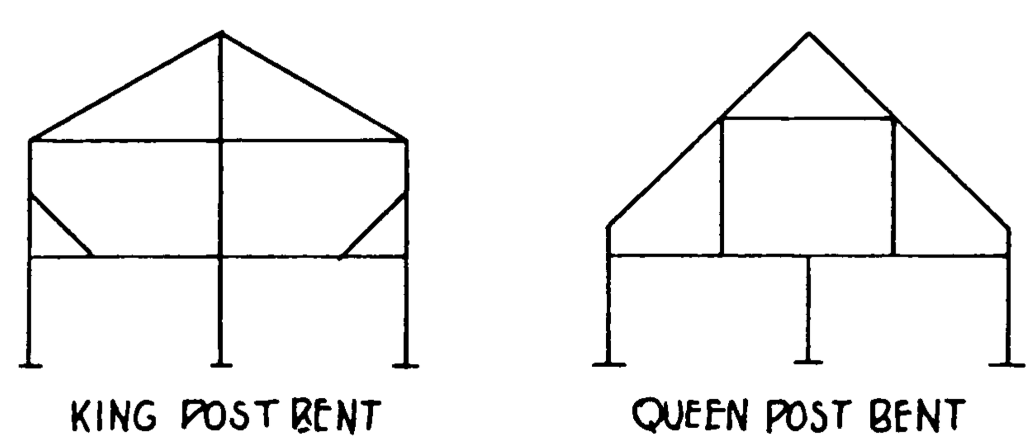
The knee brace from post to girt: A knee brace or strut from near the post top running down to the top of the girt will also help restrain the post and resist the outward thrust.

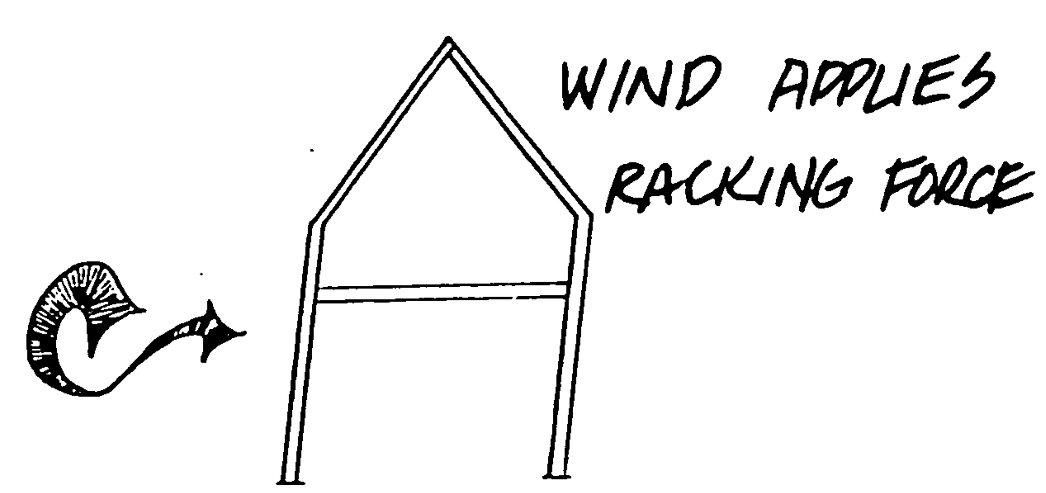
In a more complicated bent it may be necessary to use a king post or queen posts to help transfer the loads of the rafters to the rest of the frame. A king post removes the hinging potential of a joined rafter pair, thereby eliminating thrust potential. Queen posts help by reducing the rafter span.

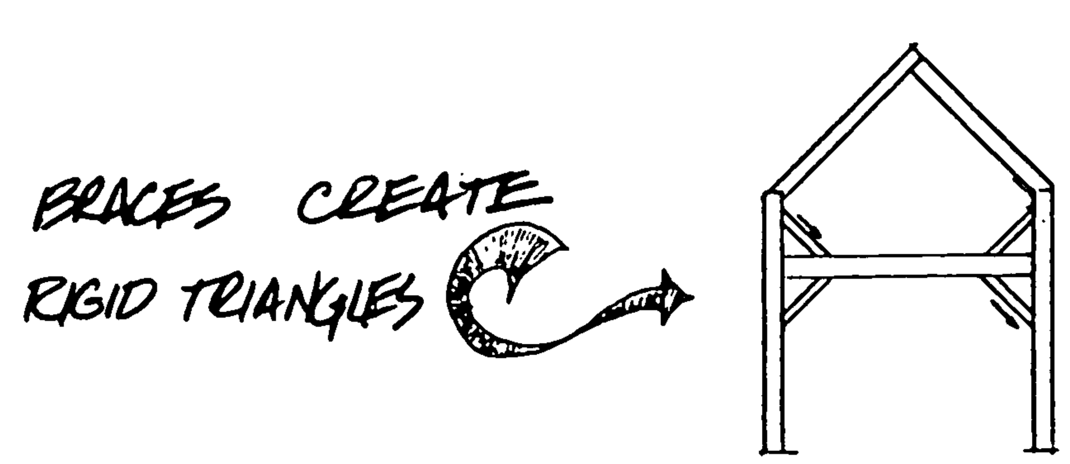
*Building codes often allow a reduction of snow load design values on steeply pitched roofs. Check with local code for specific formulas.

Wind Braces (aka knee braces or braces): The gable wall of our little Cape frame has a surface area of 432 square feet. At a velocity of twenty five miles an hour, the wind load on the gable wall is a little over a pound and a half psf--next to nothing. At one hundred miles an hour it is 25psf--significant. Braces are added to the frame to stiffen connections between post and beam. They transform non-rigid rectangles into rigid triangles. Braces work best in compression and in pairs with the leeward brace best transfering the wind load to the post.







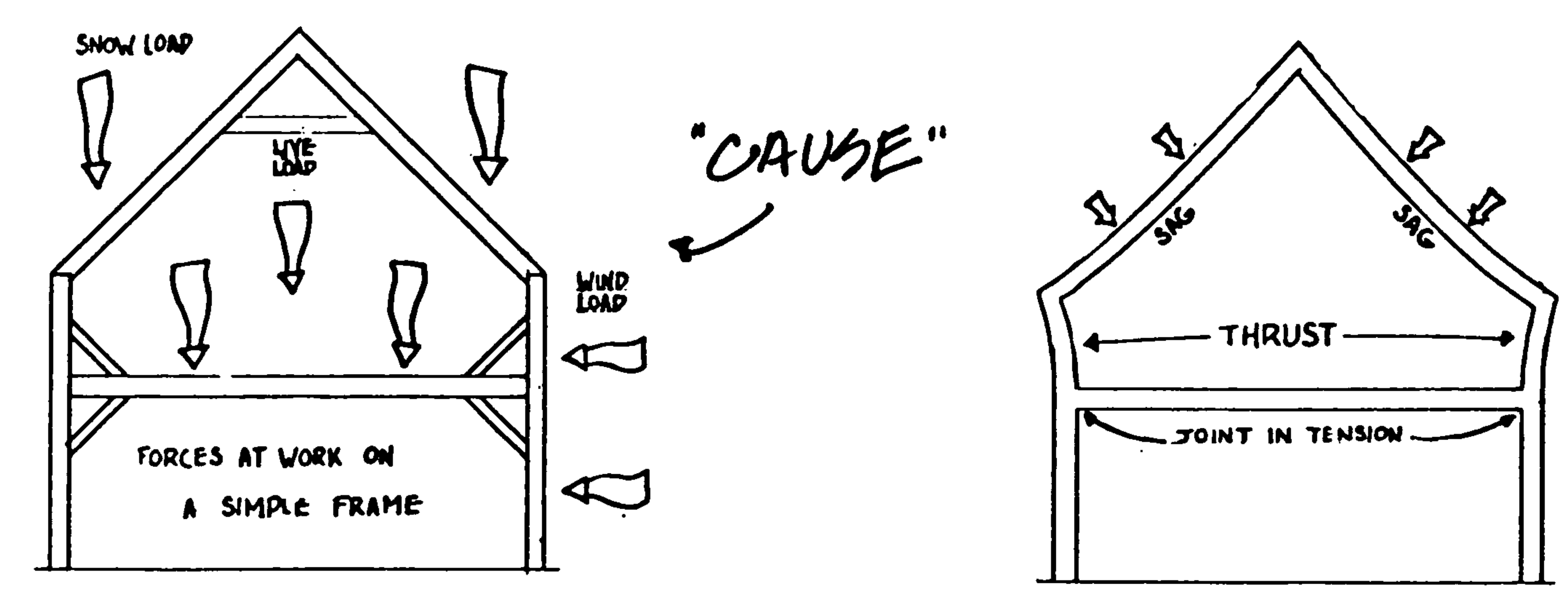


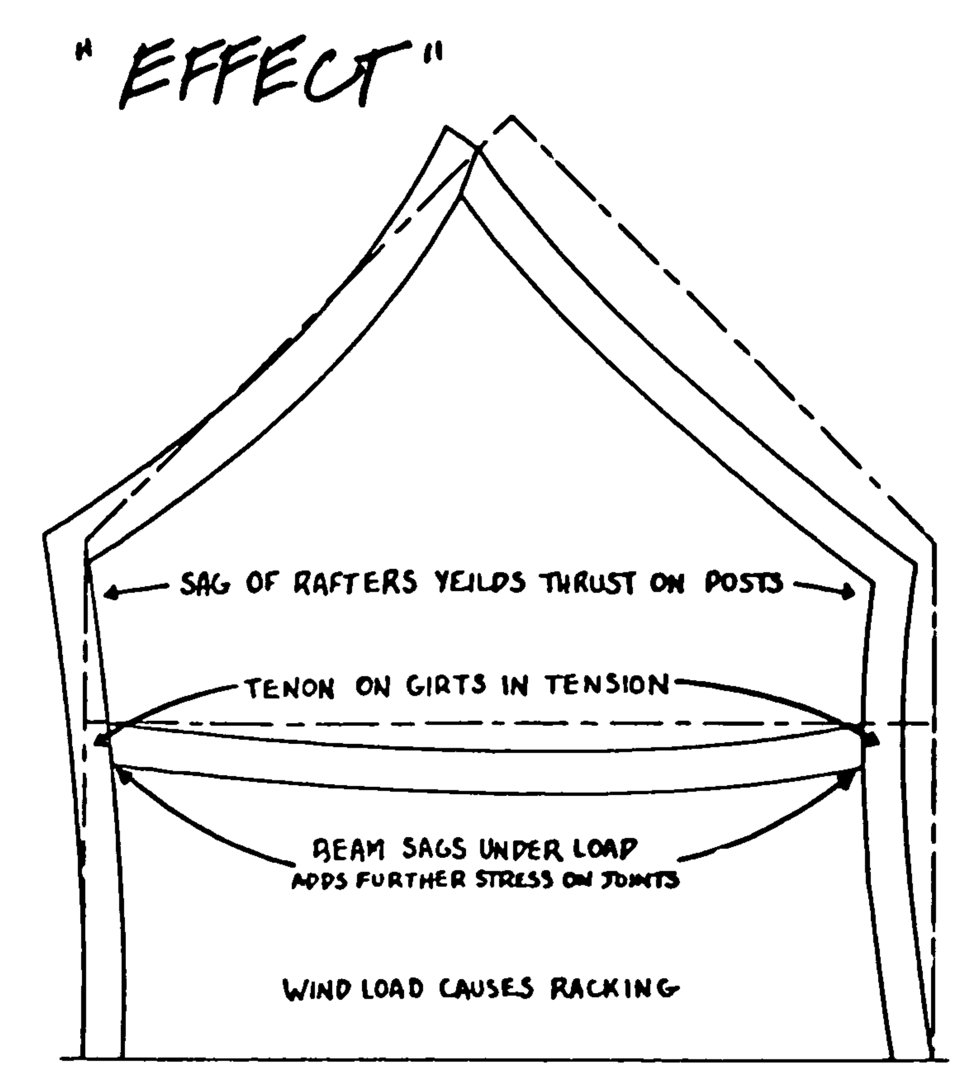
WALL MEMBERS

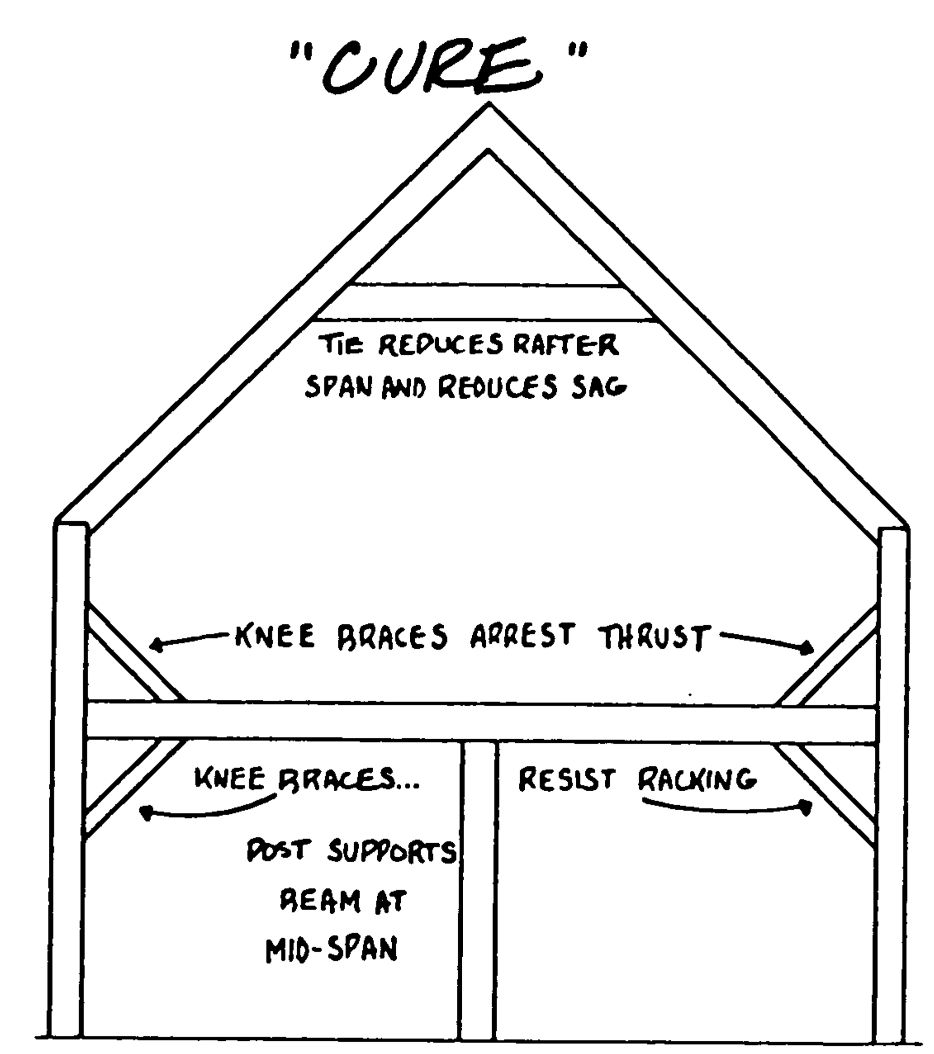
Wind braces: Because the gable end of a building presents a large surface to the wind, the braces in the wall planes are especially important. If, for example, our little frame presents 432 square feet to the wind, the 100mph wind imparts a 10,800 pound load to the wall that must largely be counteracted by the braces.

Connecting girts: Assuming the beams that connect bents are properly sized to carry their loads, and that the post to girt joints are adequately braced against racking forces, the connecting girt is a fairly simple piece. Unlike the bent girt, its joints are not subjected to the rafter thrust.

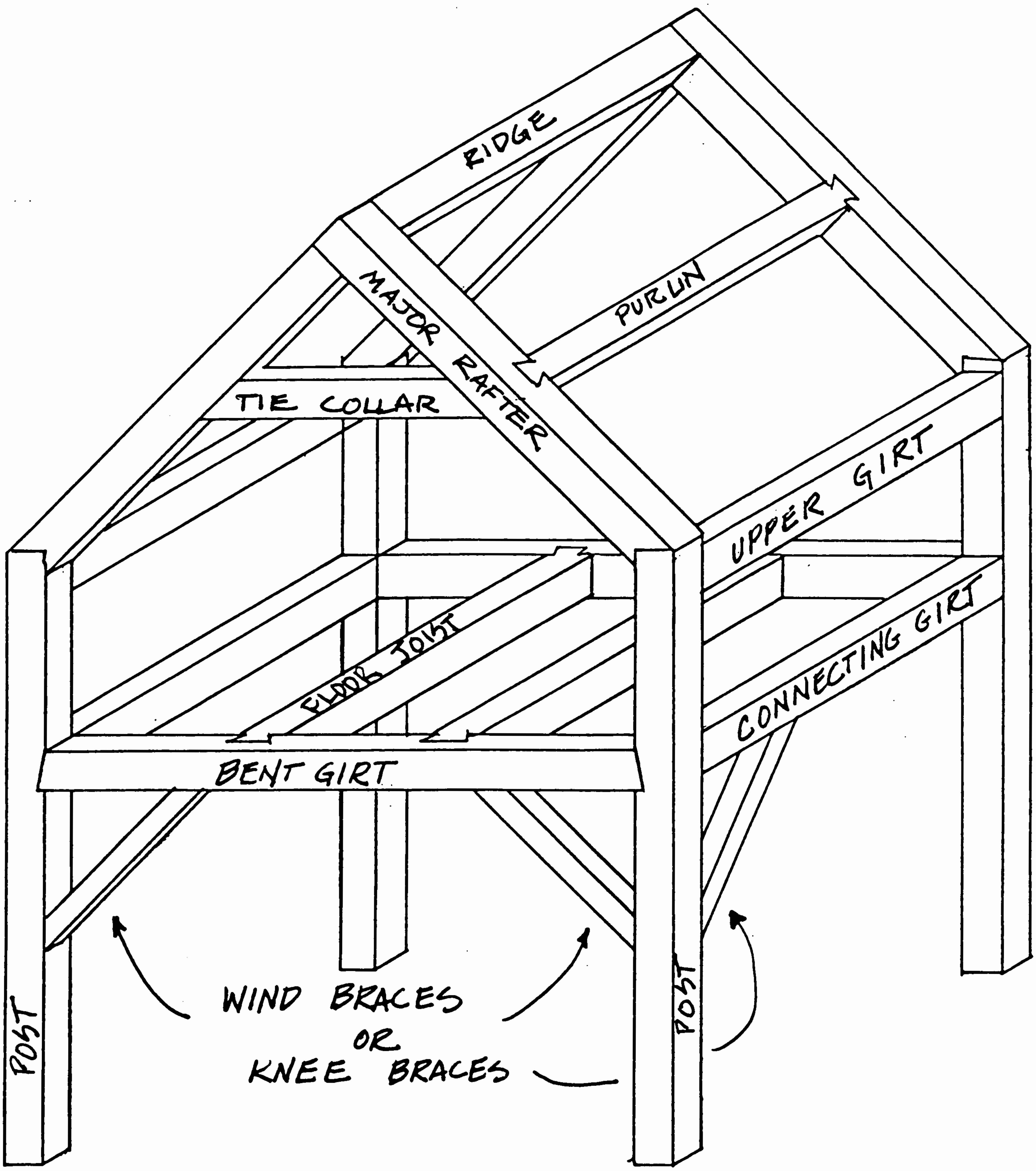
SECONDARY PIECES: Joists and purlins are smaller framing members that span between girts (joists) or rafters (purlins). They are subjected to the same bending stresses as the girts or rafters, but they carry much smaller loads.





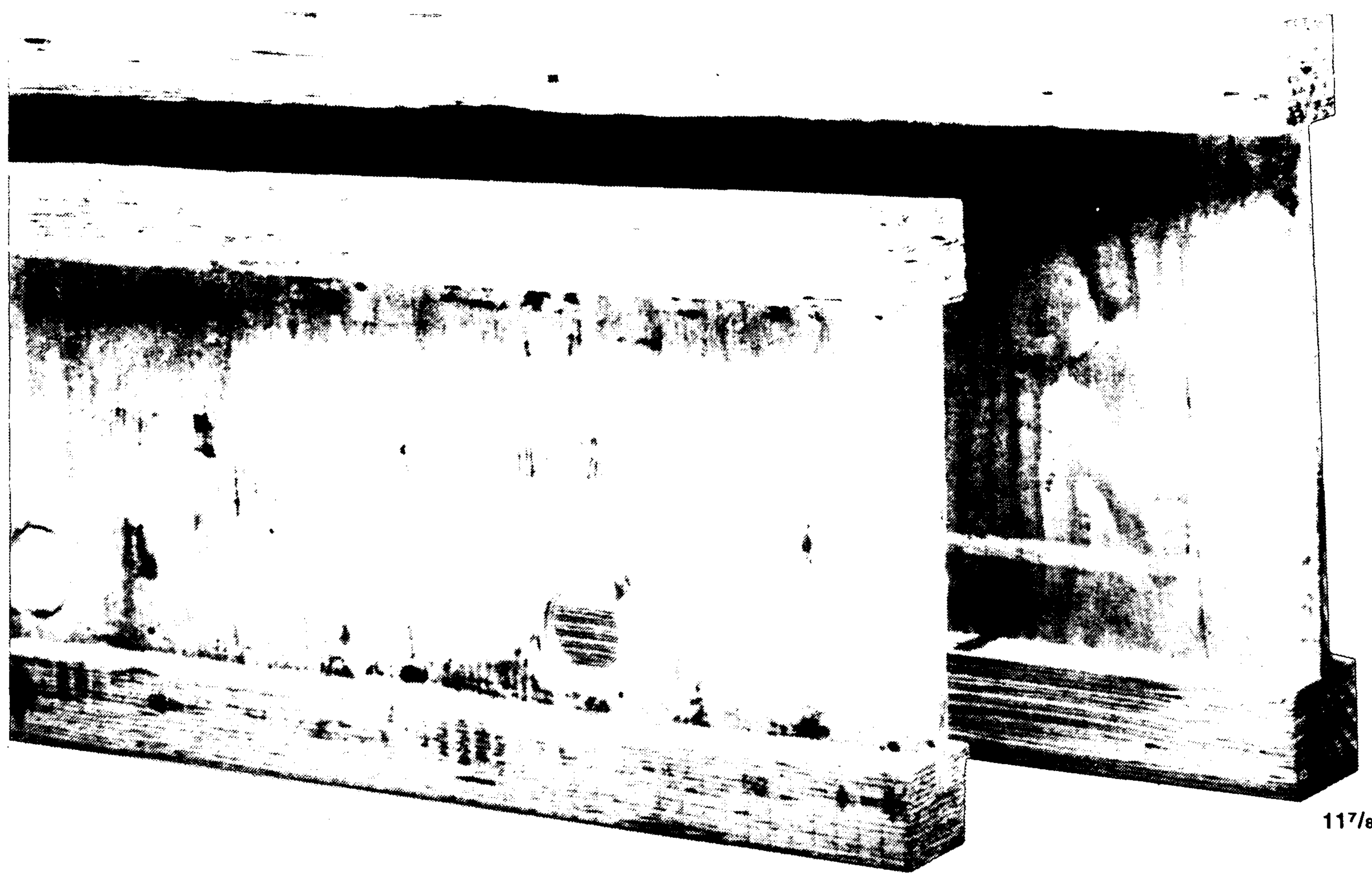


JOINERY HANDBOOK: PIECES of the FRAME



Appendix 9

THE TJI®/25 JOIST



The Residential TJI®/25 JOIST

Trus Joist Corporation's Residential TJI/25 Joist is a lightweight structural component that just may be the most cost efficient floor joist around. Available in 9½" and 11⅞" depths, the Residential TJI Joist has a plywood web pressure-fitted between flanges of MICRO = LAM laminated veneer lumber.* Pound for pound, tests prove it's one of the strongest structural components ever made, and one of the easiest to use.

