USES OF ELECTRICITY IN POULTRY
AND DAIRY PRODUCTION AND GRAIN PROCESSING

by

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ABBREVIATIONS AND SYMBOLS

Btu  British thermal units
cfm  cubic feet per minute
cm  centimeters
deg.  degrees
F.  Fahrenheit
fps  feet per second
ft.  feet
hp.  horsepower
in.  inches
kw  kilowatts
lb.  pounds
min.  minutes
mmf  magnetomotive force
R  Rankine
sq.  square
w  watts
USES OF ELECTRICITY IN POULTRY
AND DAIRY PRODUCTION AND GRAIN PROCESSING

INTRODUCTION

The first time electrical power was put into public service was when Thomas A. Edison opened his and the world's first central electric station in New York on September 4, 1882. After that men began to realize the usefulness and qualities of electricity as compared with other kinds of energy that could be put into use. A great amount of thought, effort, and money have been spent in the searches for the knowledge of its nature and how to utilize it. As a result, electricity has become a tool so important that without it the living of men in the modern world will be extremely difficult. Electric power is nowadays providing comforts and conveniences for home and office, creating and improving methods used in industry, communication, welfare, education, agriculture, and all other types of business.

The use of electricity in agriculture can be dated back to the early days of the electrical power development itself. The October 13, 1906, issue of Electrical World reported that in 1878 there were the first serious experimental use and the first real installation in regular operation of electric farm equipment. In the
1890's some farmers in the far west states of the United States began to use electrically-driven pumps for irrigation purposes. At the present time, more than five hundred applications of electricity for the farm home and the farm have been found. These applications have benefited the farmers in several ways; the important ones are increase in production, improvement and preservation of products, reduction in labor, providing comforts and conveniences and elimination of drudgeries of farm chores.

In comparison with other kinds of energy used in agriculture electricity has several advantages; the chief ones are the ease of control, compactness and high efficiency of equipment, cleanliness and simplicity in operations. The main disadvantages of using electrical equipment are the high first costs, high energy costs, and the dependence upon the reliability of power supply.

Of all fields of farming, those that are highly suitable for electrification are several in number. These include poultry farming, dairy farming, and grain processing. Each of these operations require a great amount of equipment, much of which can be operated electrically with benefits.

A completely electrified poultry farm allows one person to take care of several thousand hens without trouble. Electricity does such labor consuming jobs as
watering, feeding, cleaning out droppings, as well as such
delicate or precise jobs as incubation, brooding, and
ventilation. On a dairy farm electricity may free a
farmer from such back-aching chores as barn cleaning, feed
handling, and may perform such sanitation-needed opera­
tions as milking, sterilization, and pasteurization. In
grain processing operations, electricity may operate fans
used for grain cleaning and drying, run the equipment used
for grain milling, and perform the handling of both the
raw materials and products.

Agricultural Uses of Electricity in Thailand

The economy of Thailand, a country in Southeast Asia,
depends principally upon agriculture, having about 65 per
cent of the total population of twenty million living on
the farm and more than 90 per cent of the total export
value being agricultural products (16, p. 147, and 17).
Farming methods in Thailand are still very much under­
developed, using mostly human and animal labor. Although
a small scale farm mechanization has been introduced with
some success, farm electrification is practically non­
existent. There are four major obstacles to the develop­
ment of farm electrification in Thailand, namely:
(1) lack of electrical power service in rural areas,
(2) low income of farmers, (3) inexpensive manual labor,
and (4) low education level of farmers.

The development of electric utilities in Thailand is still in an early stage. A rough estimation for the total kilowatt capacity of all utility power plants is about 100,000, which is solely used for supplying power for urban and suburban areas. However, plans have been made for the increase of the generating capacity; the important one of which is a hydroelectric power project in the northern part of the country, having an estimated capacity of 320,000 kilowatts (19, p. 176). Another development of natural resources which has great importance upon power generating purposes is the opening of lignite mines in the southern and northern parts of the country. It is expected that lignite will benefit the power generating industry by economically supplementing and replacing expensive and scarce firewood, imported coal, fuel oil, and Diesel oil, which constitute the fuels used in Thai power plants at the present time. When the time of abundant and inexpensive electric power arrives, the excess portion of the power from the uses in urban and suburban areas will naturally overflow to the farm.

Nowadays, Thai farmers constitute one of the lowest income group of the country. This situation provides them with a very small amount of money for buying tools and farm equipment. Therefore, it is a great
obstacle to farm electrification which requires a considerable amount of money for the purchasing and installation of electric equipment. Several programs have been conducted by the Thai government to raise the economical status of farmers; the important ones are land reclamation projects, irrigation projects, cooperative organization expansion, and research works upon the improvement of farming methods. If the outcomes of these programs are favorable, they will contribute to the growth of farm electrification in Thailand. It is obvious that farmers always desire to possess the equipment that will help in increasing their production profitably, and the main factor that prevents them from doing so is the lack of money.

Manual labor in Thailand in comparison with the United States is rather inexpensive. For the purpose of demonstration the approximate average labor cost in Bangkok, which is the greatest source and consumer of labor force of Thailand, will be used in comparison with the power cost in the same area, which consumes about 70 per cent of the total utility power production of the country. Labor cost in the Bangkok area is about 10 ticals per 8-hour day or about six United States cents per hour, one tical being equivalent to about five United States cents. The power rate is one tical or five cents per kilowatt hour. Still this seemingly high power cost
can compete favorably with the low labor cost. The Westinghouse Electric Corporation stated that "on any job that can be done by motor power a 1/4-horsepower motor will do the work of one man" (25, p. 2). Assuming a power of 1/4 kilowatt is required to operate a device motored with 1/4 horsepower motor, working for one hour electrically will cost only about 1 1/4 cents, whereas the equivalent man labor will cost six cents. A better illustration can yet be seen when one considers the statement made by the Vocational Agriculture Service of the University of Illinois that one kilowatt hour of electricity will do as much or more work than can be performed by a man in an eight-hour day (9, p. 2), or five cents working electrically as compared with 50 cents working with man labor. It is then apparent that in Thailand too, electric power costs less than manual labor. Taking into consideration the prospect of the decrease in power rate due to the new power development projects and the ever-increasing scarcity of manual labor, the growth of the uses of electricity on the Thai farms may be expected in the not too distant future.

Another important stumbling block in the growth of farm electrification in Thailand is the low educational level of Thai farmers. Most of them are able only to read and write in their native language, and also
seriously lack technical training and opportunity to get acquainted with electrical devices. This problem can be solved by providing educational facilities such as extension services, training courses, and literature. Adequate education on the proper use of electric devices will assure benefits in both the economy and safety for the farmers.

**Prospective Fields for the Agricultural Uses of Electricity in Thailand**

In general, applications of electricity on the farm may be classified into seven groups, namely, (1) crop processing, (2) dairy, (3) field operations, (4) horticulture, (5) insect, (6) livestock, and (7) poultry. Farm shop equipment is excluded from this list due to the fact that it is not farm equipment in the real meaning. Of all these, the prospective fields for electrification in Thailand are poultry production, dairy production, and grain processing. Each of these operations require numerous tasks that are adaptable for and will be beneficially served by electrification.

Although poultry farming in Thailand has been mostly of a small-scale operation, several programs have been carried on by the Ministry of Agriculture to encourage bigger- or commercial-scale operation with the purposes of
higher home consumption and greater export quantity. At the present time, there are several more medium- and big-scale poultry farmers in the country than in the past ten years. The electric incubator is one equipment that is highly favored by them. It is obvious that when abundant and cheap electric power is available to them, the utilization of more electric equipment and the increase in power consumption will result.

Except in some experimental projects, there are practically no electrified dairy farms in Thailand. Two important factors that encourage the uses of electricity in dairy farming in Thailand are the demand for higher sanitary level of marketed milk and the demand for the expansion of dairy farming of the country. Practically all phases of operation on a Thai dairy farm are done by hand. Not much attention has been paid to obtain and keep milk at a desirable sanitary level. The uses of electric pasteurizer, sterilizer, and refrigerator will greatly contribute in the achievement of this. The expansion of dairy farming on a national scale is needed to meet the demand of the home consumption of milk, which costs the country about three per cent of its total import (16, p. 71 and 83). The uses of electric equipment for replacing manual labor will benefit the dairy farmer who operates on a rather large scale, of which the profit will
be large enough to justify the investment on the equipment.

Rice is the vitally important crop of Thailand. It is the staple food of the Thai people, constitutes about 55 per cent of its total export earnings, and occupies about 90 per cent of the cultivated area (19, p. 175). Other and less important grain crops are corn, peanuts, and beans, which altogether are about two per cent of the total grain crop production and five per cent of the export, both in tonnage. Therefore, the grain industry in Thailand provides a huge field for electrification. The rice mills in Thailand are mostly of the medium and large sizes, ranging between about 40- to 600-ton per day capacities. Practically all of these mills use steam-driven milling equipment and employ manual labor for the handling of both raw and finished products. Recently in some big mills electric conveyors of various types are used successfully and economically, therefore it is only a matter of the availability of the power service that more uses of electricity will result. The invention of small milling units of about 5- to 10-ton milling capacity has also widened the area of the application of electric power for grain processing, due to their adaptability for electric drive.
Purposes and Organization of this Thesis

This thesis is written to serve the purpose that an electrical engineer who may be interested in or work upon farm electrification in Thailand, which is practically an entirely new field of that country, will be able to find information on how electricity may be used in poultry production, dairy production, and grain processing in that country. A second and minor purpose is that the information in this thesis may be found useful by other Thai persons who are associated with the works in these 3 fields, such as the government agricultural officers, utility personnel, students, and farmers. The third and least important purpose is that this thesis may have some uses for other persons besides those previously mentioned.

Due to the fact that Thailand has no agricultural engineering institution of its own, it may be seen that electrical engineers who are placed for doing the farm electrification job will inevitably need considerable knowledge of an agricultural engineer. Besides this field, the applications of electricity are also new to that country. For these reasons, this thesis is written.

The applications of electricity in poultry production, dairy production, and grain processing may be classified according to the method of use into five
groups, namely: (1) lighting, (2) heating, (3) motorizing, (4) control, and (5) miscellaneous applications. Each of these groups will be briefly discussed, in the following parts of this text, from the electrical and agricultural engineering points of view, and also other aspects if found necessary.

Literature which will give full information on each application is listed in the appendix of this text. Although it is a great wish that one may find complete information when referring to this literature, the appendix is made principally by the research work of the available material in the library of Oregon State College, with special emphasis on the material published during the 1945-1956 period, due to the time limitation of this work.
LIGHTING

Light is a form of radiant energy. It consists of ordinary, ultraviolet, and infrared. All of these may be used in agriculture to serve various purposes. Since infrared light is used principally for heating jobs its applications will be discussed later in the Heating Chapter of this text.

The term "light" is commonly used for describing the illuminating or ordinary light. This portion of radiant energy spectrum has wavelengths between 3,800 and 7,600 angstroms (1 angstrom is equal to $10^{-8}$ cm). The portion of the spectrum between approximately 2,000 and 3,800 angstroms covers the ultraviolet range.

Illumination

Illumination is the supply of light for seeing purposes. In general, good illumination has several advantages such as providing eye comfort, helping workers to work faster and better, and providing safety in working areas.

Good illumination requires both quality and quantity of light. The quantity should be sufficient to make the object or the surface being observed clearly visible. Good quality of light demands the absence of glare, shadow, or sharp contrast between lighted objects
and their background. Glare can be controlled if the light sources are properly shaded or placed above eye level and glossy surfaces in the working area are eliminated. Shadows and sharp contrasts can be avoided if several lamps are used instead of one or few lamps in order that light will be uniformly distributed.

The unit used for measuring the quantity of light on a surface is called "foot candle". It is the illumination on a surface, one square foot in area, on which a light flux of one lumen is uniformly distributed.

**Light Sources.** For farm uses, incandescent and fluorescent lamps are the most common electric light sources. An incandescent lamp is essentially a tungsten-filament heated electrically inside a glass enclosure at such a high temperature that it gives off light. A fluorescent lamp is essentially a glass tube coated internally with phosphor which emits light when exposed to ultraviolet radiation, which is generated by the passing of electrons through the mixture of mercury vapor and rare gas in the tube. Fluorescent lamps have a negative resistance characteristic, hence it must be operated in series with a current controlling ballast. Fluorescent lamps may be classified according to their manner of starting into instant and preheat starting. In the
preheat starting type, a starter is required. Fluorescent lamps are manufactured in many types according to their purposes; these are the ordinary, sun-lamp, bactericidal (or germicidal), and black-light types. Each of these is used in several farm applications.

Fluorescent lamps are better than incandescent lamps in several ways. The average life of fluorescent tubes ranges from 6,000 to 7,500 hours, depending on the types and manufacturers, but that of incandescent lamps is from 750 to 1,000 hours. A fluorescent lamp produces about three times more light per watt than does the incandescent, consequently it also generates less heat per watt than the incandescent does. The principal disadvantages of fluorescent lamps are that they do not operate satisfactorily at voltages lower than 90 per cent of the ratings, the light output decreases if room temperatures are other than from about 70 to 80 degrees Fahrenheit, starting difficulties occur when room temperature is lower than about 50 degrees Fahrenheit, and their high first costs.

There are some hints for the proper use of fluorescent lamps. A long delay in the lighting of the tube may indicate worn out starter that should be replaced. If an objectionable humming sound occurs in a fixture, the ballast should be replaced. If the tube blinks it also should be replaced; otherwise the starter and ballast may
be damaged.

In general illuminating works, industrial-type light fixtures are recommended for farm application. These units are simple in design, rugged, and efficient. Their reflectors should be durable and easily cleaned.

Levels of Illumination for Various Seeing Tasks.
Different jobs need different levels of illumination. As a basic rule, difficult seeing tasks require high level of illumination and simple seeing tasks require low level of illumination. The foot-candle values suggested for the farm are shown in the following table:

Table 1. Foot-Candles Suggested for Farmstead Area

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<td>Service-walk alleys</td>
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<td>Milking area</td>
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<td>Pump house</td>
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<td>Yard lighting</td>
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Poultry Buildings Illumination

Illumination in poultry houses is necessary for the proper care of the flock and the maintenance of the houses. Illumination in laying house also stimulates egg production.

Laying Houses. The property of light in that it stimulates egg production is used by poultry farmers to increase the profits of their operations. Artificial lights are used during fall and winter which are the times when egg prices are highest. Another application is to bring slow-maturing pullets into production. For old hens that begin to drop their production, light is used to hasten them to lay their last eggs so that the hens can be disposed of as soon as possible. The lighting of laying houses may be one of the following methods:

Morning Lighting. In this method light is maintained 12 to 14 hours daily by turning on before day-break. The time of turning on depends on the time of sunrises and the number of hours of daylight in that locality. A 40-watt incandescent lamp for each 200 square feet of floor space is recommended. The lamp should be suspended 6 feet above the floor. A 12-inch porcelain enamel reflector with 4-inch depth should be used. Lamps with built-in reflector are very suitable since their
reflectors are free from the dirtiness caused by dust, dirt or smoke.

Evening Lighting. This is similar to morning lighting. The differences are that in this method the lamps are turned on at twilight, and at the end of the lighting period of the day they are dimmed so that hens can find their way to perches before darkness arrives. The dimming can be done by operating an auxiliary circuit of 10- or 15-watt lamps, one for each 400 square feet of floor area, for a few minutes. A dimming device is sometimes used to serve this purpose.

All-night Lighting. In this method one 15- to 25-watt lamp for each 200 square feet of floor area is recommended. There should be at least two lamps or lamp circuits to prevent black-out in the case of lamp burning out or circuit opening. The lamps should be suspended 6 feet above floor and halfway between the front and rear walls. They should shine directly on the food-hoppers and roosting space, and also the entire floor space if possible.

