

THE INFLUENCE OF FORAGE
CONSERVATION METHODS ON THE
DEVELOPMENT OF FEED LOT SYSTEMS
FOR BEEF AND DAIRY CATTLE

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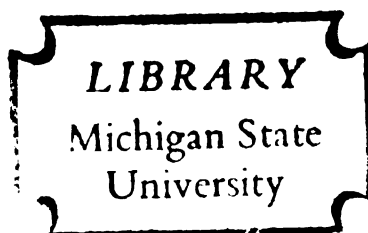
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ABSTRACT

THE INFLUENCE OF FORAGE CONSERVATION METHODS ON THE DEVELOPMENT OF FEED LOT SYSTEMS FOR BEEF AND DAIRY CATTLE

By

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Mechanization can be credited with effecting a significant improvement in the working conditions of present day farms by reducing physical effort and drudgery, as well as by aiding a more effective employment effort. Livestock production has not kept pace with the efficiency in crop production. The reasons frequently cited are the difficulties of mechanization among present buildings and permanent fixtures of a farmstead. The pattern of farm buildings today shows evidence of an individualistic approach to farmstead planning and development.

The purpose of this work was to study forage conservation methods and to develop forage storage and feeding systems for beef and dairy cows. A review of forage harvesting techniques showed that there are many improvements to be made in current practices which will lead to the preservation of more and better quality forages. The conservation and

mechanical handling problems of hay are not yet solved and it was found many farmers are now making little or no dry hay and feed most forage as silage.

A feed lot design was shown to include 3 functional components:

1. Feed storage; 2. Feeding facility; 3. Livestock area. Feed storage includes units for forage, feed grains and the preparation and blending of the food items. The feeding facility is the method and manner in which food is presented to the livestock. The livestock area includes the lot area, shelter or loafing barn and other essential physical requirements.

Methods of organizing and integrating these components, in their varied forms, were examined and a procedure was developed for analyzing forage storage and feeding systems. Design requirements of such systems were stated and discussed, as well as other restrictions on the design of feed lots imposed by the behavioral characteristics of the livestock and their physical requirements.

Feed lot system layouts were presented with considerations for the future, but in the main, intended for use with equipment and machinery currently available. Essential qualities of each system were; the capability of expansion; development in discrete steps and mechanization in stages. It was shown how the plans should be modified to obtain most advantages from local conditions.

Approved J H Buelow

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I. INTRODUCTION

Throughout the years the role of a husbandman has grown and changed as the life around him has become more complicated and civilization more sophisticated. At first his preoccupation was to provide food and clothing for his family and dependents, then he needed to produce more and more to feed those of his neighbors who provided him and others with a special service, until today in at least one of the more industrialized countries (U.K.) less than 4% of the nation's wage earners are actually employed in producing food. This is not to say that the food producers have necessarily become more important; on the contrary the status of food producers the world over has been amongst the lowest offered by the dependent society.

In the long run the competition from industry has given force to the need for improving the standing of farmers. The "way of life" farming offered as a career or livelihood was not a sufficient attraction to hold those who had alternative opportunities. A greater degree of equality with industry was required, in conditions of work, leisure, opportunities and personal income. It is a sad reflection on the degree to which this equality has been reached that in the same week the average income in the United States was officially estimated at over \$100 per week, Higbee (1963) stated that the income of farm labor was on average only 84¢ per hour.

Nevertheless improvements have been made and although much of this has resulted from a combination of improved technology and heavy capital investment, mechanization can be credited with effecting a significant improvement in working conditions by reducing or removing much of the physical effort and drudgery associated with crop production as well as a more effective employment of effort. Thus the total man hour requirements in agriculture in the United States have decreased from 22.5 million in 1910 to about 14 million in 1960 (F.E.R.D. 1957). Many authorities are now satisfied that arable mechanization has achieved a satisfactory level and that further efforts in this field should be directed more specifically towards work simplification and cost reduction than greater outputs in shorter time.

Livestock production efficiency however, has not kept pace with the efficiency in crop production. Indeed the publicity accorded to general farm mechanization camouflages the fact that few livestock farmers are mechanized at all. "Many of the machines which will form the backbone of the livestock industry are not yet numerous enough to be counted by the census taker." (Van Arsdall 1961). For example Brodell and Phillips (1957) estimated that in 1955, 73 million tons of silage was produced on over 600,000 farms. The great proportion of this was field chopped with flail harvesters and about $\frac{3}{4}$ (over 51 million tons) was stored in upright silos, but only 4% (less than 3 million tons) was removed by mechanical unloaders. Before World War I feeding and caring for livestock accounted for less than 30% of the work done on farms, by 1955 the labor for livestock had increased to 40% of the total. According to Seferovich (1958) only in the production of milk, broilers and

eggs was there any significant breakthrough in the technological barrier in livestock production at this date. Over the period 1945 - 1958 the total production per man hour increased 124% or 6.4% compounded annually, the increase in livestock products per man hour was 3.6% annually, but the comparative increase in meat animals amounted to only 1% annually. (Mason 1961). This disproportionate improvement in productivity identifies the need for a careful study of farmstead operations where the feeding and caring for livestock are centered.

However, more than today's comparisons, the challenges of the future press on the husbandman. Mason (1961) said that to maintain the present growth rate of agricultural productivity, the equivalent of some 1.8 million full time workers will need to be moved off United States' farms before 1975, of which 0.8 million must come from livestock enterprises. The suggested rate at which labor will be removed during the remainder of this decade is 64,000 man years per year. Ferris and Hoglund (1962) calculated that over this same period the per capita consumption of meat will be 43% greater than in 1962. As per capita incomes increase consumers will show a particular preference for steaks and roasts, putting beef cows high in the priority for anticipated expansion.

The reasons for laggardness in livestock production efficiency are frequently cited as being due to the difficulties of mechanization among the present buildings and permanent fixtures of a farmstead. These are often telling, and sometimes unpaid for, reminders of conditions decades ago. The pattern of farm building even today shows evidence of an individualistic approach to farmstead planning and devel-

opment and the lack of appreciation that the farmstead is the location of all post harvest operations. This includes appreciating its importance as a processing center where the arable production of the farm is stored, processed and converted into meat, milk, eggs and other marketable commodities. Early attempts at livestock mechanization were concerned with unit load movements and the substitution of mechanical power for human. Only recently has mechanization been associated with what the industrialist calls "flow process problems" and the natural integration of individual components into a system of processes or production.

Materials handling per se has been lauded for so long in the popular press as the general panacea of all production problems that many young farmers have been indoctrinated so as to believe that a high level of mechanization with augers, elevators, forage boxes and tractors is the quintessence of livestock production. However, the handling of materials needs implementing to increase labor productivity, integrating into a system, and capitalizing to give the best return of all the other possible alternatives. It must be considered in relation to the buildings and fixed equipment with which it is to be associated. In the recent past the long life and permanence of farm buildings relative to technological change has been accepted as part of the price of progress, and forced compromises between ideal requirements and the need for general utility. New structures have been continually added to old patterns, extending the heterogeneity of the farmstead and preventing the adoption of standard techniques. At some point in this cycle a break has to be made to prevent the self perpetuation of a systemless expansion. The tools of any process or production need to be considered in relation to

that operation only, and utilized to give the optimum return in capital investment, resource availability and managerial capability. We have seen this concept practiced in broiler and egg production, it is being applied in the production of pig meat, it needs extending to all farmstead operations.

This study is concerned in part with the systems for the production of red meat and milk from the arable resources of the farm. It purports to show that sufficient data are available for the design of production systems for these two commodities to meet the conditions outlined above, and to present a number of schemes of a standardized design to cater for the more commonly found farm situations. It is also suggested how these schemes may be modified to meet local or personal requirements without essentially changing the standard system of machinery, labor and other resource use.

II. OBJECTIVES

The general purpose of this study is to examine the influence of forage conservation methods on the development of feed lot systems for beef and dairy cattle.

Specifically the objectives are:

1. To evaluate systems of forage conservation in respect to efficiency, mechanization and adaptability to systemization.
2. To determine present and likely trends in forage use.
3. To design alternative feed lot systems for different methods of forage conservation.
4. To show how standard feed lot systems may be modified to meet local conditions.

III. METHOD OF PROCEDURE

The engineer is at the present time faced with the responsibilities of selecting equipment and methods and organizing them into efficient materials handling systems. This study is concerned with the storage of forage, including hay, corn silage, high moisture corn and small grains, the pre-storage treatment of the material required by each method of storage, the effects that this method of storage has on the manner in which forage is fed to livestock and the optimum orientation of the machinery, equipment and other structures that are associated with the loose housing of beef and dairy cows.

The individual stages in the procedure of the study were:

1. A review was made of the investigations into methods of forage conservation and of the methods and techniques recommended to improve the efficiency of each. A great deal of this information was contained in popular articles in weekly and monthly journals, other information was found in scientific papers, reports, and extension bulletins. Generally greater credence was given to the reports of original work. In reports of studies, where possible, the original source of data was found and the original reference is given. In assessing the value of popular writings it is noted that this represents a more timely influence on establishing trends in farming practices than do the writings in more scientific journals. Accounts of new practices were considered important in determining likely

trends in feeding habits and conservation requirements.

2. Livestock physical requirements were established from a study of published recommendations, and in discussion with Agricultural Extension Service personnel.
3. Visits were made to two distributors in Michigan of forage storage and feeding components for information on the range of machinery and equipment available.
4. Field visits were made to some 20 farms in the company of machinery dealers, extension personnel and as private visits, to study existing farm layouts.
5. A review was made of published reports on materials handling systems analysis to evaluate their use for this study, and to select a method of analysis and synthesis that would be practical.
6. From information obtained as aforementioned, criteria were established for the design requirements of forage storage and feed systems, and other limitations on layout design imposed by related considerations.
7. Using the design criteria, layout plans were prepared including components for forage storage, feeding and other necessary and related items. Each layout included provisions for expansion since this was considered one of the more important criteria.
8. The results were analyzed and summarized.

IV A. MEASUREMENT OF FORAGE QUALITY

The relative importance of forage crops conserved for animal feed largely depends upon the climate, topography and soil conditions of any particular location. Materials that may be conserved as forage include cereals, legumes, sugar beet tops, potatoes, pea cannery waste etc. Of these pasture, alfalfa, corn and cereals are considered pertinent to this study. In order to be able to compare different forages and methods of conservation it is essential to have a unit of quality for evaluating their nutritional value.

Dry matter is a comparatively easy method to use, since the determination of moisture content requires only a short time and relatively simple equipment. It may be used in comparing crops which are similar and substitute equally for each other in livestock rations, but will not differentiate between crops having dissimilar nutrient content and value.

Total Digestible Nutrients are mostly used in North American literature. Starch Equivalents (S.E.), Protein Equivalent (P.E.) and other measures of the net energy value of feeding stuffs are widely used in Europe. If the percent digestible constituents are known for any particular feed, it is possible to convert to either system.

Hay Equivalent is a crude rule of thumb valuation assuming 3 tons corn silage as being equivalent to 1 ton hay. Comparison of nutrient content of hay crop forages on the basis of number 1 alfalfa hay will give reasonable results. The Peterson system is a method of including an economic assessment of value in comparing crops against their replace-

ment cost of corn meal and soy bean meal at prevailing prices.

These methods do not take into account the relative value of the same feed for milk production, weight gain or maintenance of the same class of stock, or between classes for the same purpose. The value of forages will also be influenced to a considerable extent by the management capabilities, as this is expressed in conservation practices, feeding practices, stocking rate, livestock productivity and other feeds fed.

IV B. HAY MAKING

Hay making is the oldest method of preserving forages and still today is more widely practiced than any other method. Morrison (1956) defines the ideal or high quality hay as being made from material cut at a suitable maturity, leafy and green with soft pliable stems. It should also be free from mustiness or mold and have an attractive fragrance that adds to its palatability.

The primary object in hay making is to dry the green plants sufficiently so that the hay can be stored without heating or becoming moldy. Commonly accepted moisture contents at which hay will satisfactorily store are 25% for long hay, 22% for baled or chopped hay. (Shepperson 1956).

The difficulty in making hay is to dry to these storage moisture contents without loss of nutrient, through respiration, leaching, mechanical losses, and other causes. There is a considerable amount of published literature on the losses in hay making. Watson and Nash (1960) point out however, that most of the published work has dealt only with the loss of dry matter and no cognizance has been taken of the fact that the actual loss of feeding value exceeds that of the dry matter, since the material which is lost is the most digestible part of the plant. The losses in Table 1 are given as typical examples of dry matter and nutrient loss when a conventional system of hay making is followed -- that is without the use of newer techniques and equipment.

TABLE 1
PERCENTAGE LOSSES IN HAY MAKING BASED
ON NUTRIENTS IN THE FRESH CROP.

Details of Treatment	Dry Matter	Dig. Prot.	T.D.N. ¹
No rain - No mechanical loss	8.7	13.8	22.6
No rain - No mechanical loss	14.7	32.7	38.6
Rain	23.7	40.4	49.7
1-2 showers (1-20 mm.)	18.9	27.8	43.6
5-6 showers (12-63 mm.)	27.1	49.8	54.2
Average	20.3	36.2	44.7

Source: Watson and Nash (1960), p. 76.

¹Calculated from data Morrison: (1956) Appendix Table 1, p. 1086.

Under favorable conditions it is suggested that the total loss of dry matter should not exceed 20% - 30% for legume hay and 10% - 15% for grass hay, but under unfavorable conditions the loss will be considerably higher.

Text books on husbandry and forage conservation give details on hay making techniques. (Morrison 1956. Watson and Nash 1960). Studies have also been made, and are widely reported, on the probability of suitable hay making weather. (For example see Vary 1954. Maddex and Hoglund 1962.).

The importance of this research is that it indicated the time for hay making should be made as short as possible to prevent excessive field loss, if possible during the one day that fair weather conditions seem assured. This in turn influences the choice, use and capital investment in hay making machinery and any drying process that may be associated with it. It will also influence the labor demand if continuous systems of hay making and handling are contemplated.

Hartwig (1942) reported on studies that indicated there is no advantage in delaying cutting until the dew has dried. Rees and Mitchell (1954) found that there was no advantage in cutting hay after 2 p.m., late afternoon cut hay dried no sooner than hay cut early the following morning. Morrison (1956) states that hay dries more rapidly in the swath than in the windrow and advocates leaving it in the swath until the hay is partly cured, if good weather continues it may be completely cured in the windrow.

This author believes that following the conventional mowing machine, hay swaths should at least be immediately turned with a swath turner, since this exposes the stems which are the most difficult part of the plant to dry and causes the leaves to remain moist for second and subsequent handling, thus reducing leaf loss. Some writers, quoted by Morrison (1960), have suggested that by maintaining the leaves alive continued respiration may draw water from the stems to facilitate their drying.

Bruhn (1955) reported on the current use of forage crushers to increase the field drying rate. In subsequent work Bruhn (1959) indicated that crushing or other laceration of the tissues should take

place immediately following cutting. Delaying crushing time loses the advantage of the higher dry rate of the crushed material prior to treatment. Double treatment, with a delay between the 1st and 2nd crushing, produced a very high drying rate with a considerable jump at the time of the second treatment. Lehmann, et al. (1931) reported that crushing of alfalfa shortened the time of drying by slightly more than half of that needed for hay in mower swaths. Similar results were found from Agricultural Experiment stations at Pennsylvania, Cornell, Missouri, Alabama.

Some workers have commented that crushed hay picks up moisture more easily. Turk, et al. (1951) found that even after overnight rain, crushed hay dried more rapidly than normal hay. Mitchell and Shepperson (1955) in England found that crushed herbage absorbed more water at night and was likely to suffer damage by rain. They also report that crushing can reduce field time in England by about one day in three and may make all the difference between getting in or losing a crop in unsettled weather. Nevertheless, even though the drying rates for herbages are far below those for continental climates as in the United States, the risk of crushed hay suffering serious nutrient losses through rainfall is likely to more than outweigh the advantages of the operation.

Flail harvesters have been used with apparent success to 'make hay in a day', and farmers' and machinery dealers' ad hoc. and successful demonstrations have been reported from time to time in the popular press. Many manufacturers of these machines market special hay making attachments which direct the flow of lacerated material into a windrow. Other modifications include reducing the peripheral speed of the flails to reduce the mechanical losses by over severe laceration. Bruhn (1959)

suggests that to approach an acceptable drying rate through the use of a flail chopper, the machine will need to be operated in such a way as to cause excessive mechanical losses. In some instances over 40% separation (by weight of material that will pass through a 2 in mesh poultry netting) with flail choppers was recorded, compared to less than 10% for roller crushers. In view of this, and the mediocre drying rate of the material conditioned with flail machines, he questions its use as a forage conditioner (cf. roller crushers).

When the hay crop is considered to be dry, the leaves are normally drier and more brittle than the less easily dried portions of the stem. Watson and Nash (1960) report that the possibility of loss increased as the hay approached a 30% average moisture content even though the shattered material varied from 9.3% - 11.8%. Dobie et al. (1953) found that to ensure minimum loss of leaf from alfalfa, the hay should not be raked or handled if its moisture content is below 55%. When hay is carelessly made leaf shatter losses may reach 20% - 30%, but can be reduced in hay under 55% m.c. by raking in the early morning in conditions of high humidity.

Hay drying is now an established practice in the United States where it is found to eliminate some of the weather risks in hay making and produce hay of superior quality. Considerable interest is shown in Western Europe, but the practice has not yet become truly established. The techniques to be employed in drying are described in Agricultural Experiment Station bulletins of many northern and western American universities. (Tennessee, Wisconsin, Michigan, Cornell, New Brunswick, Idaho, Pennsylvania, etc.) More serious discussions will be found in

Hall (1957) Shepperson (1958). The consensus of the recommendations is that chopped hay dries more evenly and faster. Length is important and 2 in theoretical cut appears to give the best results. Optimum moisture content at commencement of drying for baled or chopped hay is 35%. Small loose bales are most satisfactory and may be hand stacked on edge or random stacked.

Recirculation of the drying air has recently come into prominence through a claimed reduction in operating costs and in some cases an increase in hay quality is reported. (Roberts 1961, Weaver 1962).

Equipment for Handling Hay.

Many studies have been made on the problems of hay making over the past few years and have resulted in a rapid change of methods and techniques. However, many problems still remain to be solved and it is expected that changes will continue to be made until some system can be devised to eliminate the problems of weather vagaries and those caused by the nature or physical condition of hay. At the same time these changes must take into account the competition of alternative methods of conservation.

What is attempted in this section is to delineate the area of knowledge, especially of current trends and anticipated developments, needed to appreciate the problems involved in gathering, storing and feeding hay crops in feed lots.

The methods of handling hay may be listed as:

- | | | |
|---------------|---|------------------------|
| 1. Hay loader |) | long hay stored loose. |
| Buck-rake |) | |

2. Baled.
3. Chopped.
4. Pelleted or wafered.

Long Hay.

Long hay stored loose is still a common method of handling but it is rapidly giving way to more modern systems that allow a high degree of mechanization.

At the present time the only worth while consideration in using this method is the small amount of capital investment in machinery. Handling systems are not geared to high annual outputs and can rarely be considered within the context of this study. However, Lewis (undated) suggests that ranchers and producers of feeder stock in the west find loose hay a satisfactory and inexpensive method when the hay is to be fed within a relatively short distance from the field.

Baled Hay.

Baled hay per se does not permit elimination of manual handling. Clayton, Kleis and Gaunt (1960) list the individual stages of bale handling:

1. Loading on to vehicle.
2. Piling on load.
3. Placement on elevator.
4. Distributing in mow.
5. Stacking in mow.
6. Removal from mow.
7. Breaking, distributing and feeding.

Several techniques and machines have been developed to eliminate much of this man handling. Shepperson and Wright (1957) devised a system using front- and rear-mounted buckrakes to pick up heaps of bales left by a manually loaded bale sled. More than 4 tons per hour of hay bales were loaded, transported and unloaded, over a 1000 yard trip, per operator. This system has been developed to the extent that using manually loaded sleds, bale heaps can be picked up and transported by specially designed buckrakes and built into a bale stack some 12 bales high without man handling. To eliminate the limiting output of manually loading sleds, automatic sleds have been developed which leave heaps of 8 - 12 bales (standard size) to be picked up by a clamp arrangement mounted on the frame work of front end loader and loaded into self unloading wagons for random stacking in a barn. Bale throwers attached to the end of the baler will also eliminate the physical task of loading onto a vehicle and piling on a load.

On level ground less orthodox systems are adopted for loading direct from a baler such as pushing the bales up a chute onto the wagon. Whilst this is simple and cheap it requires manual effort to load the wagon or at least keep the end of the chute clear. Also considerable variation is found in bale densities if there is any ground undulation and this could lead to uneven drying in the mow. Weaver and Bruhn (1962) describe four methods of loading hay from a baler, including two methods of direct loading baled, but not tied material. These methods of loading provided hay of sufficiently consistent density to give good results when dried using a recirculatory system of drying in the wagons into which the hay was loaded.

The short bale, a nominal 14 in x 18 in x 20 in, normally used with the mechanical bale ejector almost presupposes that the bales will be randomly stacked in the mow. Using self unloading wagons and conventional general purpose elevators the procedure for filling the barns will often be as varied as the buildings used for storage. Uniform distribution is necessary within the barn, existing conveyor distribution systems appear satisfactory.

The greatest problem now with baled hay is the method of removing it from store and feeding it to the stock. Schnieder (1955) and (1957) describes a conveyor feeding system for dairy cows in stanchions and loose housing in which the operator was required to pitch the hay onto the conveyor. Kleis and Wiant (1960) comment that removal from storage has continued to be a manual operation for all forms of hay, except where self feeding is involved. Witz (1963) describes a unit to slice and meter baled hay but which also requires hand feeding from the stored heap of bales. Sturrock (1960) shows that when bales are hand stacked, the simplest method is to break open the bales and throw them down behind a portable feeding barrier. Even when broken, baled hay, since it is essentially long, will not feed reliably through forage boxes.

Thus whilst many of the manual handling operations of bales can be eliminated, there are still parts of a bale handling system that defy adequate mechanization or systemization.

Chopped Hay.

Chopped hay allows complete mechanization of harvesting and storage operations permitting free use of auger conveyors, blowers and gravity in handling. 4 in - 8 in is generally taken as the optimum length of chop (Clayton, Kleis and Gaunt 1960, Luddington 1960). A 2 in theoretical cut will usually give a 4 in cut length in practice. For chopped hay it is almost mandatory that a drying system be used for finishing the hay because of increased mechanical loss when chopping material that has field dried sufficiently to be stored. Shepperson (1956) concluded storage should be restricted to a density of 5 - 6 lb per cubic foot and in special cases this would imply a moisture content of not higher than 20% at chopping. In view of the difficulties attached to drying hay to this level in the swath the practice of direct chopping in the field should be limited. The disadvantages in respect of risk and quality would seem to outweigh the obvious advantages to be gained in labor economy.

Pneumatic conveyors are used for conveying chopped material but these are not altogether satisfactory. At low moisture content there is a shattering of the leafy material and much of this may be lost as dust. (Watson and Nash 1960). Further, the difference in bulk weights of the leaf particles and stems causes poor distribution in the mow. Hansen (1952) stated that a severe limitation in the use of chopped hay was the lack of adequate mechanized equipment to distribute the hay over the mow dryer uniformly and without leaf/stem separation. Millier (1958) found that forage blowers would not handle chopped hay satisfactorily and developed a belt tube elevator designed to elevate all types of

chopped forages at all angles and with a reasonably high elevating efficiency. The principle of operation is that of elevating by means of one or two belts running inside a tube, which grip the material and move it upwards at a high speed. Brooks (1957) describes a hay drying and handling system to load chopped hay into a barn which had performed satisfactorily for two years, except for some difficulty with the hay distribution equipment. Luddington (1960) describes a similar system. Front unloading, as opposed to rear unloading, wagons were used and the hay discharged into a modified farm elevator with slats to prevent the hay tumbling backwards, thence onto a mow hay conveyor and a mechanical hay distributor. Weeks and Kleis (1962) claimed that no commercially available automatic mow unloader was available for chopped hay. They developed an unshrouded cantilever mounted auger which would both distribute hay during loading and unload chopped hay. Although the auger moves in a circular sweep within a square storage unit it is claimed that 90% - 95% of the hay is subject to mechanized handling.