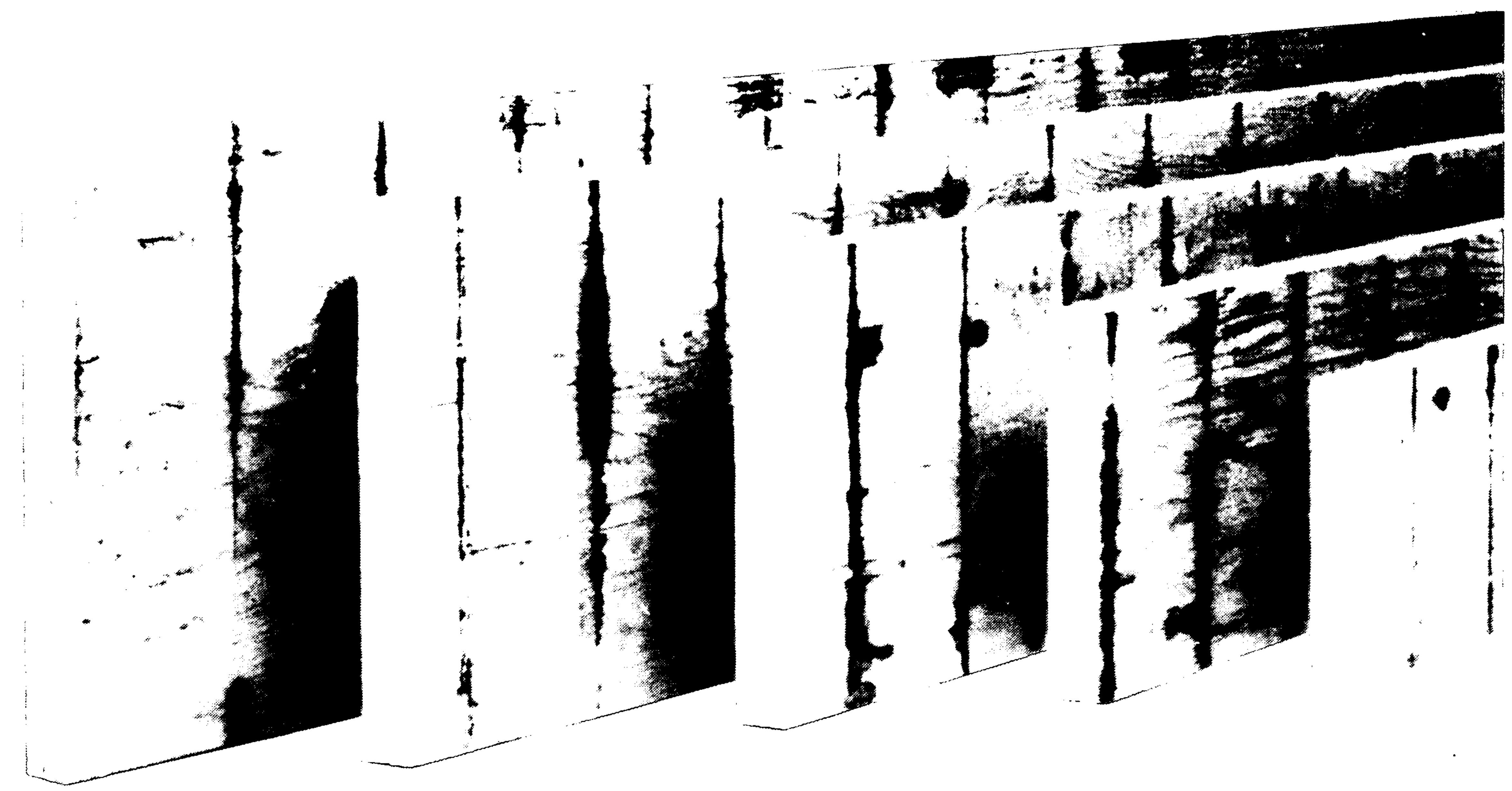
Long lengths — up to 60 feet — eliminate lapping over beam or wall line. The TJI Joist's continuous multiple span capabilities mean fewer pieces to handle and faster installations.
Lightweight and easy-to-grip, the Residential TJI Joist is simple for one man to handle alone. A 26 foot joist weighs approximately 50 pounds. You can use standard job site tools and easily cut the TJI Joist to any required length on the job site. The joist's wider, straighter wood flanges make nailing easier, while its plywood web can be easily cut to accommodate utilities and ductwork.

When Trus Joist developed the TJI Joist, it gave designers and builders a cost-effective alternative to conventional joists with performance "plus." This highly engineered product all but eliminates the troublesome problems of warping, shrinkage, twisting, splitting, crown, uneven lengths and defective pieces. Straighter and uniform in all dimensions, the residential floor system brings an end to most floor problems and results in fewer call backs. Tap into the new generation of residential floor joists for a better buy and full support.

The TJI Joist has been accepted by:
FHA 689 NRB 119 NRB 200 NOTE: NRB acceptance includes BOCA, ICBO, and SBCC.

* Residential TJI Joists manufactured in our Valdosta, Georgia plant are produced with high grade machine stress-rated Southern Pine flanges.

MICRO = LAM® LUMBER HEADERS AND BEAMS



MICRO=LAM® Lumber Headers and Beams

MICRO=LAM headers and beams provide both greater carrying capacity and consistent quality to save you time, money and material. MICRO=LAM laminated veneer lumber – a major technological breakthrough – has been acclaimed as one of the most useful developments in efficient wood fiber utilization ever.

Headers and beams made with MICRO=LAM engineered lumber are always consistent in performance, and free from defects. They are stiffer and stronger than conventional lumber. And, they permit increased economy and efficiency over other headers and beams.

MICRO=LAM lumber is produced from ultrasonically-graded veneers which are coated with waterproof adhesives and densified into continuous billets. These billets are then precision cut to custom or standard lengths and widths. The MICRO=LAM lumber manufacturing process virtually eliminates twisting, shrinking, splitting and checking.

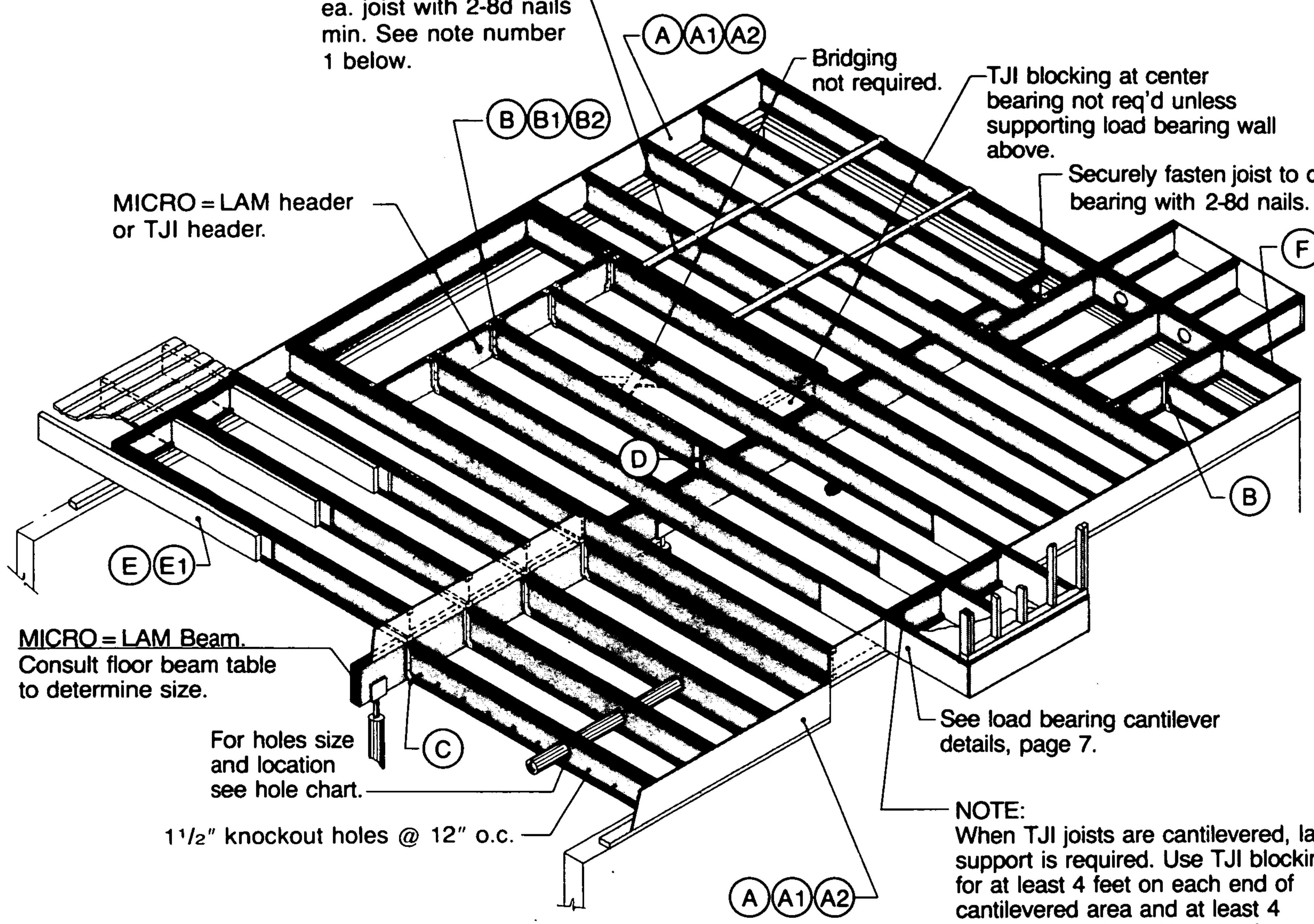
MICRO=LAM headers and beams are available in five depths, 9½", 11⅞", 14", 16" and 18", and these can be used separately or in multiples to fit almost any application. Two 1¾" pieces of MICRO=LAM lumber equals a full 3½" width. This matches standard wall framing and eliminates time-consuming shimming.

MICRO=LAM lumber has been accepted by FHA 925 NRB 126 NOTE: NRB acceptance includes BOCA, ICBO, and SBCC.

Trus Joist Corporation's Residential Products are ready when you want them from hundreds of lumber dealers in the United States and western Canada. Ask your local lumber supply dealer, or contact Trus Joist Corporation for the location of your nearest stocking dealer.

TJI® and MICRO=LAM® are registered trademarks of Trus Joist Corporation, Boise, Idaho.

RESIDENTIAL TJI®/25 JOIST INSTALLATION GUIDE AND TYPICAL DETAILS



NOTE:
When TJI joists are cantilevered, lateral support is required. Use TJI blocking for at least 4 feet on each end of cantilevered area and at least 4 feet every 25 feet of length of bearing wall. Nail blocking to plate with 8d nails @ 6″ o.c.

Nailing of Sheathing to Top Flange.

Nail Size	Closest o.c. spacing per row
8d box	2″
8d common	2″
10d, 12d box	2″
10d, 12d common	3″

- Maximum spacing of nails is 24″ o.c.
- If more than 1 row of nails is used, the rows must be offset at least ½″.
- 14 ga. staples may be substituted for 8d nails when having a minimum penetration of 1″ into the TJI joist.

Installation Bracing – TJI Joists and MICRO=LAM Lumber Joists and Headers

WARNING

DO NOT ALLOW WORKMEN ON TJI JOISTS AND MICRO=LAM LUMBER JOISTS AND HEADERS UNTIL ALL BLOCKING, RIM JOISTS, HANGERS AND TEMPORARY BRACING ARE COMPLETED IN ACCORDANCE WITH ITEMS 1, 2 AND 3 BELOW.

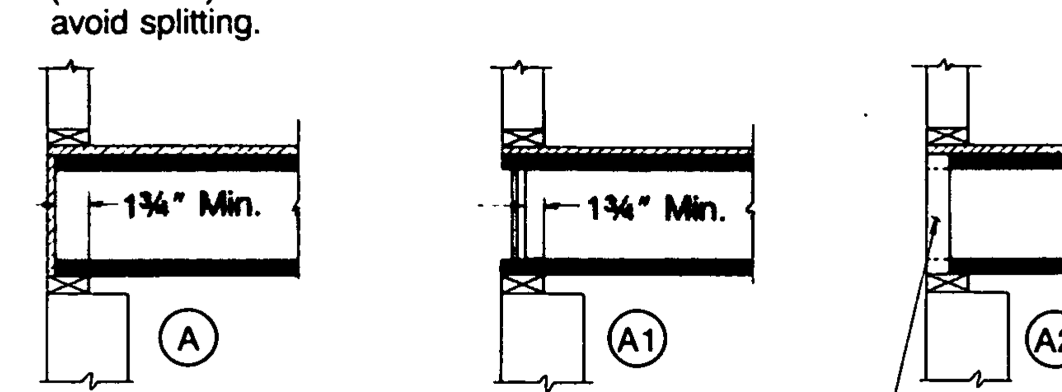
Improper concern for bracing during construction can result in serious accidents. Under normal conditions if the following guidelines are observed, accidents will be avoided.

1. A lateral strength, like a braced end wall or an existing deck must be established at the ends of the bay. This can also be accomplished by a temporary or permanent deck (sheathing) nailed to the first 4 feet of joists at the end of the bay.
2. All blocking, hangers and rim joists at the end supports of the TJI joists and MICRO=LAM lumber joists and headers must be completely installed and properly nailed.
3. Temporary strut lines of 1x4 minimum, must be nailed to the braced end wall or sheathed area as in 1 above and to each joist at the on-center spacing shown. Without this bracing, buckling sideways or roll over is highly probable under light construction loads - like two workmen and one layer of sheathing.
4. Sheathing must be totally attached to each TJI joist and MICRO=LAM lumber joists and headers before additional loads can be placed on the system.
5. Ends of cantilevers require strut lines on both the top and bottom flanges.
6. The top flanges must remain straight within a tolerance of ½″ + from true alignment.

Note: TJI joists and MICRO = LAM lumber should be protected from the weather during job site storage and after installation.

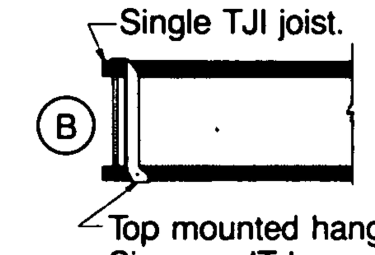
NOTES: DETAILS (A)(A1)(A2)
- Use ¾″ plywood rim joist for single story applications or second floor of two story applications. Nail to TJI joist with 2-8d nails.
- Use TJI joist or 2 layers of ¾″ plywood or squash blocks for main floor rim joist in two story applications or in areas where roof snow load exceeds 40 p.s.f., unless otherwise calculated.
- TJI blocking, when required, and ¾″ plywood as rim joist in lieu of solid sawn lumber is used to avoid problems that could result from the natural tendency of lumber to shrink and change size.
- Plywood, the TJI rim joist, or squash blocks, must be positioned under the wall to help carry the load.

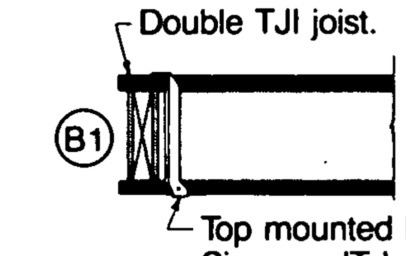
Minimum bearing of TJI joist is 1¾″. Nail TJI joist at bearing with 2-8d nails (1 ea. side) minimum 1½″ from end to avoid splitting.



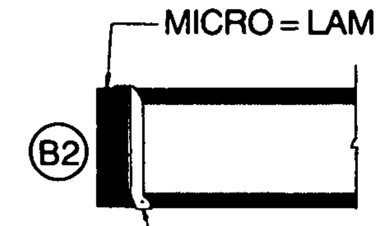
Bracing complying with code shall be carried to the foundation or TJI solid blocking used for a minimum of 4 feet at each end and at least 4 feet every 25′ of length of bearing wall.

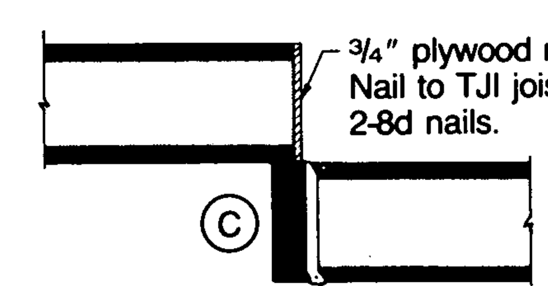
Squash block each side. Blocks to be 1/16″ longer than depth of TJI joist.



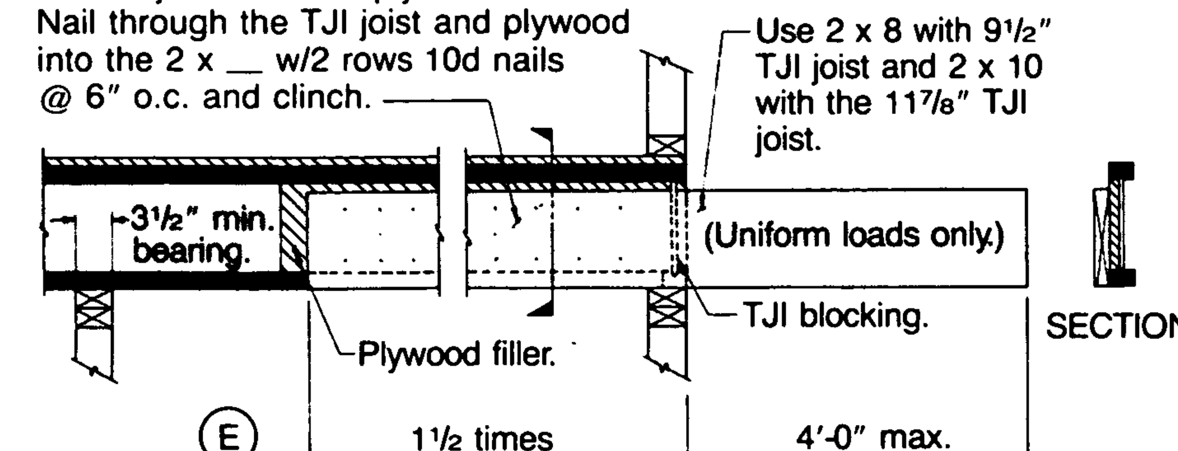


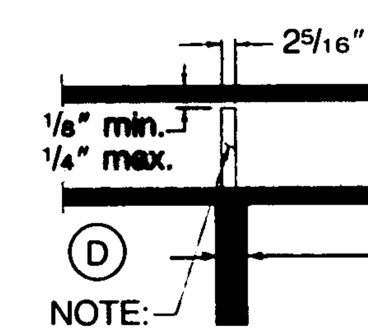
When using double TJI joist, block together with 2 x 6 vertical block at each hanger location. Nail with 5-10d nails and clinch.





2 x __ nailed to the side of the TJI joist with ¾″ plywood filler. Nail through the TJI joist and plywood into the 2 x __ w/2 rows 10d nails @ 6″ o.c. and clinch.

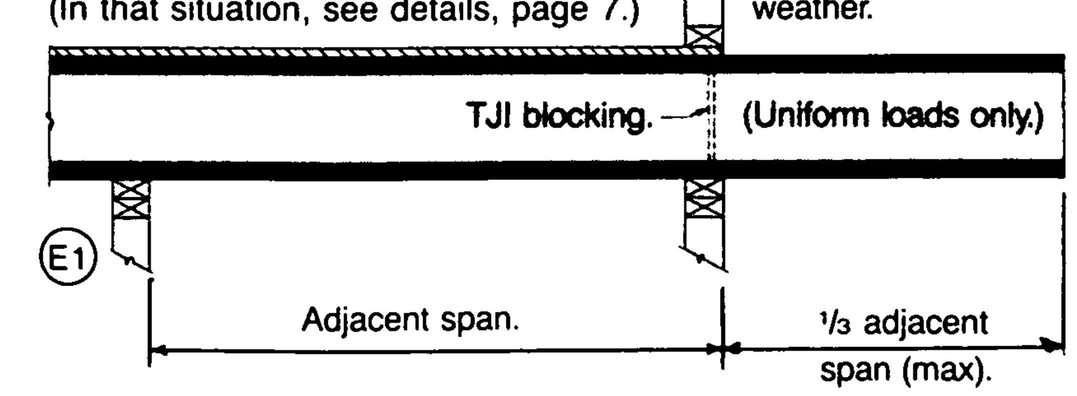


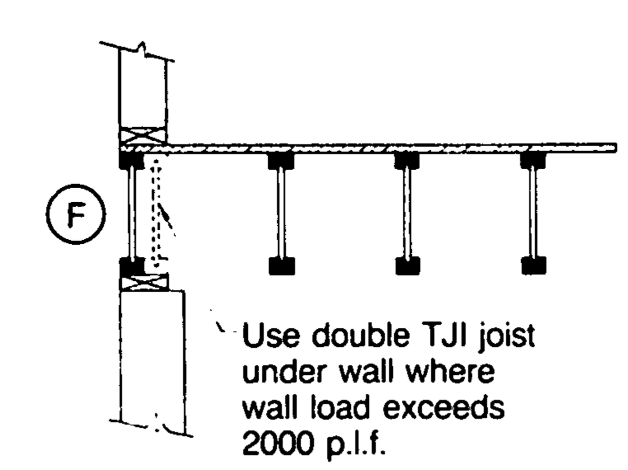


NOTE:
¾″ web stiffeners on both sides are required with 11⅞″ TJI joists and only where the bearing width is less than 5½″. Nail with 2-8d nails and clinch.

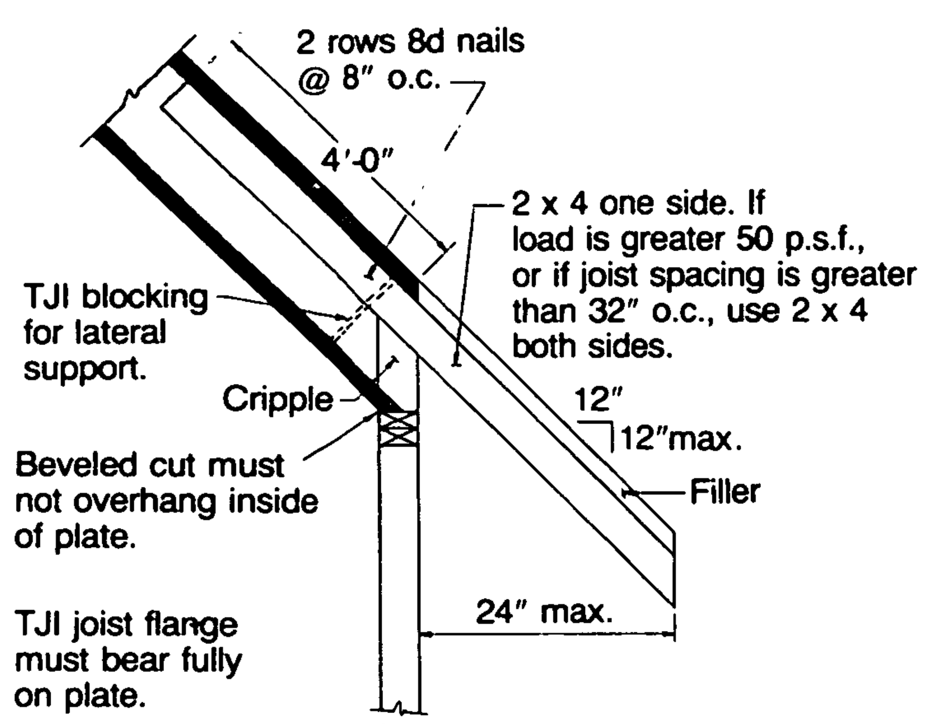
TJI joists may be cantilevered up to ⅓ the adjacent span if not supporting concentrated load at end of cantilever. (In that situation, see details, page 7.)

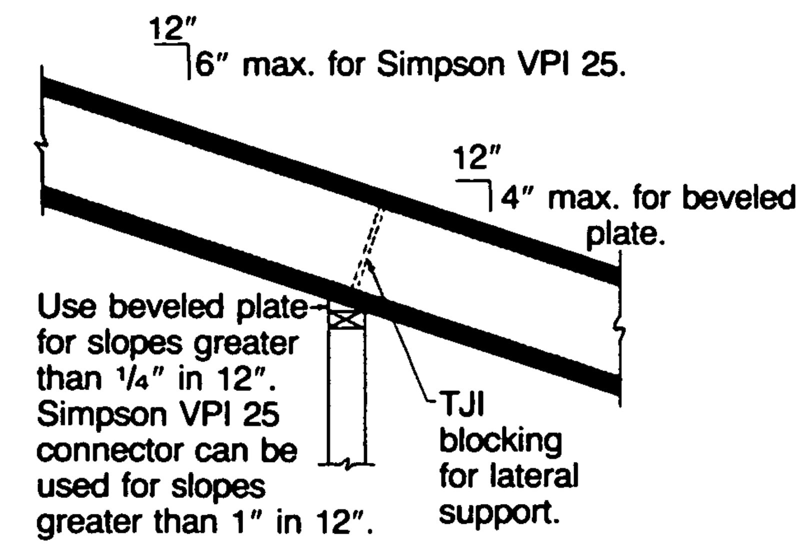
TJI joists should be protected from the weather.

