WATER SUPPLY ON THE DAIRY FARM

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Milk hygiene on a dairy farm is impossible without an adequate supply of suitable water. If this statement is to be fully understood, the concepts of " milk hygiene ", " adequate supply " and " suitable water " must be defined. An understanding of these three points, which encompass the three elements of use, quantity and quality, will go far towards clarifying many of the technical details relating to farm water supplies. However, water is essential on a farm not only for milk hygiene, but for a great variety of other purposes—watering livestock, and for human uses, such as drinking, cooking, and personal and household hygiene. Except in cases where a separate supply of water is available for irrigation, a single source commonly serves all farm purposes. For these reasons, in analysing the elements of use, quantity and quality it is necessary to consider the water supply as a whole and not simply the portion used for milk hygiene.

Use of Water

Although in this instance it is the reason for considering farm water supplies, milk hygiene is not the most important use for farm water. The primary requirement for water is to support life, first human, then animal. Without sufficient water for drinking there could be no farm, and no milking animals. After this primary and essential need is satisfied, a supply of water must be made available for other household uses. These include cooking, bathing, laundering, cleansing of dishes and utensils, cleansing of floors, and in many cases flushing away of excreta and other wastes. After household needs have been satisfied, water must be provided for farm uses. Farm uses of water, other than irrigation of crops, include the watering of livestock and poultry, cleansing of buildings and equipment, processing of farm produce, making up liquid fertilizers and insecticides and a variety of other purposes. On any farm where milk is produced, one of the very important uses of water is to maintain proper milk hygiene.

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What is milk hygiene? Milk hygiene on the farm has for its purpose the production of milk free from bacteria or organisms which may produce disease among consumers or cause the milk to spoil too quickly, and to preserve the milk in this state until it is taken from the farm. Water for milk hygiene includes that used to wash the milking animals, to cleanse the equipment and utensils used for milk, and in many cases to cool the milk and keep it cool pending collection or delivery. It includes water for washing the floors or other parts of the buildings used for cattle or for milk-handling. In dusty areas milk hygiene might also include sprinkling the immediate surroundings of the milking sheds to prevent dust from flying and contaminating the milk.

Amount of Water

Each use of water must be examined in detail to determine the amount required. This seems to imply a simple exercise in addition, but there are certain complicating factors. In the first place, there are many parts of the world where water is not universally and freely available. In fact, this situation is the more common one, and it is in the minority of cases that water shortage is not a problem, either seasonally or throughout the year. This lays a controlling limitation on the uses to which water may be put, it forces the farmer to put priorities on certain uses, and in many instances puts a limit to his scale of operations. In short, water use is inextricably linked to water availability. One must strike a balance, and it is prudent to appraise the resources and face alternatives in each situation.

Human consumption

The amount of water needed to support human life varies with age and body weight, climatic conditions, amount of energy used, and the elements of the daily diet. Houssay et al. (1955) give the following information:

WATER BALANCE OF AN ADULT MAN, WITH MODERATE ACTIVITY AT A TEMPERATURE OF 18°-20°C

Intake		Output	
Source	Volume (ml)	Route of elimination	Volume (ml)
Beverages	1 000	Kidney	1 500
Food	1 200	Skin	600
Oxidations	300	Lung	300
		Faeces	100
Total	2 500	Total	2 500

The amount of water drunk in a hot climate, especially when manual labour is performed, may rise to 2 litres per hour, and to 10 or even 13 litres per day. In a hot desert an intake of 6 litres per day is quite usual.

Slightly different values are developed by S. Wright (1952), who gives the following approximate quantitative data (both average and range) for daily water exchanges between the body and the environment:

Water intake :	as water	1500 ml (range: 0 to several litres per hour)
	in food	1000 ml (depending on composition of the diet)
	from oxidation in tissues	300 ml
Water loss :	in urine	1500 ml (range: under 20 ml to over 1200 ml per hour)
	via skin	insensible perspiration (constant at 600-800 ml)
		sweat (range: 0 to nearly 2 litres per hour)
	via lungs	400 ml
	in faeces	100 ml (increased in diarrhoea)

Other authorities confirm the high rate of sweat loss. Lee (1953) mentions that an adult man doing moderately hard work under hot dry conditions may lose as much as 4 gallons (15.2 litres) in one day, and this must be replaced by drinking.