Witz (1962) suggested that in common with ground feed and silage, chopped hay is often quite free flowing if it is kept in motion, but if allowed to accumulate it becomes a non free flowing material. Using this idea, stationary flat bottomed bins of silage and chopped hay were loaded with drag-chains as on the manure spreader and feed wagon. Conditions were defined for which it was concluded that, by occasional calibration, a constant flow of materials could be obtained which would be satisfactory for all normal rations. Discharge rates could be varied and were approximately linear for chain speeds of 7 - 37 feet per minute. Such storage bins could be incorporated into a unit of several, each

containing different materials allowing proportioned rations to be withdrawn as required. McKibben (1962) suggests two ways of removing chopped hay from storage, to remove the hay along a horizontal face, or remove it vertically allowing the hay to fall when drawn free of the stored mass -- this requires a vertical face. The second alternative is favored since the hay removal will be across any variations in hay layers resulting from materials or haymaking conditions. It will allow greater flexibility of filling and feeding so that hay may be stored in portions of the structure that have been emptied without disturbing the removal equipment or feeding arrangements. Also the structure and equipment can allow drying of hay in refilled portions and mechanical removal of other hay without interference of one with the other.

Finner (1962) regards removal of chopped hay from storage as a bulk handling problem and suggests the use of a fork lift truck with a large fork to place material from storage into a metering device consisting of a large permanently installed self unloading wagon. One of the problems to be overcome will be to decide on the optimum length of chop of the hay, since most of the existing feed box mechanisms, including the unit of McKibben described above, work better with a chopped length of 2 in or less.

Self feeding of chopped hay has been developed in Missouri (McKibben 1962) and Iowa (Barnes and Beresford 1954). Plans are available for the design of 50 ton storage units including drying facilities and provision for self feeding from the unit. (Shove 1947).

Pelleted or Wafered Hay.

Pelleted or wafered hay is in the ultimate physical form that can at present be field produced. In this form hay can be considered to be changed from a non free flowing form to one which is relatively free flowing, thus widening the scope for use of materials handling equipment (Hall 1958). Bruhn (1956) presented a study of engineering and nutritional problems of feeding pelleted (pre ground) and wafered (short chopped) feeding stuffs. He showed from a variety of experimental work that for ruminants pelletized forages should be limited to those coarsely ground or chopped because of the reaction of the cow to finely ground forage. Bruhn, Zimmerman and Niederman (1958) stated that two types of pellets are necessary, the coarse large type made of chopped or long hay for dairy cows and the conventional ground forage pellets for other livestock. Pellets of the proper size, density and consistency will be utilized by the average dairy cow as well as hay in any other form. The moisture content of the material being pelleted is important, alfalfa pellets can be made up to 30% moisture, but lower moisture contents seem to be desirable. Storage of pellets, even when wetted did not seem to present any particular problems. Fischer (1962) suggested that in well designed pneumatic conveying systems breakage of pellets should be maintained at a level lower than, or no more than that experienced in a mechanical system.

In the future field pelleting or wafering machines may become basic harvesting tools. However considerably more research and development needs to be done on the formation of these wafers in order for the system to be of value as a method of fodder conservation in competition

with others. Present wafering machines not only demand large power units, they operate effectively only in hay of 20% - 25% moisture content, which to obtain the greatest benefits needs to be field dried.

IV C. SILAGE

Silage is the name given to the succulent material produced by the process of controlled changes from a green crop or other materials of high moisture. The process is known as ensilage and the container, when used, the silo.

During the ensiling process the changes which occur in the material are affected by respiration, micro-organisms, temperature, moisture and chemical changes. Watson and Nash (1960), Morrison (1956) and others detail the essential conditions for good ensiling. Briefly they may be listed as:

- a. The exclusion of oxygen by close packing of the forage to prevent permeation by air,
- b. The exclusion of water, including that which is normally present in growing plant tissues as well as precipitation on to the top of ensiled material,
- c. The establishment of conditions which will induce fermentation of the material and formation of lactic acid.

These conditions or requirements are directly influenced by the initial condition of the material and of the method of ensiling. In other words they are under the control of the farmer, and his exercise of this control will to a large extent determine the quality of ensiled materials, the loss of nutrients and the acceptability or palatability of the silage to the stock. The type and physical condition of the silo contributes to the attainment of the ideal requirements for ensiling.

Since it also determines the system of forage harvesting and feeding we can list the following as inter-dependent variables of a conservation system:

1. Management of conservation and feeding processes.
2. Silos which determine conservation methods.
3. Mechanization of conservation.
4. Feeding methods.

Each variable has a separate contribution to make to the production and handling of a quality silage. The effects of management and silo structures merit further consideration. Mechanization and feeding are discussed in later sections.

1. Management. Wastage or loss of nutrient value during ensiling is associated with the three essential requirements:

- a. Exclusion of oxygen. So long as air is present the plant cells will continue to respire, converting carbohydrates with the release of energy. The direct loss of dry matter is referred to as the "unavoidable loss." It is however only unavoidable in the conditions actually prevailing in the silo at the time, alteration of the process will change the magnitude of these losses. A second loss caused by excess oxygen and frequently referred to as waste is the spoilage due to mold and bacterial growth on the surface and sides. It is a variable quantity and depends on the efficiency of compaction. It should be minimal in tower silos. The third loss is that due to over heating which causes a chemical change in the proteins, rendering them indigestible.

(Morrison 1956).

- b. Exclusion of water. The drainage from a silo will contain soluble nutrients representing a significant loss of dry matter, whether the water was contained within plant tissues or percolated through the crop from precipitation. Watson and Nash (1960) give 6% of the original dry matter as the average loss in effluent, calculated from published experimental data since 1938, or direct made silage. The comparable figure for wilted silage was 0.5%. Gordon (1961) listed 7 causes of seepage and showed that dry matter loss in seepage approached 15% of original dry matter at 80% m.c. ensiled material, the loss approached 0% at 65% - 70% m.c. in stored forages. A further problem with effluent is the difficulty of disposing of material having such a high biochemical demand for oxygen. (M.A.F.F. 1960) (Ministry of Agriculture, Fisheries and Food).
- c. Establishment of conditions for fermentation. By providing the first two requirements much has already been done to establish the conditions needed for fermentation. It is necessary for the cells to cease respiring and die and for the micro-organisms to multiply using the cell material as a medium. The course taken by this fermentation will decide the value of the final product and its acceptability to cattle. McCullough (1962) suggested that greater control may need to be exercised as in air tight or hermetic silos for the first 5 days of ensiling, since dairy cows appear less tolerant of various fermentations than beef cattle. This seems to mean that it is important to stop both aerobic and anaerobic respiration as quickly as possible to stimulate lactic

acid formation.

2. Silos.

- a. Stacks and clamps. Stack silage, built on level ground is the simplest method since it can be adopted without any capital outlay and at relatively short notice. It is the least efficient method. There is no protection against entry of air and the stack cannot be consolidated except using special equipment. Over heating commonly occurs and there is usually a large amount of waste material at the sides.

To make the best silage (M.A.F.F. 1960) suggests that the material should be harvested at a young succulent stage of growth, chopped short if at all mature and the stack should have vertical sides.

The clamp is also built on ground level but is usually rectangular in area, and built with sloping ends so that tractors can unload directly on the clamp and can give consolidation to exclude air. Apart from this it has the same disadvantages as a stack and needs the same consideration of material treatment. Larrabee and Sprague (1957) report the successful use of sheets of polyvinyl chloride or polyethylene for stacks. Aerobic fermentation was completely controlled and the silages were adjudged to be of excellent quality. Trials in Florida indicate that spoilage in these plastic silos may be as low as 5% (Holmes, Harrison and Skinner 1959). Similar plastic silos have been used in Britain. Although apparently successful for small circular silos Watson and Nash (1960) are not satisfied that the plastic

silo is safe to use for the slowly made large sized clamp. The plastic silo seems to be most useful when it is necessary to make provision in an emergency for a sudden surplus of ensileable material, or to guard against short term contingencies.

- b. Trench and bunker silos. The first silo in the United States is reputed to be a trench 4 ft x 10 ft deep and 24 ft long used in 1876 by Frances Morris in Maryland. This type has retained its popularity and in a refined form is today widely used in Great Britain.

It is similar to the clamp silo except that the major part of the silage settles into the ground and is protected at the sides. The walls may be lined with concrete to improve the protection afforded to the side and they can also be used to support a roof. The roofed, walled, trench silo is the most desirable method of storing silage in an horizontal position. (M.A.F.F. 1961b). In this form it fulfills the same role as a walled and roofed surface silo, or so called bunker silo. Constructional details for these silos are found in many extension bulletins. For examples see Brevik, Friday and Maddex (undated), McCalmont (1956), Holmes, Harrison and Skinner (1959), M.A.F.F. (1961b).

U.S.D.A. research (Anon. 1961a) shows that plastic covers to seal bunker silos reduce feed losses more than might be indicated by comparing spoilage layers. Visible spoilage in sealed and unsealed bunkers actually accounted for only $\frac{1}{7}$ total dry matter loss. About 20% reduction in total loss was achieved by the

plastic cover through control of seepage and respiration.

- c. Tower silos. Adams 1889 (reported by Watson and Nash (1960)) stated that depth in the silo is preferable to breadth, and this became the keynote of silo building practices in the development of the tower. A further development is to give greater control to the ensiling process by evacuating the air. Recent work in Belgium and France has shown that samples of silage from evacuated plastic silos give a better product than samples made without plastic covering. The modern form of hermetically sealed silos is an attempt to give optimum fermentation control.

Gordon (1961) gave details of minimum dry matter losses in forage stored as silage, estimated from U.S.D.A. research at Beltsville. This is reproduced as Table 2. The figures show the relative efficiencies of stack silos and the low dry matter loss of both conventional and gas tight tower silos at lower moisture content.

Management Control of Silage Quality

McCullough (1962) gives as the ideal grass silage composition

T.D.N.	not less than 64%
Crude fiber	less than 28%
pH	about 4.2
Dry matter	not less than 24%
Crude protein	about 18%

The determining factor of optimum quality in this case is that any increase in quality will not affect the rate of intake by cattle.

TABLE 2

ESTIMATE OF MINIMUM DRY MATTER LOSSES IN FORAGE
STORED AS SILAGE AT DIFFERENT MOISTURE LEVELS¹

Silo type & m.c. % of forage as stored	Dry matter losses						
	Surface ² spoilage	Fermen- tation ³	Seepage	Total silo	Field losses	Total	
	%	%	%	%	%	%	%
Stack							
85	: 12	: 12	: 10	: 34	: 2	: 36	
80	: 12	: 11	: 7	: 30	: 2	: 32	
75	: 16	: 11	: 3	: 30	: 2	: 32	
70	: 20	: 12	: 1	: 33	: 2	: 35	
Trench							
85	: 6	: 11	: 10	: 27	: 2	: 29	
80	: 6	: 10	: 7	: 23	: 2	: 25	
75	: 8	: 9	: 3	: 18	: 2	: 20	
70	: 10	: 10	: 1	: 21	: 2	: 23	
Convention- al tower							
85	: 3	: 10	: 10	: 23	: 2	: 25	
80	: 3	: 9	: 7	: 19	: 2	: 21	
75	: 3	: 8	: 3	: 14	: 2	: 16	
70	: 4	: 7	: 1	: 12	: 2	: 14	
65	: 4	: 8	: 0	: 12	: 4	: 16	
60	: 4	: 9	: 0	: 13	: 6	: 19	

¹Conservative estimates for careful filling methods and good drainage based on 6 months of storage.

Plastic caps or other good covers will reduce top spoilage.

Poor compacting and sealing of the silage and excessive rainfall or melting snow on uncovered trenches and stacks will increase losses.

²Includes side and end spoilage in trenches and stacks.

³Allowance made for some heating and flake mold at the lower moisture levels.

Data from U.S.D.A. BDI inf. 149. 1953 Mimeographed Report p. 10.

TABLE 2--Continued

Silo type & m.c. % of forage as stored	Dry matter losses						
	Surface ² : spoilage	Fermen- : tation ³	Seepage	Total	Field	Total	
	: %	: %	: %	: %	: %	: %	
Gas-tight tower							
85	: 0	: 10	: 10	: 20	: 2	: 22	
80	: 0	: 9	: 7	: 16	: 2	: 18	
75	: 0	: 8	: 3	: 11	: 2	: 13	
70	: 0	: 7	: 1	: 8	: 2	: 10	
65	: 0	: 6	: 0	: 6	: 4	: 10	
60	: 0	: 5	: 0	: 5	: 6	: 11	
50	: 0	: 4	: 0	: 4	: 10	: 14	
40	: 0	: 4	: 0	: 4	: 13	: 17	

Gordon (1961) showed that cows ate less dry matter as low dry matter silage and produced relatively less milk when compared to barn dried hay. As the dry matter of the silage increased so did the daily dry matter intake of the cows and the relative production of milk. He suggested that this demonstrated the better acceptability of high dry matter silage, and its greater effectiveness in milk production. Gordon also showed that higher dry matter silage was more efficient in producing liveweight gains of beef animals. No explanation was offered for this. Drying high moisture silage did not increase its palatability nor wetting hay decrease its acceptance. Gordon et al. (1960) found that direct cut harvesting of silage yielded a product of lower feed value than wilted silage or hay, but wilted silage approached or was equal to good hay. Werner (1960) reported similar findings. For this reason

general statements concerning the relative feed values of silage and good hay have very limited application because of the within silage variability associated with wilting. Werner (1960) also noted that cows, given a choice, preferred the higher dry matter silage. He suggested there was no limit to the minimum moisture content at which silage could be made, except for the increasing difficulty of keeping air out of the silage mass. M.A.F.F. (1961), advising on wilting ostensibly for bunker silos, recommends dry matter contents of 25%, chopping or lacerating to give consolidation, using leafy material and filling the silo as quickly as possible. Comparing wilted and unwilted silage making (apparently in trench or bunker silo although this is not stated) Mudd (1963) found that wilting did not increase ensiling time. Using two swath boards with a 60 in wide mower enabled the swath to be picked up with a 40 in wide flail chopper without needing to windrow. The mowing machine cut lower than the harvester and gave a higher gross yield.

McCullough (1962) blames many of the problems of poor silage to length of chop, and considers 2 in -- a legacy of flail harvesters -- as not short enough. Gordon (1961) outlined the precautions to be observed in making high dry matter silage, and required the material to be chopped as fine as possible -- not with a forage harvester.

The interest in high dry matter silage has been further stimulated by very telling salesmanship of gas tight silos built especially for silages of approximately 60% dry matter (referred to as haylage.). The advantage of such a silo is that fermentation of wilted silage is more easily controlled by the complete exclusion of oxygen and is said to be characterized more by the absence of undesirable ferments than by the

presence of desirable ones. (Anon. 1961b). This controlled process is believed by McCullough (1962) to be important for 4 - 5 days while the pH is lowered to about 4. Any subsequent leakage of air into the silo will not spoil the silage which will also have a longer trough life, especially in warm weather. This is the only make of silo which offers a bottom unloader so that materials may be added for ensilage at the top, as mature silage is being withdrawn from the bottom. Table 2 shows that the estimated silo losses for this type are least of any, but the additional exposure in the field during wilting increases dry matter loss as percent dry matter increases. The optimum moisture content appears to be about 60%. Gordon (1961) questions the need to wilt below this point.

Work by the U.S.D.A. at Beltsville (Anon. 1961b) showed that alfalfa haylage was more acceptable to dairy cows and that milk production and body weight gains were higher when compared with direct cut alfalfa silage. But no comparison was given of the amount of dry matter eaten. Comparing alfalfa stored in air tight and concrete stave silos Embry et al. (1960a) suggested that storage loss is a factor to consider in the choice of a structure. The amount of loss during the short trial was not an important factor against the stave silo, but digestion trials gave some indication that the high dry matter forage in concrete stave silos may have suffered losses in feeding value after 60 days in storage. Perry et al. (1962) reported that chopped hay and haylage made in air tight silos had similar feeding values and haylage stored in a conventional concrete silo was slightly inferior to that stored in air tight silos. Caps or plastic seals are necessary in concrete silos to reduce

loss due to top spoilage.

After critical trials making low moisture silage in conventional concrete tower silos Gordon et al. (1961) suggested that a dependable method for doing this could be developed. The results indicated that excessively elaborate precautions to exclude air were not necessary, although the silo walls and doors must be tight. To ensure rapid expulsion of the air the crop should be cut as fine as possible, and the silo filled rapidly. In addition Werner (1961) recommends larger diameter silos of 16 ft and upwards and considerable height of material to ensure good compaction.

Equipment for Handling Silage

Silage making can now be fully mechanized by the use of commercial-
ly available machinery. Its use on similar farming types has led to
the development of similar methods and techniques that have come to be
regarded as standard methods, not by definition or objective attainment
but by common usage. A study of field performances of such common
systems using forage harvesters and bunker silos provided more reliable
performance standards for the design of new operations, and higher attain-
ment levels to be reached by existing systems. (National Agricultural
Advisory Service 1959).

This report also indicated that there were no major problem areas
in the mechanization of silage making for bunker silos and self fed
silage. Even the new introduction of wilting, which none of the farm
systems investigated were using, could be incorporated without any loss
of efficiency. With more sophisticated systems including tower silos

and mechanical feeding there are some areas where further development is needed.

The high power requirement for forage blowers to fill tower silos is solved by the expedient of using a tractor power take-off. A rule of thumb guide that the loading rate is one ton per hour per hp. would limit the maximum loading rate, tons per hour, to the tractor horsepower available. The intermittent loading rates needed to empty wagons at harvest time will need to be several times in excess of the harvesting rate, and can approach the limit of available power. A more efficient method of elevation requiring less power could make better use of electric power. Towards this end Millier (1958) developed the belt tube elevator for chopped forages, Kempe and Herum (1960) describe a vertical elevator for fibrous feeds. Some of the difficulties experienced with this type of elevator appear due to the high coefficient of sliding friction, especially of wilted material. Corn forage, with an apparently low coefficient of sliding friction and an absence of inter-lacing, was more successful.

Decker (1960) reported that most vertical silo unloaders operated satisfactorily, but improved design was needed to overcome difficulties with grass and frozen silage. Hartsock and Larsen (1958) found that the influence of the operators handling of the feed mechanism caused considerable difference in operation efficiency. Buckingham (1962) suggested that more attention needs to be paid to the problems of keeping the outer end of the unloader against the outside wall, particularly when the material is frozen or hard packed.

The horsepower needed for unloading is often a limiting factor to output, especially for direct filling of self unloading wagons. Decker et al. (1963) found that an all-auger silo unloader has a specific unloading rate about four times that of a conventional auger with blower discharge.

Jeffers (1962) lists the disadvantages of unloaders for horizontal silos as: 1. need operator controls, 2. use high power to give high output, and the power is not usually used for other purposes, 3. few arrangements allow simultaneous addition of supplement to silage, 4. cannot deal with sloping sides. Decker (1962) reported that most farmers did not find the provision of a tractor as a power unit for the unloader an inconvenience, but he found it was essential to have the walls as near vertical as possible to reduce the hand forking necessary with sloping sides. The U.S.D.A. (Peterson 1962) has a project to develop an automatic silo unloader to overcome the disadvantages listed by Jeffers (1962).

Apart from self feeding, auger feed bunks and mechanical unloading wagons with fence line bunks have come to be accepted as the standard methods of feeding. The distribution of chopped forage with a forage wagon is good since the operator can adjust the rate of feed and the discharge into the feed hopper will remain constant, relative to the road speed. The standard of mixing when ground feed is added to the forage has not been defined beyond suggesting that it is good when forage and ground feed are added in layers. Nor is it known if any type of forage box used as a feed wagon is better than any other.

Similarly, Heege (1961) reported that no research data was available on auger feeders. In a subsequent investigation Heege found it difficult to adjust auger conveyors to give uniform distribution along their length. Slotted bottom, and punched through feeders appeared to be least satisfactory. A stationary tube auger was adjusted to give uniform distribution (by weight, no account was taken of material quality), but this was a lengthy task, and the setting needed adjusting with a change in feeding rate and material condition. When ground feed was added to the silage, all auger feeders except the revolving tube feeder, caused separation.

Heege concluded that to obtain good distribution silage should be chopped into uniform short lengths. If corn is added, it should not be ground, but perhaps it could be cracked slightly. The supplement should be in pelleted form.

IV D. HIGH MOISTURE CONTENT CORN AND GRAINS

Corn and grains are not normally considered forage. However, since the process of storing is essentially that of ensiling, and similar harvesting storage and feeding systems are used as for other forages, they may be considered as within the context of this study.

Maddex (1962) gives the following definitions:

High Moisture Corn - mature corn harvested at moisture content of 25% or above intended for ensiling either as chopped ear corn or shelled corn.

Wet Corn - Corn too high in moisture for conventional storage, intended for storage as dry ear corn or shelled corn.

Warner (1962) suggests that the practice of ensiling grew up by accident and that there is a wide range of moisture contents at which ground ear corn will store satisfactorily. The only requirement is that as the moisture content decreases the corn needs finer grinding. Warner reports feeders in Iowa find that drier material is the better. Beeson, Perry and Hennold (1956) found that ground mature dent corn at 33% m.c. stored in good condition in an air tight silo. Maddex (1957) noted that Farmers experiences showed concrete stave silos would be satisfactory for storage, but little research information was available. Work at Iowa (Culbertson et al. 1957) indicated that high moisture corn stored well in an air tight silo and when included in fattening rations was

superior to regular corn. In contrast Albert et al. (1960) found that high moisture ear corn stored at 32% m.c. (field tested) in concrete stave silos turned sour and pasty. Heifers did not find the feed palatable. A contributory cause may have been that only a 1 in layer was removed from the top of the silo daily.

High moisture corn storage is a further example of a case where a farmer innovation has developed into an established field practice without the guidance of research. Maddex (1957) reports farmers storing ground ear corn in concrete stave silos as early as 1946. A simple technique was established for filling the silos at moisture content of about 25%, water being added if necessary. The farmers found no serious problems that could not be solved by the application of normal ensiling techniques.

Pratt et al. (1961) conducted trials on high moisture barley storage. 30% m.c. grain was used and little difficulty was experienced in handling grains in this condition except during rolling when dough from the wet barley built up on the rollers. The only change needed to harvesting methods was to reduce the clearance between the concave and cylinder of the combine. Other reports from Minnesota (Anon 1961c) showed that dry barley harvested at below 25% m.c. could be moistened by adding water to it and be stored equally as well as wet harvested barley. The elimination of oxygen is important, air leaking through defective auger seals caused heating and deterioration within ten days. Once removed from the silo, the rate of deterioration depended on the ambient temperature; at 70° F the barley heated within two days, but at 32° F it could be exposed for several weeks. A series of storage

and feeding trials of high moisture barley in air tight silos are reported by Frederick et al. (1962). Farmer interviews reported from time to time in the popular press draw attention to the apparent simplicity of this method of storage and the extreme palatability of the product. There are no reports of high moisture barley being stored in concrete stave silos. Oxley and Hyde (1955) reported on the successful storage of wheat at 24% m.c.

