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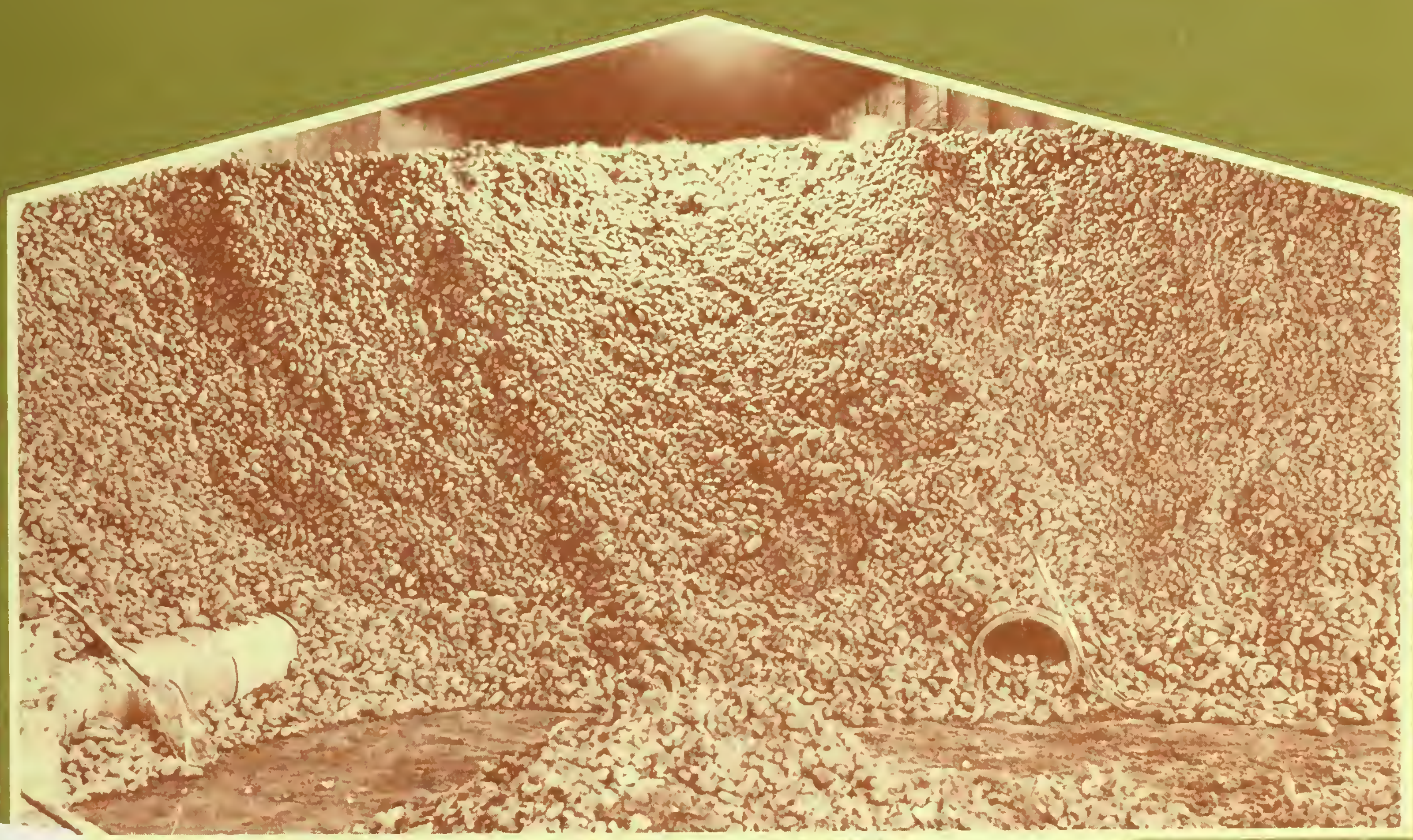
BULK POTATO STORAGE



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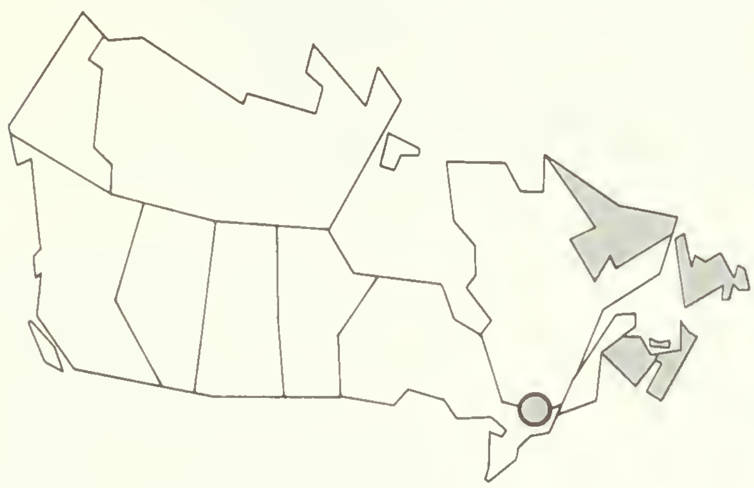

CANADA / NEW BRUNSWICK
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BULK POTATO STORAGE

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Entreposage en vrac de la pomme de terre.

INDEX

INTRODUCTION

This bulletin is designed to provide potato growers with the basic information required to make a knowledgeable decision in the choice of a storage structure.

Since maintenance of proper storage conditions is essential, emphasis has been placed on selection and operation of the ventilation system. Humidity, air movement and temperature, must all be controlled during the storage period.

Potatoes are living organisms that are affected by their environment. As living organisms, they are constantly carrying on life functions that result in the release of carbon dioxide, moisture and heat. Successful storage operation slows the life processes of the tuber by proper temperature control and a ventilation system that exhausts and replaces the storage atmosphere without causing excessive shrinkage.

Money invested in a potato storage must be recovered by increased income. Growers contemplating the construction of a storage should find the information in this bulletin helpful. However, it does not provide all the details necessary for building. To assure a successful structure, consult provincial potato storage specialists and visit storages that are operating successfully before constructing your facilities.

BEHAVIOR OF POTATOES IN STORAGE

RESPIRATION

Potatoes in storage are living material and they must remain alive throughout the storage period. As potatoes respire, or breathe, the carbohydrates stored within them are gradually converted into carbon dioxide, water and heat. The rate at which these by-products are given off is controlled largely by the temperature of the potatoes, and their accumulation within the storage must be controlled. For example, Table 1 gives the amount of heat of respiration produced at different storage temperatures.

From Table 1, it would appear that potatoes should be held at 32°F; however, this is not the case. At low temperatures (below 40°F) starch within potatoes is converted into sugar, resulting in a deterioration in quality that is particularly harmful to potatoes used for processing; high sugar content causes potatoes to darken or burn when heat processed. Table potatoes may also develop an undesirable sweet taste when stored at low temperatures.

TABLE 1 — HEAT OF RESPIRATION PRODUCED IN POTATO STORAGE

Storage temperature (°F)	Heat produced Btu*/ton/24 hr
32	700
40	1800
60	2600

*Btu, a unit measurement of heat, is the amount of heat required to raise 1 lb of water 1°F.

DORMANCY

Following harvesting, potatoes begin a dormancy period, during which time they will not sprout. The period generally lasts 6-12 weeks, depending on variety. This allows potatoes to be stored in air-cooled storages, as the rapid removal of heat is not as essential as it is with crops that do not have this dormant period (eg., carrots or apples).

At the end of the normal dormancy period sprouting will occur. The time required to break dormancy can be controlled by regulating the storage temperature and by treatment with a sprout inhibitor. Usually the higher the temperature, the sooner sprouting begins. It is, therefore, essential that the selected storage temperature during the holding period be high enough to prevent the conversion of starch to sugar and low enough to delay sprouting.

OPTIMUM STORAGE CONDITIONS

QUALITY OF POTATOES

It is very important that potatoes entering storage be mature, clean, free from disease and frost injury and have a minimum of mechanical injury. Maturity is difficult to describe, but the objective is to allow potatoes to reach maximum dry matter content as well as to induce toughening of skin. This requires the vines to be dead for at least 2 weeks before harvesting. Top killing is usually required.

TEMPERATURE AND HUMIDITY

The correct temperature and humidity must be maintained during the entire storage period.

Wound Healing and Curing Period

Disease and rot organisms present at the time of storage can be prevented from entering damaged tubers by providing conditions that promote toughening of the skin and rapid healing of wounds. This occurs most rapidly if the potatoes are held at a temperature of 55°F and a relative humidity of 95% during the first 10 - 14 days of the storage period. However, if rot is present it will spread rapidly at these temperatures and under these conditions, the potatoes should be cooled as rapidly as possible to 40°F and the humidity reduced to 90%. Often a compromise must be made between conditions for optimum wound healing and minimum loss due to rot or decay.

Storage Period

The relative humidity should be maintained at or near 95% for all seed, table and processing potatoes in storage. As soon as initial curing has been achieved, the storage temperature should be reduced to that recommended for long-term storage. This temperature is largely determined by the eventual use to be made of the potatoes. The following temperatures are recommended:

Seed Stock — 38°-40°F. This should delay sprouting for 7 - 8 months or longer.

Table Stock – 43°-45°F. This should give potatoes a storage life of 4-8 months before sprouting occurs. Lower temperatures will delay sprouting but eating quality is likely to be reduced.

Combined Table and Seed Storage – 40°F. This is a compromise. It is recommended that separate storages be provided for seed and table potatoes. At 40°F, starch within the tuber will gradually be converted to sugars giving an undesirable sweet taste. Since potatoes are usually held for several weeks following packing at store and household temperatures, much of this sweet taste will disappear before the potatoes are consumed.

Processing Potatoes – The production of potatoes for processing requires special attention during the entire growing period, at the time of harvest and throughout the storage period. Cultural and fertility practices, temperature and moisture conditions at the time of harvest have a marked influence on processing quality. If these are neglected, storage management alone can not assure a high quality product. *Discuss all details of production and storage with your processor.*

Again, the relative humidity should be kept at 95%. In general, the following temperatures should prove suitable:

French fry processing stock – 45°F is recommended for potatoes that have not been treated with a sprout inhibitor. For best possible color use a sprout inhibitor and store at 50°F.

Potato chip processing stock – The minimum suitable temperature is 50°F. A sprout inhibitor must be used as potatoes will sprout at 10 - 12 weeks at this temperature. Potatoes stored at 50°F may require reconditioning by storing at higher temperatures until sugars are reconverted to starch.

POTATO STORAGE CONSTRUCTION

STORAGE REQUIREMENTS

The following points should be considered in the design of a potato storage:

- Adequate structural design to withstand the internal vertical and lateral forces imposed by the potatoes, and external forces imposed by wind, and snow loads.
- Adequate insulation protected by a good vapor barrier to control heat transfer through walls and ceilings, so that proper conditions of temperature and humidity can be maintained.
- An efficient layout to allow storage and removal of potatoes at minimum costs.
- A ventilation system that will allow accurate and controlled air movement into the building and through the pile.

Fig. 1 Potato storage with wood frame construction, steel cladding and trussed rafters.

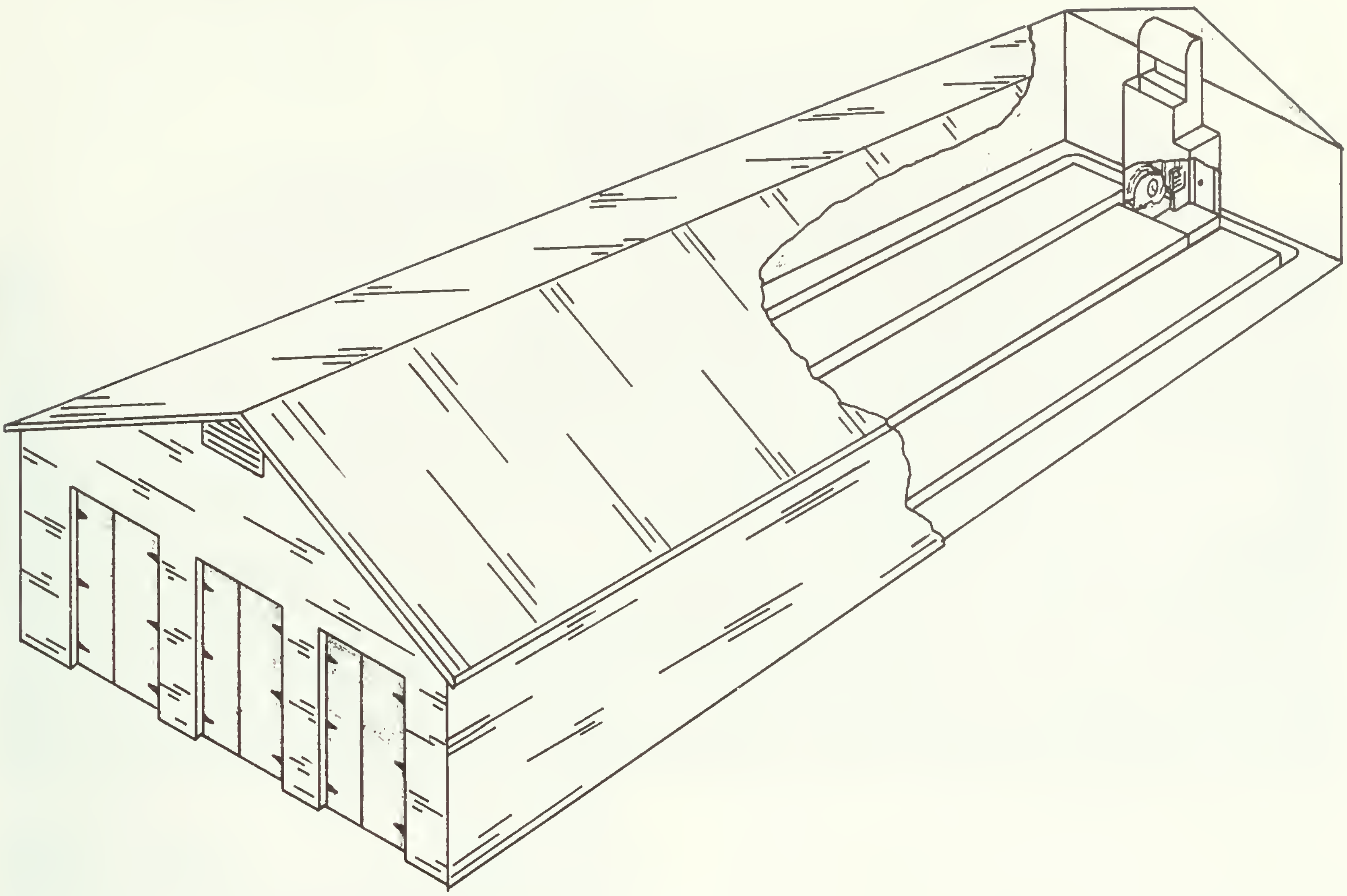


Fig. 2 Typical potato storage.

TYPES OF BUILDINGS

The type of building used for potato storage varies from area to area and frequently is influenced by the availability of local materials and climatic conditions. Potatoes have been satisfactorily stored in large insulated industrial-type metal buildings and in small earth-covered cellars. For many years before suitable insulation materials were readily available, all or part of the storage was built in the ground to conserve heat and protect against frost. Many storages of this type are still in use.

During the past 20 years, the availability of improved materials for insulation and vapor sealing, combined with a change in handling methods, has resulted in the completely above-ground, wood-frame and metal-clad building becoming one of the more popular types of new construction.

Popular types of buildings include the following:

- Wood frame, vertical stud wall, gable truss roof.
- Laminated wood arch rafters.
- Braced rafter frame (gambrel roof).
- Frameless steel arch buildings.
- Preengineered steel frame building.
- Temporary pole frame, earth banked.

Prospective builders should consider all types; and in addition to visiting existing storages, should discuss the relative merits of the various types with the extension agricultural engineer in his area. A building should be selected that best fits the needs of the individual grower.

Fig. 3 Arch roof potato storage.

SELECTION OF SITE

The site for the storage should provide:

- Convenient access to fields, preferably without crossing or traveling on a public highway.
- Convenient access to a good public highway or on trackside, to facilitate potato shipment.
- Convenient access from the farm residence, to allow frequent inspection during the storage period.
- Good natural drainage and a reasonably level area, to avoid high site-preparation costs.
- Access to three-phase power. This will reduce the initial and maintenance cost of large (1 HP and up) electric motors.

SELECTION OF FLOOR PLAN

The floor plan to select depends on:

- The quantity of potatoes to be stored.
- The method used to store potatoes – bulk, bulk in bins, or pallet bins.
- The operations to be carried out in the storage – storage only, storage and grading, storage, grading and packing.
- The handling method used in the storage.
- The need for supporting services.

A consideration of the above points will generally indicate the need for all or most of the following areas:

- Product receiving.
- Product storage.
- Storage unloading.
- Work area – handling, grading and packing.
- Shipping.

Sometimes, areas can be combined (for example, product receiving and work area), provided this dual role is included in the planning.

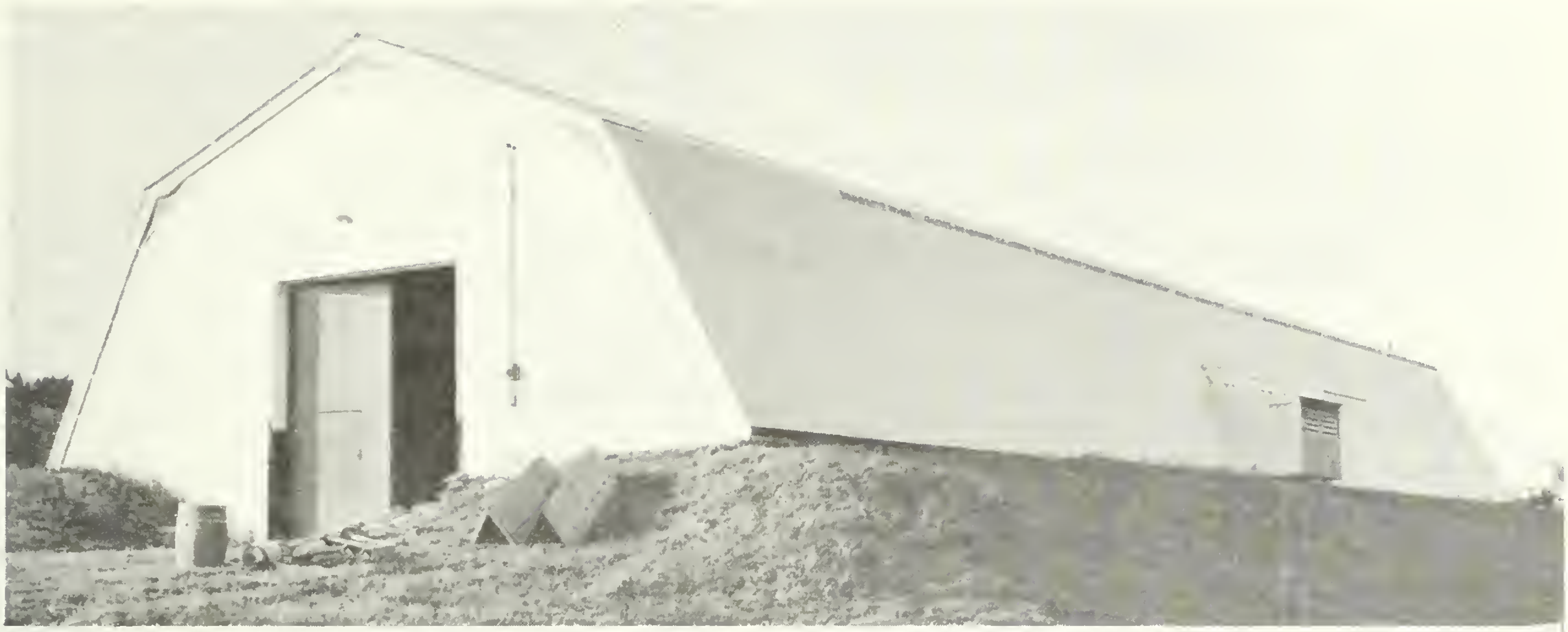


Fig. 4 Gambrel roof potato storage.

Fig. 5 Large steel frame storage.

STRUCTURAL DESIGN

The storage must be designed to withstand all external loads imposed by snow and wind and internal loads imposed by the stored product. Design wind and snow loads should be those specified in Supplement 1, National Building Code, *Climatic Information for Building Design in Canada*, NRC # 11153. Figures are given for ground snow loads and can be adjusted according to duration of load, slope of roof, exposure, etc.

Stored potatoes impose high lateral pressures on walls and bin partitions and the selection of lumber sizes and fasteners is a critical decision that will affect the life of the structure. Standard plans issued by the Canada Farm Building Plan Service and provincial extension engineers have been carefully designed to withstand these forces.

Farmers should discuss any modification of these plans or the development of special plans with a specialist experienced in structural, ventilation and handling requirements for potato storage.

Floors

In most areas, concrete floors are recommended for storages. A well finished concrete floor simplifies clean-up and disinfection between crops, facilitates the movement of trucks, bin pilers and unloaders and allows the installation of cast in the floor ducts for ventilation and possibly for water fluming.

Floors in modern storages must be able to support the heavy concentrated loads imposed by loaded trucks. The fill under the floor must be well compacted. The use of wire reinforcing mesh is highly recommended in all concrete floors to avoid cracking. The most common reinforcing used is 6″ X 6″ mesh with 6-gauge wire or $^3/_8$″ deformed reinforcing rods at 18″ o.c. both ways.

