THE ANGIRRAQ: LOW COST PREFABRICATION IN ARCTIC HOUSES

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ABSTRACT. Basic stressed skin panels with full thick insulation and cedar plywood exterior are combined with open-joint detailing to form a simple northern hut, at very low cost. Shear dowels and continuous chords tie the assembly to form a rigid box. A new two-storey arctic house shows the further utilization of the principles.

RÉSUMÉ. *L'anquirraq: Préfabrication de maisons arctiques à prix modique.* Des panneaux de base à revêtement contraint, avec pleine isolation et surface extérieure en contreplaqué de cèdre, sont combinés avec une charpente "ouverte" pour former une hutte nordique simple à très bas prix. L'ensemble, lié par des chevilles de cisaillement et des cordages continus, forme une boîte rigide. Une utilisation plus poussée de ces principes s'appliquerait aussi à une nouvelle maison arctique à deux étages.

REZI͡UME. *Ankirrak: Deshevye sbornye doma dli͡a arktiki izgotovlennye zavodskim sposobom.* Ochen' deshevai͡a khizhina dli͡a severa sostavli͡aetsi͡a iz paneleĭ, sdelannykh iz rasti͡anutykh shkur, polnost'i͡u podbitykh tolstoĭ izoli͡at͡sieĭ s kedrovoĭ fanernoĭ oblit͡sovkoĭ snaruzhi i soedinennye otkrytym stykom. Rasti͡azhnye shponki i sploshnai͡a uvi͡azka verevkami prevrashchai͡ut sobrannye paneli v zhestkui͡u khizhinu. Novyĭ dvukhètazhnyĭ arkticheskiĭ dom predstavli͡aet dal'neĭshee primenenie ètogo metoda.

THE HARSH logistics of building in the Canadian North have stimulated both the development and use of advanced prefabricated systems over the past two decades. This paper discusses the most recent attempt to improve and simplify these systems.

In recent years the Department of Northern Affairs and National Resources has turned to highly prefabricated, light-weight units for its building programs, emphasizing the stressed skin plywood approach that has proved itself throughout the North since the late 1940's. In several instances the Division of Building Research of the National Research Council (DBR/NRC) has been privileged to work with the Department on technical aspects of these programs. In early 1964, a small study was carried out that resulted in further improvements and simplifications in low-cost stressed skin design and, in particular, led to the development of the Department's unique little northern hut, known as the Angirraq. The hut has now been tested and the final model is under production for use in the Far North. Its features are also generally applicable for larger arctic buildings and some are relevant to prefabrication in southern Canada.

The Angirraq

Simplicity is the mark of the Angirraq (an Eskimo term for home). The long line of prefabricated arctic houses, developed particularly by military groups, is noted for its lightweight complete prefabrication, ease of erection and demountability, and high insulation value, but in the light of present knowledge, the

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units often appear to be complex and costly. Cross-braces and stays are used to provide strength and rigidity. Joints are pulled together with hidden cam-locks or other intricate hardware; elastomer gaskets are compressed to provide weather-tightness, and costly plastic foams and light metal extrusions and skins are often included. In contrast, most of these are eliminated in the Angirraq hut, and its costs reflect its simplicity: the production models can be built in southern Canada for $4.00 per sq. ft., complete except for services.

The Angirraq is an assembly of 4-in.-thick (10 cm.) stressed skin panels that form floor, walls and roof (Fig. 1). The prototype measured 16 by 24 ft. in plan (4.9 by 7.3 m.); present production models are 16 by 28 ft. (4.9 by 8.5 m.). Unfinished cedar plywood, ⅜-in. thick (0.95 cm.), forms the exterior skin of the walls; ⅜-in. fir plywood forms all other structural skins which are glued to wood frames. The frames are of 2- by 4-in. members 1⅝ in. by 3⅝ (4.1 by 9.2 cm.) in the ladder frame arrangement devised and tested by the Plywood Manufacturers Association of British Columbia. Glass fibre insulation is packed full-thick in the closed panels, with no vapour barrier or venting. The roof is factory-coated with a polychloroprene rubber. The walls slope inward from the 16-ft. floor to form a 13-ft. (4 m.) roof span, the economic limit for the 4-in.-thick roof panels. This slope was incorporated for aesthetic reasons in an attempt to mollify the salt box cries aimed at the typical huts of northern settlements, but it does complicate window and joint detailing and would not be recommended generally.