IV E. LIVESTOCK PHYSICAL REQUIREMENTS

Feeding Standards

Feeding practices for beef and dairy cows are tending to be simpler and with fewer ingredients than was the custom only a decade ago. Unfortunately this trend is not universal, nor is it a move in the direction of uniformity.

Niedermier (1960) suggested that the trends in dairying in Wisconsin were towards fewer and larger dairy operations, using more silage in preference to other forages. Morrison S.H. (undated) reported some beef feeders in Michigan were using only high moisture corn, silage, supplement, and no other dry roughage. Frederick et al. (1962) demonstrated that yearling Hereford steers fattened as quickly and efficiently using rolled high moisture barley without alfalfa hay as with. Warner (1962) states that no hay is necessary with corn silage fed ad libitum and corn fed 1 lb daily per 100 lb live body weight and supplement. While further information is needed on the extent to which silage alone can be used as the source of roughage for beef, it would seem that many feeders have already found an acceptable level. Even more important there appears to be some difference of view between the recommendations arising out of research and what farmers are actually doing. For example, Hillman (1959) found that the addition of hay to a silage ration for dairy cows increased the dry matter intake and that milk production on silage, with up to 25% of the dry matter (d.m.)

intake as hay, was significantly lower than rations with a higher proportion of hay. Brown (1961) similarly found that dairy cows consume less dry matter as silage than hay although in this experiment the silage was direct cut and no moisture content was stated.

It seems likely that further simplification will take place, stimulated by the need for simpler conservation systems and less labor consuming methods of feeding. For this reason to specify the actual rations required for all classes of stock at this time would involve legion of variations that would be useless for general design purposes. In an attempt to provide some guide lines for future design work Schulz (1960) presented data on feed requirements as dry matter requirements lb per 100 lb body weight for representative classes of beef stock. These figures are useful in calculating the total dry matter requirements but give no indication of the most suitable or likely proportions of dry matter in ground feeds and those in roughages. Evans (1960) describes a method of computing rations for beef and dairy cows on the basis of dry matter appetite, starch equivalent (S.E.) and protein equivalent (P.E.) requirements, using home produced forages with nutrient deficiencies made good by ground feed or purchased supplements. Two possible rations calculated by this method for baby beef production are shown in Table 3. One comprises wilted alfalfa silage, the other high moisture ground ear corn silage at 33% moisture content. In both cases the nutrient requirements are met, but the storage requirement for the silages differ by 320%.

Aldrich (1961) gives beef feeder feed storage requirements assuming 25% d.m. from hay (at 15% m.c.) and 75% d.m. from silage

(at 75% m.c.). Hillman et al. (undated) give estimates of hay and silage requirements for Holstein cows for varying combinations of hay and silage.

TABLE 3

RATIONS FOR BABY BEEF PRODUCTION TO PUT ON 2 LB LIVE WEIGHT
INCREASE PER DAY FROM 560 - 1060 LB BODY WEIGHT USING
WILTED ALFALFA HAY AT 36% DRY MATTER AND GROUND EAR
CORN AT 66% DRY MATTER

Body weight lb	Appetite dry matter lb	Silage fed lb	lb. S.E. per day	lb. P.E. per day	Total weight silage
<u>Alfalfa silage</u>					
560	14.5	47.5	8.35	2.06	2620 ¹
672	17	55.6	9.8	2.4	3110 ¹
784	19	62.3	11.0	2.7	3500 ¹
896	20.5	67	11.8	2.9	<u>2140²</u>
					11370

Volume 11370 lb alfalfa silage at 45 lb cubic foot = 253 cubic foot.

<u>Ground ear corn silage</u>					
560	14.5	14.5	8.6	.78	815 ¹
672	17	17	10.4	.92	950 ¹
784	19	19	11.4	1.04	1065 ¹
896	20.5	20.5	12.0	1.1	<u>656²</u>
					3486

Plus 1 lb Soy bean oil meal fed daily.

Volume 3486 lb ear corn silage at 45 lb cubic foot = 78 cubic foot.

Calculated from Evans (1960).

¹56 day feeding period.

²32 day feeding period.

Thus in designing forage storage requirements for feed lots the designer should rely on the stated preferences of the farmer for the feeds he will be using. For small lots the error in assuming general figures, such as those published by Aldrich (1961) will not be overly serious since there is a general tendency to add a margin to storage unit sizes by choosing the next largest commercially available size, or rounding dimensions upwards during construction. In large feeding operations it is more important to have a close approximation of the type and size of storage accommodation needed. A good design will always allow for a margin of safety to cater to the variation that exists in feeding standards and appetites of stock, and to enable a surplus of feed to accumulate as a contingency against unfavorable fluctuations. However, safety margins are insurances, they are also expensive, and it is an essential precaution to know the calculated limit of the margin.

In the absence of any guidance the trend of feeding habits indicates planning should assume that most forage will be consumed as silage. A study of some of the recommendations for feeding requirements and the forages used in feeding trials shows that, when all feeds are converted to the equivalent of wilted alfalfa silage at 35% d.m., the beef feeder requirement closely approximates to 56 lb per day. In arriving at this figure it has been assumed that; 1. corn silage will replace equally alfalfa silage, 2. both will replace equally haylage or high dry matter silage corrected for a moisture content of 65%, 3. that 8 bu ground ear corn will replace 1 ton silage. In fact these equalities do not exist but it is considered that in the absence of more specific guidance the approximations are sufficiently accurate. Energy,

protein or other deficiencies in the rations would be made good by supplement feeding. Details of the rations considered are shown in Table 4.

TABLE 4

SUGGESTED REQUIREMENTS AND RATIONS FED DURING FEEDING TRIALS
COMPARED ON THE BASIS OF THEIR DRY MATTER EQUIVALENT TO
WILTED ALFALFA SILAGE AT 65% M.C.

Source	Suggested feed or feed used	Livestock	Daily silage equiv. lb
<u>Beef Animals</u>			
Aldrich (1961)	Hay, silage, corn	200/300 day feeding	57
Evans (1960)	Silage	2 lb per day live weight gain	56.5
Pick (1963)	Silage, hay	Body weight up to 1680 lb	about 60
Embry <u>et al.</u> (1960a)	Haylage	Average 80 steers	52
Embry <u>et al.</u> (1960b)	Haylage	Average 80 steers	56
Warner (1960)	Corn, silage, hay	675 lb steers	51
<u>Milk Cows</u>			
Gordon <u>et al.</u> (1960)	Hay, silage, grain	3 expts. Milk yield 25 lb 4% FCM	89.4
Volker & Bartle (undated)	Haylage, grain		122
Farmer (1963)	Haylage, grain	Yield 10 lb milk Yield 25 lb milk	88 115
Comerford (1963)	Silage only) Hay only) Hay, silage) Silage, hay) & grain)	Corrected for 25 lb milk yield. Grain allowance converted to silage equiva- lent	<u>range</u> 73- 75 76-106 30-107 75-134 74 92 92 83

Calculations on milk cow rations show a wide divergence. The results in Table 4 have been calculated on the basis of maintenance plus 25 lb 4% FCM. (Fat corrected milk). Any attempt to estimate a single representative figure of daily silage requirements is little more than an intelligent guess. Such a guess would be about 90 lb. Comerford (1963) notes that a milk cow can consume a maximum of about 100 lb silage (24.1 lb d.m.) per 1000 lb body weight and that it is sufficient for maintenance and production of 28 lb 4% FCM milk. The equivalent figure for hay is 36 lb (31.0 lb d.m.). He then reasons that 1 lb hay d.m. replaces 0.78 lb silage d.m. Brown (1961) found that 1 lb ground feed d.m. replaced 0.56 lb roughage d.m. with an additional production of 0.82 lb of 4% FCM. Comerford suggests that with this data it is possible to calculate the daily feed intake per 1000 lb body weight of low and medium yielding milk cows when fed grain, silage or hay.

Housing and Feeder Requirements

The requirements for shelter, lot area and bunk lengths published by various authorities are generally in close agreement with each other. These are summarized in Table 5. A comparison of some of the standards from which the summary was prepared are shown in the appendix Table A1.

TABLE 5

SUGGESTED MINIMUM FEED LOT AREAS AND FEED BUNK LENGTHS
DERIVED FROM VARIOUS SOURCES ON A PER ANIMAL BASIS

	Beef	Cows
Area square foot		
Covered	20	30
Open paved	20	50
Unpaved	200	over 300
Bunk length foot		
Restricted feeding	24	28
Unrestricted feeding	4-6	6

V. MATERIALS HANDLING SYSTEM DESIGN

A. General Considerations

A decision to make changes in a farming system or even to maintain the status quo is not to be made lightly if the consequences are to be meaningful and beneficial. No enterprise in any form can be considered in isolation from the rest of the farming operations under the management of the entrepreneur since each competes for the resources at the disposal of management -- land, capital, labor and in those cases where management is also the farm owner operator managerial competency would be a resource.

The need to consider changes in a farming system may be established in a variety of ways, acting singly or in concert: The economic necessity to optimize profits so that the available resources may be used to the best advantage; a change in resource availability which might arise from the development of local industries that drain the surrounding farm land of hired farm labor, or make available seasonal labor in the wives and families of men who come to work in the industries; the positive desire to establish that the best job is being done; the results of the constant evaluation that is a function of management. This is essentially a continuing and dynamic appraisal of the relative conditions of the business situation.

The methods used in studying and analyzing the considerations that lead to changes are mainly economic. The economists and others concerned with this study may use one or more of many techniques from

simple budgeting to the use of mathematical models. The conclusions of the study which are formulated as a statement of the changes that need to be made, i.e., a plan for development, must satisfy the farmers preferences and be adapted to his particular skills. It is axiomatic that there are limitations implicit in any proposed plans. These need to be appreciated if the best success is to be made of the projection of the plan either into the farming operation as a whole or into a single enterprise.

The outlook in respect of distance relationship is important. For example in dairy production in the short run the majority of individual farm plans may call for upgrading of milk cows and increasing the size of the herd. But in the long run it can easily be seen that since the present total milk production is almost enough to meet the demand, the increase in output brought about by the aggregation of these recommendations may reduce the net output of dairy farms below the level of the pre-planning stage.

Secondly, the common resources of the farm are of themselves inflexible. Such resources in the development of a beef enterprise may be characterized by capital, land, labor, buildings, machinery. Land has a limited productivity determined by soil type, topography and climate, buildings have limited space and accommodation. Labor is a discrete factor and therefore a limiting one where the smallest unit is the full time worker. It can be considered a continuous factor only in those cases where seasonal or temporary help is freely employed. Machinery similarly is a discrete factor, of which each unit has a limiting output. The limiting factors of machine output may be

occasioned by; a shortage of labor which prevents the machine from operating at full output; timeliness which requires that work be done between two closely defined conditions or times; availability of crops or materials for processing. Kleis (1957) suggests that if the services rendered instead of the units themselves are considered, by hiring machinery or custom work, the indivisibility of machinery units can be overcome.

Thirdly, in those cases where planning calls for an upgrading or any major change to an existing enterprise, the plan must always be based on the situation as it exists before the change, and allow for the transition as experience and economic investment will allow. This inevitably forces some compromise on to the attainment of the ideal organization by the presence of buildings and structures that may not be paid for, machinery that is not obsolete and a way of doing things that always carries with it a resistance to change. Indeed if the ideal solution is very different from the present methods, the change may be too drastic or risky or need too much capital for any change to be taken at all.

In the preparation of farm plans for forage conservation, Hoglund (1962) suggests that the economist must rely on agronomists, nutrition chemists and agricultural engineers to provide the basic input-output data relative to:

- a. production, harvesting, storing and handling the various forage crops,
- b. substitution rates between different forage crops when fed to dairy and beef cattle,

- c. production response of cattle when fed forages of different qualities and harvested by various methods,
- d. appropriate cost and price coefficients to apply to physical input-output data in determining relative costs and returns for alternatives studied.

As used here, "economist" is meant to be applied formally to the professional, but it is clear that an agricultural engineer responsible for planning machinery use, needs to have substantially the same information and cannot divorce the desire for mechanical perfection from the economics of capital investment in machinery.

B. System Design Analysis

A working definition of farm systems analysis is given by Ross (1962) as:

"The study of a farm production unit which takes into account the succession of all handling processes, forms of products, structures and conveying equipment, and which results in plans and specifications which maximize or minimize a desired entity.....(most often) maximum financial return or minimum work involved."

The literature is full of references to the meaning of materials handling and what is to be achieved by a study of it in relation to farm materials. The simplest approach is that by Mellard (1961) who considers materials handling as a fundamental attitude of mind as regards to:

1. The elimination of unnecessary handling both in the number of times handled and distances moved.
2. The minimization of remaining movements by a combination of processes and reduction in number of varieties.

3. Mechanization, provided this is practicable and economically worth while -- but only after elimination and minimization.

Other writers have commented on the need to consider handling systems as a whole, before substituting machinery for hand work. (Kleis 1957, Van Arsdall 1957, McKenzie 1958).

Peart et al. (1963), in presenting a mathematical programming of materials handling systems, review the efforts of research workers to consider the entire farm materials handling system and its relationships, rather than to select equipment and methods on the basis of only one process. Pinches (1956) stated that "systems engineering in agriculture should start with analysis of farm operations or processes and proceed through work flow, or process layout to implementation on a farm layout." Hall (1958) described several theoretical design methods applicable to farm materials handling systems. He suggested that a simple method is needed to relate various components into a materials handling system to determine the most economical arrangements. Linear programming techniques were suggested as possible solutions to this need. Doane (1959) stated that linear programming can, to a considerable degree, substitute mathematics for bias or prejudice in determining the best operating plan for a farm.

There are reports of a number of studies of farming systems using this technique, including Lambert (1960) Armstrong et al. (1962). Swanson (1961), in an appreciation of programmed solutions to practical farm problems, reports that one commercial organization using linear programming for farm management plans has programmed ten farms over the previous two years. He notes also that the cost of such a plan is

sufficiently high (from \$1000 up) that the existence of this market is currently limited to the large farms but still considers this a significant beginning.

Programming of individual farms by the extension service is presently being done on a very limited basis. In some instances solutions are used as teaching devices to stimulate thinking and discussion in group meetings. Swanson (1961) comments that linear programming has been used in some states mainly in the form of optimum plans for typical hypothetical farms. But, because of the difficulty of developing appropriate procedures to apply the typical farm solution to individual farms being considered, "the impact of these optimal benchmark plans on the planning of commercial farms has been minimal." McKee (1961) considers that the most serious shortcoming in the linear programming approach is the implicit exactness in the quantitative statements of the applied restrictions. Further research is likely to mitigate this problem. Hoglund (1962) and others feel that the most important obstacle to be overcome in the acceptance of this method of planning is an understanding by the farmer and the program operator that alternative solutions usually exist which are almost as profitable as the 'best' solution and often may be more acceptable in respect to investments.

DeForest and Forth (1958) stressed the system planning approach by developing a colorful flow chart that showed alternative methods and their interrelationship in the movement of all materials. McKenzie (1958) developed grain and feed storage system fundamentals and recommended the multiple use of equipment in a complete materials handling

system. Ross (1957) used industrial techniques with process and flow charts to analyze existing systems and present improved methods. This method is long and tedious and the accuracy depends on the validity of the assumptions made by the analyst and the soundness of the basic data used in summarizing process charts. Ross suggests that while this type of analysis would be too costly for planning systems it might be applied usefully to general farm types and employed to establish requirements of existing or proposed systems. McHardy (1959) suggested that farmstead materials handling problems could be approached by considering them to fall within a limited number of categories and used flow chart relationships to compare existing and alternative methods. The pay off period calculated from capital cost and operating cost was used as the cost criterion.

Pomroy et al. (1961) developed a method of materials handling evaluation by the use of moveable models. The advantages claimed for this system are that it presents 'before' and 'after' plans in an easily understandable form for farmers with no technical background, especially in presenting the third dimension. This method is generally limited to farmstead layouts and requires that scale models be available for all of the units to be considered.

Maddex (1960) said that in working with farm operators the essence of materials handling was to consider the large and total problem of material movements rather than augers, conveyors and elevators which, although important in many systems, represent only a small part of the solution either in investment or results achieved. He suggested two approaches to the development of the materials handling on the farm:

1. Labor saving -- the development of equipment to reduce the energy or time needed,
2. Materials flow.

Larsen (1962) studied traffic patterns in farmsteads and the various methods of analysis for comparing alternative arrangements. He stated that the ultimate tool was not available yet but that time and motion studies can be used to develop a standard data system for all agricultural operations. This would give a measure of the efficiency of any combination of possible arrangements. Seale Hayne Agricultural College (undated) use output equations as a quick method of arriving at the optimum organization of men and machine systems. This is more suited to field operations for which reliable time work data is available. Using a similar method Belshaw and Scott (1963) derived work performance data in a form able to be used in a comparative analysis of the present farm organization and in the synthesis of a more profitable farming pattern. This data gives: a. a guide to the overall labor requirements, especially of the regular force, b. a detailed indication of the ways in which a particular restriction, imposed by labor, can be removed by improving work methods or by investing in new machinery or buildings, c. target performances.

VI. DEVELOPMENT OF SYSTEM LAYOUTS

In the synthesis and integration of farming systems the first essential is to propound the limiting conditions within which the system can be built. McKenzie (1957) referred to this as a conceptual framework containing the basic assumptions on which the analysis is based, and design fundamentals which outline the form of the planning. These limiting conditions are derived in part from the essentials of materials handling considerations and the need to conform to the nature of farming and livestock operations. It bears reiterating that the farm operator also has a considerable influence in their formulation; his preferences and desires as well as his capabilities and work habits are an integral part of the system.

Assumptions

In the development of feed lot layouts in relation to the methods of forage conservation, the following assumptions are made:

1. Each system must be capable of being built in component units. This will enable a farmer with existing facilities to change as convenient and necessary and to allow those newly starting to develop at a pace suited to their abilities. In many ways each separate component -- hay conditioning, storage and feeding, silage storage, etc. can be considered as sub systems requiring the same consideration as the complete integrated system.

2. Each storage and feeding system should ultimately be capable of the maximum practical mechanization. In this instance the limit of mechanization is taken to be complete automation and the use of labor limited to program planning. Not all of the systems considered are capable of this degree of mechanical handling at the present time, but of those that are the limit is set only by the cost of the equipment and the need to have regular overlooking of the stock in the interests of good husbandry.
3. The system design must include consideration of the anticipated and possible development, not only of the particular enterprise but also of the farmstead and the farming policy. Storage structures with concrete foundations are more or less immovable units. They dictate to a considerable extent the orientation of other permanent features around them -- paved yards, roads, structures, and thus their siting indirectly determines the ultimate development of the layout or plan of the feed lot and possibly the farmstead.

Design Requirements

The more specific requirements for successful forage storage and feeding system design may be listed under 6 headings:

1. Adaptable
2. Flexible
3. Compact
4. Capable of expansion
5. Adaptable to mechanization in stages
6. Plan for linear development

1. Adaptable

Beef animals, dairy cows and even hogs have in common the ability to process forage, as defined in this study, into animal products. It is necessary to conceive as production tools the structures, storage and equipment for handling and feeding forage. Furthermore, since they have a relatively long life in relation to the changes in economic climate, and to ensure that as wide a use is made of them as possible, the system needs to be adaptable to the current most profitable class of livestock. Hogs are perhaps an extreme contrast but the change from beef to dairy cows by the addition of a milking parlor is not unlikely and the opposite is common. Adaptability can be improved by using non specialized equipment and general planning. The probability of changing a farming system, however marginal its profitability, is very small when considerable amounts of capital have been invested in special equipment, as, for example, in milking rooms and dairy equipment in milk production.

2. Flexible

For some time the trend in forage conservation has been towards silage. It is in a far from ideal form with respect to materials handling since it involves the lifting, transporting and storage of large quantities of water, which as an essential to an animals diet could more easily and cheaply be obtained from the water trough. Its unique merits are; that it can be completely mechanically handled, particularly when feeding; that the net yield of forage per acre is as high as other methods of conservation and it is relatively independent of seasonal intemperance.

However, many still regarded hay as an essential part of the ruminant diet, especially for dairy cows and its attendant disadvantages are tolerated for this reason. The position may be changed if a system of chopped hay storage and feeding could be completely automated or pelleting and wafering machines developed to produce hay pellets and wafers in economic competition with other forms of roughages.

3. Compact

There are two alternative conditions in the feeding of forages. In the first instance the material is self fed essentially in the same location in which it was stored and no handling is involved. (In some cases called the "easy feed method," silage or hay is thrown down by hand behind a movable barrier. To this extent handling is involved, but the important consideration -- that the location of feeding is also that of storing -- still holds). In the second case forage is handled from storage to the feeding location. In all cases when handling of forage is necessary the forage storage units, grain-feed storage and processing units need to be sited in close proximity to each other, and a focal point established within the storage area through which all material flows converge. At this focal point material may be blended, mixed, proportioned and/or weighed and the subsequent direction of flow chosen. For example in a system including hogs and beef steers, the ingredients may be the same for both classes of stock, but the proportions of each will vary and the ultimate feeding locations will be different.

The need for this common point of material flow is at once evident when automatic programming of feed ration composition and feeding is contemplated. Once all the ration ingredients have been

assembled, distance acquires a new context and becomes relative to the size of the operation. The machinery for subsequent transport may be a forage wagon in larger or more extensive designs, or mechanical conveying equipment in simple intensive designs.

The use of a bunker silo with automatic emptying equipment does not invalidate or lessen the need for this requirement. A forage wagon may be used as the conveying equipment with its advantages of unlimited movement. Thus it can easily be made to convey material through a flow point determined by more restrictive conveying equipment.

4. Capable of Expansion

This fundamental requirement is generally accepted by most planners of industrial and farming operations. The evidence of unbalanced and botched systems that have grown 'like Topsy' on too many farms tends to indicate that this requirement is too often applied with too little emphasis. Many times the farmer is much to blame since he rarely appreciates that small increases in production each year can, over the life of machinery and especially buildings and structures, in the aggregate lead to quite substantial increases in the physical requirements of the farmstead. These increased requirements are particularly evident when a materials handling system has relieved the operator of chores. Rather than use the energy and time so released for leisure or alternative occupations the tendency is to maintain the same work load of the original enterprise, thus necessitating its growth and development. An increase in efficiency through better work routines and management has the same result.

It is a particularly important requirement to have in mind when existing machinery and buildings need to be included in the initial phases of a system. It requires considerable experience and forethought to be able to assess the influence that these items can have on the development of any system towards a reasonable functional unit, and when there is any doubt that the influence will seriously detract from the ultimate efficiency of the proposed system, then the offending item must be disregarded and alternative plans for development made. As testimony to this the author is familiar with many cases where too much consideration was given to the apparent value of existing buildings, which later use showed to be unsuited to the purpose. A new start had then to be made which expended much of the earlier efforts and cost.

5. Design for Complete Mechanization

McKenzie (1957) so succinctly expressed the position on man power in all applications of materials handling as; "Use man-time first to think and last for power." The sequence in the mechanization of any operation would be:

1. Remove the drudgery.
2. Mechanize all handling.
3. Apply simple on off control.
4. Integrate the control system.
5. Introduce automatic programming.

Some of the savings that can occur from mechanization are likely to be attenuated by bad habits. Two of the more common are: inefficient and careless operation leading to excessive breakdowns and stoppages; and secondly, the unprofitable use of time while a man watches the machine work.