Foundations

Foundations should be protected from frost heaving, from tilting inwards due to external soil pressure or outwards due to potato pressure, and from sinking due to weight. For frost protection either place the footing below maximum frost depth, or use enough exterior perimeter insulation to prevent frost penetration under edge of a shallow wall footing. Where the floor inside the building is much below exterior grade, the foundation should be reinforced to the footing to prevent inward collapse. When the storage floor level is at or above external grade, it is best to tie the foundation into the floor reinforcing to prevent tilting outwards. And the width of the footing must be great enough to spread the total wall weight into the bearing soil without sinking.

Since wet soil is more susceptible to frost heaving and to sinking, roof drainage should be carried away from the building, and the grade should slope away from the foundation for good surface drainage.

Walls

All walls must be designed to support lateral and vertical forces imposed by the potatoes. This includes selection of the proper sizes of framing lumber and of fasteners used to tie the walls together. The most critical fasteners are those that secure the sill to the foundation, the studs to the sill, the studs to the plate and the plate to the ceiling joists or lower chords of the truss. Special connectors designed to support the lateral forces must be used at these points. Table 2 may be used as a guide in the design of walls and the selection of stud sizes. Figure 6 shows one method of connecting studs to foundation.

Since all bins are not filled and emptied at the same time, bin partitions must be as strong as exterior walls. Fasteners used should be able to accept thrust in either direction. The high humidity maintained in potato storages provides ideal conditions for the decay of structural members. The critical location is the base of the stud wall. Pressure-treated lumber should be used for sills and the lower ends of the studs should be treated by dipping in wood preservative to a depth of 4 feet.

Roof

Trussed rafters are cheaper and stronger for roof constuction than common rafters supported by inner posts and purlins. The use of trusses allows bin partitions to be moved or removed if handling methods or building use are changed.

Roof trusses should be designed to withstand the expected snow loads and in some cases potato lateral loads. Information on the representative snow loads at specific locations is supplied in *Supplement # 1, National Building Code of Canada*, National Research Council, Ottawa.

Insulation

Insulation is required to prevent excessive heat loss that would allow potatoes near the storage walls to freeze or overall temperatures to reach a level too low for optimum storage. A potato storage cannot be considered adequately insulated if it will not maintain the required temperature when half filled with potatoes.

The actual insulation requirement usually is determined by the need to control condensation on walls and ceilings. At the high relative humidity required for storing potatoes, interior building surfaces must be maintained at temperatures not more than 2°F below room air temperature.

The selection and application of insulation in walls and ceilings is extremely important in potato storage construction. Most commercial insulating products are rated according to their resistance to heat flow. This is known as the "R value." The higher the R value, the greater the resistance. Insulation requirements for a particular storage should be based on the design temperature for the region in which the storage is to be constructed. This information is available in Supplement 1 to the National Building Code, *Climatic Information for Building Design in Canada*, issued by the Associate Committee on the National Building Code, National Research Council, Ottawa. The insulation thicknesses shown in Table 3 are the minimum thicknesses of materials to be used in a region having a January design temperature of −20°F.

Fiber Glass Insulation — This material is available in paper-sealed batts, either with or without a vapor barrier backing, in an expandable form known as "friction fit" and as a granulated pouring wool. Friction fit is most commonly used for walls. It should be carefully fitted between the studs to avoid gaps or voids adjacent to the studs or at the horizontal joints. This material makes use of the space between the studs. Since it offers no resistance to moisture, it must be protected by a vapor barrier. The use of sheathing paper under the exterior steel cladding is advisable to reduce the effect of wind. Granulated pouring wool is suitable for ceilings but should not be used in walls.

Insulation in Board Form — Various types of expanded plastics are available in board form. These include expanded polystyrene in beadboard and extruded forms. The extruded form has a higher percentage of closed cells and may be used without a vapor barrier. Expanded polyurethane is also available in board form. It is usually supplied with an attached polyethylene vapor barrier. All joints in the board should be sealed with self-adhesive tape. Insulation boards with a pulp or fiber base are not recommended for storages.

TABLE 2 – DESIGN FACTORS AND RECOMMENDED SIZE OF WOOD STUDS FOR BULK STORAGE EXTERIOR (EXT) AND BIN PARTITION (INT) WALLS

Wall height (ft)	Potato depth (ft)	Height centroid of lateral potato pressure (ft)	Height of max. moment (ft)	Sill force (lb/stud)	Plate force (lb/stud)	Max. moment (lb-in./stud)	Axial Force at point of max. moment (lb/stud)		Stud spacing (in.)	Stud Sizes								Anchor bolt spacing (ft)
										#1 spruce		#2 spruce		#1 douglas fir		#2 douglas fir		
							EXT	INT		EXT	INT	EXT	INT	EXT	INT	EXT	INT	
10	8	3.21	4.25	522	247	12,316	729	189	24	2x8	2x8	2x8	2x8	2x6	2x6	2x6	2x8	6
10	8	3.21	4.25	348	165	8,211	486	126	16	2x6	2x6	2x6	2x8				2x6	6
12	10	3.97	5.14	728	360	20,879	816	276	24	2x10	2x10	2x10	2x10	2x8	2x8	2x8	2x10	6
12	10	3.97	5.14	485	240	13,919	544	184	16	2x8	2x8	2x8	2x8	2x6	2x6		2x8	6
14	12	4.73	6.04	1049	536	35,470	950	410	24	2x12	2x12	2x12		2x10	2x10	2x10	2x12	4
14	12	4.73	6.04	699	357	23,647	633	273	16	2x10	2x10	2x10	2x12	2x8	2x8	2x8	2x10	4
16	14	5.51	6.95	1427	749	55,710	1112	572	24					2x12	2x12	2x12		4
16	14	5.51	6.95	951	499	37,140	742	382	16	2x12	2x12	2x12		2x10	2x10	2x10	2x12	4
16	14	5.51	6.95	713	375	27,855		286	12				2x12					4
18	16	6.3	7.86	1239	666	54,978	869	509	16					2x12	2x12	2x12		2
18	16	6.3	7.86	929	500	41,234	652	382	12	2x12	2x12						2x12	2
18	16	6.3	7.86	619	333	27,489	435	255	8			2x12	2x12					2
20	18	7.1	8.78	1169	643	58,266	762	492	12					2x12	2x12	2x12		2
20	18	7.1	8.78	779	429	38,844	508	328	8	2x12	2x12	2x12				2x10	2x12	2
20	18	7.1	8.78	584	322	29,133		246	6				2x12					2
22	20	7.92	9.71	953	537	52,866	590	410	8					2x12	2x12	2x12		2
22	20	7.92	9.71	715	402	39,650	443	308	6	2x12	2x12	2x12					2x12	2
22	20	7.92	9.71	477	268	26,433		205	4				2x12					2
Column 1	2	3	4	5	6	7	8		9	10	11	12	13	14	15	16	17	18

Notes (1) Potato lateral load $P_L = \sqrt{0.1\ H}\ (17.8 + 8.52h - 0.18h^2)$, adapted for bins of any width from ARS 52-32, Lateral Pressures on Walls of Potato Storage Bins, Agricultural Research Service, USDA. Potato vertical wall load $Pv = 0.765 \times P_L$ from AMS-401, predecessor of ARS 52-32. In above, H is total pile depth in feet and h is distance below top of potato pile in feet. For $H < 10$, H is set equal to 10.

(2) Wall design – For locations remote from sources of vibration (railways, etc.), four load combinations were considered as follows:

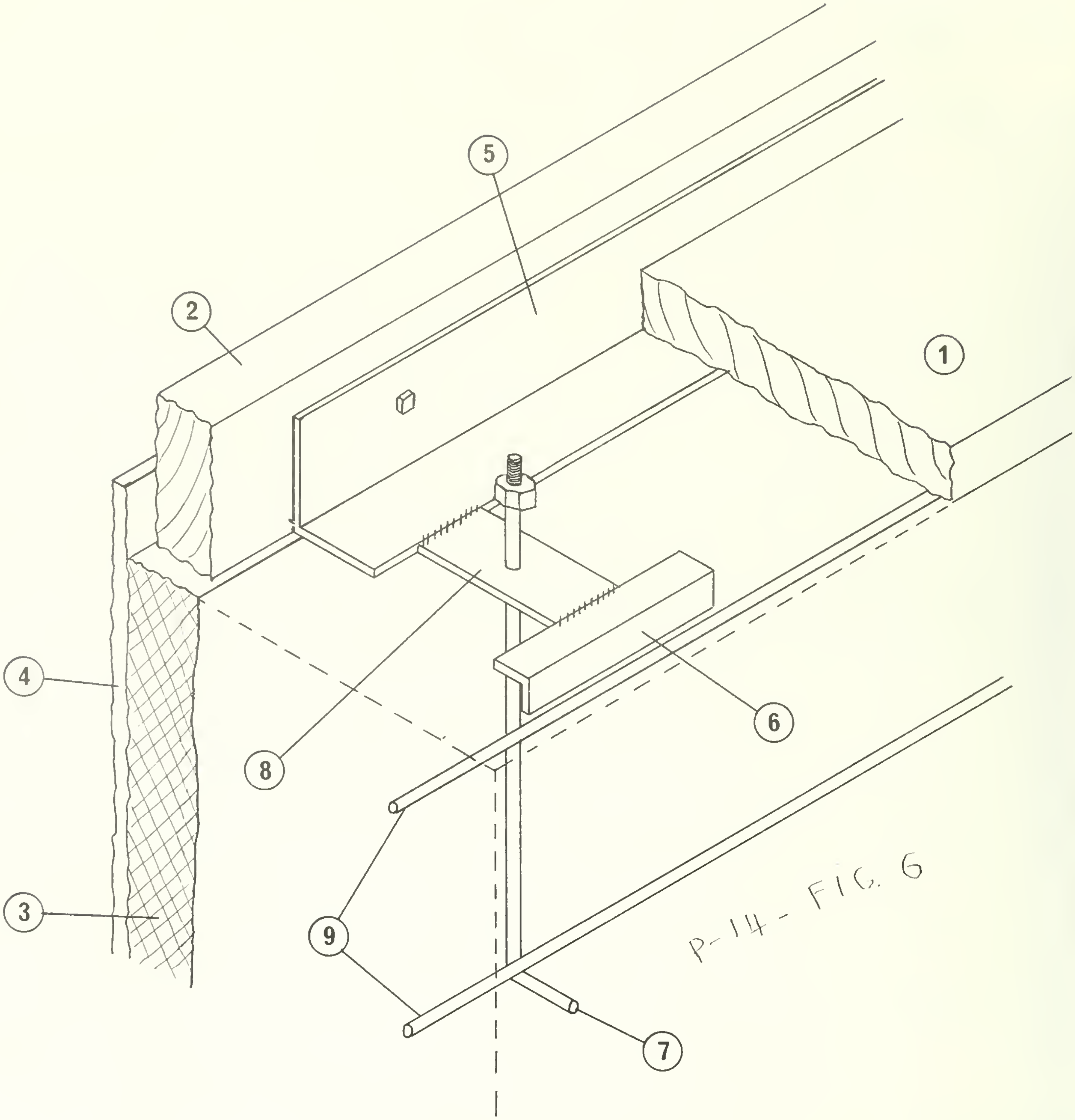
Load Combination	Stress Modification Factors for Wood
(a) $D + P_L + Pv$	1.25 x 1.10 x M
(b) $D + L + P_L + Pv$	1.25 x 1.10 x 1.15 x M
(c) $D + W + P_L + Pv$	1.25 x 1.10 x 1.33 x M
(d) $0.75\ (D + L + W + P_L + Pv)$	1.25 x 1.10 x 1.33 x M

where M = service condition factor, ext. walls 1.0, int. walls 0.84

D = dead load — 1.25 = low hazard bldg. factor
L = roof live load — 1.10 = load sharing factor
W = wind load — 1.15 = load duration factor (snow)
1.33 = load duration factor (wind)

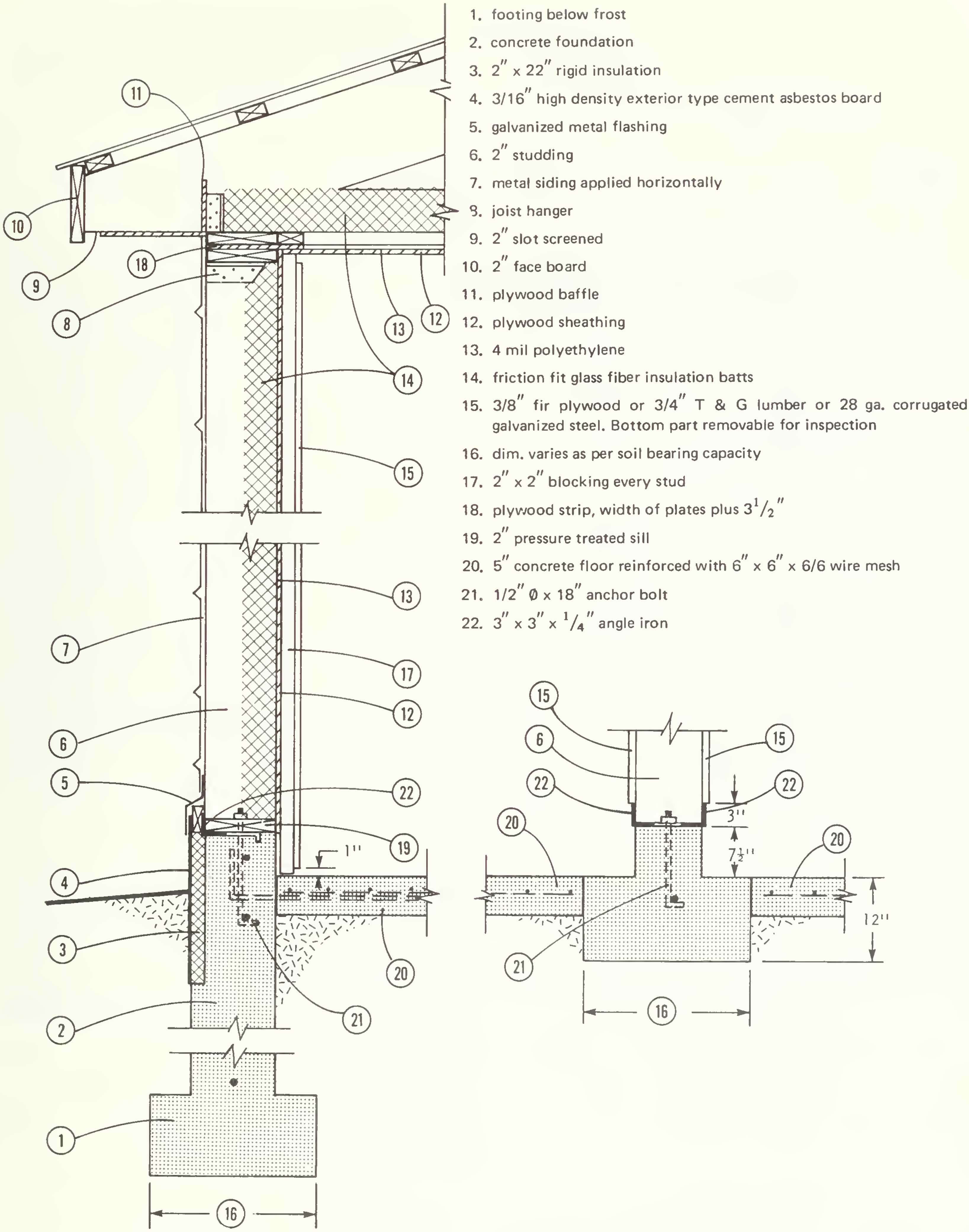
In a 60′ clear span gable roofed building with a roof dead load of 9 psf, roof live load of 41 psf and a gust wind pressure of 12.5 psf on the leeward side, load combination (a) was critical. The stud sizes listed are based on load combination (a).

(3) Use columns 5 and 6 to design studs-to-foundation and studs-to-ceiling connections. Use column 18 for anchor bolt spacing applicable to the studs-to-foundation detail shown in figure 6.



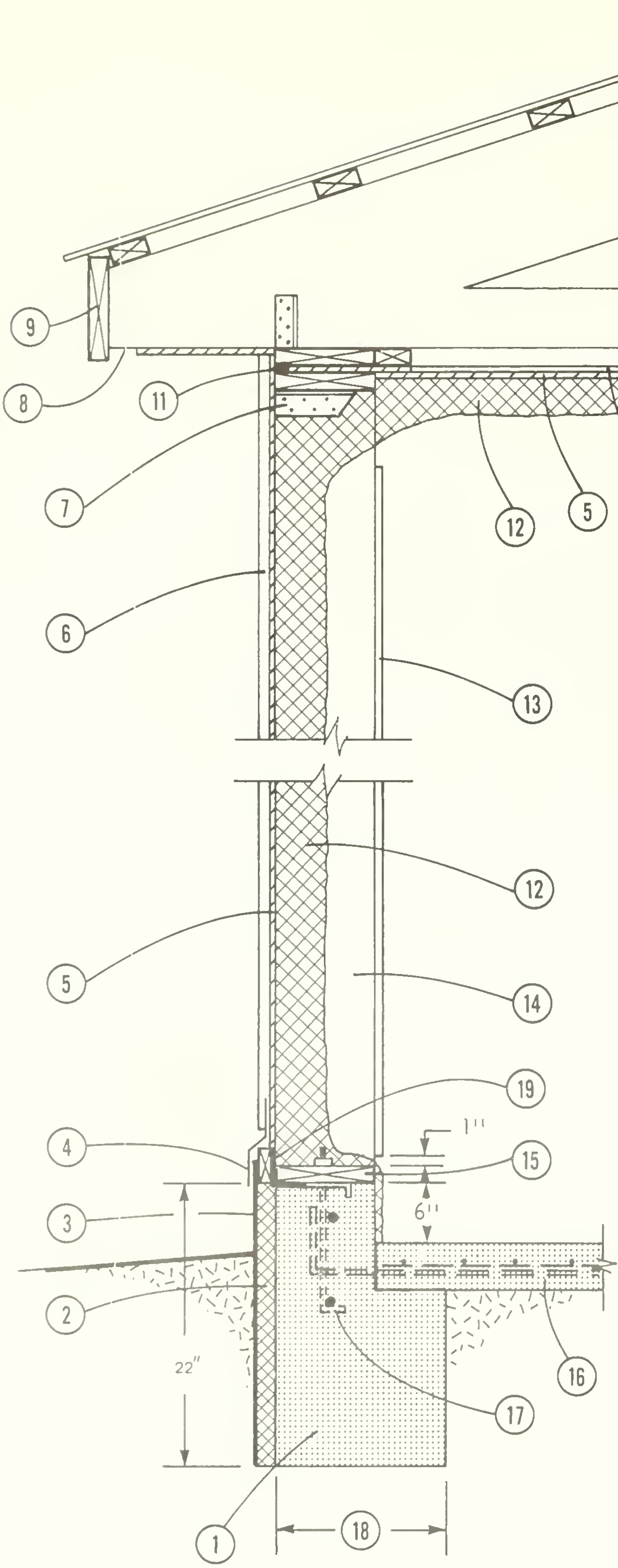
1. 2" sill same width as studs
2. 2" x 4" nailer
3. 2" x 22" rigid insulation, expanded polystyrene
4. 3/16" x 24" high-density re-compressed exterior type cement asbestos board.
5. 3" x 3" x 1/4" steel angle continuous 3/8" x 1 1/2" lag screws into 2" x 4".
6. 1" x 1" x 1/4" x 6" long steel angle.
7. 1/2" Ø x 18" anchor bolt.
8. 1/4" x 2" plate drilled for (7) and welded to (5) and (6), coat welds with primer. Length of plate to be actual stud size minus 5 inches.
9. #4 reinforcing bars continuous.

Fig. 6 Wall connection at sill, bulk potato storage.



1. footing below frost
2. concrete foundation
3. 2" x 22" rigid insulation
4. 3/16" high density exterior type cement asbestos board
5. galvanized metal flashing
6. 2" studding
7. metal siding applied horizontally
8. joist hanger
9. 2" slot screened
10. 2" face board
11. plywood baffle
12. plywood sheathing
13. 4 mil polyethylene
14. friction fit glass fiber insulation batts
15. 3/8" fir plywood or 3/4" T & G lumber or 28 ga. corrugated galvanized steel. Bottom part removable for inspection
16. dim. varies as per soil bearing capacity
17. 2" x 2" blocking every stud
18. plywood strip, width of plates plus $3^1/_2$"
19. 2" pressure treated sill
20. 5" concrete floor reinforced with 6" x 6" x 6/6 wire mesh
21. 1/2" Ø x 18" anchor bolt
22. 3" x 3" x $^1/_4$" angle iron

Fig. 7 Typical exterior and partition wood stud wall construction showing deep foundation at exterior wall.



1. concrete foundation
2. 2″ rigid insulation
3. 3/16″ high density exterior type cement asbestos board
4. galvanized metal flashing
5. plywood sheathing
6. metal siding applied vertically
7. joist hanger
8. 2″ slot screened
9. 2″ face board
10. plywood spacer
11. plywood strip, width of plates plus $3^1/_2$″
12. sprayed on polyurethane insulation
13. 3/8″ fir plywood or 3/4″ T & G lumber or 28 ga. corrugated galvanized steel. Bottom part removable for inspection
14. 2″ studding
15. 2″ pressure treated sill
16. 5″ concrete floor reinforced with 6″ x 6″ x 6/6 wire mesh
17. 1/2″ Ø x 18″ anchor bolt
18. dimension varies as per soil bearing capacity
19. 3″ x 3″ x $^1/_4$″ angle iron

Fig. 8 Typical wood stud wall construction showing polyurethane insulation and shallow foundation. Exposed foam insulation may be in variance with local fire codes.

