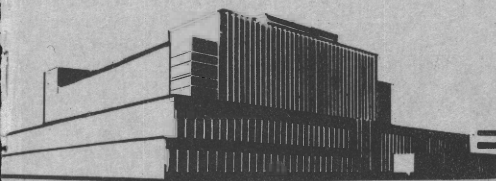
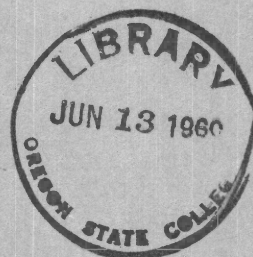


# ADHESIVES AND THEIR APPLICATION TO FABRICATION OF FARM STRUCTURES

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UNITED STATES DEPARTMENT OF AGRICULTURE  
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In Cooperation with the University of Wisconsin

ADHESIVES AND THEIR APPLICATION  
TO FABRICATION OF FARM STRUCTURES<sup>1</sup>

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Summary

Application and service characteristics of presently available wood-working glues are reviewed, with emphasis on durability of adhesive bonds under conditions of service characteristic of farm structures. Casein glues are convenient to use and are adequate for items that will not become repeatedly or continuously damp or wet in service. Phenol-, resorcinol-, and melamine-resin adhesives have adequately proven durability under severe service conditions. Phenol- and melamine-type adhesives require rather high temperatures (250° to 310° F.) for adequate curing. Resorcinol and phenol resorcinol adhesives may be cured adequately for many purposes at 70° F. and above and, consequently, are favored for farm structures.

Development of the Art of Gluing

The gluing of wood is a very old procedure, apparently going back as far as reliable history does (3).<sup>3</sup> The earliest recorded use of glues

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<sup>2</sup>Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

<sup>3</sup>Underlined numbers in parentheses refer to Literature Cited at the end of this report.

with wood seems to be for the purpose of enhancing the beauty of the product. The earliest use of glues to produce items that could not be fabricated from wood and mechanical fastenings seems to have passed without record. By the 17th century, however, the production of glued-wood items, which could not have been carved from solid wood, was well advanced, as the very fine violins of that period illustrate. One of the most important developments in the field of glued-wood products occurred in the latter part of the 19th century when the commercial production of a crossbanded assembly of glued veneers, now known as plywood, got under way. This outstanding development made available a product that was better than a solid wood panel in dimensional stability in width and in resistance to splitting. In this century, the use of glued-wood products has expanded to an almost unbelievable extent, as illustrated by the increase in the production of Douglas-fir plywood from 153 million square feet (3/8-inch base) in 1925 to 6,240 billion square feet in 1958, and by the increased use of structural elements of glued-laminated wood.

The use of glue to fabricate items of wood is not the answer to all problems of the wood-using industry. Some of the advantages and disadvantages to consider are listed as follows:

#### Advantages

- (1) Gluing side grain to parallel side grain can develop the full strength of the wood, a goal that cannot be achieved by mechanical fasteners.
- (2) The use of glue permits the fabrication of wood items having desirable properties that can be realized in no other way, as for example plywood with its high degree of stabilization in width.
- (3) Gluing permits production of items for which large timbers are no longer available, such as large arches and ship timbers.
- (4) The use of glue permits fabrication of large structural elements from thin lumber that, before laminating, can be dried easily to uniform and suitable moisture contents and thoroughly treated with preservatives, if so desired.
- (5) Gluing is often the most satisfactory way of assembling such items as hollow- and solid-core flush doors.

(6) Glues permit the fabrication of strong but light structural elements, such as box beams, stressed-skin panels, and sandwich-type constructions.

### Disadvantages

- (1) Solid wood items, providing they will serve satisfactorily, are less costly for many uses than glued-up items, as for example, the heavy beams and columns in mill-type construction.
- (2) No one glue has all the desirable characteristics. Hence, the glue must be selected that will meet the probable use requirements of the item.
- (3) No glue is foolproof. To realize the advantages of glued construction, all joints must be well made. To produce joints of consistently high quality requires skill and a rather exacting control of gluing conditions.
- (4) Improper use of glues and glued products may result in costly repairs or replacements.
- (5) End-to-end or end-to-side butt joints of adequate strength cannot be made with any glue and gluing techniques now available.

### Development of Glues

The two essential elements in making strong and durable glue joints are (1) the selection of the proper glue for the probable service conditions to which the glued item will be exposed in normal service, and (2) the maintenance of good gluing conditions to insure the best possible results with the glue selected.

At the present time, the woodworker has available some 10 different types of glues and several mixtures or combinations of these basic types. Some are of natural origin and some are based on synthetic resins. Those now being widely used have been on the market long enough so that their characteristics and limitations are reasonably well known. Other resins and combinations have exhibited some promise as woodworking adhesives, but they have not been sufficiently evaluated to permit completely reliable judgments of their characteristics.



The more important developments in adhesives all have taken place in this century. Until about 1903, when starch glues for wood gluing came on the market, the only type of glue known to be adequate for production work was that produced from the skins, tendons, and bones of animals, usually cattle.

