The adaptation of farm buildings to meet changes in farm operation

Norval Herbert Curry
Iowa State College

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THE ADAPTATION OF FARM BUILDINGS TO
MEET CHANGES IN FARM OPERATION

by

Norval H. Curry

A Thesis Submitted to the Graduate Faculty
for the Degree of

MASTER OF SCIENCE

Major Subject: Agricultural Structures

Approved:

Henry Giese
In Charge of Major Work

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Head of Major Department

R. E. Buchanan
Dean of Graduate College

Iowa State College

1946
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1.

I. INTRODUCTION

A. Justification for the Study

The general decline in the condition of agricultural buildings in Iowa and nationally during the past 25 years should be obvious to even the rather casual observer. U.S. Bureau of Agricultural Economics data setting forth relative annual depreciation and replacement of agricultural buildings during this period are presented in Figure 1 as an indication of the extent of this decline.

Many factors have contributed to this condition. In general these include:

1. A low level of farm prosperity during the decade from 1930 to 1940. As the comparative service life of farm buildings is very long, even with considerable neglect, when contrasted with that of other consumer durable goods which farmers require, replacement of these other items took priority in the gradually improving economy in the latter part of this decade.

2. Specific regulations in April of 1942 with many later revisions limited construction during the war to only the most essential buildings. These regulations were made effective at about the same time that farm building replacement had equaled depreciation for the first time in nearly 20 years.
3. Nearly one half of the farms in the North Central region of the United States are tenant operated. Standard forms of tenant-owner agreements provide little incentive to the owner to invest money in either new buildings or improvements since the tenant receives practically all direct benefits accruing from the owner's expenditure.

4. Developments in agricultural machinery and power equipment for farm field operations within the lifetime of now existing farm buildings have permitted individual farmers to increase the labor efficiency in field operations many fold. While some devices which promote labor economy in chore operations have also been adopted, they do not, in general, provide the same degree of increase in labor efficiency. It is therefore normal that farmers have first invested in production machinery which would appear to produce a higher rate of return on the money invested than money invested in new or improved buildings.

5. The mechanization of farm operations has not only adversely affected the desirability of further investment in agricultural buildings but has so completely changed and often confused the function of existing buildings as to make them almost useless in their present form. The near elimination of horses as a source of power on Iowa farms with the resulting decrease in need for horse stalls, hay and bedding storage, oats storage, etc. has not been compensated by increased housing and feed storage require-
ments for other animals. Consequently, the horse barn, largest and most imposing building on most Iowa farms, is of little practical value to either the tenant or owner. Since no provision for alteration of these buildings for entirely new uses was included in the original construction plans, cost of alterations to return the buildings to a useful state would in many cases far exceed the actual productive value of the remodeled structure.

6. Changes in the type of meat animals demanded by the market, changes in the harvesting methods and form in which hay is stored, storage of shelled rather than ear corn, and many other developments have altered the function of other agricultural structures to almost the same extent as has power machinery altered the function of the horse barn.

The economic depression of the 1930's, the necessary regulations on wartime construction and the present forms of tenant-owner agreement are all factors beyond and outside the field of control of those involved in farm structures research, design or construction. However, the latter three factors which have contributed to the present depreciated condition of these buildings spring primarily from technological and engineering developments in agriculture. These maladjustments are physical and as such are subject to control by engineering methods and devices. A study of the particular factors in conventional construction of both buildings and building equipment which tend to limit the adaptability of the structures to new uses and, if possible, the attempt to develop corrective measures, seems entirely justified.
B. The Project

This study was undertaken in February 1944 as Project Number 879 of Iowa Agricultural Experiment Station and was entitled, "The Adaptation of Farm Buildings to Meet Changes in Farm Operation."

The Farmers' National Company of Omaha, Nebraska assumed sponsorship of the project, contributing a large portion of the required budget and making accessible the improvements on farms under their management for study as well as their own data acquired in the normal management of those farms.
II. REVIEW OF LITERATURE

There is little evidence that any previous studies have been made on this particular problem. While it is probable that every competent designer gives some consideration to alternate uses which may be made of his client's structure, no instances of research projects directed toward the adaptation of agricultural buildings to varied uses have been reported. Carter (1) developed the system of "unit space" planning for general purpose barns which tends to create considerable flexibility in possible future plan arrangement. However, ease in original space planning rather than flexibility of plan arrangement was his apparent objective.

The plan publications of the Midwest Plan Service, the Structural Clay Products Institute and the Portland Cement Association were extensively studied and used as a basis for determination of standard space units used in principal farm building types. These studies are later reported in detail under New Construction Studies.
III. OBJECTIVE OF THE INVESTIGATION

The general objective of this investigation was to determine those factors in conventional farm building design which tend to prevent a continuous readaptation of those buildings to meet current needs and to devise measures, equipment, or structural devices which would improve the general adaptability of farm structures.
IV. METHOD OF PROcedURE

A. Remodeling Studies

1. General approach

The adaptation of obsolete farm buildings to meet present needs seemed a logical starting point for this study. Surveys to gather data on the arrangement and construction of buildings not fully utilized were instituted. Pertinent data on the farmsteads were recorded and building requirements of the farms studied in detail. Present experience indicates that definite classification of the problems encountered is possible and also rather generalized solutions to the remodeling of buildings of a specific type.

A large portion of the anticipated "boom" in post-war farm building construction should consist of remodeling and improvement of existing structures. Some such work is now in progress. Publication of the results of these remodeling studies at an early date should be of both immediate and future value to farm owners and managers.

For those engaged in carrying on the project it has furnished an excellent background for work on new building plans. The advantages of such initial survey and analysis included:

1. Actual contact with farm owners, owner operators, tenants and managers.
2. Direct observation of existing conditions.

3. Development of a facility for more quickly and accurately observing planning and structural defects.

4. An observation of the performance of various materials in actual use.

5. A preview of obstacles likely to be encountered in designing new farm buildings for maximum flexibility.

6. An understanding of remodeling methods and remodeling costs.

7. The development of systematic techniques of analysis and design for converting buildings to new and different uses.

8. Familiarity with latest established functional requirements for the various building types.

All of the buildings inspected were on farms managed by the Farmers' National Company. It is apparently a rather fixed policy of this organization to avoid specialized farming operations except where the advantages of such operations are extremely evident. This general policy permits development of the farmsteads without overcapitalization in equipment for one specialized operation and greatly increases the potential number of suitable tenant operators. Tenure of operators is of far shorter duration than on owner-operated farms and placing of new tenants with just the right amount and type of livestock and equipment to make the greatest use of the existing facilities is difficult if not impossible. To accommodate such operation successfully, buildings with an unusual degree of flexibility are
required. The recommended alterations of some of the building plans illustrated and discussed on the following pages were therefore more extensive in some cases than might be required or warranted if these buildings were on owner-operated farms.

It will be further noted that rather standardized plan arrangements for some building types have been developed. Since these farms are in the same general farming area and operation of the farms tends toward a rather standardized pattern, considerable standardization of the buildings required seems both consistent and logical.

2. Inspection trips

The week of March 6-10, 1944 was spent with Mr. H. C. Breckenridge, Fort Dodge Office, Farmers' National Company, inspecting buildings on farms under his supervision in Hamilton, Humboldt, and Wright counties. The week of June 26-30 was spent with Mr. R.A. Elliott of the same office, inspecting buildings on the farms under his supervision in Calhoun, Greene, and Pocahontas counties. Data appearing at the head of the following individual descriptions of the "problem buildings" inspected were recorded together with basic dimensions of the buildings and freehand sketches of the plan and section of each building were made on cross-section paper. Data on adjacent buildings, general layout of the farmstead, etc. were also recorded when such information appeared to influence the probable remodeling scheme. This material was analyzed, classified where possible, and fairly complete suggestions for improvements made in each case.
3. Barn remodeling

For comparative study and ease in presentation the original plans and suggested remodeling schemes are here presented by groups representing building types rather than in chronological order of inspection. Identifying numbers for the individual farms are those used by the Farmers' National Company representing account number and name of owner. Exact location of the various farms is shown by the accompanying maps (Figures 4-9).