TABLE 3 – INSULATION VALUES (R) FOR VARIOUS MATERIALS AND INSULATION RECOMMENDATIONS FOR POTATO STORAGES

Insulation and construction material	*R Value (Resistance to heat flow, units per inch of thickness) At 25°F	At 75°F
Mineral wool or glass fiber, blanket batt or loose fill types		
0.65 lb/cu ft density	3.7	3.3
0.75 lb/cu ft density	3.7	3.4
1.00 lb/cu ft density	4.0	3.7
1.50 lb/cu ft density	4.2	4.0
Cellulose fiber (cotton, wood pulp, etc.)		3.9
Expanded mica, "vermiculite", 4 to 6 lb/cu ft	2.5	2.3
Dry sawdust, or wood shavings, 0.8 to 15 lb/cu ft)		2.2
Straw (cut dry)		1.43
Corkboard (6.5 to 8.0 lb/cu ft)	3.9	3.7
Polystyrene form, 1.9 lb/cu ft, extruded	4.2	3.9
Polystyrene foam, 1.0 lb/cu ft, molded beads	3.9	3.6
Polyurethane foam, 1.5 to 2.5 lb/cu ft	5.9	5.9
Concrete	0.8	0.8
Concrete blocks		1.4

Wall (W) and ceiling (C) insulation resistance value (R) for air-cooled storages of potatoes (32-50°F, 90-95% RH).

Outside Temperatures (°F)	W	C
10	14	21
0	17	24
-10	21	28
-20	25	32
-30	29	36

*From 1967 ASHRAE Handbook of Fundamentals and other sources.

Sprayed-on, Expanded-in-Place Polyurethane Foam – This material has gained wide acceptance in the insulation of fruit and vegetable storages. Ideally, it is said to have sealed cells and low permeability, with good adhesion to wood, concrete and metal when applied correctly under proper conditions of temperature and absence of grease or moisture on the surface to be applied.

Fire Caution

Exposed plastic foam insulation, particularly sprayed-on polyurethane, can burn explosively if exposed to fire hazards such as open flames, cutting and welding torches, electric heating, smoking, etc. If welding, cutting or soldering must be done nearby, shield the insulation with cement asbestos board. In areas of high human occupancy such as grading and packing rooms, workshops, show arenas, cover exposed plastic insulation or use a less hazardous insulation material.

There has been a mixed history of success and failure with polyurethane foam over the last decade. Since it readily conforms to irregular shapes, it has been used to insulate old remodelled buildings, new steel-frame and steel-clad buildings as well as concrete-block and plywood-lined structures. For proper use of this material, however, regard for the severity of moisture conditions within the building must be taken into account as well as the tendency for this moisture to enter and be trapped within the insulation. For example, polyurethane applied on the inside of a metal siding without an inside vapor barrier, tends to load up with moisture over prolonged periods of extreme moisture conditions, such as during winter storage of potatoes, especially at 50-55°F and 90% Relative Humidity. Moisture reduces the insulation value of any insulation material, and freezing can cause the insulation to push away from the metal to which it is applied. In practice, the polyurethane applied on some jobsites is more porous than polyurethane sprayed under ideal or factory conditions, aggravating the situation.

To avoid these problems with polyurethane in potato storages observe the following guidelines:

- Use a custom applicator with a history of successful application of polyurethane.
- Aim for a uniform density of 2-2.5 pcf and relatively closed-cell texture.
- Apply to a prepared surface that is clean, dry, and up to the recommended temperature.

- Apply to surfaces that will tend to bleed off excess moisture such as plywood and concrete block rather than to metal surfaces.
- Spray a sealant on the warm side of the insulation for added protection if desired. This additional vapor barrier is frequently omitted, but some companies and applicators recommend it under extreme conditions of humidity maintained in potato storages.

Vapor Barrier

The high humidities maintained in potato storages create a positive vapor pressure that results in the movement of moisture into the wall. Without a vapor barrier, the moisture condenses in the wall and insulation, forming free water that rapidly deteriorates the structural members and insulating material.

This can be prevented by installing a vapor barrier to form a continuous seal on the warm side of the walls and ceiling. For this purpose, the most commonly used material is polyethylene film, which is available in various thicknesses. For potato storages, 6 mil (.006") material is recommended; the minimum thickness acceptable is 4 mil (.004").

The polyethylene vapor barrier should be placed between the insulation and the interior sheathing. Sheets should be lapped a minimum of 6 inches at joints and all joints should be made at framing members. Before applying the interior sheathing, the vapor barrier should be carefully inspected and all breaks repaired.

Electrical Services

The storage will require electrical services for lighting, to power the ventilation system and for potato handling and grading equipment. The size of service selected should be based on present and proposed electrical loads. The minimum service that should be considered is 100 amperes. If larger motors are to be used, the provision of three-phase power should be investigated. This is becoming more readily available in rural areas. It allows the use of cheaper, more reliable motors and of larger motors if desired.

Whatever system is selected, the electrical installation must comply with local regulations.

Three special conditions that exist in potato storages should be brought to the attention of the electrician. First, the vapor barrier must not be damaged; the use of exposed wiring is recommended for this reason. Second, the wire needs to be protected from mechanical injury.

Fig. 9 Temporary post method of supporting bin front in a wide bin.

And third, electrical controls should be located away from dampness and the corrosive effect of sprout inhibitors, such as CIPC, and storage sanitizers such as copper sulfate. For the same reasons, rigid plastics are preferred over metal conduits.

Bin Fronts

The use of bin fronts is justified because they provide better space utilization in the bin, create a level pile for better ventilation, separate bins from alleyways and provide pressure relief at the doors.

In narrow bins, fronts can be contructed using 2" X 10" or 2" X 12" planks supported by an angle bolted to the end post in the bin partition. In wider bins, special designs must be used. These include panels, trussed panels, swinging-door panels, removable parts, cable tiebacks and semi circular sheet metal.

Since bin fronts must support heavy loads, they must be designed to support these loads.*

It is important that the front column of the partition that supports the bin front be securely tied to the partition and anchored at both the ceiling and the floor.

*See ARS bulletin #52-32, *Lateral Pressure in Walls of Potato Storage Bins,* Agricultural Research Service, United States Department of Agriculture, Washington, D.C. Information necessary for the design of bin fronts is provided in Market Research Report No. 893, *Bin Front for Potato Storages,* available from the same address.

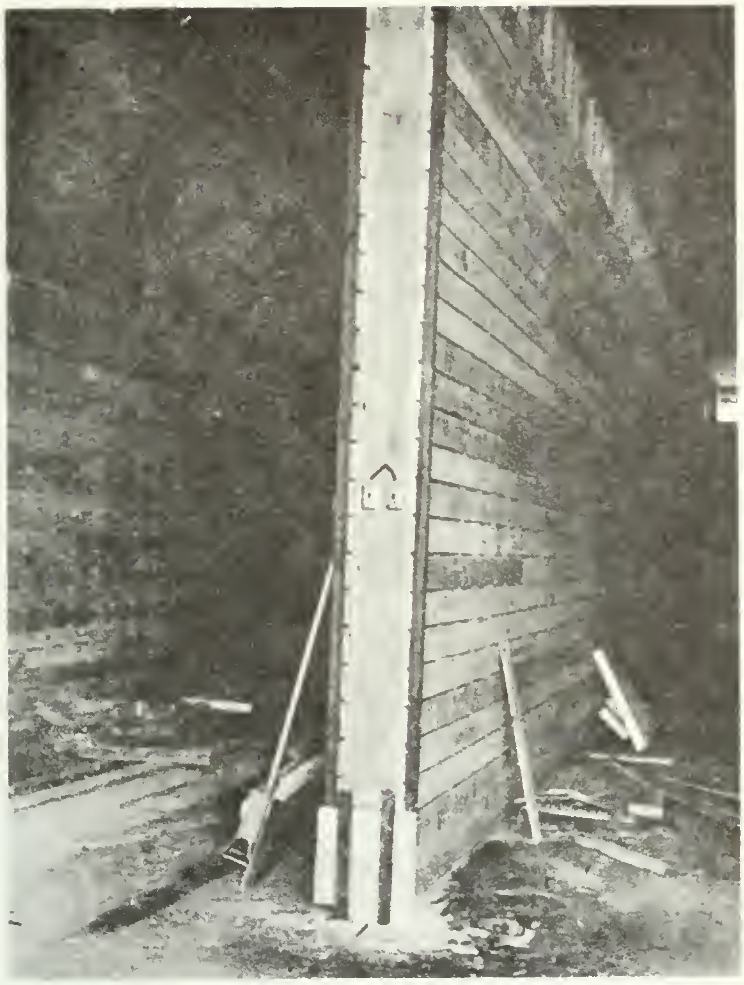


Fig. 10 Angle iron bolted to partition column to support bin front. Short planks at bottom can be driven out to start bin.

VENTILATION SYSTEMS

A good ventilation system supplies the air necessary to control temperature and humidity in the storage, delivers this air to where it is required, and circulates the air within the storage to assure uniform conditions.

Ventilation systems may range in complexity from the simplest exhaust fan to completely automatic proportioning systems for blending air. Some may incorporate refrigeration. Most systems are of the following types, in order of effectiveness and cost:

1. Simple exhaust fan system
2. Individual duct and fan system
3. Proportioning ventilating system

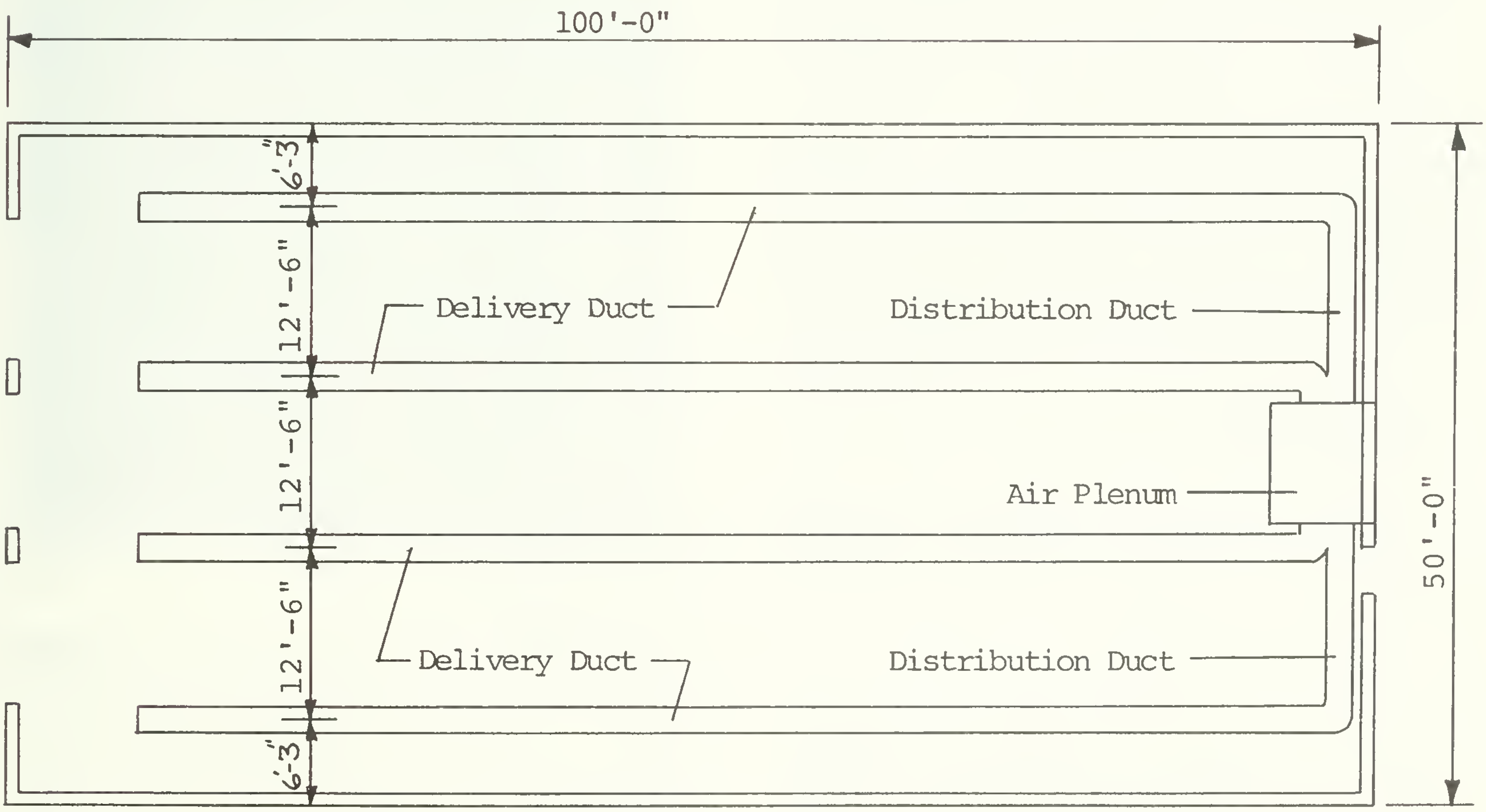


Fig. 11 Typical duct layout.

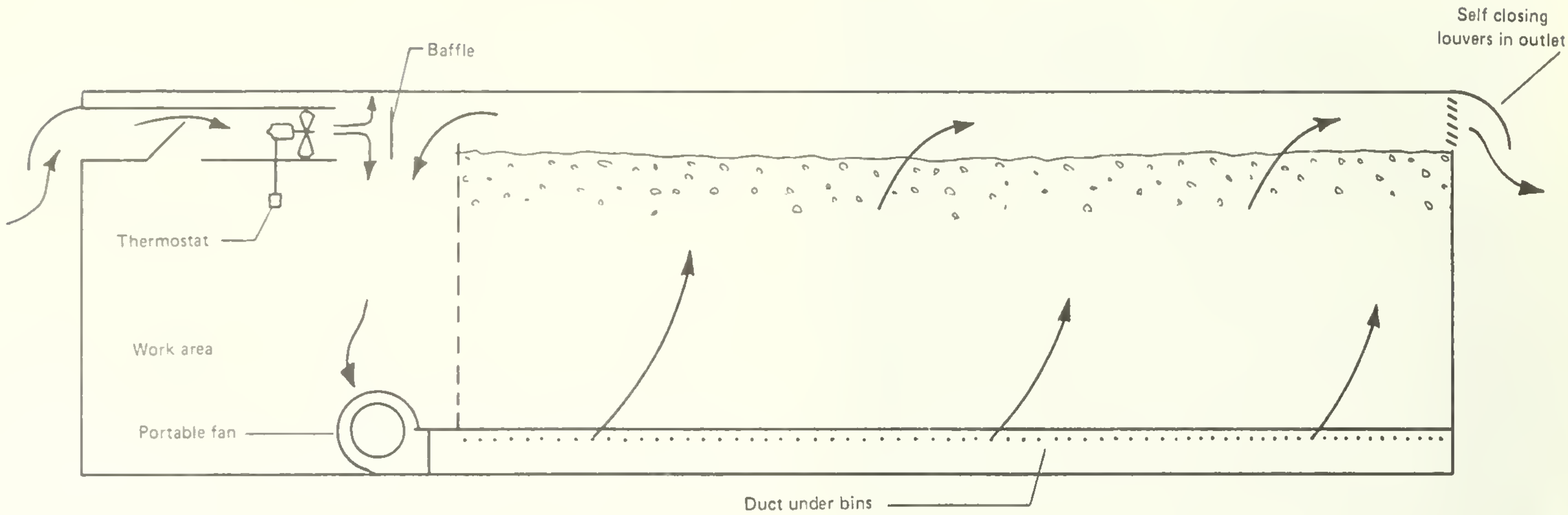


Fig. 12 Individual duct and fan system

SIMPLE EXHAUST FAN SYSTEM

This system consists of a fan or fans installed in the wall of the storage to exhaust warm air that is collected over the potatoes. Ventilation air is usually provided by opening doors in the opposite end of the building.

The exhaust fan system provides only minimum benefits, and is satisfactory only when potatoes are placed in storage in excellent condition. This system will only remove warm air, it does not supply air through the pile for cooling or control of decay, nor does it provide for the humidification necessary for optimum conditions.

The exhaust fan system reacts to inside temperature only. It can therefore ventilate when outside air temperature is above the potato temperature. The warm incoming air can cause "sweating" on the tubers and decay if the condition persists. During the storage period heat and moisture rising by natural convection from the interior of the pile will also cause condensation unless the relative humidity of the storage is reduced, which is not a desirable situation.

The only effective way to provide controlled ventilation is a system of through-the-pile ventilation as described by methods 2 or 3 following.

DUCT AND FAN SYSTEM

This system can be made very effective for short- or medium-term storage, and represents a vast improvement over the simple exhaust fan system at moderate cost. The following steps represents the stages of development of this system:

Construct floor ducts as illustrated in Figure 11. Place ducts in the center of each bin or at 10′ intervals if storage is not divided. Ducts should extend into the front of the pile, and the ends should be left open. This will produce some air movement through the pile as warm air rises and is replaced by air drawn into the ducts. This is the cheapest method and should only be considered as the first step.

The system can be made more effective if in addition to placing ducts in the floor, small blower fans are purchased and used to force air into the ducts. The fans selected should have a capacity of .6 cfm/cwt, 1 cfm/bbl or .36 cfm/bu.

It is also recommended that some or all of the exhaust fans be removed from their present location and used as intake fans. They should be mounted as shown in Figure 12.

The louvers should be left in their present location to serve as outlets. The small mixing damper shown in Figure 12 is used to blend inside and outside air in order to avoid bringing freezing air into the storage. Duct fans should be run continuously during the cooling period. During the holding period, it should be operated 1 to 3 hours each day, or for longer periods if 'hot spots' are detected in the pile.

Heat for humidity control can be added and distributed uniformly through the storage using this system. In the hands of a careful operator results obtained should approach those of the manually controlled proportioning system. This system falls short of the automatic proportioning system during warm periods when precise control of cooling is desired.

Storage operation requires a skilled and knowledgeable operator. If you don't know, ASK.

PROPORTIONING VENTILATION SYSTEM

The proportioning ventilation system consists of a fan, a duct system to deliver air to all points in the storage and a mixing chamber where an automatically controlled damper blends inside and outside air, thus achieving optimum ventilation.

These automatic controls are the 'brain' of the system and are responsible for its operation. An informed operator needs only to set the controls at the required storage temperature and the system will achieve and maintain these conditions.

All components of the system should be purchased from the same supplier, to ensure smooth operation.

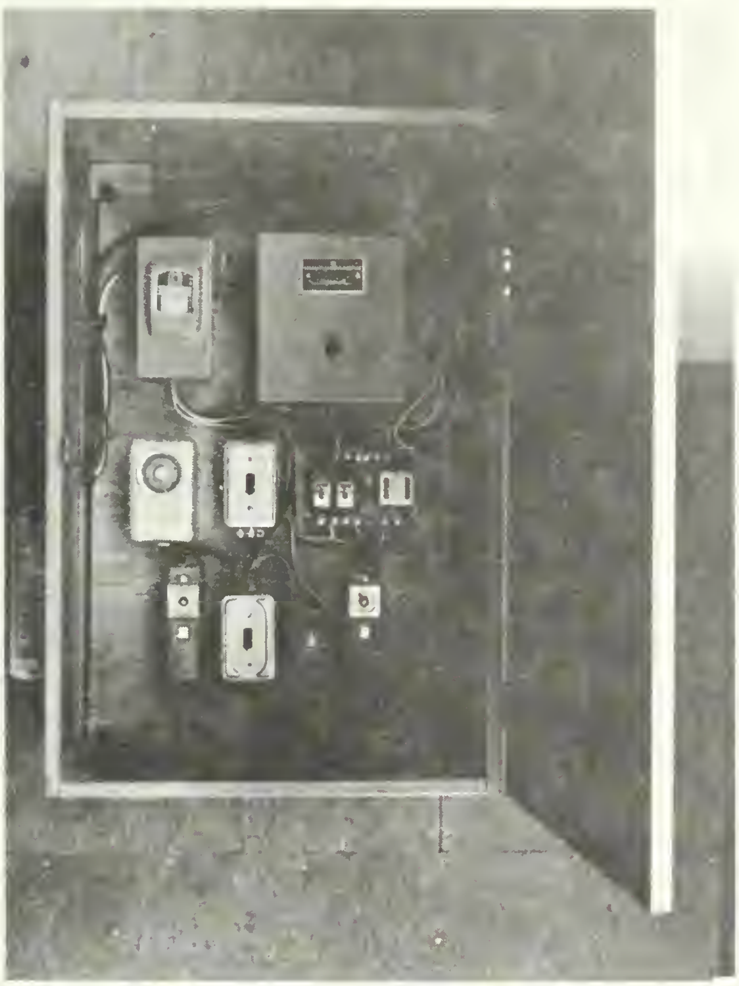


Fig. 13 Control panel for proportioning ventilation system.

The system has the following advantages over all others:

- Has greatest cooling capacity during fall, when rapid cooling to storage temperatures is essential.
- Prevents ventilation when outside temperature is warmer than inside.
- Allows the operator to maintain a uniform temperature in the storage during winter.
- Assures uniform temperatures within the potato pile. Prevents formation of hot spots in bins and chilling in remote corners, as well as large temperature differences between floors and ceiling.
- Permits the addition of moisture if a humidifier is included in the system.
- Allows heat to be added to the storage uniformly.
- Will not overventilate if controls are correctly set.

Controls

Differential Thermostat — In potato storages, the differential thermostat makes contact when the temperature of the outside sensing element is below that of the inside sensing element, and it breaks contact when conditions are reversed. This assures that outside air is brought into the storage only when it is at a suitable temperature for cooling.