In this century, the glues that were developed and accepted by industry include starch (in 1903), casein and blood (during World War I), soy bean (in 1924), phenol resin and urea resin (in 1932), and melamine resin, resorcinol resin, and polyvinyl resin (all during World War II).

In a similar field, the period since about 1942 has seen significant developments in adhesives for bonding metal to metal. These developments are of importance to the wood industry, because they provide a means of gluing metal to wood with strong and durable bonds. Some of these developments also have characteristics, such as self-reactivity, which may prove useful in special cases for the bonding of wood to wood.

Still other developments in the field of "contact adhesives" (those requiring only a low bonding pressure for a brief period) are likewise of interest to the wood user. While at the present, these contact adhesives are not considered suitable for purposes requiring very strong and durable bonds, they are useful for such purposes as bonding plastic tops to built-in cabinets and bonding the finish floor to subfloors. This field likewise appears promising and improvements seem probable.

### Characteristics of Woodworking Glues

All of the adhesives now widely used in the woodworking industry are capable of forming strong bonds that will remain so if the glued product is kept dry and at temperatures no higher than the human-comfort range. With a few exceptions, a glue for domestic or office furniture could be selected largely on the basis of price, or how its operating characteristics fit the available equipment and production schedules (4).

The difference between these glues lies in their resistance to the more severe conditions of service and in the technique of application (1).

The following tabulation, taken from the Wood Handbook (5), summarizes information of importance to the users of woodworking glues or glued-wood products:

# Characteristics, Preparation, and Uses of the Most Commonly Used Woodworking Glues

Form and testing	Properties	Preparation and application	Uses
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## ANIMAL

Many grades sold in dry form; liquid glues available; quality determined by tests on solutions of the glue.<sup>1</sup>

High dry strength; low resistance to moisture; and damp conditions; stain wood very slightly, if at all.	Dry form mixed with water, soaked, and melted; solution kept warm during application; liquid forms applied as received; both pressed at room temperatures.	Used extensively in furniture assembly joints, cabinetmaking, and millwork.
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## CASEIN AND VEGETABLE PROTEIN

Several brands sold in dry powder form; may also be prepared from raw materials by user; quality determined by tests on glue and by tests on wood joints.<sup>2</sup>

High to low dry strength; moderate to low water resistance and durability under damp conditions; pronounced dulling effect on tools; stain some woods badly.	Mixed with cold water; applied and pressed cold.	Used for gluing lumber and veneer for purposes requiring moderate moisture resistance.
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## STARCH

Different grades sold in dry form; also available in liquid form ready to use; quality determined chiefly by tests on wood joints.

High in dry strength; low resistance to moisture; and damp conditions; stain some woods moderately.	Dry forms mixed with water, usually with addition of caustic soda, and heated; applied cold; liquid form applied as received; both pressed cold.	Used primarily in gluing veneer.
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Form and testing	Properties	Preparation and application	Uses
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#### UREA RESIN

Several brands sold as dry: High in both wet and dry : Dry form mixed with : Used extensively in gluing  
 powders, others as : strength; moderately dur- : water-hardeners, : veneer for furniture and  
 liquids; may be blended : able under damp condi- : fillers, and extenders : other interior uses and to  
 with melamine or other : tion; moderate to low : may be added by user to : some extent in gluing lum-  
 resins; quality deter- : resistance to tempera- : either dry or liquid : ber and assembly joints.  
 mined by tests on glue : tures in excess of 150°F.: form; applied at room :  
 and by tests on wood : white or tan in color; : temperatures, some :  
 joints.<sup>3</sup> : stain wood very slightly, : formulas cure at room :  
 : if at all. : temperatures, others re- :  
 : : quire hot pressing at :  
 : : about 250° F. :  
 : :

#### MELAMINE RESIN

Comparatively few brands : High in both wet and dry : Mixed with water and : Used to a limited extent in  
 available; usually : strength; very resistant : applied at room tempera- : bag molding and in gluing  
 marketed as a powder with : to moisture and damp con- : tures; heat required to : lumber and veneer for pur-  
 or without catalyst; : ditions; stain wood very : cure (250° to 300° F.). : poses requiring colorless  
 quality determined by : slightly, if at all, : : and highly resistant glue  
 tests on glue and by : white to tan in color. : : lines.  
 tests on wood joints.<sup>4</sup> :

#### PHENOL RESIN

Several brands available, : High in both wet and dry : Film form used as re- : Used primarily for production  
 some dry powders, others : strength; very resistant : ceived; powder form : of highly resistant plywood.  
 as liquids, and one as : to moisture and damp : mixed with solvent, :  
 dry film; quality deter- : conditions, more resis- : often alcohol and water, :  
 mined by tests on glue : tant than wood to high : at room temperature; :  
 and by tests on wood : temperatures; stain wood : hardeners and fillers :  
 joints.<sup>4</sup> : very slightly; dark red : often added by users; :  
 : color. : most common types re- :  
 : : quire hot pressing at :  
 : : about 300° F. :  
 : :