<table>
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<tr>
<th>Farm</th>
<th>Location</th>
<th>County</th>
<th>Size of farm</th>
<th>Inspection date</th>
<th>Replacement of barn</th>
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<tr>
<td>2275 Miller</td>
<td>Laurens, Ia.</td>
<td>Pocahontas</td>
<td>320 acres</td>
<td>6-27-44</td>
<td>lost by wind</td>
</tr>
</tbody>
</table>

The barn on this farmstead was completely destroyed by wind in a storm on May 20, 1944. All other buildings on the farmstead except the house were also damaged to some degree. The owner authorized an expenditure of $1,000 in excess of the insurance adjustment for repair or replacement of buildings existing previous to the storm or for such new construction as seemed advisable. At the time of inspection necessary minor repairs had been made to the large double crib and granary and a 20'x50' cattle shelter. A new 20'x20' (approx.) poultry house was nearly completed; work had begun on a 20'x50' machine shed and foundations were poured for the new barn. The old 34'x48' barn had a concrete floor in the cow stanchion section. The recommended location of cow stanchions coincides with that of the...
Fig. 1

Expenditures for and Depreciation of Farm Buildings, Fences, Windmills, and Wells in the United States, 1900-1945

Fig. 2

Fig. 3
Fig. 4
Calhoun County Map

3120 Reichstadt
GENERAL HIGHWAY AND TRANSPORTATION MAP
GREENE COUNTY
IOWA

PREPARED BY THE
IOWA STATE HIGHWAY COMMISSION
U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
STATE-WIDE HIGHWAY PLANNING SURVEY

R-29W

13.

2907 Allen

2820 Anderson

Greene County Map
14.

GENERAL HIGHWAY AND TRANSPORTATION MAP

HAMILTON COUNTY

IOWA

REPRODUCED BY THE

IOWA STATE HIGHWAY COMMISSION
IN COOPERATION WITH

FEDERAL WORKS AGENCY
PUBLIC ROADS ADMINISTRATION

SAN FRANCISCO 1944

HIGHWAY PLANNING SURVEY

R-26W

R-25W

R-24W

R-23W

HAMILTON COUNTY

IOWA

SECONDED BY MADISON COUNTY

IOWA STATE HIGHWAY COMMISSION
IN COOPERATION WITH

FEDERAL WORKS AGENCY
PUBLIC ROADS ADMINISTRATION

SAN FRANCISCO 1944

HIGHWAY PLANNING SURVEY

R-26W

R-25W

R-24W

R-23W

Fig. 6

Hamilton County Map

1 2909 Hague

2 3153 Kettaneh
16.
GENERAL HIGHWAY AND TRANSPORTATION MAP
POCAHONTAS COUNTY
IOWA

REPRODUCED BY THE
IOWA STATE HIGHWAY COMMISSION
IN COOPERATION WITH THE
U.S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
STATE-WIDE HIGHWAY PLANNING SURVEY
1940

Fig. 8
Pocahontas County Map

1 2275 Miller
2 3192 Wilson
Fig. 9
Wright County Map
original barn. New foundations were poured just inside the old foundation walls. Framing members of the old barn were largely 6"x6" and 4"x6" members in 14' lengths and over. Careful inspection and inventory of this material were made and the plan shown here was developed the following two evenings in conferences with Mr. Elliott and the carpenter in charge of the work. Every effort was made to utilize salvaged lumber on hand and some dimensions were adjusted to accommodate materials then available in local lumber yards. Cost estimates of the entire project indicated that it was doubtful if the proposed shed addition to the barn could be erected at the present time but it was later reported by Mr. Elliott that the addition was erected. Drawings similar to Figures 2 and 3 were left with the carpenter for immediate use on the job.

<table>
<thead>
<tr>
<th>Farm</th>
<th>2907 Allen</th>
<th>Supervisor</th>
<th>R.A. Elliott</th>
<th>Location</th>
<th>Paton, Iowa</th>
<th>Type building</th>
<th>Gen. Purp. barn</th>
</tr>
</thead>
<tbody>
<tr>
<td>County</td>
<td>Greene</td>
<td>Size of building</td>
<td>34'x40'</td>
<td>Size of farm</td>
<td>320 acres</td>
<td>Wanted</td>
<td>Improved milking facilities</td>
</tr>
<tr>
<td>Inspection date</td>
<td>6-30-44</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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This barn was structurally sound and in good repair. The present tenant had some 15 dairy cows and needed additional milking facilities. The one single and four double horse stalls (See Figure 10) were considerably in excess of present or probable future requirements so it was decided to retain only two of these stalls and to develop a loafing-pen type barn by a system of dual control gates across the feed alley. The area for loose cattle thus provided is large enough to accommodate the present herd or even a few additional cows without difficulty.
This small barn was in good repair and was well constructed and braced. No structural alterations of the existing barn were recommended. Another old barn on the farm was being torn down and the lumber reclaimed approximately met the requirements for the shed addition except for siding. The extremely narrow width of this building presented some problems in remodeling and alley space in the new plan arrangement (See Figure 11) is in excess of normal proportion. Resulting accommodations are, however, probably adequate for a farm of this size.

An alternate solution of this problem was prepared which was more economical of space but would require a 16' width for the addition plus an addition for feed room and separator room. The plan was essentially a duplication of the proposed plan No. 2 for the alteration of the barn on the farm 2820 Anderson appearing in Figure 21, but with one double horse stall omitted. Space for loose cattle could have been considerably increased in this manner.

This barn was apparently sound structurally and in fairly good repair. Elimination of numerous temporary partitions, not all of which
appear on the plans (Figure 12) would permit the present tenant to utilize most of the building. It is doubtful, however, if the building will ever be entirely satisfactory until major remodeling is done. Being a drive-through type barn, the mow floor extends over only a portion of the building so that it is cold and drafty unless almost completely filled with hay. The lean-to portion containing the horse stalls and the cattle shed attached at the opposite end prevent filling of the mow through a hay door in either end of the barn. The horse stalls are no longer used. There is a third shelter for beef cattle in a shed some 50' south of this barn so that the total amount of shelter for cattle is abnormally large. The farmstead has no permanent hog house and no provision for housing any dairy cows.

The barn might be remodeled as shown in Figure 13, eliminating the lean-to portion which is not now used and thus provide access for more efficient handling of hay. The salvaged material should substantially complete the recommended changes in other portions of the barn.

The present tenant is not interested in having sows farrow in late winter or early spring so intends to use a portion of the cattle shelter previously mentioned for pens for late spring farrowing. Portable hog houses are used throughout the remainder of the season.

<table>
<thead>
<tr>
<th>Farm</th>
<th>3153 Kettaneh</th>
<th>Supervisor</th>
<th>H.C. Breckenridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Blairsburg, Ia.</td>
<td>Tenant</td>
<td>Homminger</td>
</tr>
<tr>
<td>County</td>
<td>Hamilton</td>
<td>Type building Horse barn</td>
<td></td>
</tr>
<tr>
<td>Size of farm</td>
<td>240 acres</td>
<td>Size of building 52'x64'</td>
<td></td>
</tr>
<tr>
<td>Inspection date</td>
<td>3-7-44</td>
<td>Wanted remodel into general purpose barn</td>
<td></td>
</tr>
</tbody>
</table>

It is obvious that this barn had been rather haphazardly altered.
from time to time without much thought to keeping a really workable plan arrangement. A large portion of the old horse stalls were used for hogs. It was rather hard to determine the original purpose of the enclosure in the central alley (See Figure 16) which was at the time of initial inspection, used as storage space for a corn-picker.

The only machine shed on this farm was a very temporary structure attached to the south side of a double corn crib and granary. The barn was larger than necessary for animal shelter and it was suggested that a portion of the building be used for a machine shed.

This farmstead was visited again in June 1945. The barn had been remodeled according to the plan which we had furnished (See Figure 17) at a cost of $1100.00. The tenant and manager were both well pleased with the results.