Proportioning Thermostat —This operates in conjunction with a *proportioning damper motor* to provide the correct damper positioning for air mixing.

The actual operation of the system is illustrated in Figure 15. The position assumed by the damper is shown for three different sets of conditions.

The thermostat is set at the desired storage temperature (see page 7). It begins to function when the outside temperature falls below the storage temperature. The proportioning damper motor slowly rotates the damper to any position between fully open and fully closed to give the proper air blend for the desired temperature. The damper automatically closes when the fan is not running.

A check for accurate adjustment can be made after the system is in operation by measuring the temperature of the air at the discharge of the main duct. If it is consistently higher or lower than the dial setting, it indicates the dial should be adjusted to agree with the measured temperature.

The proportioning thermostat and the proportioning damper motor form a single operating unit that has been calibrated to give accurate performance. It is important to select a proportioning thermostat that corresponds with a damper motor recommended by the manufacturer.

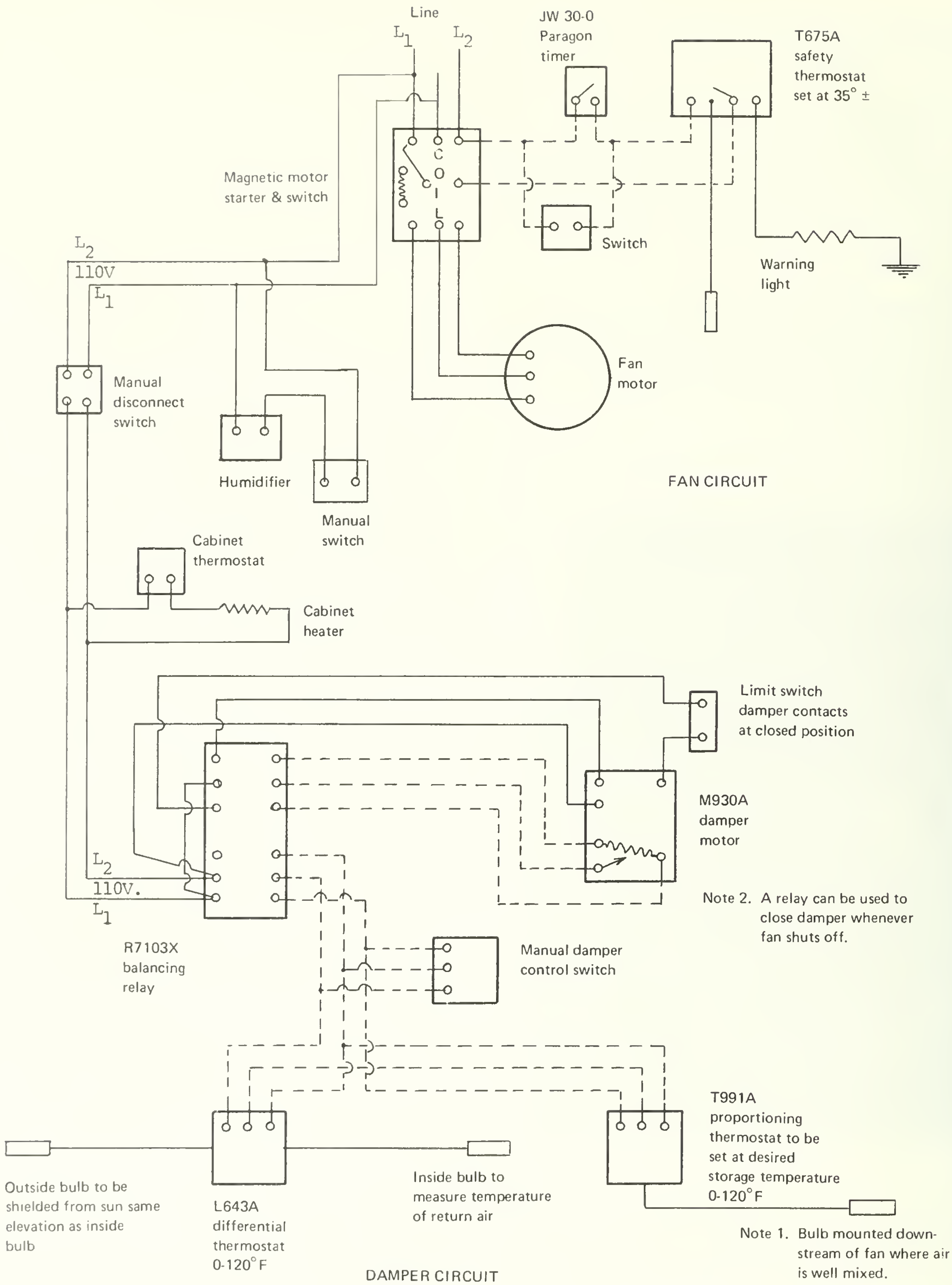
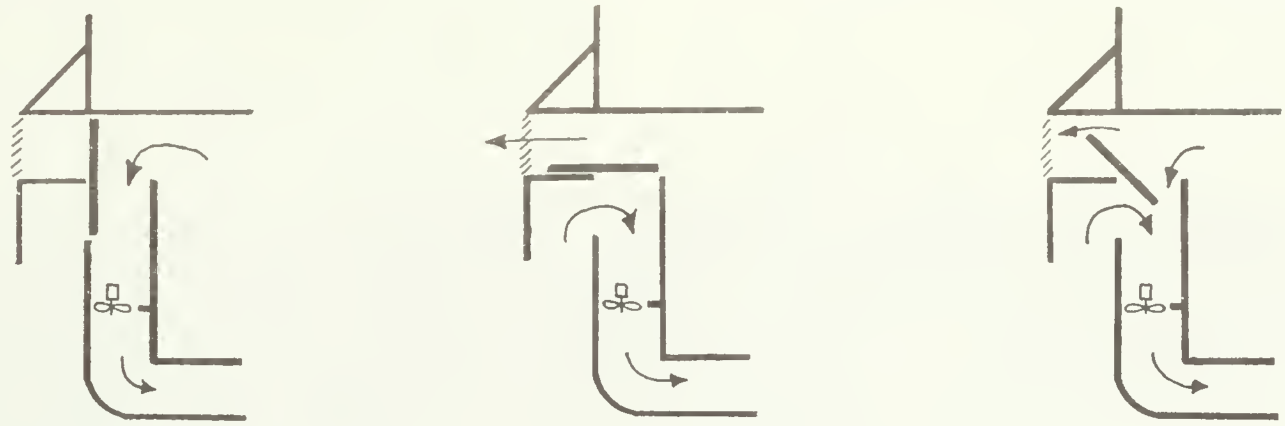


Fig. 14 Wiring for proportioning ventilation system. NOTE: Circuits shown in broken line should be in separate conduit.



A

No Ventilation. Periodic recirculation. Damper assumes fully closed position when:

(1) Air outside is too warm for cooling storage.
(2) Storage is at required temperature.
(3) Air outside is too cold to allow ventilation.
(4) Proportioning thermostat is not functioning.
(5) When fan is stopped between ventilation periods.

B

Full Ventilation. Damper assumes fully open position when:

(1) Storage temperatures rise above thermostat setting.
(2) Air outside is cool enough to ventilate storage.
(3) Outside air temperature slightly below thermostat setting.

C

Proportioning Damper automatically assumes appropriate partially open position when:

(1) Storage requires ventilation.
(2) Outside air is suitable for cooling but below storage temperature.
(3) Cold incoming air is proportionally mixed with warm air from storage to provide desired temperature for cooling.

Fig. 15 Typical damper positions in proportioning ventilation system.

Safety Thermostat — The safety thermostat protects the storage against possible chilling or freezing injury caused by faulty operation of the proportioning thermostat or failure in the damper system.

Humidity Controller — Humidity controllers have been used but are often unsatisfactory at 90 to 95% humidity. They require frequent adjustment and calibration and operators may prefer a manual switch. The humidifier should be wired into the fan circuit to prevent operation when the fan is stopped.

Interval Timer — The interval timer is essentially a clock with a switching action. It provides for periodic circulation of the air when fresh air is not being brought into the storage. This circulation is necessary during the storage period to eliminate hot spots and maintain a uniform temperature within the pile. Operation of the fan 2 to 4 hours per day is usually sufficient.

Relays — Relays are switching devices designed to take the line current load of the operating equipment off the contact points of the controllers. This prevents arcing and burning.

Magnetic Switches — Magnetic switches serve the same purpose as relays and, if provided with a heater element, give protection against overloads. They are used to start and stop fan motors.

To Protect Controls — It is advisable to group all control equipment in a single panel installed in a small control room separated from the main storage by a tight wall. Some suppliers mount all controls in a metal cabinet, to protect them from dust. Dry conditions are assured by providing a small heater or a 40-watt bulb in this cabinet.

Fan Capacity

For adequate cooling of potatoes using the proportioning ventilation system, select fans and controls for 0.6 cubic feet of air per minute (cfm) per 100 pounds of potatoes stored, at a static pressure of 1 inch water gage. However in areas subject to early fall frost during harvest operations, increase ventilation to 0.8 cfm/100 lb at 1.5 inches static pressure to control soft rot in frosted tubers.

Be sure to select a fan from the manufacturer's catalogue that is capable of moving the required air through the potato pile at the total static pressure required to move air through the ductwork plus the potatoes.

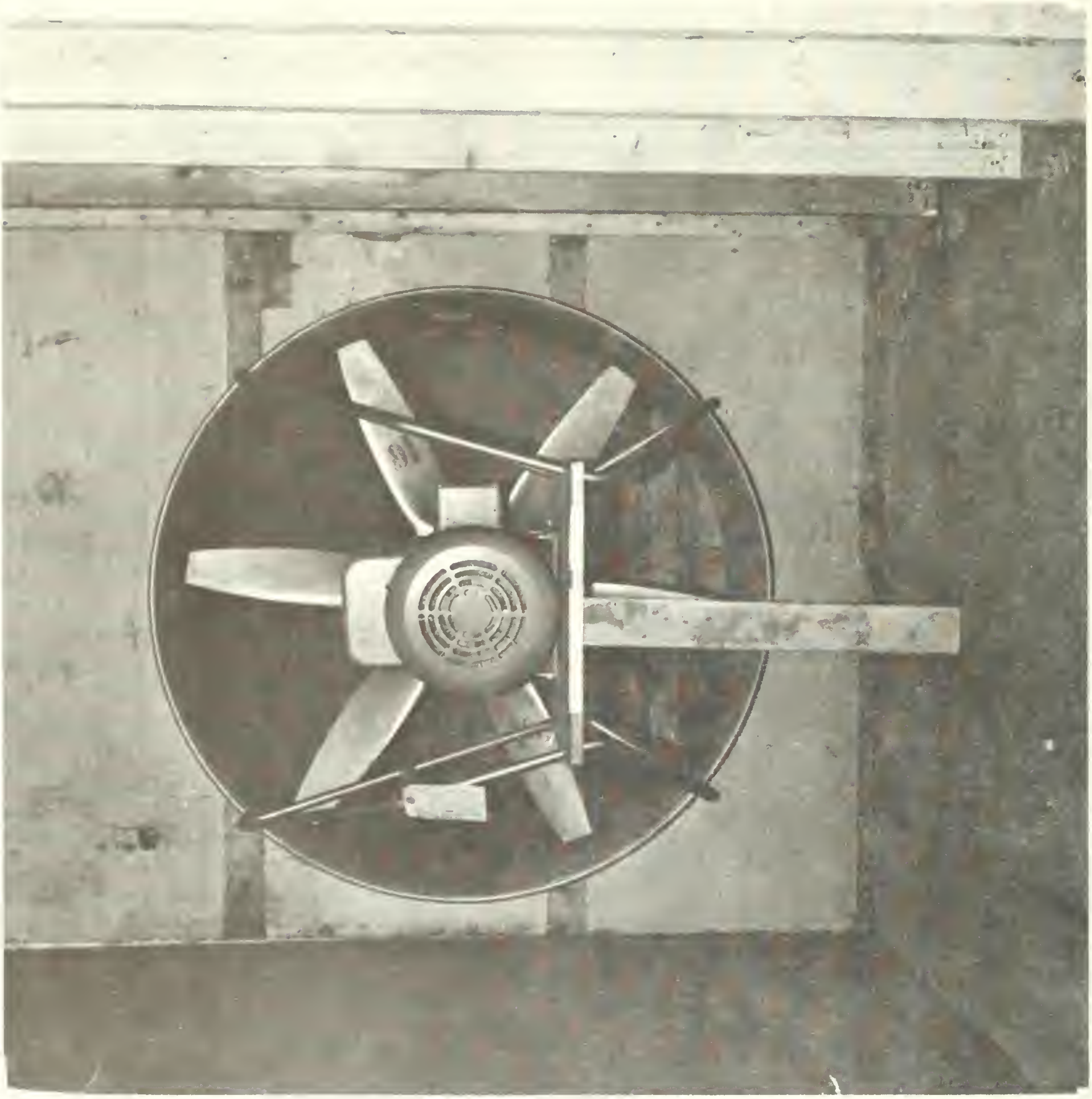


Fig. 16 Propeller fan installed in air duct.

Types of Fans

There are two basic types of fans – axial flow (propeller) fans and radial flow fans (centrifugal) – and both are suitable for use in potato storages.

Propeller fans are designed to deliver large volumes of air at low static pressures. They perform at any range between design delivery and free delivery with very little change in horsepower requirements. There is no danger of motor overload at reduced static pressures. As they are usually cheaper and lighter in weight than centrifugal fans of equal capacity, and require little space for installation, they are commonly selected for potato storage systems. Their only disadvantage is the relatively high noise level encountered in the sizes and speeds used in potato storage ventilation.

Two types of centrifugal fans are available:

Forward Curve Blade Fan – This type of fan will deliver large volumes of air at a wide range of static pressures at relatively low speeds. It will overload if static pressure is reduced by removing a duct cover and cause the motor to burn out. If this fan is used, the motor should be oversized; this does not increase cost of operation. Another disadvantage is that the airflow varies widely with changing static pressure.

Backward Curve Blade Fan – This high-speed fan is slightly more efficient than the forward-curve type. It has a self limiting characteristic that reduces the chance of motor overload.

Fan Housing

The damper and fan are located in a fan house (Figure 17). This may be located on any outside wall of the storage but preferably in a location that is readily accessible and requires a minimum length of distribution duct. It is often located in the center of the end wall opposite the loading doors and in this location it needs an access door. The fan house should be fully insulated to prevent condensation. While commercially manufactured dampers may be used, it is preferable to construct a fully insulated swing damper (see Figure 18).

Air is brought into the fan house through a hooded, louvered inlet. This inlet should be sized to allow 1 square foot of air inlet for each 1000 cfm of fan capacity. (Figure 19).

Air should be exhausted from the storage at a point at least 4 feet above the inlet, to prevent it from being drawn into the storage. This outlet should also have an area of 1 square foot for each 1000 cfm of fan capacity.

WEIGHTS AND MEASURES

1 cwt = 100 lb
1 ton = 2,000 lb
1 barrel of potatoes (weight measure) = 165 lb
1 bushel of potatoes (weight measure) = 60 lb
1 bushel (U.S. volume measure) = 1.244 cu ft
Bulk density of potatoes
1 cu ft weights approximately 42 lb
1 bushel volume weights approximately 53 lb

TABLE 4 – SUGGESTED FAN SIZES AND CAPACITIES FOR VARIOUS SIZES OF STORAGES

Storage capacity cwt	Rate cfm/cwt	Fan capacity at 1″ static pressure cfm
10,000 (6,000 bbl)	.6	6,000
15,000 (9,000 bbl)	.6	9,000
20,000 (12,000 bbl)	.6	12,000
30,000 (18,000 bbl)	.6	18,000

The fan should be mounted rigidly in the fan house. Care should be taken to locate the fan so that no obstacles or corners are within a distance of four diameters from the fan. If this is not possible, round the corners where the duct changes direction and install flow straighteners (Figure 20).

Air Ducts

Air delivered by the fan is conveyed to underbin ducts by a distribution duct. This duct must have a total cross section area equal to that of the floor ducts it supplies. The distribution duct should be reduced in size after each floor duct is passed. Corners should be rounded (particularly on the outside) to reduce turbulence. Uniformity of air delivery is the most important consideration in duct design.

Duct size is determined primarily by the volume rate of air to be delivered at a specified velocity.

Floor ducts are usually cast in the concrete when new storages are constructed. Where belt conveyors are used for unloading, the duct width should be sufficient to accommodate the equipment. Minimum duct width for a 16″ wide conveyor is 20.″ The ledge supporting plank covers for infloor ducts should be carefully cast and planks should be planed to uniform thickness to allow them to fit flush with the floor where they will not be caught by the bucket on the bin unloader.

Two methods can be used to assure uniform delivery from floor ducts. The discharge opening can be restricted so that static air pressure changes within the duct

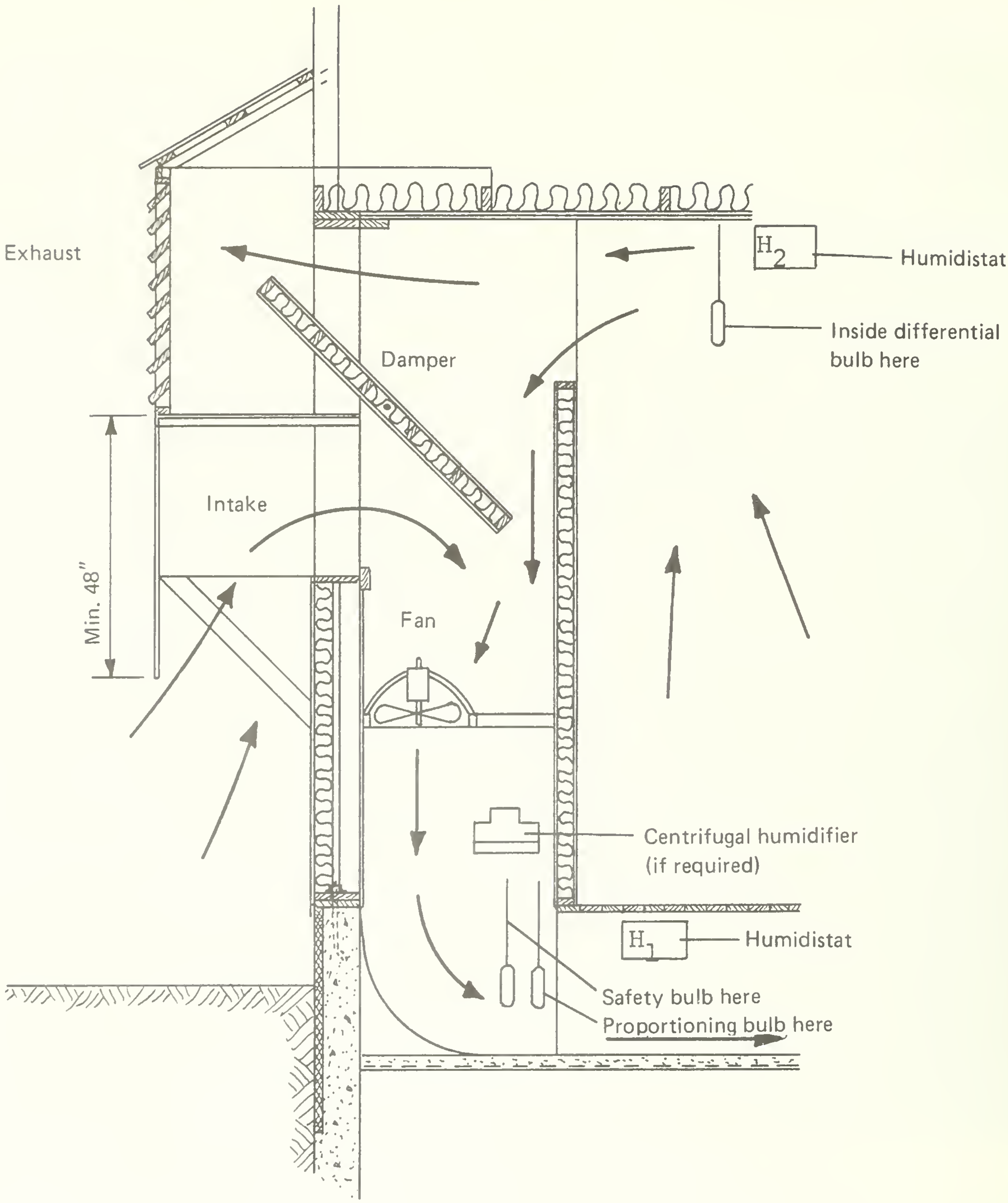


Fig. 17 Fan house showing location of fans, damper and controls.