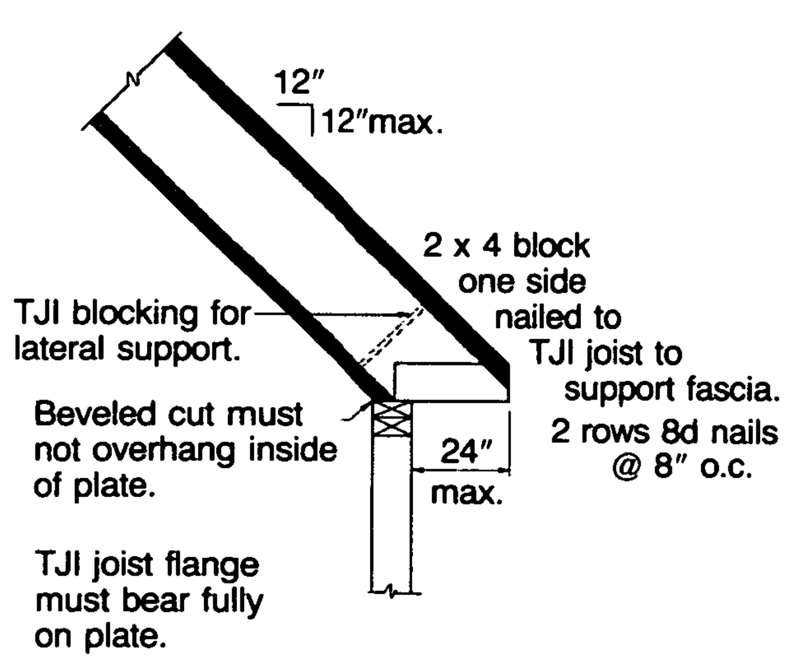


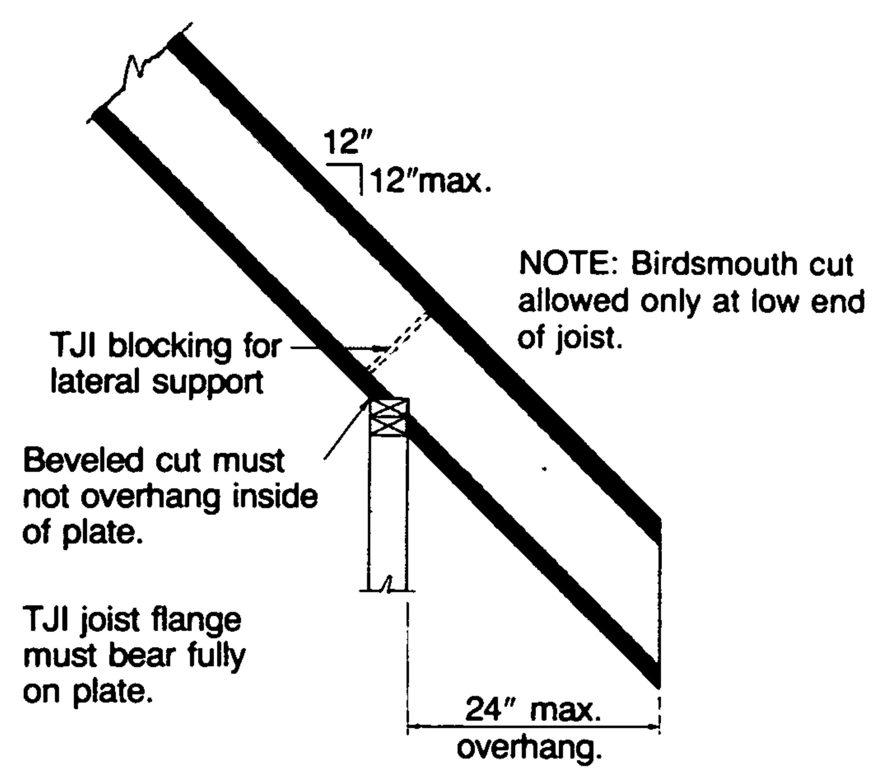


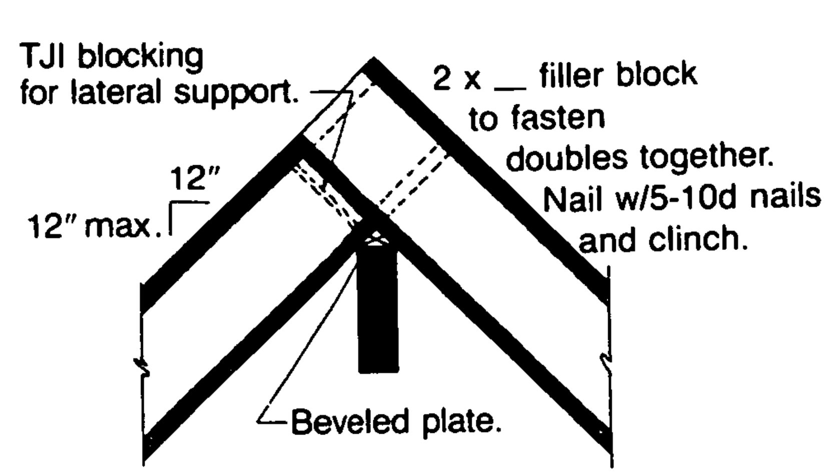
INSTALLATION DETAILS

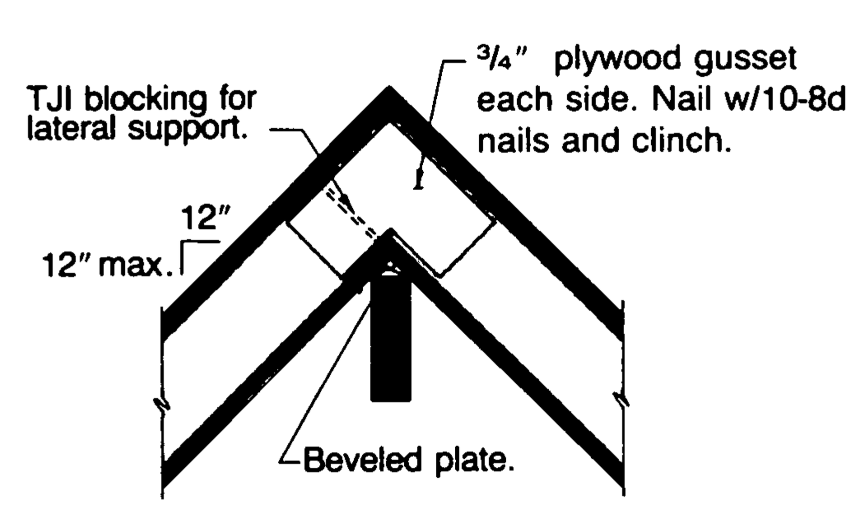


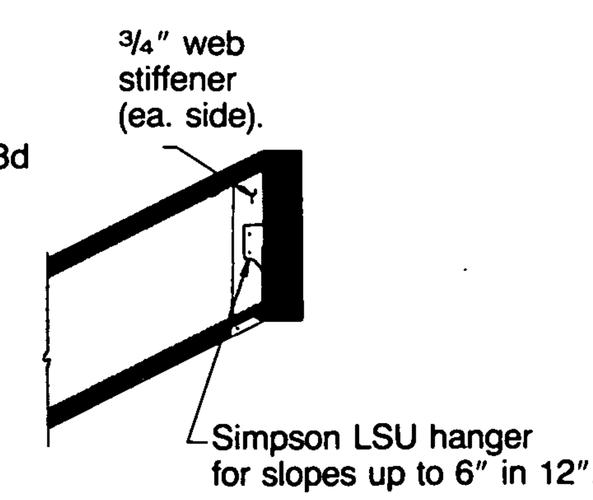


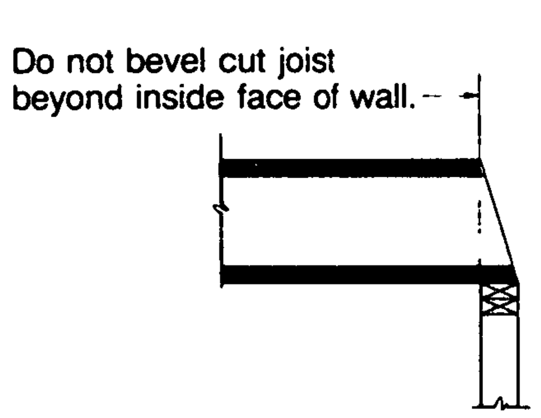


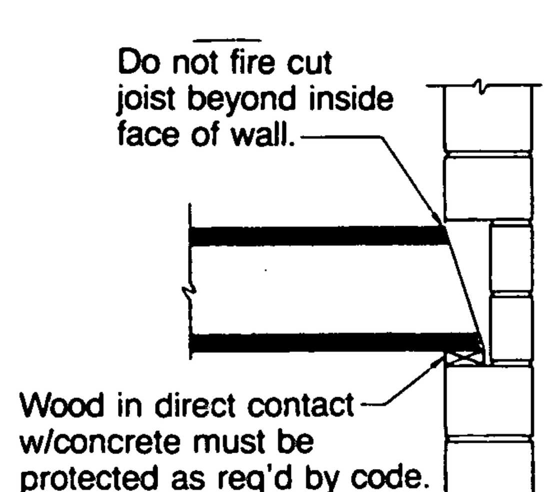


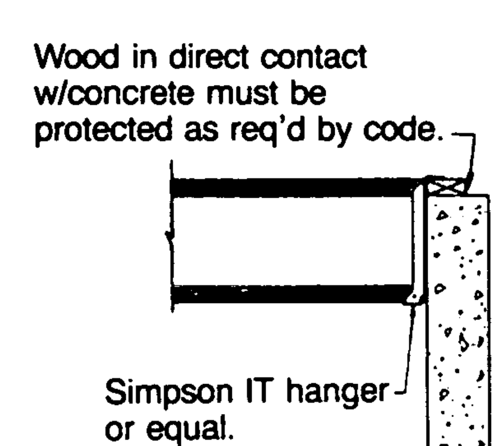






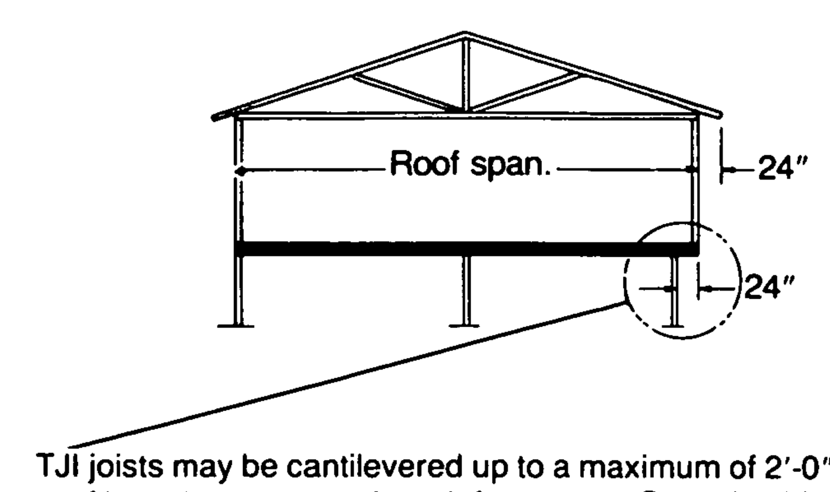






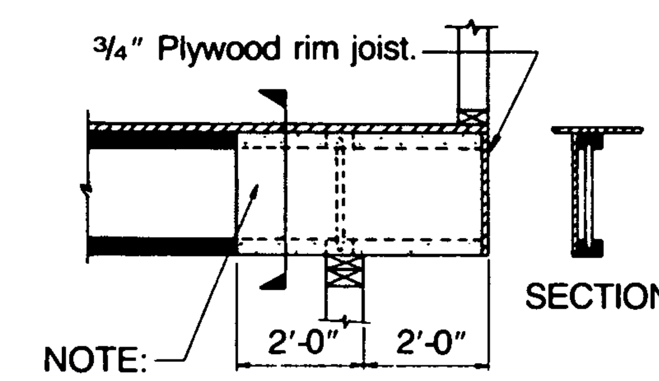
NOTE: Nail joists at bearing w/2-8d nails (1 ea. side).

LOAD BEARING CANTILEVER DETAILS

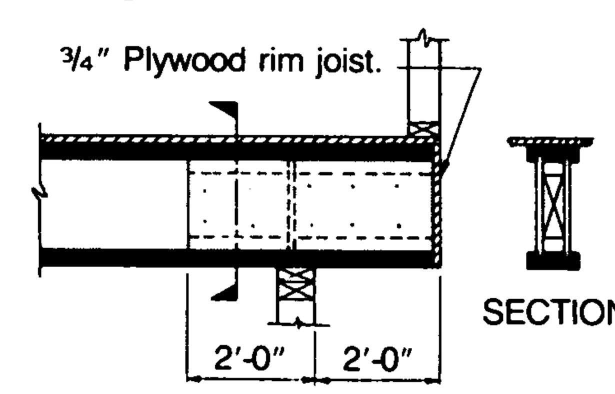


TJI joists may be cantilevered up to a maximum of 2'-0" when supporting roof load, but may require reinforcement. Consult tables this page to determine req'd reinforcement and details this page for methods of reinforcement.

CANTILEVER REINFORCEMENT DETAILS



3/4" x 48" CDX plywood reinforcement must match the full depth of the TJI joist. Nail to the TJI joist with 8d nails @ 6" o.c. When reinforcing both sides, stagger nails to avoid splitting. Face grain horizontal.



Block together w/2" x 6" x 4'-0" long filler blocks. Nail block w/2 rows 10d nails @ 6" o.c. and clinch.

ALTERNATE DETAIL

9½" Load Bearing Cantilever Table										
Roof Total Load		30 PSF			40 PSF			50 PSF		
Joist Spcg.		16"OC	19.2"OC	24"OC	16"OC	19.2"OC	24"OC	16"OC	19.2"OC	24"OC
Roof Truss Span W/24"Soffit Assumed	24'	1	1	2	2	2	3	2	3	4
	26'	1	2	2	2	2	3	2	3	4
	28'	1	2	2	2	3	3	3	3	4
	30'	1	2	3	2	3	4	3	4	4
	32'	2	2	3	2	3	4	3	4	4
	34'	2	2	3	2	3	4	3	4	4
	36'	2	2	3	3	3	4	3	4	4

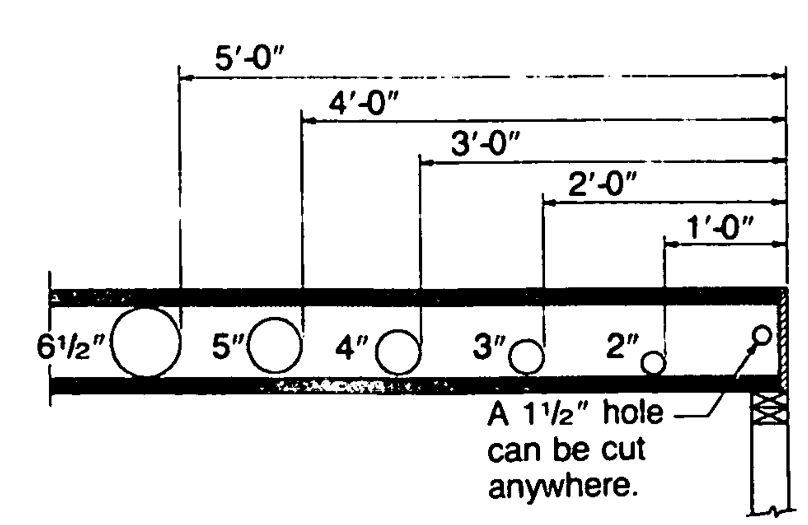
11⅞" Load Bearing Cantilever Table										
Roof Total Load		30 PSF			40 PSF			50 PSF		
Joist Spcg.		16"OC	19.2"OC	24"OC	16"OC	19.2"OC	24"OC	16"OC	19.2"OC	24"OC
Roof Truss Span W/24"Soffit Assumed	26'	1	1	2	1	2	2	2	2	3
	28'	1	1	2	1	2	2	2	2	3
	30'	1	1	2	2	2	3	2	2	3
	32'	1	2	2	2	2	3	2	2	3
	34'	1	2	2	2	2	3	2	3	4
	36'	1	2	2	2	2	3	2	3	4
	38'	1	2	2	2	2	3	3	3	4

(Numbers in charts refer to footnotes below.)

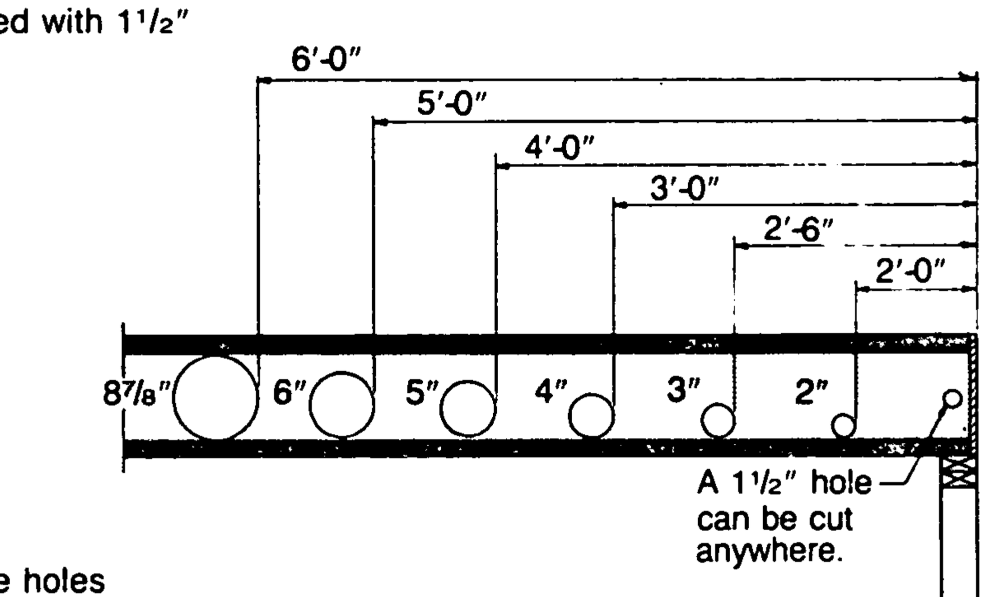
1. **No reinforcement required.**
2. 3/4" x 48" plywood reinforcement required on 1 side of joist or double the joists as shown in alternate detail.
3. 3/4" x 48" plywood reinforcement required on 2 sides of joist or double the joists as shown in alternate detail.
4. Will not work. Reduce spacing of joists.
   NOTE: Assumes a 10 p.s.f. roof dead load and 60 p.l.f. wall load.

ALLOWABLE HOLE CHART

TJI joists are manufactured with 1½" perforated KNOCKOUTS in the web @ 12" o.c.



9½" TJI joist

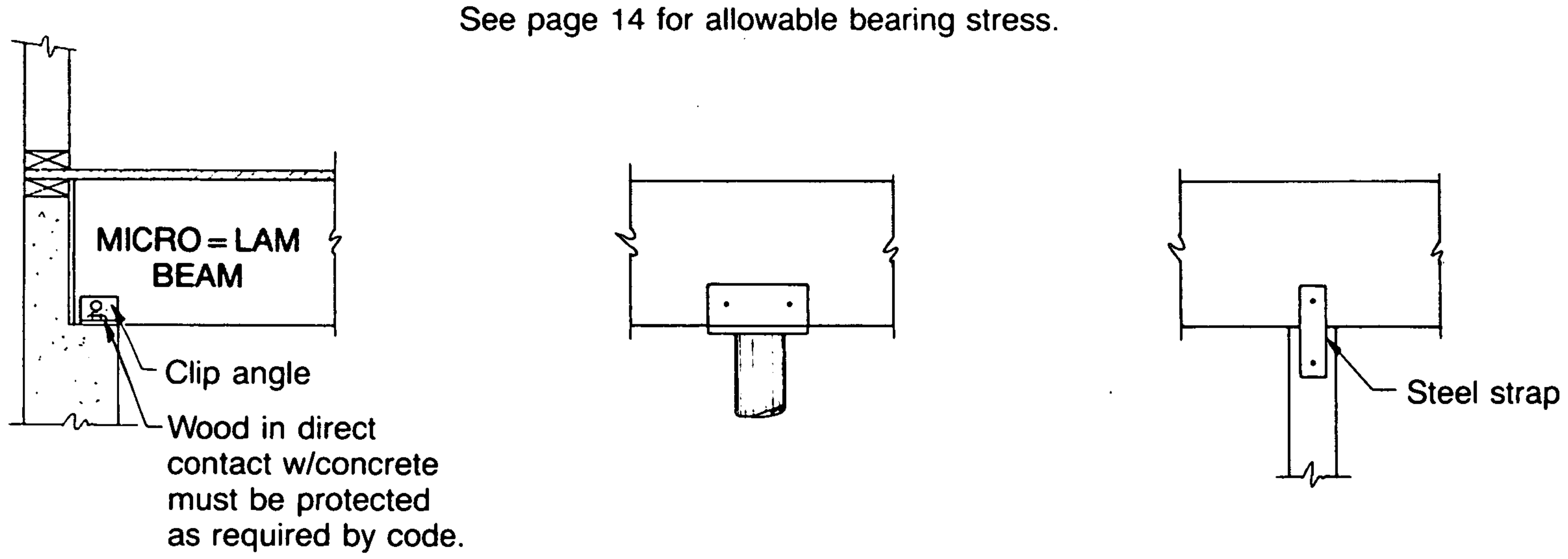


11⅞" TJI joist

Allowable hole sizes. For multiple holes space double the diameter between. Do not cut or notch flanges. For rectangular holes, multiply the allowable diameter times 0.8.

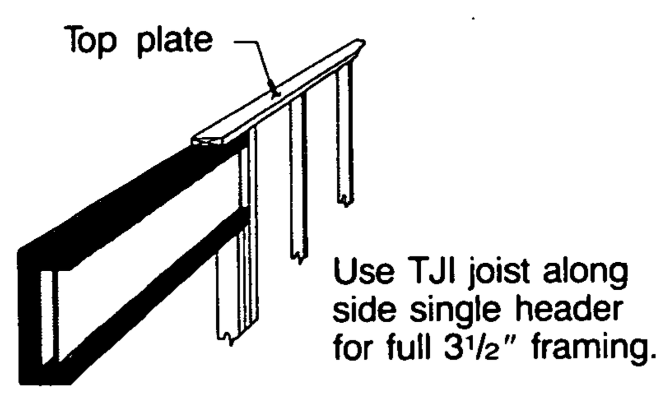
INSTALLATION DETAILS

BEAM BEARING DETAILS NOTE: Beam supports and connections to be designed for specific application. See page 14 for allowable bearing stress.

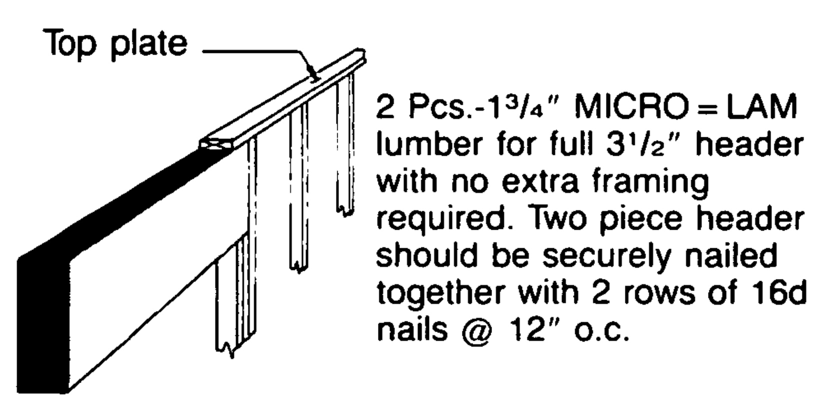


BEARING @ CONCRETE WALL BEARING @ PIPE COLUMN BEARING @ WOOD COLUMN

GARAGE DOOR HEADER INSTALLATION DETAILS

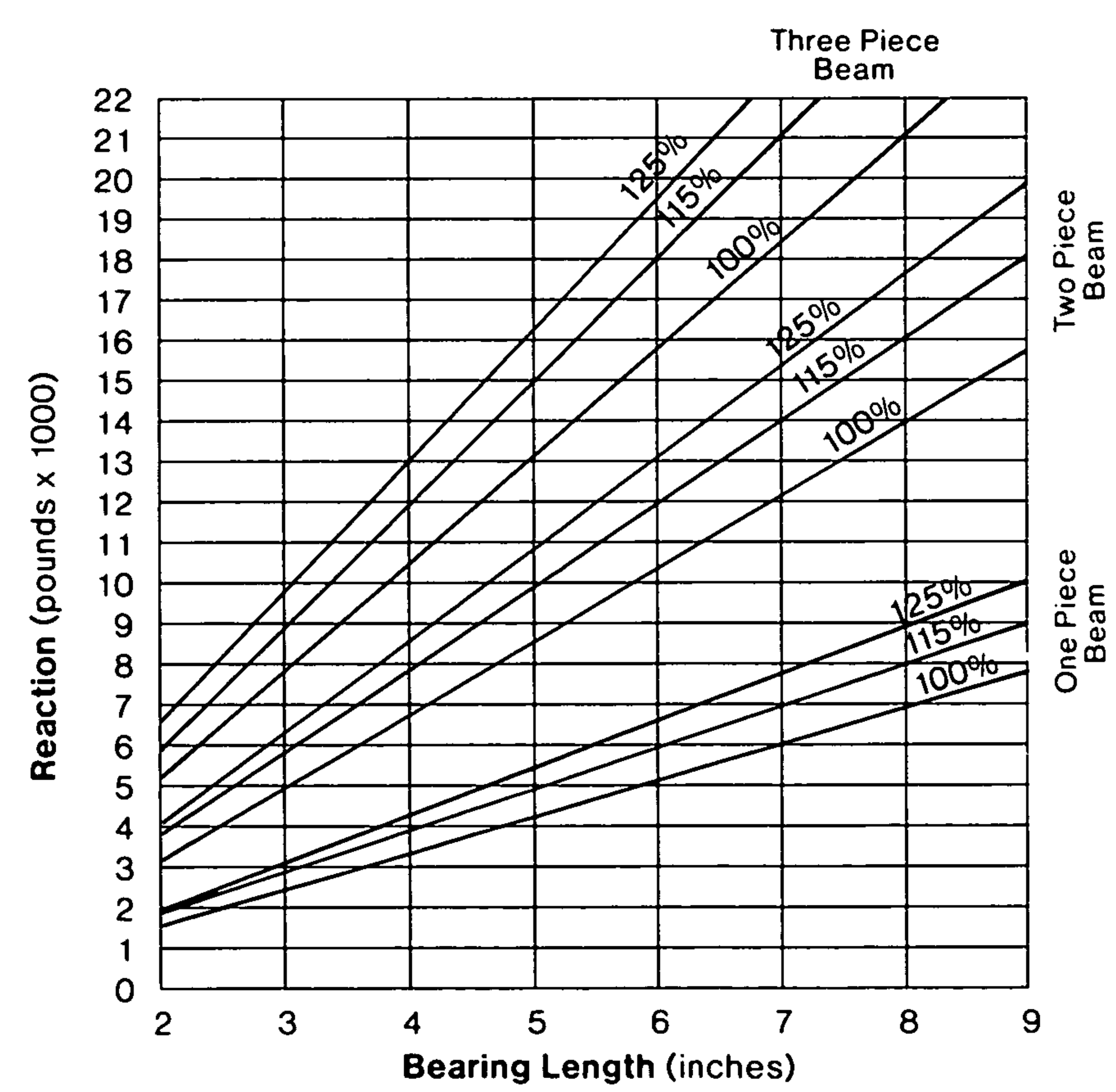


NOTE: Double trimmer required for adequate bearing on openings larger than 9'-0".