6. Plan for Linear Development

This is almost a corollary to the consideration of compactness and expansiveness and the need for it certainly arises out of implementing these two conditions. It is a consequence of the use of mechanical conveyors to integrate the different storage and processing units into one system. These conveyors move material in a straight line; they can be arranged to have one or any number of storage units feed on to them, and they can be made to discharge at any convenient point. Being also relatively cheap they may be extended, replaced or repositioned if a change in feeding practices is required. In short they are essential and versatile components of a system of materials handling but, they can only operate effectively and cheaply in a linear direction. Because of this all other components must be arranged to conform to this requirement. A general but not inviolable rule to facilitate expansion would be to avoid obstructing the projection of any mechanical conveyor.

Other Design Considerations

Selecting the method of feeding.

There is no single answer to the best method of getting forage to the livestock. The solution lies in a consideration of factors which are peculiar to the situation of that farm including the capital available, the size of the facility and the anticipated expansion. If an existing facility is being developed or extended, the presence of gates, fences, congested environs to the lots and forage storage may make vehicular movement impracticable. The requirement of an automatic feeding system demands mechanical bunk feeders. A single auger feeder

is limited in length to about 150 ft which establishes a lower limit to the cost per head of capacity. The addition of more yards with auger feeders will increase the cost per head due to the necessity of cross conveyors.

Fenceline bunks with self unloading wagons for feed distribution have the advantage as the size of the facility increases. Then maximum capacity is limited to the number of hours in which the cattle can be fed. On small and medium sized systems the wagons can also be used during forage and corn harvesting for bringing the crops from the field. The precise breaking point between the two methods is different for each case considered.

Restricted or Continuous Feeding

Restricted feeding may be defined as the condition when livestock are without access to feed for more than two hours during daylight. This, of course, is a purely arbitrary definition since it has been clearly established that cattle do eat during darkness. In practice it will mean feeding four or more times daily. The physical requirements show that with free access the linear bunk space allowed for each animal can be reduced substantially. It may simplify the design of the feed lot and certainly reduces the cost. However, once the decision for continuous feeding has been incorporated into a lot design of minimum dimensions it cannot be abrogated without reducing the stocking capacity or adding to the bunk length.

Silo Unloader Capacity

The average unloading capacity of the popular silo unloaders in corn silage is about 4000 lb per hour, the maximum being in the range

8000 - 10,000 lb per hour. This rate of flow appears quite satisfactory for all mechanical bunk feeders. The only stipulation is that each successive conveyor should have a conveying capacity at least equal to the last. With "open bottom" conveyors the speed of the bunk mechanism is of little consequence with regard to distribution in the bunk, but with chain and flight bunk feeders, the conveyor speed must be reduced so that all of the required ration is fed onto the belt before that which was loaded first reaches the end of the bunk.

A 400 bu forage box will need to wait of the order of one hour for a load at an unloading rate of 4000 lb per hour. Only in the small lots, where one load or less will be sufficient for the total capacity of the yard, can this period of delay be accepted as reasonable. But, contrary to the concept of most farmers, the comparatively slow output of the unloaders is still satisfactory on large installations. By allowing silage to accumulate in an elevated temporary holding or buffer bin, it can be discharged almost instantaneously into the wagon when needed. At 8000 lb per hour unloading rate the maximum capacity of a single unloader is about 1500 head of beef or half the daily capacity of a forage wagon.

A further advantage of a temporary holding bin is when the unloading rate falls due to change of silage physical characteristics such as a change from corn to grass silage, or the silage freezes around the periphery of the silo.

The Choice of Storage Methods

The structures for ensiling may be classified into two broad categories, horizontal and vertical silos. These may be examined per se.

to see how each meets the relevant functional requirements of feed lot design.

1. Vertical Silos - Planning Assumptions

a. At the moment the only storage system which could meet the requirement of complete mechanization.

b. Each silo is a discrete component, available in a range of sizes and can be used singly or in any numbered combination.

c. Unrestricted as to siting, the only consideration is the 'front' or discharge face which must be correctly positioned with respect to the conveying system. If incorrectly sited or orientated, these silos can not be moved or turned without expending the structure.

d. Any degree of mechanization can be applied to the smaller units. In larger silos mechanical unloaders are essential because of the physical effort needed to manhandle the silage across diameters greater than 16 ft.

e. Most compact method of storage, a 30 ft x 70 ft silo will store 3700 lb per square foot of floor area.

f. Expansion is possible by increasing height of each silo (if allowed for in design requirements) or the number of silos.

g. The common type of concrete stave silo has been shown satisfactory for all materials presently ensiled. Specially designed structures such as the air tight silo are also adaptable to most materials.¹

¹There may be factors which render such silos unsuitable for special crops such as acidic corrosion in bolted galvanized silos, impracticability of emptying, etc.

2. Horizontal Silos

a. Mechanization is presently limited to mechanical unloading under manual control. Self feeding could be considered a special form of complete mechanization.

b. Each silo comprises a separate component. Can be made large or small as required.

c. The silos singly or in groups may be built into the plan in rectangular orientation, the long axis of all silos being parallel. This will make possible the use of mechanical conveyors, even though successful commercial units are not yet available.

d. Mechanization can be achieved in discrete stages from hand work through commercial machines which need manual supervision. Automatic unloaders are being developed.

e. Extensive form of storage; at 5 ft depth settled silo floor loading is 190 lb per sq ft, at 8 ft depth loading is 350 lb per sq ft. As the silage is removed the point of discharge of the unloader changes, making delivery to a focal point difficult. This in turn adds difficulties and complications when processing, mixing and weighing are needed.

f. Expansion is possible by increasing the height of the settled silage when not self feeding, otherwise by extending the length of silo or adding additional units.

g. Horizontal silos have been used successfully for wilted grass silage (not over 30% dry matter) and ground ear corn silage.

Restrictions on Design

There are other restrictions on the design of feed lots, which although not related to forage storage, or the manner of feeding, influence the plan and layout of lots and need stating briefly at this point to maintain perspective. They are listed, in what this author would consider diminishing importance, as:

- | | |
|---------------------------------|-------------------------------|
| 1. Drainage | 5. Animal handling facilities |
| 2. Lot orientation | 6. Paved areas |
| 3. Cleaning and manure disposal | 7. Shelter |
| 4. Lot size | |

1. Drainage. An essential requirement on all functional sites; no lot area should be without adequate drainage. In many instances the natural lie of the land will give all the slope that is needed, in flat areas the low cost of mechanical grading to provide the necessary falls of about 2% (Midwest Plan Service (1963) suggests 4%) increases the total cost of the facility by very little. The accepted practice is to slope away from buildings, and run parallel rather than normal to feed bunks.

2. Orientation. The aim is to reduce exposure to the cold in winter and conversely temper the effects of the sun in summer. Most creature discomfort is occasioned by hard driving rain and cold winds and the most prevalent directions from which these come should be given consideration. Tall silos on the south side of lots cast long winter shadows covering much of the yard, lessening the chance of drying or thawing the yard surface. With already developed farmsteads, much natural protection may be afforded by buildings and tree shelter belts.

3. Lot cleaning and manure disposal. Little evidence is available to determine the effect of dirty yards on the economic production of beef or milk. But it is desirable that lots should be kept clean for aesthetic as well as for sanitary reasons. The requirements are that areas are made easy to clean, are kept clean, and that there is a place into which mud and manure can be cleared. In paved lots the whole lot (excluding the bedded-loafing area) should be cleaned. Unpaved lots need to have paving on areas of high traffic density in front of feeding bunks, waterers, and in traffic lanes. These similarly need to be kept clean. The disposal of manure is largely a function of climate and topography. What ever method is finally chosen should have its individual design requirements built into the lot plan.

4. Lot size. It is commonly recommended lots be limited to 75 - 125 head of cattle. With dairy cows maximum convenience in handling will be obtained when the lot contains a whole multiple of the milking parlor capacity.

5. Animal handling facilities. Yards need to be arranged so livestock can be easily selected for shipment, or moved from one yard to another. Dairy cows have to be moved through the milking facility via a holding area at least twice daily. Loading and unloading chutes, cattle crush and scale pen should be included for beef lots.

6. Paved areas. Paving increases the level of cattle comfort, improves drainage and facilitates regular cleaning. To offset the cost of paving, the facilities can have reduced area, fewer fences, and shorter roads.

7. Shelter. The orientation needs to be towards the west and south.

It is considered important that this area should be bedded and the bedding be kept clean and dry on top. Frequently the shelter can serve as storage for hay and bedding and as these are consumed the animals are allowed to retreat further into the building. In these cases calculations on space requirements for both hay, bedding and animals should allow for the stock to have the minimum space allocation within the shelter during the severe weather of winter.

VII. PRESENTATION OF FEED LOT LAYOUTS

A feed lot design includes 3 basic functional components:

1. Feed storage.
2. Feeding facility.
3. Livestock area.

Feed storage includes the storage units for forage, feed grains, and the preparation, assembly and blending of the feed items.

Feeding facility is the method and the manner in which feed is presented to the livestock: in a mechanized bunk feeder, fence line bunk, or by self feeding. The conveying system is the means of integrating the feed store with the feeding facility and may be considered as belonging to either component.

Livestock area comprises the lot area, paved and unpaved, shelter, water, drainage etc. It is associated with the feeding facility since it is within the livestock area that feeding is done.

In contemplating the design of feed lot layouts, the identification of each system and item within its functional component provides a convenient and simple classification of the factors to be considered. Also it often aids in clarifying the objective to be attained by the system or the use of an element or item of equipment. Two or more components may be associated in one unit or structure, as in self feeding at a horizontal silo when storage and feeding are combined, or the use of the shelter or loafing area as hay storage, when all three components are amalgamated in one structure.

All these functional components are present in any feed lot layout however simple or crude. As the layout develops or expands it is the systems and units comprising these components which develop. Provided that a plan or blueprint exists covering the development of the whole feed lot layout and its possible expansion, each system or unit may be developed at any time. The periodic expansion need not be related to each system simultaneously since the developed components will be completely integrated on completion of the overall plan. Obviously, if development is being spread over a period of time some thought has to be given to the sequence of building. For example, there would be little advantage in erecting silos for forage storage without having yards for the livestock. On the other hand, if the shelters and yards already exist, temporary provision can be made by building stack or surface silos within the lots and self feeding silage or using self feed hay stores.

It is clear that in practice each farm system could be unique in its shape and conformation. The possible combinations obtained by storing the forages and feeding them as outlined in Fig. 1 represent over 150 possible variations of practical value. To a degree this is unavoidable since the whole enterprise must fit into, and derive the most benefit from the topography of the locality.

A ready-made shelter belt of buildings or trees, slopes to provide drainage, complementing existing facilities and the use of ready-made roads and access, all influence the planning decision. Only by specifying precisely the physical conditions of the area can ready-made layout plans be prepared. In the following presentations an attempt has been made to show distinct forms of layout characterized

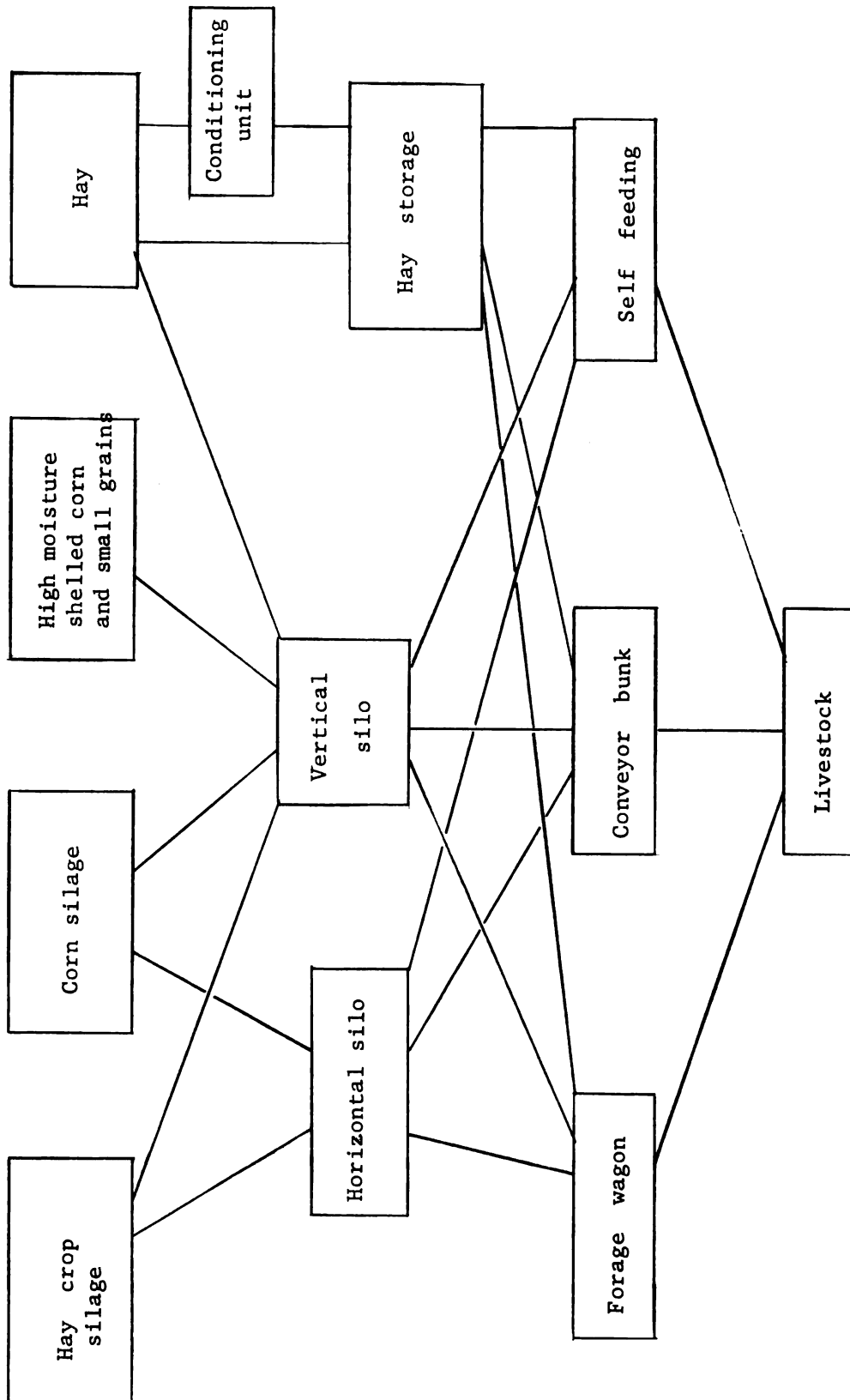


Fig. 1. Methods of storing and feeding forage

by the storage of forage and the feeding facility.

The different patterns and shapes that can exist within a form may appear more diverse than those which exist between forms embodying different methods, especially is this true when existing facilities and buildings are incorporated into a new design. However, the important requirement when selecting a layout is to identify the form which most closely meets the planning objectives and modify this for the particular location and conditions.

A. Vertical Silos. Conveyor Bunk Feeding

The simplest layout is shown in Fig. 2. This is a basic layout and illustrates the integration of the three functional components. The single lot is limited to about 100 head of beef animals 400 lb and up, fewer if dairy cows, more if small beef animals. This limit is imposed by the behavioral characteristics of the animals. In this simplest form all the assumptions and design requirements of the lot are met. Suitable dimensions would be 60 ft x 72 ft for the paved open lot and 60 ft x 30 ft for the shelter.

The simple layout makes it most likely to be built in one operation as the beginning of a complete system but it can be developed in stages. For example:

- a. Pave or outline the lot, using existing structures for shelter, or build final shelter.
- b. Self feed silage in the yard or use self feed hay wagons or storage units.
- c. Erect the silo. Use self feeding wagons filled by hand and pulled into the yard.

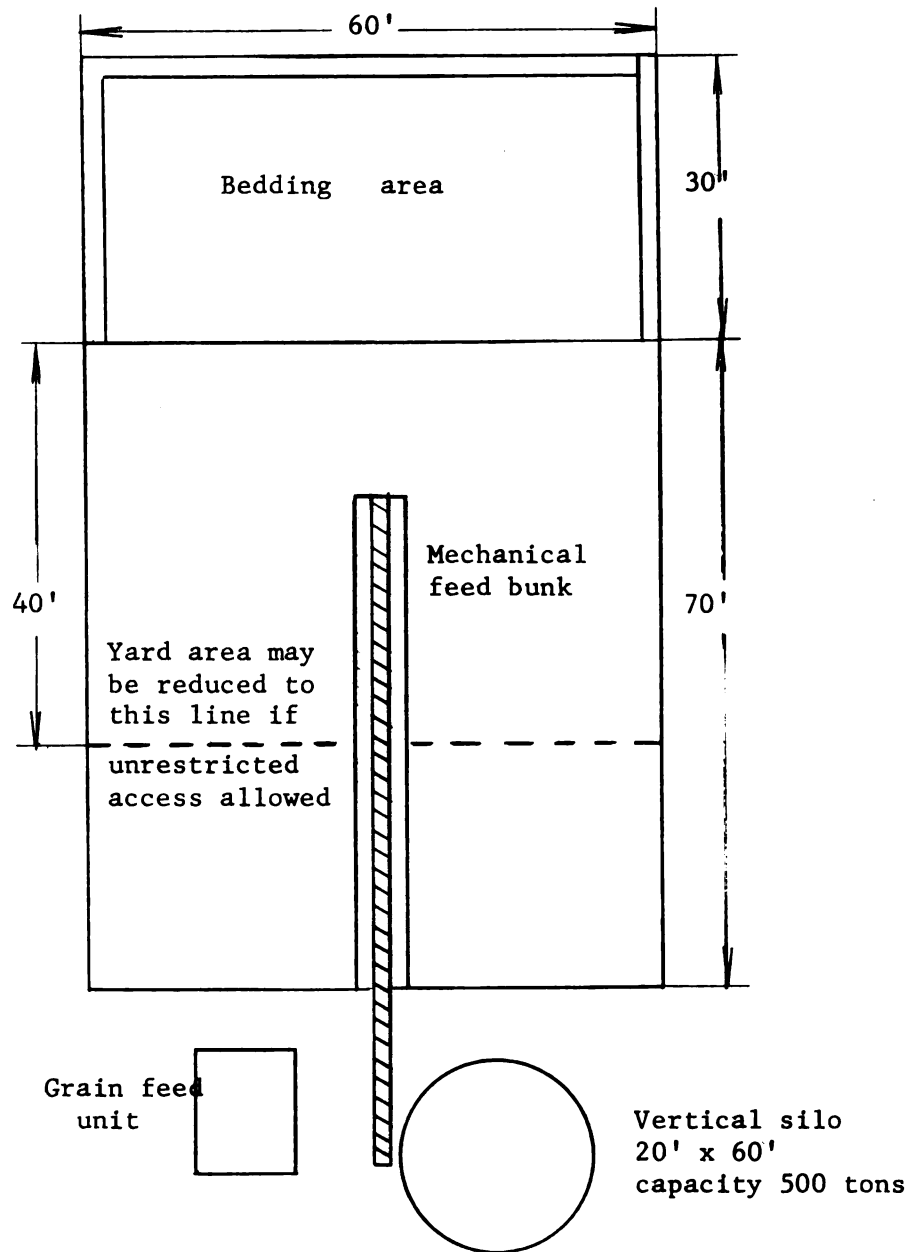


Fig. 2. Feed lot layout with vertical silo suitable for 100 beef animals, showing essential requirements of feedstore, feeding facility and livestock area

- d. Install the conveying/feeding system.
- e. Complete animal handling facilities.

The open simplicity of the layout makes it adaptable for milk and beef cows and also hogs. The length of the lot open area has been extended to give 24 linear in per head of stock for restricted feeding and to allow movement of livestock at the end of the bunk without passing into the shelter.

The feeder in the center of the lot is more than half of a fence line, which when extended into the shelter can be used to divide the lot into two. Each side may be used for different categories of stock, the bunk feeder must be of the type that fills each side of the bunk alternately if the two half lots need different rations. The single silo imposes a limitation on the length of time stock may be fed in the yards. It is quite impossible to calculate precisely the feed needed for the time when the silo will be empty and during the filling and ensiling process. For dairy cows this may be met by a period of early summer grazing, but for hogs and beef cattle it makes the feeding management more difficult.

For a top unloaded silo the maximum removal of silage should be during the late summer. At an assumed 3 in per day necessary to prevent excessive spoilage of the top layers, a 20 ft diameter silo will require a minimum daily removal rate of 1.6 tons, i.e., sufficient for 58 beef stock or 36 dairy cows. With chopped ear corn silage the quantities would be 1 ton daily, 38 beef stock or 24 dairy cows.

The position of the silo determines the area of feed storage development. All additions to forage storage and feed grain storage will be in close proximity to the original silo. Provided that the projection of the auger conveyor is not obstructed by the silo, the discharge face of the silo may point into the feed lot or normal to the line of the conveyor.

Figs. 3a and 3b show the development of the plan, and the influence of the orientation of the first silo on subsequent siting.

In Fig. 3a the extension of the forage silos has been parallel to the projected line of the original feed bunk. This was determined by having the first silo with the discharge face adjacent to the extension of the bunk conveyor. The silo location is shown as 8 ft from the lot boundary to give a movement passage for animals. The silos discharge into a transfer conveyor which may be above or below ground level. On the opposite side of the conveyor is the feed grain unit which may take the most suitable form for the requirements of the farm. In essence feed grains with such supplements as may be necessary are added to the transfer conveyor with the forage. An inclined conveyor lifts the material to a minimum height of 7 ft over the 8 ft wide passage, and then into the second transfer conveyors which deliver the material into the outside lots.

The 3 lots in Fig. 3a can be fed different rations if occupied by different classes of livestock and by dividing each lot into two, six individual groups may be established. Material flow from the grain feed unit and silos converging at one point makes control of ration ingredients simple.