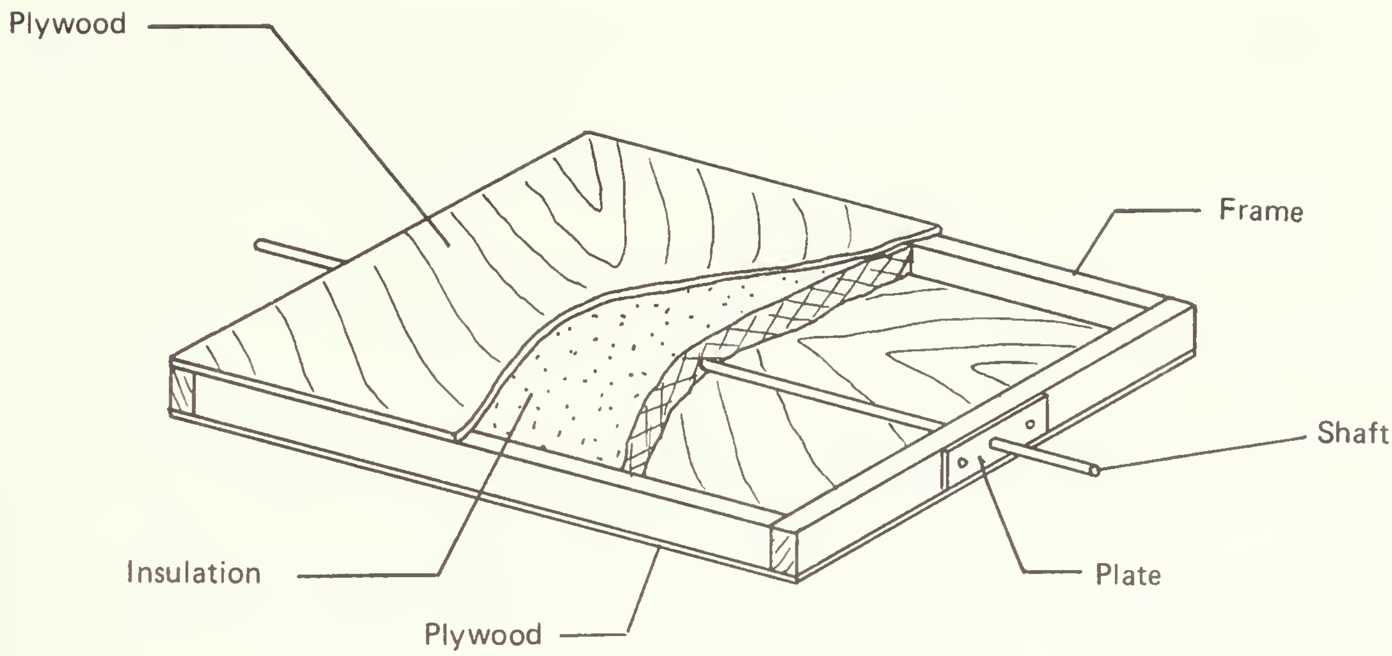


Fig. 18 Fully insulated swing damper.

Fig. 19 Air intake and exhaust housing showing exterior bulb of differential thermostat and system failure warning light.

become less significant; or the equal-friction method can be used to design ducts with a uniform reduction in cross-section area throughout their length. This reduction can be accomplished by varying the depth.

If the uniform-pressure method is used, the air is usually delivered to the bin through a series of equally spaced holes with diameters of $1^1/_4$". Spacing of these holes is determined by the following formula:

$$S = \frac{120}{H}$$

where S = spacing of holes in inches and H = depth of pile in feet.

This formula is based on 10-ft spacing between ducts and air pressures of 0.5".

If the equal-friction method is used to design ducts, the following table may be used to determine depth of duct at different points:

TABLE 5 — RECOMMENDED DUCT AIR CAPACITIES (CFM)[1] FOR DIFFERENT DUCT LENGTHS AND PILE DEPTHS

Duct Spacing(ft)	Duct Length[2] (feet)	Pile Depth (feet) 8 feet	10 feet	12 feet	14 feet	16 feet	18 feet	20 feet
8	30	484	605	726	847	968	1089	1210
	60	968	1210	1452	1693	1935	2177	2419
	90	1452	1814	2177	2540	2903	3266	3629
	120	1935	2419	2903	3387	3871	4355	4838
	150	2419	3024	3629	4234	4838	5443	6048
10	30	605	756	907	1058	1210	1361	1512
	60	1210	1512	1814	2419	2419	2722	3024
	90	1814	2268	2722	3175	3629	4082	4536
	120	2419	3024	3629	4234	4838	5443	6048
	150	3024	3780	4536	5292	6048	6804	7560
12	30	726	907	1089	1270	1452	1633	1814
	60	1452	1814	2177	2540	2903	3266	3629
	90	2177	2722	3266	3810	4355	4899	5443
	120	2903	3628	4355	5080	5806	6532	7258
	150	3629	4536	5443	6350	7258	8165	9072

[1] based on ventilation rate of 0.6 cfm per 100 lb of potatoes.

[2] Lengths given are from the end of duct farthest from the fan or distribution duct. For example, a duct 105 ft long would be 19" deep where it joins the distribution duct, tapering to 3" deep at the end. Width of duct is determined by volume of air to be moved. Good design calls for air velocities of not more than 1000 fpm.

When ventilation systems are installed in older buildings without floor ducts, air can be supplied by rectangular or triangular wood ducts placed at 10-ft intervals on top of the floor. They should be constructed in 8-10 ft lengths (8-ft for plywood tops) so that they can be set aside as the storage is emptied.

An alternative duct system uses the bin partitions and outside wall spaces as delivery ducts. Partitions are sheathed on both sides with plywood and the interior sheathing is secured to 2" X 2" spacers attached to the studs after the vapor barrier has been applied. Air is delivered to the partitions and wall spaces by triangular ducts at the ceiling and discharged into the bin at floor level through a series of holes. The spacing of these holes is determined by the formula used for uniform pressure design. (Above).

The blanketing of outside walls with air at storage temperature is one advantage of this system.

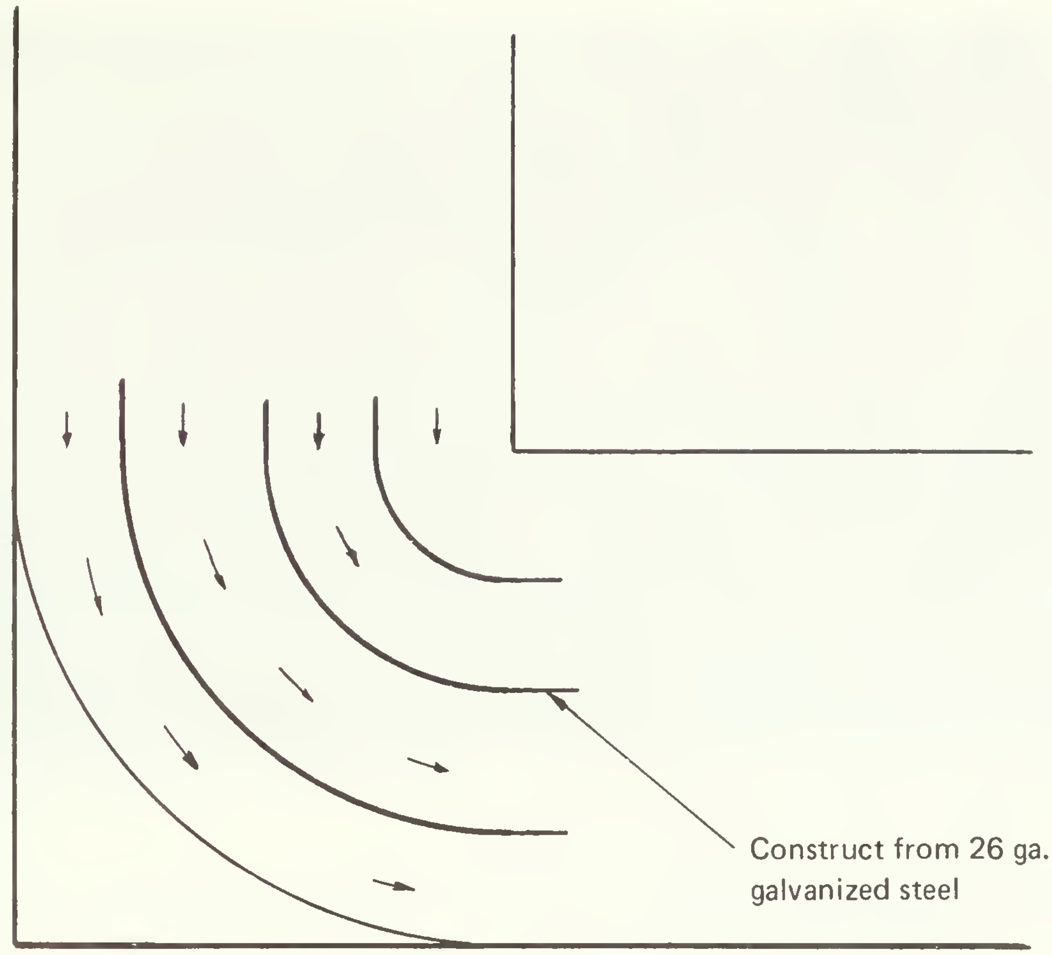


Fig. 20 Flow straighteners (vanes) to prevent turbulence at right angle corners in ducts.

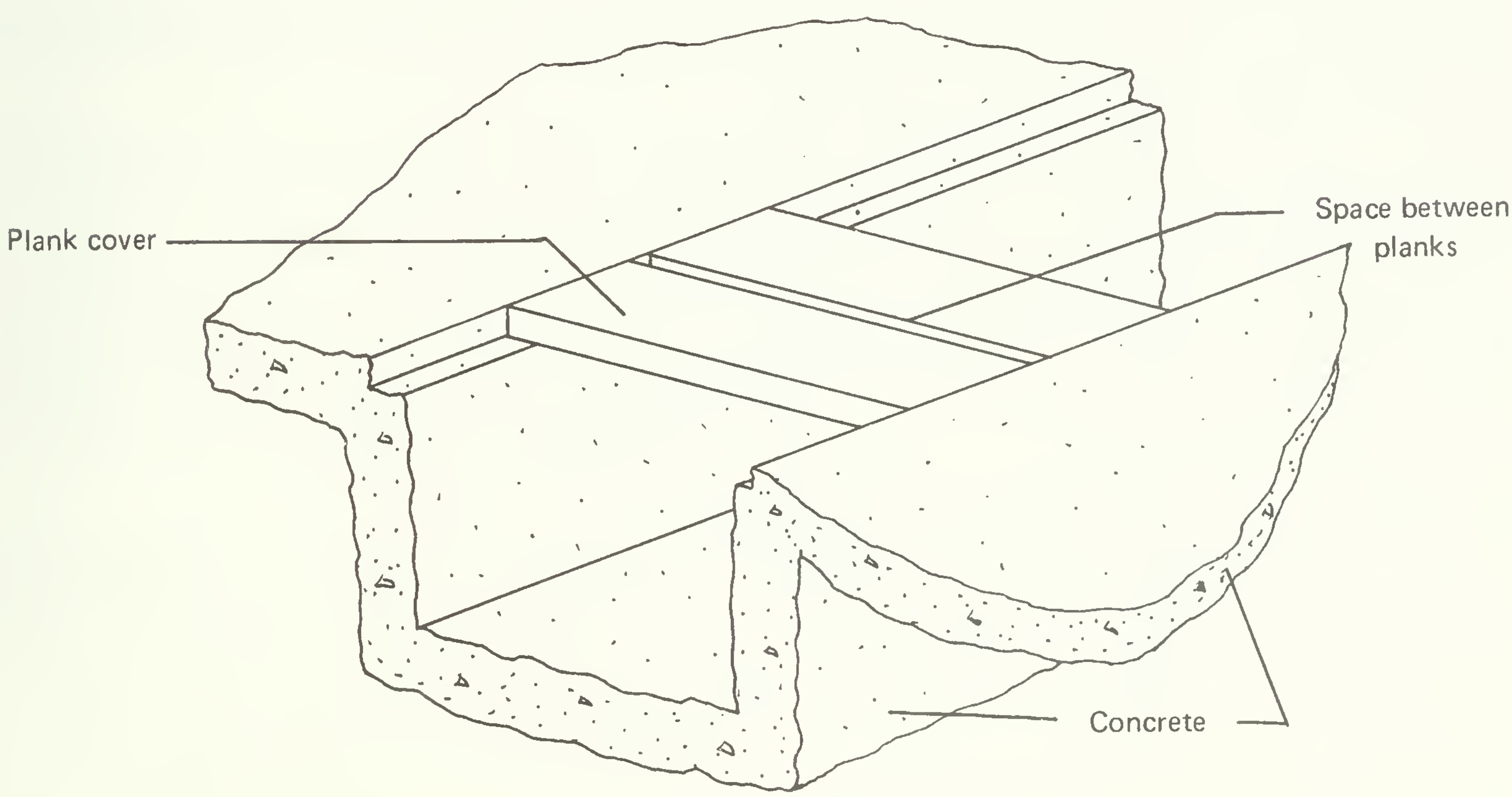


Fig. 21 Cast in place floor delivery duct.

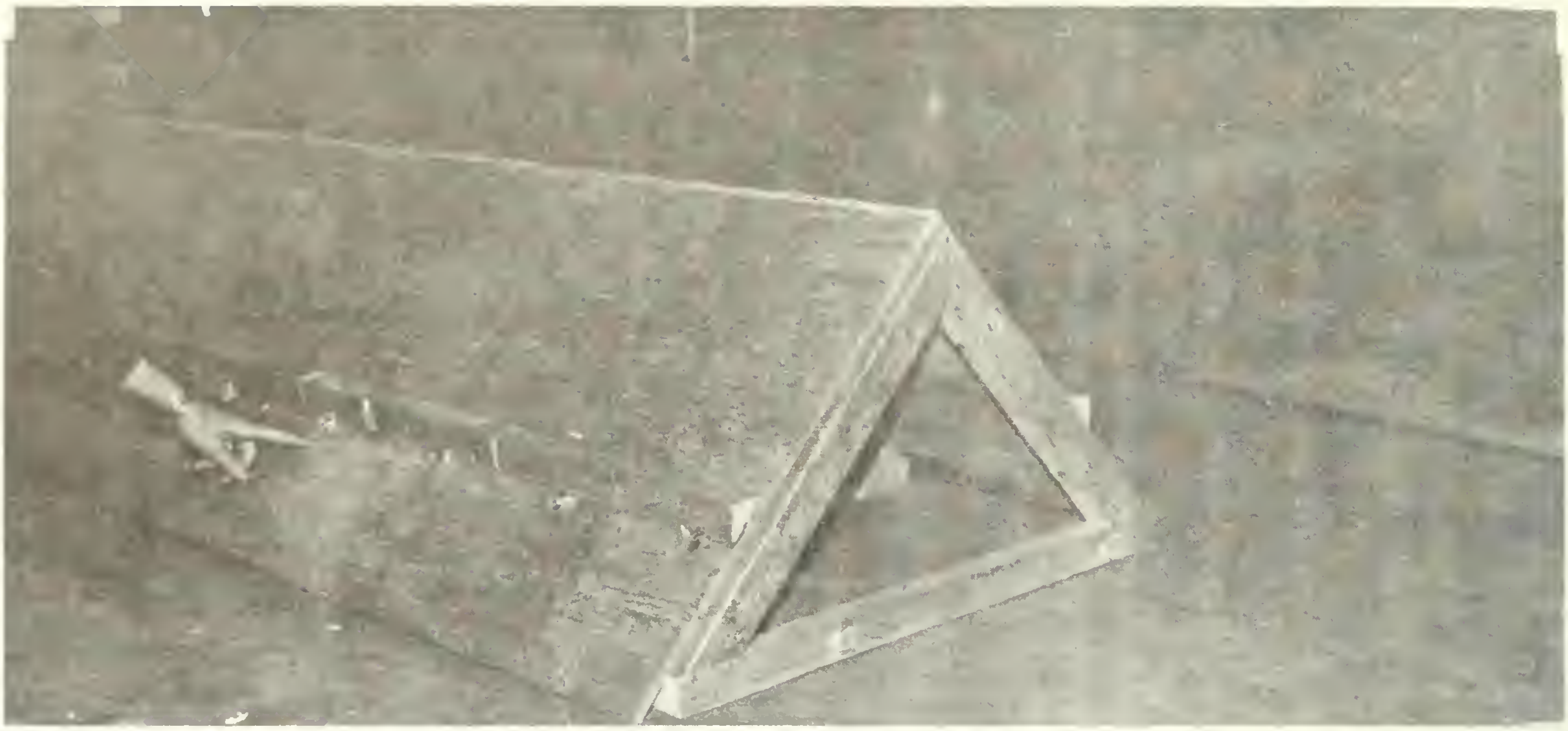


Fig. 22 Triangular above floor duct. Note air discharge holes (see text).

Humidity Control

The relative humidity (RH)* of the storage air has an influence on pressure bruising, weight loss and life processes. The lower the humidity in the ventilation air and higher the rate of air delivery, the higher the weight loss and the incidence of pressure bruising will be. Wounds on potatoes stored at low humidities often fail to heal while tubers stored at 95% RH usually heal rapidly. The maintenance of a high relative humidity is particularly important during the harvest and cooling periods, when high volumes of air are brought into the storage. The storage operator should endeavour to hold the relative humidity at 90-95%. During the drawdown period, dehydration can be reduced by avoiding the introduction of ventilation air at temperatures much below storage temperature.

There is considerable evidence that regional conditions determine the need for special humidifiers in the storage. In humid potato-growing areas, as in the Atlantic Provinces for example, nighttime humidities during the curing period are usually in excess of 85% during the period September 15 to November 30. Since outside air is seldom suitable for cooling during the daylight hours and is not introduced into the storage, the days of high water loss are considerably reduced. In drier areas, such as in southern Alberta, where nighttime (8:00 PM to 8:00 AM) humidities remain low, the provision of mechanical humidifiers is considered essential if wound healing is to be promoted and excessive weight loss avoided.

Little research on the need for humidifiers has been conducted in Canada. Tests conducted in the Atlantic Provinces have indicated humidities as low as 70% in a number of storages. All the low relative humidities were in storages where exhaust fans were used and may have been due to overventilation. Records obtained from two storages equipped with proportioning ventilation systems showed humidities of 90% or higher in the period December through March.

The most efficient method of maintaining humidity is to use centrifugal-type humidifiers. In the capacities normally used in potato storages, the cost is approximately $650. Centrifugal humidifiers should be mounted in the fan house downstream from the fan. Since they offer resistance to airflow, the fan house or main duct should be designed to accomodate the type of humidifier selected. Small, residence-type humidifiers are not effective.

*Relative humidity is expressed as a percentage. It is defined as the amount of moisture in the air at a given temperature, compared with the amount of moisture the air would hold if completely saturated at this temperature.

Potato farmers should be conscious of the effect of low relative humidities and should equip themselves with an instrument for measuring humidity. If the humitity in a potato storage is below 90%, steps should be taken to add moisture to the air. This is particularly important during the cooling period. Consult the potato storage specialist in your area for advice on the selection of a humidifier.

If a centrifugal humidifier is not available, excessive dehydration can be partly controlled by:

- Placing wet burlap sacks in the airstream. A low pressure spray nozzle can be located to spray water on these sacks.
- Keeping floors of ducts covered with water.
- Use a special air atomizing nozzle to spray water into the air.

Heating

If a storage insulated as specified in this bulletin is filled to 50% of capacity, sufficient heat will be provided by the potatoes to maintain required storage temperatures.

Additional heat will be required if:

- The storage is filled to less than 50% of capacity during prolonged cold periods (−10° to −20°F for periods of 4-5 days).
- Outside doors are being opened to ship potatoes on cold days.
- Reconditioning is required.
- The humidity has become too high and condensation is occuring.

It will then be necessary to replace wet storage air with cold outside air that is preheated before entering the storage area.

TABLE 6 — RECOMMENDED INSIDE DIMENSIONS *OF RECTANGULAR, ROUND AND TRIANGULAR DUCTS FOR DIFFERENT AIR CAPACITIES

Approximate Air Capacity* (cfm)	Rectangular Ducts (w, h)		Round Ducts (d, inches)	Triangular Ducts (s, inches)
	Above Floor (w x h, inches)	Cast-in-Place** (w x h, inches)		
800	12 x 10	20 x 6	12	16
1075	13 x 12	20 x 8	14	19
1400	17 x 12	20 x 10	16	22
1800	22 x 12	20 x 13	18	25
2175	26 x 12	20 x 16	20	27
2650	32 x 12	20 x 19	22	29
3025	27 x 16	20 x 22	24	31
3700	33 x 16	20 x 27	26	35
4275	34 x 18	20 x 31	28	38
4900	35 x 20	20 x 35	30	40
5600	34 x 24	20 x 40	32	43
6300	32 x 28	20 x 46	34	46
7000	36 x 28	20 x 51	36	48
7875	36 x 32	20 x 57	38	51
8725	36 x 35	20 x 63	40	54
9625	36 x 38	20 x 69	42	57

*Based on duct air velocity of 1000 fpm and smooth inside duct surface. If ducts are corrugated or have exposed inside framing, increase duct size accordingly.

**20-inch minimum width for mechanical unloading equipment.

TABLE 7 – TYPICAL COSTS OF AUTOMATICALLY CONTROLLED PROPORTIONING SYSTEMS

			Approximate costs*			
Size of storage, cwt	Air delivery required, cfm @ 1" static pressure	Fan HP required	Fan & controls	Installation, electrical supply, ductwork, fan house & damper	Total, complete system ready to operate	Cost per cwt
			$	$	$	¢
8,000	4,800	1	1,400	1,000	2,400	30
16,000	9,600	2	1,500	1,200	2,700	16.8
24,000	14,400	3	1,700	1,300	3,000	12.5
33,000	19,800	3	2,000	1,500	3,500	10.6

*Considerable variation can be expected due to regional differences in labor and material costs.

Heat may be supplied by using gas or oil-fired, hot-air furnaces or electric heaters.

Furnaces – A furnace with a capacity of about 100 Btu/ton (5 Btu/cwt, 8.4 Btu/bbl or 3.3 Btu/bu) is usually selected for heating the storage. If the furnace is also used to heat a separate grading room it will be necessary to calculate the heat loss from this area and to size the furnace accordingly.

The furnace should be installed in accordance with local safety and fire regulations.