<table>
<thead>
<tr>
<th>Farm</th>
<th>2226 Painter</th>
<th>Supervisor</th>
<th>H.C. Breckenridge</th>
</tr>
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<tbody>
<tr>
<td>Location</td>
<td>Renwick, Ia.</td>
<td>Tenant</td>
<td>Abner Strait</td>
</tr>
<tr>
<td>County</td>
<td>Wright</td>
<td>Type building</td>
<td>Gen. Purp. barn</td>
</tr>
<tr>
<td>Size of farm</td>
<td>160 acres</td>
<td>Size of building</td>
<td>48'x48'</td>
</tr>
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<td>Inspection date</td>
<td>6-8-44</td>
<td>Wanted</td>
<td>Remodel</td>
</tr>
</tbody>
</table>

The tenant had several large cows which could not be accommodated in the small stanchions provided. Provision for hay carried to the floor prevented lengthening of stanchions in their present location. (See Figure 16). The feed room had been constructed only recently and had a very good concrete floor and tight walls. The five double horse stalls were far in excess of requirements. The building was in good repair and newly painted. Space in the north end of the barn was too inaccessible to be of value.
The remodeling scheme (Figure 15) included conversion of the three East double stalls to properly sized cow stanchions, completion of the mow floor, conversion of the entire North end of the barn into space for loose cattle and the addition of a separator room. A concrete floor was recommended for all portions of the barn except the space for loose cattle.

<table>
<thead>
<tr>
<th>Farm</th>
<th>2820 Anderson</th>
</tr>
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<tbody>
<tr>
<td>Location</td>
<td>Cooper, Iowa</td>
</tr>
<tr>
<td>County</td>
<td>Greene</td>
</tr>
<tr>
<td>Size of farm</td>
<td>305 acres</td>
</tr>
<tr>
<td>Inspection date</td>
<td>6-30-44</td>
</tr>
<tr>
<td>Type building</td>
<td>Gen. Purp. barn</td>
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<td>Size of building</td>
<td>42'x56'</td>
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<td>Wanted</td>
<td>Remodel</td>
</tr>
<tr>
<td>Tenant</td>
<td>K. Netherton</td>
</tr>
<tr>
<td>Supervisor</td>
<td>R.A. Elliott</td>
</tr>
</tbody>
</table>

The condition of this barn was evident from the photograph (Figure 18). The owner had approved the construction of a new barn or the remodeling of this one but had limited the expenditure to $1,000. This would not provide a building of adequate size to handle the requirements of the farm and efforts to secure additional funds had not then been successful. Remodeling of the existing barn, despite its present condition, seemed the only solution under the cost limitation imposed.

The proposed scheme calls for the removal of the north lean-to shed and also the bearing partitions in the main structure (Figures 19, 20, 21). The intended purpose of these partitions, other than providing structural support to the mow floor, was somewhat obscure. Lumber thus salvaged would provide most of the material required for completing the proposed scheme. Some shingles left over from another re-roofing job were on hand. Sheet metal siding was available in some quantity and was being recommended here as perhaps the cheapest method of covering the old walls to obtain a reasonably tight enclosure.
Fig. 18. Barn on Farm 2820
Anderson Farm Southeast

Fig. 19

Fig. 20

Fig. 21
Necessary structural improvements to the main portion of the old building included a new concrete foundation for the entire structure, new mow floor framing to replace existing 2"x6" joists which were in bad condition, and a redesign of the roof bracing. Suggested remodeling schemes No. 1 and No. 2 are identical with the exception of the location of feed room and separator room. Scheme No. 1 was considered most desirable but would involve some additional initial expense. The proposed budget was so limited that "cutting-of-corners" would be necessary. The value of this building after remodeling would still be questionable and the recommendations made here were not considered to be an ideal solution of the problem but only a reasonably practical solution of the problem under the difficulties imposed.

This barn (Figure 24) is about 75 years old. Present condition of the building is shown by the photographs (Figures 22 and 23). This study was made to obtain material for determining probable costs of returning the old barn to a functional condition so that a decision might be made on remodeling of the barn or replacing it. The proposed remodeling scheme (Figure 25), if adopted, is considered minimum and rough preliminary estimates of materials and labor required would indicate a required expenditure considerably in excess of $2,000.
Fig. 22. Barn on Farm 3192 Wilson from Southeast.
Fig. 23. Barn on Farm 3192 Wilson from North.

Fig. 24

Fig. 25
If materials and labor for new construction become available in the rather near future it would seem desirable to replace the old barn with a smaller structure better adapted to the present requirements of the farm. Some provision for proper housing of livestock on the farm must, however, be made soon and later developments may require the remodeling of the old barn in a manner similar to that illustrated.

- Farm 3121 Frazer
- Location Humboldt, Ia.
- Tenant Steve Hawkins
- County Humboldt
- Type building Dairy barn
- Size of farm 323 acres
- Size of building 44'x64'
- Inspection date 6-9-44
- Wanted Correct structural defects

This bank-type dairy barn (Figure 26) is of fire resistant wall construction. Some pointing of mortar joints was necessary and should be done before water entering the open joints does further damage. Approximately 16' of the length of the building at the south end of the mow floor was used for five double horse stalls and the design of the roof trusses (two of which are over this area) had been altered to allow the trusses to bear about seven feet above the mow floor level. The floor placed over the horse stalls at approximately the same level as the spring line of these trusses was not designed in such a manner as to provide an effective tie between opposing truss supports with the result that walls were being pushed out of alignment at these points. The horse stalls were not and probably never would be completely utilized and elimination of the end stalls was recommended to permit redesign of the lower members of the roof trusses in this section to conform with those used throughout the remainder of the building.
Damage to the wall was not irreparable but this entire section of the building was highly susceptible to wind damage while in this weakened condition.

Materials and barn equipment used in the construction of this barn were of unusually high quality and the structure was sound with the exceptions noted. It had been neglected for a number of years and minor repair to both building and equipment were necessary in many places.

The structural bracing of this building was almost wholly ineffective. It probably remained standing only because it was well sheltered from wind by surrounding trees and high ground. The north and east walls were in a very bad state of repair with numerous studs broken off where notched to receive continuous ribbands. Posts in the mow were obviously incapable of carrying any load (See Figure 27).

There was a considerable quantity of both dimension lumber and 10" drop siding (this matched the siding originally used on the barn) in an old building nearby which had been partially dismantled. Nearly all necessary materials for making the repairs and alterations recommended could be salvaged from this old building. Used as a beef feeding barn, the proposed extension of roof bracing to the sill would not seriously interfere with the use of this building but would
strengthen the structure considerably. This would also permit the economy of splicing broken studs rather than replacement.

4. Barn remodeling summary

It will be noted that it was necessary to eliminate most of the horse stalls in every plan revised to make effective use of the space. Adequate provision for handling of any dairy cows was originally provided only in the dairy barn on the farm 3121 Frazer and the general purpose barn on the farm 2907 Allen. Six to eight cow stanchions were recommended in each of the remaining general purpose barns.

The few remaining horses on these farms were kept in the barn during only a small part of the year. Consequently, double horse stalls retained have been equipped with gates to permit use of stalls as either horse stalls or box stalls. It was also recommended that mangers in horse stalls have the top 2"x10" board on the stall side hinged to drop down. This permits a quick adjustment of manger height to accommodate either horses or cattle.

Most of the old barns for which remodeling was recommended were over 40 feet in width. To make effective use of the space in the center of these buildings a cross alley arrangement was required. According to H.B. White (4), the length of chore routes resulting from this arrangement is approximately 27 per cent in excess of the length of chore routes obtained with an arrangement where animals are "faced in" to a central feed alley. The "face in" arrangement is not prac-
tical, however, on barns which exceed 36 or 40 feet in width.

Completion of the mow floor and conversion of the first floor space directly below has been recommended in all cases for both space economy and temperature control. Hay storage space remains adequate for anticipated needs in all cases. The same considerations dictated elimination of the drive-through feature of the barn on the farm 2909 Hague.

After providing for the rather fixed features of about six cow stanchions, two double horse stalls or box stalls, feed room, and in several cases a separator room, remaining space in general purpose barns was devoted to provisions for loose cattle. Space thus allotted is excessive in some cases. Completion of the remodeling as recommended would, however, largely remove all obstructions from those areas and future placing of fixed equipment in any portions of this space could be accomplished with minimum difficulty. Wherever width of the space for loose cattle permitted, recommended bunk and manger equipment was so arranged as to permit feeding without direct contact with the animals. An attempt was also made to arrange the buildings in such a manner as to permit conversion to a loafing pen type dairy unit by the simple addition of dual control gates across the feed alley as used in the alteration recommended for the general purpose barn on the farm 2907 Allen. This did not spring from any preference for the loafing pen type barn but from the greater resulting flexibility. Only those barns originally equipped with cow stanchions
had concrete floors in any section of the barn and these floors were in stanchion and feed room section only. Four barns were equipped with feed rooms, one of which was not in serviceable condition.