Form and testing	Properties	Preparation and application	Uses
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# RESORCINOL RESIN

Several brands available : High in both wet and dry : Mixed with catalyst and : Used primarily for gluing in liquid form; catalyst : strength; very resistant : applied at room tempera- : lumber or assembly joints supplied separately; some : to moisture and damp con- : tures; resorcinol glues : that must withstand severe brands are combinations : ditions; more resistant : cure at room tempera- : service conditions. of phenol and resorcinol : than wood to high temper- : tures; some resorcinol- : resins; relatively high : atures; stain wood very : phenol blends cure best : priced; quality deter- : slightly; dark red in : under moderate heat : mined by tests on glue : color. : (100° to 200° F.). : and by tests on wood : : : : joints.<sup>4</sup>

# POLYVINYL RESIN EMULSION

Several brands are avail- : Generally high in dry : Marketed as a liquid : Used in assembly joints in able, varying to some : strength; low resistance : ready to use; applied : furniture, cabinetmaking, extent in properties; : to moisture and elevated : and pressed at room : and millwork. marketed in liquid form : temperatures; joints tend : temperatures. : ready to use; quality : to yield under continued : : : : determined largely by : stress; white in color; : : : : tests on glue joints.<sup>5</sup> : stain wood little if at : : : : : all. : :

<sup>1</sup>Specification MM-A-100, "Adhesive; animal gelatin." 1955.

<sup>2</sup>Specification MM-A-125, "Adhesive; casein-type, water and mold resistant." 1955.

<sup>3</sup>Specification MM-A-188, "Adhesive; urea-resin type (liquid and powder)." 1955.

<sup>4</sup>Specification MIL-A-397B, "Adhesive; room-temperature and intermediate-temperature setting resin (phenol, resorcinol, and melamine base)." 1953.

<sup>5</sup>Interim Federal Specification MM-A-00193, "Adhesive; vinyl acetate resin emulsion."



From the information in the column headed "Properties," it is not difficult to select the type of glue suitable for the probable service conditions under which the glued item is expected to perform. Possibly the greatest chance for error in selecting an adhesive occurs when the common understanding of "normal service" does not include periods of "abnormal conditions" that frequently develop. As an example, several military structures were erected in World War II under a demand schedule that required using any material available that would serve with reasonable satisfaction for an estimated period of about 5 years. On these buildings, interior-type plywood was frequently used as the exterior covering of the walls. On the assumption that the "normal service" was for 5 years, the choice was reasonable. In this case, however, "abnormal conditions" prevailed; the "temporary use" extended for 10 years or more, and the interior-type plywood on the exterior surfaces could not be expected to serve satisfactorily over such a prolonged period.

#### Importance of Gluing Techniques

Besides selection of a glue suitable for the expected use, the gluing operation must be well controlled to produce consistently strong bonds (2). In addition to the limited information in the preceding tabulation, the quality of glue bonds is dependent on (1) conditioning the wood to a uniform moisture content at a level suitable for the conditions of service; (2) preparing mating surfaces that are smooth and well fitted mechanically; (3) spreading an adequate amount of well-mixed glue uniformly over the faying surfaces; (4) adjusting the interval between spreading and pressing to suit the characteristics of the glue; (5) applying an adequate and uniform gluing pressure; (6) maintaining the gluing pressure long enough to permit the glue to set; and (7) in some cases, conditioning before further work is done on the item.

The lasting qualities of well-made glue joints are reasonably well known, but the long-term serviceability of poorly made joints is open to question even under service conditions that may be quite normal.

## Application to Farm Structures

With this information on glues as a background, their application to farm structures and the fabrication of products may be considered.

### Barns

Among the most striking examples of glued-wood products in farm structures are glued-laminated rafters that form the gracefully curved roofs of barns (fig. 1). This application raises two questions that are typical of all uses of glued-wood products in structures: What type of glue should be selected, and what control of gluing conditions must be maintained to insure adequate strength and durability of bond? Some laminated rafters bonded with casein glue have failed because the conditions of service permitted the development of molds and other microorganisms to which casein glues are not permanently resistant. Such unfavorable conditions are very likely to develop in northern dairy barns during the colder seasons, when the moisture in the air from the stables condenses on the roof members. Highly resistant resorcinol or phenol resorcinol types of glue should be used in barns that are reasonably tight and are used to shelter animals. It would probably be advisable to purchase these laminated rafters from established laminators rather than to fabricate them with improvised equipment and local help. While not impossible, it is unlikely that the farmer could control all the factors necessary to insure bonds of uniform and adequate strength.

Moisture barriers installed at or near the interior of the walls and ceiling of the stable area will prevent the high moisture-laden air from coming in contact with the wood structural members and the insulation. Good construction practices of this type prevent decay of the wood, paint failures, and delamination of laminated members that are bonded with casein or interior types of glues. Due to openings to the barn loft and possible punctures and deterioration of the moisture barrier, however, a still safer procedure would be to use rafters constructed of the more resistant glues.