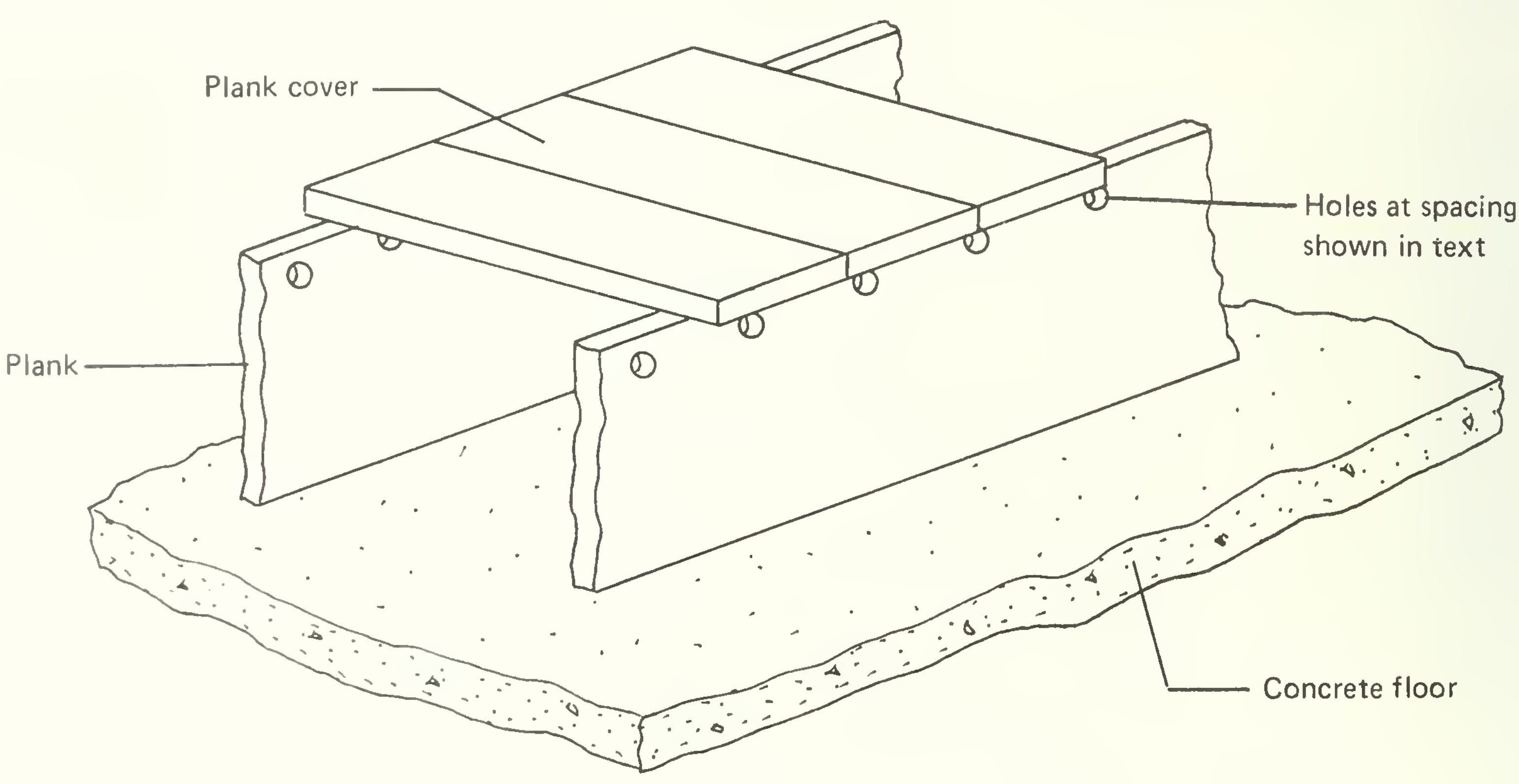


Fig. 23 Rectangular above-floor delivery duct.

Fig. 24 Portable ventilation fan unit attached to duct opening.

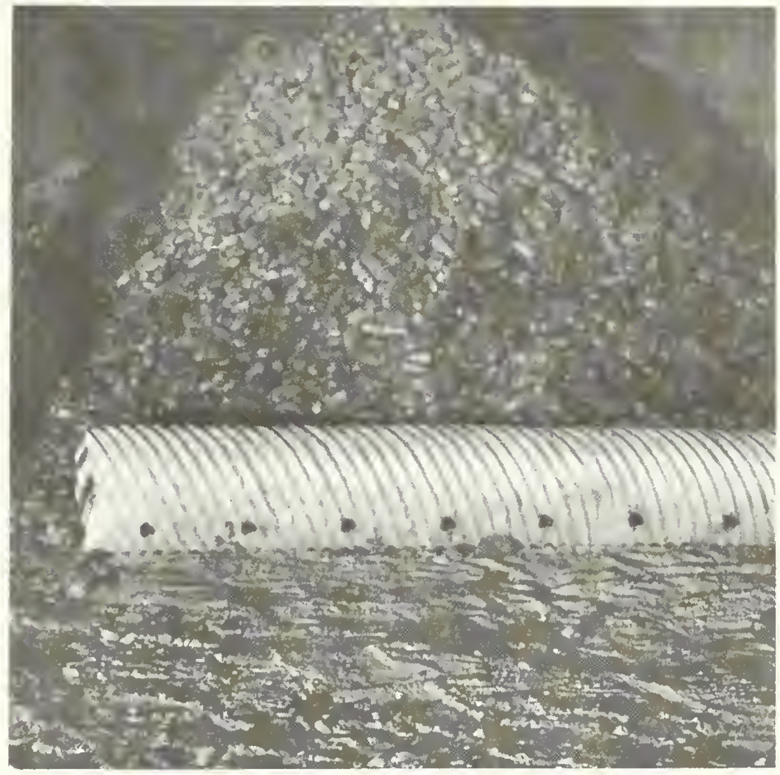


Fig. 25 Corrugated metal duct for above-floor air distribution. Note air discharge holes.

Fig. 26 Air delivery system using wall and bin partition spaces as air ducts.

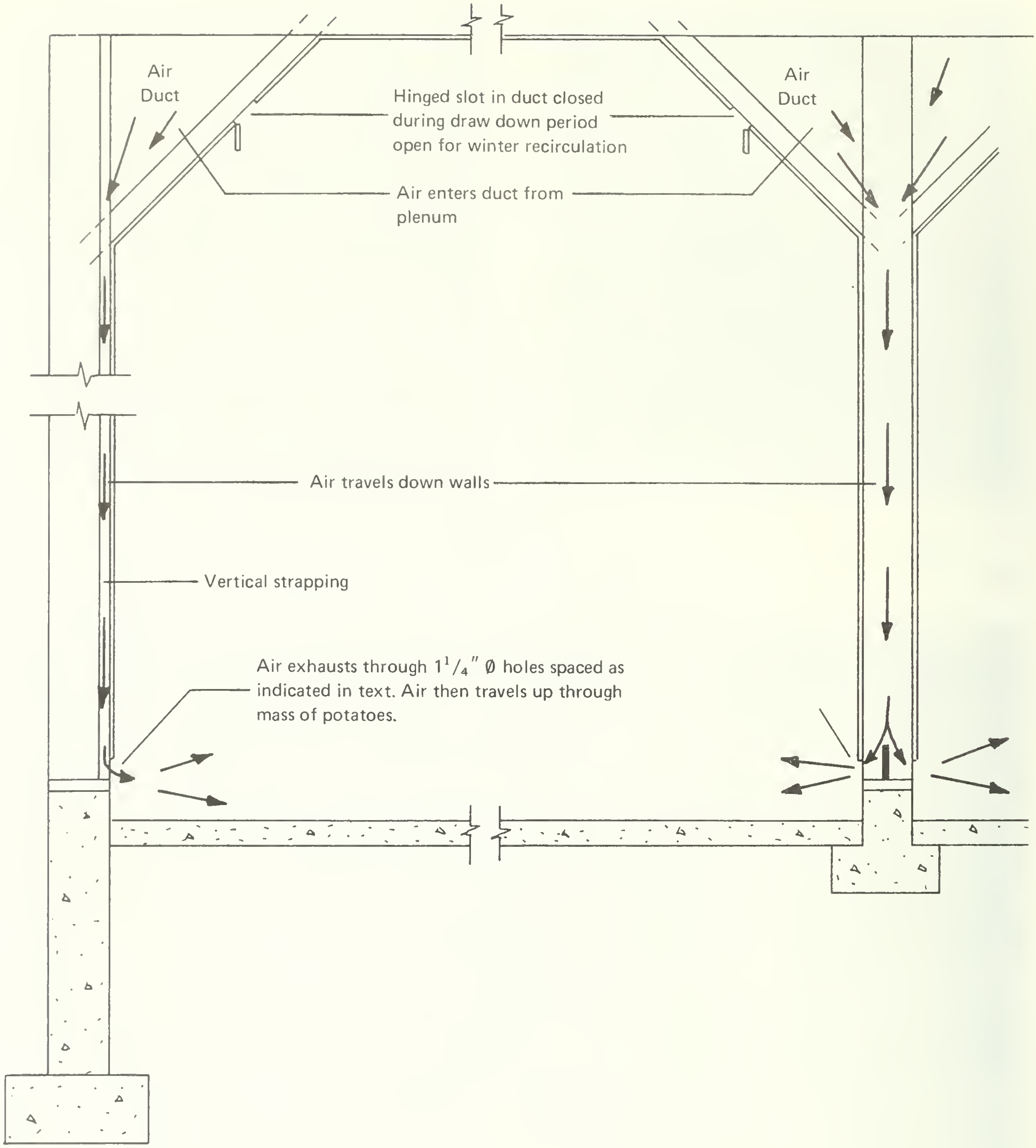


Fig. 27 Construction of wall delivery duct.

Condensation Control

Condensation, or sweating, is a common problem in potato storages during prolonged periods of subzero temperatures. It is quite acceptable for ceilings and walls to be damp as long as water droplets do not fall on the potatoes.

The provision of adequate insulation is essential if this problem is to be minimized. However, at recommended relative humidities (90-95%) sweating or condensation will occur on any surface that is more than 2°F colder than the air to which it is exposed. It is impractical to provide the insulation required to maintain interior surface temperatures very close to inside air temperatures. Therefore, in addition to adequate insulation, good air circulation and humidity control are essential.

When it becomes necessary to control condensation by permitting a temporary reduction in storage humidities, the storage should be operated as follows:

Storage Equipped with Proportioning Ventilation System — Start furnace by setting thermostat slightly higher than storage temperature. Heat produced will rise to the ceiling and be drawn into the fan house. This will automatically cause the damper to open and outside air, in sufficient quantity to cool air to storage temperature, will be blended with the air from the furnace. Check conditions in the storage by observing condensation on the ceiling and measuring humidity. As soon as condensation disappears, stop furnace. Damper will close automatically when return air from storage is at desired temperature.

Storages with Exhaust Fans — Start furnace by setting thermostat slightly higher than room temperature. Open door or intake to admit outside air. Start exhaust fans. It is recommended to preheat the incoming air in a small room before admitting it to the storage area. This will help prevent fogging and/or freezing.

WARNING: AIR MUST BE ADMITTED TO STORAGE OR FANS MAY REDUCE AIR REQUIREMENTS FOR BURNER CAUSING A FIRE HAZARD. IN DRIER AREAS, THIS PRACTICE OF USING FURNACES AND ADMITTING AIR SHOULD ONLY BE USED AS A LAST RESORT BECAUSE IT REDUCES STORAGE HUMIDITY AND RESULTS IN POTATO WEIGHT LOSS.

IMPROVING PRESENT SYSTEMS

The proportioning ventilation system is the only system that offers optimum control of potato storage environment. However, as the costs as outlined in Table 7 may be prohibitive for a small grower, the following recommendations are given for improving the performance of existing exhaust fan installations.

Construct floor ducts as illustrated in Figure 12. Place ducts in the center of each bin or at 10-ft. intervals if storage is not divided. Ducts should extend to the front of the pile and the ends should be left open. This will produce some air movement through the pile as warm air rises and is replaced by air drawn into the ducts. This is the cheapest method and should only be considered as the first step.

The system can be made more effective if in addition to placing ducts in the floor, a small blower fan is purchased. This may be moved from bin to bin and used to force air into the duct. The fan selected should have a capacity of .6 cfm/cwt, 1 cfm/bbl or .36 cfm/bu.

It is also recommended that some or all of the exhaust fans be removed from their present location and used as intake fans. They should be mounted as shown in Figure 12.

The louvers should be left in their present location to serve as outlets. The small mixing damper shown in Figure 12 is used to blend inside and outside air, to avoid bringing freezing air into the storage. The portable fan should be moved once or twice each day and allowed to run continuously during the cooling period. During the holding period, it should be operated one hour each day on each bin.

Heat for humidity control can be added and distributed uniformly through the storage using this system. In the hands of a careful operator results obtained should approach those of the manually controlled proportioning system, but it will still be impossible to obtain all of the benefits of the automatically controlled proportioning system.

Storage operation requires a skilled and knowledgeable operator. If you don't know, ASK.

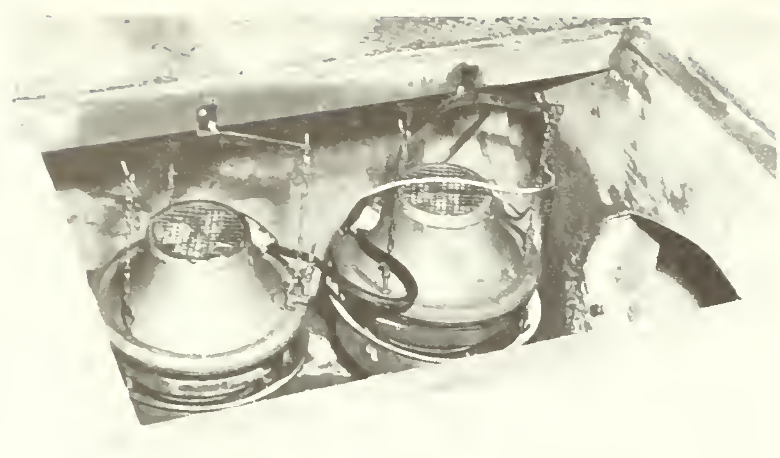


Fig. 28 Centrifugal humidifier installed in supply duct.

STORAGE MANAGEMENT

Storage management is a continual process that includes all aspects of the potato operation from preharvest until the storage is cleaned up following the marketing season.

BEFORE HARVEST

The storage should be thoroughly cleaned and disinfected. Repairs or preventive maintenance should be completed.

The ventilation system should be started and checked out. This is very important if the storage has an automatic proportioning system. To ensure efficient operation of the system:

- Check fan for free operation; clean dust and dirt from blades.
- Check damper for free movement.
- Check all thermostats and controls to see that they are functioning.

The storage's walls and floor should be sprayed with water and kept wet for a week before harvesting. This is especially important in new storages as it helps reduce initial moisture loss from the potato.

The storage should be precooled before potatoes are put into it.

CURING PERIOD

It is important that stored potatoes 'suberize' or heal, quickly to keep out disease and rot organisms. The first 10-14 days of storage are referred to as the healing period. During this time, the potatoes should be held at 55°F and 95% relative humidity.

Temperatures will normally remain at this level or higher because of field heat and heat of respiration. Since wound healing requires oxygen, air movement through the pile is essential at this time. It is also required to maintain uniform temperatures throughout the storage. If cooling air has a low relative humidity, water loss may be accelerated. Ventilate only at night when relative humidities are high and, if necessary, install a humidifier.

If potatoes have blight infection, cool and dry them immediately.

COOLING PERIOD

Following the curing period, the ventilation system should be utilized to its fullest extent to cool the stored crop to its recommended holding temperature (see page 7). A proportioning damper ventilation system makes optimum use of cold night air and gradual cooling results. A maximum cooling rate of 1°F/day is possible under normal fall temperatures.

To minimize weight losses during the cooling period, the use of a humidifier is beneficial (see page 30). If a humidifier is not used, try to limit the temperature of the cooling air in the ducts to within 3-5°F of the potato temperature. Normally, ventilation should be done during the period 8:00 p.m. and 8:00 a.m., as relative humidities during the night are usually 85% or higher. This will help maintain a satisfactory relative humidity.

HOLDING PERIOD

Once the recommended storage temperature is reached, ventilation through the pile is needed only to maintain a uniform temperature. This is most important for potatoes used for processing. Fluctuating temperatures may cause condensation within the pile and speed up sprouting.

Potatoes are continually giving off moisture in the form of water vapor. Unless this moisture is removed from the storage, the air will become completely saturated (100% RH) and excessive sweating and fogging will result. During severe cold spells, the relative humidity in the storage may have to be reduced to avoid excessive condensation (see page 36). When the weather moderates, the RH can be allowed to build up to its recommended level.

Excessive ventilation and/or supplemental heat increases shrinkage (water loss from tubers). Above-normal shrinkage results in increased losses due to pressure bruising, lower quality and less weight to be marketed.

During a 180-day holding period, normal shrinkage should not exceed 5% by weight. A 10% shrinkage seriously reduces the weight of potatoes that can be sold.

MARKETING PERIOD

The marketing period may vary from a few weeks following storage to 8-12 months. Potatoes stored under good management should maintain good quality for 8 months. Refrigerated storage would be required for a 12-month market season.

It is recommended that potatoes be warmed to 50°F before handling to avoid bruising and cracking. The potatoes should be graded in an area separated from the storage area. To avoid fogging and condensation, do not open the large doors on cold days.

INSTRUMENTS FOR MEASURING TEMPERATURE AND HUMIDITY

A storage manager must know the conditions existing in the storage at all times if he is to maintain proper temperatures and humidities.

An ordinary household thermometer is recommended for measuring air temperature within the storage. It is also helpful to have a thermometer over each bin to indicate air temperatures at the ceiling and give some idea of the temperature of air rising through the pile.

Remote temperature sensing is possible by using thermocouple wires. Temperatures within the pile can be read from anywhere within the building. Cost of wiring an average storage with thermocouple wires is between $50 and $100. The meter for use with these wires costs about $400; since it is portable, it could be used by a number of growers.

Humidity measuring instruments are available for $25 and up. The simplest and most basic of these is called a sling psychrometer. This instrument has two thermometers mounted side by side. The dry bulb thermometer measures the actual temperature of the air. The wet bulb thermometer has a wet wick attached to it. As this instrument is rotated by hand, the wet bulb temperature is depressed due to the evaporation process requiring heat. The relative humidity of the air is determined from a (pyschometric) chart (see Appendix B) using the temperature difference between the two thermometer readings.

Various forms of dial-reading, relative-humidity meters are available. These should be calibrated once or twice during the storage season by comparing the dial reading with that of a sling psychrometer.

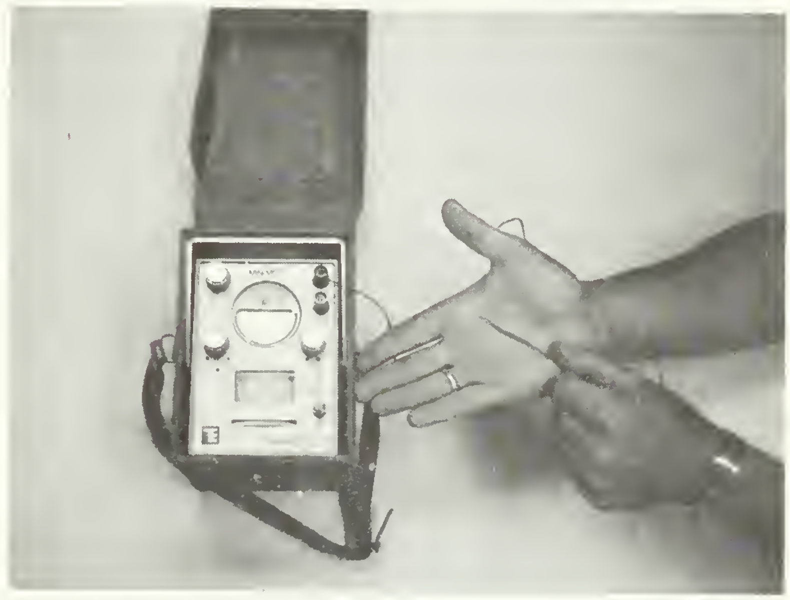


Fig. 29 Potentiometer used with thermocouples to measure temperatures within the potato bin.

Fig. 30 Sling psychrometer (left) and dry bulb – wet bulb meter (a small fan blows air over the wet and dry bulbs).

POTATO HANDLING IN STORAGE

The quality of potatoes leaving a storage will be no better than when they were stored. It is important that potatoes entering the storage be mature, free from disease, mechanical injury, rocks and debris. Obvious diseased tubers and debris should be removed as the potatoes enter the bin piler.

Potatoes may be damp or have damp soil on them without this reducing storage quality. It is very important not to store potatoes that have free water (that is, rain) on their surface, as this usually causes severe rotting.

CONVEYING POTATOES INTO STORAGE

Operation of a bin loader for delivering potatoes from bulk trucks to the storage pile is the first phase of potato handling in storage.

A bin loader that will allow for efficient operation and reduce bruises should have the following features:

- An easily adjustable hopper height to keep the drop of potatoes from the truck to a minimum.
- A hopper with sufficient capacity to prevent spilling.
- A short draper chain conveyor between the hopper and the boom conveyor to allow dirt to sift through.
- Provisions for connection of electrical outlets convenient to the operator, with a reel for storing excess cords.
- Sufficient length of boom conveyor (about twice the height of the pile), so that it will never operate at an inclined angle in excess of 45°.
- A wide range of swing for the boom conveyor.