The use of artificial light must be done regularly, otherwise the stimulating effect becomes erratic, leading to a sudden fall in egg production. Cutting off the lighting period suddenly can be disastrous, hence toward
the end of the season the period of lighting should be slowly decreased until there are 12 to 14 hours of daylight.

The automatic time-switch is widely used for turning the lights on and off. It relieves the farmers to attend other jobs and eliminates the losses due to human errors.

Several research works have been done to find other methods of laying house lighting. There was a report mentioning that dim red lights were more beneficial for egg production; and that good results were achieved with "shock" illumination in which a 1,500-watt lamp is turned on for 20 seconds at 4:00 A.M. and at 4:45 A.M., as a substitution for night lighting from 7:00 A.M. onward with 75-watt bulb (11, p. 466).

Brooder Houses. Lighting in the brooder room provides convenience for the person attending the chicks, and also better living area for the chicks. They can see their feed better, and any undesirable condition may be easily detected by the farmer. For brooder room lighting it is recommended that one 60-watt bulb with 12-inch dome reflector should be used for every 100 square feet of floor area. The mounting height of the lamps should not be less than the spacing in order to avoid dark spots
Incubator and Egg Rooms. Lighting in these rooms are intended for the convenience of the workers and for the better quality of their jobs. For general lighting one fixture of 60-watt bulb in 12-inch dome reflector should be used for each area 12 feet square. The mounting height should not be less than the spacing. Supplementary lamp is required at the places where special seeing tasks are done, such as at working tables, egg cleaning machine, and egg grading machine.

Dairy Buildings Illumination

Cleanliness is a very important factor for the success of dairy farming due to the fact that milk must be sanitary and odorless. Good illumination in dairy buildings will help the farmers keep the places clean and perform their jobs sanitarily. All fixtures in the dairy rooms should be controlled by wall switches for convenience. They should also be moisture-proof and rust-proof because of the presence of high moisture and ammonia fume in the area.

Dairy Barns. Usually dairy barns are arranged in a series of alleys. This arrangement lends itself to the installation of fixtures in line along the center of each
alley. The fixture may be one 200-watt, inside-frosted bulb with dome reflector, or two 40-watt fluorescent tubes with reflector. One fixture is recommended for every third stall over the litter alley; also at every 10 to 25 feet over the feed alley, and over each maternity or calf pen.

Milk Houses. One unit of the mentioned dairy barn fixtures should be used for every 100 square feet of floor area. There should also be one of those fixtures at the wash tub, storage rack, cooler, or loading platform.

Grain and Feed Buildings Illumination

Hay Storages. Lighting in hay storage is necessary because it enables farmers to perform feeding job on dark mornings and evenings. Due to the dusty atmosphere of hay storage, dust-tight fixture should be used for avoiding ignition of the dust. A 200-watt bulb is recommended for each unit. Usually two fixtures are required for an average-size storage. Their locations must not become obstructions to working men or moving equipment such as hay carrying equipment.

Silos. Lighting in silo helps workers handle silage with less effort, provides safety in climbing and descending the ladder, and helps in the detection of spoiled silage. One fixture of 100- to 150-watt bulb
with dome reflector is recommended to be installed at the top of the chute and the top of the silo.

**Grain and Feed Rooms.** In these rooms the dust-tight unit with a 100-watt bulb and dome reflector is recommended. Fluorescent lamps are also suitable because they produce less heat, and one 40-watt tube can be used in the place of one 100-watt bulb. For additional protection explosion-proof or mercury wall switch should be used if switches are located inside the rooms.

In the preparation room lighting is needed to facilitate the preparing and handling operations. One fixture is required for every 100 to 200 square feet of floor area. Lighting in storage rooms is required only for handling jobs, hence one unit is sufficient for 400 square feet of floor area.

**Applications of Ultraviolet Energy**

Ultraviolet energy spectrum ranges between the wavelengths of 2,000 angstroms to 3,800 angstroms. The radiation in the range from 2,200 to 3,000 angstroms have bactericidal effects with the greatest effectiveness at about 2,600 angstroms. The ultraviolet energy radiations that have sun-tan and vitamin D-producing effects are between 2,500 and 3,400 angstroms with the greatest
effectiveness at the wavelength of 2,970 angstroms.

Sunlamps are artificial sources of sun-tan and vitamin D-producing ultraviolet energy. Those that are suitable for farm applications are the fluorescent and mercury-vapor types. In the latter type the radiations are achieved by passing an electric discharge through mercury vapor. Sunlamps are available with the wattages from 20 to 400. On the farm, the 20- and 40-watt fluorescent units are widely used. Sunlamps are built to have their effectiveness resembling the peak output of direct sunlight in the region of 2,900 to 3,000 angstroms (10, p. 16 of section 18).

Bactericidal lamps used for agricultural purposes are generally of the fluorescent type. Hot cathode fluorescent type of 8-, 15- and 30-watt can operate on the same auxiliaries used by standard fluorescent lamps of the same wattage. About 95 per cent of the energy is radiated at a wavelength of 2,537 angstroms. These lamps operate most efficiently at 80 degrees Fahrenheit. Sufficient exposure to the radiations from these lamps causes inflammation of skin and injures eyes; frequent exposures may result in permanent injury to the eyes. In most applications on the farm the lamps are installed high enough to prevent these dangers. Glass goggles that exclude radiations of wavelengths shorter than 3,400
angstroms may be used for those who are exposed to the radiations from these lamps. Reflector is usually required for these lamps to irradiate as much of the air and room as possible. Dust and dirt reduce the effectiveness of the lamps, therefore the fixtures should be wiped regularly.

**Ultraviolet Irradiation for Poultry.** Both sunlamps and bactericidal lamps have been widely used in poultry farming.

**Sunlamps.** In the places where chickens are raised without sufficient exposure to sunlight either cod-liver oil or sunlamp can be used to supply vitamin D for them. The use of sunlamps in poultry houses has the following advantages:

1. Increased egg production
2. Improvement of the rate of growth
3. Elimination of the loss caused by lack of vitamin D
4. Increase in hatchability of eggs and decrease in shell breakage

One 20-watt unit in a reflector is generally sufficient for irradiating a flock of layers in a house of up to 400 square feet of floor area. The unit should be suspended about 6 feet over the feeding trough and operated throughout the day (18, p. 209).
Bactericidal Lamps. These lamps are used to control poultry diseases caused by microorganisms. Chickens raised with the help of these lamps are said to have more vigor and grow faster than the others. The units generally used are the 15-watt fluorescent type. One lamp is recommended for each 50 square feet of floor area (22, p. 44).

Ultraviolet Irradiation for Dairy. Since sanitation is very important in dairy farming, bactericidal lamps are very widely used as a tool of serving this purpose.

Sunlamps. The purpose of the use of sunlamps for dairying is similar to that for poultry farming. One 40-watt fluorescent sunlamp is recommended for each two stalls, or for each three animals confined in alleys in a barn. The mounting height should be about six to eight feet above the floor, to be clear of the animals but yet provide maximum irradiation upon them. All-day exposure is recommended (18, p. 210).

Bactericidal Lamps. The radiations from these lamps will minimize the chance of respiratory cross-infection in cow-barns and also will destroy bacteria in milk houses. One 15-watt lamp is usually sufficient for 50 square feet of floor area (1, p. 156).
Another use of bactericidal lamps for dairy farming is sterilization of milk cans, which may be done by bolting two standard fixtures back to back and inserting the unit in the milk cans for a few minutes (24, p. 67).

Pasteurization of milk by bactericidal ultraviolet radiations has also been tried. One difficulty to be solved is that an objectionable taste is left in the milk due to the occurrence of ozone or the deterioration of fats and protein of the milk in the process (17, p. 558 and 24, p. 68).

**Black Light.** Black light is the radiations of ultraviolet energy in the wavelength range of approximately 3,000 to 4,000 angstroms. In agricultural fields black light is used as a tool for the inspection and grading of various products. Among these are classification of sound seeds and removal of old or damaged seeds, differentiating various strains of grains, and determining quality of eggs as in egg candling job.

**Light for Insect Trapping**

One application of light in agriculture is to lure insects. It has been found that the light sources for insect trapping should produce light with the wavelengths
close to the blue end of the spectrum as much as possible; the lamps should be bare; brighter source gives better attractive power (10, p. 11 of section 18).
HEATING

Heating by electricity has become very popular for practically all heating jobs. As compared with other types of heating it has several advantages as follows:

1. Low initial cost and simplicity of installation of the equipment
2. Easy and accurate control
3. High efficiency
4. Absence of smoke, ashes, moisture, dirt and other products of combustion
5. Elimination of fire and explosion hazards due to the heat sources
6. Healthful and comfortable working condition
7. Less labor and attention
8. Noiseless operation

The principal disadvantages of electric heating are the relatively high energy cost and the dependence upon the reliability of power supply. On the farms, incubation and brooding of chickens, water heating, steam generating and several other heating jobs are beneficially done electrically.

Quantity of Heat

A widely used unit for measuring a quantity of heat is the British thermal unit (Btu); one Btu is the amount of heat required to raise the temperature of one
pound of water one degree Fahrenheit (degree F.). It is also equal to the mechanical energy of 778 foot-pound; and the electrical energy of one kilowatt hour is equal to 3,413 Btu. Temperatures are sometimes denoted in degrees Rankine (degree R). The temperature in R is equal to degrees F plus 460.

Heat Transfer

In practically all electric heating applications, heat is transferred from sources to the objects required to be heated. There are three methods of heat transfer: conduction, convection, and radiation. An electric heating application involves one or a combination of these methods of heat transfer.

Conduction is the transfer of heat between adjacent molecules either of the same body or different bodies. An example of this phenomenon is the way a metal rod conducts heat from the heated end to the cold end. All substances have the ability to conduct heat, but usually solid can conduct heat better than liquid or gas, and liquid can conduct better than gas. The rate of heat transfer by conduction through a substance can be expressed as
\[ q = -k A \frac{dt}{dx} \] ---(1)

where \( q \) = heat transferring rate, Btu per hour

\( A \) = cross-sectional area of the path of heat transfer, sq. ft.

\( t \) = temperature, degrees F

\( x \) = length of the path of heat transfer, ft.

\( k \) = thermal conductivity, Btu per (hr. sq. ft. degree F per ft.)

Convection is the transfer of heat accomplished by the motion of the heated fluid material which may be liquid or gas. An example of heat transferring by this method is that in a heated-air grain drying process air carries heat from the heat source to the grain mass. The principal resistance to this method of heat transfer is in the film of fluid between the surface of a solid object and the adjacent surface of the heat-carrying fluid. The rate of heat transfer at the solid-fluid interface can be expressed by:

\[ q, \text{ Btu/hr} = h_c A(t_s-t_f) \] ---(2)

where \( h_c \) = unit-surface thermal conductance for convection or the heat-transfer coefficient, Btu per (sq.ft.hr. degree F)

\( t_s \) = temperature at the surface of solid, degrees F

\( t_f \) = temperature at the surface of liquid, degrees F

Radiation is the transmission of heat from a hot body to a cold body in the similar manner to the way light is transmitted. Consequently, an object being shadowed
by another object will not be able to receive this energy. A good example for heat transfer by radiation is the radiations from a light bulb, which creates the feeling of warmth to a person near it. The rate of emission of heat may be expressed by:

\[ q, \text{ Btu/hr} = A e \delta T^4 \]  

(3)

where \( e \) = emissivity of the source or the ratio of its emissive power to that of a perfect radiator

\( \delta = \text{Stefan-Boltzmann constant, Btu per (hr.sq.ft. degrees R)}^4 \)

\( T = \text{temperature of the source, degrees R.} \)

**Heat Loads**

The heat load of a system, whether it is a plant, house, freezing unit, or drying unit, consists of the following:

1. Wall losses or heat transferred through surrounding wall
2. Infiltration or heat added to or taken from air entering an enclosure
3. Product load or sensible heat of the product and heat produced by the product
4. Miscellaneous heat, consisting of the heat liberated within the structure from any other source

**Electric Heating Elements**

There are wide choices of electric heating elements
to suit the various methods of application. The types that are generally used on the farm are immersion heaters, conduction heaters, open heating elements, infrared lamps and heating cable.

**Immersion heaters** are constructed so that their heating sections are safely submerged in liquids. The heating element is completely enclosed in a seamless tube and is generally made of nickel-chromium wire or ribbon. Water, oil, and other liquids that have sufficient fluidity to maintain convection currents may be heated by heaters of this type.

**Conduction heaters** may be classified as strip heaters and cartridge heaters. Strip heaters are generally made of coiled nickel-chromium wire. The wire is embedded in a refractory insulator which is enclosed by a sheath. The wattage capacity of this type varies widely, usually ranging from 150 to 1,350. They are intended to be fastened in such a manner that heat will be carried from them by conduction. Cartridge heaters are used for localized heating. They are of cylindrical shape, have both terminals at one end, and are fastened to the object to be heated by means of drilled holes. The capacity of this type usually ranges from 75 to 1,000 watts.
The surface of the conduction heaters must fit tightly against the surface of the object to be heated, otherwise the heat will not be carried away as fast as it is produced, thus causes overheating of the heater unit. Heaters of this type may be used in chick brooders, dairy sterilizers, water heaters, and several other farm equipment.

Open heating elements are also made of nickel-chromium wire or ribbon mounted on refractory supports. If equipped with a reflector, the unit is a radiant heater. If equipped with a fan or blower, the unit is a convection heater. Their sizes may be as large as several kilowatts and an installation may have many units or groups of unit. This type of heater is very suitable for grain driers due to its high efficiencies. It is also widely used in chick brooders, incubators, and other kinds of space heating.

**Infrared Lamps.** Infrared energy is a radiant energy and its spectrum covers from the wavelength of 7,600 angstrom to about 10 million angstroms or 0.1 cm. The infrared energy radiated from infrared lamps ranges from 7,600 to 50,000 angstroms, longer wavelengths being absorbed by the glass enclosure.

Infrared lamps are available with tungsten filament
or carbon filament. The tungsten-filament type has power ratings from 250 to 1,000 watts whereas the carbon-filament type has from about 130 to 375 watts. Carbon-filament lamps have a higher initial efficiency than tungsten-filament, but they depreciate much faster, after about 100 hours of operation. The average life of a tungsten-filament type is about 5,000 hours. In the long run tungsten-filament lamps are considered more economical.

Both types of infrared lamps are available with either ordinary glass or red hard-glass enclosure. The hard-glass bulb will not break easily when subjected to splash of water or moisture, but it costs about two and one-half times that of the ordinary bulb. The most common infrared lamps are of the R-40 class which have a built-in reflector that remains very efficient throughout the bulb life. Infrared lamps should always be used with special socket and cord that can stand the heat in the operations to prevent fire hazards.

An ordinary incandescent lamp is also an efficient source of infrared radiation, and its cost is very low. These lamps are also available with built-in reflector. The one without should be used with a reflector in heating applications.

The principal advantages of heating by infrared lamp are high heat-transfer rate and directional energy
control. One of the popular uses of infrared lamps in agricultural field is chicken brooding. Their applications for grain drying and insect destroying have also been tried. When the lamps are located where contact by working men or animals is possible they should be protected with a strong wire guard.

**Heating Cable.** There are two types of heating cable for farm uses: synthetic-covered and lead-covered. There are great variations in their lengths and wattages but the most popularly used on the farm are the lengths from 30 to 240 feet with the wattages from about 200 to 1,600. The length of a particular cable used at a certain voltage is a fixed value. The use of shorter lengths will increase the temperature of the cable and overheat it. The use of longer lengths will decrease the wattage, and also the generated heat. When a cable is installed in a closed air space a thermostat should be used for protection against overheating.