While dairy barns have been used to illustrate the effect of condensation on the choice of glues, the principles apply also to any farm building in which condensation of moisture on the structural elements is a possibility, such as laying and broiler houses for poultry and farrowing and nursery quarters for hogs.

Many older barns are of the heavy timber type of construction. The timbers were often sawed at local yards from logs furnished by the farmer from his woodlot. Under such conditions, the cost of raw material for this type of construction may well be lower than that of the laminated rafter type, but the cost of labor required to erect the laminated-rafter structure is lower (fig. 2). The overall costs, therefore, are not necessarily in favor of the heavy timber construction.

Plywood is another glued-wood product that is used in barn construction. The buyer has a choice of both hardwood and softwood plywood in various species and types. The term "type" refers to the resistance of the glue to severe service conditions. Douglas-fir and other West Coast softwood plywood are available in two types (6), Exterior and Interior, which are indicative of the intended use. The commercial standards for hardwood plywood (7) list four types, Technical and Types 1, 2, and 3. Technical and Type 1 require a fully waterproof and weatherproof bond, Type 2 utilizes a moderately water-resistant bond, and Type 3 has somewhat lower water resistance than Type 2.

Any plywood used on the exterior surfaces should, of course, be Exterior or Type 1. Likewise, plywood in exterior locations where it may be repeatedly wetted and dried also should be of Exterior or Type 1. Plywood that will be in contact with the ground or in locations that remain warm and damp for long periods should be of Type 1 or Exterior type, and treated with wood preservatives if long service is expected.

### Silos

Glued-wood products can likewise be used in the construction of silos. Exterior or Type 1 plywood should be used for both the outer and the inner surface material, and laminated members, bonded with a highly resistant glue, should be used for framing. In considering the probable service conditions, only the phenol- or melamine-bonded plywood and the phenol resorcinol-bonded laminates are likely to be suitable. Framing members that are not of a decay-resistant species also should have preservative treatment. With some unloading systems, an interior surface of metal or enamelized metal would probably serve more satisfactorily than the surfaces of bare plywood. If so, adhesives and bonding procedures are available by which reliable bonds of metal to wood may be achieved.

## Implement Sheds

Another kind of farm building in which glued-wood products could be used to advantage is the implement shed. The term "implement shed" here includes those structures that are not heated, or regularly occupied by livestock, and in which the temperature and relative humidity are essentially equal to outside conditions (fig. 3). Depending on design and overall costs, glued-laminated rafters, roof trusses with glued gussets, and plywood may be used. Such glued items require that a choice of glues be made. Since these sheds are unheated and not so tight as to prevent a rather free circulation of air between the inside and the outside, no serious condensation problems should occur.

Roof trusses that are protected by a tight, well-maintained roof with adequate overhang, should give satisfactory service, with casein-glue bonds between the gussets and the frame, although, of course, the more resistant glues would provide a greater margin of safety. While a good casein bond may be made at temperatures below 70° F., the advisability of fabricating the trusses on the job is open to question. If lumber at a desirable moisture content between 10 and 15 percent can be smoothly surfaced shortly before gluing, if a protective shelter is available, and if the workmen are reasonably skilled in the use of glue, the chances of producing serviceable trusses are good. If the lumber is rough and poorly seasoned, and if the trusses must be fabricated more or less in the open by unskilled workers with hurriedly improvised equipment, then nailing the gussets in place would be the safer procedure.

Plywood, of course, can be used to advantage for such sheds. Generally, the siding will be of single thickness and, consequently, only Exterior or Type 1 plywood should be considered. In most cases, it can be assumed that the shed will be painted for the sake of appearance. If so, it may prove desirable to purchase plywood overlaid with a resin-impregnated paper, because the bulk of commercial plywood consists of species that do not hold paint particularly well. Interior-type plywood may give satisfactory service for roof sheathing, provided it is covered with a tight, well-maintained roofing and the exposed edges are treated with water repellent and then protected either mechanically or by well-maintained paint coatings.

The use of Type 2 hardwood plywood that has been glued with a straight urea-resin glue is questionable, because the temperature may become high enough to weaken urea-resin bonds. Roofs of implement sheds and similar structures, moreover, are not always well maintained,



because an occasional leak is unlikely to cause any serious deterioration of the implements. For this reason, the use of Exterior or Type 1 plywood would be a safer procedure.

Exterior-type plywood has been suggested as the only roof covering that is laid directly on the rafters with no cover on the weather side. While the glue bonds in Exterior or Type 1 plywood are probably adequate for this severe service, there are some disadvantages. The surfaces will check markedly in a short time, darken, and become rough. Some separation of summerwood from springwood also may develop. The general appearance then may become rather unsightly. If the outside surfaces are to be painted, satisfactory paint service can scarcely be expected from conventional house paints, because the wood species commonly used for commercial plywood will not hold paint well, and the low-angle exposure of roofs is much more severe on paints than are vertical exposures. If painting is considered essential, three coats of aluminum paint, or a primer of aluminum paint followed by two coats of iron oxide paint, would probably be the best choice.