Small girders and close spacing of interior posts was one of the most serious obstacles to remodeling. In a few cases, replacement of existing posts and girders in one or more bays was necessary to carry out the remodeling scheme proposed.

Structural defects observed were so numerous and varied that no complete classification will be attempted. Some defects occurred so frequently and others were so obvious that they are here mentioned. Despite the rather common close spacing of posts, condition of the girders indicated that in nearly all cases the mow floor joist system was capable of transmitting a far greater load to the girders than those girders could safely carry. Even in the mow floors using 2"x6" joists the girders showed more evidence of overload than did the floor joists. Free standing posts, 2"x6" and 2"x8", or wind bracing members exceeding 16 feet in length were observed in two cases. No real structural support was afforded by these members.

Only one of the barns inspected had collar beams at the roof peak. With only one exception, additional braces for the roof (other than collar beams) were necessary in some part of all structures where rafters were sprung from a point above the mow floor line. The one barn excepted was only 24 feet in width.
Broken studding, resulting from the use of continuous ribbands let into the studs at the point of support for mow floor joists, was observed in only one of the two barns inspected where this framing method was used. Additional bracing to reduce bending in the studs was, however, recommended in both cases.

5. Hog house remodeling

Farm 2905 Porteous Location Humboldt, Ia. Supervisor H.C. Breckenridge
Location Humboldt Tenant Carl Weigert
County Humboldt Type building Hog house
Size of farm 400 acres Size of building 76'x76'
Inspection date 3-10-44 Wanted Remodel into beef feeding barn

The present replacement cost of this 28 pen hog house (Figure 28) would exceed $300 per pen. It was not in use because the space enclosed was so large in proportion to the potential number of animals housed that hogs could be kept comfortable only by supplying artificial heat in winter months. A careful study of the original plan and construction detail indicates the unusual quality of the construction employed.

The roof framing for the north-south axis gable roof was completed and the east-west gables then added. As a result the mow floor space in the east and west gables is separated from the rest of the mow floor by rows of 2"x6" studs at 2'-0" centers. Heavy valley rafters should be installed and the above mentioned studs removed to make this space available for hay storage.
Improvements on this farm were far in excess of average and have been kept in excellent repair. No provision for the housing of feeding cattle was available so it was recommended that this building be converted into a beef feeding barn as illustrated in Figure 29. The feeding floor between this building and the frame farrowing house to the north was shaded most of the day by this building. There also seemed to be no convenient method for bringing cultivated lots up to the smaller hog house and feeding floor so relocation of the frame hog house was recommended.

<table>
<thead>
<tr>
<th>Farm</th>
<th>3121 Frazer</th>
<th>Supervisor</th>
<th>H.C. Breckenridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Humboldt, Ia.</td>
<td>Tenant</td>
<td>Steve Hawkins</td>
</tr>
<tr>
<td>County</td>
<td>Humboldt</td>
<td>Type building</td>
<td>Hog house</td>
</tr>
<tr>
<td>Size of farm</td>
<td>323 acres</td>
<td>Size of building</td>
<td>24'x24'</td>
</tr>
<tr>
<td>Inspection date</td>
<td>3-9-44</td>
<td>Wanted</td>
<td>Improved insulation</td>
</tr>
<tr>
<td>of building</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This building seemed structurally sound despite the use of a non-loadbearing type tile construction (Figure 30) for an outside bearing wall. All wall repairs necessary could be made in a very few hours. The owner and tenant were not satisfied with the house because of lack of temperature control. The owner had been contemplating placing another tile wall outside the existing wall with an air space to be left between walls. Theoretical heat transmission coefficients for the existing wall and roof construction were nearly equal. Total wall area was approximately equal to the floor area indicating that heat loss through the roof is probably greater than that through the walls. Lining of the underside of the rafters with 25/32 inch rigid insulation board was therefore recommended on
the basis that it would provide an over-all insulation value equivalent to the method originally proposed at considerably less expense. Total glass area in the south wall was equivalent to less than 2 per cent of the floor area. Need for retaining the roof lighting dictates lining of the under side of rafters rather than constructing a flat ceiling at the plate level.

6. Poultry house remodeling

<table>
<thead>
<tr>
<th>Farm</th>
<th>2909 Hague</th>
<th>Supervisor</th>
<th>H.C. Breckenridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Blairsburg, Ia.</td>
<td>Tenant</td>
<td>John Williams</td>
</tr>
<tr>
<td>County</td>
<td>Hamilton</td>
<td>Type building</td>
<td>Poultry house</td>
</tr>
<tr>
<td>Size of farm</td>
<td>346 acres</td>
<td>Size of building</td>
<td>12'x30'</td>
</tr>
<tr>
<td>Inspection date</td>
<td>3-6-44</td>
<td>Wanted</td>
<td>Remodel and enlarge</td>
</tr>
</tbody>
</table>

A poultry house large enough to successfully accommodate 150 to 200 laying hens was desired for this farm. The old building was in rather poor condition but framing was sound and shingles on the north roof slope apparently good for several more years. The revised and enlarged plan (Figure 32) called for increasing the width of the building to 18 feet and removing the existing partition. New siding placed over the old siding is far less effective as insulation than lining of the studs on either side but it was not believed possible to salvage much of the old siding if it was removed. Since the revised plan is still only 18 feet in width, north lighting was not deemed essential and droppings pits were placed against the wall. Insulation of the ceiling in the revised building is considered essential and walls should also be lined and insulated as soon as possible.
Farm 3121 Frazer  Supervisor H. C. Breckenridge
Location Humboldt, Ia.  Tenant Steve Hawkins
County Humboldt  Type building Poultry house
Size of farm 323 acres  Size of building 14'x60'
Inspection date 3-9-44  Wanted Remodel

The south face of this building contained 52 window sash (4 light 9"x12"). The proposed remodeling scheme (Figure 33) included increasing the width of building to 18' and dividing the building into two pens with a solid partition between. Only five windows per pen were specified in the revised plan. The gable roof for the revised building was provided by tilting up the existing roof to 1/4 pitch and framing in a south slope. Arrangement of droppings pits, feeders, and other equipment in each pen was almost identical with that recommended for the poultry house on the farm 2909 Hague.

7. Grain bins and corn cribs

Farm 2907 Allen  Supervisor R.A. Elliott
Location Paton, Ia.  Tenant Lloyd May
County Greene  Type building Double corn crib
Size of farm 320 A.  Size of building 26'x48'
Inspection date 6-30-44  Wanted Add overhead grain bins

This crib was apparently well built and braced. Bin space available, if completed (as shown in Figure 31) would provide storage for approximately 4,000 bushels of shelled corn or small grain. The proposed addition called for 2"x14" or 3"x12" joists at 24" o.c. for bin floors and 2"x6" ties with the same spacing at tops of bins. Four by six inch whalers to receive tie rods were recommended for the existing walls with new bin partitions to be framed with a double
2"x6" plate approximately six feet above the bin floors to eliminate need for whalers on these walls.

8. General remodeling summary

The number of buildings of types other than barns included in these surveys was not sufficient to permit classification of problems likely to be encountered in remodeling each type. Some features of these buildings are covered in the following summary applying to all buildings inspected.

Not one of the buildings inspected was insulated and few had any ventilation controls.

None of the buildings was equipped with roof gutters or leaders.

Windows and doors were in generally poor repair.

With the exception of one poultry house, the ceiling height of every livestock and poultry shelter inspected was in excess of heights now recommended.

Glass areas in one poultry house and one hog house were quite excessive. Glass area of the poultry house was over five times the area now recommended.

An interior post and girder arrangement for barns using posts 8'-0" o.c. located in rows adjacent to a 4 foot central feed alley appears to be most adaptable to remodeling. On barns of average width this would require floor joists 2" deeper than would be required if the posts and girders were placed to create three bays of approximately equal width. Girder loading would, however, be somewhat reduced.
since a larger portion of the total floor load would be carried by the outside walls. At present materials prices, the extra cost of providing the more flexible arrangement suggested should not exceed $15 per 1000 square feet of floor area. The extra cost of making all one story buildings 24 feet or less in width clear span structures would be still less.