NOTE: Nails installed parallel to glue lines on the narrow face shall not be spaced any closer than 4" for 10d common and 3" for 8d common.

BEARING DISTANCE CHART



1. The chart is based on 500 P.S.I. allowable perpendicular to grain (parallel to glue-line).
2. A minimum of 1½" of bearing length is recommended.
3. Bearing across full width of a beam is assumed.
4. Assumes structural adequacy of supporting member.

GUARANTEE

TRUS JOIST warrants the products to be free from manufacturing errors or defects in either workmanship or materials. TRUS JOIST warrants that the products referenced herein will carry the loads specified in this installation guide provided they are used in strict accordance with the information contained herein and installed in a workman-like manner. TRUS JOIST members are structural and cannot be cut, notched, drilled, or in any way altered except as provided herein. IN THE EVENT THE PRODUCT IS ALTERED OR USED BEYOND THE LIMITS AS SET FORTH HEREIN, THEN TRUS JOIST MEMBERS ARE PURCHASED BY THE BUYER "AS IS", AND TRUS JOIST DOES NOT WARRANT THAT THEY ARE OF MERCHANTABLE QUALITY, OR THAT THEY CAN BE USED FOR ANY PARTICULAR PURPOSE.

TJI®/25 JOIST DESIGN DATA

RESIDENTIAL FLOOR SPAN CHART

	JOIST DEPTH	
o.c. spacing	9$^1/_2$"	11$^7/_8$"
12"	18'-2"	21'-9"
16"	16'-6"	19'-9"
19.2"	15'-6"	18'-6"
24"	14'-4"	17'-1"
32"	11'-4"	14'-4"

1. Based on floor load of 40# live load and 10# dead load.
2. Based on deflection of L/360 at live load.
3. Assumes composite action with single layer of nailed plywood decking for deflection only.
NOTE: For other load conditions, refer to allowable uniform load chart.

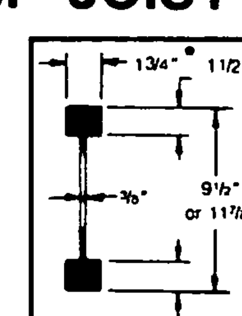
A WORD ABOUT FLOOR PERFORMANCE

The spans indicated in the charts above meet all code requirements and will provide acceptable performance for the typical user. In addition to safely supporting the loads to be imposed upon it, a floor system must perform to the satisfaction of the user. Since expectancy levels vary from one user to another, designing a floor system becomes a subjective issue requiring judgement as to the sensitivity of the occupant. For example, a floor system which is entirely satisfactory for a low-cost apartment project may be less than acceptable for a luxury condominium. The following suggestions will help the builder obtain a stiffer floor system for the high expectancy user.

- Use a stiffer decking material. A glue-nailed floor will perform better than a nailed floor; subfloor and underlayment will perform better than a single layer of plywood; a single layer of 2-4-1 plywood will perform better than a layer of subfloor and underlayment, etc.
- Reduce o.c. spacing of the joists.
- Reduce the allowable span in the chart above.

Workmanship in the field is critical to floor performance. TJI joists offer dimensional consistency and stability which enhance the proper installation of the system. However, full bearing, adequate and level support for the product, proper installation of the decking and care in fastenings (nailing, adhesives, etc.) are most essential!

TABLE OF TJI® JOIST PROPERTIES



Joist Depth (Inches)	Weight (Lbs./Ft.)	Weight (Lbs./Ft) S. Pine Flanges	EI** 10^6 in ^{2} lbs.	Max. Vertical Shear (Lbs.) 100%	115%	125%	Max. Resistive Moment (foot-lbs.) 100%	115%	125%
9$^1/_2$"	1.9	2.3	170	756	869	940	2940	3380	3675
11$^7/_8$"	2.0	2.4	285	875	1006	1094	3935	4525	4920

* 1$^5/_8$" for Southern Pine Flanges

** The following formula approximates the uniform load deflection of Δ:

$$\Delta = \frac{5w\ell^4}{384\,EI} + \frac{w\ell^2}{2.7d \times 10^5}$$

w = uniform load in pounds per lineal inch
ℓ = clear span in inches
d = out to out depth of the joist
EI = value from table

TJI®/25 JOIST DESIGN DATA

RESIDENTIAL ROOF SPAN CHART

O.C. SPACING	JOIST DEPTH	NON-SNOW (125%) 20 PSF LIVE LOAD 10 PSF DEAD LOAD	NON-SNOW (125%) 20 PSF LIVE LOAD 20 PSF DEAD LOAD	SNOW (115%) 25 PSF LIVE LOAD 10 PSF DEAD LOAD	SNOW (115%) 30 PSF LIVE LOAD 10 PSF DEAD LOAD	SNOW (115%) 40 PSF LIVE LOAD 10 PSF DEAD LOAD	SNOW (115%) 50 PSF LIVE LOAD 10 PSF DEAD LOAD
12″	9 1/2″	25′-0″	22′-10″	23′-9″	22′-9″	21′-0″	19′-9″
	11 7/8″	30′-0″	27′-0″	28′-0″	27′-0″	25′-0″	23′-6″
16″	9 1/2″	22′-9″	20′-6″	21′-6″	20′-7″	19′-0″	17′-10″
	11 7/8″	27′-0″	24′-4″	25′-7″	24′-6″	22′-7″	21′-1″
19.2″	9 1/2″	21′-4″	19′-4″	20′-3″	19′-4″	17′-10″	16′-8″
	11 7/8″	25′-4″	23′-0″	24′-0″	23′-0″	21′-1″	19′-8″
24″	9 1/2″	19′-9″	17′-10″	18′-8″	17′-10″	16′-4″	14′-6″
	11 7/8″	23′-6″	21′-2″	22′-3″	21′-1″	19′-5″	16′-8″
32″	9 1/2″	17′-10″	16′-0″	16′-10″	16′-0″	13′-2″	10′-10″
	11 7/8″	21′-2″	19′-0″	19′-10″	19′-1″	15′-1″	12′-7″
48″	9 1/2″	15′-4″	11′-10″	12′-6″	10′-10″	8′-8″	7′-3″
	11 7/8″	18′-0″	13′-8″	14′-4″	12′-6″	9′-11″	8′-4″

1. Roof joists to be sloped 1/8″ in 12″ minimum. No camber provided.
2. Maximum deflection is limited to L/180 at total load.
3. The above spans apply to roof slopes 2″ in 12″ or less. For slopes greater than 2″ in 12″ consideration must be given to the increased dead load and deflection caused by actual slope length.

NOTE: For loads not shown, refer to allowable uniform load chart.

ALLOWABLE UNIFORM LOAD in lbs. per lin. foot

9 1/2″ TJI® JOIST

Span		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Floor	L/360 Deflection	591	428	318	241	186	147	117	95	78	65	54	46	39	33	29	25	22	19	17	15
	Allowable Total Load	252	216	189	168	151	137	126	116	108	101	92	81	73	65	59	53	49	44	41	38
Sloped Roof	115% Snow	290	248	217	193	174	158	145	135	124	116	105	91	78	67	58	50	44	39	34	31
	125% Non-snow	315	270	236	210	189	172	158	145	135	126	108	91	78	67	58	50	44	39	34	31

11 7/8″ TJI® JOIST

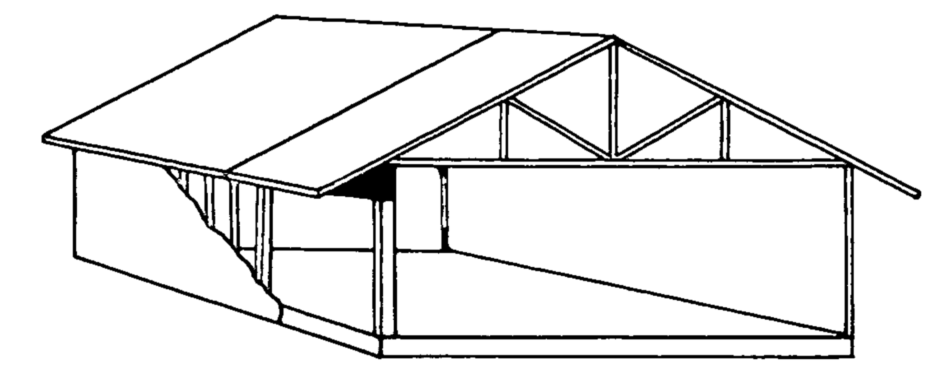
Span		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Floor	L/360 Deflection	364	286	227	183	150	124	103	87	74	63	54	47	41	36	32	28	25	22	20	18
	Allowable Total Load	194	175	159	146	135	125	117	109	103	97	87	79	71	65	60	55	50	47	43	40
Sloped Roof	115% Snow	223	201	182	167	155	143	134	125	118	111	100	90	81	72	64	56	50	45	40	36
	125% Non-snow	242	218	198	182	168	156	146	136	128	121	108	94	82	72	64	56	50	45	40	36

1. Load capacity assumes no composite action provided by sheathing.
2. Roof joists to be sloped 1/8″ in 12″ minimum. No camber is provided.
3. Deflection is limited to L/180 at total load for roofs.
4. For deflection limits of L/180, L/240, and L/480, multiply L/360 deflection loads by 2.0, 1.5, and .75, respectively.

MICRO = LAM® LUMBER DESIGN DATA

MICRO = LAM® GARAGE DOOR HEADER TABLE

For Single Story Applications



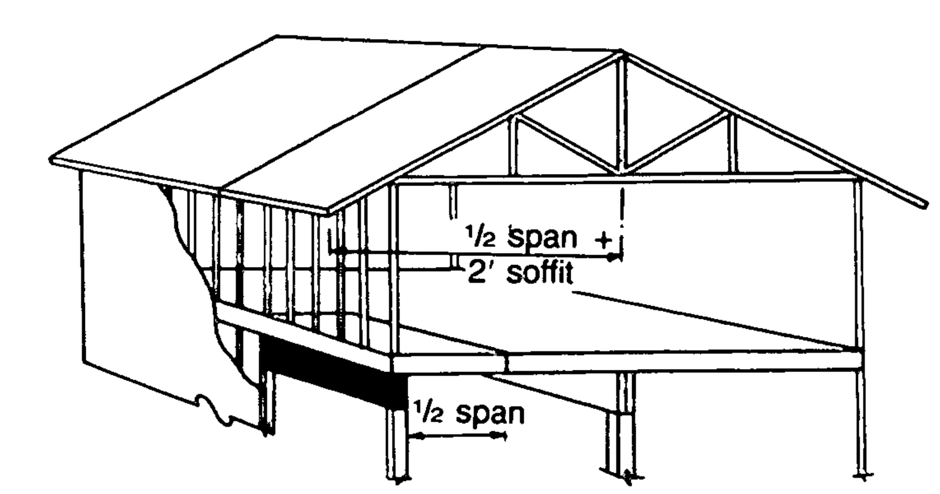
Non-shaded portion indicates area of load on header

ROOF LOAD		125% NON-SNOW 20# L.L. + 10# D.L.			125% NON-SNOW 20# L.L. + 20# D.L.			115% SNOW 25# L.L. + 10# D.L.			115% SNOW 30# L.L. + 10# D.L.			115% SNOW 40# L.L. + 10# D.L.		
DOOR OPENING SIZE		9′-3″	16′-3″	18′-3″	9′-3″	16′-3″	18′-3″	9′-3″	16′-3″	18′-3″	9′-3″	16′-3″	18′-3″	9′-3″	16′-3″	18′-3″
ROOF TRUSS SPAN IN FEET WITH 24″ SOFFIT ASSUMED	22′	1-9½″	2-11⅞″ or 3-9½″	211⅞″	1-9½″	211⅞″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″ or 3-9½″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-14″
	24′	1-9½″	2-11⅞″ or 3-9½″	2-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″ or 3-9½″	2-14″ or 3-11⅞″	1-9½″	2-11⅞	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-14″
	26′	1-9½″	2-11⅞″ or 3-9½″	2-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-16″ or 3-14″
	28′	1-9½″	2-11⅞″ or 3-9½″	2-11⅞″	1-9½″	2-11⅞	2-14″ or 3-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-16″ or 3-14″
	30′	1-9½″	2-11⅞″ or 3-9½″	2-14″ or 3-11⅞″	2-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-16″ or 3-14″
	32′	1-9½″	2-11⅞″ or 3-9½″	2-14″ or 3-11⅞″	2-9½″	2-14″ or 3-11⅞″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-14″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-16″ or 3-14″
	34′	1-9½″	2-11⅞″ or 3-9½″	2-14″ or 3-11⅞″	2-9½″	2-14″ or 3-11⅞″	2-14″ or 3-11⅞″	1-9½″	2-11⅞″	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-16″ or 3-14″	1-11⅞″ or 2-9½″	2-16″ or 3-14″	2-16″ or 3-14″
	36′	1-9½″	2-11⅞″ or 3-9½″	2-14″ or 3-11⅞″	2-9½″	2-14″ or 3-11⅞″	2-14″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-14″ or 3-11⅞″	1-11⅞″ or 2-9½″	2-14″ or 3-11⅞″	2-16″ or 3-14″	2-9½″	2-16″ or 3-14″	2-18″ or 3-14″

NOTE:
- This table is for headers carrying roof load only. For compound loads (i.e. 2nd floor **and** roof) refer to table below.
- For loads in excess of those shown, refer to MICRO = LAM® ALLOWABLE LOAD TABLE.
- Deflection limited to L/240 at live load or L/180 at total load.
- Reduction in live load for 125% load condition only, per UBC section 2306.

MICRO = LAM® GARAGE DOOR HEADER TABLE

For Two Story Applications



Non-shaded portion indicates area of load on header

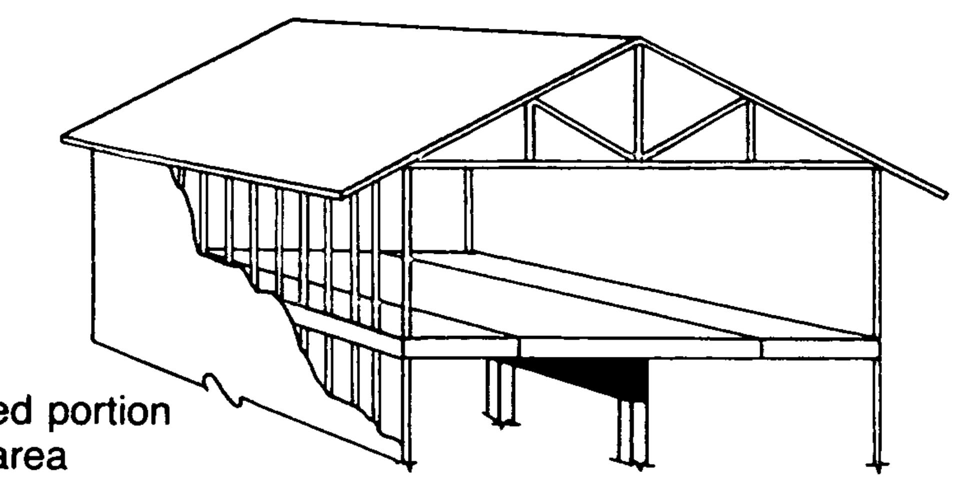
Instructions for sizing:
1. Calculate roof load (plf) by multiplying 1/2 truss span + 2′ soffit times total load per sq. ft.
2. Calculate floor load (plf) by multiplying 1/2 span of floor joists times total load per sq. ft.
3. Add weight of wall (60 plf in most cases.)
4. Add roof load (plf), floor load (plf), and wall load (plf) to obtain total load (plf).
5. From chart at right, select a header that will carry the total load (plf).

	ALLOWABLE LOAD IN LBS. PER LINEAL FOOT (plf)		
DOOR OPENING SIZE	9′-3″	16′-3″	18′-3″
MEMBER QTY. & SIZE: 2 pcs 9½″	1118	238	170
3 pcs 9½″	1677	357	255
2 pcs 11⅞	1704	458	328
3 pcs 11⅞″	2556	687	492
2 pcs 14″	2344	740	531
3 pcs 14″	3516	1110	796

MICRO = LAM® LUMBER DESIGN DATA

MICRO = LAM® FLOOR BEAM TABLE

1. Determine supported floor joist span by adding 1/2 the sum of the joist spans on both sides of the beam
2. Determine column spacing
3. From chart below, select proper beam size

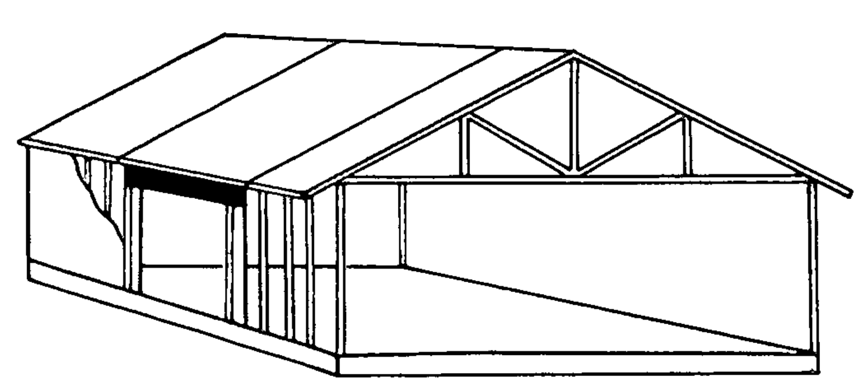


Non-shaded portion indicates area of load on header

COLUMN SPACING	FLOOR JOIST SPAN (Use ½ the sum of the joist spans on both sides of the beam) 11′	12′	13′	14′	15′	16′	17′	18′	20′
10′	2-9½″	2-9½″	2-9½″	2-9½″	2-9½″	3-9½″ or 2-11⅞″	3-9½″ or 2-11⅞″	3-9½″ or 2-11⅞″	3-9½″ or 2-11⅞″
12′	3-9½″ or 2-11⅞″	3-9½″ or 2-11⅞″	3-9½″ or 2-11⅞″	2-11⅞″	2-11⅞″	2-11⅞″	2-11⅞″	2-11⅞″	3-11⅞″ or 2-14″
14′	2-11⅞″	3-11⅞″ or 2-14″	3-11⅞″ or 2-14″	3-11⅞″ or 2-14″	3-11⅞″ or 2-14″	3-11⅞″ or 2-14″	3-11⅞″ or 2-14″	3-11⅞″ or 2-14″	3-11⅞″ or 2-14″
16′	3-11⅞″ or 2-14″	2-14″	3-14″ or 2-16″	3-14″ or 2-16″	3-14″ or 2-16″	3-14″ or 2-16″	3-14″ or 2-16″	3-14″ or 2-16″	3-14″ or 2-16″
18′	3-14″ or 2-16″	3-14″ or 2-16″	3-14″ or 2-16″	3-16″ or 2-18″	3-16″ or 2-18″	3-16″ or 2-18″	3-16″ or 2-18″	3-16″ or 2-18″	3-16″ or 2-18″
20′	3-16″ or 2-18″	3-16″ or 2-18″	3-16″ or 2-18″	3-16″ or 2-18″	3-18″	3-18″	3-18″	3-18″	3-18″

- Based on residential loading of 40 PSF live load and 10 PSF dead load.
- Deflection limited to L/360 at live load.
- Calculations are based on continuous floor joist span and simple or continuous beam span conditions.
- For applications other than shown, special engineering may be required.

MICRO = LAM® WINDOW & PATIO DOOR HEADER SPAN TABLE

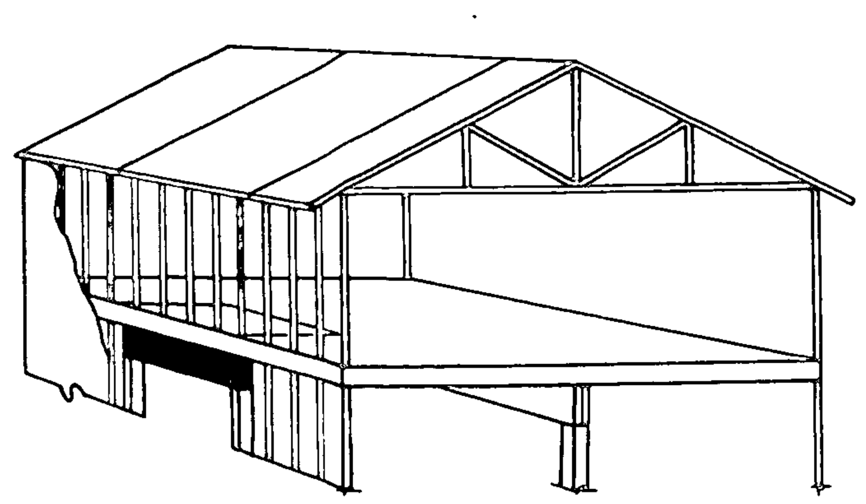


Non-shaded portion indicates area of load on header

WINDOW HEADER MAXIMUM SPAN TABLE
For 1 Story Application

Roof Total Load		30 PSF (125%)	40 PSF (115%)	50 PSF (115%)
Header Size	1-9½″	8′-6″	7′-9″	7′-4″
	2-9½″	11′-0″	10′-4″	9′-8″
	1-11⅞″	9′-11″	9′-2″	8′-8″
	2-11⅞″	12′-6″	11′-7″	10′-11″

Table shows maximum span capacity of indicated members assuming 10# dead load with 36′ roof truss with 2′ soffit.



WINDOW HEADER MAXIMUM SPAN TABLE
For 2 Story Application

Roof Total Load		30 PSF (125%)	40 PSF (115%)	50 PSF (115%)
Header Size	1-9½″	6′-9″	5′-6″	4′-9″
	2-9½″	9′-9″	8′-10″	8′-3″
	1-11⅞″	8′-10″	8′-3″	7′-9″
	2-11⅞″	11′-2″	10′-7″	10′-2″

Table shows maximum span capacity of indicated members assuming 10# dead load with 36′ roof truss with 2′ soffit.