More important, probably, is the decay hazard. Few of the species commonly used for plywood are highly resistant to decay, and water seeping into the exposed edges may create conditions favorable to decay. Some of these disadvantages can be overcome by the use of preservatively treated plywood that is overlaid with a resin-impregnated paper or sheet plastics, but the final cost may then exceed that of conventional roofs.

While not often seen on farms, shelters are occasionally designed that violate some of the principles of the use of glued-wood items. Some shelters, whose cross section resembles that of the quonset huts, have curved glued laminated beams supported at the ends by concrete abutments as their main structural elements. The laminates bonded with casein glue that are protected by a roof extending down over the abutment may give satisfactory service. If the roof ends above the abutments, however, unsatisfactory service of casein-bonded laminates result because of delamination and, ultimately, decay in the exposed ends.

### Shelters

The remarks about the use of glued-wood items in implement sheds apply equally well to fixed or movable shelters consisting essentially of a roof under which livestock may find shelter. In this type of open structure,

condensation is not likely to cause serious trouble because free circulation of air tends to keep temperatures and relative humidities, inside and out, at nearly the same level. On roofs that are tight and well maintained, rafters may be laminated with casein glue, provided that the ends are sloped back and both the ends and the part of the rafters extending beyond the walls are kept well painted.

With wood trusses, casein glue should serve satisfactorily for bonding the gusset plates to the framing members, again assuming a tight and well-maintained roof. On roofs that will be well maintained, Interior-type plywood can be used for roof sheathing, provided that the exposed edges are brushed with water-repellent preservatives and kept well painted.

The use of Type 2 plywood bonded with straight urea-resin glues may be questionable because of possible temperature effects. The safer procedure, of course, is to use a phenol resorcinol type of glue for rafters or gussets and Exterior or Type 1 plywood for roof sheathing. Exterior or Type 1 plywood can be used as the only roof covering, if appearance and absolute freedom from leaks are not important. The serviceable life of bare plywood for roofing has not been established, however, and, unless a tight roof is maintained, phenol resorcinol glues should be used for bonding the gussets on the trusses.

The shelter type of construction serves to illustrate the cases in which the expected length of service is a factor to be considered. In permanent structures, the few added dollars that result from the use of more resistant glues and Exterior or Type 1 plywoods are well spent. If the service life of the item is expected to be short, 5 years or less, taking somewhat greater chances on material using the less resistant, but cheaper glues, may be justified.

### Dwellings

In farm dwellings, just as in urban dwellings, glued-wood items and structures find a wide and probably increasing use. The structural elements (walls, floors, and sometimes roofs) of many of the prefabricated houses are essentially sandwich-type constructions, formed by gluing plywood to frames of solid wood. The outside plywood surfaces should, of course, be Exterior or Type 1 and should be bonded to the framing with one of the highly resistant glues. So far as glue bonds are concerned, Interior-type plywood for inside facing of the exterior walls would

probably give satisfactory service, but using wall units with Interior plywood on one side and Exterior plywood on the other side offers chances of error during fabrication. As a general rule, Interior or Type 2 plywood would be suitable for interior partitions, and the plywood could be bonded to the frames with casein glues.

In conventionally built houses, plywood is often used for subfloors, roof sheathing, and wall sheathing. The choice of the type, as in all other cases, depends on the expected service conditions. For example, Interior-type plywood for subfloors should be satisfactory over a full basement and on floors above the first, assuming, of course, that the builder provided for adequate protection from rain and moisture during the construction of the house. Type 2 hardwood plywood bonded with a moderately fortified urea-resin glue or better would likewise be suitable under these conditions. If the house has no basement, or only a partial one, and the crawl space is inadequately ventilated, Exterior or Type 1 plywood would be the safer choice.

Somewhat similar considerations arise with the use of plywood for wall and roof sheathing. If it is assumed that moisture barriers are properly installed, that water will not gain access through open joints or cracks in the siding or around windows or doors, and that the temperature does not rise too much above the human-comfort range, then Interior or Type 2 plywood should serve satisfactorily. Since these ideal conditions may not always be maintained during the life of the house, the use of Type 1 or Exterior plywood for wall and roof sheathing seems the safer choice. In the northern States, snow or ice dams that frequently form near the eaves and permit water from rain or melting snow above the eaves to seep back under the shingles, thus wetting the sheathing, are added hazards. Occasionally, builders use Exterior-type roof sheathing near the eaves and Interior types above.

### Other Applications

#### Implements

Outside of the field of farm structures, glued-wood products may find use in farm implements. It is desirable for the user of such implements to know the limitations of the glued-wood product, if any, and be prepared to make necessary repairs by gluing with the types of glues required for this service. While the farm implement field has been taken

over to some extent by metals, some parts made of plywood and glued laminates certainly give good service in many items. Since many farm implements must withstand long-continued exposure to the elements, any glued products used should be bonded with the most resistant glues, such as, phenol resin for the plywood and resorcinol or phenol resorcinol for the laminates. In addition, any parts that are usually in contact with or very near the ground and those located where water will accumulate and remain indefinitely should be treated with preservatives.