B. New Construction Studies

1. Introduction

One primary purpose of the remodeling studies just described has been the acquisition of background for determining those features of building construction which by incorporation, omission, or by alteration either improve the function of farm buildings without increasing their service cost or reduce service cost without impairing the building function. Adaptation of farm structures to new and different uses is first of all an economic problem. Any contribution toward reduction of initial costs, maintenance costs, remodeling costs, or total annual service costs would be a contribution toward increased adaptability so long as methods used maintain or improve present housing standards.

The principal sources of remodeling difficulty discussed previously may be classified as follows:

1. Non-functional details.
2. Basic structural dimensions.
3. Basic equipment dimensions.
4. Basic structural schemes.
It was presumed that these same features might present similar
difficulties in the future re-adaptation of buildings constructed
from plans for new construction now being offered by the Midwest Plan
Service which acts as the official agency for the distribution of farm
building planning recommendations for Iowa State College and other
Land Grant Colleges of the North Central States. Various commercial
and industrial agencies also distribute farm building plans in large
quantities and review of the plan offerings of both the Midwest Plan
Service and independent outside agencies from the standpoint of plan
adaptability was initiated.

2. Analysis of new plan offerings

The last general issue of Midwest Plan Service plans was in 1937.
Since that time miscellaneous plans have been added largely from those
prepared for individuals by the Iowa Agricultural Experiment Station
on a fee basis and those prepared for use on Experiment Station farms.
Since much of this material was prepared for very specific uses by
individuals not performing general routine farming operations or for
strictly experimental purposes it was believed that the original 1937
offerings were more representative of present new construction practice
than were the entire present offerings. These plans were predominantly
drawn for frame construction so present plan offerings of masonry
buildings as prepared by the Structural Clay Products Institute and
the Portland Cement Association were added to the group. All basic
plan features and dimensions, equipment dimensions, bay widths, serious remodeling obstructions noted, and non-functional detail were classified and tabulated.

a. Barn plans. All conventional barn plans appearing in the plan offerings of the three agencies above mentioned are listed and classified in Table 1. Detailed analysis of this material is later presented.

b. Minor service buildings. Comparable offerings by these agencies of plans for minor service buildings are listed and classified in Table 2. These include the following building types: Single row general purpose barns, walk-through dairy barns, cattle sheds, sheep sheds, two-row farrowing houses, poultry houses, farm shops, 2 car garages, car and truck garages, and machine sheds. The two classifications thus cover the common types of farm service buildings with the following exceptions: portable small buildings, very small service structures (pump houses, fuel sheds, etc.), which are too small to be of serious economic consequence and storage buildings designed for bulk storage of grain and forage crops which must contain permanent internal bracing or ties to resist lateral wall loadings and are thus made unsuitable for other purposes.

In addition to the remodeling obstructions and non-functional details listed, certain troublesome features were consistently repeated in buildings constructed of each basic wall material. These seem to spring from rather standardized construction practices which have been
## Table 1

### CLASSIFICATION OF BASIC PLAN FEATURES IN BARNS

All Dimensions in Feet

<table>
<thead>
<tr>
<th>Source</th>
<th>Plan no.</th>
<th>Building type</th>
<th>Date fi. plan</th>
<th>Double horse stalls</th>
<th>Cow stalls</th>
<th>Front pens</th>
<th>Side pens</th>
<th>Single horse stall</th>
<th>Feed room</th>
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<td>1.50</td>
<td>36.00 30.00 7.50</td>
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<tr>
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<td>12.35 12.35 12.35 12.35</td>
<td></td>
</tr>
</tbody>
</table>

### Functional Details

- **Side center hay and storage areas**: Side center hay and storage areas
- **Serious remodeling constraints**: Side center hay and storage areas
- **Non-functional details**: Side center hay and storage areas

### Footnotes

- **Average dimensions used on one plan.**
- **Note**: Indicates center driveway.

### Notes

- **Note**: Indicates center driveway.

### G.F.P. - General Purpose Barn
<table>
<thead>
<tr>
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<th>Building type</th>
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<th>Length Width</th>
<th>Lot per.</th>
<th>For areas pens</th>
<th>Farrowing pens</th>
<th>Stall pens</th>
<th>Interior hay width</th>
<th>Length (ft.)</th>
</tr>
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<tbody>
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<td></td>
<td></td>
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<td>Length Width</td>
<td>Lot per.</td>
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developed for the various materials without particular regard for the possible obstructions thus presented in future alterations of the structures. These details and construction practices are discussed in considerable detail in the following section.
V. RESULTS

The work upon this project involved a series of related studies. It was necessary to make current interpretation of much of the data in order that results and conclusions might be used in following studies. Results of the earlier studies are presented and discussed at some length in the previous chapter but should be considered largely as background material for use in the study of new construction of buildings and building equipment. It should be noted, however, that most remodeling obstacles observed are common to both existing buildings and present plan offerings and certain results of the studies on new construction might be applied to existing structures.

A. Elimination of Non-Functional Detail.

Detail Simplification

High concrete foundation bulkheads were frequently noted as a serious remodeling obstruction on buildings which have frame walls. In a great many cases these concrete bulkheads extend only a few inches above the floor. The purpose of such construction is to elevate the wood sill of the frame wall a sufficient distance above the floor level to prevent deterioration of the sill and lower side wall from rain water splashing against the exterior or from contact with wet litter and manure inside the building. When only slightly elevated the
Concrete bulkhead remains a serious obstacle to the relocation of door openings but the decay protection sought is not provided. The poultry house plan (Figure 35) is adapted from the Iowa Laying House Plan prepared and now distributed by the Iowa State College Extension Service. Comparison with the original plan (Figure 34) shows the required change in construction at the sill to completely eliminate the concrete bulkhead and permit relocation of doors to any point of any wall without disturbing the concrete foundation.

Analysis of the roof framing of this same structure indicated that the roof as framed on the original plan has ample structural capacity without use of the interior post and girder shown. The post and girder is non-functional and has been eliminated in the remodeled plan. These changes in foundation wall and interior support permit certain other detail simplifications in the building. Without reduction of the minimum clear ceiling height the entire ceiling can be lowered an amount equivalent to the girder depth. A very slight adjustment in this ceiling height would then permit use of both siding and studding in standard available lengths with no cutting waste. It likewise brings the plate height to the height originally recommended for the door height, thus eliminating necessity for separate header framing over door and window openings.

Construction of the building according to the original plan would require approximately 10 cubic yards of concrete for footings. At 4000 lbs. per cubic yard, the customary weight allowance for concrete,
Fig. 35. Revised Iowa Laying House Plan.
the building foundation would weigh approximately 40,000 lbs. The total calculated weight of the superstructure is approximately 8000 lbs. If it can be assumed that the footing specified is necessary, 83 percent of the footing capacity is used to carry its own weight. This appears to be a very disproportionate and highly inefficient use of material. Seelye (3) in his recommendations for the design of sub-base stabilization for highway pavement slabs shows a map of the depth of frost penetration for all areas of the United States. Iowa falls in the zone of frost penetration from 29 to 41 inches. He also presents the method of modifying the required depth of soil stabilization by water table level and by classification based on the size of soil particles. This data would indicate that there are relatively few locations in Iowa which would require stabilization of sub-base of a pavement slab to a depth appreciably greater than would be required for rat protection in a building foundation. Mr. W.E. Jones (2), Engineer of Design, Iowa State Highway Commission, states that it is not the practice of the Commission to specify continuous sub-base stabilization under pavement slabs but to require stabilization only in such locations as previous experience and soil samples taken at the particular location would dictate. He further states that the locations where stabilization is necessary would not generally be considered as fit locations for building sites and that in no case is stabilization carried to a depth equivalent to the depth of frost penetration.
In frame buildings, distortion of the structure in amounts greater than the permissible distortion of highway pavement slabs should be permissible without appreciable aesthetic or structural consequences. The remodeled plan is shown with a floor design based on a conventional slab construction modified only by carrying the sides down to a sufficient depth to provide rat protection. Experimental work on the possible reduction of foundation materials used to support light farm buildings is badly needed.