Assembly and jointing methods are the critical parts of any prefabricated panel building. It is here that the simple Angirraq has much to offer. The floor, roof, and particularly the walls are assembled to form stiff diaphragms or deep beams, which are then tied together to form a rigid box. Wooden dowels are placed to provide shear resistance between the panels, and continuous wooden plates run longitudinally to withstand all axial forces, acting as the chords of the assembled planes (Figs. 1 and 2). These chords also obviate any need for panel-to-panel ties or fasteners along the joints that are always expensive and complicate the panel manufacture.

The tying of plane-to-plane completes the rigid box structure, allowing simple siting of the hut as will be shown. The Angirraq's exterior wall skins of

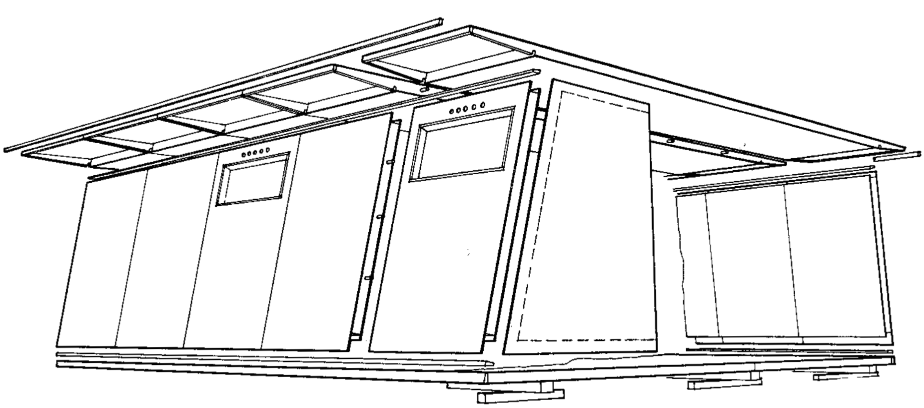


Fig. 1. Structural assembly of Angirraq hut.

⅜ in. (0.95 cm.) plywood project at top and bottom, overlapping the ends of the floor panels and the soffit frames of the roof panels (Fig. 2). Strong tie-down is readily effected with small nails through the projecting plywood, or screws where demountability is desirable. This avoids costly cam-locks or the more generally used heavy lag screws or toe-nailing through the panels, the last two methods being awkward and weak in practice. Similar overlaps tie the wall corners.

The joints between panels are adaptations of the open-rain-screen approach, a principle now gaining much attention as it promises simpler and lower cost through-joints for curtain wall and other enclosure components. Following the pioneering work of the Norwegian Building Research Institute, the Division has studied the principle and discussed possible applications to windows and walls. Briefly, the open-rain-screen principle involves the placing of a loose shield or rain screen over the exterior face of the joint, with an air space in the joint gap having free access to the outside, followed finally by an air-seal placed near the inside face of the joint. Under wind pressure, little or no pressure difference can exist across the wetted portion of the joint since it is freely vented. The shedding of water or snow by the rain screen is thus greatly simplified. The full wind pressure is exerted on the inside air-seal but it operates under dry conditions.

Fig. 2 shows the Angirraq wall joint, illustrating the simplicity of manufacture and the assembly tolerance allowed by this open approach. The inner air-seal gasket is formed from 4-mil (0.1 mm.) polyethylene film folded into six layers, and loosely stapled into a ribbon for ease of handling. The gasket is placed across the joint with its surfaces parallel to the direction of possible joint movement. It forms a limp filler between the batten and the panels, accommodating movement through multi-layer slip rather than material distortion. It is obviously not a high-pressure, elastomer gasket, able to perform under extreme deformations, but in the position shown these functions should never be required.