MICRO = LAM® LUMBER DESIGN PROPERTIES

SIZE	MAXIMUM VERTICAL SHEAR (LBS) 100%	115%	125%	MAXIMUM RESISTIVE MOMENT (FT-LBS) 100%	115%	125%	MOMENT OF INTERTIA IN.(4)	WEIGHT (LBS/FT)
1¾″ x 9½″	3160	3630	3950	6300	7240	7870	125	4.25
1¾″ x 11⅞″	3950	4540	4940	9600	11050	12000	245	5.30
1¾″ x 14″	4650	5345	5810	13100	15065	16375	400	6.25
1¾″ x 16″	5320	6120	6650	16870	19400	21085	595	7.15
1¾″ x 18″	5985	6880	7480	21080	24240	26350	850	8.00

ALLOWABLE DESIGN STRESSES

Modulus of Elasticity	$E = 2.0 \times 10^6$ psi	*For 12-inch depth; for other depths, multiply by $\left(\frac{12}{d}\right)^{1/9}$
Flexural Stress	$f_b^* = 2800$ psi	• See NRB 126 for additional design information.
Tension parallel to grain	$f_t = 1850$ psi	• Assumes continuous lateral support.
Compression perpendicular to grain parallel to glue line	$f_c = 500$ psi	
Compression parallel to grain	$f_{c\parallel} = 2700$ psi	
Horizontal shear perpendicular to glue line	$f_v = 285$ psi	

MICRO=LAM® LUMBER ALLOWABLE LOAD TABLES (FLOOR)

ALLOWABLE LOAD LBS./LIN. FOOT

SPAN	ONE - 1¾″ x 9½″ DEFLECTION L/360	ALLOWABLE TOTAL LOAD	ONE - 1¾″ x 11⅞″ DEFLECTION L/360	ALLOWABLE TOTAL LOAD	ONE - 1¾″ x 14″ DEFLECTION L/360	ALLOWABLE TOTAL LOAD	ONE - 1¾″ x 16″(1) DEFLECTION L/360	ALLOWABLE TOTAL LOAD	ONE - 1¾″ x 18″(1) DEFLECTION L/360	ALLOWABLE TOTAL LOAD
6		1401		1964		2539		3192		3990
7	903	1029		1569		1995		2455		2993
8	629	788		1201		1639		1995		2394
9	454	623	837	949	1293	1295		1667		1995
10	338	504	629	769	981	1049		1350		1686
11	258	417	484	635	760	867	1085	1116		1394
12	201	350	379	534	599	728	861	937		1171
13	160	298	302	455	480	621	694	799	952	998
14	129	257	245	392	390	535	566	689	781	860
15	105	224	201	342	321	466	468	600	647	749
16	87	197	167	300	268	410	390	527	542	659
17	73	174	140	266	225	363	329	467	458	583
18	62	156	119	237	191	324	280	417	390	520
19	53	140	101	213	163	291	240	374	335	467
20	45	126	87	192	141	262	207	337	290	422
21	39	114	76	174	122	238	180	306	252	382
22	34	104	66	159	107	217	157	279	221	348
23	30	95	58	145	94	198	138	255	194	319
24	26	88	51	133	83	182	122	234	172	293
25							109	216	153	270
26							97	200	136	249

1. To size a beam for use in a floor it is necessary to check both deflection and allowable total load.
2. **CHECK LOCAL CODE FOR DEFLECTION CRITERIA.**
3. For deflection limits of L/240 and L/480 multiply loads shown in L/360 column by 1.5 and .75 respectively.
4. Make sure the selected beam will work in both columns.

NOTE:
- This table is based on uniform loads and simple spans.
- Table is for one beam. When top loaded, double the values for 2 beams, triple for 3, etc., when properly fastened together with a minimum of 2 rows of 16d nails @ 12″ o.c.
- MICRO=LAM lumber beams are made without camber; therefore, in addition to complying with the deflection limits of the local Building Code, other deflection considerations should be evaluated such as ponding (positive drainage is essential) and aesthetics.
- Assumes continuous lateral support of the top edge of beam.
- Bearing area to be calculated for specific application.

(1) 16″ and 18″ deep beams are to be used in multiple member units only.

MICRO=LAM® LUMBER DESIGN DATA

MICRO=LAM® LUMBER ALLOWABLE LOAD TABLES (ROOF)

ALLOWABLE LOAD LBS./LIN. FOOT

To size a beam for use in a roof structure, it is necessary to check the allowable total load column and the appropriate deflection column.

	ONE - 1¾″ x 9½″				ONE - 1¾″ x 11⅞″				ONE - 1¾″ x 14″				ONE - 1¾″ x 16[1]				ONE - 1¾″ x 18″[1]			
	DEFLECTION		ALLOWABLE TOTAL LOAD		DEFLECTION		ALLOWABLE TOTAL LOAD		DEFLECTION		ALLOWABLE TOTAL LOAD		DEFLECTION		ALLOWABLE TOTAL LOAD		DEFLECTION		ALLOWABLE TOTAL LOAD	
SPAN	L/180	L/240	115% Snow	125% Non-Snow	L/180	L/240	115% Snow	125% Non-Snow	L/180	L/240	115% Snow	125% Non-Snow	L/180	L/240	115% Snow	125% Non-Snow	L/180	L/240	115% Snow	125% Non-Snow
6			1611	1751			2259	2455			2920	3174			3671	3990			4588	4988
7			1184	1286			1804	1961			2294	2494			2824	3069			3441	3741
8			906	985			1381	1501			1885	2049			2294	2494			2753	2993
9		681	716	778			1091	1186			1489	1619			1917	2083			2294	2494
10		507	580	630			884	961			1206	1311			1552	1687			1939	2108
11		387	479	521			731	794			997	1084			1283	1395			1603	1742
12		301	403	438		569	614	667			838	911			1078	1172			1347	1464
13	319	239	343	373		454	523	569			714	776			919	998			1147	1247
14	257	193	296	322		367	451	490		586	615	669			792	861			989	1075
15	211	158	258	280		301	393	427		482	536	583			690	750			862	937
16	174	131	227	246	334	250	345	375		401	471	512		586	606	659			758	823
17	146	109	201	218	280	210	306	332		338	417	454		494	537	584			671	729
18	123	93	179	195	237	178	273	297		286	372	405		420	479	521		586	599	651
19	105	79	161	175	203	152	245	266	327	245	334	363		360	430	467		503	537	584
20	90	68	145	158	174	131	221	240	282	211	302	328		311	388	422		435	485	527
21	78	59	132	143	151	113	200	218	244	183	274	297		270	352	383		379	440	478
22	68	51	120	130	132	99	183	199	213	160	249	271	315	236	321	349		331	401	436
23	60	45	110	119	116	87	167	182	187	141	228	248	277	207	293	319		292	367	398
24	53	40	101	109	102	77	153	167	166	124	209	228	244	183	270	293		258	337	366
25	47	35	93	101	90	68	141	154	147	110	193	210	217	163	248	270	306	229	310	337
26	42	31	86	93	81	60	131	142	131	98	178	194	194	145	230	250	273	205	287	312
27	37	28	80	86	72	54	121	132	117	88	165	180	173	130	213	231	244	183	266	289
28	33	25	74	80	65	49	113	123	105	79	154	167	156	117	198	215	220	165	247	269
29	30	23	69	75	58	44	105	114	95	71	143	156	141	105	185	201	198	149	231	251
30	27	20	64	70	53	40	98	107	86	64	134	146	127	95	172	187	180	135	215	234

NOTE:

- This table is based on uniform loads and simple spans.
- Table is for one beam. When top loaded, double the values for 2 beams, triple for 3, etc., when properly fastened together with a minimum of 2 rows of 16d nails @ 12″ o.c.
- MICRO=LAM lumber beams are made without camber; therefore, in addition to complying with the deflection limits of the local Building Code, other deflection considerations should be evaluated such as ponding (positive drainage is essential) and aesthetics.
- Assumes continuous lateral support of the top edge of beam.
- Bearing area to be calculated for specific application.

[1] 16″ and 18″ deep beams are to be used in multiple member units only.

The TJL™ Truss

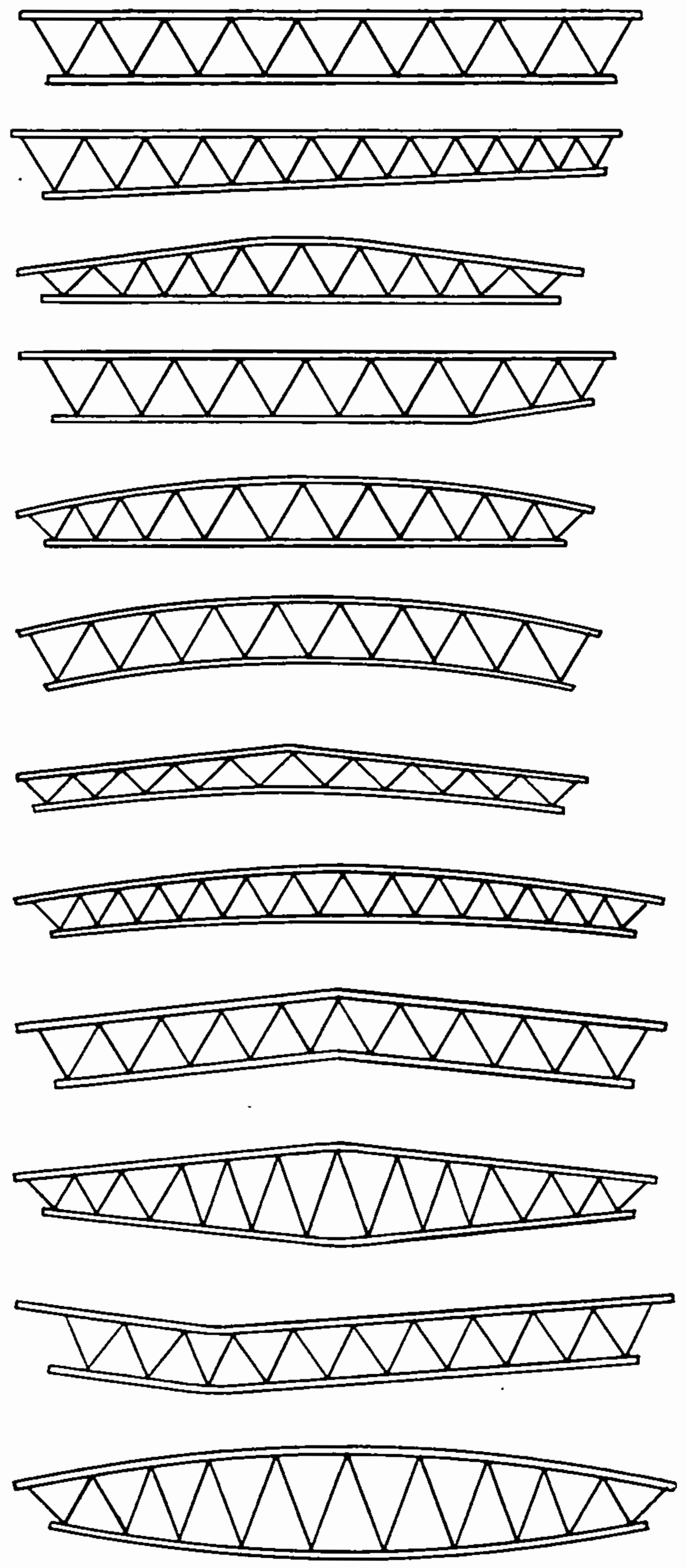
The TJL truss makes complicated jobs easy. Design flexibility is the key. A variety of truss configurations each can be manufactured to the precise loading requirements of designs in the medium span range without sacrificing the exceptional workability of the truss. The architect can combine pleasing aesthetics with pleasing budget targets.

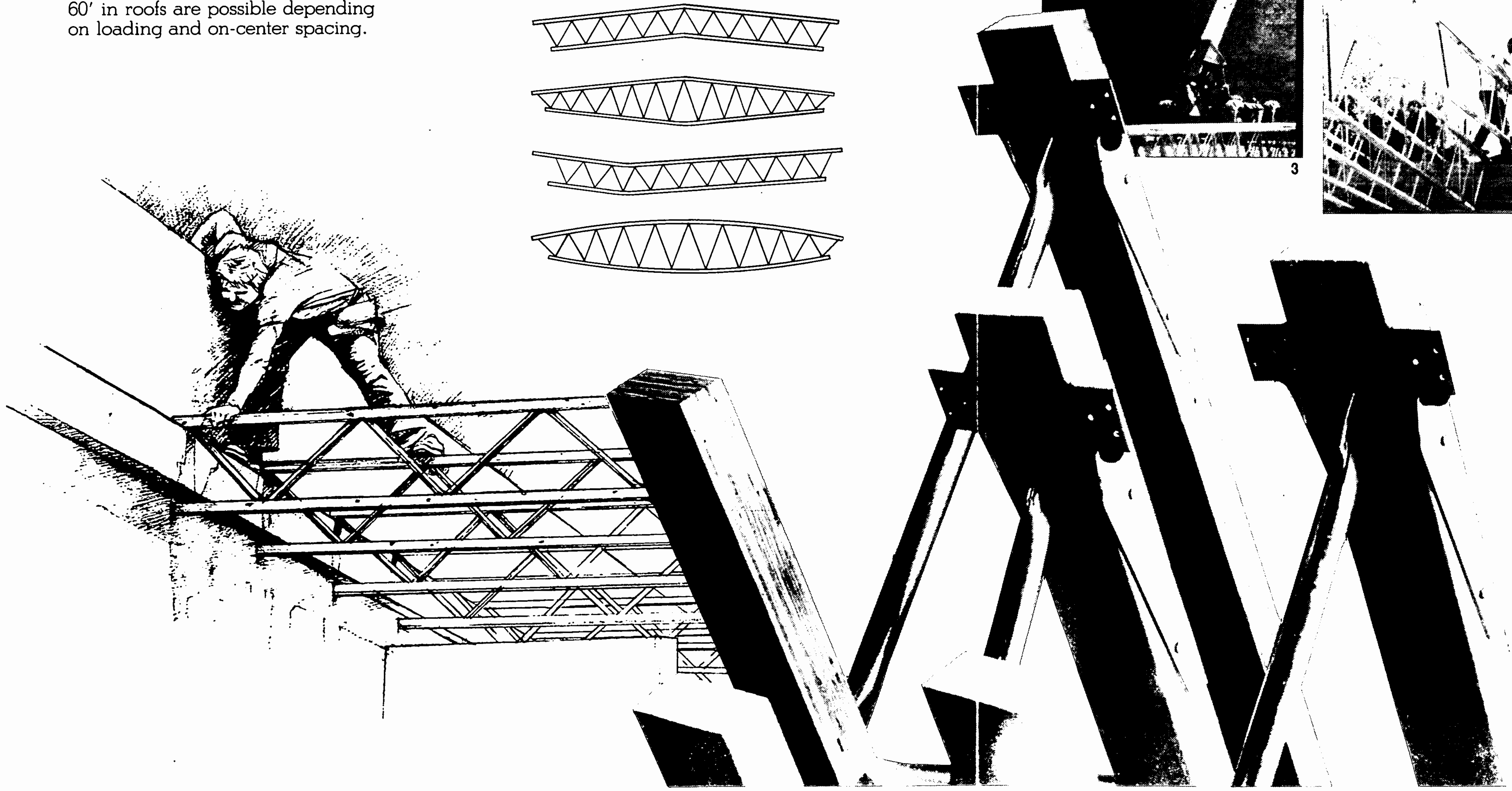
Regardless of the configuration, a TJL truss is strong, light weight, stable, and nailable. It's simple to install. Two men can handle a 40′ TJL truss easily. And, because of its wood chords, carpenters can finish it quickly.

The TJL truss, is made with 2″ × 4″ machine stress rated lumber chords and tubular steel webs.

Spans up to 38′ in floors and 60′ in roofs are possible depending on loading and on-center spacing.

Profiles





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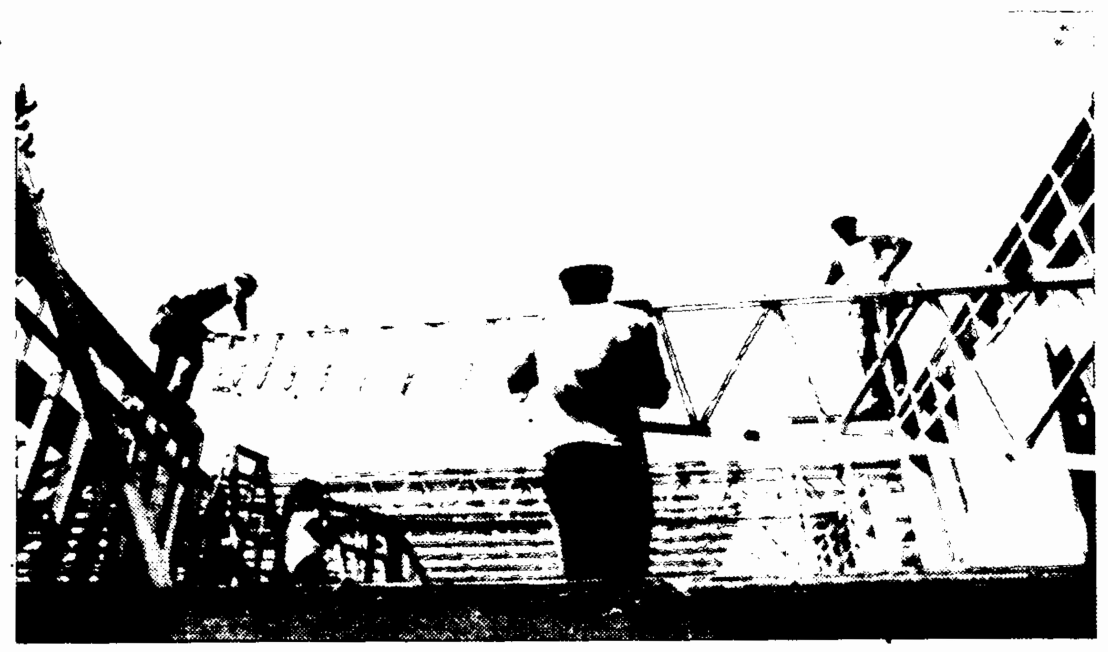

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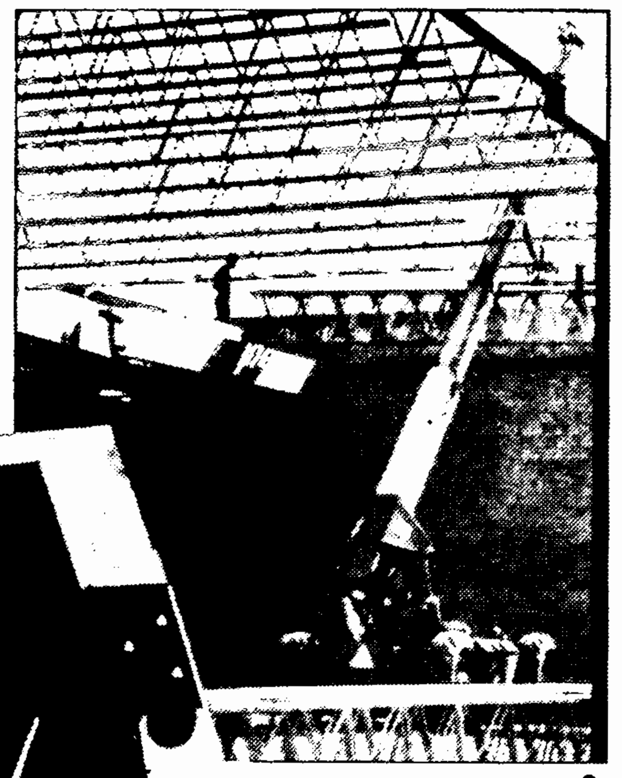
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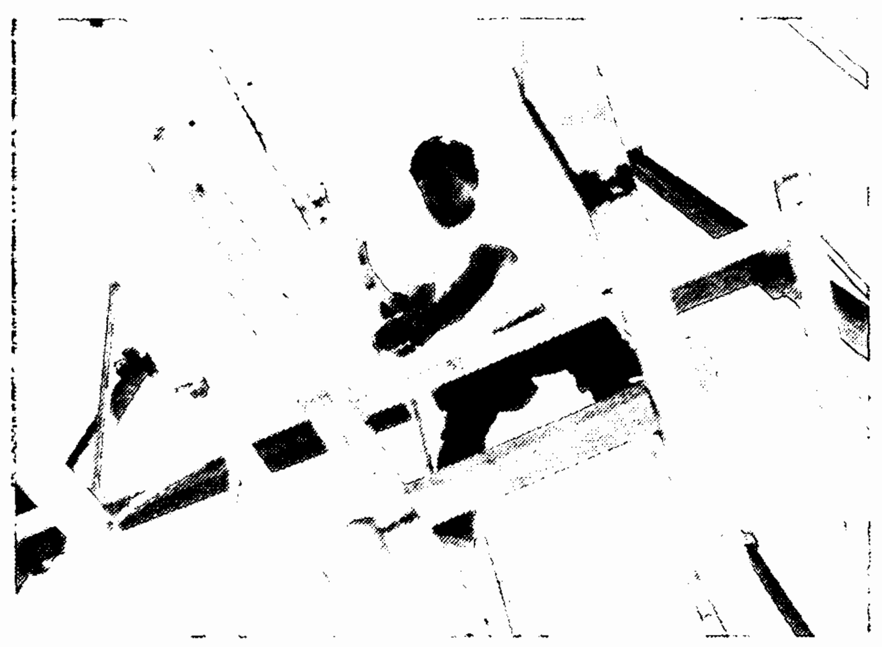

5

1. This TJL truss will span 28′ at 24″ on-center in the second floor of this three story office building.
2. Sheathing nails down easy on TJL trusses because of their 3¹/₂″ wide chords. The MICRO=LAM lumber top chord in these TJLX trusses is an added bonus because MICRO=LAM lumber takes more nails and holds them better than ordinary solid-sawn lumber.
3. A forklift sets 33″ deep TJLX trusses in the roof of this retail shopping outlet. The trusses span 35′ at 4′ on-center.
4. TJL trusses are lifted into place in the first floor of this three story office building. These 30″ deep trusses, spaced at 24″ on-center over a 24′ span, were designed for a 250 plf load.
5. Bridging makes all trusses in a bay act as one unit, equalizing deflection from non-uniform loads. Bridging is a required component of the system and bridging clips are built into all TJL trusses.

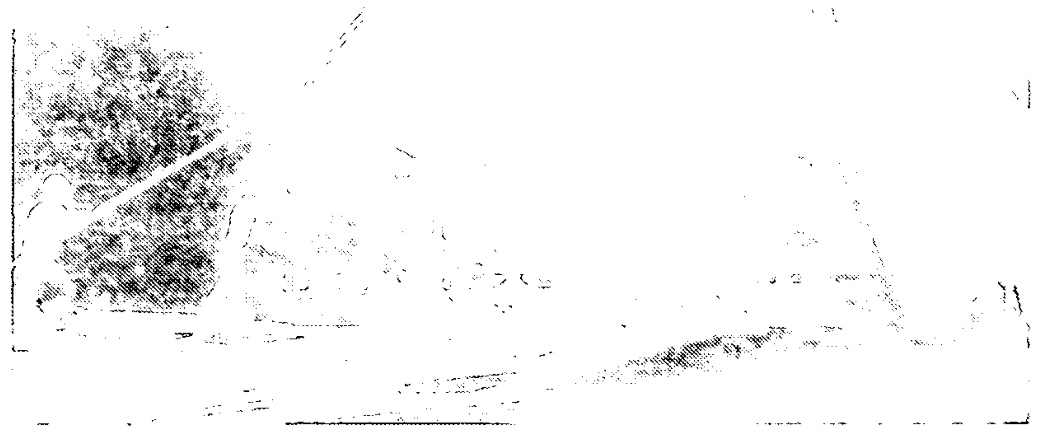
Appendix 10

Techline

Truss-Framed System

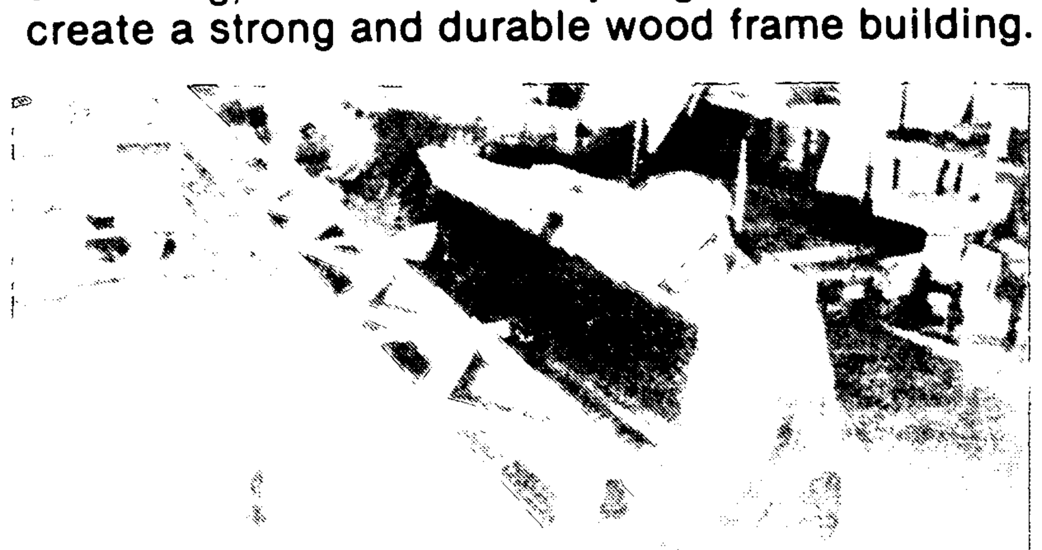
United States Department of Agriculture | Forest Service | **Forest Products Laboratory**

The Truss-Framed System (TFS) is an innovative new building system for residential and light-commercial construction. The new system offers substantial savings in both materials costs and construction time, with improvement in structural durability and strength. The idea for TFS was conceived at the Forest Products Laboratory in the late 1970s to meet the need for less costly, high quality home construction.



TFS construction enables a small crew of laborers to frame up an average house in only a few hours.