The general purpose barn plan, Midwest Plan No. 72132, has been widely distributed and the original design of the gothic arch construction employed has been the basis of several Iowa Experiment Station projects. Special analysis of this building was made to effect simplification and eliminate non-functional detail. It was noted that certain traditional features of this building no longer served their intended function. A roof sweep appeared at the cornice line which served the original purpose of shedding water at some distance from the building foundation. Later, sheet metal gutters and down spouts had been recommended to catch and dispose of the roof drainage but the roof sweep was retained and the gutter installed at the extremity of the sweep. This requires two elbows in the leaders to return them into contact with the wall. Suggested revision of this feature is shown in Figure 36. The sweep has been entirely removed and the entire assembly replaced with a one-piece wood gutter. The gutter has also been lowered
so that the trim at the heads of windows completes the cornice assembly. The resulting detail performs the function of the original assembly but with a resulting elimination of over 200 pieces in constructing a 36'x60' barn.

Wind bracing for the gable ends of this barn was provided by a triangular truss standing on its point at either side of the hay door opening and at a comparable location in the other gable of the barn. This truss was made up of standard sizes of dimension lumber with nailed and bolted joints. Analysis shows that required strength of the truss to resist maximum wind loadings could be developed only by exceeding the elastic limit of the joints. Consequently, the behavior of the truss could not be predicted by customary methods of structural analysis and its actual behavior under load would be largely dependent upon the quality of workmanship employed in its fabrication. In the remodeled plan a built up girt of 2"x12" lumber was substituted for the truss with some saving in materials. Its behavior under load can be predicted by the most elementary method of analysis. At the same time, lintels over openings in the end walls were extended from outside wall to the center alley opening. This eliminated a double plate across both ends of the building and numerous short studding. Together with slight modification of the window framing the total changes effected a considerable material saving and resulted in the elimination of over 400 pieces from the barn.
B. Basic Structural Dimensions

As stated in the summary of work on remodeling existing buildings, much of the difficulty in remodeling arose from the use of basic dimensions in the structure of width and height which vary considerably from present recommendations. Widths of barn plans now offered by the Midwest Plan Service and some outside agencies are listed in Table 1. Seventeen of the 19 plan offerings are for barns 32, 34, and 36 feet in width. The average width for all offerings including the wide barns was 36.08 feet and the mean width was 34 feet. The two wide barns are designed specifically for cattle feeding but the cattle feeding barn shown which is only 36 feet wide would appear to offer comparable accommodations. The variations in space allowances within the barns of the three standard widths appear to lie almost entirely in the widths of service alleys. Since the same operations are performed in these service alleys, regardless of their exact width it seems entirely logical that the alley widths might be standardized which would result in complete standardization of barn width. Dimensions given for the lengths of pens, stalls, etc. are from front edge of manger to inside face of wall for barns of "face-in" arrangement and from front of manger to center of driveway for "face-out" arrangement. Horse stalls are the longest item of stall or pen equipment with an average length of 14.11 feet. If to this is added the average alley width of 4.33 feet plus 14.11 feet for a duplication of the stall on the other side of a "face-in" barn and an allowance of 2.5 feet is
made for outside wall thickness and thickness of interior posts projecting into the alley a width of 35.05 feet is obtained as a practical width for a face-in barn to be used under a variety of conditions. By the same method the width of a flexible "face out" barn would be 2x14.11 ft. plus 4.33 ft. on each side for a feed alley plus 1.5 feet for outside walls or 38.38 feet. However, the average length of horse stalls in barns with "face-out" arrangement and it would seem that no practical difficulty would develop in standardizing the width of the barn at 36 feet regardless of the direction in which animals are faced. A barn of this width would accommodate animals of any type usually housed in barns.

The heights of barns ranged from 7.00 feet to 10.00 feet. The heights of 14 of the 19 barns were in the range of 8.00 to 8.67 feet with the average at 8.35 feet. Four of the 10 barns containing horse stalls have ceiling heights of 8.00 or less. With the exception of a horse, man is the tallest animal on a farm. It seems logical, therefore, that comfort and convenience of the operator should largely determine the height of animal shelters in which horses are not housed. To maintain necessary head clearance under girders a clear height of 6'-6" to 7'-0" is required. Adding to this a maximum girder depth of 12" a minimum ceiling height of 7'-6" to 8'-0" is obtained. Since a height of 8.00 ft. is apparently adequate for both horses and man
and is also the length or an even multiple of the length and width
in which almost all structural units are produced, it would seem
practical to standardize the heights of barn ceilings at this level.

Within recent years the use of tractor mounted manure loaders has
become popular. Investigation of manufacturers' literature shows,
however, that nearly all makes will operate inside buildings with this
head clearance.

Widths of minor service building plans now offered by the same
planning agencies appear in Table 2. Thirty-eight of the 43 plans
listed lie in the range of 18.00 to 26.00 feet. With the ex-
ceptions of the 2 one-row barns and the two-row farrowing houses for
hogs these buildings contain practically no fixed pen equipment and if
such equipment exists the pens are designed to handle large numbers of
animal or poultry units in one pen. Of the multitude of items which
might be housed in these buildings the only units likely to have a
greater length than 22.00 feet are horse drawn implements with the
tongue fully extended. This is easily correctible by folding back or
removing the tongue so no apparent obstacles would exist to prevent
the standardization of the width of these structures at the mean width
of 22.00 feet or slightly above the average width at 24.00 feet.

It was also observed that the mean ceiling height of these
structures is just under and the average height just over 8'. The
same analysis as applied to the heights of barns should again apply
and a uniform ceiling height of 8.00' throughout the area in which the
operator performs most of his work would seem a practical standard on all of these minor building types with the exception of truck garages and machine sheds which are sometimes required to store units which exceed 8.00 feet in height. It may be concluded that building shells 22 feet and 38 feet in width and with ceiling heights of 8.00' would meet the requirements in most cases for all minor service buildings of the types studied and for barns.

The accompanying drawings of multiple-use building frames (Figure 37) illustrate a potential application of the standards just established in the fabrication of standard building frames which might be either prefabricated or built on the job. Some initial construction economy should result in prefabrication of these standard units since few standard parts are required. The principal advantage, however, would probably be in the high salvage value of the buildings when dismantled since all framing could be re-used, without alteration in the construction of other building types.

A study of the dimensions of the buildings listed in Tables 1 and 2 shows that width and height of the structure are determined by building use and that length is determined by required capacity of the building. Exact lengths are not of great importance to the building function when the building contains no interior pens, partitions or other fixed individual space divisions. In the planning of barns and those minor service buildings such as two-row farrowing houses overall length is usually obtained by adding up the widths of all stalls and
FRAME TYPE A ON HIGH FOUNDATION

FRAME TYPE B

MULTIPLE JOINTS

FRAME TYPE A

FRAME TYPE B

MULTIPLE USE BUILDING FRAMES

2 FRAMES TYPE B

USE FOR ALL doubly TYPED TYPES

MULTIPLE JOINTS

FRAME TYPES A

FRAME TYPES B

MULTIPLE USE BUILDING FRAMES

2 FRAMES TYPE B

USE FOR ALL USE TYPES

MULTIPLE JOINTS

FRAME TYPES A

FRAME TYPES B

MULTIPLE USE BUILDING FRAMES

2 FRAMES TYPE B

USE FOR ALL USE TYPES

MULTIPLE JOINTS

FRAME TYPES A

FRAME TYPES B

MULTIPLE USE BUILDING FRAMES

2 FRAMES TYPE B

USE FOR ALL USE TYPES

MULTIPLE JOINTS

FRAME TYPES A

FRAME TYPES B

MULTIPLE USE BUILDING FRAMES

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USE FOR ALL USE TYPES

MULTIPLE JOINTS

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MULTIPLE USE BUILDING FRAMES

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USE FOR ALL USE TYPES

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MULTIPLE USE BUILDING FRAMES

2 FRAMES TYPE B

USE FOR ALL USE TYPES

MULTIPLE JOINTS

FRAME TYPES A

FRAME TYPES B

MULTIPLE USE BUILDING FRAMES
pens, cross alleys, feed rooms, partitions, etc., to obtain an overall length to exactly fit the equipment housed. Table 3 lists the mean and average widths of the units found in the offerings previously described:

Table 3. Widths of barn equipment units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Mean width</th>
<th>Average</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horse stall</td>
<td>8.00'</td>
<td>8.28'</td>
<td>8.00' to 9.00'</td>
</tr>
<tr>
<td>Cow stall</td>
<td>3.50</td>
<td>3.44</td>
<td>3.00 to 3.50'</td>
</tr>
<tr>
<td>Box stall</td>
<td>10.00</td>
<td>9.99</td>
<td>7.50' to 14.00'</td>
</tr>
<tr>
<td>Maternity pens</td>
<td>9.83</td>
<td>9.24</td>
<td>7.17 to 11.00'</td>
</tr>
<tr>
<td>Calf pens</td>
<td>10.36</td>
<td>10.00</td>
<td>7.00 to 20.25'</td>
</tr>
<tr>
<td>Bull pens</td>
<td>9.92</td>
<td>10.17</td>
<td>9.00 to 11.50'</td>
</tr>
<tr>
<td>Farrowing pens</td>
<td>8.00</td>
<td>8.15</td>
<td>8.00 to 9.00'</td>
</tr>
<tr>
<td>Cross alley</td>
<td>3.50</td>
<td>3.67</td>
<td>3.00 to 4.50'</td>
</tr>
<tr>
<td>Feed room</td>
<td>6.92</td>
<td>7.21</td>
<td>4.00 to 12.00'</td>
</tr>
<tr>
<td>Stairway</td>
<td>3.00</td>
<td>2.61</td>
<td>2.00 to 3.00'</td>
</tr>
</tbody>
</table>

Of the group of units just listed box stalls, maternity pens, calf pens, and feed rooms vary through a wide range of widths with no more than two of all the plans listed showing the same width for these units. It would appear, therefore, that no standards exist for these units. Eliminating these items from the listing it was observed that nearly all of the units lie close to even multiples of 4 feet. Actual deviation from a standard width increment of 4 feet or multiples of this increment are shown in Table 4.
Table 4. Deviation of barn equipment unit dimensions from modular standard

<table>
<thead>
<tr>
<th>Unit</th>
<th>Mean width</th>
<th>No. 4' units</th>
<th>Per cent deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>D. horse stall</td>
<td>8.00</td>
<td>2</td>
<td>0.00</td>
</tr>
<tr>
<td>Cow stalls</td>
<td>3.50</td>
<td>1</td>
<td>12.50</td>
</tr>
<tr>
<td>Bull pens</td>
<td>9.92</td>
<td>2 or 3</td>
<td>17.30</td>
</tr>
<tr>
<td>Farrowing pens</td>
<td>8.00</td>
<td>2</td>
<td>0.00</td>
</tr>
<tr>
<td>Cross alley</td>
<td>3.50</td>
<td>1</td>
<td>12.50</td>
</tr>
<tr>
<td>Stairway</td>
<td>3.00</td>
<td></td>
<td>25.00</td>
</tr>
</tbody>
</table>

It will be noted that bull pens and stairways vary somewhat from the standard 4' increment proposed. These units, however, always appear singly in any one plan and the extra space required to accommodate these units in widths of 12 feet and 4 feet respectively would not, therefore be of consequence. The 4 foot increment would also provide for 1 to 4 possible widths of the units removed from the listing which would fall within the range of the widths of units now shown in plan offerings. This appears sufficiently flexible in view of the lack of width standards for these units.

It has been shown previously that buildings 36 and 22 feet in width with 8 ft. ceiling height would meet requirements for the building types analyzed. The study just described indicates that no apparent difficulties are encountered in adaptation of stall, pen, access, and storage units of approximately standard sizes if the buildings are also constructed in 4 foot length increments.

With building cross-sections and length increments established the
possibility for prefabrication of either complete structures or building parts and sections in large sized units is obvious with certain resulting construction economics. These parts might also be made interchangeable so that alteration of the buildings at any future date could be very easily accomplished by recombination of the parts into various patterns.

C. Basic Equipment Dimensions

The 4 foot increment of barn length previously suggested was derived from the widths of equipment used within the building. The maximum height of equipment is also set by the standard 8 foot ceiling height. This convenient 1 to 2 relationship of width and height of individual equipment units suggested the possibility of securing almost complete flexibility within the equipment itself by use of panels 8 feet long which would provide a full height partition when standing on end or would reach across two 4 foot units when placed horizontally. If a convenient increment of equipment length could be established the entire planning of both structural shell and equipment could be reduced to a modular planning basis and standard component parts of the equipment interchanged at will to produce any number of plan arrangements within a given structural shell.

A study of the interior units of barns in the plan offerings previously noted shows that box stalls, maternity pens, calf pens, bull pens, and feed rooms extend from center alley to outside wall
regardless of the building dimensions and the direction in which animals are faced. In a 36 foot barn with interior posts adjacent to the center alley to provide for the maximum clear pen area the distance from outside wall to posts would lie between 12 and 13 feet for "face-out" barns with central driveway and approximately 15 feet for "face-in" barns with a nominal 4' central alley. The overall length of horse stalls from front of manger to back of partition is approximately 9 feet. This is also the approximate overall length of cow stalls from front of manger to back of gutter. Mangers for these two units lie between 2 and 3 feet in width. Lambing pens are seldom fixed in place and the remaining equipment units listed are cross alleys and stairways which are bounded by the other equipment units in one case and permanently fixed in the other. It will be noted that all of the lengths of equipment units described above are almost even multiples of 3 feet. Since this is also very close to the height of farrowing pen partitions, lambing pen partitions, movable gates, etc., customarily used, panels 3 feet by 8 feet with a few fractional units to permit enclosure of any space 3 feet by 4 feet in plan and 8 feet high or multiples of these space units could be used to provide any type of stall or pen enclosure desired.

Photographs of steel units made up at a scale of one and one-half inches per foot appear in Figures 39. These were made up to represent standard high-carbon steel tubing panels which are now obtainable from all barn equipment manufacturers. The only change from the units
now available is that the units are produced in only three sizes nominally 3 feet by 4 feet, 3 feet by 6 feet and 3 feet by 8 feet. Hinging the panels from the outside would present a serious complication in arriving at an exact standard dimension for these units. Consequently the units were made self-hinging by incorporating the hinge with the end rail of the panels. Scale models of 2"x6" and 2"x10" planks 8 feet long together with angle irons punched to permit bolting of the planks together to form mangers and an 8 foot length of steel tubing used to support equipment in either a horizontal or vertical position completed the standard items of equipment required. Figures 38, 40, 41, 42 and 43 show the various scale models of equipment items which were assembled from these standard units.

The built-in hinge feature (See detail Figure 45) has the effect of converting each panel into a gate. All panels swung from walls or adjacent panels can thus be used as gates and all panels supported floor to ceiling can be swung upward to facilitate easy cleaning or to render the space temporarily useful for some entirely different purpose without removing any of the equipment. Figure 44 is a composite plan drawing showing the application of the units to all common types of stall and pen arrangements and illustrates how all partitions lie over a grid pattern on the barn floor laid out in 4 foot increments of barn length and 3 foot increments of width between outside walls and interior posts.
Figure 38. Assembled Equipment in Structural Frame. Note hinge feature of panels.

Figure 39. The Seven Basic Items of Equipment. Panels are 3'x4', 3'x6', 3'x8'. Lumber is 2"x6" & 2"x10" x8'–0".
Figure 40. Scale Model of 8' Section of Feed Bunker and Manger.

Figure 41. Scale Model of Combination Horse Stall and Box Stall.

Figure 42. Scale Model of Farrowing Pen.

Figure 43. Scale Model of Dairy Cow Stanchions. (Standard stanchions and sectional platforms are required in addition to the seven basic items).
Fig. 44. Composite Barn Plan. All areas are laid out upon a Modular scheme.
In July of 1945 full scale items of this equipment (Figure 45) were procured from the Clay Equipment Company of Cedar Falls, Iowa. Arrangements were made with Mr. Ed Morris, a farmer living two miles north of Ames, Iowa, to try out the assembly of the units in a cattle shed on his farm, the dimensions of the shed being near enough to the standards established to permit their assembly within the building.