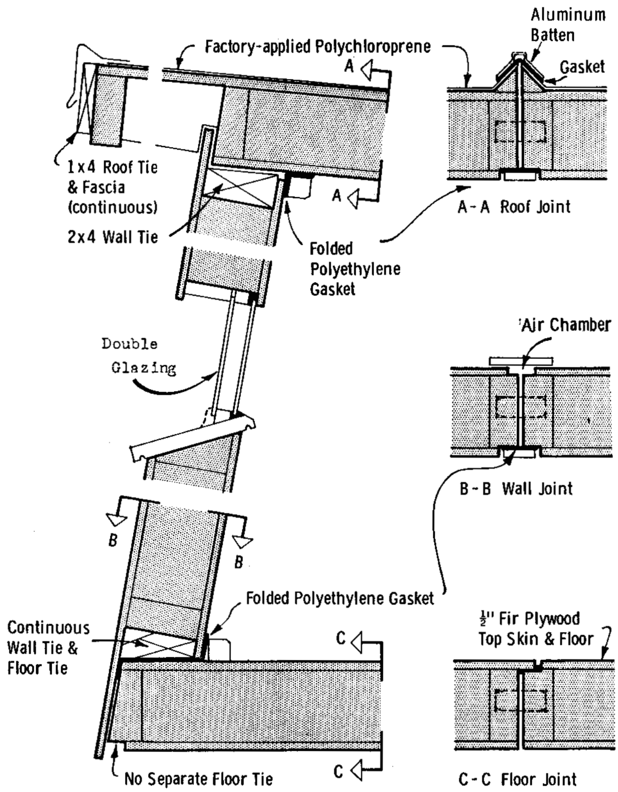
All windows are fixed double-glazing, mounted close to the interior wall surface with minimal sill protrusion (Fig. 2). This helps prevent or reduce condensation on the room-side surface, as will be seen. The inner glass is sealed with mastic, with the outer one mounted dry for nominal venting to help prevent condensation between the panes. Fixed screened holes placed low in the entrance door and high on the front wall, above the windows allow a *chimney* effect with the heated indoor air, which assures ventilation of the hut. Control is by means of pivoted wood covers.

Trials

The performance of a northern prefabricated hut involves many considerations: ease of handling and field assembly; general tolerances; effects of base movements; surface temperature, condensation or frost effects on joints, on windows, in corners; condensation within panels; panel bowing; infiltration of air, rain, or snow through or into the joints; general weathering effects; and structural integrity. Despite the relatively short and moderate Ottawa winter — compared with the Far North — the trials of a prototype hut through the winter of 1964-65 provided sufficient information on most of these points.

The prototype hut was manufactured by the Tower Company Ltd. in Quebec, a company that has had considerable experience with the use of stressed

Fig. 2. Construction details, Angirraq hut.



skin buildings throughout the Far North since 1947. The manufacturer erected the hut on DBR/NRC grounds in May 1964 (Fig. 3). The assembly proceeded smoothly; the complete shell was erected and reasonably finished in less than 35 man-hours. Concerning assembly tolerance, doubtful points of design had been the wood dowels and the roof undercuts designed to fit over the wall plywood projection (Fig. 2). Neither feature caused any trouble.

Base Movement

The Angirraq is designed to sit as a rigid box on the ground, accepting some movement without structural damage. An insulated floor, vented under-floor space, and a gravel pad are frequently relied on in arctic use to prevent thawing of the permafrost, and thus retain a stable base. This floating approach is widely used throughout the Far North for small buildings, with success where soil drainage and ice-content conditions are carefully noted. (It was first widely used by the engineer-founder of the Tower Company, Dr. George Jacobsen.) It allows much lower costs than do deep piles or other fixed foundations. It can also be used for larger buildings by articulating them in plan, as a series of small rigid boxes. For example, row housing units in the North could use split walls as the party walls, allowing some independence of movement and at the same time improving their fire-resistant and sound-barrier qualities.