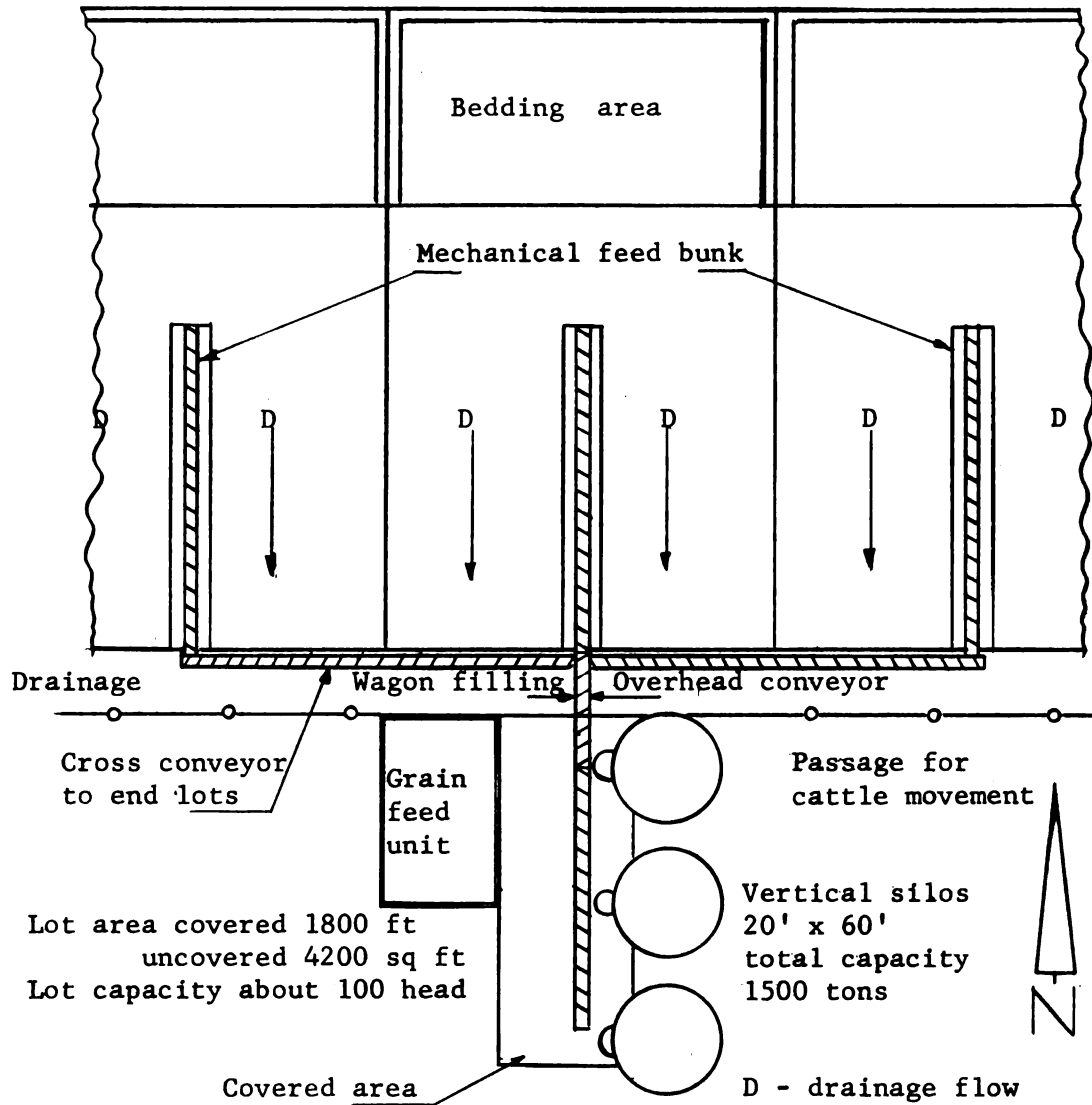


Fig. 3a. Feed lot layout with vertical silos.
Extension of a single lot unit to
3 separate lots

The space between the grain feed unit and the silos is shown as a covered area. This seems desirable for a number of reasons. Primarily it protects the electrical control equipment that must be located in this area, the metering and other machinery associated with the blending of rations. It also provides a center from which the operation control may be felt to emanate, since feed is the most expensive part of the enterprise this is important, and because this area is protected from the elements it induces tidy housekeeping habits and more hygienic work routines.

Expansion is theoretically unlimited, separate lots could be extended on each side, requiring only an extension of the conveyors and feed and forage storage units. Practical limitations are imposed by the site and the inadequacy and cost of the conveying system. An estimate of this limit is 5 separate lots.

Mechanization in some degree is most usual and can be carried to complete programming of rations and feeding sequence.

The necessity for linear planning is demonstrated in the joint use of the transfer auger by the forage and grain feed storages.

It is often debated that the silos should be put into the lot area to eliminate much of the transfer conveying. It is true that in this way the conveyor length will be reduced but this extra length has no influence on the functional efficiency of the system. The extra cost has to be balanced against the convenience of the movement lane for livestock and its use in disposal of manure. Drainage flows will normally run parallel to the bunks and into the movement lane, which then becomes a drainage channel. Gutter cleaners may be used to move

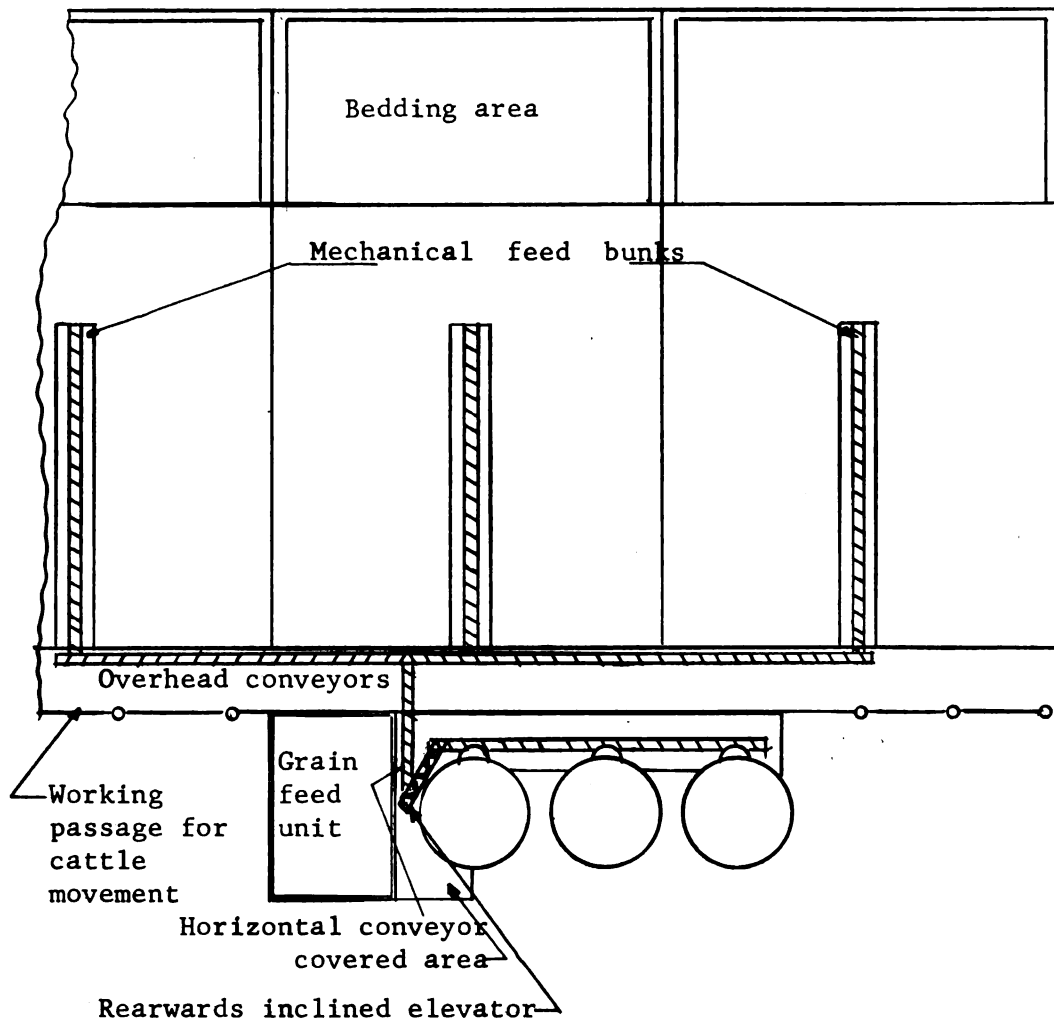


Fig. 3b. Feed lot layout with vertical silos. Alternative arrangements of silos for extension of single lot to multiple units

manure to a pond or tank or directly into spreaders for immediate disposal.

Changes in the layout may be needed to provide shelter from the west or east.

Fig. 3b is almost the same layout except the orientation of the silos is normal to the line of the feed bunks. This is a consideration when the storage units need to be built along the already established building line without projecting into and spoiling an area that may be needed for other development. It is more usual to find that this layout is made necessary by having the discharge face of the first silo facing the lots or even at the end of the feed bunk as shown in the sketch. If there is no movement lane between the silo and the lot the installation of the conveyors is simple. However it is much more difficult when the conveyors have to span the movement lane at a height of 7 ft and additional conveyors and elevators may be needed. One possible solution is shown, an elevator is inclined away from the lot in order to gain height, and the material is conveyed forwards in a horizontal conveyor to the second transfer conveyor.

This layout offers more shelter along one side of the lot which, if on the southern aspect could be undesirable in winter in the more northern regions. On the other hand access to the silos for filling is excellent in contrast to the layout in Fig. 3a where there may be some difficulty in getting sufficiently close to the first silo. The efficiency of silage making operations can be seriously impaired if unloading the forage trailers is not made simple and almost fool proof. In cases with poor access a permanent filling elevator conveniently

placed, with cross conveyors to fill each silo, may be a satisfactory solution.

Some writers feel that it is so important to avoid shade on the southern aspect that they require the feeding unit to be placed on the northerly side. This means feeding through the bedded area, as depicted in Fig. 4. The essential conditions of the rectangular layout previously shown have been maintained. The main difference is in the additional lengths of conveyor needed. By suitable planning this layout can lead to a pleasing appearance.

The layout shown is especially suitable for beef and dairy cows. The storage units have been built up to the margin of a 10 ft lean-to on to the north side of the cattle shelter. The passage formed by this lean-to serves as a movement lane and also the covered control area for the storage and blending units. All the storage units are served by a continuous reversible conveyor built either below or above ground level. Although subject to contamination the below ground level unit will give more convenience. At each end of the long conveyor is an inclined portion or elevator to a cross conveyor giving headroom in the movement passage and also in the bedded area. The feed bunks are sited in the open; no feeding is done within the bedded area.

The covered passage on the north and the open lane on the south allow complete recirculation of any pen either for weighing beef animals or for milking cows. The southern lane may also be used as a drainage channel as described for Fig. 2a, this would be especially useful if the center lane were used as a holding and washing area for milk cows. The width of each lot and the center passage is determined by the necessity

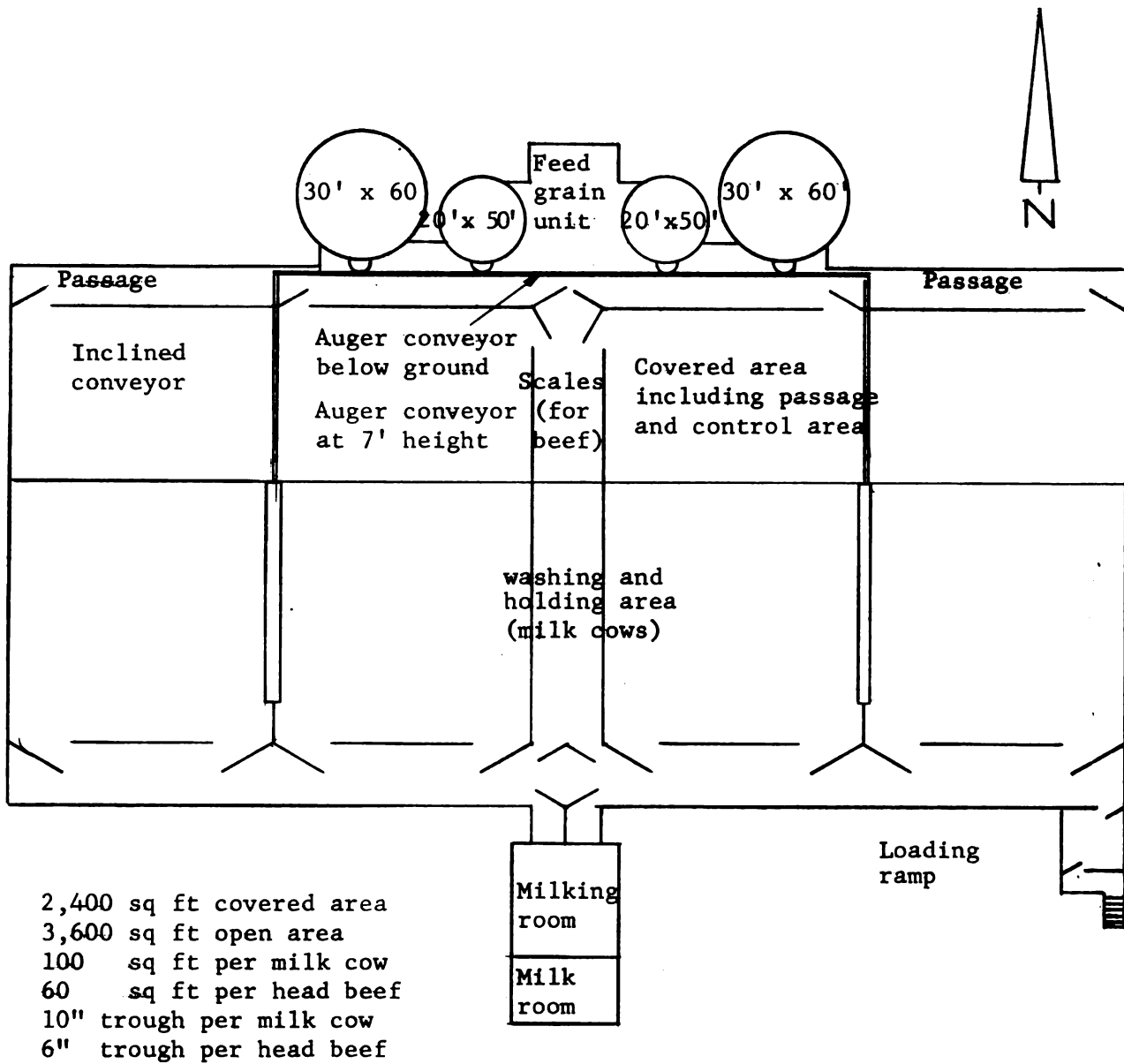


Fig. 4. Feed lot with vertical silos. 4 unit layout for beef or dairy cattle with silos and shelter at north of area

of conforming to the available standard building components. In this case 15 ft bays were assumed as standard.

The flexibility of the unit has been described. In the sketch two 30 ft x 60 ft silos are shown for hay crop and all corn silage, and two 20 ft x 60 ft silos for high moisture shelled corn and small grains. Silo requirements beyond this would need additional cross conveyors to feed the main conveyor. The four individual lots shown are the probable limit of expansion, although additional lots could be added to each end. The basic unit is probably half the layout shown. In other respects the form is that of the layout in Fig. 3b.

An interesting theoretical layout is shown in Fig. 5. This is an attempt to produce maximum efficiency. A focal point of material flow from the store has been defined as an essential in determining feed movement. By developing this concept further and using a rotating conveyor all feed bunks have in effect been made to terminate at a locus and the locus is fed by a single conveyor from the grain feed and forage store. The resulting lot areas become sectors but since circular designs are difficult to fit into established farmstead development, the overall shape is shown rectangular. Into the center of the radii are focused cattle movement routes and drainage. This makes for a convenient dairy cow layout since movement lanes and labor controlled movement are minimized.

The layout shows how a milking unit may be included in the compact arrangement. Shelter is arranged around the periphery of the rectangle giving the maximum protection in all directions. The unit would be adaptable to hogs as well as cattle. Lots 3 - 6 would make a

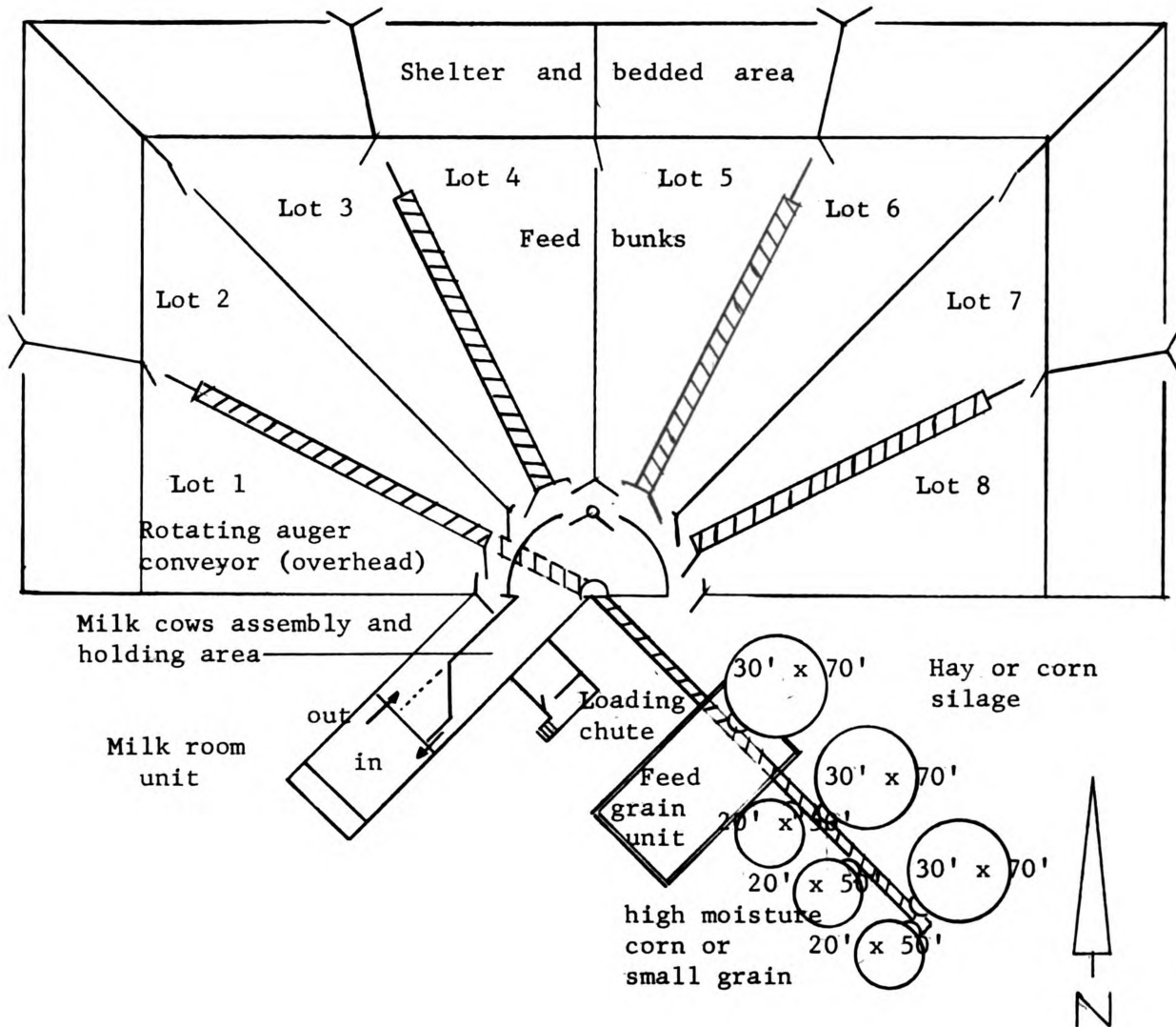


Fig. 5. Feed lot layout with vertical silos, circular arrangements of feeding and cattle movement for beef and dairy cows

useful initial unit with which to begin, additional lots could be added as necessary. Without the dairy unit the lot area can be extended to include 270°.

There are a number of changes needed for an effective practical design. The difficult cleaning in the corners of the buildings and the cost of using non standard building components in the corners. Adequate provision would be needed for a supply of bedding to the shelter area, which must be through the rear wall of the shelter. In an enlarged design this form of layout is known as the pie shape layout and may be extended to give lot areas sufficiently large to remain unpaved. The shelter is then moved into isolated units on the circumference but it may also be incorporated into the radial fence lines separating the areas. Other features remain substantially the same.

Vertical Silos. Forage Wagons and Fence Line Bunks

The forage wagon serves the role of a flexible conveying system between the focal point, where feed, grain and forage are blended, and the location of consumption in the livestock area. Because the forage wagon is so accommodating, there is no necessity for the forage silos to be oriented especially to the lot and this relieves considerably the problems of siting and design. The silo location needs primarily to have good access for filling and feeding. Roads and access ways need to be hard surfaced for all-weather operations.

The layout of the feed grain unit and silos is almost the same as previously discussed except that the transfer auger needs to discharge into the wagon. In the discussions on silo unloaders reference was made

to the slow rate of unloading especially under difficult conditions and the use of overhead bins for silage, as for ground meal. The building height should be made sufficient to allow for their subsequent installation. The overhead bins with flat bottom doors should cover the whole area of the wagon. Ground feed and supplement may be added to the top of the silage in the forage wagon or elevated into the wagon or bin at the same time as the silage.

Fig. 6 shows a similar arrangement of feed grain and silo unit that was used in Fig. 3 modified to drive through with a forage wagon. All of the storage layouts so far shown can easily be fitted with an auger conveyor for loading a wagon but overhead bins would have to be put outside the covered area to allow access for filling. Fig. 6 may be varied for large or small quantities by changing the size and number of silos. The only prerequisite is that the covered drive through be built large enough in the first instance. The plan shown has a clear floor area of 30 ft x 40 ft giving adequate length for a tractor and forage wagon to be preloaded and left ready for use and afforded some protection against rain and freezing temperatures. The scale may be added when convenient.

On small installations where time of filling is not critical the overhead bins will not be necessary for forages. The forage conveyor will need to be high enough to clear the side of the wagon. (Some 11 ft to point of discharge at 45° in order to fill the center of wagon with 8 ft high sides.

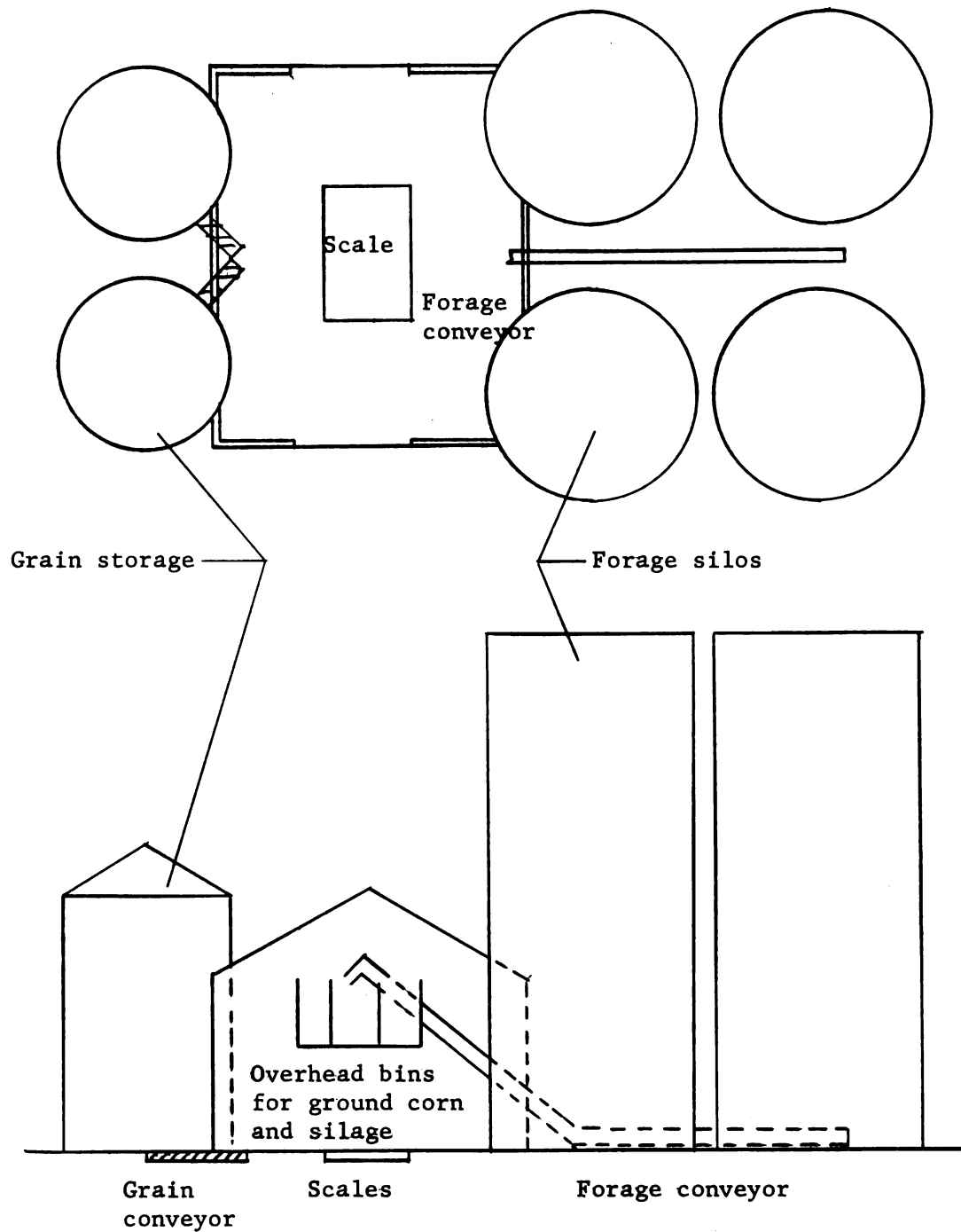
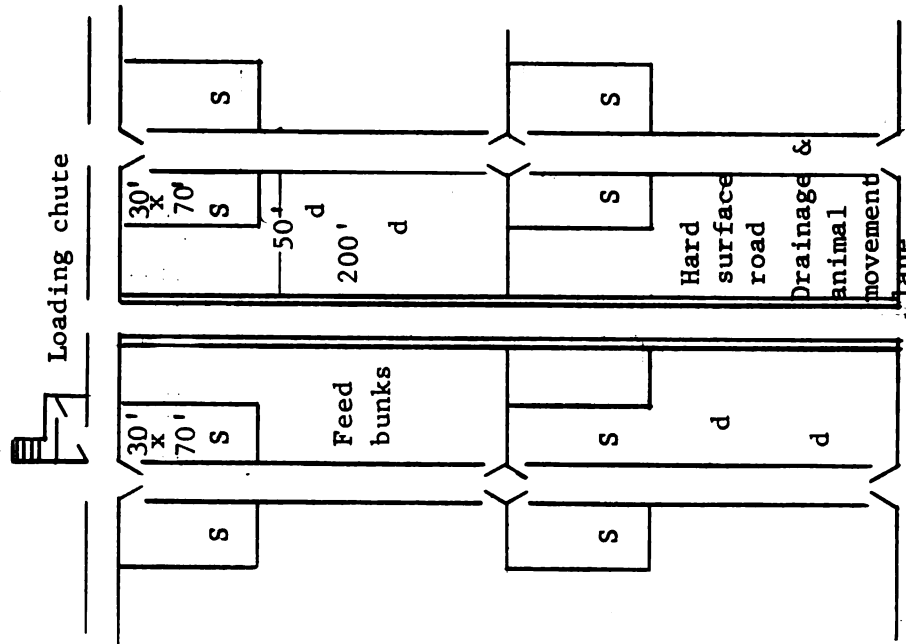


Fig. 6. Feed grain and forage storage layout for use with forage wagons

The lots used for forage wagon and fence line feeding are different in two respects from the forms shown with mechanical bunk feeders; one is the necessity implied in the name, that of moving the feed bunks to the outside fence line, second, especially in the more intensive lots, is the need to change the shape to give the necessary length of feed bunk. This involves a more critical determination of the periodicity of feeding. Most authorities quote only two figures for length of feed bunk per head, for restricted feeding, and unrestricted feeding. It would seem that there is another condition to consider, the stimulation given to the animal when it sees and hears the food being put before it. This "come and get it" appeal may cause temporary congestion at the feeding bunk, even though sufficient food is provided to eventually satisfy their appetites.