For drinking purposes alone, it can be concluded that the water requirement per adult man per day varies from 1 litre in temperate climates with moderate activity to nearly 16 litres in hot dry climates with moderately heavy work.

Other domestic uses

Domestic uses of water for purposes other than drinking would include food preparation, dish-washing, hand-washing, bathing, laundry and toilet flushing. Figures given (page 45) by Wagner & Lanoix (1959), which have been gathered from sources representative of different parts of the world, indicate that domestic water consumption per person per day varies from 10 litres where the water is carried from an outside source to 190 litres where the house is equipped with hot and cold running water, and with kitchen, laundry and bath. Their recommended design figures (page 209) are:

15 litres per person per day for outside source
250 litres per person per day for water piped into the house

Swift (1958), in presenting the figures used for official practice in England, states that for design purposes it is now usual to take as the basis for domestic demand 30 gallons (136 litres) per person per day in rural areas. Bidaut (1958) quotes the French *Circulaire interministérielle du 12 décembre 1944*, which has set the needs of the rural population of France at from 50 to 60 litres per person per day for drinking, cooking and washing. F. B. Wright (1956) uses the figures of 46 litres per person per day where there is running water in the kitchen only, and 152 litres per person per day where there is running water in kitchen, bathroom and laundry.

Animal consumption

F. B. Wright also gives some interesting figures on water use in food production. He states that to produce one quart of milk a cow requires from 3½ to 5½ quarts of water. His recommendations for daily water allowances for animals are:

Animal	*Litres*
Each horse	45.5
Each steer, heifer or dry cow	45.5
Each milk-producing cow (high-producing)	133
Each hog	15.2
Each sheep	5.7
Turkeys (per 100)	68
Chickens (per 100)	19

Bidaut, in presenting French experience, gives the following consumption per head per day:

Animal	*Litres*
Oxen, cows, horses	50
Hogs	20
Sheep	5 - 10

In Great Britain, the Ministry of Agriculture, Fisheries and Food, as quoted by Swift (1958), allows the following amounts per head per day:

Animal	*Litres*
Each cow in milk	136
Other cattle (each)	45.5

Wagner & Lanoix, quoting from the US Joint Committee on Rural Sanitation, present the following estimates, per head per day (page 44):

Animal	*Litres*
Horses, mules or steers	45
Dairy cows, drinking only	57
Dairy cows, drinking and dairy-servicing	132
Hogs	15
Sheep	7.5
Chickens (per 100)	15
Turkeys (per 100)	26.5

Milk hygiene

The quantity of water needed in connexion with milk hygiene is the amount used for cleansing purposes and for milk cooling. For cleansing, which includes wiping the cows' udders, cleansing utensils and for general washing-up, various estimates are available. Wagner & Lanoix (by subtraction) allow 75 litres per milking cow per day (page 44). F. B. Wright (1956), discussing American practice, allows 228 litres per day for a herd of 30 cows, or about 7.6 litres per head per day. Julitte & Pezard (1958) suggest a figure of 5 litres of water for each litre of milk handled.

The amount of water needed to cool milk depends on the amount of milk to be cooled, the temperature of the cooling water, the temperature to which the milk is to be cooled, and the method of cooling. Since milk has virtually the same specific heat as water, in a simple heat-transfer device such as a surface cooler, the theoretical final temperature of both the milk and the water used to cool it is equal to the weighted temperatures of milk and water. For example:

	5 litres of milk at 36°C	180
	40 litres of water at 5°C	200
Total:	45	380

Temperature resulting from exchange: 380/45 = 8.5°C

However, in practice, perfect heat transfer does not take place and an extra allowance of water must be made to take into account the fact that, after cooling, the milk is somewhat warmer than the cooling water discharged.