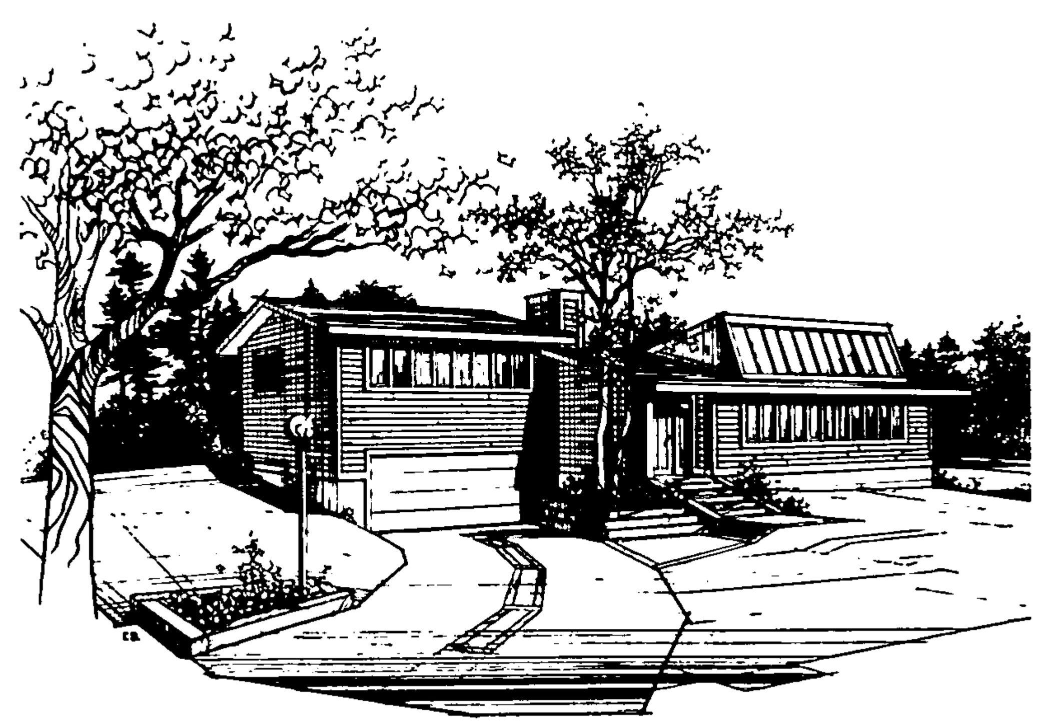
The system's key structural component is a unitized floor-roof truss which is joined together by regular wall studs and spaced at 24-inch intervals. The system is a marriage of factory and site-built construction. Trusses are fabricated in a plant under quality conditions and delivered pre-built to the construction site where they are erected by a small crew or with light mechanical equipment such as a crane or forklift. The entire unitized frame is constructed from 2x4 dimension lumber rather than the more expensive 2x8 or 2x10 lumber used in conventionally-designed homes. Because the trusses can be designed to span the width of most homes, supports are not needed in the basement and load-bearing walls are not necessary on the first floor. Once connected with sheathing, the structurally-engineered trusses create a strong and durable wood frame building.



Unitized truss frames are fabricated in a plant to insure maximum material efficiency and quality control.

Truss framing was developed after field observations of building damage from natural disasters showed that roof-to-wall or wall-to-floor joints often failed before the structural members. These observations were confirmed by FPL full-scale house tests. Since the unitized frame assures structural continuity between the critical joints, TFS buildings are often sturdier than those constructed through conventional means.

The innovative system also requires about 30 percent less structural framing lumber than the conventional stick-built home. Because less on-site effort is needed to frame up a structure, the average size home can usually be erected in a few hours. As a result, builders have reported savings of about 10 percent of the overall costs by using the TFS building technique.



Built with truss frames, this contemporary split-level house offers stylish architectural design and incorporates solar collector panels for increased energy efficiency.

Since January 1982, U.S. builders have used TFS to construct over 2,000 homes, apartments and office buildings in 31 states. TFS has been assigned a public patent and is available to anyone who wishes to use it. A TFS Construction Manual has been published by the National Association of Home Builders Research Foundation in cooperation with the Forest Products Laboratory. The manual includes sections on the design, detailing and construction of TFS buildings.

Copies of the construction manual are available from: National Association of Home Builders Research Foundation, Inc., P.O. Box 1627, Rockville, MD 20850; (202) 452-0200. Price is $5.00 ($4.00 for multiple copies).

FPL Spaceboard—A new structural sandwich concept

Vance C. Setterholm

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Present-day commercial corrugated fiberboard (CCF) manufacturing concepts do not fully utilize the higher strength of press-dry linerboards. This failure may be caused by the limited ability of corrugated fiberboard to resist buckling in the unsupported paperboard between the flute tips.

One solution to this problem may lie in "FPL Spaceboard," a new structural sandwich concept that provides equal strength in both principal directions of the structure. In this concept, the core component and facing component for each half of the sandwich are formed in a single pulp-molding process. The core density is nonlinear, with highest density and support closest to the facing. The core design is cellular and can be wafflelike in appearance. FPL Spaceboard components can be strengthened by press drying or resin treatment.

In edgewise compression tests, FPL Spaceboard is at least 30% stronger than CCF loaded parallel to the flutes and anywhere from 160% to 215% stronger than CCF loaded perpendicular to the flutes. Flexible rubber molds produce strong boards at much lower press pressure (70 vs. 1000 Pa) than rigid metal molds.

Keywords: FPL Spaceboard* • C-Flute corrugated fiberboard* • Edgewise compression* • Structure sandwich*

Experimental research with the goal of better support for structural sandwich facing and more efficient use of fiber led to the concept I call "FPL Spaceboard."[1] Whereas the original concept and experimentation was aimed at the same applications as those of corrugated fiberboard, it was immediately apparent that the FPL Spaceboard concept would have even broader impact and potential for a wide variety of structural sandwich designs.

The chief function of structural sandwich core materials is to position the sandwich facings and hold them in place so they can support a load. Cores contribute to the edgewise compression strength if they have structural integrity, as in the case of corrugated board loaded parallel to the medium flutes. Cores may also be virtually unable to support a load, as in the case of low-density foam cores or corrugated board that is loaded edgewise and perpendicular to the fluting. Whether load-bearing or not, sandwich cores must transmit shear stresses between the facings if the structure is to resist imposed bending stresses.

During experiments at the Forest Products Laboratory (FPL), fiberboard containers with press-dried linerboards and conventional corrugating media failed to deliver the increased top-to-bottom compression strength I had anticipated based on preliminary tests of paperboard alone. I suspected the problem was one of an inability of the corrugated core to adequately support the facings against buckling. This idea was further substantiated in unreported experiments by myself and Dennis Gunderson of FPL, which show that sandwich facing supported with foam cores gives higher edge loads than the same facings supported by a conventional corrugating medium. (The effect of scoring on compression strength is another factor under investigation to explain these differences.)

A key idea to solve this problem is included in research by Piotr Wrzecioniarz showing that sandwich structures having a core with a nonuniform density gradient (that is, one that increases in density as it approaches the facing) can be 68% stronger under edgewise loading than one with a same-weight core with a uniform density gradient.[2]

The work of this report dwells mainly on experiments aimed at FPL Spaceboard having a range of weight and thicknesses comparable to that of C-flute commercial corrugated fiberboard (CCF).

Our objectives here are to introduce the FPL Spaceboard concept, to demonstrate the superior strength-to-weight ratio for FPL Spaceboard tested in edgewise compression, to determine the appropriate cell size for FPL Spaceboard having the thickness and basis-weight range comparable to CCF, and to demonstrate the importance of pressure distribution when press drying fiber products made from wet pulp fibers.

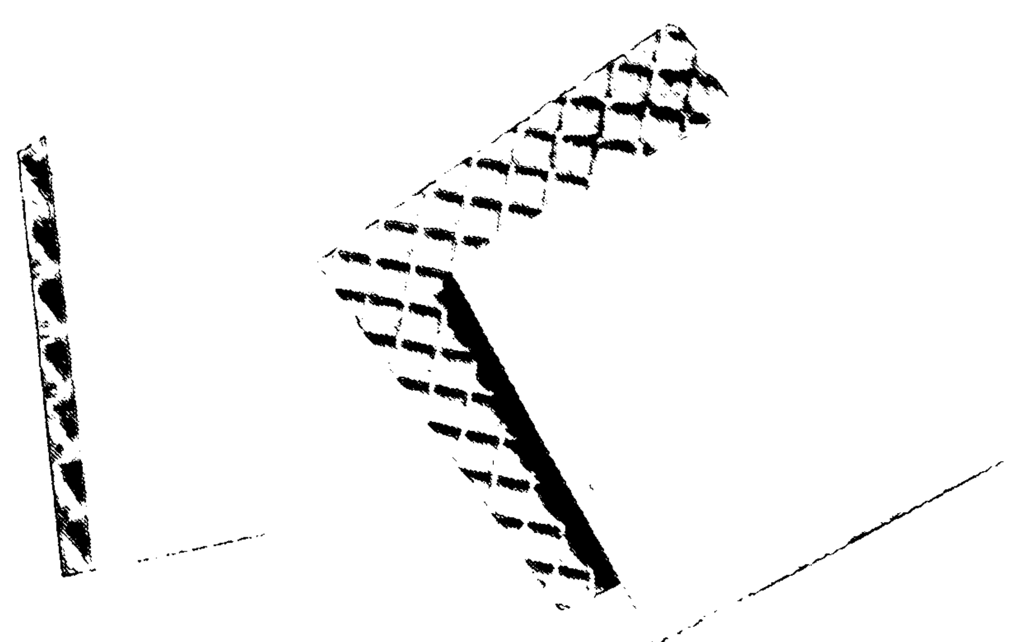
What is FPL Spaceboard?

FPL Spaceboard is a pulp-molded fiber or composite structural sandwich usually made of two identical components bonded together at the neutral axis of the sandwich. It may or may not contain natural or synthetic polymers as a binder or other component. An example of FPL Spaceboard and component parts is shown in Fig 1. An edgewise view of this sandwich (Fig. 2) is contrasted with CCF of similar weight and thickness. Components can also be

[1]Public patent applied for.

[2]Wrzecioniarz, Piotr. J. Eng. Mech. 109(6): 1460(1983).

1. FPL Spaceboard and components.



made by combining wet webs with a pulp-molded core.

Sandwich thickness, weight, composition, cell size, cell pattern, core flange, shape and thickness, and facing thickness are all potential design variables that should be adjusted for each structural design and service application.

For superior FPL Spaceboard sandwich performance, the core cell walls or flanges should flare out at the point of blending with the facing. The resultant gradually increasing volume of core or core density (when viewed from the neutral axis outward) provides increased support for the sandwich faces, which in turn increases the specific sandwich edgewise compression and bending strength.

This description of spaceboard is applicable to structural panels, including those up to several inches thick, and FPL research is presently underway on these thicker applications.

Methods and procedures

Samples of FPL Spaceboard reported in this study were made 5 × 5 cm or 6.5 × 6.5 cm in size. This small size facilitated repeated modification of press mold variables. The samples were also large enough to provide one or two edgewise compression specimens. Edgewise compression was the only test made. While other properties can be critical to performance, the edgewise compression strength of containerboard is usually recognized as the single most important property.

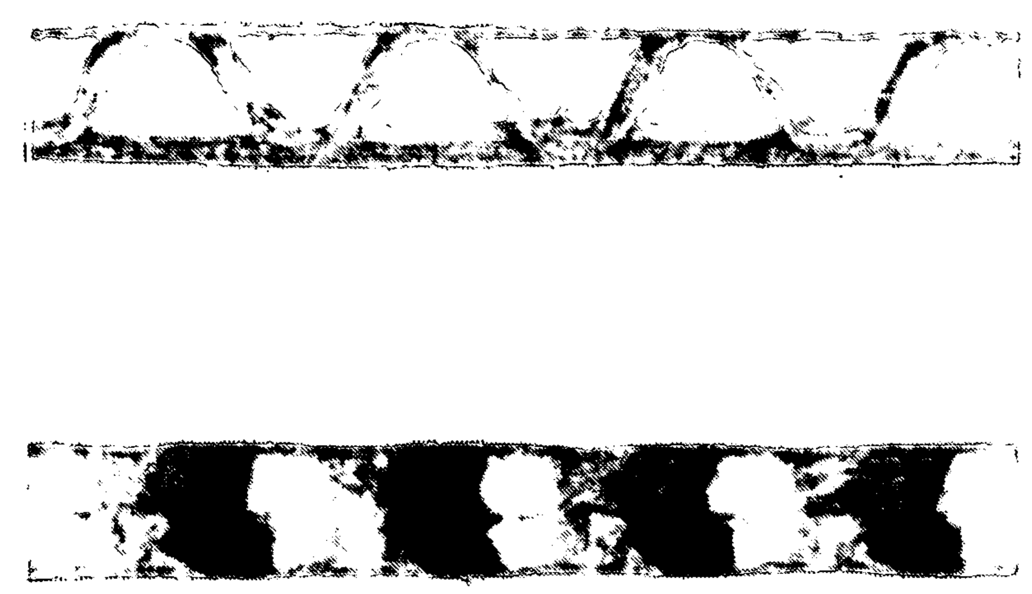
Pulps used in the manufacture of spaceboard components included an unbeaten 70%-yield birch kraft pulp and an unbeaten 60%-yield oak kraft pulp. One sample was also made from slushed postconsumer news.

The molds for pressing and drying were made from either aluminum or heat-resistant silicone rubber similar to that shown in Fig. 3. Cell sizes of the molds were 5.08, 7.62, and 11.5 mm.

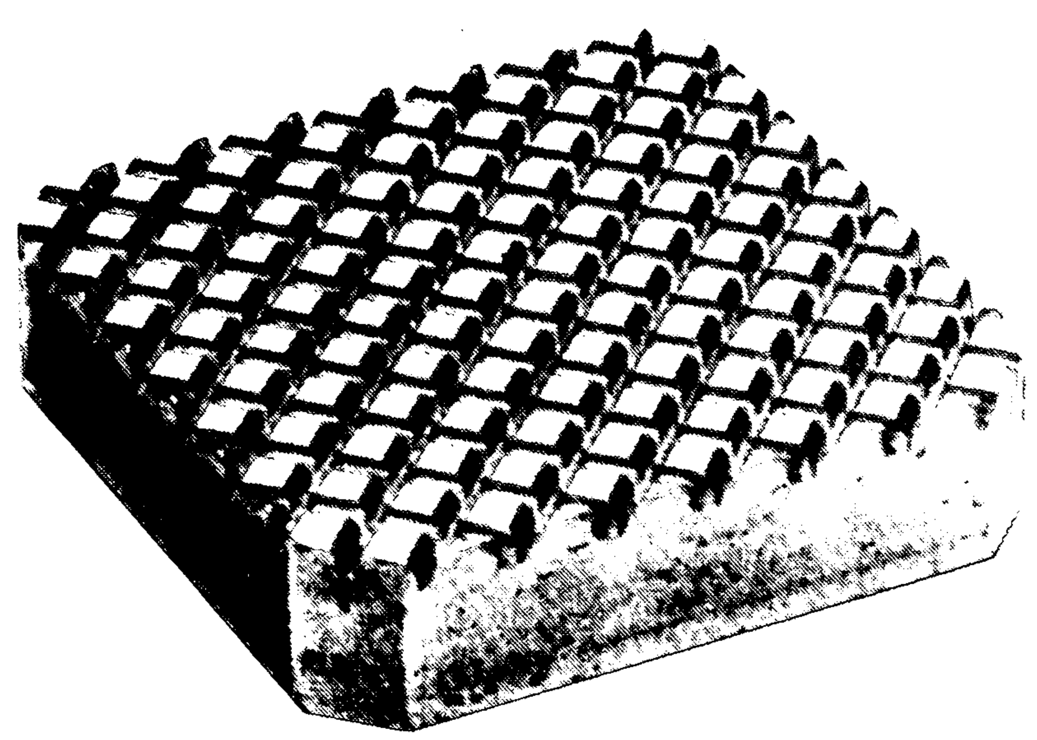
Samples were press dried in a hot platten press at 190°C. A fine screen (88 × 92 phosphor bronze or 150-mesh stainless steel) was placed over the pulp at time of pressing to allow for moisture escape. Drying time was 20 s-2 min.

In the case of samples pressed against the rubber mold,

2. Edgeview of FPL Spaceboard (top) contrasted with C-flute commercial corrugated fiberboard having the same basis weight.



3. Aluminum mold for press drying FPL Spaceboard (rubber molds were replicated from metal molds).



the mold and sample were encased in an aluminum retainer to prevent spreading and unwanted distortion of the rubber when the pulp web was being dried under heat and pressure.

Satisfactory densification of the sample required about 1000 Pa of pressure when using aluminum molds. When press drying with rubber molds, I obtained equivalent densification with only 70 Pa of pressure.

The basis weight of the finished FPL Spaceboard sandwiches, including adhesive (polyvinyl acetate), ranged from about 400 to 1200 g/m². One sample was made to a very low basis weight of 90 g/m², and a special sample was made from slushed newsprint at 1000 g/m².

Edgewise compression tests were made on 50 × 32 mm samples conditioned to equilibrium at 73°F, 50% RH. Compression tests were made using a H&D tester.[3] To ensure failure within the body of the sample, specimen ends were dipped in hot paraffin before being conditioned for test.

Results and discussion

Edgewise compression test results are plotted on Figs. 4 and 5, along with values for CCF tested with flutes parallel to the test. Values for test perpendicular to flutes were estimated from B- and A-flute test results obtained from FPL files.

Figure 4 shows data for samples made using metal molds with a 5-mm cell size, pressed with about 1000 Pa of pressure from either oak or birch pulp. These data show FPL Spaceboard at 600 g/m² to be from 30% to 37% stronger (6.5-8.4 kN/m and 6.5-8.9 kN/m) than the average value for C-flute containerboard tested in its strongest direction. As expected, birch pulp at 70% yield produced stronger board than one made from oak kraft pulp at 60% yield. When compared at a basis weight of 1000 g/m², FPL Spaceboard from oak was 67% stronger than the CCF and the FPL Spaceboard from birch pulp was 125% stronger (11.2-25.3 kN/m) than the CCF. Of course, when FPL Spaceboard compression strength is compared with CCF tested in its weaker direction, the differences were more dramatic in that they ranged anywhere from 180% to 216% greater (3-8.9 kN/m to 8-25.3 kN/m) over the basis weight range of 600 to 1000 g/m².

The point at 1000 g/m², marked ∇ in Fig. 4, is the result of one test made by press drying spaceboard using slushed and unrefined old newsprint pulp bonded with 2% PVA adhesive based on dry weight.

The use of silicone rubber molds in place of metal molds allows us to press at much lower pressures. We see in Fig. 5 data for birch pulp using FPL Spaceboard made in cell sizes of 5.08 and 7.62 mm. (Tests were also made at 11.5 mm, and these data fell between that shown for the smaller-cell-size data.) These test results indicate a very important point; high-strength spaceboard can be achieved with relatively low (70 Pa) pressing pressures, even when spaceboard is being made using an unbeaten high-yield pulp fiber. This fact suggests commercialization of the FPL Spaceboard concept will be easier than it would be if metal molds and higher press pressures were required. The 7.62-mm spacing seems to be near the ideal cell size (for the weight and thickness range covered).

Conclusions

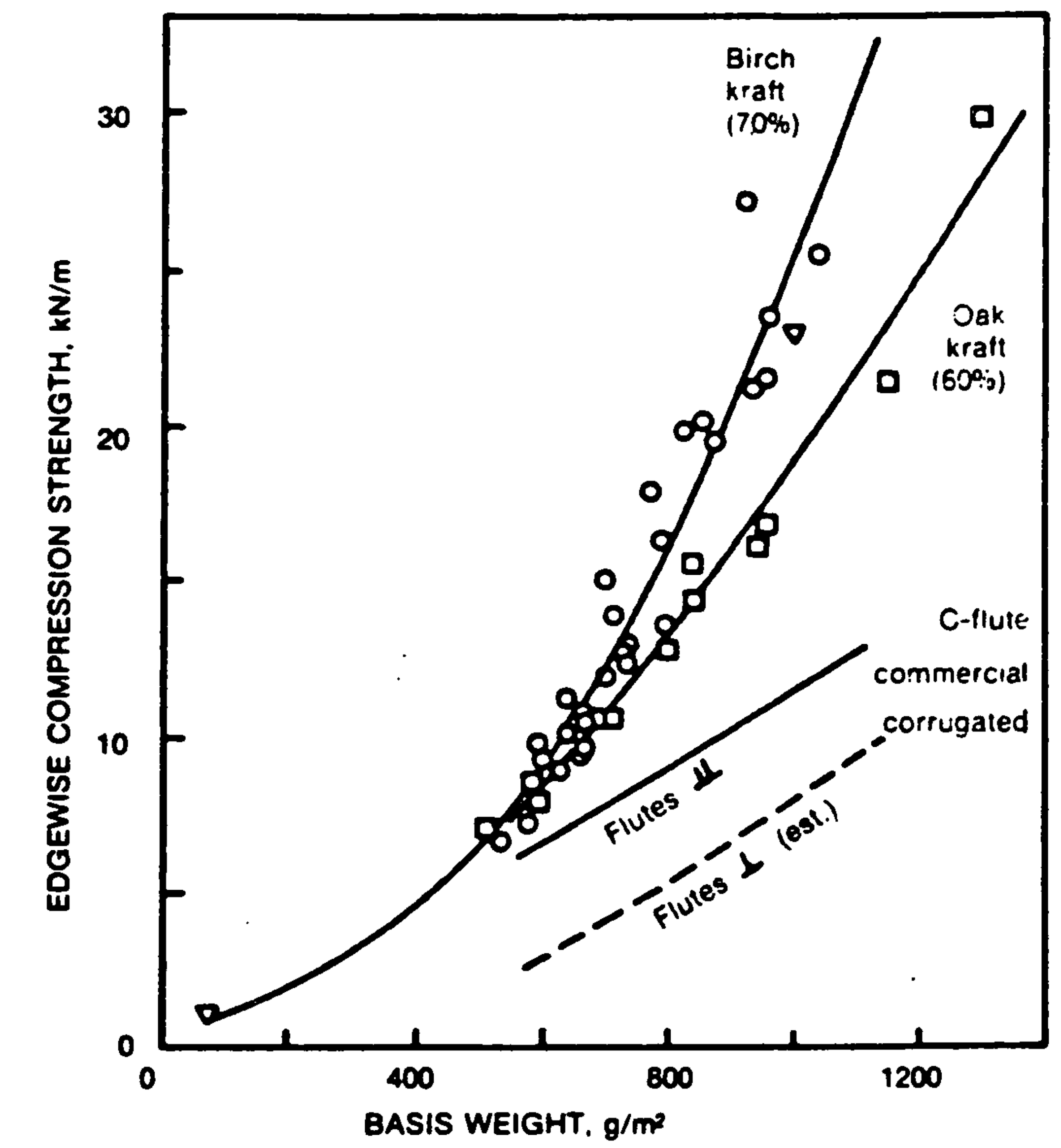
When made in weight and thickness equivalent to CCF, FPL Spaceboard material using high-yield hardwood pulp has much higher edgewise compression strength than can be expected from CCF using low-yield softwood pulp. It will also have equal strength in either of its principal directions.

The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin. This article was written and prepared by U.S. Government employees on official time, and it is therefore in the public domain (i.e., it cannot be copyrighted).