Synthetic-covered cables cost less, are more flexible and lighter in weight than the lead-covered type, but they are more difficult to install on a smooth surface. Among the popular uses of heating cable on the farm are chicken brooding, floor heating, and moisture removing processes.
Water Heating

Hot water is used in various farm jobs. For example, washing hands and utensils, feed mixing, and cleaning. It is a very essential requirement in the operation of a dairy farm where sanitation is of particular importance. The advantages of electric water heating are apparent. The unit is compact and clean, requires very little attention, and is free from fire and explosion hazards.

Methods of Heating. In water heating processes heat-transfer from heating element to water may be by conduction, convection, radiation, or a combination of these. Heated portion of water transfers the heat to cold portion of the mass principally by convection, and to a minor degree by conduction. There are two general methods of water heating, the instantaneous and the thermal storage methods.

Instantaneous Water Heating. In this method water is heated when it is drawn from faucet. The heating elements of this type are usually inserted in the passage-ways where they are kept in close contact with the water. In some units heat is generated by the passage of electric current through the water between two graphite electrodes.
In both types turning the faucet makes or breaks the circuit.

Instantaneous water heaters are very efficient but their capacities are limited. It is suitable where small quantities of hot water are required intermittently. Too large a unit draws high current which demands wiring and accessories of large capacity. Its first cost is also high. Therefore, its service will not be economical.

**Thermal-Storage Water Heating.** This method provides a lower demand of current but higher energy consumption than the instantaneous type. Hot water is reserved in a storage tank, large enough to take care of the users' demands, hence the service is more satisfactory. There are various types of thermal-storage heating; they are space, clamp-on, immersion, and circulation heating.

In the space-heating units, a water tank is suspended in an insulated chamber and the heaters are mounted in the space between the walls of the tank and the chambers. It is apparent that heat-transfer from the heaters to the water is principally by radiation and convection.

The heaters of clamp-on heating units are fastened directly against the metal walls of a water tank, and are covered with insulation. Heat is transferred to the water solely by conduction through the metal walls.
In the immersion type, the heater unit is inserted near the bottom of water tank to warm the water from the bottom part. This type probably is the most efficient method of water heating. Heat-transfer to the water is solely by conduction.

In the circulation heating method, water is heated in a similar manner to that of a water-tube boiler. A metal pipe externally connects the bottom of the water tank to a point on its wall close to the top. This pipe is heated by an electric heating unit, thus causing the temperature of the water in the pipe to rise and causes water in the tank to circulate through the pipe by means of its own gravity. In this manner the whole mass of water is heated. There are many types of the heating units of this method. One is in the form of a bayonet around which water circulates; another type is in the form of a hollow tube through which water flows. The induction type develops eddy currents in an iron core surrounding the water passage.

**Energy Consumption.** To raise the temperature of one pound of water one degree F requires an electrical energy of 0.293 watt-hour without taking losses into account. Allowance should be made for the losses in the calculation of heat load. The energy consumption in
heating an amount of water depends primarily upon the outlet and inlet water temperatures, and also the design and construction of the unit.

**Dairy Utensil Sterilizers and Milk Pasteurizers**

**Dairy Utensil Sterilizers.** Sterilization is a process of destroying germs or bacteria. In sterilizing dairy utensils, heat in the form of live steam or boiling water can be used. The temperatures are usually from about 170 to 250 degrees F. The utensils are first cleaned thoroughly and then placed in the sterilizing chamber. Holding time of five minutes at 200 degrees F. or fifteen minutes at 170 degrees F. is used in some units (19, p. 36).

A self-contained electric sterilizer is clean, compact, and efficient. The operation can be completely automatically controlled, hence it is reliable and requires little attention. The heating element is generally of an immersion type. The sizes and kilowatt capacities vary widely. The energy consumption averages about three kilowatt-hour for 100 pounds of utensils.

**Milk Pasteurizers.** Milk pasteurization is the process of destroying disease germs in milk. One method is heating it to 143 degrees F. and holding it at that temperature for 30 minutes. Milk may have a cooked flavor if held above this temperature. Electric
Pasteurizers are usually automatic in operation and are built in several types. The units that have an agitator will keep the milk in gentle motion, thus providing uniform distribution of the heat.

**Double-Boiler Pasteurizers.** In this type the principle of a double-boiler is employed. The milk vessel is placed in a water jacket which is heated by an electric heating element. Milk pasteurized by this method has less tendency to burn on the vessel which gives out a cooked flavor.

**Heat-Air Pasteurizers.** This type is similar in principle to a space-heating water heater. The milk vessel is placed inside an insulated chamber and the air in the space between the walls is heated by an electric heating unit.

**Resistance-Type Batch Pasteurizers.** In this type two electrodes of graphitized carbon are placed in a milk container. Electric current flowing through the milk generates the heat required for pasteurization.

Energy consumption in milk pasteurization depends on the equipment used and the starting temperature of the milk. About 0.3 kilowatt-hour per gallon is required for a starting temperature of 40 degrees F., and about 0.15
kilowatt-hour per gallon for a starting temperature of 90 degrees F.

**Air Heating**

Heated air is utilized as a tool in many heating processes. It is used as a medium to convey heat from a source to the object to be heated. Some of the uses in the agricultural field are chicken brooding and incubation, room heating, and crop drying. Heating of air by electricity has several advantages. The heat can be readily obtained; complete automatic control is possible, and very little attention is required. The operation provides cleanliness, healthfulness, and safety.

**Types of Heaters.** Conduction heaters and radiant heaters have found very limited uses in air heating for agricultural purposes, whereas convection heaters are very widely used. A convection heater is designed primarily to warm the air, hence air must be kept in close contact with the heating elements. The area of the source of heat should be large to afford the best heat absorption by the air. The heating elements of convection heaters are usually nickel-chromium wire or ribbon. They are generally operated at low temperatures. If used without an enclosure it is called the open-element type, and if enclosed it is called the enclosed-element type. The units may be equipped
with fan, thus providing forced-draft feature.

**Chicken Brooding**

The success of poultry farming depends largely upon the results of rearing young birds. The care they receive during the first few weeks of their life has a great influence upon their later life. Poor brooding operation usually results in high mortality in the brooding period and low egg production.

There are several advantages of electric brooding, in which the important ones are: saving of labor, possibility to be completely automatically controlled, and better sanitary condition for both the chicks and the workers. The principal disadvantages are high power cost, and the losses caused by interruption of operations due to power failure.

**Brooding Methods.** Brooding method in which heat is localized on a certain portion of the floor is called cold-room brooding. It is claimed to be the closest way to the nature on the points that chicks have a source of heat to warm up their bodies and also have cooler surrounding space for exercise. Brooding method in which the entire floor is heated is called hot-room brooding. It has the advantage that heat will still remain in the room for some
time in the case of power failure, thus keeps the chicks warm until the power is restored or an auxiliary heating device is put into use. Chicks from cold-room brooders will feather earlier and will be more prepared for weather changes.

Electric brooders may also be classified according to the nature of the heater as: black-heat, radiant heat, under-heat and contact heat.

**Black-heat Brooders.** These brooders use heater wire or other enclosed-type heating units, operating at low temperatures. By this virtue they have long life and the least fire hazard of any type, electric or fuel burning. The heating units are mounted inside hovers which may be made in various sizes and shapes. The most widely used is a conical, galvanized-iron hover with its inside surface insulated for maintaining the heat in the hover.

**Radiant-heat Brooders.** This type is generally heated with infrared lamps with the chief advantages of low initial cost and the chicks being always in full view. The principal disadvantages are high power consumption and complete loss of heat in the case of power failure.

Infrared brooder may be homemade, but care must be exercised in its construction to prevent fire hazard during its use. For lamps vertically mounted, the lamp surface
should not be less than 15 inches above the litter to avoid igniting it due to the heat radiated from the lamp (21,p.3).

**Under-heat Brooders.** These employ electric heating cable which is embedded in either sand or concrete floor at 1- to 1½-inch depth. A hover is sometimes used to keep the heat close to the floor.

The advantages of the under-heat brooder are the ability to retain heat if the power supply is interrupted, and the ability to keep litter dry. The main disadvantage is that it does not provide enough air movement which may result in poor ventilation for the chicks unless a ventilating system is provided.

**Contact-heat Brooders.** These devices have a felt composition or a rubber sheet, electrically heated, hanging above the chicks. Chicks warm themselves by standing with their bodies against the heating surface. It is claimed to be the closest to the natural method in which chicks get the warmth from the hen's body. Feathers of the chicks are claimed to be smoother in this method. The disadvantages are that the height of the heated sheet must be carefully adjusted and that the air movement is restricted, resulting in poor ventilation.

**Brooder Requirements.** There are several factors to
be considered in the design and operation of an electric brooder:

**Size.** For mild climate the area of about seven to nine square inches per chick should be enough, the smaller space for brooding lighter breeds and the larger space for heavier breeds.

**Ventilation.** Some brooders are equipped with ventilating fan, some utilize natural draft or gravity ventilation. In any method the rate of air flow should be adjustable. Usually the air exchange to keep the litter dry is greater than that required by the chicks. The air requirement of 100 chicks during the first few weeks is about two cubic feet per minute (14, p. 6). For older chicks greater quantity of air is needed.

A cardboard guard of about fifteen inches high should be placed around the brooder to prevent floor drafts. Other equally strong materials may be used. During the first days the guard should be placed six inches away from the brooder, and the distance should be increased as the chicks grow.

**Humidity.** Experiments have shown that a relative humidity ranging from 40 to 73 per cent has no harmful effect to the chicks (15, p. 6). High humidity is
good for feathering, but also creates a wet, unhealthful litter. Humidity can be kept to a low value by supplying heat and adequate ventilation. During hot, dry weather air may be drawn through wet excelsior pads to keep the temperature down, and the humidity up.

**Temperature.** During the first two or three days of brooding the temperature of the brooder should be about 95 degrees F. It can be lowered about five degrees each week to about 70 F. or to normal air temperature (13, p. 161).

A thermostat is usually needed in electric brooders. It provides proper brooding temperature and also reduces power consumption. In small infrared brooders the temperature control is done manually, by observing the response of the chicks to the mounting heights of the lamps. Thermostats used for chick brooding should be rugged, simple, and easily adjusted.

**Hover.** Hovers can be made of any material that has good insulating quality and is light in weight. Some modern infrared brooders have plastic hover for the visibility purpose.

There should be an attraction light under the brooder to help the chicks find their way back. An observation window is recommended so that the chicks can
be easily seen. A curtain made of durable material is required to retain the heat in the hover. Means should be provided for adjusting the mounting height of the hover for convenience in operation.

**Energy Consumption.** In other well-insulated brooders, the heater wattage should be about 1½ to 1 3/4 watts per chick, but in an infrared brooder, the wattage should be about 2½ watts per chick or one 250-w lamp for every 100 chicks. The power consumption in brooding generally ranges from 0.5 to 2 kilowatt-hour per chick per brood.

**Chicken Incubation**

An incubator is an apparatus for hatching eggs artificially. The invention of the forced-draft incubator has brought the favor of electric incubators ahead of other methods. Although in some large incubating units heating is done by means of hot water, electricity is generally used for the operation of the fans.

Electric incubators have the advantages that they are compact, require very little attention, and they do not create unhealthful fumes nor reduce the oxygen supply. Electrically hatched chicks are strong and active.

**Types of Incubators.** Incubators can be generally
classified as farm type and commercial type.

**Farm Incubators.** The use of small electric incubators for farm hatching has been increasing following the development of more rural power lines. Most of these incubators use natural draft. The heating elements are usually of the radiant-heat type and are located in the top of the incubator. Air is heated and circulated in the incubator by its own convection currents set up by the difference in temperatures in the air mass. Farm incubators of large capacities, using forced-draft system, are similar to a commercial incubator.

**Commercial Incubators.** Practically all commercial incubators use forced-draft system. Heat is given off from electric heating units and the heated air is circulated around the eggs by means of electric fans. Eggs are placed on multiple decks in an insulated cabinet, which in larger units may be as large as a room, thus furnishing the possibility of using one set of control devices and eliminating a great amount of labor and attention. Most commercial incubators have automatic device for turning eggs.

**Incubation Requirements.** Several factors are vitally important in the incubation of chicks. The
direction furnished by the manufacturer of the incubator should be carefully observed.

**Temperature.** The desirable temperatures for natural-draft machines have been found to be about 101 degrees F. at the starting, increasing gradually to about 103 degrees F. at the hatching time. The recommended temperatures for forced-draft machines vary from 99 to 100 degrees F. (13, p. 136).

**Humidity.** In natural-draft machines the relative humidity should be between 30 to 60 per cent. The optimum relative humidity is about 60 per cent (13, p. 138).

**Air.** For normal embryonic development the oxygen concentration of the air in the incubator should approach the amount in normal air, i.e., 21 per cent. Carbon dioxide content should not be greater than 0.5 per cent (2, p. 128).

It was found that with the temperature held constant at 100 degrees F., the oxygen content kept at 21 per cent, the CO₂ content kept below 0.5 per cent, and the rate of air movement at 12 cm per minute, the best hatches were obtained at a relative humidity of 61 per cent (2, p. 129).

**Energy Consumption.** Small incubators consume more energy per egg than large ones. The average is about 180
kilowatt-hours per 1,000 eggs for small incubators, and 20 kilowatt-hours per 1,000 eggs for large commercial units.

**Calf Dehorners**

Calves are dehorned to make cattle safer and easier to handle and to eliminate injuries due to fighting between animals. Electrically heated dehorners provide less pain than other methods and also eliminate bleeding and open sores.

An electric dehorner is similar to a heavy-duty electric soldering iron except the tip has a special hollow-cone. The wattage is about 200. It may be made from an ordinary electric soldering iron by sawing off the top to leave the end about 5/8 inch square; countersinking it to form a cup approximately 5/16 inch deep at the center and 1/2 inch diameter; then round off the corners and rough edges with a file.

In dehorning, the calf's head is held firmly. The hair around the horn buds should be clipped. The dehorner is heated to a dull red and applied on the bud for about five seconds. After 10 to 15 seconds the dehorner is applied a second time. The dehorner should be rotated several times to assure good contact until a copper-colored ring shows. This operation will destroy the blood circulation to the horn and the bud will drop off some
three to six weeks later. The earlier the operation the less pain results. One week to three weeks are the optimum ages of the calves for the operation.

**ChickenDebeakers**

Chicks may be debeaked to stop losses from picking each other. Debeaked birds grow faster because they cannot sort out the feed they do not like. Feed is not wasted by billing out of the hopper. Market quality is better because no scar is found on the carcass. Electric debeaking is designed to cut off the upper beak and cauterize to prevent bleeding at the same time.

An electric debeaker consists principally of a metal blade heated by a heating element, and a water-cooled copper tube serving as the beak rest. The unit may be operated by a hand lever, a pedal, or may be motor driven. The speed of a manual operated debeaker is about 200 to 400 birds per hour and the wattage is about 250. The motor driven unit can operate as fast as 1,200 chicks per hour, requiring about 50 watts higher than the manual type. Chicks can be debeaked successfully at any age from three days old.
MOTORIZED EQUIPMENT

Electric Motors

Electric motors are used on the farm to replace manual labor. Work can be done more quickly, efficiently and also with greater convenience by means of electric motors. Production can be increased and expenses can be lowered. Therefore, besides lessening farm chores, its application will help increase the income of a farm.

Advantages. In comparison with hand labor and other mechanical power sources, electric motors have the following advantages:

1. High efficiency. When correctly used its efficiency can be about 85 per cent.

2. Low in first cost and operating cost.

3. Long life. An electric motor can last as long as thirty years. Very little maintenance is needed during its life.

4. Ease of operation. It can be started and stopped within seconds and with the least effort. After starting it performs its function smoothly and requires practically no attention.

5. High starting torque. It can develop a starting torque several times the torque at rated speed. By this quality neither clutch nor gear unit is required.