The temperature of water drawn either from wells or from surface sources can be readily measured. Seasonal fluctuations in temperature can be very great, depending on the nature of the water source. Shallow surface water, whether in ponds or in flowing streams, is subject to both daily and seasonal variations in temperature. A shallow body of water exposed to strong sunlight will warm up rapidly to the temperature at which heat loss through evaporation and radiation balances the heat input from the sun. The exact temperature depends on atmospheric conditions, but it is not unusual in hot climates for the temperature of shallow water to rise above 26°C during the day. The temperature of deeper bodies of surface water is not affected so strongly by daily changes, but seasonal temperatures may range between 0° and 25°C, depending on the climate. Since the need for cooling milk is greatest during the warmest season, and since surface water is the least suitable for cooling at precisely that season, it follows that surface water can seldom be depended on for milk cooling. There are exceptions to this rule. Water in the deeper parts of lakes or reservoirs is frequently much colder than at the surface, and deep intakes can be installed to make use of the cooler water. Also, the temperature of spring-fed streams or ponds may remain quite uniform.

The temperature of water taken from wells is relatively constant. According to Todd (1959), the annual range of the earth's temperature at a depth of 30 ft (9 m) may be expected to be less than 1°F (0.5°C). Analysis of thousands of records of ground water temperature in the USA revealed that the temperature of ground water occurring at a depth of 30-60 ft (9-18 m) generally exceeds the mean annual air temperature by 2°-3°F (1°-1.5°C). Todd's analysis shows a range of ground water temperatures at this depth from 42°F (5.5C) in northern Maine (latitude 45°N) to 77°F (25°C) in southern Florida (latitude 27°N).

Below these shallow depths the temperature increases in accordance with the geothermal gradient of the earth's crust. Todd expresses this gradient as 1°C for each 100 ft (30.48 m) of depth. Dumbleton (1953) reports that the allowance usually made gives the mean rate of increase in Great Britain as about 1°F for about 57 ft (1°C for 30.80 m) of descent. He mentions that Walferdin found in Paris that the increase was at the rate of 1°C for 30.87 m. At Rouen the geothermal gradient was found to range from 1°C for 20.2 m to 1°C for 30 m. More accurate experiments on the artesian well at Grenelle showed remarkable regularity in the increase below the 28-m depth, the figure being 1°C for 31.8 m.

From these observations it can be estimated that water taken from wells about 20 m deep has a constant temperature of about 1° or 2°C higher than the mean annual air temperature at that locality, and with deeper wells the temperature will be about 1°C higher for each additional 31 m of depth. The temperature of water taken from wells less than 20 m deep may vary somewhat with the season. There are, of course, many areas where the normal geothermal gradient is disturbed, such as in volcanic regions, or where hot springs exist, and in such cases the temperature of sub-surface water might be almost anything.

Water Quality

In considering whether water is suitable for farm use there are two elements of water quality that must be taken into account. The first relates to those qualities that may affect human health, principally the presence in water of disease organisms or excessive amounts of poisonous or harmful chemical substances; the second relates to substances which interfere with the useful purposes of water, such as excessive amounts of calcium and magnesium, which result in the formation of scale in pipe, or of iron or manganese, which reduce the value of water as a cleansing agent.

Bacteria in water

The safety of water for human consumption has been the subject of intensive study. The examination of water to determine its bacteriological quality is a complex undertaking involving not only the proper laboratory techniques, but also a complete sanitary survey of the source, and a systematic programme of sampling. One of the principal difficulties lies in the fact that in laboratory results based on the examination of 30-50 ml a single sample of water must be used to judge the quality of many thousands of litres. The sample examined can represent only imperfectly the conditions existing at the moment of its collection. A sudden downpour of rain, or any of a number of other events, can grossly affect the quality of the water between samplings. It is seldom practical or wise to judge the quality of a farm water supply on the basis of laboratory tests for bacteria. WHO, in its *International standards for drinking-water* (1958), gives a careful description of every aspect of this most complicated subject.

In dealing with farm water supplies from the practical viewpoint, the most constructive course is to take every reasonable precaution against contamination, and to rely on the excellence of protective measures for continued safety of the water rather than to base any conclusions on bacteriological examinations.