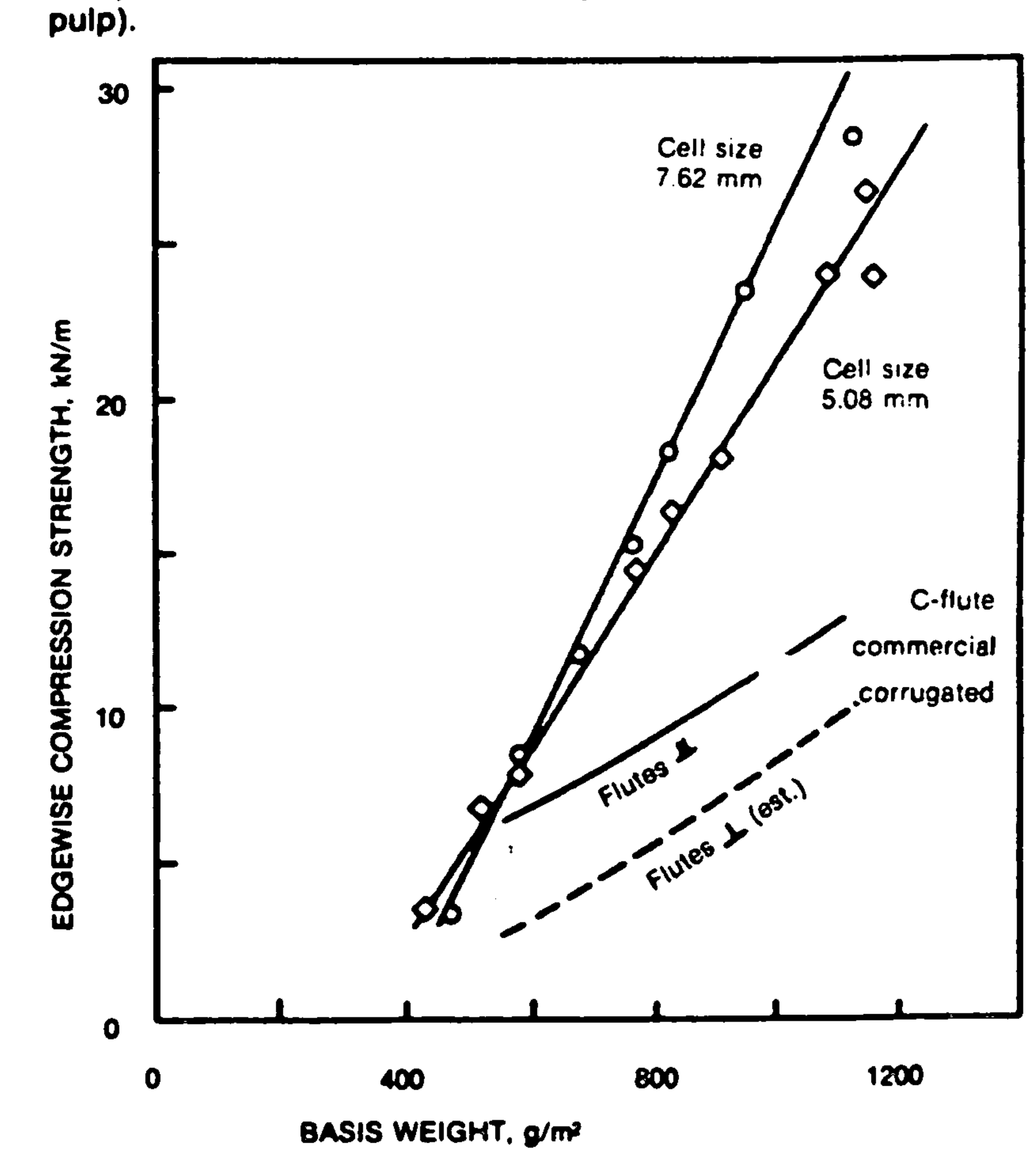
The author wishes to acknowledge the cooperation and assistance of FPL technician Paul Cahoon and FPL machinist John Simonsen.

[3]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

4. Edgewise compression test results of FPL Spaceboard formed from metal molds and press dried at 1000 Pa pressure compared with commercial corrugated fiberboard (5-mm cell size). ∇ = one test using unrefined old newsprint pulp.



5. Edgewise compression test results of FPL Spaceboard formed from silicone rubber molds and press dried at 70 Pa pressure compared with commercial corrugated fiberboard (birch kraft pulp).



Appendix 11A

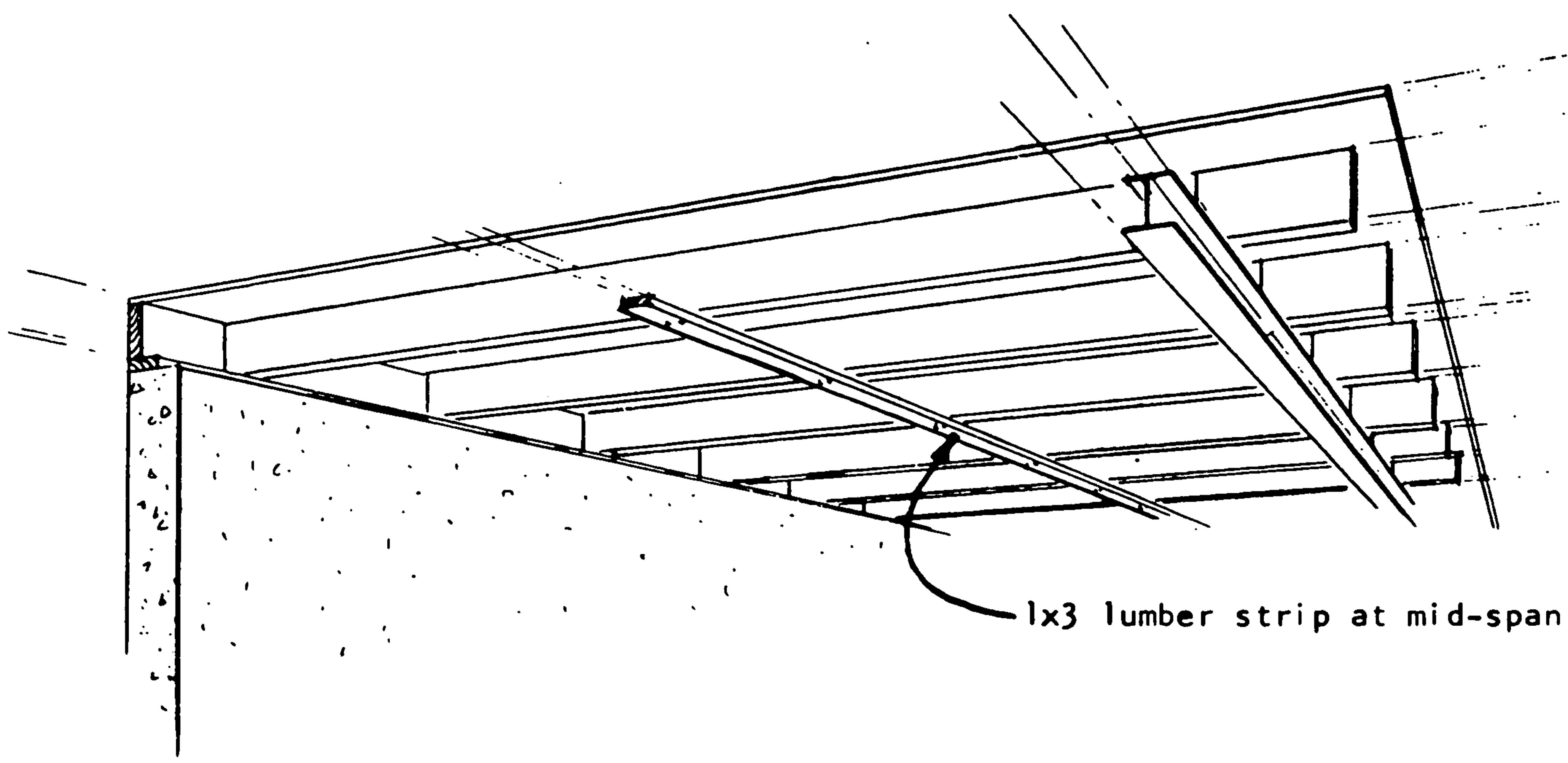


FIGURE 4-G. Floor bridging is not normally required, however, where greenjoists have a known tendency to warp, a 1x3 strip of wood will provide restraint where the ceiling is otherwise unfinished.

Appendix 11B

4.4.3 <u>Off-Center Spliced Joist Design</u>

If two unequal joist lengths are spliced together so that the splice occurs at a certain point off-center, joist spans may be increased significantly. This arrangement provides structural continuity over the center support as compared to the use of individual joists which start at the center support (see Figure 4-D). It can provide up to a forty percent increase in joist stiffness — the basis for residential floor joist design.

Under theoretical uniform load conditions for common residential floor spans, the bending stress on a continuous joist is zero at a point several feet from the center support. A spliced joint located at or near this point is subjected to minimal bending moment. This permits use of a splice having less moment resistance than the joist itself. The splice may be formed with plywood or metal plates applied to both sides of the joist.

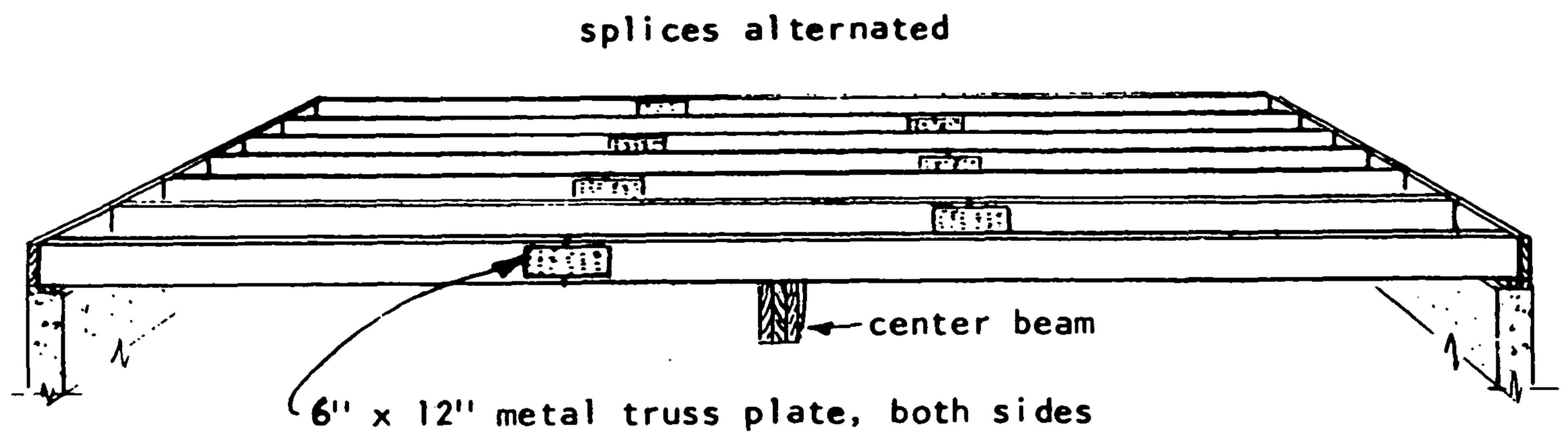
Research conducted by NAHB Research Foundation, Inc., for HUD showed that properly designed 2x8 spliced joists, spaced at 2 feet on center and with glue-nailed 5/8" plywood sheathing, are structurally adequate for a 28-foot-deep house with center bearing. A floor section constructed of spliced joists in combination with a glue-nailed plywood subfloor was tested in the laboratory. Full-scale loading tests showed this floor system to be substantially stiffer and stronger than commonly used code requirements (see Technical Supplement C).

This floor system was used in the OVE demonstration house described in Chapter 1. Full-length 28-foot joists were preassembled from No. 2 Hem-Fir lumber by splicing a 2x8-10 to 2x8-18. The splice was formed with standard 6"x12" truss plates applied to both sides. Joists were installed 2 feet on center, with the splices alternating on either side of the center support (see Figure 4-D). A 5/8 inch thick tongue and groove plywood sheathing was glue-nailed to the joists with the tongue and groove joint glued. The full length spliced joists handled well under field conditions and greatly simplified floor construction to provide a significant reduction in labor cost. The resulting floor proved satisfactory in every respect.

Based on this experience, a 2x8 off-center spliced joist floor system, as described, is considered suitable for houses up to 28 feet in depth with center bearing. Spliced joists for other typical house depths may be fabricated from standard lengths of the same quality of 2x8 lumber, as shown in Figure 4-D.

Additional research to develop more complete span tables for off-center spliced joists with glued subfloors is now under consideration. Off-center spliced joists offer all of the benefits of an in-line joist layout, plus a significant increase in spanning capability over conventional joists.

Appendix 11B



Note: Use lumber with minimum "E" = 1,400,000 and "f" = 1,350 (repetitive member). Use glue-nailed plywood floor

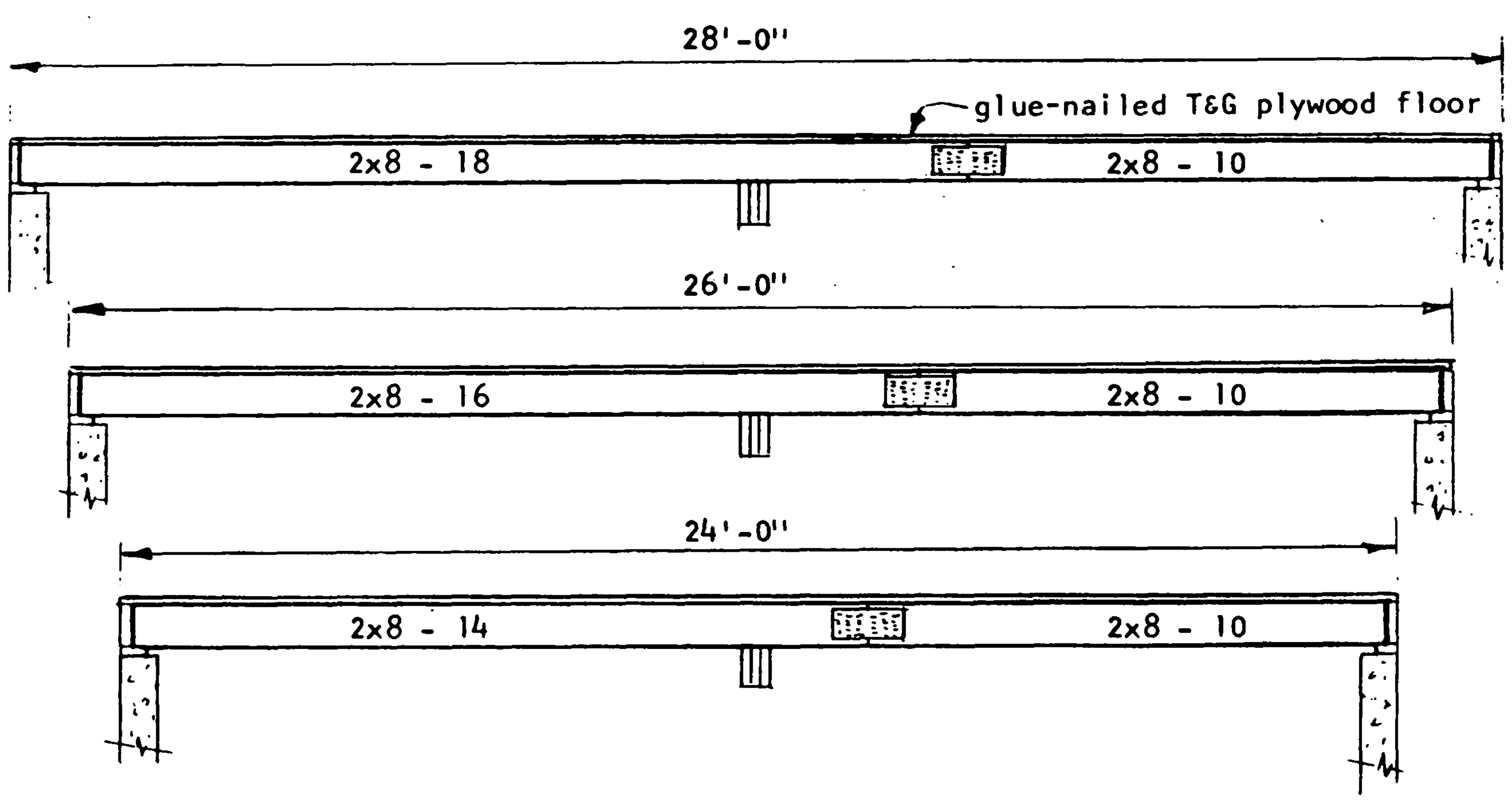


FIGURE 4-D. Off-center spliced joist designs span further than simple joists of the same dimension

Appendix 11C

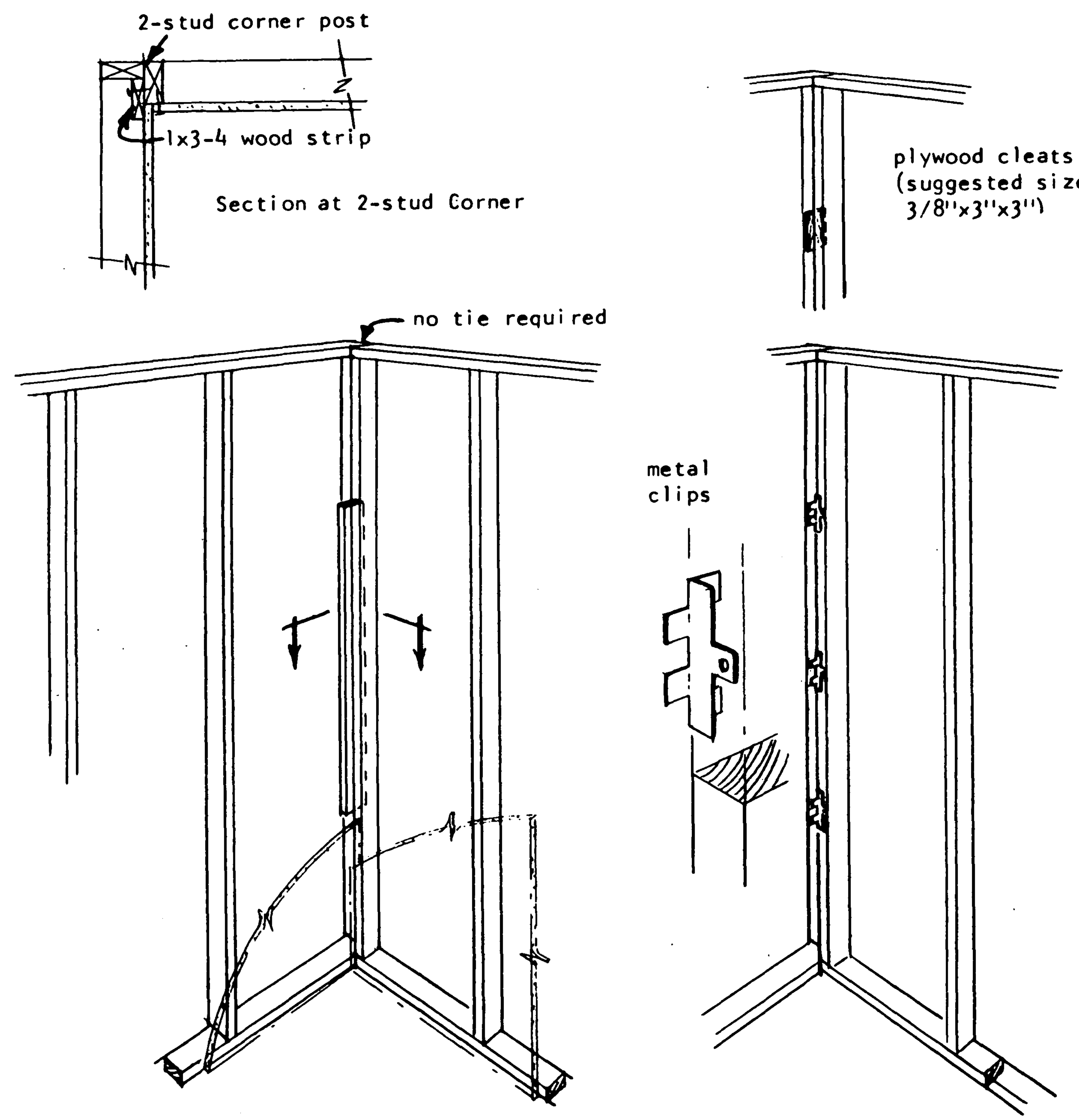


FIGURE 5-B. Alternate methods for providing drywall back up with a 2-stud "corner post."

Appendix 11D

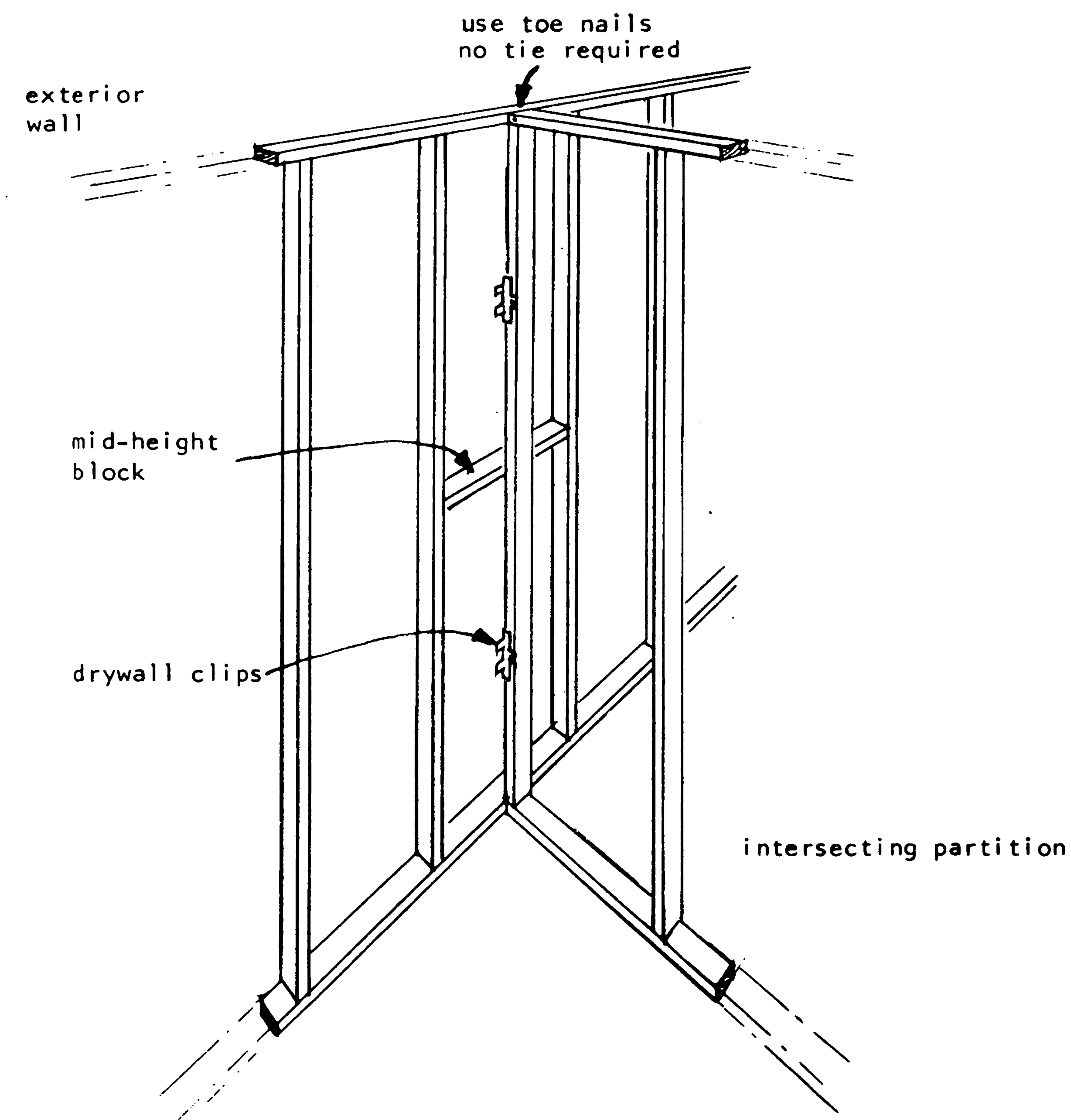


FIGURE 5-C. Attachment of partitions and drywall backup at exterior walls without using a partition "post".

Appendix 12

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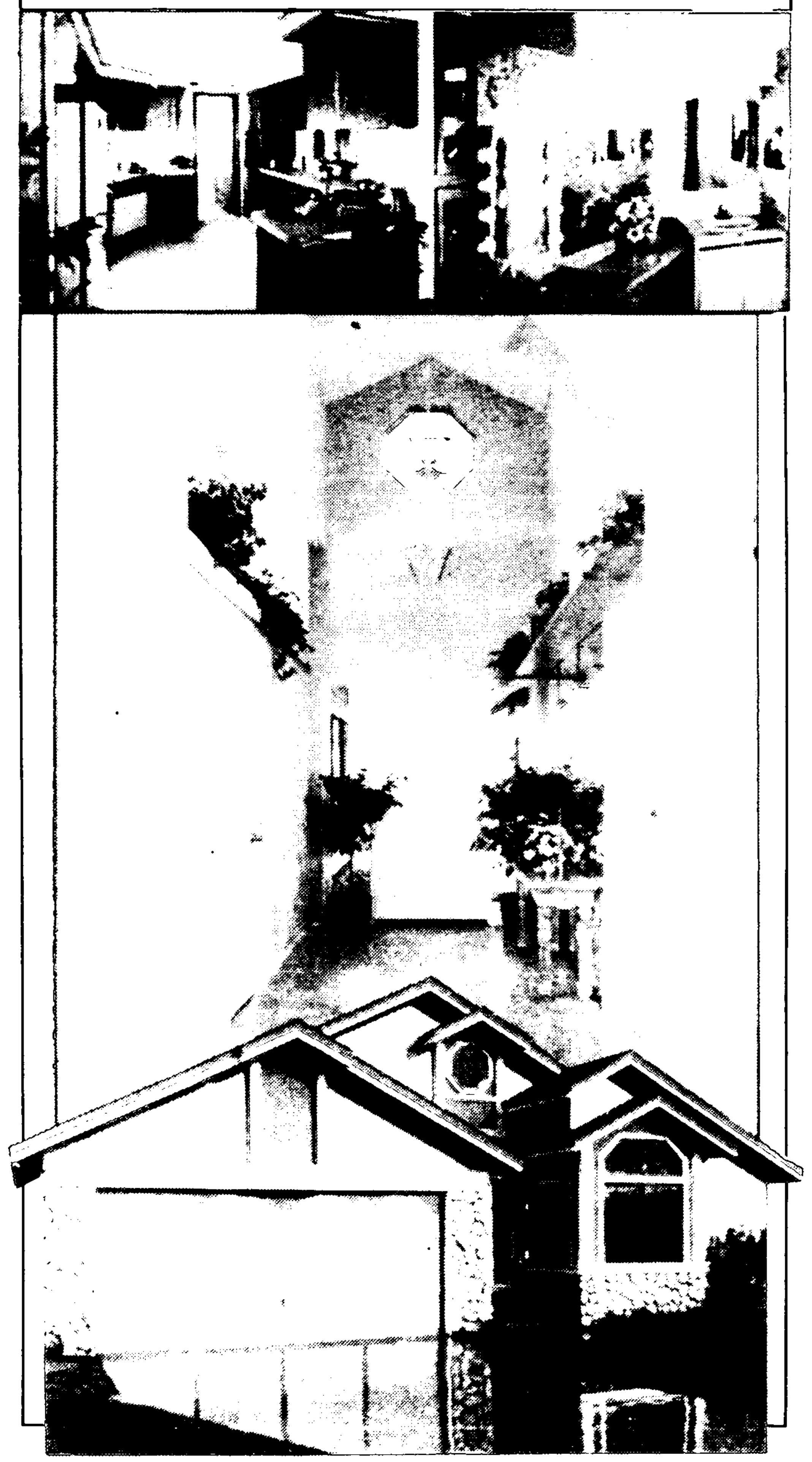
FACTS

ABOUT THE MANUFACTURED HOUSING INDUSTRY



MANUFACTURED HOMES

Most homes built today have factory-made components such as roof trusses. Because there is better quality control and work does not stop for the weather, factory-built housing is efficient and saves money.