### Recreational Equipment

In a somewhat lighter vein, glued-wood products are found in much of the recreational equipment that is common to both farm and urban families, and a knowledge of the characteristics of glued-wood products is helpful in the use and repair of such items. If the horse lover has a good trotter or pacer, he is likely to find that the better thills for the sulky are glued-wood laminates, bent to form during the gluing operation. His sons and daughters likewise will probably be using glued-wood laminates in such recreational equipment as baseball bats, bowling pins, tennis rackets, bows, and skis. If any of these must be repaired by gluing, the glue should be selected on the basis of probable conditions of service and storage, recognizing that it is never a mistake to use a glue with greater resistance than the minimum required.

### Probable Future

As the country's supply of large sawtimber decreases, more glued products may be expected on the market, because gluing offers a method of fabricating large or specially formed products from the supply of small timber that is available. For example, serious consideration is being given to producing 2 by 4's by gluing together two 1 by 4's. When well glued with resorcinol or phenol resorcinol glues, such laminates should serve as well as solid 2 by 4's in any use. At least one company is producing edge- and end-glued nominal 1-inch lumber as a substitute for solid wood in order to utilize effectively their short and narrow stock.



A considerable amount of experimenting has been done on lumber overlaid with resin-impregnated paper or vulcanized fiber in order to permit use of lower grades of lumber. This provides a surface that will retain paint well and be suitable for a product with miscellaneous uses. One of the most promising uses for such a composite of paper and lumber appears to be for the wide siding that is in demand for architectural and style reasons.

Literature Cited

- (1) Blomquist, R. H.  
1954. Evaluation of Glues and Glued Products. Jour. of Forest Products Research Society 4 (5): 290-299. Madison, Wis.
- (2) Freas, A. D., and Selbo, M. L.  
1954. Fabrication and Design of Glued Laminated Wood Structural Members. U. S. Department of Agriculture Tech. Bull. No. 1069.
- (3) Perry, Thomas D.  
1942. Modern Plywood. Pittman Publishing Corp., New York.
- (4) Truax, T. R.  
1929. The Gluing of Wood. U. S. Department of Agriculture Dept. Bull. No. 1500.
- (5) U. S. Forest Products Laboratory.  
1955. Wood Handbook. U. S. Department of Agriculture Handbook No. 72.
- (6) U. S. Office of Technical Services.  
1959. Commercial Standard CS 45-55, Douglas-fir Plywood. U. S. Department of Commerce.
- (7) \_\_\_\_\_  
1956. Commercial Standard CS 35-56, Hardwood Plywood. U. S. Department of Commerce.