6. Good overload capacity. Electric motor can be momentarily overloaded, thus prevents interruption of the flow of a process due to temporarily overload of an equipment.
7. Ease of control. It can be automatically and remotely controlled, thus provides adaptability and convenience for its use.

8. Quietness in operation.

9. No vibration.

10. Safe in operation. No smoke, fumes, hot parts, or open gears.

11. Compactness.

Torque in Electric Motors. The expression for the torque in an electric machine is given by

$$T = K F_{\text{peak}} \phi \sin \delta \quad \text{(4)}$$

where $F_{\text{peak}}$ = the amplitude of the peak of an mmf wave

$\phi$ = the flux per pole

$\delta$ = the angle between the mmf wave and the flux density wave

$K$ = a constant.

(7, p. 104-111)

Quantitatively, it indicates that the torque which will be exerted between the rotor and stator of an electric machine is proportional to the amplitude of the flux-density wave, the amplitude of the mmf wave, and the sine of the angle $\delta$ between their axes. With this basic concept of torque in an electric machine in mind, the principles of operation of various types of electric motors can be clearly understood.

Practically all electric motors that are used on
the farms are of the alternating-current type. They may be classified according to the nature of the power supply as single-phase and poly-phase, or according to the principle of operation as synchronous and induction types. Since single-phase motors and three-phase induction motors constitute those ordinarily used on the farms, their principles of operation and application will be discussed.

Single-Phase Induction Motors. Functionally a single-phase induction motor consists of a rotor and a stator. The rotor is generally of the squirrel-cage type. The stator winding is distributed in slots to acquire sinusoidal space distribution of the magnetomotive force.

The space wave of stator mmf $F_1$ may be expressed as

$$F_1 = F_1(\text{peak}) \cos \Theta \quad (5)$$

where $\Theta$ = the electrical space angle measured from the stator coil axis

$F_1(\text{peak})$ = the instantaneous value of the mmf wave at the coil axis and is proportional to the instantaneous stator current.

If the stator current is a cosine function of time, the instantaneous value of the spatial peak of the pulsating mmf wave is

$$F_1(\text{peak}) = F_1(\text{max}) \cos wt \quad (6)$$

where $F_1(\text{max})$ = the peak value corresponding to maximum instantaneous current.

By substituting Equation (6) in Equation (5), the
mmf wave as a function of both time and space is

\[ F_1 = F_{1(\text{max})} \cos \omega t \cos \theta \]

\[ = \frac{1}{2} F_{1(\text{max})} \cos (\theta - \omega t) \]

\[ + \frac{1}{2} F_{1(\text{max})} \cos (\theta + \omega t) \]  \(---(7)\)

which are two sinusoidal waves rotating around the air gap in opposite directions at the angular velocity \(\omega\) radians per second. Both waves have equal peak values and meet each other at the axis of the stator winding. Each of these component mmf-waves will produce induction motor action, having the corresponding torques in opposite directions. When the rotor is at rest the component torques are equal but opposite, hence no starting is produced. When the rotor is revolving there will be a resultant torque which is the algebraic sum of the two components. Therefore if the motor is started by an auxiliary means it will produce torque in the started direction.

Three-Phase Induction Motors. Structurally 3-phase induction motors are similar to single-phase induction motors but no starting device is needed. The stator has 3-phase winding and the rotor if of wound type also has 3-phase winding.

To study the resultant field of a 3-phase winding analytically let \(a, b,\) and \(c\) designate the three phases.
At any time \( t \) and any point making an angle \( \theta \) from the axis of phase a, the mmf contributed by the three phases are \( F_a(\text{peak}) \cos \theta \), \( F_b(\text{peak}) \cos(\theta-120^\circ) \), and \( F_c(\text{peak}) \cos(\theta-240^\circ) \), respectively. The resultant mmf at point \( \theta \) is then

\[
F_\theta = F_a(\text{peak}) \cos \theta + F_b(\text{peak}) \cos(\theta-120^\circ) + F_c(\text{peak}) \cos(\theta-240^\circ)
\]

But the mmf amplitudes vary with time. Assuming that the windings are excited by balanced 3-phase current, their maximum amplitudes will be equal; let it be symbolized by the term \( F_{\max} \); therefore

\[
F_a(\text{peak}) = F_{\max} \cos \omega t
\]

\[
F_b(\text{peak}) = F_{\max} \cos(\omega t-120^\circ)
\]

and

\[
F_c(\text{peak}) = F_{\max} \cos(\omega t-240^\circ)
\]

Equation (8) accordingly becomes

\[
F_\theta = \frac{3}{2} F_{\max} \cos(\theta-\omega t)
\]

which is the desired expression for the resultant mmf wave. This wave has a constant amplitude and rotates around the air gap at constant angular velocity. In the stator of a 3-phase induction motor this wave will induce a voltage in the rotor and a starting torque is produced.

**Electric Motors for Farm Uses.** There are four general classes of single-phase motors used on the farms: single-phase induction, capacitor, universal, and repulsion.
The single-phase induction motors may be classified according to the methods of starting, as: split-phase, capacitor-started induction-run, and shaded-pole. In the 3-phase category only the induction motors are used for farm jobs.

Split-phase Motors. A split-phase motor has a starting winding, the axis of which is 90 electrical degrees from the axis of the main winding. These two windings are connected in parallel at the time of starting. The starting winding is constructed with a smaller wire so that it will have a high resistance-to-reactance ratio as compared with the main winding. Therefore, the currents in the auxiliary and main winding will differ in phase. As the result, a revolving field is developed and a starting torque occurs. After the motor reaches about 75 percent of its synchronous speed the starting winding is disconnected by a centrifugal switch. The rotor of a split-phase motor is generally of a squirrel-cage type which is simple and rugged.

The starting torque of a split-phase motor is low and the starting current is high. About six times the rated current is needed to exert the rated torque when starting. Motors of this type are suitable for constant speed drives requiring low starting torque such as fans and small blowers. Although the sizes larger than
1/3 horsepower are rarely built due to their high starting currents, they are available at the ratings from 1/20 to one horsepower.

**Capacitor-start Induction-run motors.** A motor of this type has a capacitance connected to the starting winding in order to obtain the phase displacement of the currents in the starting and main windings. The fluxes in the two phases may be separated by nearly 90 electrical degrees, the optimum for a 2-phase motor. The starting torque is, therefore, considerably greater than that of the split-phase motor of the same rating, and the starting current is less. Since dry-type, a-c electrolytic capacitors, inherently sensitive to overvoltage, are used, care must be exercised in their applications. Motors of this type usually have squirrel-cage rotor and are available in sizes up to 7½ horsepower. Examples for their applications are a deep-well pump, and a compressor.

**Shaded-pole Motors.** For very small motors, the starting action may be achieved by using "shading coils". A motor of this type has its stator constructed with salient poles built up of laminated iron. A short-circuited turn of low resistance is placed around half of each pole face. Induced currents in the shading coil cause the flux in the unshaded portion of the field pole
to lead the flux in the shaded portion, thereby producing a sweeping of the flux across the pole face. This flux induces current in the rotor conductors resulting in a torque sufficient to start the motor. The shaded-pole motors are built only in fractional-horsepower sizes and are used for the jobs that require very small starting torque, such as small fans. These motors are always built with squirrel-cage rotor.

**Capacitor Motors.** In this type the capacitor is designed for continuous duty and usually is the impregnated-paper type. Both the capacitor and the starting winding remain in the circuit throughout the operation of the motor, hence its performance is essentially that of a 2-phase motor. For better results the capacitance is gradually reduced as the speed is increased. A fixed value of capacitance is satisfactory for a motor that requires about fifty per cent full load torque at starting. If higher starting torque is needed two capacitors may be used. Capacitor motors usually have squirrel-cage rotor.

The characteristics of a capacitor motor are much better than those of a motor of usual construction. In starting performance the starting current is small and the starting torque is good. The power factor is close to one hundred per cent and the efficiency is high. The motor is also quiet as a result of the elimination of
torque pulsations due to the backward field.

Because of their good characteristics, capacitor motors are used for such a load as fan, blower, or refrigerator, which are relatively continuous loads.

**Repulsion Motors.** An a-c series motor can be changed to act as a repulsion motor by short-circuiting the brushes. Rotor current is set up by induction. If the brush axis is at right angle with the stator axis the net inductive coupling will be zero, hence no rotor current exists and consequently no torque is produced. If the brush axis is in line with the stator axis no torque can be produced because the torque angle is zero. To be able to start the brush is located at an intermediate position.

The characteristics of the repulsion motor are similar to those of the series-type motor. The d-c series motor will attain very high speeds if the load is removed whereas the repulsion motor will stop at a certain limited speed. Starting torque is high and the torque-speed characteristic can be adjusted by brush shifting. The sizes of repulsion motors range from 1/2 to 10 horsepower.

In "repulsion-induction" motors a squirrel-cage rotor winding is added to obtain both repulsion and induction torques. In "repulsion-start induction-run" motors the commutator segments are short-circuited and
usually the brushes are lifted when the motor reaches about 75 per cent of the synchronous speed.

Repulsion motors are used for loads that are very hard to start, such as feed grinders, hammer mills and large compressors.

**Universal Motors.** These are small series-wound motors of fractional-horsepower sizes that can be operated on either alternating or direct current with almost identical performance. The characteristics are very much like those of the d-c series motor. The no-load speed is rather high and the speed decreases continuously as the load is increased.

Actually any d-c series motor will start and operate on alternating current but there will be considerable heat losses, low power factor, and excessive sparking at the brushes. To overcome these difficulties the yoke, poles, and armature core are built up of very thin sheets of steel to reduce eddy current; field turns are reduced to decrease the inductance; high-permeability sheet steel in the magnetic circuit and smaller air gap are introduced to compensate for the reduction in field turns; high-resistance leads, between the armature coils and the commutators, and high-resistance brushes are used to reduce sparking.

Universal motors can be classified into two groups:
concentrated pole for low-horsepower ratings, and distributed pole for higher ratings, usually from 1/4 horsepower up. The power factor of the first type is much lower than the second. At low speeds it may be as low as 70 per cent.

Universal motors are used for small appliances such as vacuum cleaners, blowers, and portable drills.

**Three-phase Induction Motors.** There are two basic types of three-phase induction motors: squirrel-cage and wound-rotor. The first type is the most often used on the farms. The wound-rotor type has the advantages that a heavier starting torque can be developed and a limit degree of speed control can be achieved by connecting an external resistance in series with the rotor coils. The squirrel-cage motor is substantially a constant-speed motor. Squirrel-cage motors are usually available in size from 1/6 to 200 horsepower and wound-rotor from 1/2 to 75 horsepower, although in both types larger units may be built.

Three-phase motors are relatively low in first cost. Requiring no starting device, they are simple in construction, strong, and free from trouble. They have high power factors, good efficiencies, and constant running speeds. Wherever three-phase power is available, three-phase induction motors should be used except for very small loads for which single-phase motors are more suitable.
Types of Enclosures. Enclosure protects the working parts of the motor. In selecting a motor for a specific job the proper type of enclosure is needed to be considered; otherwise the life of the motor may be greatly reduced. For farm jobs there are four main types of enclosures: open, splash-proof, totally enclosed, and explosion-proof.

Open. This is the most common type of enclosure and is suggested for general-purpose uses around the farm. It is designed for indoor uses where the atmosphere is clean of foreign particles and splashing liquids. It has openings in the end shield to permit ventilation which cools the windings of the motor. All types and sizes of electric motors are available with this type of enclosure and the prices are also the least expensive.

Splash-proof. Openings in the end shields are also provided in this type of enclosure but in such a manner that splashing liquids cannot pass through. Motors of this type may be used indoor where washing of equipment is done. It can also be used outdoor if the climate is mild. It is seldom used for motors of the sizes 3/4 horsepower and smaller.

Totally-enclosed. There is no opening in the end shields of this type. It is recommended for farm
uses where there is excessive noninflammable dust or dirt. All types and sizes of motors are available with this kind of enclosure.

**Explosion-proof.** There are two types of explosion-proof motors. One type is designed to operate safely in the atmosphere of gasoline or inflammable vapor without igniting it. The other type is designed so that it will not ignite the dust in dusty atmosphere. This type is used where there may be dust in hazardous quantity such as flour mills, feed mills, and grain elevators.

**Types of Mountings.** Motor frames are manufactured in various types to fit the requirements of the jobs. For general farm uses they are of the steel foot type, which can be either rigid mounting or resilient mounting. The rigid-mounting type has heavy steel feet rigidly welded to the motor frame. In the base there are four slotted bolt holes for anchoring the motor and belt adjustment. The resilient-mounting type is designed to prevent vibrations by having the base attached to rubber rings. This kind of mounting is recommended for many types of grain processing machines in which mechanical vibration is great.

The footless type of motor frames are those used for special mounting arrangements such as end mounting
and vertical mounting. Some of these are also manufactured to have resilient-mounting performance.

Types of Bearings. There are two types of bearings used in electric motors: sleeve and ball. Sleeve bearings are usually steel backed, and babbitt-lined which need regular lubrication. They are generally designed for horizontal mounting. If mounted on the wall or ceiling the end shields of the motor are rotated for proper lubrication. Ball-bearing motors may be mounted in any position since grease is used as the lubricant. They are designed in both with or without relubrication. Motors constructed for operating with axial load on the shaft are equipped with end-thrust bearings.

Motor Protection. Motor protection is used to prevent damage to the motor caused by overloading, short-circuiting, or overheating due to poor ventilation. There are several devices used for this purpose.

Motor Branch-circuit Overcurrent Protection. Ordinary fuse or circuit breaker is used to protect a motor branch-circuit against short-circuits or grounds. This branch-circuit includes the motor, the control device, and the wires connecting them to the branch-circuit overcurrent protective device. Because the motor draws higher current at starting than at running, the maximum rating or setting
of the protective device is usually from 150 to 300 per cent of the full-load current, depending on the types of the motor and the device.

**Motor-running Overcurrent Device.** Overcurrent in a motor may be caused by overloading, low operating voltage, or failure to start. A device is required to protect the motor from this damage, and is usually set at or has the rating of 115 to 125 per cent of the motor full-load current. Overload relay, built-in thermal protector, or delayed-action fuses are used as such device. A delayed action fuse is different from an ordinary fuse in that it is designed to allow heavy current to flow through the circuit with sufficient time for starting, but if the overcurrent continues for some time the fuse will blow.

**Belts and Pulleys.** Besides direct drives, belt drives are extensively used as the means of transmission of mechanical power from motor shaft to the load in farm applications. In comparison with gear drive, belt drive has the advantages that it absorbs shocks, does not require lubrication, and is quiet. When properly applied, belt slippage will not exceed two per cent, and power-transmission efficiency ranges from 97 to 99 per cent.

Flat belts are seldom used for farm applications.
They are suitable for long-distance drive. They also have better slipping action. Therefore, when the motion of a part of the equipment is interfered with the flat belt will slip upon the pulleys more easily than V-belts.

V-belt drives are very popular for farm uses because the belts are light, compact, and have better grip due to the wedging action. They are very suitable for close-center shaft arrangements. V-groove pulleys come in both single- and multiple-groove combination. Sometimes a drive known as V-flat is used in which the driven machine has flat, large pulley to supply enough friction.

Centrifugal tension is the principal factor that limits the maximum speed of a belt. For good practice the belt speed should not exceed 4,000 fpm.

**Pumps**

A pump is a device used for moving a liquid, changing its internal pressure or velocity, or a combination of any of these.

**Types of Pumps.** Pumps may be classified on the basis of the principle of operation into five general classes—reciprocating, centrifugal, rotary, regenerative turbine, and jet pump.