For this reason a precise intent must be stated about the number of daily feeding operations or else the feed bunk length allowance should be sufficiently increased. The allowance used in the layouts (Figs. 7 and 8) is 24 in per head. This length is most easily provided in the larger unpaved lots which have a long periphery. It becomes more difficult to include on smaller lots incorporated within a developed farmstead.

Separation of the storage units and lot allows a simplification of lot design. Provision of adequate space, shelter and feeding facilities are the only important functions of each lot. The integration of several lots needs consideration of the necessity to provide hard all-weather roads for the forage wagon, and the amount of space needed for maneuvering a tractor and trailer combination.



S - Shelter

Fig. 8. Multiple feed lot units for fence line bunk feeding

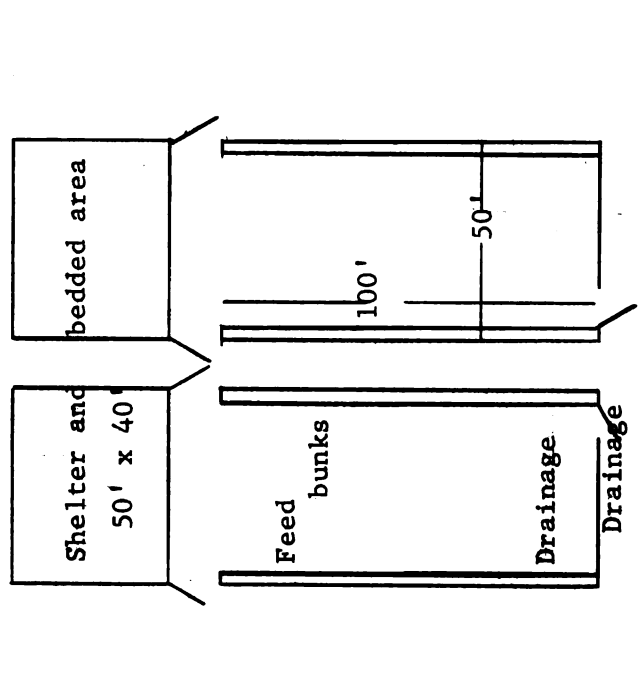


Fig. 7. Feed lot units with fence line bunk feeding

Fig. 7 is a layout of two small lots which can function satisfactory as single units. It has been necessary to increase the uncovered area allowance for each animal in order to accomodate 200 linear ft of feeding bunk. The overall dimensions of each lot are 152 ft x 50 ft including 12 ft gateway in each long side. If cattle access is provided at the rear of the shelter this gateway may be omitted reducing the length to 140 ft and the space allocation to 66 sq ft per animal including 20 sq ft of shelter.

Feed bunks have not been shown on the south fence line. The turning area needed at corners is considerable and the risk of damage to structure and equipment is further increased when maneuvering in restricted areas. A further advantage is the opportunity the open end offers to allow free drainage and disposal of manure. The layout shown will need some site modification with respect to shelter on the west and east.

When two or more yards are planned the 12 ft roadway between each adjacent pair is sufficient for satisfactorily operating a forage wagon and minimizes the amount of road surfacing needed. This is further elaborated in Fig. 8 which shows a number of lots for fence line feeding capable of considerable extension. The feed bunk is restricted to one side of the lot only, necessitating elongation of the lot and the feeding bunks of adjacent pairs of lots facing each other. The intervening hard surfaced road is used as the feeding lane. An open lane has also been provided on the side opposite to the bunk for livestock movement and as a drainage channel. It may be convenient to have additional gates to allow vehicles into the lot for removal of manure.

B. Horizontal Silos

The problem of system design with horizontal silos is the necessity of incorporating a suitable method of integrating forage with grain and ground feeds and of conveying this to the feeding facility.

The present position of equipment for unloading horizontal silos has already been discussed. There is no machine yet developed that can replace the unique combination of top or bottom unloaders and gravity. Horizontal silo unloaders, tractors with buckets on front mounted loaders for short chopped silage and manure forks for longer hay crop silage used in conjunction with wagons or trucks have proved to be an acceptable substitute. Self feeding combines the storage component for forage with that of the feeding facility and is popular on account of low installation and operational costs. In designing layouts for horizontal silos, the planner has 3 alternatives which can be identified in terms of the ultimate form of the feeding facility as outlined in Fig. 1.

1. Forage wagon. This would be a design for the permanent use of mechanical unloaders and a self propelled conveying system using truck or tractor.
2. Conveyor bunk feeding. Designed for ultimate installation of automatic unloading and conveying equipment, and pro tem. to use equipment as in the first alternative or self feeding.
3. Self feeding. Considering the present design as temporary and expendable, and plan for lowest first cost and maximum immediate advantages or as a permanent self feed system.

Horizontal Silos. Forage Wagon and Fence Line Bunks

The form of the system is identical with that of using vertical silos with forage wagons. The layout will differ only in so far that the forage store is removed from the feed grain store. A feed grain layout as illustrated in Fig. 6 will still be needed, including, in the attainment of the ideal, the overhead storage bins for ground feed and the scales but without the forage storage units. The location of the silo can be independent of the feed lots and should be chosen with most regard for its own requirements. Drainage and access for filling and emptying are the most important. As with the feeding lanes, the floor of the silo needs paving for all weather vehicular operation.

This system is most likely to be adopted for use on the larger and expanding feed lot units. In its ultimate form of complete mechanization the operator will be wholly engaged in selecting the ration ingredients and transporting these to the livestock. Since this operation can incorporate the over looking of the livestock there would seem to be little point in further automation, although with the development of magnetic tracer tapes for industrial truck control, the elimination of the wagon driver is a practical possibility.

Horizontal Silos. Conveyor Bunk Feeding

This form corresponds to that of vertical silos with conveyor bunk feeding with the three functional components integrated into a compact unit. Fig. 9 shows the same layout as Fig. 3b modified for use with bunker silo. The silo in this case is oriented east-west to conform with the existing development line. A space of four feet is left

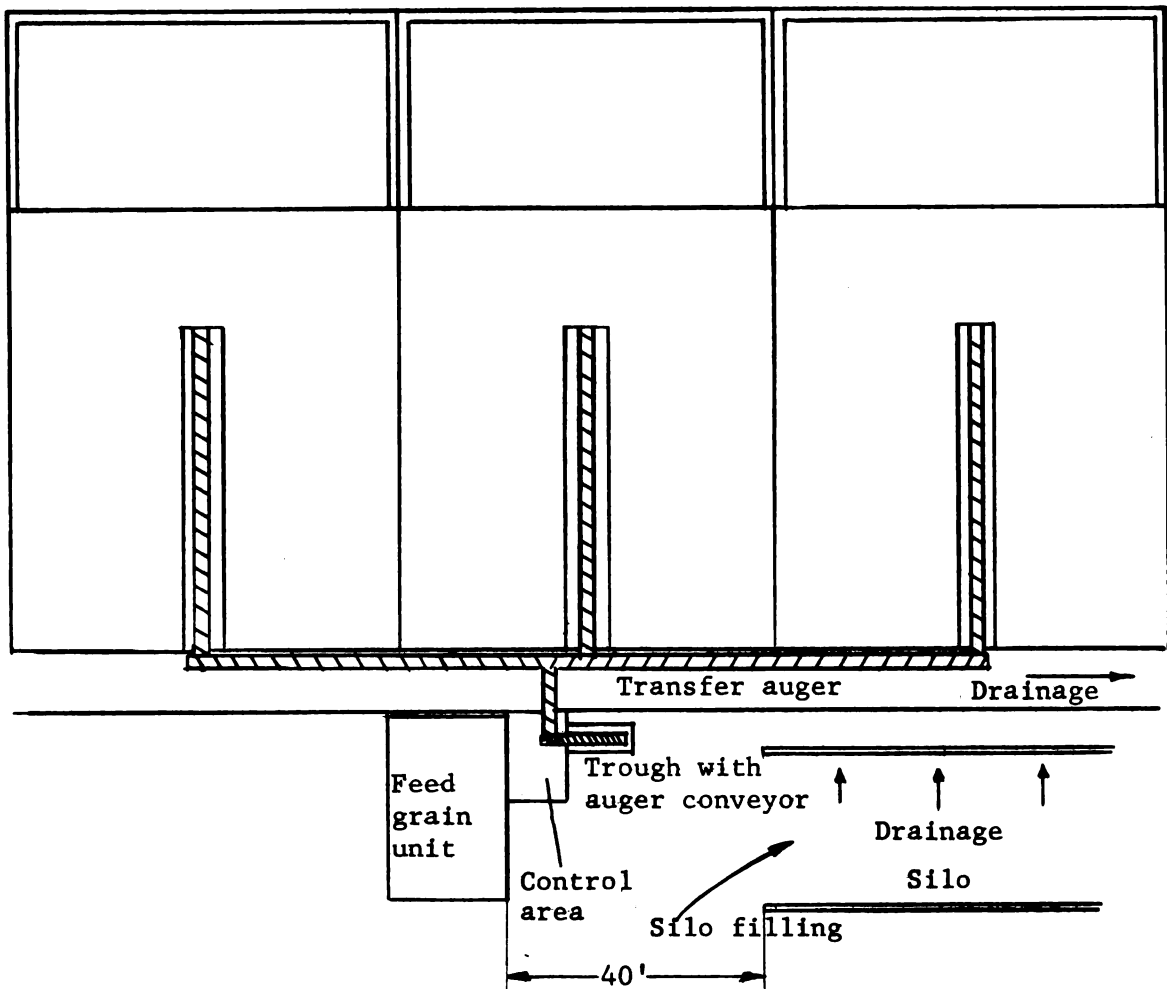


Fig. 9. Horizontal silo. Mechanized feeding in conveyor feed bunks using trough filled by tractor scoop

between the outside wall of the silo and the movement lane fence for maintenance purposes. Access for filling is provided by leaving 40 ft clearance between the control area and the leading edge of the silo walls. (This control area may be incorporated into the feed grain unit.) The principal operational component of this design is a trench or hopper box fitted with a drag or auger conveyor. Feed is removed from the silage face and dropped into the box, the conveyor then simulates the function of a transfer conveyor moving the material into control area for mixing with ground feed and thence onto the second transfer conveyor to the feed bunks.

The hopper should be sufficiently large for all the forage for one feed to be dumped into it prior to feeding, which can then be done conventionally as from a vertical silo. The design of the hopper box permits inclusion of the features discussed by Witz (1962) for metering silage flows. The box needs to be wider at the bottom than the top, and for accurate metering the height limited to 8 ft. Drag chains are used as the conveying mechanism and to prevent excessive chain tension exposure in the box limited to 4 ft depth. The width of the box is variable, but one drag chain is needed for every 6 in of width. The limiting factor to width is the need to keep the diameter of the drive shaft and its bearing requirements to sensible proportions. The material has to be chopped short and of a granular structure.

By this system the forage units and feed grain units are essentially linked together. The layout can be expanded by increasing the length of the silo, increasing the height of silage stored or building a second adjacent and parallel to the first. Research by the

U.S.D.A. (reported by Peterson 1963) indicates that the development of an automatic silo unloader will include a silage conveyor removing silage from the cutting mechanism in a direction parallel to the longitudinal axis of the silo. Layout in Fig. 9 will permit the use of such a machine to maximum advantage. The silo may be oriented 90° to simulate Fig. 3b.

Horizontal Silos. Self Feeding

The design problem in incorporating a self feed system into a layout is that feed storage and the feeding facility must be contained within the livestock area confines. This can be done by ensiling the forage within the feed lot or extending the lot by means of movement lanes to the face of the silo. Putting silage within the lot modifies lot form by necessitating an increase in area to allow for that taken up by the silo and the changes in traffic patterns.

Fig. 10 shows a simple permanent installation for about 30 milk cows or 50 beef cattle. The overall dimensions of the lot are 100 ft x 25 ft including the silo area of 25 ft x 75 ft. The silo is covered for protection to the silage and the livestock from rain and snow and to give shade in summer. The silage face is 25 ft x 6 ft high, almost too high for small beef animals. If there are small animals in the lot some hand trimming may be needed, throwing silage off the top behind the feed barrier until it is sufficiently low for the animals to reach. This manual operation would be done at the same time as the top seal is removed.

The silo dimensions are sufficient for 50 head of young beef cattle for 12 months continuous feeding or 30 cows. At this rate of consumption a full yard would consume a $3\frac{1}{2}$ in slice of silage per day, about sufficient to prevent spoilage. If the yard numbers are substantially below this the face will have to be divided into two halves and a 12 ft wide slice eaten. Although this will cause molding and waste on the exposed surface, the animals will be eating mostly unspoiled material each day. The shelter is shown as a lean-to on the high roofed silo cover. This extra height is needed when filling the silo to allow for consolidation and after ensiling can be used as storage space for hay and bedding materials. This will be thrown over the silo wall into the animal shelter as the silage is eaten.

Since provision will have to be made for supplementary feeding, a fence line bunk is shown on the long side of the lot. Drainage is down the silo from the back to the front. The biggest disadvantage to the layout is poor access when filling the silo. Buckrakes with long grass or long chopped hay crop forage will be quite satisfactory, but forage wagons will require careful planning of gates and fences. A blower can be also used with forage wagons from outside the lot area.

Expansion of the facility can be accommodated by extending the silo and shelter on the side away from the exposed face. The lot areas can however be easily duplicated as shown in Fig. 10b, in this example the silo covered by a single span building. Ensiling can be simplified by having the fencing in the open yard removable, with no fence inside the silo. The silage then has a 50 ft wide face which can be allocated to each lot as the stocking rate in each demands.

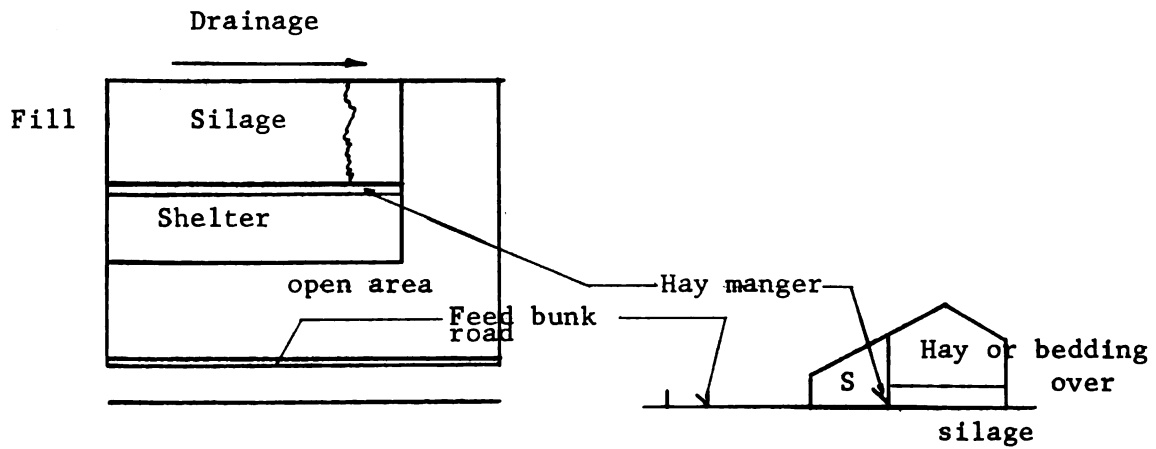


Fig. 10a. Horizontal silo. Self feed layout, with silo covered and inside lot. Hay and straw storage on top of silage

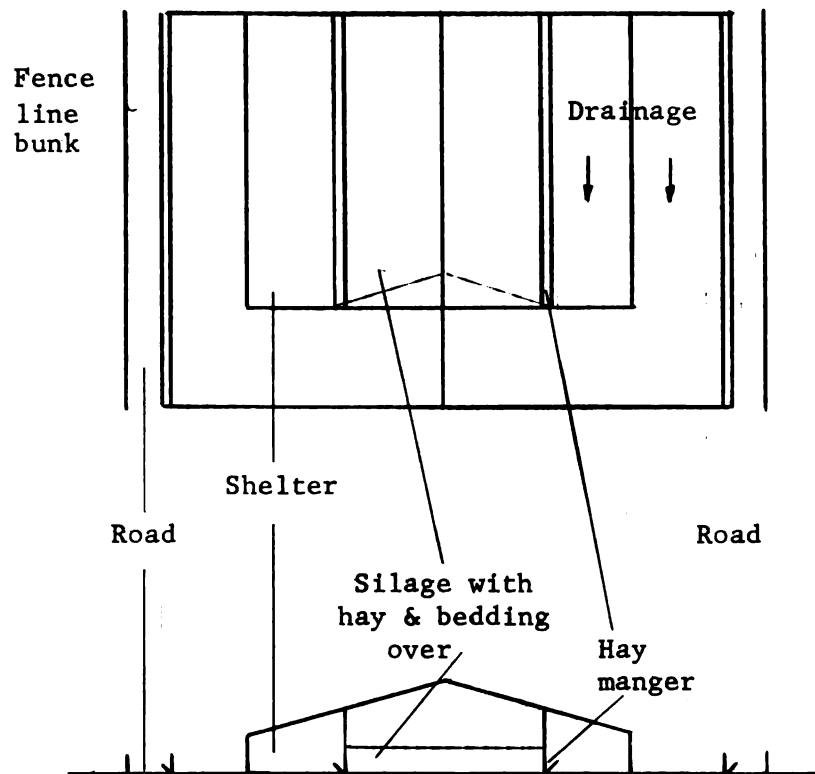


Fig. 10b. Horizontal silo. Self feed layout of 2 lots

The layout shown in Fig. 11 is a temporary self feeding silo of the same design. No cover is given to the silage and the area allocated to the silo is of the same dimensions as the two adjacent lots. This layout is intended for subsequent conversion into 3 lots with conveyor bunk feeders of the same form as in Fig. 2. Access to the silo for filling with temporary fences at each end is excellent until the shelter is built. The lot dimensions are 40 ft x 90 ft with the longest fence line 80 ft. This is rather short for fence line feeding of supplements, self feeders may have to be used instead. The disadvantage of adding to the length of fence line bunks by using the south fence is its interference with drainage.

One half of this layout may be achieved by building a silo adjacent to an existing cattle barn. The general design is most satisfactory and can be arranged to give good shelter since the silo and barn are at right angles. Another variation is shown in Fig. 12.

Silos within lots raise problems if stock is to be confined in the lots for 12 months. Sufficient silage has to be made for all the year round consumption, there is the difficulty of needing to make silage in a partially emptied horizontal silo and to continue to feed simultaneously with stock in the yards. With dairy cows the problem can be offset by a grazing period during early summer. With beef animals or dairy cows green chopped forage can be fed in fence line bunks or self feeding wagons from the time that the silage is almost finished to when the new material is sufficiently ensiled. To get good results calls for a high standard of management of grass and arable silage crops. When

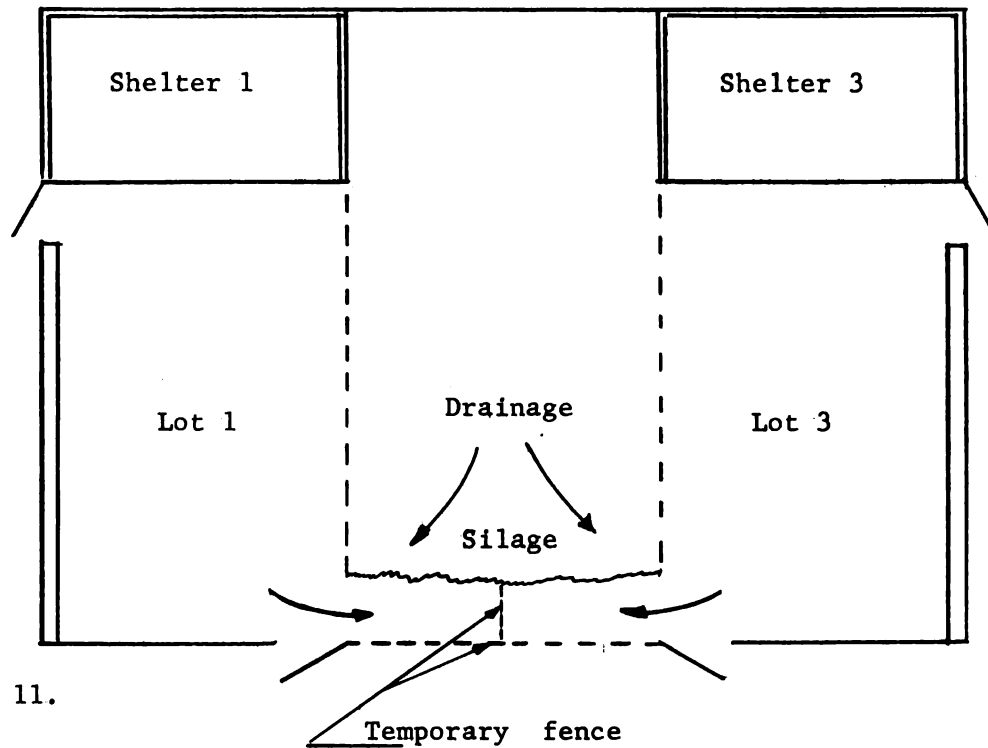


Fig. 11.