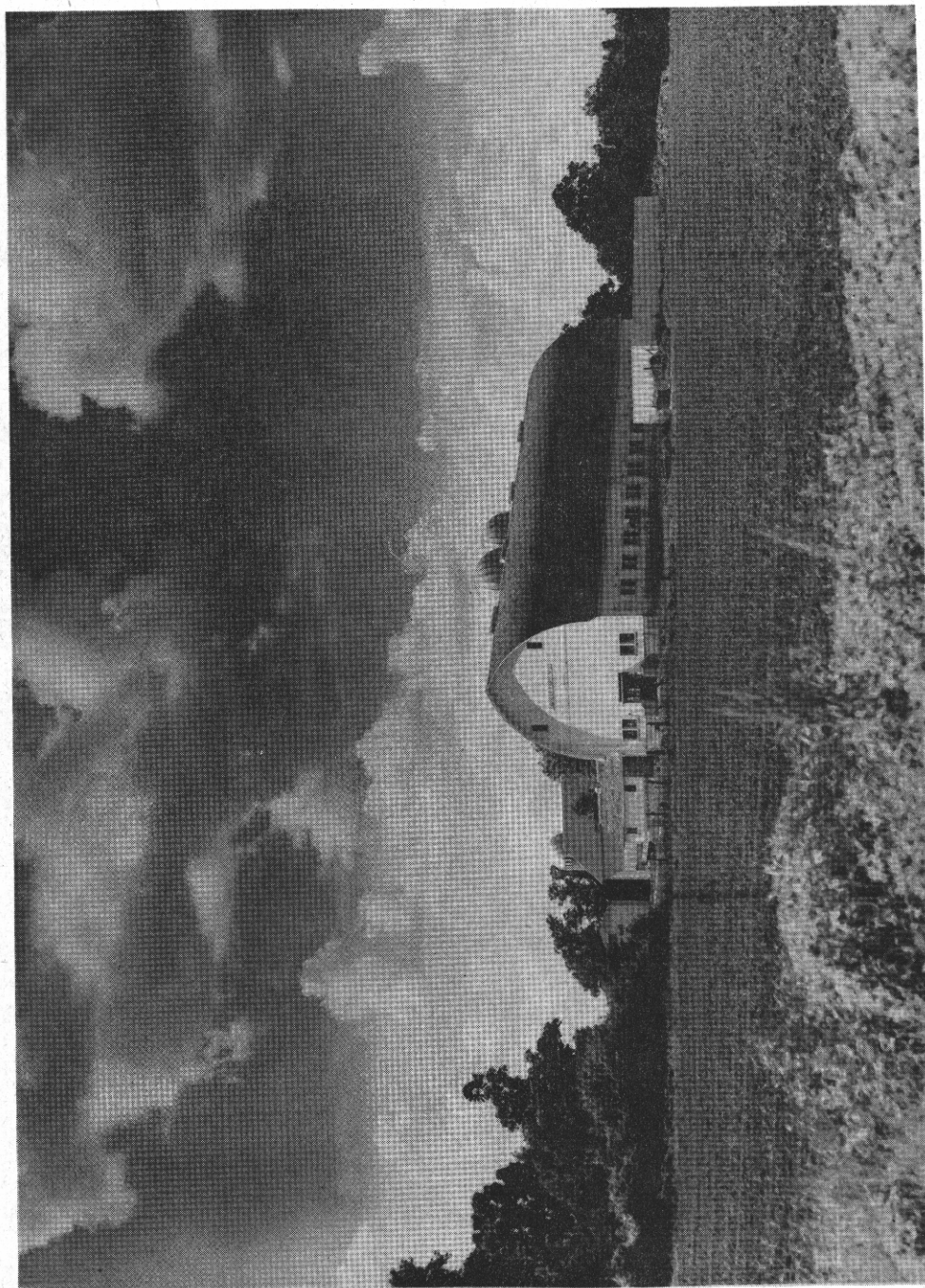


Figure 1. -- The graceful roof curves made possible with laminated rafters enhance the appearance of this dairy barn.

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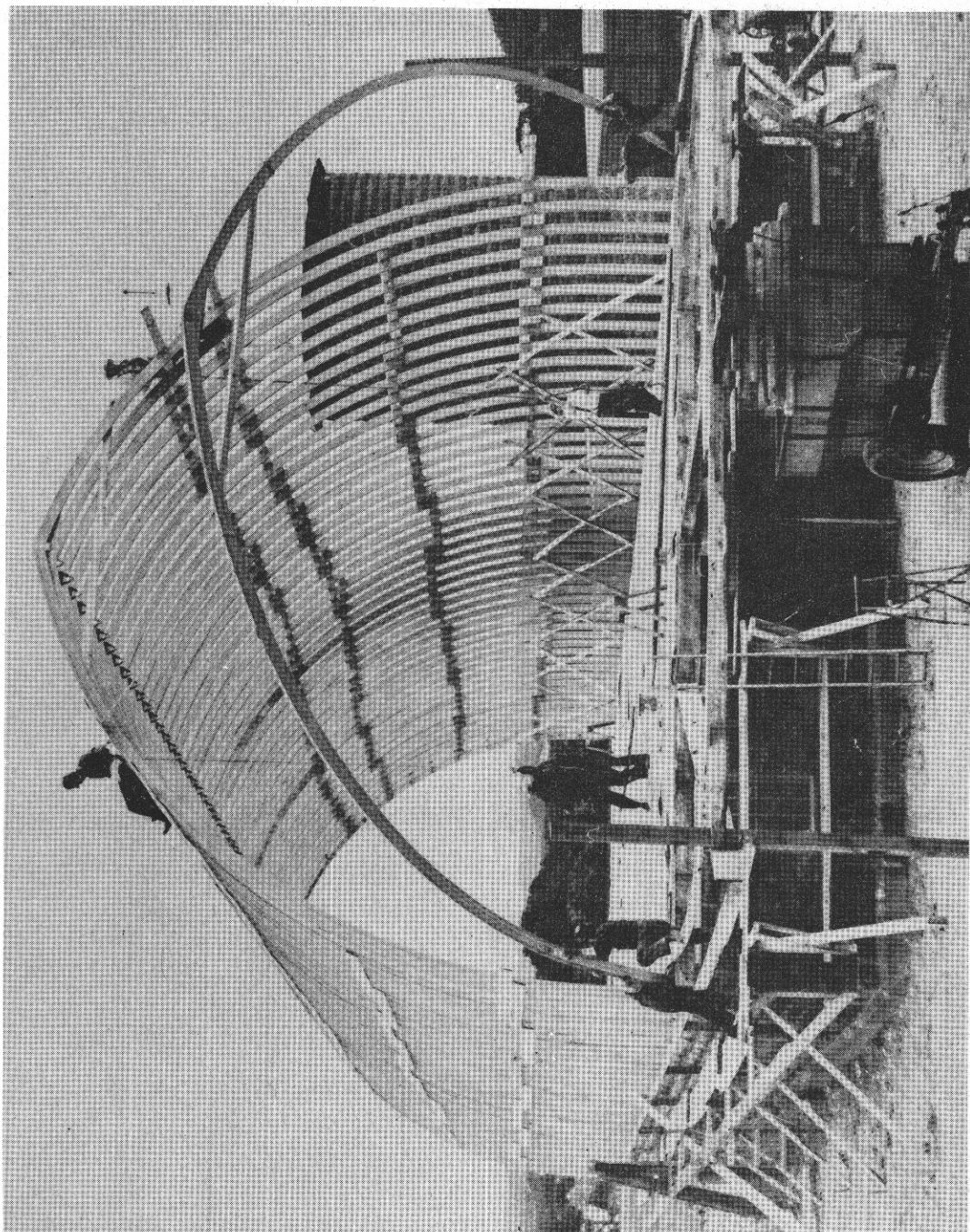