Many homes are built entirely in a factory. Most of these are manufactured homes. In 1986, a quarter of *all* new single-family homes sold in America were manufactured homes. Other types of factory-built homes include modular houses, panelized houses, log and kit houses.

Manufactured homes used to be called mobile homes. But since they are permanent residences—most are never moved—and since their wheels and axles are not for continuous use but simply are a built-in means of transportation to the homesite, they are not called mobile homes any more. The U.S. Congress recognized this in 1980 when it changed the name to manufactured homes in all federal laws and publications.

The main difference between manufactured and modular homes is the building code that applies to them. Manufactured homes are built to federal standards and are inspected by federally certified agencies. Modular houses are built to state and local codes.

Federal Standards

All manufactured homes built since June 15, 1976 must conform to the National Manufactured Home Construction and Safety Standards established by the U.S. Congress. The standards, the only national building code, are administered by the U.S. Department of Housing and Urban Development. Manufactured homes are the only homes with a national building code. Every manufactured home has a red and silver seal certifying that it was built in compliance with the federal code.

This building code regulates manufactured home design and construction, strength and durability, fire resistance and energy efficiency, as well as the installation and performance of heating, plumbing, air conditioning, thermal and electrical systems. The federal program also regulates factory certification.

STYLE AND FEATURES

Manufactured homes offer all the style and amenities buyers demand for comfortable and gracious living. Exteriors are designed for easy care and run the gamut from formal to informal, traditional to contemporary treatments.

Interiors of homes can be modest or feature spacious living rooms with vaulted ceilings, full dining rooms, eat-in kitchens with the latest conveniences, elegant bedrooms with walk-in closets, dressing areas and bathrooms with recessed tubs and whirlpools.

Many new manufactured homes are sold fully furnished with major appliances, draperies, lamps and carpeting in a choice of decors and colors included in the price. Of course,

MANUFACTURED HOME TRENDS

Manufactured Home	Length	Width	1982	1983	1984	1985	1986
Single Section	48′ to 76′	12′ to 14′*	79%	73%	71%	67%	63%
Multisection	36′ to 70′	24′ to 28′	21%	27%	29%	33%	37%
			100%	100%	100%	100%	100%

*There are some 16 foot-wide single-section homes produced in limited market areas

	1984		1985		1986	
Type of Home	Retail Price	Average Price	Retail Price	Average Price	Retail Price	Average Price
Single Section	$ 8,250-36,000	$17,700	$ 8,400-37,000	$17,800	$ 8,400-37,000	$17,800
Multisection	$15,000-65,000	$30,450	$15,000-70,000	$30,100	$15,000-70,000	$30,800

COST AND SIZE COMPARISONS OF MANUFACTURED HOMES AND SITE-BUILT HOMES SOLD

Manufactured Homes	1982	1983	1984	1985	1986
Average Sales Price (All Lengths & Widths)	$19,700	$21,000	$21,500	$21,800	$22,400
Cost per Square Foot	$19.70	$20.29	$20.48	$20.57	$20.18
Average Square Footage	1,000 sq. ft.	1,035 sq. ft.	1,060 sq. ft.	1,060 sq. ft.	1,110 sq. ft.
Single Section					
Average Sales Price	$17,200	$17,600	$17,700	$17,800	$17,800
Cost per Square Foot	$19.01	$19.13	$19.03	$18.84	$18.84
Average Square Footage	905 sq. ft.	920 sq. ft.	930 sq. ft.	945 sq. ft.	945 sq. ft.
Multisection					
Average Sales Price	$28,400	$30,500	$30,450	$30,100	$30,800
Cost per Square Foot	$21,52	$22.59	$22.30	$21.97	$22.08
Average Square Footage	1,320 sq. ft.	1,350 sq. ft.	1,364 sq. ft.	1,370 sq. ft.	1,395 sq. ft.
Site-Built Homes	**1982**	**1983**	**1984**	**1985**	**1986**
Average Sales Price	$83,900	$89,800	$97,600	$100,800	$111,900
Land Price*	$16,780	$17,960	$19,520	$ 20,160	$ 22,380
Price of Structure	$67,120	$71,840	$78,080	$ 80,640	$ 89,520
Cost per Square Foot	$39.25	$41.65	$43.87	$45.18	$ 49.05
Average Square Footage (Living Space)	1,710 sq. ft.	1,725 sq. ft.	1,780 sq. ft.	1,785 sq. ft.	1,825 sq. ft.

Source: U.S. Department of Commerce and Jon Whitney Associates
*National Association of Home Builders Research Foundation

buyers can provide their own furnishings. Options such as air conditioning, garbage disposals and compactors, central vacuuming and stereo systems are available.

Homes can be heated by natural gas, LP gas, oil or electricity. Energy efficiency requirements are established by federal regulation for three major temperature zones. But many energy-saving options, from automatic set-back thermostats to double- and triple-glazed windows, air infiltration barriers and extra insulation, are available and selected by 90% of the buyers in the colder climates. Some models offer a choice of energy-efficient appliances.

MANUFACTURED HOUSING INDUSTRY

There are some 130 companies building manufactured homes in about 320 factories throughout the United States. In 1986, manufactured home sales amounted to almost $5.5 billion.

The average manufactured home factory has 64,000 square feet. It takes about 250 worker hours to build a manufactured home.

Retailers

There are about 8,500 manufactured home retailers in the United States. Most homes are bought from these independent business people. Some homes are sold through sales centers owned and operated by the manufacturer.

The home purchase price generally includes transportation and installation on the homesite. Most retailers can arrange for customer financing and insurance.

Suppliers

The manufactured housing industry is a $3-billion-plus market for producers of building products, supplies and services. Suppliers represent a broad spectrum of the nation's leading firms, from large national companies selling products to many industries to smaller companies specializing in items for manufactured home builders. In addition, the industry provides desirable markets for service firms such as land developers, financial institutions, aftermarket distributors and insurance companies.

MANUFACTURED HOUSING DEVELOPMENTS

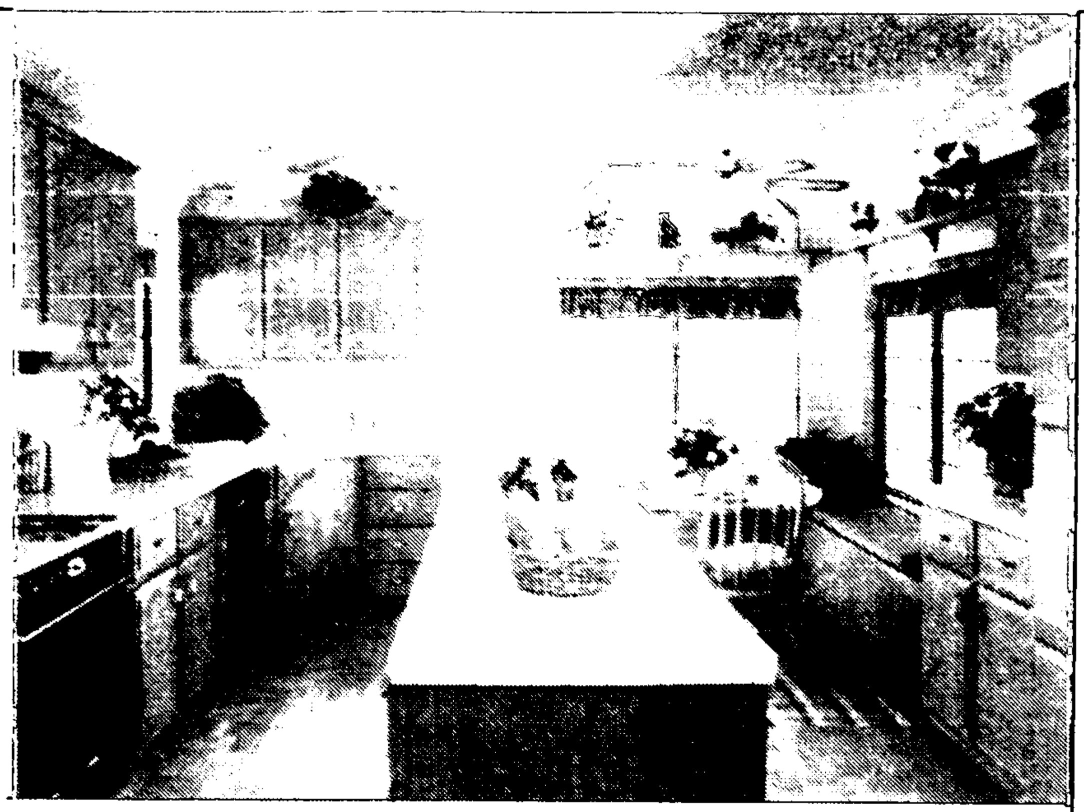
Nearly 245,000 new manufactured homes were sold in 1986. Of those, 37% were multisection homes, up from 33% in 1985 and 29% in 1984. Average prices of single- and multisection homes and all manufactured homes combined increased only modestly in the last several years. The square foot construction cost of manufactured homes is less than half that of site-built homes and has decreased slightly over the last year.

Single-Site Occupancy

Today's manufactured homes are the equal of their site-built counterparts in construction and appearance. Nearly 60% of manufactured homes are placed on individually owned property, and 16 states have passed laws prohibiting discrimination against them. The trend is toward fairer treatment in zoning. Sales of manufactured homes in combination with land, where the home is permanently attached to a foundation with permanent utility hookups, continue to increase.

Manufactured Home Communities

The traditional manufactured home rental community with its amenities for the use of the tenants is a very successful pioneering effort in what planners today call the Planned Unit Development (PUD). There are more than 24,000 rental communities nationwide with more than 1.8 million homesites. Most newer communities have an average of 150 to 175 sites. Homesite rentals range from $50 to $300 per month, with the greater percentage renting for between $80 to $150 per month. While it is still common for the home buyer to rent a homesite and facilities, many are purchasing and locating their manufactured homes in subdivisions, cooperative ownership and condominium developments.



COMPARISON OF MANUFACTURED HOME SHIPMENTS TO SALES OF NEW SINGLE-FAMILY SITE-BUILT HOMES

	1982	1983	1984	1985	1986
Site-Built Homes* Sold					
(in Thousands)	412	623	639	688	750
Percent of Total	63%	68%	68%	71%	75%
Manufactured Homes Shipped					
(in Thousands)	239	295	295	283	245
Percent of Total	37%	32%	32%	29%	25%
Total New					
(in Thousands)	651	918	934	972	995

*U.S. Department of Commerce, Bureau of Census Data Conventional Homes, C25 Construction Reports

COMPARISON OF MANUFACTURED HOME SHIPMENTS TO ALL PRIVATELY OWNED SITE-BUILT HOUSING STARTS

	1982	1983	1984	1985	1986
Site-Built Homes					
(in Thousands)	1,062	1,703	1,750	1,742	1,805
Percent of Total	82%	85%	86%	86%	88%
Manufactured Homes					
(in Thousands)	239	295	295	283	245
Percent of Total	18%	15%	14%	14%	12%
Total New					
(in Thousands)	1,301	1,998	2,045	2,025	2,050

Source: U.S. Department of Commerce, Bureau of Census Housing Starts, C20 Construction Reports

Lenders, recognizing the feasibility of manufactured home communities, are entering this field as suppliers of development and long-term mortgage funds. The Federal Housing Administration (FHA) can insure loans on new manufactured home rental developments and for rehabilitating existing communities for up to 90% of FHA's appraised values. Although there is no dollar limitation on the amount of the loan, the per-site limitation is $9,000 with up to a 75% increase permitted in high-cost areas.

Local governments, too, are recognizing the possibilities for manufactured homes in solving housing problems. Through their public housing authorities, some are developing and managing manufactured home communities.

Urban Housing

Manufactured homes are ideal for scattered city lots as part of urban infill projects or developments. Much urban redevelopment relies on building high-rise housing. The technology and cost efficiency of manufactured homes can restore single-family home ownership to urban areas.

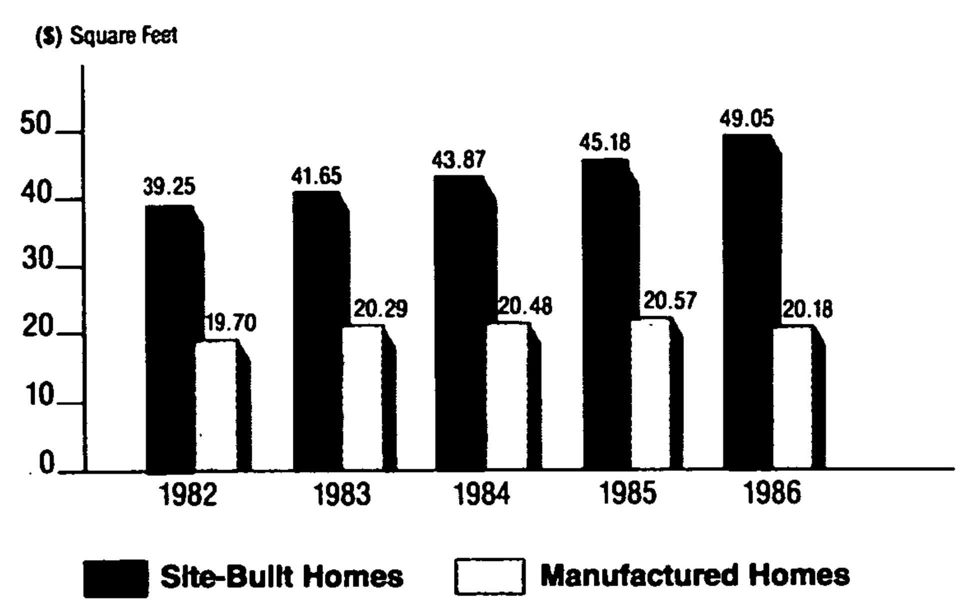
HOMEOWNER TRENDS

Approximately 12 million people live in more than 6 million manufactured homes, according to Manufactured Housing Institute estimates. With most of the nation's households priced out of the site-built single-family home market, according to the U.S. Department of Housing and Urban Development, manufactured homes have become an attractive choice for prospective buyers.

A 1984 nationwide survey of nearly 10,000 manufactured home residents by Foremost Insurance Company showed that most plan to stay in their homes indefinitely or move to another manufactured home. The survey showed that more than 70% of new buyers are under 40, with an average age of 36.6 years. Their median household income is $19,800 and 16% have annual family incomes topping $30,000. Most buyers (87%) finance their homes.

All types of conventional and government-backed financing plans are available for manufactured homes. The most common method of financing manufactured homes is through a retail installment contract. These can be arranged through the retailer or by the home buyer directly with a financial institution. Manufactured home financing, like other types of financing, is subject to federal truth-in-lending regulations requiring disclosure of the annual percentage rate (APR) of interest being charged.

COST PER SQUARE FOOT



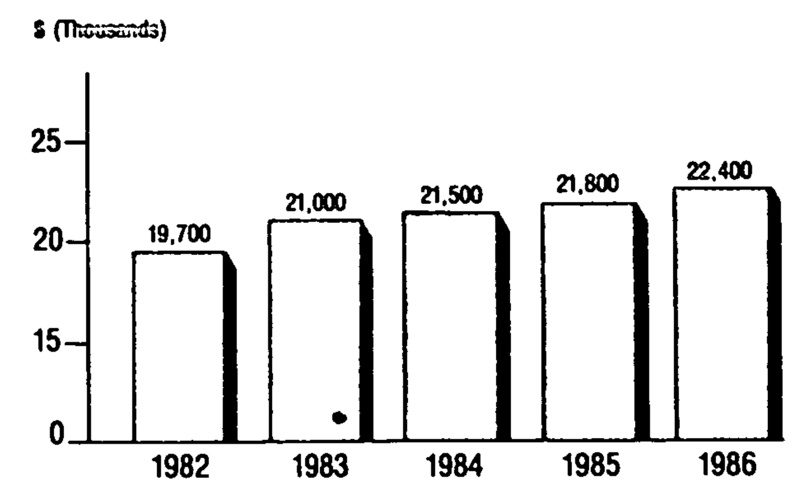
The Veterans Administration (VA) guarantees loans for the purchase of new and existing manufactured homes and homesites, provided all VA requirements for construction, design and safety are met. The VA will guarantee a manufactured home loan up to 50% of the principal amount or $20,000, whichever is less.

Under the current program, the loan terms are:

1. 15 years for the purchase of a homesite only on which to place a manufactured home already owned by a veteran;
2. 20 years to purchase a single-section manufactured home or combination home and homesite;
3. 23 years to purchase a multisection manufactured home only, or
4. 25 years to purchase a multisection manufactured home and homesite.

A down payment is not required under the VA loan program, but one may be required by the lender depending on loan underwriting guidelines.

MANUFACTURED HOMES AVERAGE SALES PRICE



Manufactured Home (Only) Loan Program

The National Housing Act provides that federal insurance may be granted to financial institutions for loans covering the purchase of a manufactured home. It is a coinsurance program that provides 90% insurance to the lender. The borrower must intend to use the home as a principal place of residence and must have enough money to make the minimum down payment.

Under this program, the maximum insurable manufactured home loan is $40,500 for the purchase of a single-section or a multisection home. The loan term may not exceed 20 years. The minimum down payment required on a loan to purchase a new manufactured home is 5% of the first $5,000 of the total cost plus 10% of the amount in excess of $5,000. For a loan to purchase a previously-owned manufactured home, the minimum down payment is 10% of the purchase price of the home.

The maximum loan amount guaranteed for a combination single-section or multisection manufactured home and homesite is $54,000. The maximum term of the insured loan is:

1. 20 years for a single-section manufactured home and a suitably developed homesite;
2. 25 years for a multisection manufactured home and a suitably developed homesite, or
3. 15 years for a suitably developed homesite on which to place a manufactured home owned by the borrower.

ANNUAL MANUFACTURED HOME SHIPMENTS

Year	Manufacturers' Shipments to Retailers in U.S.	Estimated Retail Sales (Millions)
1986	244,660	$5,480
1985	283,489	$6,180
1984	294,993	$6,342
1983	295,079	$6,197
1982	238,808	$4,705
1981	240,907	$4,794
1980	221,616	$4,388
1979	277,372	$4,882
1978	275,871	$4,386
1977	267,289	$3,796

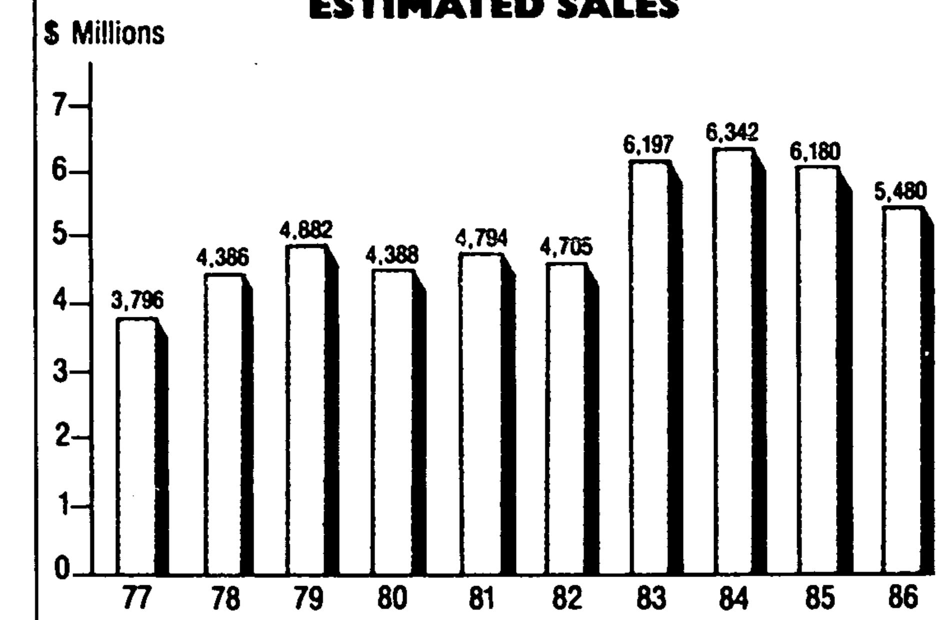
The minimum down payment for a combination manufactured home and homesite must be at least 5% of the first $5,000 of the purchase price plus 10% of the amount in excess of $5,000.

FHA- and VA-insured loans can be pooled by lenders and sold under the mortgage-backed securities program of the Government National Mortgage Association. There are also private pass-through securities markets for manufactured home retail paper.

Loans also can be guaranteed or insured through private sources, allowing the lending institution to effectively manage the normal loan risks.

When a manufactured home is permanently attached to a foundation and sold with land, in many areas it can be financed with a long-term real estate mortgage. Both FHA and VA consider permanently sited manufactured homes, classified as real estate, as eligible for their regular single-family mortgage insurance or loan guarantee programs. Further, the Federal National Mortgage Association and the

ANNUAL MANUFACTURED HOMES ESTIMATED SALES



Federal Home Loan Mortgage Corporation will buy loans backed by manufactured home real estate.

The Manufactured Housing Institute is a nonprofit national trade association of manufactured home builders and their suppliers. Its builder members produce the majority of the nation's manufactured homes. Some 160 supplier firms are members.

From its headquarters near Washington, DC, MHI works with federal regulatory agencies and Congress to promote the interests of the industry and its home buyers. The Institute works with private and government lenders for equitable treatment in financing and publishes statistical reports about the industry. Its technical activities program works to maintain reasonable construction standards to keep manufactured homes safe and comfortable.

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8-87 100K

Appendix 13

List of Organisations and Contacts

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Amos Winter Homes Inc
RR 5 Box 168B
Glen Orne Drive
Brattleboro
VERMONT 05301
(David Bergeron)

Building Systems Council
(see National Association of Home Builders)

County of Riverside
4080 Lemon Street
Riverside CALIFORNIA 92501
(Michael Shearer, Supervising Planner)

Custom Mobile Homes
7717 Church Ave
Highlands, CALIFORNIA 92346
(Bill Sack, Sales Manager)

Fleetwood Enterprises, Inc.
3125 Myers Street
Riverside, CALIFORNIA 92523
(Nelson Potter, Director International Housing)

Lindal Cedar Homes Inc.
4302 S. 104th Pl
Seattle
WASHINGTON 98178

Manufactured Housing Institute
1745 Jefferson Davis Highway
Suite 511
Arlington VIRGINIA 22202
(Bruce Butterworth, Communications Director)

Nanticoke Homes
P.O. Box K, Greenwood
DELAWARE 19950
(Wanda Bowers)

National Association of Home Builders (NAHB)
15th & M Streets
N.W. Washington D.C. 20005
- Building Systems Council
  (Jim Birdsong, Executive Director)

  Economics, Housing Policy and Mortgage
  Finance Division)
  (Robert Villaneuva, Research Economist)

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(Kevin O'Sullivan, Research Engineer)

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Madison, WISCONSIN 53705
(Ron Wolfe, Wood Products Research)

Wausau Homes Inc.
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(Tom Mason)

Wick Building Systems
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The Building Research Association of New Zealand is an industry-backed, independent research and testing organisation set up to acquire, apply and distribute knowledge about building which will benefit the industry and through it the community at large.

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