Water drawn from surface sources cannot be considered to be continuously free from disease-producing organisms. This is an axiom of public health. Consequently if there is no alternative to the use of surface water it must be treated in some way to remove harmful organisms. Clark (1956), in discussing the purification of small amounts of water for drinking purposes, gives three general methods of treatment—boiling, chemical disinfection, and filtration. The types of treatment he recommends might be useful for quantities of water up to about 1000 litres per day. Wagner & Lanoix have dealt quite fully with the methods of filtering and chlorinating rural water supplies, and almost any good textbook on water supplies contains information on this subject.

However, the use of treated surface water on a dairy farm should be considered only as a last resort. Treatment of water involves a daily operation. Even in large well-supervised water-filtration plants there are lapses in treatment. Wagner & Lanoix state (page 171): " Experience in many parts of the world has shown that, once a water-treatment plant is constructed, there is need for constant vigilance—both present and past literature abounds with the history of water-borne outbreaks of typhoid fevers, cholera and epidemic jaundice caused by a breakdown of treatment processes for which inexperienced or unqualified operators were responsible." If this happens in large water plants, the chances of its happening on farms is immeasurably greater.

The safer course is to use water from properly protected wells. With certain exceptions water occurring deep underground is free from contamination with disease-producing bacteria. The chief exception is in regions where dolomite or limestone occurs, which has been channelled into fissures or caverns through which the water can flow without being subjected to the filtering action of soil or permeable rock. Under certain less frequent conditions other rock formations may contain underground channels, due to fracturing or to cleavage planes.

The danger of contamination reaching farm wells by passage underground through the soil is often over-emphasized. Pit privies, cesspools, septic tanks and seepage units should, of course, be separated by a reasonable distance from wells. So also should barnyards, manure heaps and other sources of contamination. But by far the most common mode of pollution is by the entrance of contamination into the top of the well. The well cap and the top two metres of the lining constitute the most vulnerable area. In a very high proportion of all cases good watertight construction here, so built as to prevent any water from the surface leaking in, will eliminate the danger of harmful bacteriological contamination in wells. The quality of construction of a well top is a reasonably accurate index of the bacteriological quality of the water in the well.

Mineral substances in water

There are many mineral substances that make water less suitable for use. WHO (1958) lists the more important under two headings, *Toxic substances* and *Chemical substances affecting the potability of water* (pages 27, 28-29):

" *Toxic substances*

" There are certain substances which, if present in supplies of drinking-water at concentrations above certain levels, may give rise to actual danger to health. A list of such substances and of the levels of concentration which should not be exceeded in communal drinking-water supplies is given below:

Substance	*Maximum allowable concentrations*
Lead (as Pb)	0.1 mg/l
Selenium (as Se)	0.05 mg/l
Arsenic (as As)	0.2 mg/l
Chromium (as Cr hexavalent)	0.05 mg/l
Cyanide (as CN)	0.01 mg/l

" The presence of any of these substances in excess of the concentrations quoted should constitute grounds for the rejection of the water as a public supply for domestic use.

" It is realized that the limiting value for chromium is well below the known toxic concentration, but it is considered that this element should not be present in drinking-water, and a minimum limiting concentration has been set to provide rejection of a water supply...

" *Chemical substances affecting the potability of water*

" The following criteria are important in assessing the potability of water. In view of the wide variations in the chemical composition of water in different parts of the world, rigid standards of chemical quality cannot be established. The limits hereafter designated " permissible " apply to a water that would be generally acceptable by consumers; values greater than those listed as " excessive " would markedly impair the potability of the water.

" However, these limiting concentrations are indicative only and can be disregarded in specific instances.

	Permissible	*Excessive*
Total solids	500 mg/l	1500 mg/l
Colour [platinum-cobalt scale]	5 units	50 units
Turbidity [turbidity units]	5 units	25 units
Taste	unobjectionable	—
Odour	unobjectionable	—
Iron (Fe)	0.3 mg/l	1.0 mg/l
Manganese (Mn)	0.1 mg/l	0.5 mg/l
Copper (Cu)	1.0 mg/l	1.5 mg/l
Zinc (Zn)	5.0 mg/l	15 mg/l
Calcium (Ca)	75 mg/l	200 mg/l
Magnesium (Mg)	50 mg/l	150 mg/l
Sulfate (SO_4)	200 mg/l	400 mg/l
Chloride (Cl)	200 mg/l	600 mg/l
pH range	7.0-8.5	less than 6.5 or greater than 9.2
Magnesium + sodium sulfate	500 mg/l	1000 mg/l
Phenolic substances (as phenol)	0.001 mg/l	0.002 mg/l "