*Reciprocating Pumps.* This type has
positive-displacement action. On its intake stroke a volume of liquid is drawn into the cylinder through suction valves. On the discharge stroke the liquid is forced under positive pressure through outlet valves. The pulsating discharge is smoothed out by various means such as the use of double-acting performance and the use of air chamber. Reciprocating pumps have the advantages in their flexibility of capacity, head, and speed. They are suitable for high pressure pumping in small and medium capacities.

**Centrifugal Pumps.** A centrifugal pump consists essentially of an impeller rotating at high velocity so that the liquid, entering through an intake at its center, will be discharged by the centrifugal force into the casing surrounding the impeller. The speed of the liquid is decreased while traveling in the casing, thus the velocity head is converted into the pressure head needed for the discharge. Advantages of centrifugal pumps are: low cost, compactness, smooth flow, low stresses in pipe line, and adaptability for direct coupling to high-speed motors.

For pumping large quantities of water at low head propeller pumps have been developed. Propelling or lifting action of the propeller on the liquid develops the required head and discharges the liquid in axial-flow manner. For the intermediate jobs between those of a
centrifugal pump and a propeller pump, a mixed flow pump is used. In this type the pressure head is produced by both centrifugal force and lifting action, the liquid enters axially but is discharged both axially and radially.

**Regenerative Turbine Pumps.** In this type liquid is circulated and recirculated through a series of rotating vanes of an impeller continuously from suction to discharge. This type is well suited for operation under high working heads. Since it can be designed for simple disassembling to provide the ease of cleaning, it is suitable for pumping milk. Multi-stage turbine pumps are used for deep-well pumping.

**Rotary Pumps.** A rotary pump has one or more rotating elements whose action produces positive displacement of liquid. There are six common forms of rotary pumps: external-gear, internal gear, cam or lobe, screw, sliding-vane, and swinging-vane type. The advantages of rotary pumps are compactness, simplicity in construction, ease to install and maintain, high volumetric efficiency, and great adaptability. Rotary pumps are suitable for handling thick and viscous liquids, but also are used for many other jobs such as pumping highly volatile liquid, vacuum, and high pressure. For satisfactory performance close tolerances should be maintained, therefore these
pumps should be used only with liquids that are relatively free of abrasive materials.

Jet Pumps. In a jet pump a centrifugal pump is used to force a fluid through an ejector at high speed. This velocity energy, in turn, is applied directly to the fluid to be moved, thus forces it into motion. Another centrifugal pump may be required to move the liquid to the discharge end of the pipe. It is suitable for the deep-well pumping that requires the pump to be installed at some distance from the well.

Milking Machines. Milking job was found to take about one-half of the total dairy chore time. By using milking machine the milking time may be reduced to about one-half or less, and also udder injury due to rough hand-milking is eliminated.

The milking machine consists of double-chambered teat cups. The inner-chamber is made of rubber and is connected to the milk line at constant vacuum. The outer chamber has metal casing and is connected to a pulsator supplying vacuum and air pressure alternately. When vacuum is applied in the outer chamber, milk flows from the teat and when air pressure is applied the rubber cup collapses, thus stopping the flow of milk and massaging the teat. Two types of electric milking machines are
used: the portable and the pipeline. In the pipeline type
the motor and vacuum pump are stationary and metal pipes
are installed permanently to function as the air lines. In
the portable type the whole unit is moved to the point of
milking operation. Motors from 1/3 to one horsepower are
used for the milking machines, depending upon the numbers
of the milking unit. The energy consumption is about 1½
to 2½ kilowatt-hour a month per cow.

Farm Water Supply. Three sources of power may be
used for water pumping: electric motors, windmills, and
internal-combustion engines. Electric power, being the
most ideal for this job, has the advantages in its
adaptability to automatic control and trouble-free
operation.

For shallow-well pumping all of the previously
described types of pump are used, but in deep-well
pumping only the reciprocating, turbine, and jet types
are suitable. The required horsepower of the motor for a
pumping job may be calculated by the equation:

\[ \text{Hp required} = \frac{\text{gallon per minute} \times \text{total head of water, ft.}}{3,960 \times \text{efficiency of pump}} \]

If the efficiency is not known, 0.50 may be used
for shallow-well and 0.30 for deep-well pumps. The total
head in the equation includes total elevation, pipe
friction, and back pressure of the pressure tank (23, p. 36-37). Motors used for water supply systems are usually of the capacitor start-induction run type, although repulsion-induction motors may be found in some deep-well, reciprocating-pump units.

**Liquid Manure Pumps.** These pumps are used for removing manure from the manure storage tank to the manure spreader or carrier. Practically all manure pumps are of the centrifugal type, and can be classified as the surface type and the submerged type. Usually the maximum size of the motors required for this job is three horsepower. A magnetic overload switch is desirable since the pump can be clogged by straw, hay, or other foreign materials.

**Fans and Ventilations**

In agricultural fields, fans are used for serving several purposes, e.g., ventilating, drying, sorting and cleaning jobs.

**Fundamental Terms and Formulas** (14, p. 1908-1909)

**Pressure.** The term "pressure" is generally used for the static pressure. The sum of the static pressure and the velocity is the total pressure.

**Velocity.** The relation between the
velocity of a gas of density d pound per cubic foot and
the velocity pressure p_v inch of water is given by

\[ \text{Absolute velocity, } V = 18.3 \sqrt{\frac{p_v}{d}} \text{ fps} \tag{11} \]

**Air Horsepower.** The fan power output may be
determined by

\[ \text{Air hp} = 0.0001575 \frac{pQ}{\text{in. of water}} \tag{12} \]

where \( p \) = total pressure, in. of water
\( Q \) = volume, cfm.

**Air Density.** Standard air density used in
Manufacturers' publications of tables and curves is 0.075
pound per cubic foot.

The approximate air density may be found by

\[ \text{Density, lb. per cu.ft.} = 1.325 \frac{p_b}{T} \tag{13} \]

where \( p_b \) = absolute or barometric pressure, in. of
mercury
\( T \) = absolute temperature, deg. F.

This value may be used for most calculations with­
out appreciable errors.

**Types of Fans.** Fans, blowers, and compressors
differ from each other by the pressure produced. Fans are
used for moving large volume of air at very low pressure,
compressors for small volume at high pressure, and blowers
for the intermediate values of the two. Fans may be
generally classified as axial-flow and centrifugal.
Axial-flow Fans. In this type the air flow is parallel to the shaft. The number and shape of the blades mounted on its rotor vary. These fans may be classified as propeller, tube-axial, and vane-axial fan. A propeller fan consists of a propeller or disc type wheel within a mounting ring or plate. A tube-axial fan consists of a propeller or disc type wheel within a cylinder. A vane-axial fan consists of a disc type wheel within a cylinder, and a set of air guide vanes located either before or after the wheel. The sequence: propeller, tube-axial, vane-axial, indicates the general trend of increasing static pressure, air horsepower, and efficiency of the fan. Their fundamental operating principles are similar.

Centrifugal Fans. There are three fundamental types of centrifugal fans: forward-curved blade, radial-tipped blade, and backward-curved blade type.

The forward-curved blade type has the advantages over the other two in that they are smallest in size and lowest in price. However, it is also the least efficient type. The radial-blade type has better efficiency and also operates at higher speed than those of the first type. The backward-curved blade type has a very high efficiency and operates at a very high speed, which makes it the most suitable type for electric motor drive.
fans are suitable for operating against high static pressure or for delivering large volume of air.

**Poultry House Ventilation.** Ventilation in poultry house is important to the health of the chicks. The principal purposes it serves are:

1. To remove water vapor given off by the chicks' breath and droppings, which total about 45 pounds of water per 100 heavy breed hens per day. Damp air in a poultry house will result in poor health of the chicks, deterioration of the building, and dirty eggs.

2. To provide fresh air and to remove foul air in the poultry house.

3. To maintain proper room temperature for the chicks.

**Air Requirement.** For satisfactory ventilation on warm days the ventilating system that will provide an air flow of four cfm per heavy breed hen is needed (6, p. 3 of Section 17). Provision to reduce the air flow on cooler days should be made. The proper poultry house temperature is between 50 and 70 degrees F. From tests it has been found that chicks survived a temperature of 90 degrees F. if the relative humidity did not exceed 75 per cent; at 95 degrees F. they survived at the humidities below 60 per cent; and 100 degrees F. at 30 per cent or lower (2, p. 166-167). However, the more uniformly temperature can be maintained at a suitable
level and extremes avoided, the more satisfactory will be the results (3, p. 369).

Methods of Ventilation. Two methods of ventilation are used: natural and forced-air. Forced-air ventilation is better adapted to and more justified in larger units. Electrically operated fan, thermostatically controlled is generally used for this system.

Three methods are usually used in the forced-air system: one fan with shutter thermostatically operated; two fans—one running continuously and the other thermostatically operated; and one two-speed fan with thermostatically speed-controlled. In any of these methods air should enter the house uniformly from every direction, and flow across the litter without creating draft. The fan should be located away from the prevailing wind. It should be near the ceiling and have a duct extending down to within fifteen inches from the litter. The duct should have a door directly back of the fan to exhaust warm air near the ceiling during warm weather. The fan should be at least eight feet from any fresh-air intake.

Fans and Motors. The blades of the fan should be self cleaning and made of noncorrosive material. The fan should have non-overloading characteristic for protection in operating against wind. The static pressure
rating should be about 1/8 inch of water to overcome friction of the ducts and inlets.

The motor used for this job should be of the enclosed type, require very infrequent servicing, and should have built-in thermal protection to prevent fire hazard. Capacitor motors are usually used for 1/4 horsepower or bigger fan sizes; split-phase motors for fans up to 1/4 horsepower; and shaded-pole motors for 1/25 horsepower and smaller fans. Since shaded-pole motor has low starting and breakdown torque the fan should be installed away from prevailing winds.

**Dairy Stable Ventilation.** A mature cow gives off about 1 1/2 to two gallons of water per day. The reasons for the necessity of ventilation for the dairy stable are similar to those of the poultry house, i.e., to remove water vapor and foul air, to provide fresh air, and to maintain proper room temperature. Dairy stable ventilation is of much greater importance in a cold climate than in a warm climate because of the need of closed sheltering for the animals in cold weather.

**Air Requirement.** A quantity of 30 to 200 cfm of fresh air is needed by an average 1,000 pound-cow depending on the climatic condition; the allowable temperature range is from 40 degrees F. to 60 degrees F.;
and the satisfactory relative humidity is 70 per cent with 80 per cent as the upper limit (6, p. 3 of Section 15).

Methods of Ventilation. Similar to those of poultry house ventilation, dairy stable ventilation may be either natural or forced-air method, using single or multiple fans. Ducts similar to those used in the poultry house are needed. If space does not permit the installation of the duct, the fan may be located in the wall at floor level. One intake should be provided for every four cows, or about every 14 feet along the walls. The intake should be designed to direct the incoming air against the ceiling. Its discharge opening should be twelve inches below the ceiling, and the intake cross-sectional area should be 60 square inches. The air velocity in the exhaust duct should not exceed 500 fpm and the duct cross-sectional area should not be less than twice the area of the fan circle.

Each fan should be protected against overloading. A totally enclosed motor of the split-phase or capacitor type may be used. Energy consumption may average about 0.15 kilowatt hour per day per cow for a fan running continuously.

Drying

Drying of a material is the removal of moisture in
that material to a moisture content in equilibrium with normal atmospheric air. Dehydrating is the removal of moisture to a very low moisture content.

**Equilibrium Moisture Content.** The moisture in any material exerts a moisture vapor pressure. If this vapor pressure is greater than the water vapor pressure in the surrounding air at the temperature of the material, the material will decrease its moisture content approaching the value corresponding to the air vapor pressure. This value is called equilibrium moisture content which may be calculated from the equation

\[
1 - rh = e^{-cT} M_E^n
\]

where
- \( rh \) = equilibrium relative humidity, a decimal
- \( M_E \) = equilibrium moisture content, dry basis, per cent
- \( T \) = temperature, deg. F. absolute
- \( C, n \) = constants

The equilibrium relative humidity is the ratio of the moisture vapor pressure to the saturated vapor pressure of pure water at the temperature of the material (8, p. 277-279).

**Types of Drier.** Both heated and unheated air are used for drying farm products. Heated air has the advantage of retaining higher moisture than air at low
temperature. Four types of driers are generally used for drying on the farm, namely: batch or bin, continuous gravity-flow, rotary, and tray driers.

**Batch or Bin Driers.** In this type the material to be dried is placed in a bin or container, and air is forced to flow through the mass until it is dried. This type is simple and inexpensive but has the tendency of overdrying of the mass in the air entrance region, and underdrying or wet mass in the air discharge region. These may be minimized by using air at lowest practicable temperature with highest practicable flow rate, and turning the material when finished.

**Continuous Gravity-Flow Driers.** The material is placed in a hopper and flows by its gravity through the hopper's bottom into a column walled by perforated material. Air is forced into the mass from one side of the walls and leaves at the opposite side. The dried material is discharged at a uniform rate from the bottom of the column. This type of drier is suitable for the material that flows readily such as grains. Its first cost is high but the handling job can be completely mechanical.

**Rotary Driers.** The material is put into a horizontally-inclined drum at its higher end. The cleat
arrangement inside the drum stirs and mixes the material as the drum rotates and heated air is supplied to the drum. The flow of the material will discharge dried material at the lower end of the drum. This type is compact but expensive. It is suitable for materials that do not flow freely, provided that they will not be damaged by the action of the drum.

Tray Driers. The material is placed in shallow trays, which are stacked in a room or tunnel in which heated air is supplied. This type is the most simple but also requires the greatest amount of labor.

Hay Curing. Hay can be cured in the field by sunlight, but in areas where rain prevails, artificial drying is necessary. Either long, chopped, or baled hay may be dried artificially. The advantage of drying by this method is the elimination of the losses due to unsuitable weather condition, handling, and improper curing.

In fair weather, hay may be left to dry in the field until its moisture content is about 35 to 40 per cent, then it is cured artificially to a safe storage level of about 20 per cent. Barn curing, or batch drying, is the most common method used although rotary drier is sometimes used. A barn hay drier consists of a system of channels or ducts through which air is blown into the
The surrounding mass of hay. Heated air may be necessary if humidity of the air is too high.

The following table may be used in the calculations of a hay drying installation:

Table 2. Recommended Values for Figuring Hay-Drying Installations (5, p. 10)

<table>
<thead>
<tr>
<th></th>
<th>Long</th>
<th>Chopped</th>
<th>Baled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of air, cfm per sq. ft. of mow area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Pressure of fan discharge, in. of water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>1-1/4</td>
<td>1 1/4-1 1/2</td>
</tr>
<tr>
<td>Maximum depth of hay, settled, ft.</td>
<td>10-12</td>
<td>8-10</td>
<td>7 layers or 10 1/2 ft.</td>
</tr>
</tbody>
</table>

Fans and Motors. Axial-flow fans are the most common types used for hay curing although they have high noise level. Centrifugal fans are quiet in operation but are expensive. If forward-curved blade fans are used, damper control or variable speed drive is required to prevent overloading due to the increase of horsepower as pressure drops.

Drier units generally require a five or seven and one-half horsepower motor. They should be protected against overheating by a magnetic starting switch. If intermittent drying operation is used, a time-clock control may be used to turn on the fan at predetermined periods during the
night to prevent condensation of moisture at hay surface.

**Grain Driers.** For safe storage grain should have low moisture content about 11 to 13 per cent, depending on the kind of grain. Grain that is harvested at higher moisture content may be left to dry in the field if the weather condition is favorable, or may be dried artificially. When unheated air is used its maximum relative humidity should be about 60 to 75 per cent to be effective; and if heated air is used the temperature should not be too high, ranging from 90 to 140 degrees F. depending on the kind of grain, to prevent cracking of the grain kernel. The temperature may be higher if intended for animal feed.