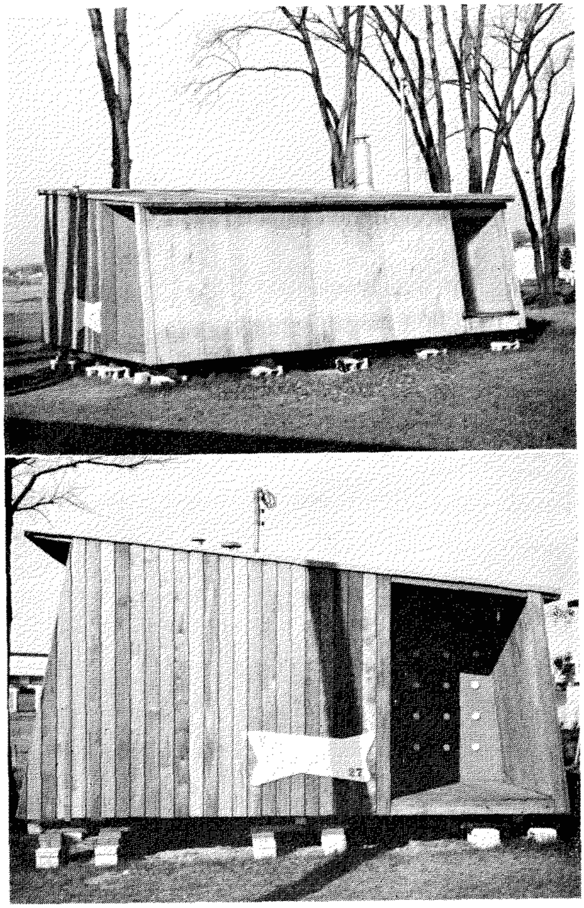


Fig. 3. The prototype Angirraq set up for tests (The production model is 4 ft. longer).

The continuous chords, shear dowels, and overlapped corners of the Angirraq did make it a structural box. Differential movements of 1 in. (2.54 cm.) were noted in the ground pads of the prototype and at one time the hut was spanning clear from one end to the other without support and with no apparent deflection or springiness in use.

Heating and Humidifying

Two 1500-watt electric heaters maintained a temperature of 70°F. (21°C.) in the hut during the winter trials in Ottawa. A humidifier with small fan was adjusted to maintain 55 per cent relative humidity, which is unusually severe for houses in cold areas. The water demand for humidifying was recorded as a measure of air leakage, which was then calculated as less than 1/4 air change per hour during the worst winter weather. (All vents were closed for these trials.) The two heaters were never on full time, even when the temperature dropped to —26°F.(—32°C.). The hut proved to be unusually tight and well insulated.

Panel Bowing

Any stressed skin panel, whether of framed or sandwich type, tends to bow in compound curvature if either skin expands or contracts in relation to the other. The curvature depends directly on the differential movement of skins and inversely on the panel thickness. A metal-skinned sandwich bows inward in the winter as the skins adjust to temperature, the cold outer skin contracting in relation to the warm inner skin. A plywood-skinned panel (or door) bows outward in the winter as the inner skin dries to equilibrium with the 20 to 40 per cent relative humidity indoors, and the outer skin remains in equilibrium with about 80 per cent relative humidity prevailing outdoors.

The Angirraq panels behaved true to form. The only significant bowing was observed in the roof panels, which rose in the winter about ½ in. (1¼ cm.) at the centre of their 13-ft. span (4 m.). In such cases, partitions or end walls must either tie to the roof and restrain it from arching upwards, or trim must be positioned to slide up and down over the tops of the walls, hiding the opening. The Angirraq panels were fully restrained at all intersections of planes, and no joints showed any effects.

Condensaton Within Panels

The field trials allowed a further check of the adequacy of closed stressed skin panels in restricting condensation within panels. Calculations and field inspections in the Far North suggested that such panels need neither vapour barriers nor vents if no openings exist to allow moist air flow through their inside skin. (*See:* Platts, R. E., 1962. Condensation control in stressed skin and sandwich panels. Forest Products Journal, XII, 9: 429-30.) Much of the stressed skin practice in Canada now follows this method, including the Angirraq.

Clear plastic ports were glued in place on the outer plywood skin as the heating-humidification trials began. The winter trials were run for 124 days, from December to April, maintaining 70°F. (21°C.) and 55 per cent relative humidity in the hut. From inspections through the special ports, at no time could water or dampening effects be seen in the insulation or the plywood. Additional inspection holes were drilled in early April, but these too revealed the same dry conditions. Moisture content readings were then taken with an electrical resistance meter. These indicated an average moisture content of 18 per cent (by weight) in the inner veneer of the outer plywood. In early May, further readings indicated 14 per cent relative humidity, a result of summer drying effects. The closed panels had performed as previously calculated, despite the excessive humidification of the hut.

Surface Condensation

In below-zero weather, the relative humidity that can be maintained in a heated building is limited to about 35 per cent by the temperature of the inner pane of the double-glazed windows. Any extra water vapour is removed from the air as condensate on the glass. All too often severe wetting of wall and floor is the result. Despite the forced humidification of the prototype to 55 per cent relative humidity, the windows remained surprisingly dry most of the time. Apparently the position of the inner pane close to the interior wall surface allowed the warm air to flow over most of the glass area thus increasing the surface temperature. Compared with windows of conventional design, flush-surface window design may be an easy step towards allowing Canadian houses to carry higher humidities in the winter without water-staining problems.