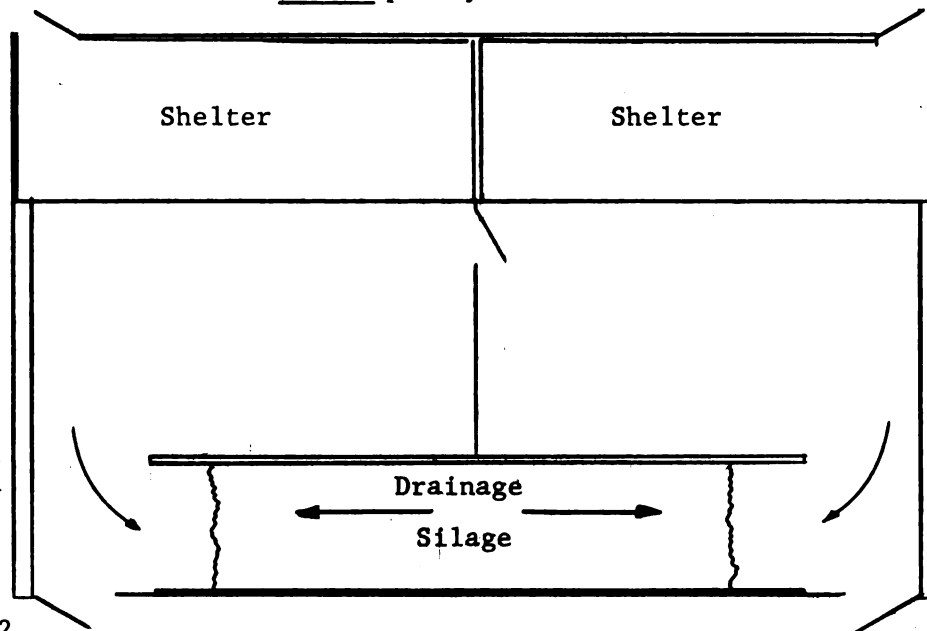


Fig. 12

Fig. 11. Horizontal silo. Temporary self feed surface silo built between two lots for later conversion to lot with conveyor bunk feeders.

Fig. 12. Horizontal silo. Temporary self feed silo built in two adjacent lots

the self feed silo is built outside the lot area, lot design is made easier since the layout needs only an access to the silo. Fence line bunks or self feeders may be needed for supplementary feeding as in the previous case. As a stage of development, silos external to the lot may be considered the initial stage in the use of a tractor and scoop with conveyor bunk feeders as in Fig. 9. Siting of the silo will need to conform to the same requirements. This layout modified for self feeding is shown in Fig. 13. The movement lane is utilized by the stock in walking to the silo and supplemented by temporary fencing. Stock from lots 1 and 3 start at each end and eat towards each other, lot 2 stock feed into the center of the silo at a portion where the retaining walls have been removed. It is a matter of daily adjustment whether they eat towards lot 1 or 3. Drainage slopes are important and should be toward the movement lane which also acts as a drainage channel for tractor cleaning.

An excellent example of a permanent installation of self feeding for a dairy herd is shown in Fig. 14. The design is suitable for about 60 cows, the shelter is 40 ft x 50 ft and the open area 50 ft x 100 ft. Good use is made of the surrounds to the lot, although this does restrict the outlet for expansion. Cattle movement is reduced to a minimum for feeding and milking and the whole system is confined in a relatively compact area. If an increase in herd size is needed, since the open area is sufficient for up to 100 cows, additional shelter can be provided on the south side and the length of the silo increased. In this case drainage should flow to a point immediately south of the hay barn. Subsequent mechanization of feeding using conveyor bunk feeders will be

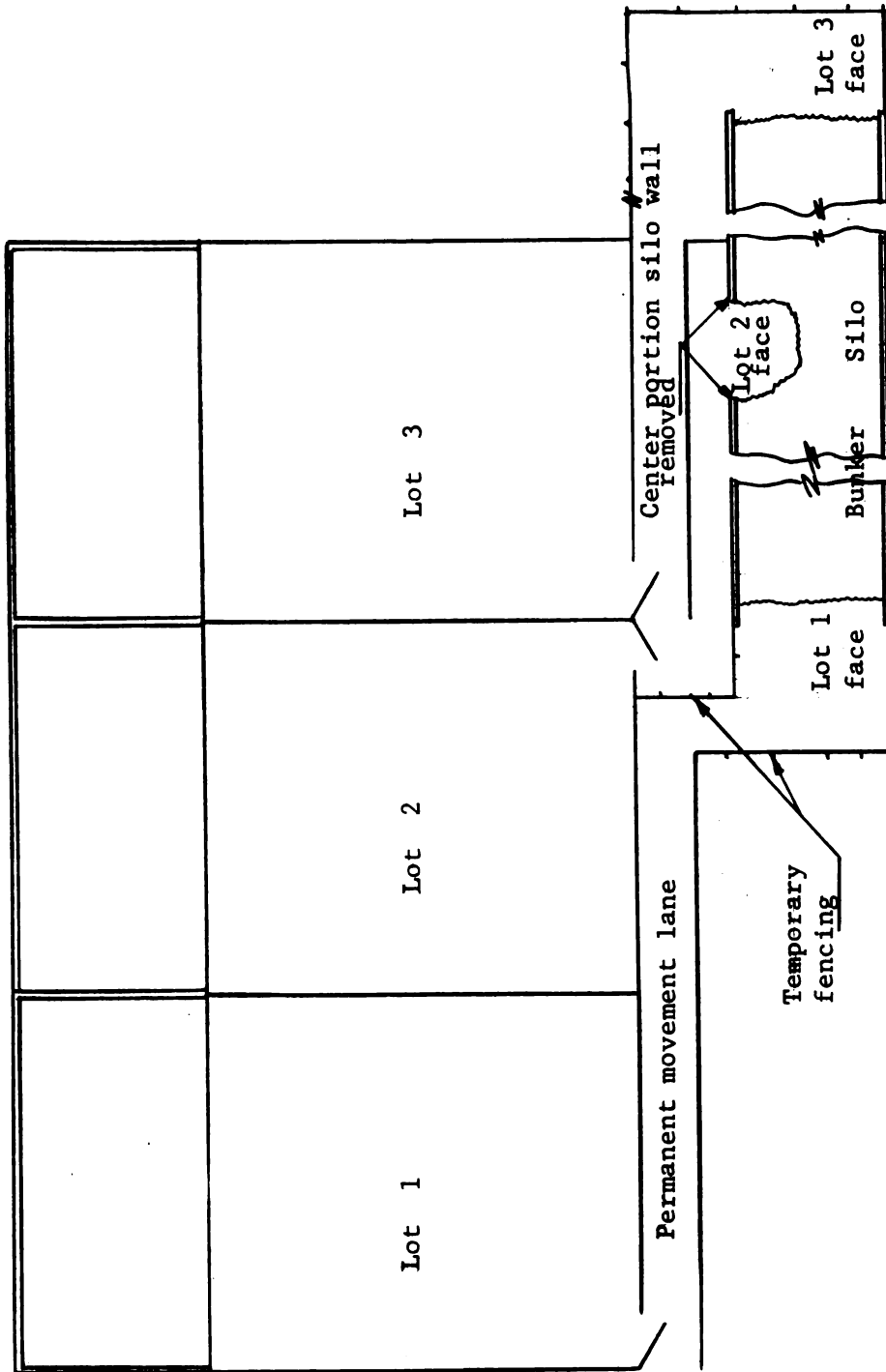


Fig. 13. Horizontal silo. Temporary self feed layout for three lots feeding from silo external to the lots

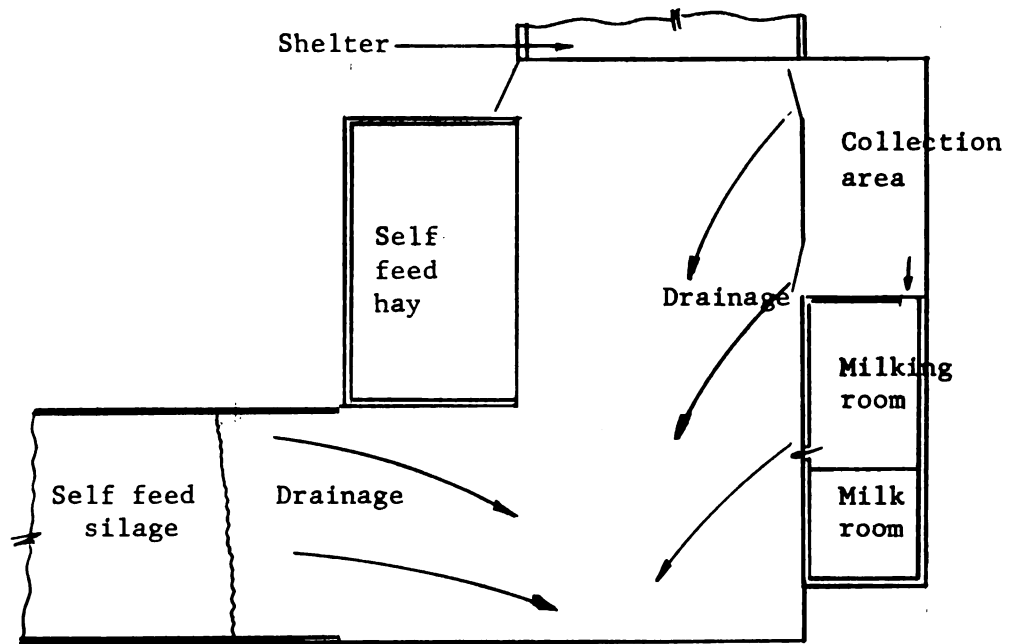


Fig. 14. Horizontal silo. Self feeding layout for dairy herd

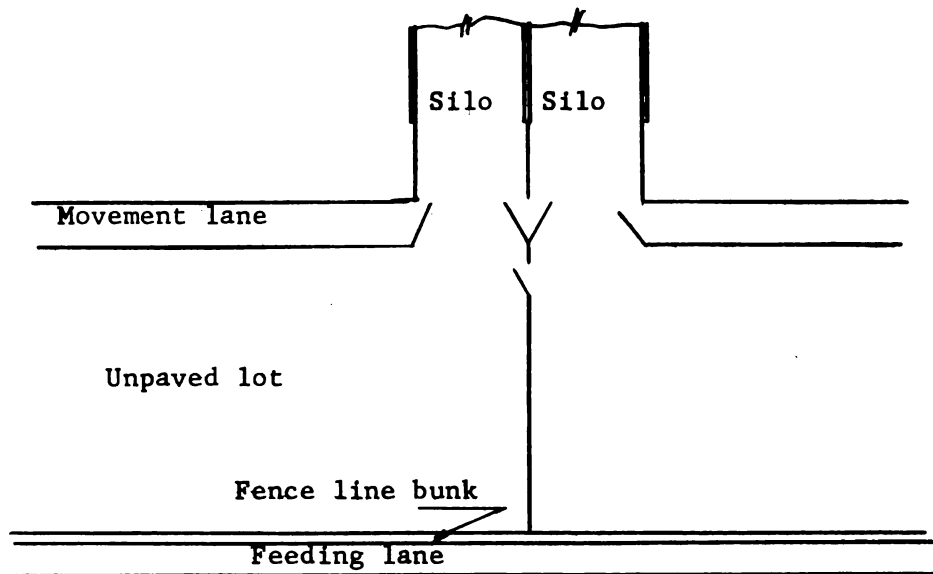


Fig. 15. Horizontal silo. Self feeding silo for large unpaved lot

possible.

In cold climates the position of the milking room and milk room building and collecting area should be reversed to give shelter to cows waiting to be milked.

Fig. 15 shows a simple self feed design for large beef feeding or dairy cow lot, but of an identical form to that of layout 14.

C. Hay

Hay drying, as a process of conservation, may be completed wholly in the field, either naturally by climate conditions or by using mechanical methods, or it may be completed at the farmstead in structures designed and built for this purpose. Whatever is used depends largely upon the weather and assumes a climatic distribution. It can be expected that the methods of storing and feeding hay will be similarly influenced.

Because the physical nature of hay and the inability of current commercially available equipment to completely mechanize its handling, expedients have to be used in order to obtain near achievement of the assumptions and design requirements of feed lot layout in which it is to be incorporated. Long hay may be discounted because its poor mechanical handling characteristics and high labor requirements at all stages of its making and feeding. Pelleting, in which the hay is finely ground and pelleted with other ground feeds, is used to some extent, but for the purposes of analysis in this study may be more appropriately considered as part of the feed grain component, since much of the processing plant and equipment is common to both feeds.

Unlike silage, hay is seldom fed as the sole source of roughage for fattening and adult cattle, although possibly for calves. It has been shown that cattle will eat good silage in preference to good hay, therefore hay consumption can to a degree be controlled by the availability of alternate succulent forages. This helps the design of hay feeding systems as self feeding can be satisfactory for most types and conditions of stock. In this way the need to move hay from store to feeding facility can be obviated and those two functional components included in one structure. Self-contained, self feeding structures by eliminating the need for conveying and feeding machinery and the controls to operate them, assume the characteristics of the machines they replace and may be thought of as being mechanized.

There are 7 systems of practical merit of conserving, storing and feeding hay:

1. Condition and store adjacent to lot, feed with conveyor feed bunks.
2. Condition and store remote from lot and feed with forage wagon in fence line bunks.
3. Condition remote from lot, store adjacent to or in lot or self feed or easy feed¹.
4. Condition and store adjacent to or in lot and self feed or easy feed.
5. Condition in field, store adjacent to lot and feed with conveyor bunks.

¹In this context easy feed would mean throwing down hay behind a fixed or moveable feeding barrier.

6. Condition in field, store remote from lot, feed with forage wagon.
7. Condition in field, store adjacent to lot and self feed or easy feed.

These are graphically illustrated in Fig. 16. With the exception of those systems using mechanical feeders, all are suited to baled, chopped or wafered hay. Baled hay cannot be used in mechanical feeders.

Anticipating future developments, wafered hay may be stored in vertical structures, removed and fed using chain and flight or auger conveyors for movement and feeding. These structures would need to be sited in close proximity to the feed grain and silage units to make use of the established distribution and feeding conveyors. Wafers could also be distributed by forage wagons and fed in fence line bunks. The optimum shape of the storage structure, whether it includes processing or drying facilities is largely unresolved at the moment. Such a structure would need to be incorporated into the feed storage unit so that the flow of hay would converge with the material flow of other feeds as already discussed. It may be envisaged that a round or vertical unit, not unlike a corn or small grain silo, with conditioning equipment would be used and this may be sited close to the silage or feed grain units.

Chopped hay, being considerably bulkier would need larger buildings for the same weight of wafered hay. This will increase the concentration of buildings in one area to connect all of them to a common conveying system. It may be noted though, that feeding hay will reduce the quantities of silage needed and the number of silos.

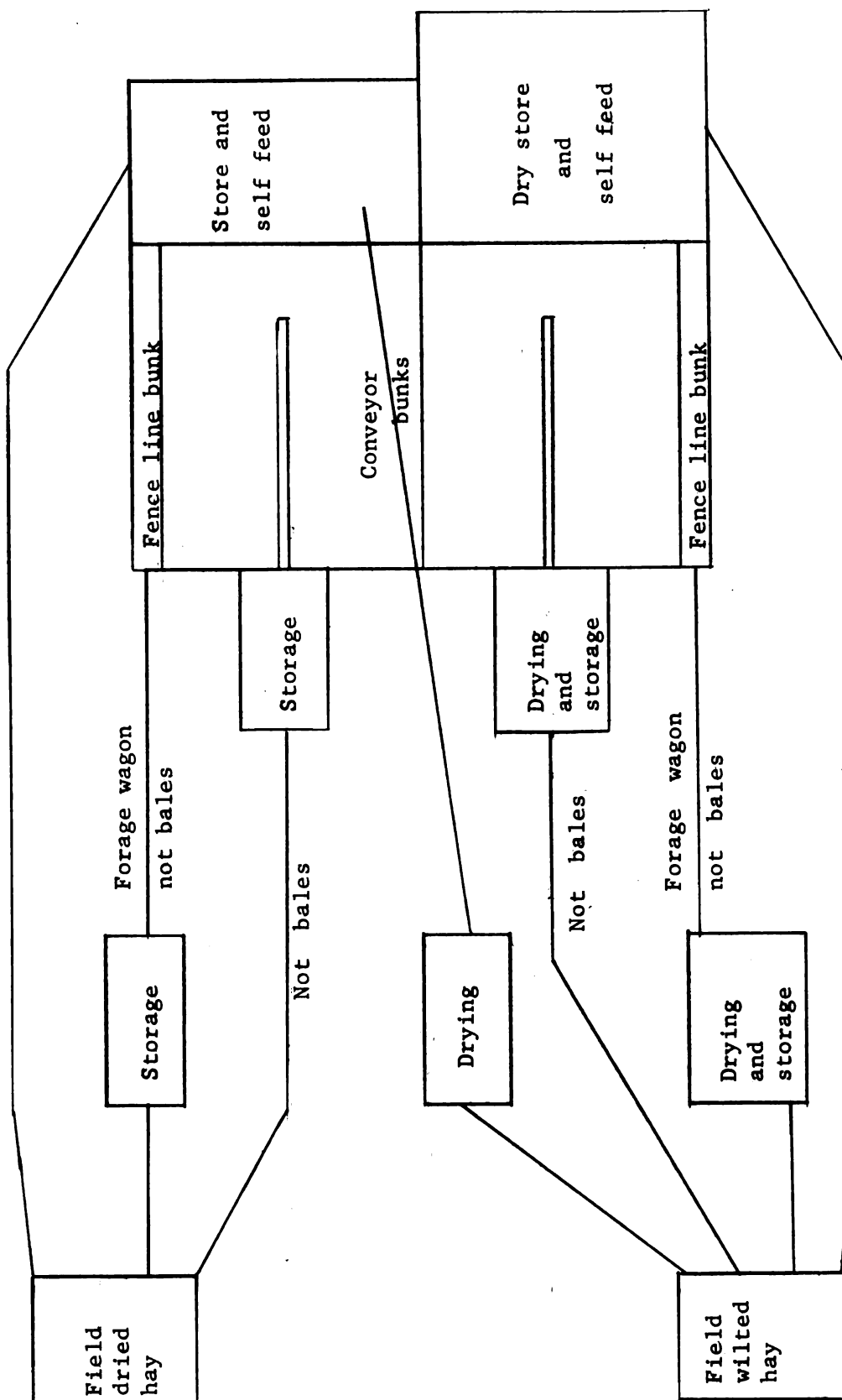


Fig. 16. Practical systems of storing and feeding hay

Fig. 17 suggests how these hay structures may be incorporated into the feed storage units. In other respects the lot design is the same form as in Fig. 3. The additional buildings will cast more shade and their siting needs especial consideration.

Hay dried and stored away from the feed lot and fed by forage wagon in fence line bunks (systems 2 and 6, p 105, 106) has the same requirements as for silage feeding outlined in the layouts in Figs. 7 and 8.

The remaining systems (3, 4 and 7, p. 105, 106) require a structure in the lot area or on the periphery. Its shape and form may be determined by the method of self feeding. Either the animals consume their way through the stored forage which remains stationary or the cattle feed from a fixed position and the stored forage moves to them. The first method usually involves a flat structure, the second a vertical structure. Where the structure may be included with the shelter or bedded area, its extension may be the only change needed to fit the examples of layouts already presented.

Fig. 18a shows a small lot for about 30 cows. Baled hay is stored behind a fixed feed bunk and easy fed into a fixed manger which is so positioned that no feeding is done inside the building to cause a disturbance to cattle lying down. This is an excellent layout for a small unit with controlled feeding of hay. It needs adequate shelter area and a higher building than normally required for cattle only. Furthermore, it is limited to hay dried in the field or conditioned at an intermediate location.