Any of the previously described driers may be used for grain drying. The most common method for on the farm jobs is the batch-type drying; which may be done with the grain in or out of the sacks, and air is supplied either through a system of ducts or holes in the floors. For large or commercial scale operation the continuous gravity-flow type is generally used.

**Fans and Motors.** Axial-flow fans are generally used for grain drying. The pressure of the fan discharge of about seven inches of water is usually required in the continuous gravity-flow type, and about 2½ inches for the batch or platform drying.
Motors should be of the dust-explosion proof type since the operation is always dusty. Overloading protection should be provided to prevent damage to the motor if operated against clogged air passages. The heater unit in the heated-air system should have a hand-reset thermal cut-out for protection against fire hazard during the failure of air supply.

Refrigeration

In general there are three ways of obtaining cooling effect: by the use of chemical means, by bringing into contact with a cooling medium, and by supplying energy to operate a heat pump. The last method is called mechanical refrigeration which may be broadly classified as the absorption and vapor compression systems.

In the vapor compression system the liquid refrigerant, kept in a receiver under high pressure, is released through an expansion valve into a region of low pressure produced by suction action of a compressor. This region is called the evaporator. The expanding action of the refrigerant will make it evaporate and the heat required for the evaporation is taken from the surrounding; a cooling effect thus results. The vapor is then compressed in the compressor and moved into a condenser where the refrigerant is cooled and turned into liquid form by using
air or water as cooling medium in most cases. The liquid refrigerant then flows back into the receiver and the process is repeated. The cooling effect, taking place in the evaporator, is either applied directly to the material to be cooled or a cooling medium.

The absorption system is similar to the vapor compression, but an absorber, generator, and pump are used in the place of the compressor. The refrigerant after leaving an evaporator is dissolved into a solution in an absorber at low temperature and pressure. The solution is then pumped into a generator and is then distilled by application of heat in the generator. The vapor, now having high pressure is then moved into a condenser and follows the same course as in the vapor compression system until it reaches the evaporator.

**Milk Coolers.** There are several types of equipment used for milk cooling which use the mechanical refrigeration principle. The purpose of a milk cooler is to keep down bacteria growth in the milk during its storage time so that it will be fit for human consumption.

**Surface Coolers.** This type of cooler gives rapid cooling and is expensive. The cooling medium is circulated inside metal tubes over which milk is let to flow by gravity. The cooler usually consists of two sections:
the upper one is cooled by water from the water supply and the lower one either uses brine as a cooling medium or is the evaporator itself. Surface coolers are sometimes called aerators since it allows air to contact the milk.

**Double-tube Coolers.** In this type milk is pumped through the inner tube of a double-tube arrangement, and the cooling medium is circulated in the space between the inner and outer tube. This device is a closed system thereby preventing evaporation loss of milk or absorption of air.

**Flat-surface-type Coolers.** This type uses the walls of the tank or a hollow plate suspended in the milk tank as the cooling surface. Coolers of this type may be classified as dry, immersion or wet-tank, and bulk type.

The dry walk-in type is actually a room-size refrigerating cabinet in which milk in cans is cooled and stored. The dry box-brine system cooler is a smaller refrigerating cabinet of the dry type using brine as cooling medium. In the immersion type cans of milk are immersed to shoulder height in water, used as a cooling medium of the refrigerating unit. There are two systems used in the bulk type in which the whole bulk of milk is cooled and then stored in the same tank; ice-bank system,
and direct expansion system. In the ice-bank system, an ice-bank is formed around the evaporator. Water is circulated over the ice to act as the cooling medium for the milk tank. In the direct-expansion system, the refrigerant is circulated through an evaporator in contact with the milk tank. The direct-expansion cooler has higher power demand but requires less energy to operate than the iced-bank cooler of the same capacity; however the latter type is lower in first cost.

Motors and Energy Consumption. Size of motor used for driving the cooler unit ranges from 1/3 to nine horsepower, for capacities ranging from 50 to 400 gallons of milk. The energy consumption ranges between 8 to 16 kilowatt-hour per 100 gallons per year, depending upon the type of cooler and location of application.

Heating Water with a Milk Cooler. If the condensing unit of a cooler is designed in a form of a condensing coil and is placed in an insulated tank, it can be used for warming water.

Egg Coolers. If eggs are kept at room temperature they will deteriorate rapidly. In order to maintain the quality they must be cooled and stored at low temperature. The humidity of the air in storage space should be high, about 70 to 85 per cent; otherwise dehydration of the eggs
will occur and lower their quality. Two methods of egg cooling are used: evaporation system and refrigeration system.

In the evaporation system baskets of eggs are placed and cooled in an egg room. Air is circulated by means of a fan and picks up moisture from water which is also placed in the room. This cool, damp air, being forced around the eggs will provide the cooling effect. Eggs are kept at the temperature of about 55 degrees F. in this method. It is effective only when outside air is low in humidity and fairly constant in temperature.

In the refrigerating system eggs are placed in a refrigerating cabinet or cooled by the air blown through the evaporator of a refrigerating unit. By this method eggs can be cooled more rapidly and stored at constant temperature. The temperature may be about 30 degrees F. The unit that cools eggs to about 55 degrees F. should operate with water pan inside the cabinet to provide the necessary humidity.

Materials Handling

Materials handling is the moving of materials in any direction. Since the movement of fluids has been discussed, only that concerning solids will be mentioned. There are five types of conveyor generally used on the
farm, namely: belt, chain, screw, bucket, and pneumatic conveyor.

**Belt Conveyors.** A belt conveyor consists essentially of a moving endless belt operating between two or more pulleys. Belt conveyors may be used for handling materials of almost any size and shape except that the temperature must not be too high. It has long life, high efficiency, and produces little damage to the materials; but its first cost is high.

The installation of a large belt-conveyor system is costly and should be done or supervised by a well-trained engineer only. Basically, the width of the belt is determined by the capacity, and the weight and size of the material; belt thickness is determined by the pull under-load; and the cover thickness by the nature of the service.

High torque is required to start a belt conveyor. Usually a general-purpose squirrel-cage motor will do the job satisfactorily. A motor with double rotor windings is used frequently on major installations. It has high starting and running torques and low starting current. Open or splash-proof type may be used in most cases. Belt conveyors are widely used for handling grain and feed, both in bulk and in sacks.
Chain Conveyors. This type is inexpensive, simple, but has low mechanical efficiency. Chain conveyors are used for a great variety of jobs on the farm.

Types. There are three types of chain conveyors: trolley, scraper, and apron.

A trolley conveyor has an overhead steel rail with trolleys which are fastened together by a chain from which the material is suspended at regular intervals. This type is generally used in a processing plant, for material that should be hung, or to save floor space.

A scraper conveyor consists of a trough in which a chain with flights at regular intervals moves through. The motion of the chain causes the flight to scrape the material inside the trough from one end to the other where it is discharged. The chain may be designed to travel back and forth, or, by being an endless chain, to travel in one direction only. The scraper conveyor can operate on an upward slope of 40 to 45 degrees. It is extensively used on the farm for moving various kinds of material such as grain, feed, manure, and other raw products.

An apron conveyor consists of steel slats supported between two strands of roller chain. It can handle abrasive materials that should not be scraped along a
trough. It is also suitable for conveying sacked materials and materials of large sizes. The limit of inclination is about 25 degrees.

**Power Requirement.** The theoretical power requirement of a flight conveyor may be determined from the following equation

\[
\text{Horsepower} = \frac{2v L_c W_c F_c + Q (L F_m + H)}{33,000} \quad \text{(15)}
\]

where
- \( v \) = speed of conveyor, ft. per min.
- \( L_c \) = horizontal projected length of conveyor, ft.
- \( W_c \) = weight of flights and chain, lb. per ft.
- \( F_c \) = coefficient of friction for chains and flights
- \( Q \) = lb. material to be handled per min.
- \( L \) = horizontal projected length of loaded conveyor, ft.
- \( F_m \) = coefficient of friction for material
- \( H \) = height of lift, ft.

(6, p. 190).

The power requirements for the belt, trolley, and apron conveyors can be similarly found.

**Screw Conveyors.** A screw conveyor consists of a plate-steel helix mounted on a shaft which rotates in a trough usually of U-shape. The rotation causes a thrust by its lower part against the material in the trough thus moves it toward the discharge end. This type of conveyor
is suitable for handling materials of small size and damp or viscous materials. It is also used for mixing and uniform-rate feeding of materials. Grain, feed, and manure are commonly handled by screw conveyor. It can operate with an incline by using a tubular trough and short-pitch helix. With twenty degrees incline its capacity decreases to about one-half of its capacity at horizontal.

Theoretical capacity, cu.ft. per hr

\[ \text{Theoretical capacity} = \frac{(D^2-d^2) \cdot P \cdot \text{rpm}}{36.6} \]  

where

- \( D \) = screw diameter, in.
- \( d \) = shaft diameter, in.
- \( P \) = screw pitch, in.

The actual capacity is usually about 50 to 60 percent of the theoretical value.

Horsepower requirement

\[ \text{Horsepower requirement} = \frac{\text{CLWF}}{33,000} \]  

where

- \( C \) = conveyor capacity, cu.ft. per min.
- \( L \) = conveyor length, ft.
- \( W \) = bulk material weight, lb. per cu.ft.
- \( F \) = material factor

The value of \( F \) for beans, bran, shelled corn, cleaned rice, and wheat is 0.4; for unshelled peanut is 0.7.

If the calculated horsepower is less than one, double the value; if between one to two, multiply by 1.5; between two to four, multiply by 1.25; and between four to five, multiply by 1.1 (8, p. 192-195).
Bucket Elevators. A bucket elevator consists of an endless belt or chain to which metal buckets are attached. Elevators of this type are usually used for the vertical lifting of any dry, loose material where size is not too large for the buckets. It is extensively used in grain elevators, bins, and processing plants, for grain handling.

Discharge from a bucket elevator is usually produced by the centrifugal force throwing the material out of the bucket as it goes over the head pulley. It is required that the speed of the belt or chain should be held within close limits. For the most satisfactory discharge condition, the speed of the pulley should be

\[ N, \text{ in rpm} = \frac{54.19}{\sqrt{r}} \]  

where \( r \) = the distance from the center of the head pulley to the center of the mass of material in the bucket at the top of the pulley.

(8, p.196-201).

Pneumatic Conveyors. A pneumatic conveyor uses high velocity air stream to move materials along a closed duct. A fan is used to draw the materials into the bottom of the duct and discharge it directly at the top end or into an equipment called a cyclone which is used for separating the materials from the air. Its advantages are: low first cost, no exposed moving part,
and cleanliness in the operation. Its disadvantages are: high power consumption, high wear and tear if the material is abrasive, and possible damage to the material. Grain, feed, and silage may be conveyed by this method.

The proper air rate for lifting a material can be calculated from

\[ V = 60 \, M_c \sqrt{W} \]  

---(19)

where

- \( V \) = air velocity, ft. per min.
- \( M_c \) = a constant
- \( W \) = bulk density, lb. per cu.ft.

**Table 3. Values of \( M_c \) for Equation (19)** (8, p. 203)

<table>
<thead>
<tr>
<th>Material</th>
<th>Straight Horizontal Ducts</th>
<th>Ducts with Ells and Risers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line</td>
<td>Hose</td>
</tr>
<tr>
<td>Dusty</td>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>Grains</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Gritty and uneven</td>
<td>15</td>
<td>24</td>
</tr>
</tbody>
</table>

**Hoists.** Electric hoist may be used for several handling jobs on the farm. The hay hoist is extensively used on dairy farms to lift hay from the ground into the hay mow. The hoist is also used for lifting milk cans from or into a milk cooler. For regular handling jobs between two or more locations the hoist is usually
mounted on a roller-and-track unit.

Most hay hoists require a three or five horsepower motor, although in some installations a motor as big as seven and a half horsepower is used. Power consumption for a three horsepower hoist is usually less than two kilowatt hour per hour of operation. The average power consumption per ton of hay is about 0.3 kilowatt hour. Motors used for milk-can hoists are usually of the one-half to one horsepower sizes.

Carts. Electric carts have been used for handling jobs on the farm. One of the popular uses is for conveying feed from a bin to feed troughs. Usually an electric cart is suspended from an overhead track but the floor-type is also used. The overhead types generally draw current from the power system, but the floor-type is usually powered by automotive batteries.

Special Conveying Equipment. The conveying equipment used for specific jobs on the farm is described below:

Barn Cleaners. Barn cleaning is the removing of manure from a barn. When it is done electrically it eliminates a disagreeable farm chore, provides better sanitary conditions, and saves valuable manure.

There are five main classes of electric barn
The dragline type is the most economical, trouble-free, simple, and adaptable. It consists of steel scrapers connected to two chains, one on each side of the gutter bottom. One end of both chains is wound on a steel drum whose reeling action forces the scrapers to scrape the manure along the gutter. The other ends of the chains are attached to a pull-back unit for pulling the conveyor back into the gutter. The motor of the cleaning unit is about one and one-half horsepower and the motor of the pull-back unit is about one-third horsepower.

The push-pull type consists of paddle blades hinged to a steel rod in such a manner that on the forward stroke the paddles will swing out at right angle to the drive and on the backward stroke they will fold in and cling to the drive. The steel rod is attached to a roller chain which is driven electrically to move the rod back and forth, thus giving the pushing action by the paddles against the manure on each forward stroke. This pushing action results in the movement of the manure to the discharge end of the gutter.
A screw-type barn cleaner is actually a screw conveyor whose U-shape trough functions as the gutter with the portion behind the cows covered with a heavy metal gate to avoid injury to the cows by the motion of the helix.

A portable-type barn cleaner is a self-propelling unit that picks up manure and unloads it into a manure spreader or carrier which moves forward at the same speed as the barn cleaner.

**Silo Unloaders.** An electric silo unloader relieves a farmer from a difficult, time-consuming job and from the danger of falling when climbing the silo ladder. An unloader consists essentially of a traveling scraper conveyor or screw conveyor and a blower. The unit sits on the top of the silage in a silo, and swings the conveyor around slowly, which extends from the unit to the silo wall. The silage is picked up by the conveyor and fed to the blower which will discharge it into a silo chute that leads to the ground. A three to five horsepower motor is usually required for a silo unloader.

**Automatic Feeders for Poultry.** About forty per cent of the poultry chore time and travel is used in feeding job. A great amount of time can be saved if it is done electrically. Saving in feed has also been found.
An automatic feeder consists of a feed bin and one or more feeders. The bin may be of any size but the bigger one will require less frequent filling. The feeders are essentially the conveyors of the screw or chain type and are powered by small motors, usually from one-fourth to one horsepower. The feeders are controlled by time clock to operate at predetermined hours. For a ten-week period about 26 kilowatt hours are consumed per 1,000 birds during the brooding period. For 1,000 laying hens about one kilowatt hour a day is required. Automatic poultry feeder is suitable only for a large flock because its first cost is high. An automatic manure disposer may be installed under the same principle.

Size Reduction

Size reduction includes cutting, crushing, grinding and milling. Such processes are important in feeding and grain processing jobs.

Energy Requirements. In reducing material into smaller sizes but symmetrical with the original shapes, the energy requirement can be expressed as in Kick's law and Rittinger's law:

Kick's law: \[ E = C \ln \left( \frac{L_1}{L_2} \right) \]  \hspace{1cm} (20)

Rittinger's law: \[ E = C \left( \frac{1}{L_1} - \frac{1}{L_2} \right) \]  \hspace{1cm} (21)
where \( E \) = energy required

\[ C = \text{a constant} \]

\( L_1 \) = original dimension of the particle

\( L_2 \) = final dimension of the particle

(6, p. 125-127).

Size-Reduction Devices. The devices widely used for size reduction in agriculture are: hammer mill, burr mill, crusher, and chopper.