Surface Temperatures of Joints

Open-rain-screen joints have been questioned on the basis of the thermal bridging effects of the open gap. Severe thermal bridging can cause low surface temperatures, resulting in heavy condensation or even frost. Usually such areas will be well above dewpoint temperatures, but they still may suffer from objectionable dark streaks or dust marking. The Angirraq field trials afforded a good opportunity to assess the thermal performance of such joints.

The hut was equipped with 16 copper-constantan thermocouples leading from a self-balancing recording potentiometer, allowing continuous surface temperature measurements during a late winter cold period. Some thermocouples were placed on the interior surfaces of the wall joints, some on roof joints, and others were placed over studs and over the normal insulated portions of walls and the ceiling surface of the roof panels.

The open-rain-screen wall joints with their loose exterior battens proved thermally adequate, almost exactly equivalent to the 2-by 4-in. wall studs themselves. In outdoor conditions ranging from 14°F. (-10°C.) and calm to -5°F. (-20°C.) and windy, the interior surface temperature over the joints ranged from 65°F. (18.3°C.) to 63½°F. (17.5°C.), being the same as the studs, and 1 to 1½ degrees F. (0.56 to 0.83 degrees C.) lower than adjacent insulated portions of walls. In similar conditions, a wall joint with the exterior batten removed ranged from 64°F. to 60°F. (17.8 to 15.6°C.), or about 2 to 6 F. degrees (1.1 to 3.3 C. degrees) below the adjacent insulated portions. Apparently the outer batten, although attached quite loosely, allowed the air in the joint gap to remain stagnant and cause little heat transfer. The joint gaps as tested varied from nominal closure to 1/16 in. openings (0.16 cm.) the latter dominating, while the outer battens had gaps of 1/16 in. up to ⅛ in. (0.32 cm.).

Effect on Joints of Wind Blown Rain and Snow

This aspect was of prime importance in the evaluation of the hut, particularly in relation to the special open-rain-screen joints with their liberal tolerance in design and assembly. In addition to the field trials, extensive tests of the joints were made in the laboratory, using the controlled wind-driven rain apparatus (Fig. 4) to study the effects of many variables in both the joint details and the severity of exposure. The results are being reported in detail in a separate paper; only a brief report will be included here.

The field and laboratory tests showed that the Angirraq's open-rain-screen wall joint (Fig. 3) is proof against severe wind-driven rain or snow. This also applies to the floor-wall and wall-roof junctions, which are similar in concept. Simulated 60-m.h.p. winds (96.5 km. per hour) with sustained heavy rains or very fine mists presented no problems. An air chamber as shown just under the outside batten of the wall joint (Fig. 3) prevented water entry into the joint gap under severe conditions of slanting winds, non-uniform wind

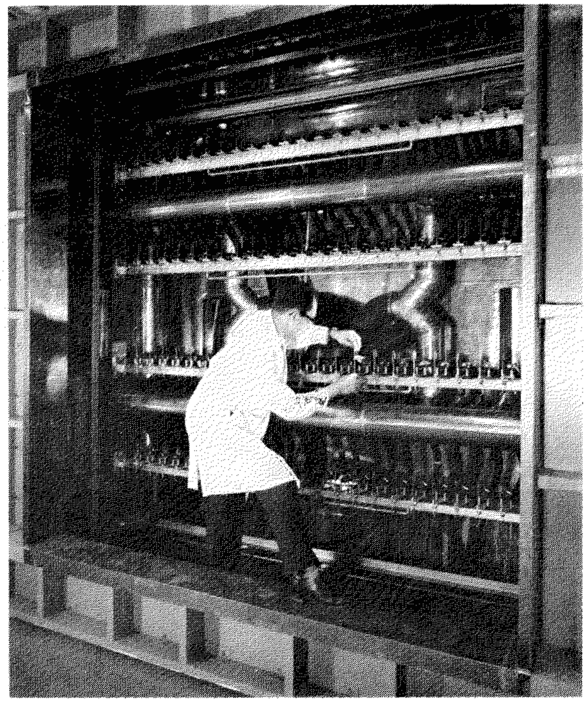


Fig. 4. Rain leakage apparatus, Division of Building Research of the National Research Council.

pressures on the joint, or where faults allow through leakage of air. Little water entered this air chamber but it should be terminated in a drain detail.