Figure 2.--Only 7 hours were required for a crew of eight men to erect the laminated rafters for this barn, an important factor in holding down labor costs.



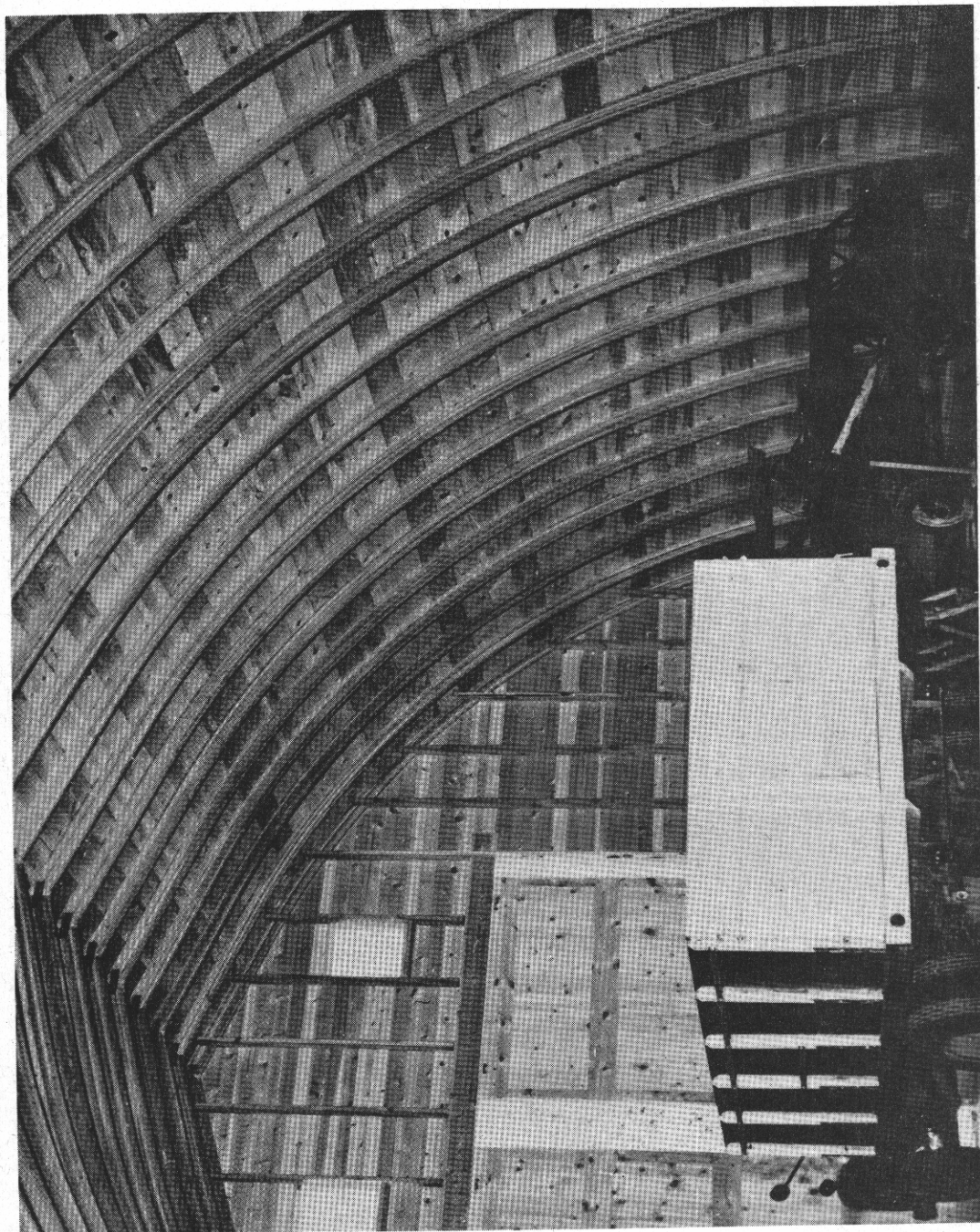


Figure 3. --Glued-laminated rafters can be used to good advantage in implement sheds by providing spacious and unobstructed interiors.