Hammer Mills. A hammer mill consists of steel hammers rigidly connected or hinged to a rotor, the whole unit spinning at high speed inside a steel screen. The material is beaten into small pieces by the impact of the hammers until the size is small enough to pass through the screen and is then conveyed out of the device. Hammer mills are widely used for grinding grains for feeding purposes. The chief advantages of a hammer mill are the simplicity in operation and long life. The main disadvantage is high power requirement.

Burr Mills. A burr mill consists of two ridged plates in parallel, one stationary and the other rotating. The material is fed into the space between the two plates and is either sheared by the ridges or crushed between the plates into fine pieces. The burr mill has
low initial cost but requires more maintenance and attention than a hammer mill. It is commonly used for feed preparation.

**Crusher Mills.** In the crusher mill the material is disintegrated by squeezing or pressing. The type that is used on the farm consists of a roll and a plate or two rolls between which the material is fed into and crushed into fine pieces. In grinding grains the product obtained is coarser than from a burr mill and the power consumption is also higher. Its cost is higher than a hammer or burr mill of the same capacity.

**Choppers.** A chopper is used for chopping hay and silage into short pieces. There are two types of chopping devices: the helical-knife similar to that of a lawnmower, and the flywheel which has knives attached radially to it.

**Motors.** Motors of no larger than five horsepower are satisfactory for grinding shelled corn and small grains. For crushing ear corn, roughage, or chopping hay or silage much larger motors are needed. The most desirable motor characteristics are high power factor, high starting and pull-out torque, and low locked rotor current. Both repulsion-induction and capacitor motors are suitable for such farm loads. Fully enclosed type is
recommended for protection against rodents, loose grains, and dust. Explosion-proof feature is not necessary. A thermostatic device to protect the motor against sustained overloads is required. The device may be used for starting and stopping the motor automatically by being energized with a mercury switch fastened to a flapper valve of a feed chute.

Grain Cleaning and Sorting

Although cleaning and sorting of grain may take several steps, usually in each step both operations are simultaneously done by the same device. The equipment commonly used are the screen, pneumatic, cyclone, disc, cylinder, and specific gravity separators.

**Screen Separators.** Screening is the oldest and simplest method of cleaning and sorting and is extensively used. The device consists of one or more screens slantingly supported in such a manner that both longitudinally- and vertically-oscillating motions occur. These motions move the grain down the screens and stir it thoroughly so that particles smaller than screen holes will pass through the screens.

**Pneumatic Separators.** In this device air is blown or drawn through a falling stream of grain so as to
remove dust, chaff, foreign seeds, and damaged grains from the mass. The separator that uses the air-drawing principle is called an aspirator.

**Cyclone Separators.** This device is frequently used for collecting materials carried by the air current of a pneumatic conveyor and separator. A cyclone is essentially an enclosed steel cone; having one cylinder piercing upward out of the center of the flat top; one piercing from the pointed bottom downward; and one through the side close and tangential to the top, serving as the air entrance. The air entering the cyclone will travel in the circular path along the wall, thus throwing the particles against the wall by centrifugal forces. The particles will fall down the wall slope by their own weight and leave the cyclone through the bottom cylinder. The air, being light, will leave the cyclone through the top cylinder. In this manner the particles are separated from the air stream.

**Disc and Cylinder Separators.** A cylinder separator is a slant, horizontal cylinder, indented on its inside surface. During its rotation small grains are picked up by the indentations and drop by their own weight into a screw conveyor to be discharged at the end of the conveyor. The remaining grains in the cylinder move down
the slope of the cylinder and are discharged at the lower end.

A disc separator consists of a series of discs indented on both faces and mounted on the same rotating shaft. During the rotation small grains are picked up and thrown by centrifugal forces into a screw conveyor. The remaining mass is forced to move by the flights, connected to the spokes of the disc, to the discharge end of the separator.

These two types of separators are suitable for grading and removing dissimilar materials. Their capacities are high. They have long life and require moderate power.

**Specific Gravity Separators.** This device is a perforated table approximately a right-angle triangle in shape. Grains are fed at the top of the triangle, whereas the table travels in crosswise-reciprocating motion, and air is blown from underneath through the perforation. Light particles are lifted by the air and travel directly down to the discharge edge at the part closest to the intake corner. Heavier particles will travel along the direction of motion of the table and will leave the table at the farther part of the discharge edge. This type of separator is accurate and suitable for difficult separations.
Motors. Most grain cleaning and sorting devices are powered by capacitor motors. Usually the totally-enclosed type is used but in the location where the air is very dusty, the dust explosion-proof type should be used.

The energy consumption for each cleaning or sorting job varies according to the kind of grain, proportion in the grain mixture, and the quality of cleaning. For an ordinary farm-type cleaner, using the screening and aspirating principles, the energy consumption is about one kilowatt-hour per 60 to 75 bushels of grain.

Feed Mixing

Feed mixing can be done during grinding operation by controlling the rate of flow of each material so that the right mixture of the feed will be obtained. It can also be done similarly by the use of a screw conveyor, thus providing the simultaneous mixing and conveying operations.

A batch feed mixer consists of a steel cone having a vertical screw conveyor at its axis and a paddle at the top. The feed at the bottom of the cone is conveyed to the top by the conveyor and is then spread by the paddle; hence the circulation of the feed results and the feed is thoroughly mixed. Motors of one to seven and one-half horsepower are used for these units. Energy consumption
is about one-half kilowatt-hour per a batch of 1,000 pounds of feed.

**Egg Cleaners and Graders**

An egg is one of the materials that cannot be handled with the conventional methods of cleaning and sorting, due to the delicacy of its shell; therefore special equipment is built to perform these operations.

**Egg Cleaners.** Clean eggs obtained higher prices than dirty eggs. In general, two methods of mechanical cleaning of eggs are used: dry and wet.

The dry-type egg cleaner removes dirt from egg shells by sanding or brushing with an electric sander or buffer. Loosened dust may be carried away by a small suction fan. A motor of about one-fourth horsepower is usually required and the energy consumption is very small.

There are several wet types of egg cleaner. One device sprays the eggs with 170 degrees F. water while moving them on a rubber, worm-type conveyor and then dries them with whirling brushes. In another device the entire egg basket is placed in the washer where cleaning action is produced by detergent bubbles. Eggs are gently agitated and cleaned in about three minutes. Motors of fractional horsepower sizes are used for both types. Electric heating units are used for warming the water
used in the cleaning process.

**Egg Graders.** Egg prices are based on their grades, in which the weight is one important factor. In a mechanical grader eggs are automatically conveyed to a weighing mechanism which separates them according to their sizes. A motor of about one-sixth horsepower is used. The unit may grade up to 1,800 eggs per hour.
MISCELLANEOUS EQUIPMENT

Farm equipment in which electricity is used for producing the effects other than light, heat, and power are few in number. The equipment using electric-shock and electromagnetic principles have been beneficially used in some agricultural fields.

Electrical Hazards to Human Beings

In using the equipment utilizing electric shocks utmost care must be exercised because electric shocks can be hazardous to lives of men and animals.

For healthy human adults the lethal values of electric current are about 25 ma even with interruption at frequent intervals. Human muscle responds to a current as low as one and one-half to two ma. Low-current shocks, however, can result in a serious accident if they occur in hazardous locations.

From a series of tests conducted at the University of California, it was found that the safe current for most normal adult men is nine ma, and for most normal adult women is six ma; these values, however cannot be applied to weak or ill persons, or children. Records have shown that children and persons with heart ailments are most of the casualties caused by electric fence accidents.
Electric Fences

An electric fence is a fence made of one or more bare wires, insulated from ground and energized by a device called a controller. If an animal touches the fence it will receive an electric shock, therefore, the animal will stay away from the fence. In dairy-farming an electric fence is used for temporarily confining animals in an area, and also for serving as an auxiliary to a permanent fence.

Advantages. An electric fence has several advantages in comparison with other kinds of fences. These advantages will be described as follows:

1. Low initial cost
2. Ease of installation, removal, and handling
3. Light in weight
4. Long life
5. Adaptability for various jobs such as temporary fencing for feeding areas, temporary confining, and supplementary fencing

Electric Fence Parts. An electric fence consists of one or more wires, posts, insulators, one or more gates, a controller, and a power source.

Wires. Either ordinary wire or barbed wire can be used. Barbed wire has the advantage that it makes
better contact with the skin of an animal. The size of wire can be about No. 14 gauge or No. 12½. For portable fencing either No. 18 gauge copper wire or No. 13 gauge aluminum wire may be used, with the purposes of ease of handling and light in weight. Larger wire has one principal advantage in that it may be easier seen by the animals, therefore keeps them from walking into the fence.

**Posts.** Posts for electric fencing need not be as strong as ordinary fence posts because they are not frequently damaged by the confined animals. Spacing of the posts varies between 20 to 50 feet, depending on the terrain the fence follows.

**Insulators.** Porcelain insulator is more suitable for permanent fencing. Rubber and polyethylene insulators are more often used with a temporary fence since they do not break as easy as the porcelain type.

Fence wires can be simply tied to the insulators or rest on the insulators by means of wire clips, which provide for easily installing and dismantling of the wires. At the place where the wire is subjected to strain, such as at the ends and corners of the fence, insulators of strain type should be used.

**Gates.** Gates are installed to provide means of passage for men and animals. A gate is actually a part of the fence wire which can be disconnected by
means of hook-and-eye arrangement at the point of disconnection. The gate must have an insulated part to provide protection against shock for the persons who open and close it. In the connecting or closing position it must be pulled tight by means of spring action to provide good electrical contact between the hook and the eye.

**Power Sources.** An electric fence is designed to operate on either the power supply circuit, or a 6-volt automotive battery, or both.

**Controllers.** The design and construction of a controller of an electric fence are utmostly important with regard to the safety of human beings and animals from electrical hazard. Electric fence controllers can be generally classified as intermittent types and continuous types, according to the nature of their output currents. Most modern units are of the intermittent types which provide an off period following a short shock period so that a man accidentally contacting the fence will be able to free himself from the circuit.

**Types of Controllers.** There are basically four types of controllers according to their electrical characteristics:

**Intermittent A-C Output Type.** In this type
a high-reactance transformer is periodically energized by an interrupter. The interrupter may be electrically-operated rotary, a simple-pendulum, or a balanced wheel device. A balance-wheel interrupter consists of a balanced wheel having one contact mounted on its rim and another contact on the end of an armature of an electromagnet. When the two contacts are in closed position the magnet is energized, thus pulls the armature downward and causes the wheel to rotate. The rotation makes the contacts depart and simultaneously tightens a spiral spring, which in turn will rotate the wheel in the reversed direction. The reversed rotation again closes the contacts, therefore an oscillating motion of the wheel results. The frequency of oscillation depends upon the weight of the wheel and the tension of the spiral spring.

The open-circuit output voltage of a controller of the intermittent a-c output type is about 2,500 rms volts and consists of 2 to 12 cycles of sine wave at the supply frequency. A thermal cutout is connected to open the circuit if the contacts fail to part or are short-circuited. The primary and secondary windings of the transformer are placed on separate core legs in such a manner that no supply frequency current can find its way to the output circuit in the case of insulation.
Fig. 1. Simplified diagram of a balanced-wheel interrupter.

Fig. 2. Simplified diagram of an intermittent a-c output controller.
failure. One output terminal, the transformer core, and
the housing are connected to the ground terminal. A
neon light is usually connected to the output circuit to
show if the fence is working.

**Inductive-Discharge Type.** The principle of
this type is similar to that of the ignition system of a
car. The controller is energized from a low voltage d-c
source, usually a 6-volt battery. A high-voltage pulse
of short duration is obtained by means of a transformer
and an electrically-operated rotating or oscillating
interrupter. The open-circuit output voltage of this
type may be greater than 10,000 crest volts.

If a controller of this type is operated from an
A-C source, a rectifier will be equipped. Unless the
steady current is limited to about 5 ma, a thermal cutout
or equivalent is generally required.

Units of this type energized from a dry cell or
battery are self-contained and can be installed without
regard to the power supply, therefore are very popular.

**Capacitive-Discharge Type.** A controller
of this type uses a half-wave rectifier to build up
charge on a capacitor; and a trigger tube is so connected
that it will discharge the capacitor when the build-up
voltage reaches a certain value. The discharge current
Fig. 3. Simplified diagram of an inductive-discharge controller.

Fig. 4. Simplified diagram of a capacitive-discharge controller.
flows through the primary of a transformer having its output terminals connected to the fence wire and ground. In Figures 5-4, \( C_1 \) is the storage capacitor. \( C_2 \) is a small blocking capacitor used for minimizing the sustained supply-frequency current in the output. The frequency of the output can be fixed by the resistance \( R \).

The chief advantage of this type is that no moving parts are present, hence noise, wear and tear are eliminated. The disadvantage is that its price is high.

In an earlier type of the capacitive-discharge controller, the fence wire is directly discharged from charge-storage capacitor. It was found that the leakage currents of the insulators were ordinarily high enough to reduce the effectiveness of the fence, therefore this type has practically disappeared.

**Continuous Type.** This type uses a high reactance transformer to energize a fence with a small continuous current. Although the maximum authorized current is safe for normal men, it may be dangerous to women and children. To lower the current is also to reduce the effectiveness of the fence. This type has practically disappeared from applications in the United States.
Regulations Pertaining to Electric Fences. As safety measures for human lives, regulations have been enforced upon the design of electric fences. The following table shows these regulations as in the United States National Bureau of Standards and the Proposed European Standard:

<table>
<thead>
<tr>
<th>Table 4. Regulations Pertaining to Electric Fences (4, p. 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inductive Discharge Type</strong></td>
</tr>
<tr>
<td>Quantity of electricity per impulse, millicoulombs, max.</td>
</tr>
<tr>
<td>United States: 3.0</td>
</tr>
<tr>
<td>Europe: 2.5</td>
</tr>
<tr>
<td>Impulse current, crest ma, max.</td>
</tr>
<tr>
<td>United States: 500</td>
</tr>
<tr>
<td>Europe: 300</td>
</tr>
<tr>
<td>Current at 0.1 sec., ma, max.</td>
</tr>
<tr>
<td>United States: 10</td>
</tr>
<tr>
<td>Europe: 5</td>
</tr>
<tr>
<td>Interval between impulses, sec., min.</td>
</tr>
<tr>
<td>United States: 0.75</td>
</tr>
<tr>
<td>Europe: -</td>
</tr>
<tr>
<td>Impulse per sec., max.</td>
</tr>
<tr>
<td>United States: -</td>
</tr>
<tr>
<td>Europe: 1.16</td>
</tr>
</tbody>
</table>

| **Capacity Discharge Type**                                   |
| Quantity of electricity per impulse, millicoulombs, max.      |
| United States: 3.0                                            |
| Europe: 2.5                                                  |
| Impulse current, crest ma, max.                               |
| United States: 500                                            |
| Europe: 300                                                  |
| Current at 0.1 sec., ma, max.                                 |
| United States: 10                                             |
| Europe: 5                                                    |

| Nonintermittent type                                         |
| Sustained current, ma, max.                                  |
| United States: 3.0                                           |
| Europe: 0.5                                                 |

| Intermittent type                                            |
| Sustained current, ma, max.                                  |
| United States: 0.0                                           |
| Europe: 0.5                                                 |
| Interval between impulses, sec., min.                        |
| United States: 0.75                                          |
| Europe: -                                                   |
| Impulse per sec., max.                                       |
| United States: -                                              |
| Europe: 1.16                                                |

| **Intermittent A-C Output Type**                             |
| Quantity of electricity per impulse, millicoulombs, max.      |
| United States: -                                              |
| Europe: 2.5                                                  |
| Impulse current, rms, ma, max.                               |
| United States: 25.0                                          |
| Europe: -                                                   |
| Duration of impulse, sec., max.                              |
| United States: 0.1                                           |
| Europe: 0.1                                                 |
| Interval between impulses, sec., max.                        |
| United States: -                                              |
| Europe: -                                                   |
| Impulses per sec., max.                                      |
| United States: 1.0                                           |
| Europe: 1.16                                                |

| **Continuous Type**                                          |
| Sustained current, rms, ma, max.                             |
| United States: 8.0                                           |
| Europe: Not authorized                                       |
**Installation.** The proper mounting height of the charged wire is about the height of animal's nose, or between 2/3 to 3/4 of the animal's height. If there are various sizes of animals, another charged wire is needed at different height.