The laboratory tests also showed that the low cost gasket of multi-folded polyethylene film proved air- and water-tight, even when it was mounted on the outer surface of the joint and subjected to repeated batten movements (up to ¼ in. gap, 0.63 cm.).

The simple principles and details as described are not limited to small huts, and following the Angirraq trials the Department of Northern Affairs incorporated many of these aspects into the new two-storey northern house as recently built and assessed (Fig. 5). This will further supplement the prefabrication choice for northern settlements.

Summary

The Angirraq is of value as a successful approach to low-cost northern prefabrication. It uses basic stressed skin panels with full thick insulation and cedar plywood exterior to achieve a highly prefabricated, thermally efficient, low-maintenance enclosure. A simple combination of shear dowels, continuous plates or chords, and projecting skins as gussets in tying plane to plane, results in a rigid-box structure that bridges across base movements. Gravel pads should, therefore, be fully suitable for the support of such units in most northern areas. Larger buildings could be of flexible multiples of such rigid units, again avoiding costly pile foundations.

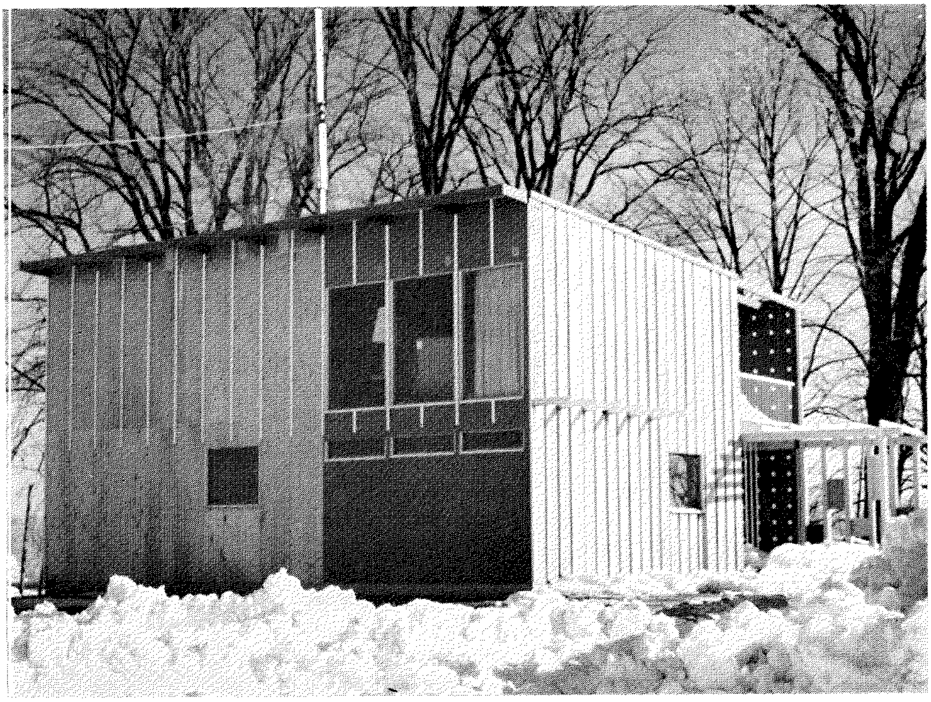


Fig. 5. The prototype built according to Angirraq principles and details for the Department of Northern Affairs by Allied Building Supply of Ottawa.

The closed stressed skin panels do not suffer from internal condensation and require neither vapour barriers nor vents. The fixed windows with sealed inner glass and dry-mounted outer glass avoid condensation between the panes. Their position close to the interior wall surface reduces the surface condensation problems that plague northern housing.

The open-rain-screen joints, liberal in design and assembly tolerance, proved fully weather-tight under all trial conditions of blowing rain and snow. The inexpensive gasket of folded polyethylene film performed well, even under considerable distortion and little pressure. Thermally, the joint proved as trouble-free as a normal wood stud. The joints and all details were easy to manufacture and over-all costs were very low.

Acknowledgement

The writer wishes to express his appreciation to the Department of Northern Affairs and National Resources for permission to publish this description of the Angirraq prefabrication system. The architectural design of the building was the responsibility of the Department of Northern Affairs and National Resources and the Division assisted by suggesting and assessing details with respect to the technical aspects of the design.