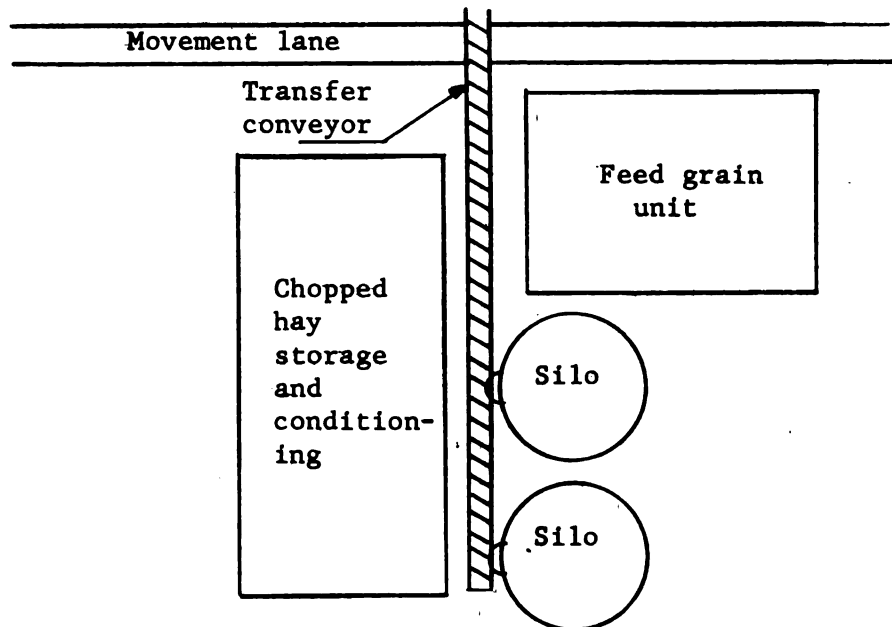


Fig. 17a. Chopped hay. A suggested layout of conditioning and storage unit for use in conjunction with conveyor bunk feeders

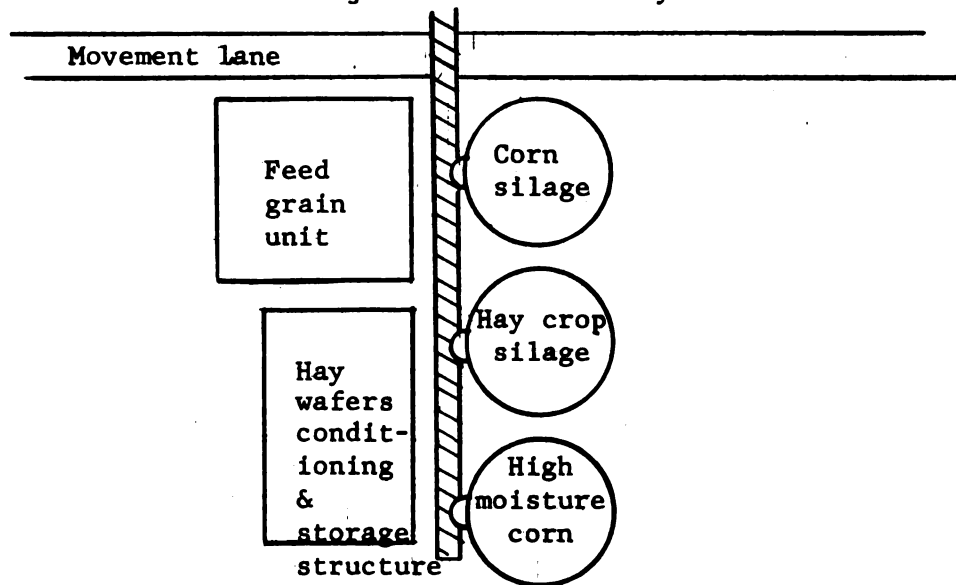


Fig. 17b. Wafered hay. A suggested layout of storage structures with silos and feed grain unit for feeding in conveyor bunks

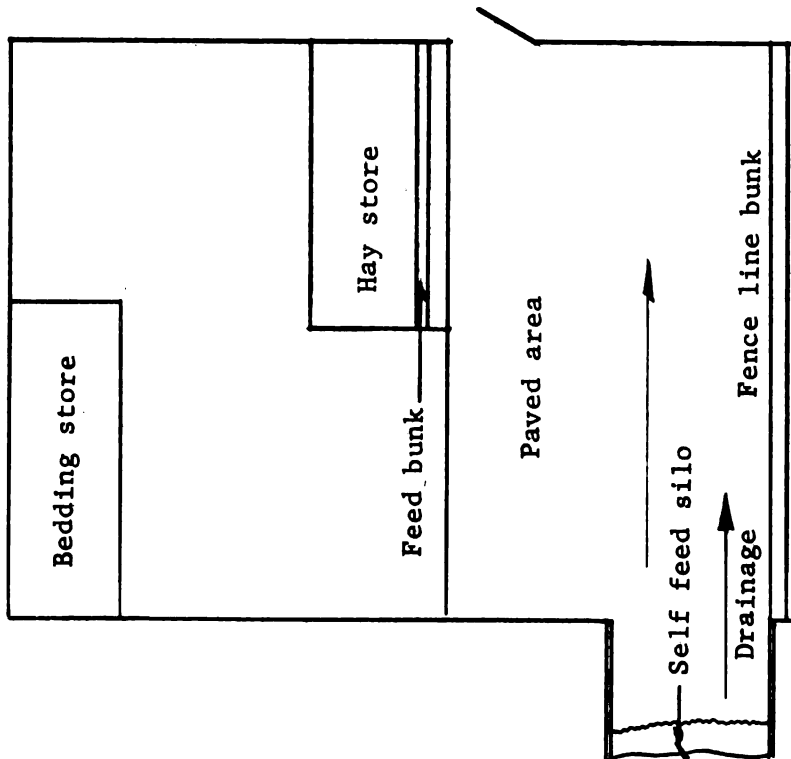


Fig. 18a. "Easy feed" hay. Baled hay stored within livestock shelter fed into fixed feed bunks

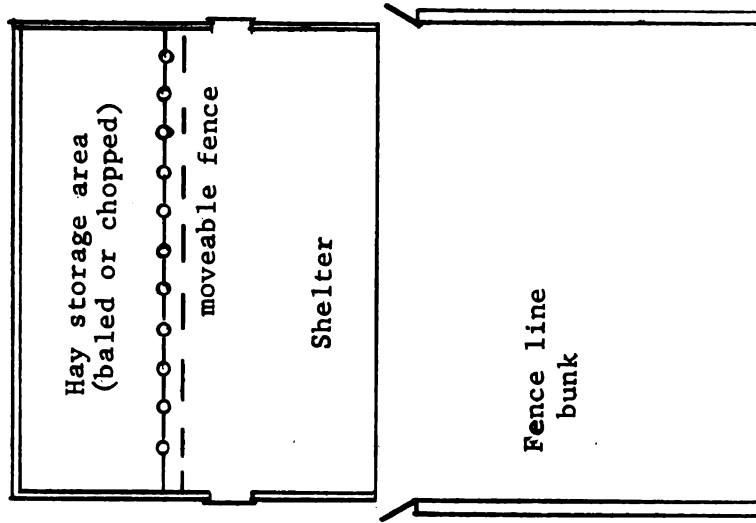


Fig. 18b. Self feed hay stored in livestock shelter

The layout in Fig. 18 shows hay fed at the rear of the cattle shelter behind a moveable fence. The hay may be baled or chopped, self fed or easy fed. The shelter area has been increased by the amount needed to store the hay, otherwise the design is the same as in Fig. 7. The disadvantage of this method of feeding hay is the traffic that must pass through what is a loafing area. It would be serious if the feeding face were limited to a particular portion of the shed, thus increasing the movement to and from this place. By providing a large exposed feeding area the passing of cattle through the shelter does appear to be serious. A similar method of feeding hay was discussed in connection with the layout in Fig. 13.

The relative size of hay feeding facilities and shelter may be reversed by making the shelter a lean-to or an addition to a hay conditioning and self feeding structure. This has the merits of hay handling being reduced to the minimum. It is more suitable for farms where a large proportion of the roughage is fed as hay.

Hay storage and feeding structures, with conditioning equipment can be placed on the periphery of the lot fence as shown in Figs. 15 and 19. Both these are designed more particularly for the dairy cow, and are good examples of their type being extremely easy and economical to work in and providing all the facilities that are needed. Their most serious disadvantage is the limited expansion that is possible. With buildings on three sides, and the needs of drainage being met on the fourth, the maximum expansion has to be built into the design at its inception. This is not so difficult with dairy cows since expansion of

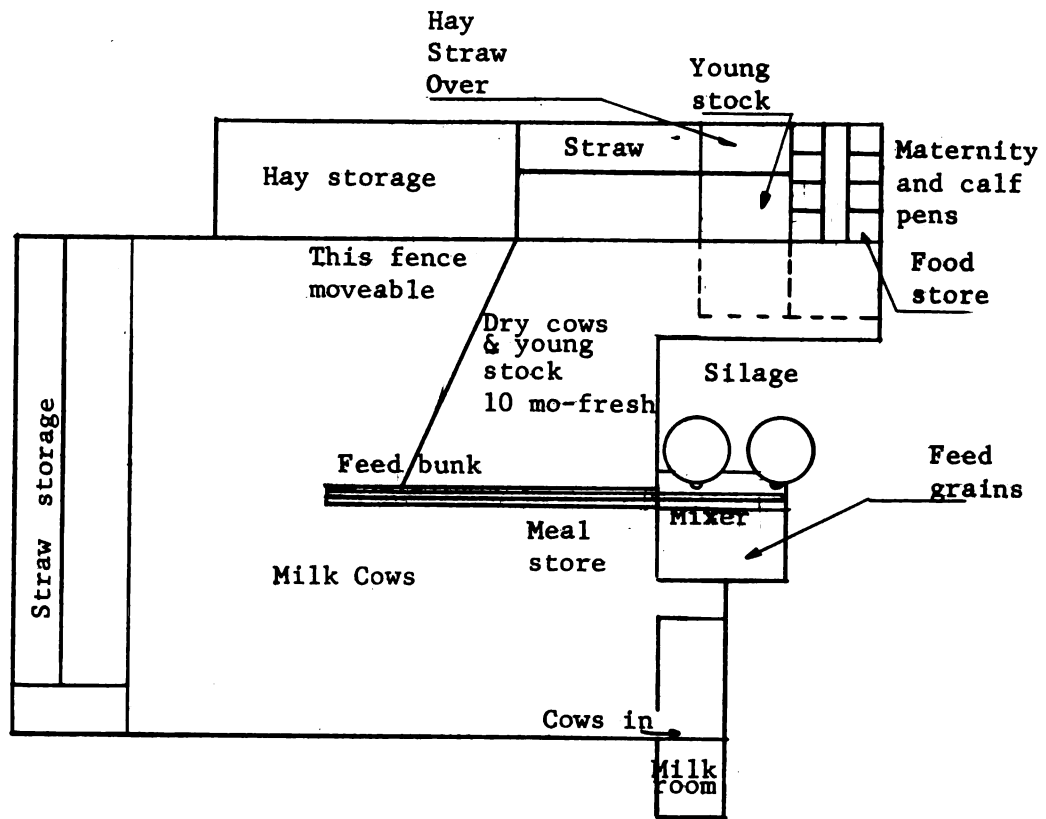


Fig. 19. Self feed hay barn in layout for dairy herd

the herd requires extra capacity from the milking plant as well as feeding and housing which places more restriction on growth than is to be found in a beef enterprise.

To relieve the perimeter of the lot for fence line feed bunks, the hay structure may be placed on the common short fence line between adjacent lots. The form of layout in Fig. 8 with a self feeder hay barn included is shown in Fig. 20. In this example each half of the hay barn has a capacity of 50 tons, it may be increased by extending the length. Singley (1963) describes a hay barn suited to this purpose. A single portable drying unit may be used to condition hay in two or more barns depending on storage capacity and the output of the dryer. For continuous feeding it is necessary to have each half of the barn divided into at least two sections to allow one section on each side to be filled and drying, as the other sections are open for feeding.

In small lots of limited capacity, vertical self feeders for chopped or wafered hay, including conditioning equipment, may be placed within the lot area. The effective diameter of these units will be about 18 ft greater than the actual diameter of the cylinder or structure and, given adequate open area, these units do not require special consideration in the design of the layout.

For continuous hay feeding two such units will be needed, one to be functional while the other is filling and drying. Alternatively green forage may be fed in fence line bunks if these are incorporated in the yard, or portable self feeding wagons or racks may be used for a time.

Other portable self feeding racks and wagons are for the most part used in lots as conveniences and expedients.

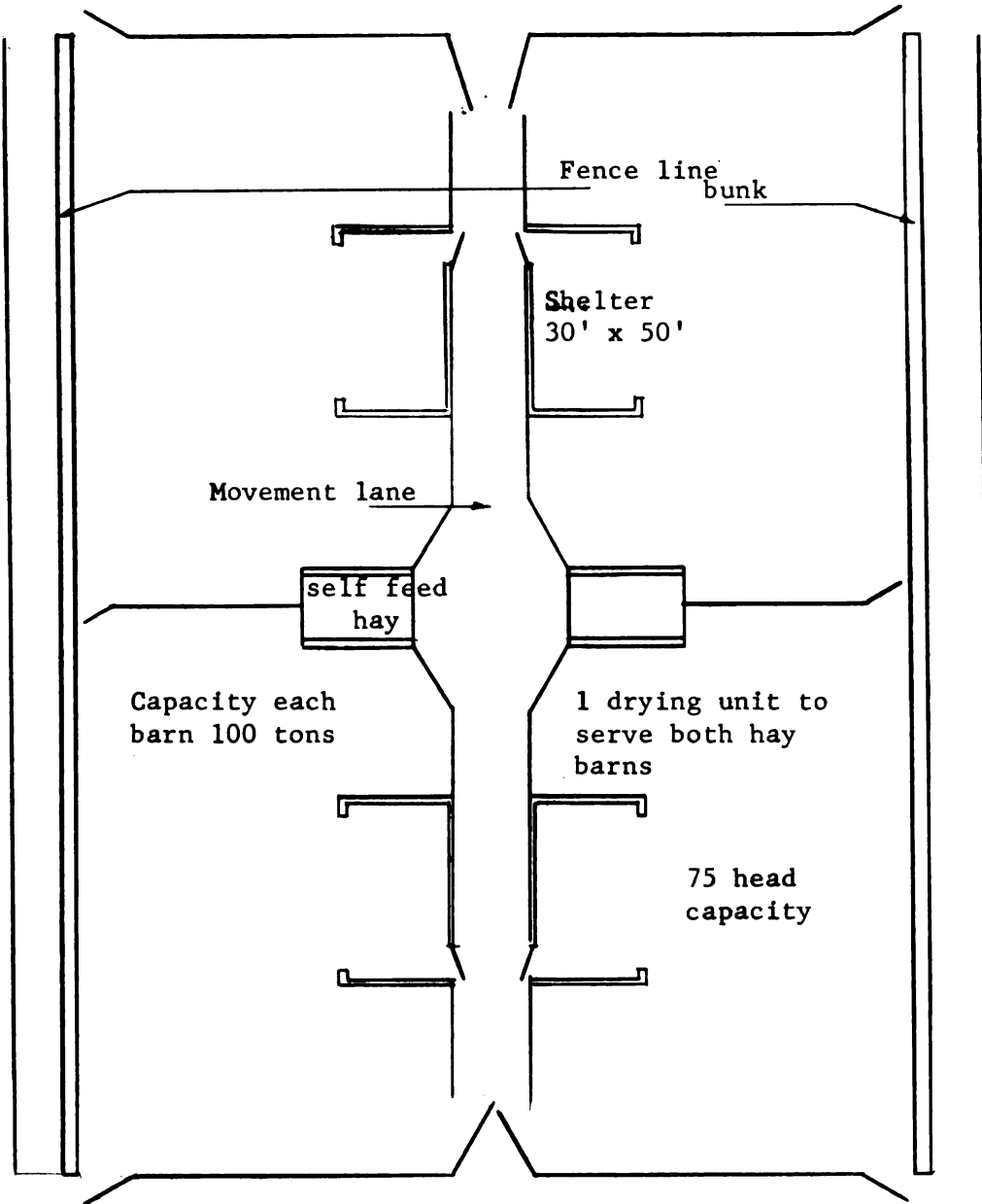


Fig. 20. Self feed hay barns in feed lots with fence line feeding bunks

VIII. SUMMARY AND CONCLUSIONS

Mechanization can be credited with effecting a significant improvement in the working conditions of present day farms by reducing or removing physical effort and drudgery, as well as by aiding a more effective employment effort. Livestock production, however, has not kept pace with the efficiency in crop production. While total production per man hour increased 6.4% per year in the decade prior to 1958, the increase in livestock products was 3.6% and in meat animals only 1%. This disproportionate improvement in productivity identifies the need for a careful study of farmstead operations, where the feeding of and caring for livestock are centered.

Studies of forage harvesting techniques showed that there are many improvements to be made in current practices which will lead to the preservation of more and better quality forage. The losses involved in hay making are often much more than is usually supposed. Dry matter loss is not the best criterion since soluble nutrients may be leached out by rain. Hay making may be speeded by crushing or laceration of the stems with final drying completed with mechanical conditioning systems. The conservation and mechanical handling problems of hay are not yet completely solved, and although it is still regarded as having unique dietary qualities it was found that many farmers are now making little or no dry hay and intend to feed all their forages as silage.

Silage making and feeding can be more effectively mechanized than hay. It caters for a wide variety of crops, is relatively independent of weather, and the equipment that is needed is commercially made. The choice of silo is largely a matter of preference and capital, the least expensive bunker or trench silos have the highest conservation losses. Chopping finely was advantageous in all silos. Livestock showed a preference for higher dry matter silage and there is some evidence that it is used at higher efficiencies than wetter material.

The storage of high moisture corn and small grains has recently become an established practice. The ensiling process is simple provided care is taken to exclude air. It is supposed that air tight storages are the most successful, but no data is available on losses in any type of silo.

In the planning of feed lots to include any or all of these forages, the design can be divided into 3 functional components.

1. Feed storage.
2. Feeding facility.
3. Livestock area.

Feed storage includes the storage units for forage, feed grains, and the preparation and blending of the food items. The feeding facility is the method and manner in which food is presented to the livestock. The conveying system is the means of integrating the feed store with the feeding facility, and can be considered as belonging to either component. The livestock area includes the lot area, shelter or loafing barn, water and the essential physical requirements, drainage and manure disposal,

orientation, facilities for handling cattle.

In any feed lot all these components are present. Two or more may be associated in one structure. In the development of a feed lot system, planning must always be based on the situation as it exists before the change and must allow for transition as experience and economic investment will allow. It is important to avoid too drastic a change, since this may involve too much risk or need too much capital for the change to be taken at all. Planning should allow for the system to be capable of the maximum practical mechanization. In this instance the limit of mechanization is taken to be complete automation, and labor used for program planning. Planning also must consider the anticipated and possible development, not only of the particular enterprise but also of the farmstead and the farming policy. Immoveable permanent structures once built dictate the orientation of other permanent fixtures around them and can determine the ultimate layout of the feed lot and farmstead.

The design requirements of forage storage and feeding systems include:

1. Adaptable to more than one class of livestock, allowing for as wide a use of the equipment and facilities as possible.
2. Flexible to accomodate changes in feeding practices and techniques of forage conservation.
3. Compact so that material flows from forage and grain feed storage units converge at a focal point, where the material may be mixed, weighed or blended. This is a most important consideration when planning

for complete mechanization.

4. Capable of expansion for both planned growth and the increase that is possible due to improved methods and greater efficiency of work habits and management.

5. Designed for complete mechanization so that "man time is used first to think and last for power." Two things to note are that man time, being made available by the use of machinery, is used wisely, and that mechanization does not take away the opportunity of the stock man to inspect his charges.

6. Plan for linear development to make the best use of mechanical conveyors. These machines convey in straight lines, plan the storage structures so that they can always be emptied on to a single conveyor serving all the other storage units. A general but not inviolable rule is to avoid obstructing the projection of any mechanical conveyor.

There are other restrictions on the design of feed lots which have a specific bearing on the plan:

- | | |
|----------------------------------|--------------------------------|
| 1. Drainage. | 5. Animal handling facilities. |
| 2. Cleaning and manure disposal. | 6. Paved areas. |
| 3. Orientation. | 7. Shelter. |
| 4. Lot size. | |

The best plan is one which fits into the farmstead situation most suited to it and derives the most benefit from the topography of the locality. This could lead to each farm system being unique, but when planning a layout, the task is simplified if a common form or pattern can be identified and used, suitably modified for the particular location and conditions.

The feed lot system layouts, planned with consideration for the future, are in the main intended for use with equipment and machinery that is now available, for it is at this time that guidance is needed in establishing the optimum procedures in this present phase of expansion.

The structures used for ensiling may be considered as vertical or horizontal. There is no best one in the sense that each has its own peculiarities which make it most suited to a given set of conditions. Vertical silos only can be fully mechanized; they can be used singly or added to when more storage is needed; and they can be used to ensile all the common materials presently used for livestock feeding. Horizontal silos are cheaper to build, can easily be used for self feeding, but no machine has yet been developed for automatic unloading, (although manually operated mechanical silo unloaders can be used) and they are limited in the range and condition of materials that can be ensiled.

The systems plan for all the feed storage to be contained in one composite unit. These units are not placed in the lot, since this restricts access for filling and adds to the difficulty of drainage and manure disposal. They may be moved to the most suitable location around the periphery of the lot, or away from the lot if a forage wagon is used for feeding. The control center for the system should be installed next to the storage unit. A simple cover will give protection to the equipment and help induce good working habits.

A forage wagon includes the function of a versatile and flexible conveyor. Its use in feeding operations simplifies the integration of

the functional components, but an essential requirement is that all roads and turning areas need to be hard surfaced for all-weather operations. The continuous use of a low capacity silo unloader accumulating silage in an overhead bin should be considered for large operations instead of a high capacity machine used for short frequent intervals.

The inclusion of horizontal silos in feed lot layouts introduces the problem of incorporating a satisfactory way of integrating forage with grain and ground feeds and conveying this to the feeding facility. A forage wagon with fence line bunks is one solution and is likely to be increasingly adopted by larger and expanding enterprises. Self-feeding offers many possibilities for including existing farmstead structures in a permanent or developing layout.

The storage and feeding of hay still presents a challenge on account of its intractable physical condition, whether it be baled, chopped or wafered. Chopping hay allows a greater degree of mechanization in field and feed lot. Self feed structures, by eliminating the need for conveying and feeding machinery and the controls to operate them, assume the characteristics of the machines they replace and may be considered as mechanized units.

IX. SUGGESTIONS FOR FURTHER STUDIES

The successful solution of materials handling problems is not the prerogative of one discipline, but is the outcome of collaboration of all those with interests in the common subject. In the design of feed lot systems nutrition chemists can contribute information on the production response of cattle when fed forages of different qualities and harvested by different methods, which will lead to the selection of the optimum material quality and condition. More data are needed from the agronomists on the most efficient methods of forage conservation in terms of the highest livestock production per unit of farm land. Accurate cost and price coefficients for input and output data are required to determine relative costs of machinery and equipment use in the selection of alternative systems.

The engineering contribution may take the form of a general consideration of the system or the study of a specialized area. Studies of general consideration include:

1. The development of standard procedures and outputs for forage harvesting.
2. Further consideration to the development of standardized feed lot layouts.
3. An analysis of farm feed lot installations from the standpoint of the design requirements stated in this thesis.

4. A study of the maximum stock carrying capacity of feed lot systems determined by the limiting output of the forage harvesting and feeding machinery.
5. A determination of the minimum feed lot capacity in relation to capital investment in the essential machinery and equipment.

More specialized studies are needed in:

6. The methods and systems for handling and disposing of manure.
7. The standard of mixing of ground feed and forage achieved in forage wagons and auger conveyors.
8. The distribution of feed in conveyor bunks.
9. Methods of filling vertical silos.

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APPENDIX A1 - RECOMMENDED FEED LOT AREAS AND FEED BUNK LENGTHS

	: Schultz ³⁷	: M.A.F.F. ¹⁰³	: Matson & Zuroske	:
	: 1960	: 1961b	: 1962	:
<u>Covered area sq ft</u>	: 15 - 25	:	:	:
below 600 lbs	: 15 - 25	: 15 - 20	:	:
over 600 lbs	: 20 - 35	: 25 - 30	:	:
mature cows	: 30 - 50	: 40 - 50	:	:
		de horned		
<u>Lot area paved sq ft</u>	:	:	:	:
below 600 lbs)	:	: 15 - 20)	: 100 no cover	:
over 600 lbs)	: 50 - 70	: 25 - 30)	:	:
mature cows)	:	: 40 - 50	:	:
		de horned		
<u>Unpaved sq ft</u>	:	:	:	:
below 600 lbs)	:	:	:)100 with cover	:
over 600 lbs)	:200 - 400	:	:)200 without cover:	:
mature cows)	:	:	:	:
<u>Bunk limited access</u>	:	:	:	:
lin. in per head	:	:	:	:
below 600 lbs	: 18	:	:)18 no cover*	:
over 600 lbs	: 24	:	:)12 covered bunk	:
mature cows	: 28	: 30	:	:
<u>Bunk unlimited access</u>	:	:	:	:
lin. in per head	:	:	:	:
below 600 lbs)	:	:	:) 8 in (4 feeds	:
over 600 lbs)	: 4 - 6	:	:) per day)	:
mature cows)	:	:	:	:
<u>Self feed lin. in</u>	:	:	:	:
per head	:	:	:	:

*Adjusted by formula $C = H61 + 25 (x - 2)$ C = corrected capacity
N = basic capacity
x = no feedings per day

:	Mielock	:	Wilson ¹⁰⁵	:	Aldrich	:	M.W.D.S. ¹⁰⁷	:	Harvey ¹⁰⁸	:
:	1960	:	1963	:	1961	:	1963	:	1963	:
:	)	:	)	:	)	:	)	:	)	:
:	20	:		:	20	:	15 - 20	:		:
:	)	:	)	:	)	:	20 - 25	:	)	:
:		:		:		:	25 - 30	:		:
:	30	:	)35 - 50	:	)	:	15	:		:
:		:	)including	:	)	:	20	:		:
:	30	:	cover	:		:	50	:		:
:		:	200	:		:	70 - 100	:		:
:		:	without cover	:		:	100 - 150	:		:
:		:		:		:	250 - 350	:		:
:	)	:	)	:	)	:	)	:	)	:
:	)18 - 24	:	)	:	)	:	)	:	)	:
:	)	:	)	:	)	:	)	:	)	:
:	6(more	:	)	:	6(more	:	)4 - 6 hay or silage	:		:
:	than 2	:	)	:	than 2	:	)3 - 4 grain or suppl.	:		:
:	feedings)	:	)	:	feedings)	:	)6 grain & silage	:		:
:	3	:	4	:	3	:		:	9" silage	:

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