Careful operation of the bin loader can prevent excessive damage and give higher returns to the grower. To reduce damage when using a bin loader:

- Assign one man to operate the bin loader and supervise the unloading operation.
- Use a progressive bin filling procedure to prevent rolling (Figure 31).
- Use straw-filled bags or baffle boards to prevent potatoes from rolling to the floor under the bin loader. This will greatly reduce floor crushing and speed the moving operation.
- Keep all drops to less than 8 inches.
- Pad all sharp edges or metal sides.
- Insure that all chain conveyors are rubberized.
- Remove any stones or diseased potatoes carried from the field, by having a sorter work beside the hopper.

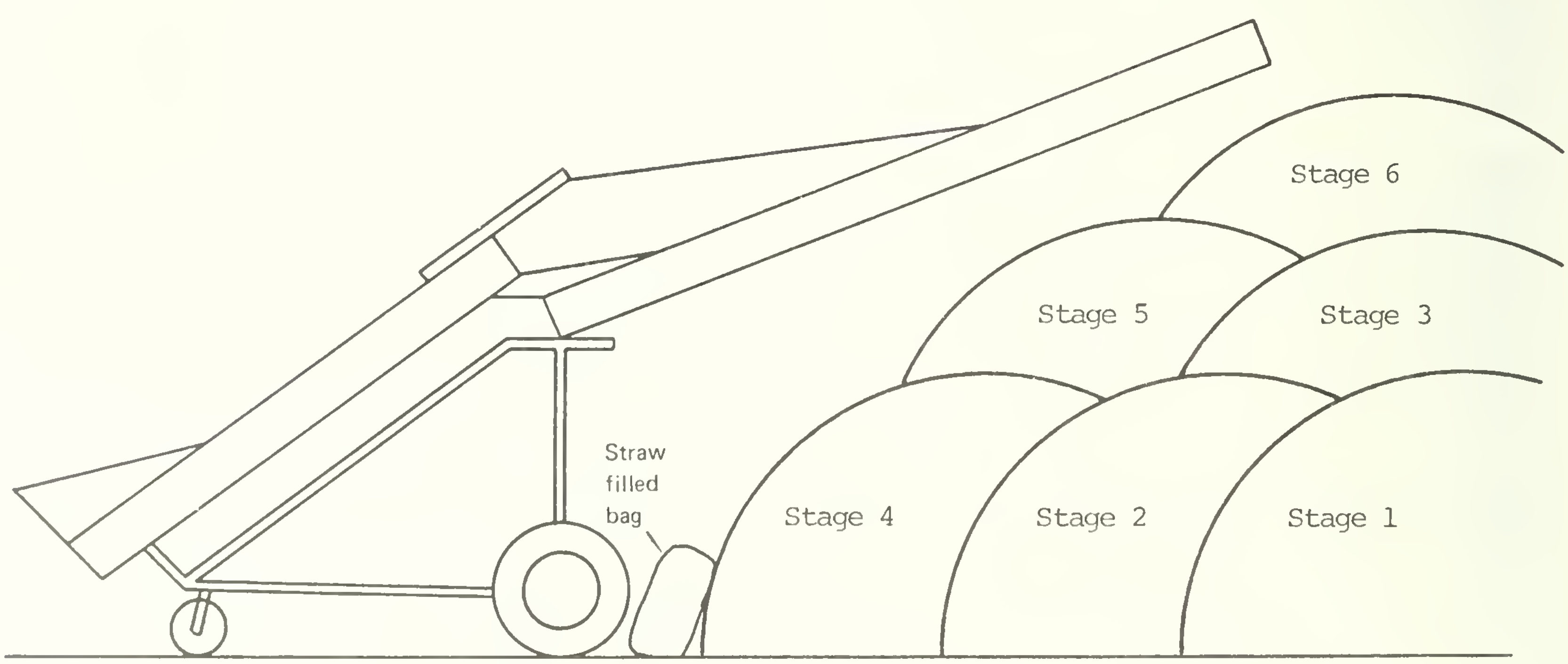


Fig. 31 Load placement with progressive bin filling to prevent rolling.

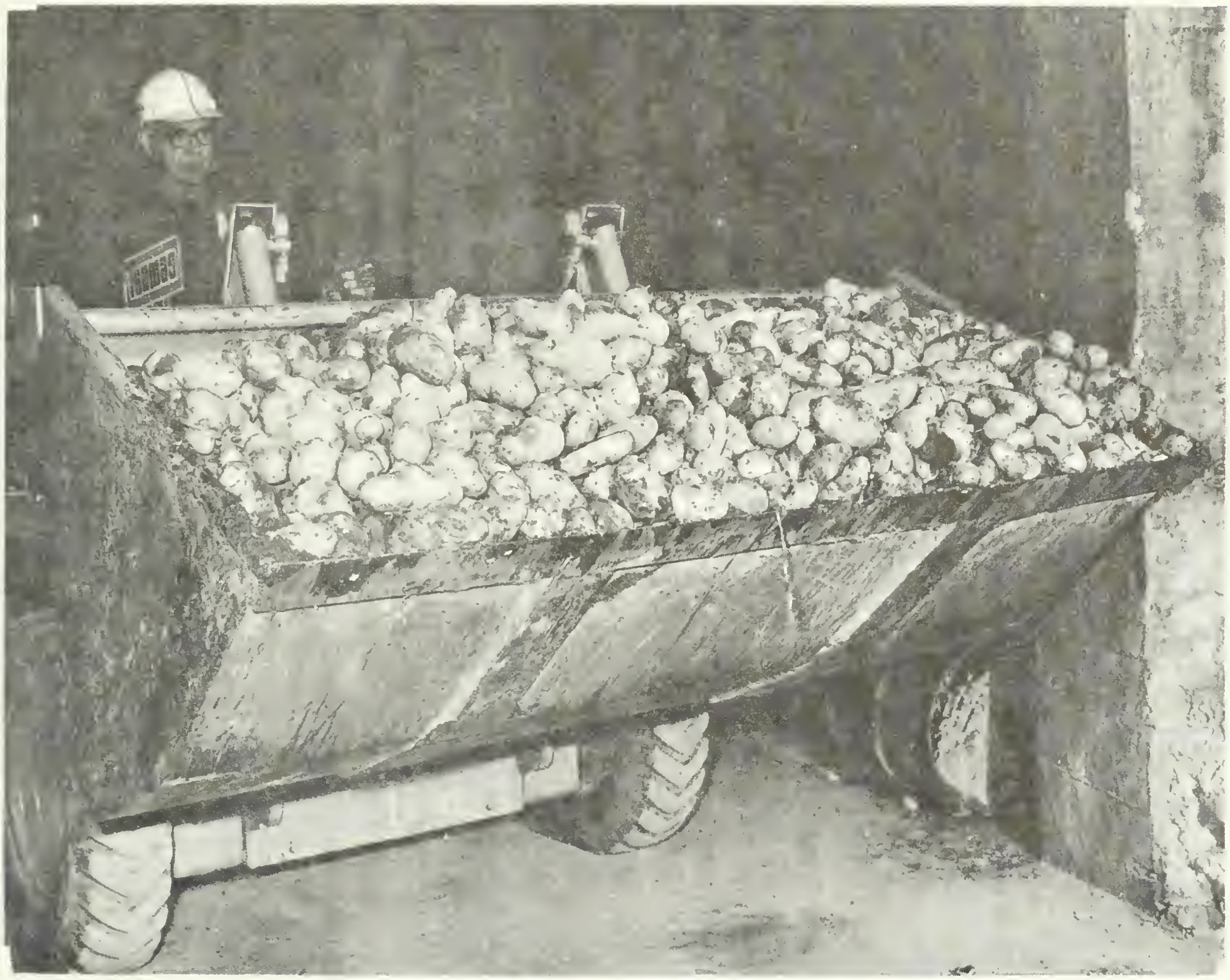


Fig. 32 Features of a well-designed potato bucket. Note pipe welded to edges.

MOVING POTATOES FROM BINS TO GRADING LINE

Various methods are used to unload storages. The most desirable one to use depends on the design of the building, required capacity, methods of handling and processing after storage, and so on.

Bucket Loader

A bucket loader is the most popular machine to use for unloading storages. Types of loaders available include fork lifts, industrial loaders, electric loaders and custom-built loaders.

The design of the bucket on the loader should include the features shown in Figure 32 to minimize potato damage. For increased capacity the bucket should be made wider and not deeper. Shields or skirts to prevent potatoes from rolling under the machine will reduce damage from floor crushing. When scooping potatoes, the least damage occurs when only the loose potatoes at the bottom of the pile are picked up and the bucket is not forced into a hard pile.

Conveyor Scoop

This consists of a metal scoop that tapers to meet an inclined belt conveyor at the rear. The wheels of the undercarriage are driven by an electric motor which provides the drive to push the scoop under the pile and the potatoes onto the first conveyor. The potatoes are then delivered to the grading line or a bulk truck by a telescopic conveyor. Being able to pivot between the scoop and the telescopic conveyor allows the machine to work in small areas and around posts, while always conveying potatoes to the same spot. The whole operation is carried out by one man sitting on the machine.

Flume System

If the potatoes are to be washed, a flume supply system can be used. This is one of most efficient and flexible handling systems for moving potatoes from the storage pile to the packing line. For further information on this system, contact an agricultural engineer.

POTATO GRADING

Potato grading equipment should be carefully selected to ensure that it has sufficient capacity and that maximum production will be realized from each component. The components needed for grading and handling depend on the type and volume of output. Most systems for table potatoes include some type of supply system, sizing machinery, washing or other cleaning equipment, grading or sorting tables, equipment for packing and, finally, conveying and handling equipment for packaged table stock and other grades of potatoes. Processing and seed potatoes generally have to be conveyed, sized and

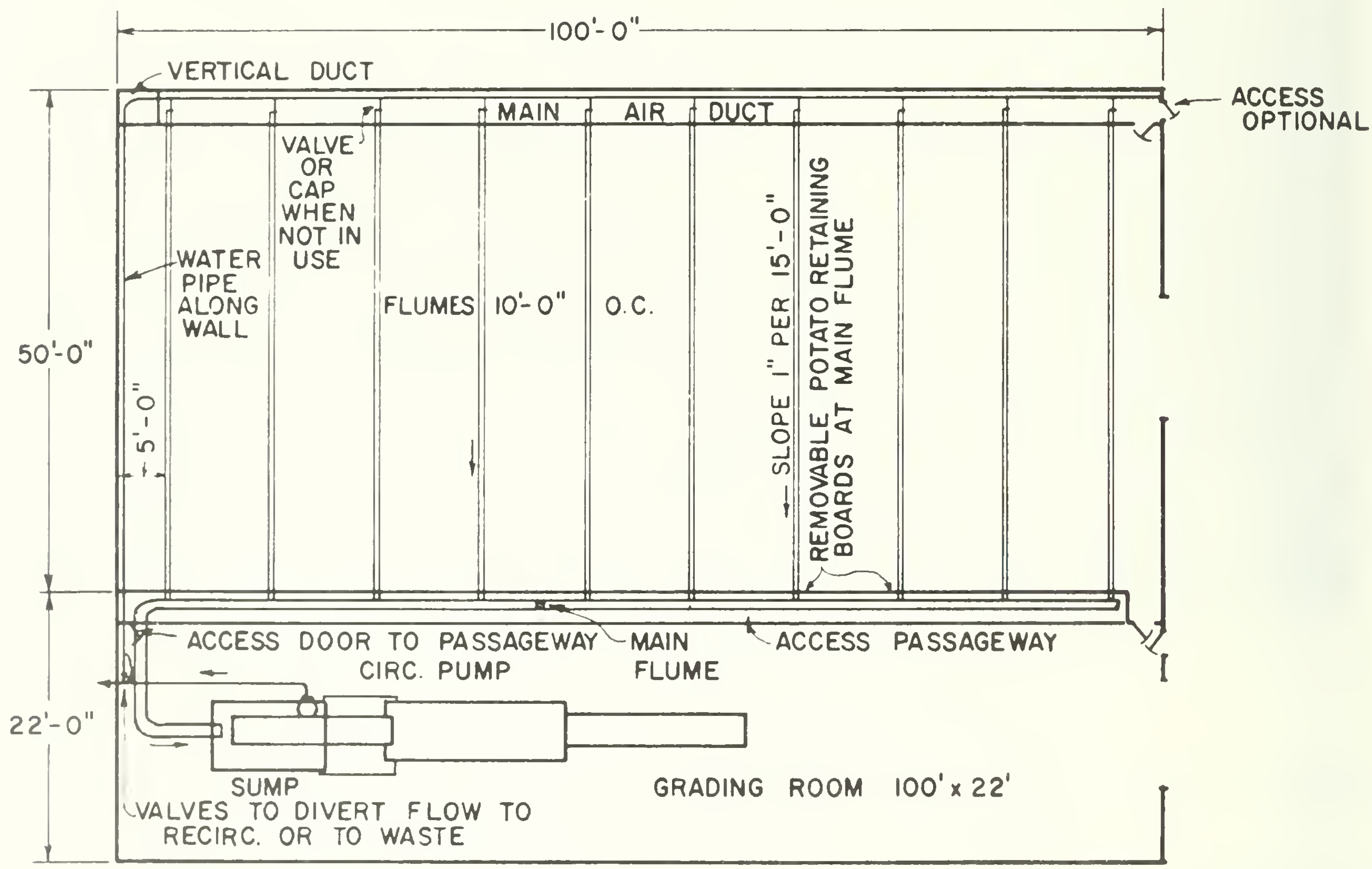


Fig. 33 Typical storage layout where potatoes are handled by fluming.

Hopper

A hopper that acts as a reservoir to keep a constant flow to the grading line should be used with all unloading methods except fluming. The hopper has a large open top to allow easy filling with a bucket loader. A small conveyor at the bottom with a variable speed drive feeds the grading line at the desired rate. The interior of the hopper should be padded, and the chain rubberized.

graded, but do not require elaborate cleaning and packing equipment.

When establishing a grading line, for efficient production you should plan to:

- Grade potatoes on moving belts or roller tables; roller tables have a decided advantage as produce is rotated as it moves along.

- Place cull chutes or conveyors at the sides.
- Have one grader for each hundredweight of potatoes graded per minute.
- Use no more than two graders on each side of the grading table.
- Have graders turn towards the oncoming flow to improve their grading efficiency.
- Position graders on both sides of the grading table (6′ X 3′) so that potatoes can be observed from both sides.
- Allow 3 ft of working space along the table for each grader.
- Move potatoes past graders at a rate of 21-28 fpm.
- Have the top of the grading table just below elbow height for convenience of those doing the grading.
- Install three or four 100-watt light fixtures above each 3′ X 6′ table.
- Shield lights so they don't shine directly into graders' eyes.
- Heat the grading area and insulate it from the rest of the storage.

POTATO DISEASES

Diseases causing loss of potatoes in storage are usually present when the crop is stored. The subject is too extensive to be included in this publication (see CDA publication 1492, *Diseases and Pests of Potatoes).*

Although storage diseases spread rapidly under warm, humid conditions, good storage management practices greatly minimize their incidence. If disease and rots are present in the potatoes at the time of storage, it is important to reduce the temperature as rapidly as possible to the recommended level. Air should circulate through the potatoes to remove excess moisture from the surface of the potatoes and provide conditions less favorable for rot development. When potatoes infected with late blight, bacterial ring rot, and blackleg are placed in properly ventilated storage, the decay that develops is usually dry instead of wet and losses are limited to those tubers that were infected before storage. Good ventilation prevents the development of wet pockets and the rapid spread of disease through the pile.

APPENDIX A – TYPICAL STORAGE LAYOUTS

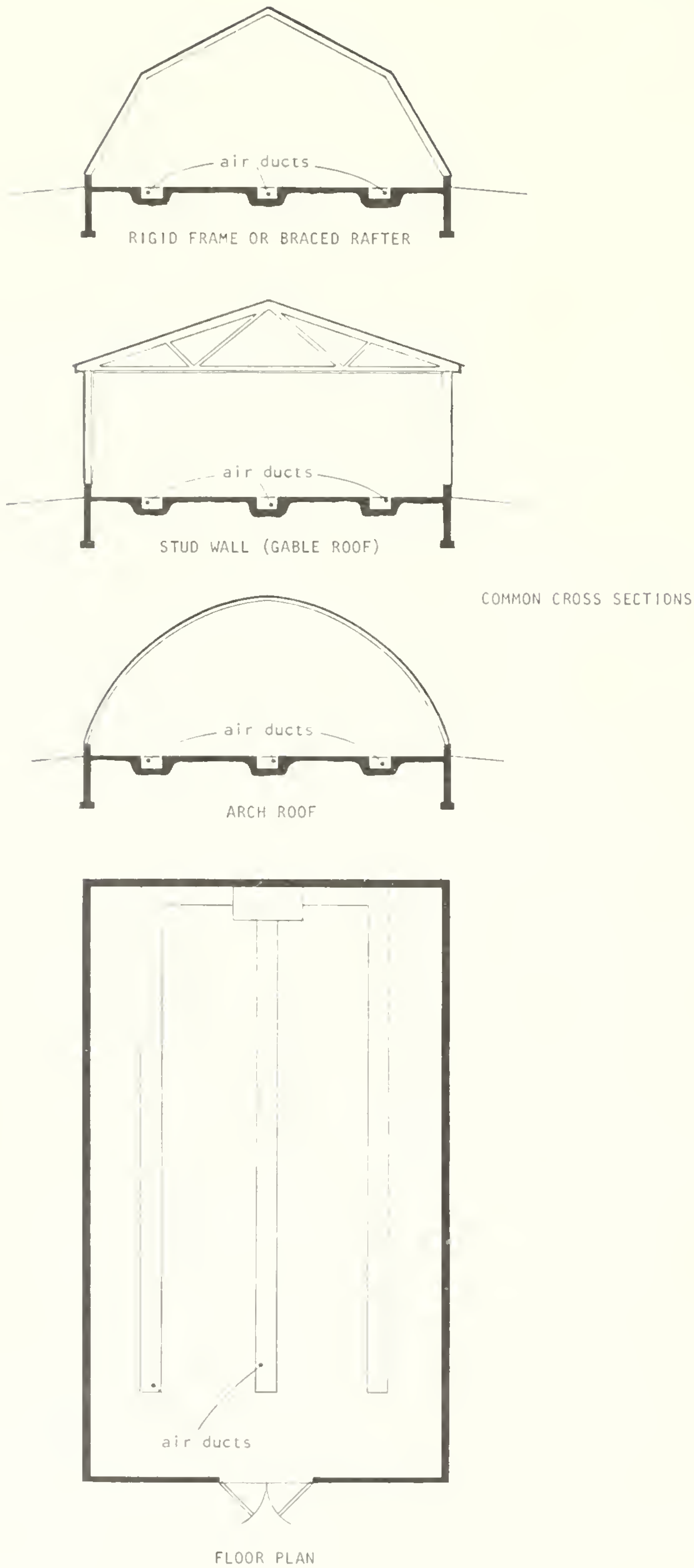
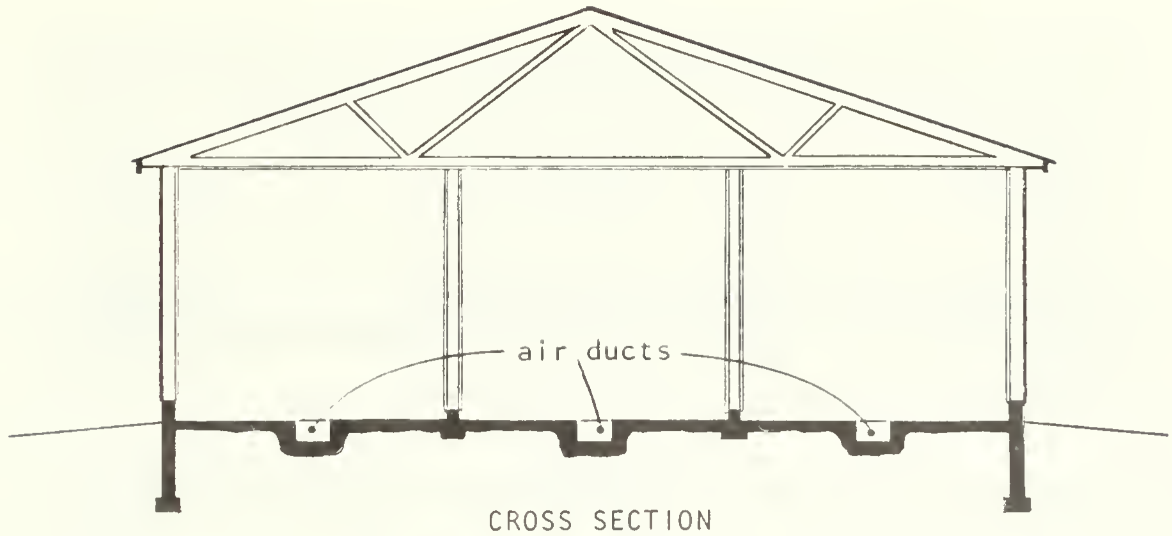
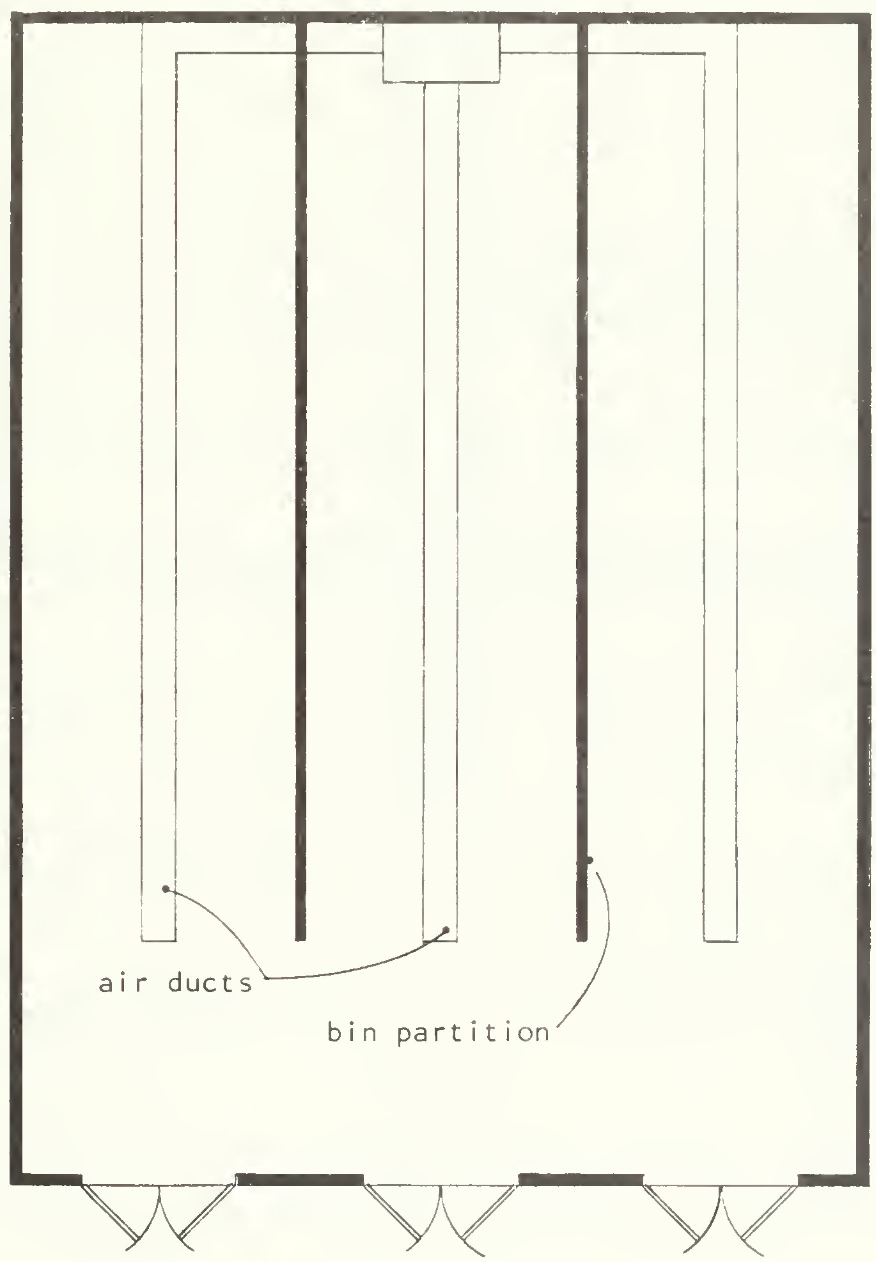


Figure A1

Bulk storage, no partitions, usual width 36′ – 50′. Three air ducts in floor. Automatic ventilation recirculation system. Frequently arch roof construction. Usual capacity 1,000 to 2,000 tons.