Grounding of a fence controller is done by driving an 8-ft. metal rod or water pipe into the ground and connect it securely to the ground terminal of the unit by means of wire and clamp. If the soil is too dry a ground wire may be needed to install between and parallel to the charged wire and ground surface. In the region where there is lightning hazard the unit should be protected by an arrester connected between the fence and the ground rod.

Animals should be trained to learn that a fence will give a shock when they touch it. This can be done by placing attractive feed in an area fenced by a charged wire. An animal in trying to get to the feed will receive a shock from the fence and stay away from it. This will reduce the injury from wire cuts caused by animals attempting to cross the fence in ordinary use on the field.

In order to make the fence effective, vegetations must be kept from touching the charged wire. The length of the fence should not be too long; the usual effective length is about one mile.
Safety Rules. To avoid serious hazard to human lives the following rules should be strictly observed:

1. No electric fence should be energized from any source except through an approved controller.
2. No electric fence should be energized from more than one controller.
3. Battery should not be charged while energizing a fence.
4. A fence controller must be connected only to its authorized source.
5. An approved lightning arrester should be installed on the fence circuit if lightning is prevalent.

Energy Consumption. For a 115-volt unit the energy consumption averages about seven kilowatt-hours per month. The battery used in a 6-volt unit needs recharging every two to three months.

Cow Trainers

Cow trainers are used for saving of time and labor in the stalls. A cow trainer consists of a T-shape bar suspended above a cow's shoulders and is energized by an electric fence controller. The trainer must be adjusted for each individual cow so that when the cow bends its back to deposit manure or urine it will receive a mild shock unless standing in the position to deposit directly into the back gutter. The advantages offered by a cow
trainer are:

1. Save time and labor required for cleaning the cows and their stalls.

2. Better sanitary condition of the dairy barn, hence better quality of milk is obtained.

3. Save on bedding for cows.

4. Provide more comfort for cows with less danger of leg, udder and teat injury.

Energy consumed by a cow trainer is negligible. Once the cow learns to step back properly the trainer can be turned off for some time.

Insect Traps

An electric insect trap consists of a lamp surrounded by an exposed grid energized by a high-voltage, low-current transformer. The output voltage is usually about 3,500 to 10,000 volts and the output current is about ten to fifteen ma. The energy consumption is about three to six kilowatt-hours a month.

The unit may be built in the form of a box or a window or door screen. The device has been found very useful in dairy buildings where high sanitary condition is required. When used indoor they should be mounted about eight feet from the floor to be out of reach of human beings. When used in the field they should be effectively grounded, with the core, frame, and housing connected to the ground terminal in order to keep the voltage of
these parts to ground voltage if there is short-circuit between them and the primary winding.

The advantages of electric insect traps are its ease of operation, low costs, and little labor required. The chief disadvantage is that the grid requires regular cleaning to remove the remains of insects sticking to it, otherwise the operation will be ineffective.

**Tramp Iron Removers**

Tramp iron that goes with hay and other kinds of feed is very harmful to the digestive organs of the animal. A magnet in the form of a plate or a pulley is used to trap it by passing the stream of the feed over. There are devices utilizing electromagnetic principle to achieve the same purpose. In one method a detector coil is used for detecting the iron. The disturbance of the magnetic field due to the movement of a piece of tramp iron through it causes a change of flux linking the detector and generates a small voltage. This voltage is electromagnetically amplified to operate a deflection gate by which the tramp iron is rejected.

**Bin Vibrators**

A bin vibrator consists essentially of two units: the upper unit being a laminated armature attached to the
vibrator body, and the lower unit being a stationary laminated electromagnet. The magnet is energized from the power supply circuit and the whole system is tuned mechanically to vibrate in resonance with the supply frequency. Very small power is used for obtaining a great vibrating force to act upon hard-to-flow materials. Smooth flow of these materials in such places as feed chute, separator, or hopper may be achieved by this method.
CONTROL EQUIPMENT

An electric controller is a device or group of devices which serves to govern the electric power delivered to an apparatus to which the controller is connected. It may be operated either manually or automatically. In agricultural applications the usual functions of electric controllers are opening and closing circuits, starting and stopping devices, and circuit protections.

Contact Materials. An important part of an electric controller is the contact through which the current flows. Its essential functions are to make the circuit, carry the current, and break the circuit.

In making a circuit if the contacts have appreciable mass and meet at high speed a considerable amount of energy will be dissipated. In practice the physical damage due to the collision is a gradual one and the amount of sparking taking place prior to the contacts first touching is small and much less than during parting. On the other hand, the loss of contact materials due to friction is of such importance that the most essential properties of a contact material during the closing operation are hardness and wear resistance.

The heat produced by the flow of current through a contact depends upon the magnitude of the current and
the resistance of the contact. The latter depends primarily upon the contact pressure and the nature of contact surfaces. For low temperature rise contact materials should have high specific heat, high thermal conductivity, high electrical conductivity; contact pressure should be high; and there should be effective ventilation.

During the separation of contacts a certain amount of wear takes place, but the most important properties of contact materials are their behavior under the effects of arcing. The application of quench circuits or arc dispersion arrangements help solve the problem. In most cases the loss of contact material due to arcing is much greater and more important than the loss due to frictional wear. The amount of material lost depends upon the energy in the arc, the ambient temperature and humidity, and the kind of material.

There are very wide varieties of contact materials. They can be classified as metals, alloys, sintered materials, and carbon and graphite. Among the principal metal contact materials are aluminum, copper, iridium, mercury, molybdenum, nickel, palladium, platinum, silver, and tungsten. Contact alloys have been developed to have definite advantages over pure metals with respect to such properties as hardness, wear resistance, and high melting points. Among those commonly used are
copper-base alloys such as gold-silver and platinum alloys. The sintered alloy material is a solid mixture of metals in which the individual properties of each component material is more or less preserved. Its important characteristics are great hardness and high melting point; the metals generally employed are tungsten or molybdenum or their carbides with either copper or silver. Carbon and graphite have one important property in that they cannot weld under the action of the current. In the past they were widely used for the arcing contacts of circuit breakers; where heavy currents were dealt with; and where welding of contacts were very undesirable. Their applications in present day circuit-interrupting devices are less frequent due to the development of better materials.

**Electromagnetic Contact-Making Devices**

These devices are commonly termed contactors or relays. There are two basic types, namely the normally open and the normally closed. The device consists essentially of contacts operated by an electromagnetic mechanism.

**Electromagnetic Operating Mechanisms.** There are two main types of relay structure for general industrial or farm applications, the clapper and the solenoid types. Both consist of a stationary portion of the magnetic
circuit, an operating coil, and an armature or moving portion of the magnetic circuit. A contact is mounted on each part of the magnetic circuit and is brought into close or open position by the flow or interruption of current in the operating coil. The difference between the two types is basically that the motion of the armature of the flapper type is hinge-like whereas the solenoid type is plunge-like.

**Operating Characteristics of Solenoids and Clapper Relays.** The mechanical and magnetic characteristics of both types of relays are similar, differing only in the details of the parts.

**Relays with D-C Electromagnet.** The air-gap flux ($\phi$) of the magnet is related to the coil ampere-turns (NI) by the relation

$$\phi = 0.4 \pi NI \frac{MA}{l} \quad \text{-------- (22)}$$

where $\mu$, $A$, and $l$ are the permeability, cross-section area, and length of the magnetic circuit, respectively. This expression shows that the magnetic force on the armature is proportional to the coil ampere-turns.

Assuming a constant voltage $V$ is applied to the coil having a resistance $R$ and $N$ turns, the power equation is

$$V_i = Ri^2 \cdot \frac{id (N\phi)}{dt} 10^{-8} \quad \text{-------- (23)}$$
The energy involved in any interval of time, \( t_2 - t_1 \),
is then
\[
V \int_{t_1}^{t_2} i \, dt = \int_{t_1}^{t_2} R i^2 \, dt + 10^{-8} \int_{t_1}^{t_2} \frac{id(N\phi)}{dt} \quad \text{---- (24)}
\]

The last term of the equation above signifies the change in energy in the magnetic field. Denote this change in energy by \( \Delta W \), then
\[
\Delta W = 10^{-8} \int_{\phi_1}^{\phi_2} \frac{id(N\phi)}{\phi_1} \quad \text{---------- (25)}
\]

which is a consequence of a change in \( i, \phi \), or the position of the armature. It represents the energy put into the magnetic field and extracted in the form of work.

Relays with A-C Electromagnets. In most A-C coil circuits the resistance drop is quite small compared to the impressed voltage, hence it can be written accurately
\[
V = IX_L
\]
\[
= I 2\pi fL
\]
\[
= I 2\pi f \left( \frac{N\phi}{\sqrt{2}I \times 10^8} \right)
\]
\[
= \frac{4.44 I N\phi}{10^8} \quad \text{---------- (26)}
\]
or
\[
\phi = \frac{V}{4.44 I N 10^{-8}} \quad \text{---- (27)}
\]
Where $V$ is the impressed voltage, $\phi$ is the total flux linking the coil, $f$ is the frequency, $N$ is the number of turns, and $L$ is the inductance of the coil. The flux linkages with the coil are thus constant and independent of the armature position. The air-gap flux will increase somewhat as the armature closes due to less breakage flux, and it tends to remain nearly constant than in a d-c magnet. (12 p. 119-120)

In comparison on the basis that both have the same force in the closed position, the mechanical work done on an a-c armature is much greater than that performed on a d-c unit. For equal pull in the closed positions, an a-c magnet will have to be appreciably larger than a d-c magnet. The magnetic circuit of an a-c device is usually laminated, whereas the d-c unit is solid.

Applications. Electromagnetic contactors are generally used for circuit opening and closing, motor starting and stopping, and as motor protective devices. They may be operated manually, or automatically such as in a motor protective device. When manually operated, the operating coil is energized through a manual switch such as a toggle switch or a push-button switch. When automatically operated, the operating coil is energized through an automatically operated switch.
Switches

Switches are the most basic of all electrical equipment. Its function is to open and close an electric circuit. A switch may be a control device in itself, or may be only a part of it such as the one used for energizing the operating coil of an electromagnetic contactor.

In order to decrease the deterioration of switch contacts to a minimum, the contacts should open and close very quickly. This is usually done by the help of a spring action incorporated in the switch mechanism.

Switches may be classified as the manually operated and the automatically operated types.

Manually Operated Switches. These are the simpler and more common. Those generally used in farm applications are toggle, knife, and pull switches. The method employed by each type for making or breaking a circuit is similar, that is, by forcing one contact into or pulling it out of the cavity in the second contact. The mechanism is so designed that this action is accomplished by the flipping of the toggle switch, pushing or pulling the handle of the knife switch, or pulling the chain of the pull switch. Toggle and pull switches are used for small currents in order of a few amperes. Knife switches are generally designed to handle larger currents.
Automatically Operated Switches. These switches are activated by various primary sensitive elements, and are classified according to the detecting manners of these elements.

Thermal Devices. In these devices an element sensitive to temperature is used for operating the contacts. There are four general classes of electric control equipment of this type: bellows thermostats, wafer thermostats, bimetallic thermostats and thermal overcurrent devices.

A bellows thermostat consists essentially of a bellows unit connected to a liquid-filled metal bulb by a tube. When temperature increases the liquid will either expand or, in other type, evaporate, thereby exerts pressure on the bellows and makes them expand longitudinally; when the temperature decreases the process is reversed. These actions actuate the contacts to make or break an electric circuit as required.

A wafer thermostat is a unit of one or two gas-filled hollow discs whose expanding and contracting actions due to the temperature changes make the contacts meet and part.

A bimetallic thermostat is a strip of two unlike metals bonded together. Due to the unequal thermal expansion of the two metals the strip bends when temperature
changes. This action is used for closing and opening a circuit.

There are two main types of thermal overcurrent devices; the bimetallic units and the melting alloy units. In both types heat is generated by a current-carrying heater unit so that when the circuit current rises to a predetermined value the heat generated will cause the contacts to part, thus opens the circuit and protects it from overheating. In the melting alloy type eutectic alloy having a low and precise melting point is used. It functions as a bonding material in the tripping mechanism to prevent it from tripping at ordinary temperature, but when the current reaches an unsafe value the alloy will melt and release the mechanism to open the circuit. When the alloy cools down enough it will again solidify thus allows the tripping mechanism to be reset into the normal position.

Thermostats are used in a great number of controlling jobs on the farm. Among popular applications are in brooders, incubators, refrigeration systems, crop driers, and ventilating systems. Thermal overcurrent devices are ordinarily used for motor protection but may be used for the protection of an ordinary electric circuit carrying heavy current.

Pressure Switches. These devices are fundamentally similar to a bellows thermostat except that
the pressure of a liquid or gas existing in the process to be controlled itself is used for activating the bellows, or in some types, a diaphragm. Vacuum switches are other similar devices; in these devices vacuum is used instead of pressure. Pressure switches are used for starting and stopping motors in air compressor units, pump units, and other devices that change in pressure of a gas or liquid is one of their operating characteristics.

Hygrostats. When humidity in the air in a certain space is to be controlled a hygrostat is used. It operates on the principle that a hygroscopic material expands and contracts with the variation in its moisture content. Materials commonly used are wood, paper, animal membrane, and hair. Hygrostats are used to turn on and off the fan motors of ventilating systems, incubators, and other humidity controlling devices.

Limit Switches. A limit switch is used for limiting the travel of a piece or mass of material. It is basically a snap-action switch actuated by a push from a part of the traveling material. The devices are useful for limiting the travel of conveyors machine parts, and the flow of materials.

Float Switches. A float switch is used
for controlling the level of a liquid. It consists of a hollow copper ball or cylinder floating on the liquid and is connected to a switch by a rod or chain. The rise or fall of the float to predetermined levels will cause the switch to turn on or off, thus stopping or starting the pump motor. In another type contacts of a solenoid valve will be closed or separated by the motion of the float, thus the flow of a liquid is directly controlled.

**Time Switches.** A time switch is a switch automatically operated by a clock. On the farm, time switches are used for controlling poultry-house lighting, automatic feeders, crop curing, and many other jobs that require intermittent operations.

**Photoelectric Relays.** The relay consists basically of a photocell and a light, ultraviolet, or infrared energy beam. Normally the cell receives energy from the beam and converts it into an electric current for energizing the relay. When the beam is interrupted the relay then is de-energized. These actions may be utilized in various agricultural applications such as door opening and closing, conveyor control, automatic counting, and production quality control.
Solenoid Valves

A solenoid valve is a control device operated electrically but it does not control the flow of electricity. It is used for directly controlling the flow of liquid or gas such as shutting off the flow of refrigerants, and controlling the flow of water in a pipe. The device is similar in principle to the electromagnetic contactors, except that instead of contacts being actuated, the plunger armature opens or closes the path of flow of a fluid by itself.
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APPENDIX

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Lighting-General


Poultry Buildings Illumination


Application of Ultraviolet Energy


HEATING

Heating-General


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**Milk Cooler**


Egg Cooler


Material Handling


Barn Cleaner


Size Reduction (Feed Grinding)


Egg Cleaner and Grader


MISCELLANEOUS EQUIPMENT

Electric Fence


Cow Trainer

Insect Trap


Tramp Iron Remover


Bin Vibrator


CONTROL EQUIPMENT