Figures 46 to 48 show typical assemblies of the units in the two days during which the assembly tests were made. To facilitate the assembly, two steel frames of light strap iron were constructed and were drilled and tapped to receive ½" diameter bolts at 18" centers. These frames were then attached to wall, ceiling and floor of the building. In a new building constructed to receive these units threaded inserts in floors, walls and ceilings should be placed at the time of initial construction to receive the panels. The panels are so drilled that inserts placed in rows 8 feet on center across the building and located in the rows 9 inches from outside walls and every 18 inches thereafter for floors and ceilings and 9 inches from the floor and every 18 inches thereafter extending up the outside walls would receive the panels in all combinations previously illustrated. Extra holes provided as standard in the panels provide necessary offsets for elevating gates above the floor level.
Figure 46. Full Scale 3' Section of Feed Bunker and Manger

Figure 47. Full Scale Lambine Pen or Farrowing Pen.

Figure 48. Full Scale Combination Horse Stall-Box Stall.

Figure 49. Box stall Panels Hinged Up and Back to Facilitate Cleaning.
VI. DISCUSSION OF RESULTS

Barn Remodeling

The final plan arrangement of most of the remodeled barns was so similar that it seems probable that the basic plan might be quite generally adapted for barn remodeling on farms in the cash grain area of the state. Plans developed from this material are now being used for discussion meetings by the Agricultural Extension Service of the college. The merits of the general scheme are primarily:

1. Cow stanchions and horse stalls are provided in quantities just sufficient to accommodate the average dairy cow and horse population per Iowa farm according to the 1940 agricultural census.

2. A far larger number of cows can be handled without any alteration of the plan arrangement or the addition of new equipment.

3. Open or loose pen areas are adapted equally well to housing dairy or beef cattle.

4. Horse stalls are convertible without cost into box stalls or maternity pens.
B. Modular Planning of New Buildings

The modular planning of agricultural buildings is consistent with current developments in other fields of the building industry. The American Standards Association has adopted a 4" module as a standard unit of measurement for the entire construction industry and the sizes of brick, tile, concrete blocks, windows, doors, and many other structural items are now being furnished in multiples of 4" in height, width, and depth. Elimination of cutting and fitting of pieces on the job is the primary objective sought. It will be noted that the standard dimensions suggested as a result of this study are consistent with this general scheme.

It is obvious that buildings might be more easily planned and constructed using structural units of standard and coordinated size. The development of modular standards has not yet been generally applied to standardize the dimensions of the multitude of items which go into building equipment and utilities.

Prefabrication of structures or large structural parts has not to date resulted in any major initial economies in building construction. Mass production of units under controlled plant conditions has, however, produced some units of much higher precision and quality than were formerly produced at the building site. It is doubtful if the standardization of farm building and farm building equipment dimensions would result in any initial cost reduction on a building of a specific size.
unless such items become so commonly used and were produced in such large quantity as to revolutionize present production methods.

Any initial cost advantage at the present time from use of the building dimensions and equipment design here presented would spring from the possibility of greater annual use of the building space through continuous adjustment of the space to meet daily or seasonal needs. Maximum annual housing requirements for various animals and crops do not occur simultaneously and the greater flexibility of such structures and equipment should permit a substantial reduction in the total space enclosure required for housing on an individual farm.

C. Barn Requirements to Receive Panel Equipment

The sizes of equipment items used in this experiment were derived from certain dimensional standards previously established for the structural shell. The requirements for buildings to accommodate this equipment are listed below:

1. The building must have a dead level floor or at least no permanent projections of the floor above the main floor plans.

2. The clear height floor to ceiling must be uniform throughout the building at approximately 8 feet.

3. No permanent posts or other space obstruction can occur between outside walls and the posts adjacent to fixed central alleys.

4. Post spacing lengthwise of the building must be in even multiples of 4 feet to insure alignment of posts with
cross partitions or boundaries of cross alleys.

5. Inserts to receive equipment should be placed in the concrete floor at initial construction.

6. End wall construction must be sufficiently flexible to permit easy relocation of doors to match possible relocation of alleys.

The basic barn plans now being developed for distribution by the Midwest Plan Service are based upon the requirements just outlined. Figure 50 shows plan and construction detail of the first of the series of Midwest Plans developed by this method. Section and end construction appear in Figure 36. It will be noted that the dimensions of this building conform exactly with the requirements just outlined and that all requirements for end construction, post location and floor construction with the exception of floor inserts have been met. Figures 51 and 52 illustrate some possible combinations of wall materials and roof construction which may be employed without altering any of the basic features required.
36' GOTHIC ARCH BARN--MASONRY WALLS

Fig. 51. Alternate Masonry Wall Construction For Barn (Fig. 50).
GUTTER TYPE CORNICE DETAILS

NOTE:

All splice plates to be glued & nailed with enough 1/2" box nails to insure intimate contact of glued surfaces.

All rafters constructed of 2 x 8 material.

LEGEND

Section 1 = 14.12, 9 Rafter
Section J = 14.10, 6 Rafter

MOW STORAGE CAPACITY

Section 1 = 10 x 10, 24.8
Section J = 10 x 10, 24.8

SECTION 1

NOTES:

Floor joists 2'-0" O.C.
Use 2 x 10 joists with wide center bay

SECTION J

See footing details

See floor details

36' 3-MEMBER-GAMBREL ROOF BARN

Fig. 52. Alternate Roof Construction For Barn (Fig. 50).
VII. CONCLUSIONS

1. Basic structural dimensions of width and ceiling height of farm structures are a most important factor in determining their adaptability to new uses.

2. Close or irregular spacing of interior supports in buildings is a serious obstacle in future remodeling.

3. There is no apparent economic justification for the use of interior supporting posts in one-story farm buildings less than 24 feet in width.

4. Concrete bulkheads on building foundations which extend only a few inches above the first floor level or concrete and steel equipment which projects above and is firmly attached to the floor are serious obstacles to remodeling. The low bulkheads fail to perform any useful purpose.

5. Greatest flexibility is achieved in barn plans when interior posts are placed outside of present or probable future pen, stall, or access areas. This is most easily accomplished by placing posts adjacent to central alleys.

6. Walls at ends of main alleys are more frequently required to accommodate new door and window locations than are the walls parallel to the alleys. Special provision should be made in original design and construction to facilitate relocation of openings in
77.

end walls.

7. Farm service buildings approximately 22 and 36 feet in width are best adapted to accommodating a wide variety of stall, pen, and access units of present standard dimensions.

8. First floor ceiling heights of all types of farm service buildings other than machine sheds and bulk storage structures may be standardized at 8 feet throughout the area in which the operator performs most of his work. This would cause neither discomfort nor inconvenience to the operator or the units housed.

9. Plan areas of conventional stalls and pens for livestock are approximate multiples of rectangular areas 3 feet by 4 feet.

10. Modular planning of buildings and building equipment is applicable to the design and construction of agricultural buildings.

11. Farm buildings and farm building equipment constructed from parts produced in modular sizes would have an inherent flexibility far in excess of that now achieved in conventional construction.
VIII. SUMMARY

The investigations carried out under this project included the following:

1. Investigation of building requirements and present building conditions on 25 central Iowa farms. Detailed studies were made and remodeling suggestions prepared in graphic form for 18 buildings on 12 separate farms.

2. An analysis was made of the remodeling obstructions encountered in the readaptation of these old buildings and where possible, remodeling recommendations included the removal of these obstructions to facilitate both present and future alterations of the buildings.

3. Standardized plan arrangements for the remodeling of general purpose barns on tenant-operated farms for this farming area were developed and made available to the Iowa Agricultural Extension Service for use as discussion and training material for meetings on rural electrification, barn planning and farmstead planning.

4. Plan offerings of the Midwest Plan Service and two outside agencies were carefully analyzed and accommodations offered classified. This material was also carefully studied to locate potential sources of construction simplification and of elimi-
ination of construction details or features likely to prevent readaptation to various uses throughout the life of the buildings.

5. Special studies were made to simplify and improve two building plans developed by and now widely distributed by Iowa State College.

6. A system of coordinated dimensional planning was developed to permit the construction of both farm buildings and farm building equipment from interchangeable units of standard dimension and construction.

7. Experimental models of this equipment were produced at one-eighth scale and at full size. Details of their construction and assembly were developed sufficiently to require only minor modification for assembly line production by any interested manufacturer.

8. Basic building requirements to accommodate such equipment were established and are now being incorporated into the plan offerings of the Midwest Plan Service.
IX. REFERENCES


X. ACKNOWLEDGMENTS

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