CROSS SECTION



FLOOR PLAN

Figure A2

Bulk storage, with bin partitions, usually vertical side walls, wood studs. 45′ – 60′ wide. Automatic ventilation system. Usual capacities 1,000 to 2,000 tons.

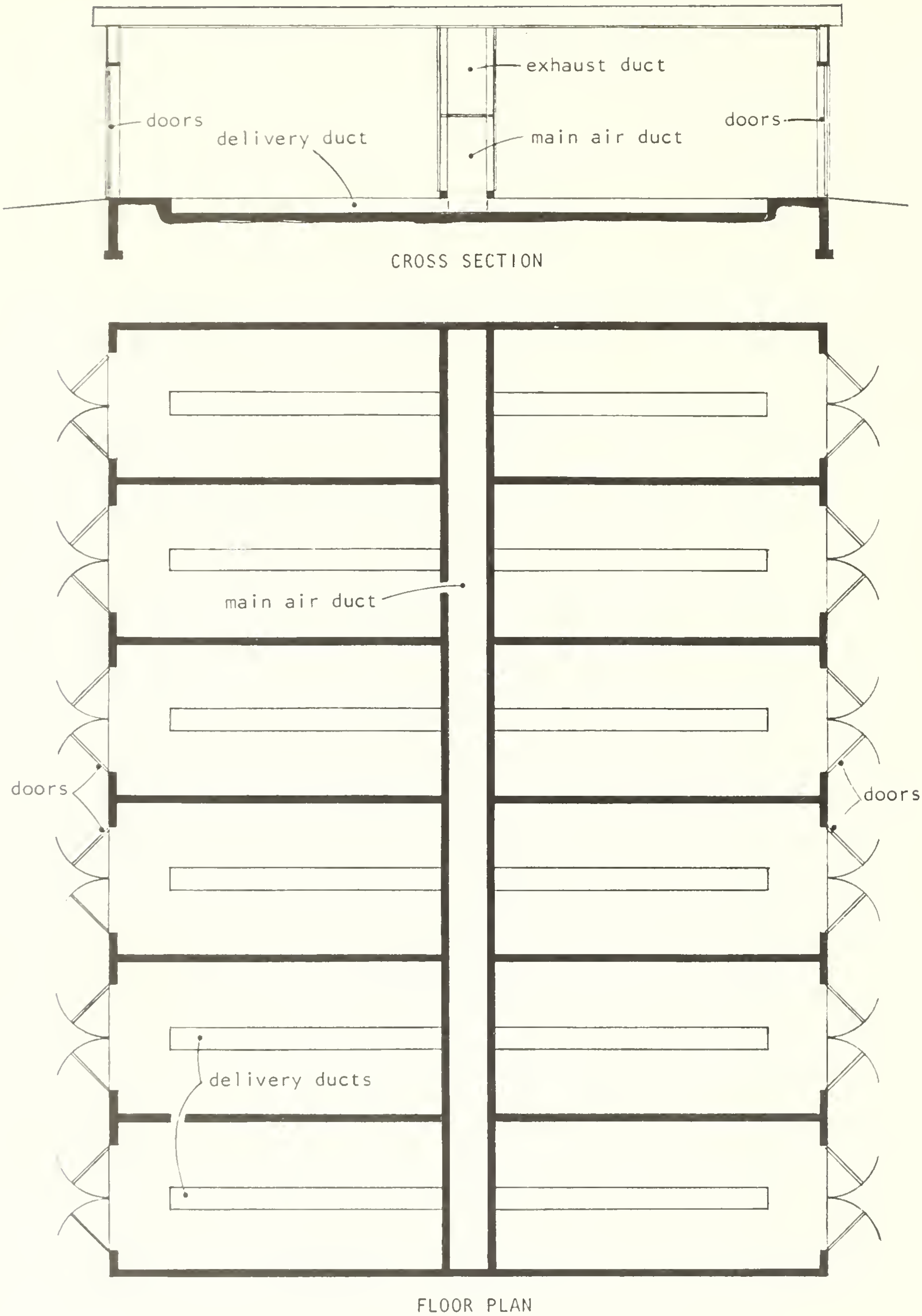


Figure A3

Common floor plan used in large storage, 3,000 to 10,000 tons. Central air delivery duct, doors on entrance of delivery ducts can be adjusted to regulate air flow to individual bins to control healing or breakdown in individual bins if required. Usually constructed with a flat roof to allow expansion. Storage is filled through side doors and emptied by fluming.

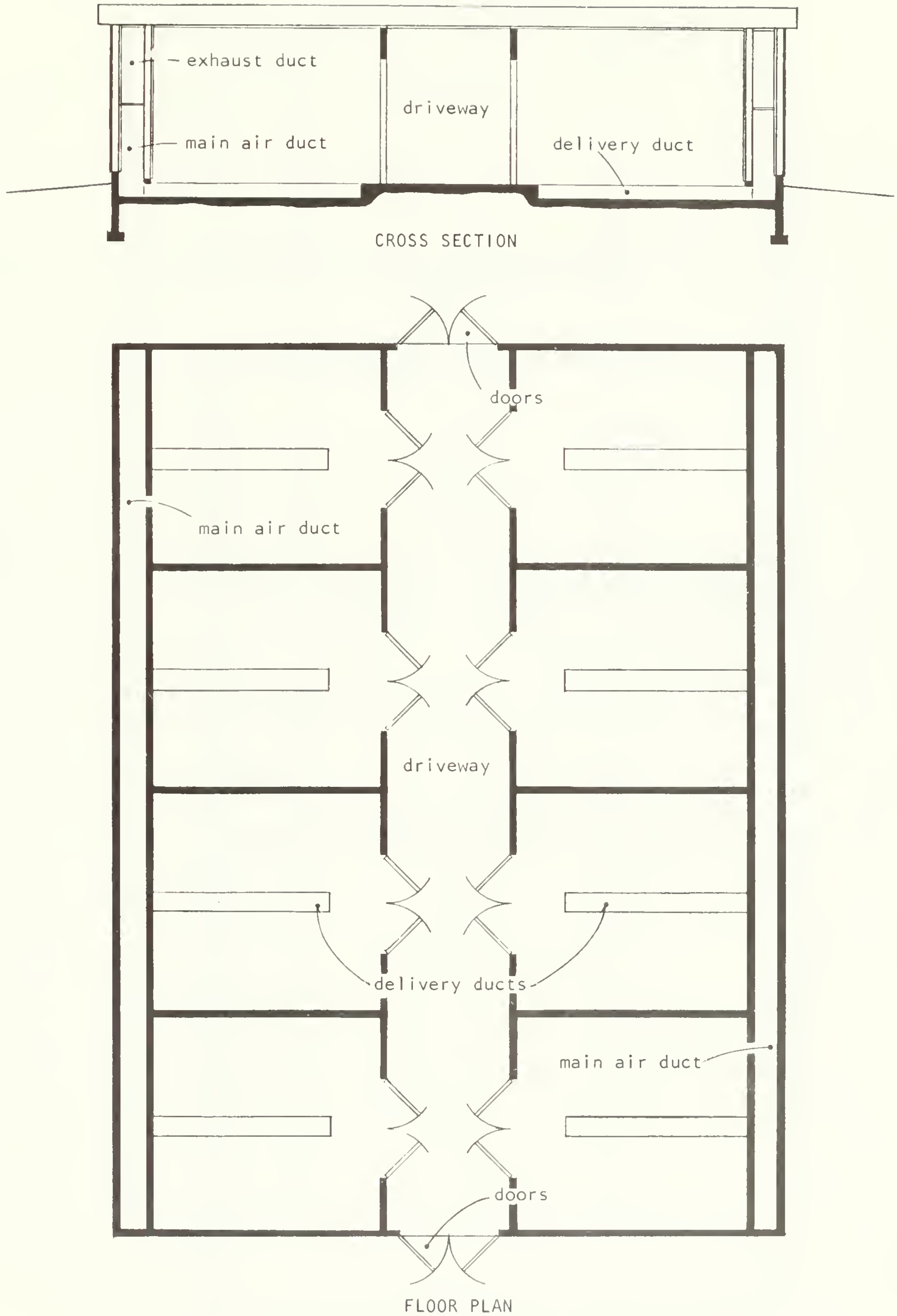
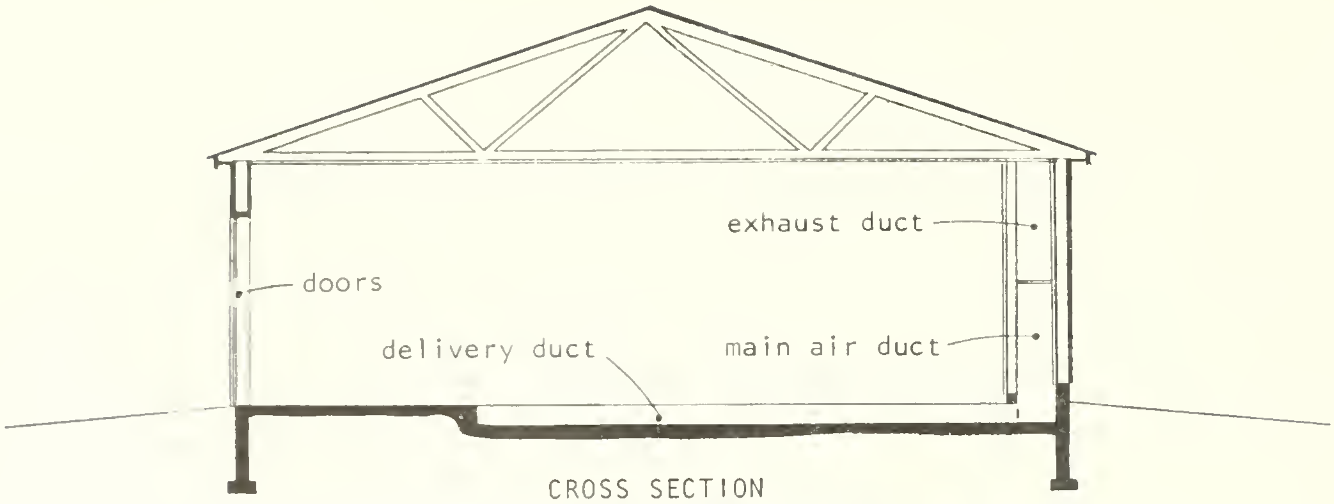


Figure A4

Common floor plans for large storages. Allows for individual control of bin ventilation. Usually constructed with a flat roof. Storage is filled and emptied through doors or by fluming. Bins may be installed at an angle to allow trucks to back in.



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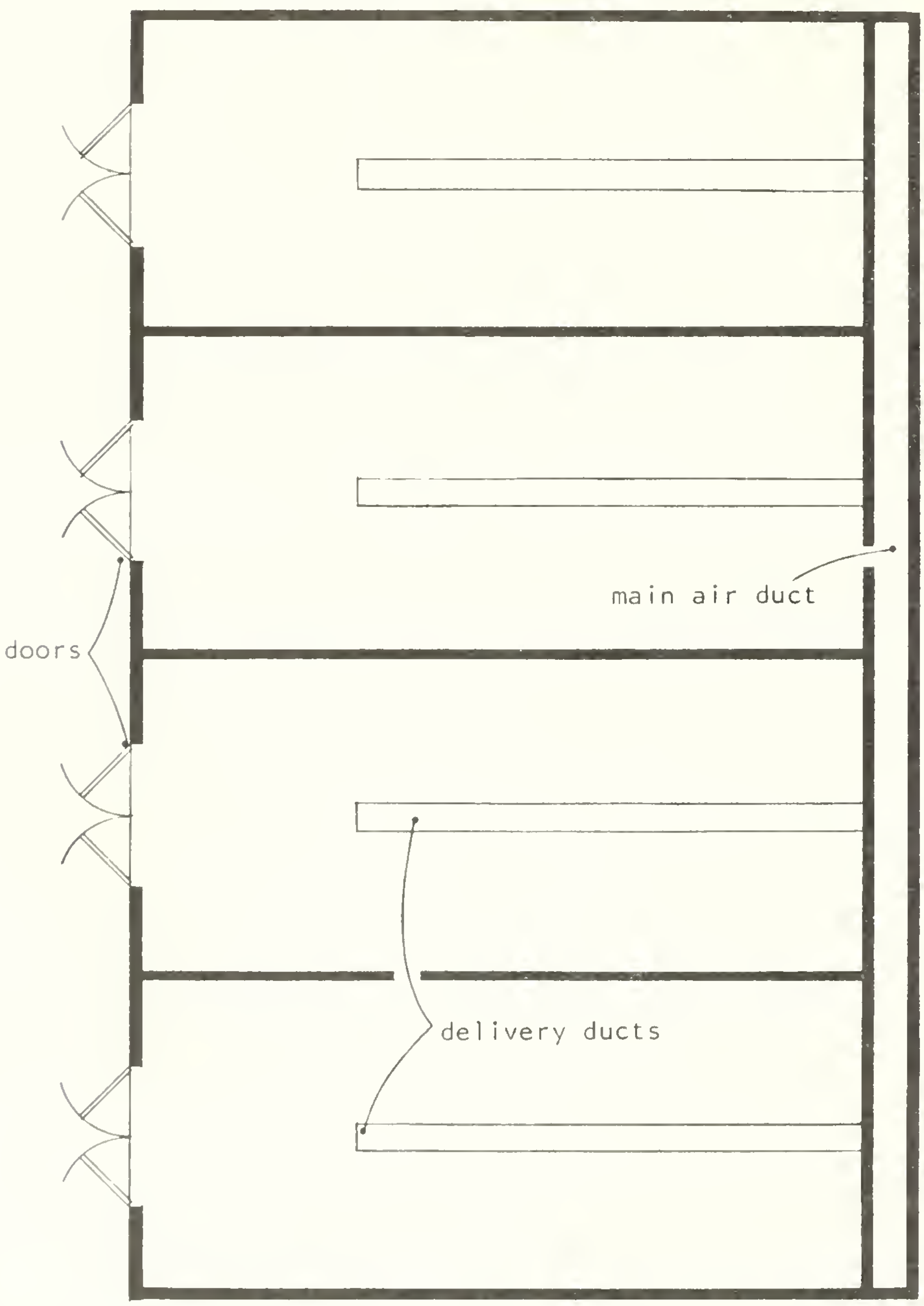


FLOOR PLAN

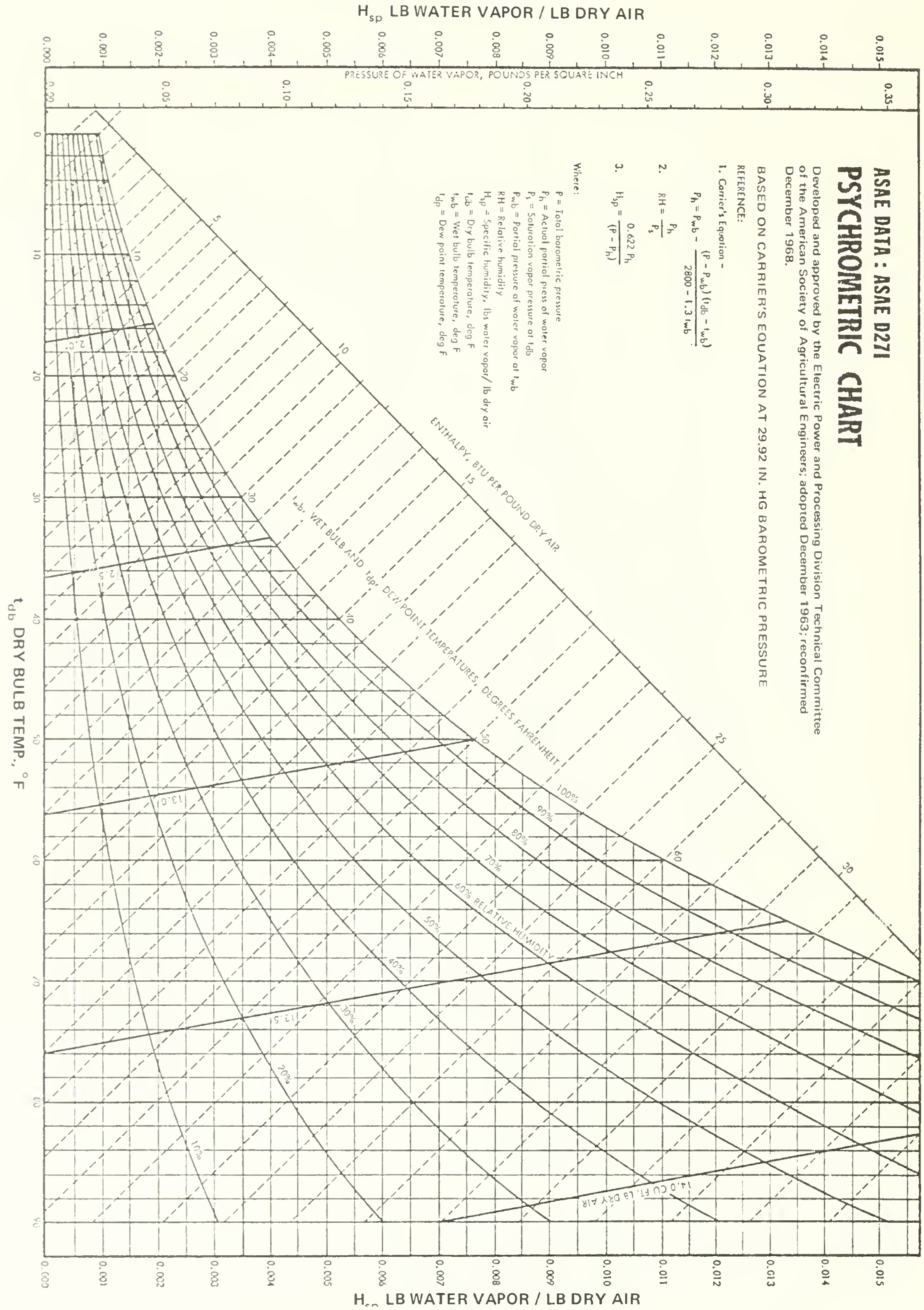
Figure A5

Common floor plan for large storage. Has bins 16-20 ft wide. Allows for individual control of bin ventilation and trucks can back directly into bins.

FLOOR PLAN
Figure A6

Common floor plan for large storage. Has bins 16-20 ft wide. Requires a more complicated air delivery system than plan in Figure A5. Ventilation equipment is usually located on mezzanine over grading area.

APPENDIX B — PSYCHROMETRIC CHART



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Prince Edward Island Department of Agriculture
Charlottetown, P.E.I.

Growing Potatoes for Processing in Prince Edward Island

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