Both of the foregoing categories of chemical substances in water relate to its suitability for drinking. On a dairy farm where water for cleansing utensils and equipment must be heated, there often arises the problem of scale, which can be extremely troublesome. It may form in pipes and water heaters in such quantities as to clog them completely; it forms on the surfaces of kettles or other containers used for heating or cleansing purposes, and is objectionable from every point of view.

Scale is the deposition of mineral salts in the water resulting from a change in chemical equilibrium. Scale-forming properties of water are closely related to the corrosiveness of water. As the chemical equilibrium varies, the water varies from corrosive to neutral to scale-forming. These properties depend on the hydrogen-ion concentration, alkalinity and calcium-carbonate saturation-equilibrium value. This last factor depends on a number of other factors including the carbon-dioxide content and temperature. Waters of low alkalinity and hardness or of high carbon-dioxide content are usually corrosive; conversely, waters of high alkalinity and hardness, such as strongly mineralized well-waters, are usually encrusting or scale-forming. Water may be in chemical equilibrium when taken from a well, but the equilibrium may change quite rapidly. The loss of carbon dioxide can take place simply by exposure to the air—especially turbulent exposure, as when water spills from a pump—and this loss can lead to the precipitation of calcium carbonate scale. Heating water also changes the chemical equilibrium, both by changing the equilibrium point and by expelling carbon dioxide, and usually leads to rapid deposition of scale. The chemical and physical reactions involved have been exhaustively described by Langelier (1936) and by Fair & Geyer (1954).

To correct the trouble of scale formation there are two general methods available: water-softening, and the addition of compounds which alter the scale-forming characteristics of the water. Water-softening can follow either of two general lines: (*a*) by the removal of calcium, magnesium and iron by precipitation with lime, or (*b*) by base-exchange—i. e., the zeolite process, by which one base, usually sodium, is substituted for another, usually calcium and magnesium. Zeolite-softened water is still mineralized, but with compounds which are neither " hard " nor scale-forming.

Hoover (1943) has given a full and accurate description of lime-softening. It is seldom practicable to use this method on individual farms because of the daily skilled operation required.

Zeolite-softening is often practicable, and the infrequent operation required is confined usually to periodic regeneration of the zeolite with salt. Fair & Geyer (1954) describe the chemistry of this process, and practical applications are set forth in Wagner & Lanoix (page 192), and Wright (1956). Technical advice should be sought before deciding on the type of softener, since there may be mineral substances in the water which require special consideration. Different equipment is needed, for example, for zeolite-softening of water containing iron.

Water can be treated with chemicals, such as polyphosphates, which reduce the amount of scale formed on heated surfaces, leaving the precipitated minerals suspended in the water. These are generally called "softening compounds" or "boiler compounds". Compounds may also be used with soap and other detergents to reduce the amount of film and encrustants deposited on equipment and utensils. The use of such compounds probably represents the most practical treatment for scale-forming water available for farm use. Freyman (1955) describes the chemistry of the softening action of some of these compounds, such as tri-sodium phosphate, sodium hydroxide, sodium carbonate and sodium sulfate. The American Society of Heating and Air-Conditioning Engineers (1959) has prepared a comprehensive description of scale, its causes and its prevention, with particular reference to the use of polyphosphates.

Winning Water

The winning of water is a term that applies to locating water, devising and constructing the works necessary to make water accessible, and installing and operating the equipment needed to bring water to a point where it can be used, or transported elsewhere for use. In the case of a farm well it means, in simplest language, locating water underground, digging a well, and installing a pump.

Locating water

Finding water underground is a tricky business, especially when dealing with a farm well. Departments of geology, working on a grand scale, or a municipality searching for thousands of cubic metres per day, can well afford the latest equipment for geophysical surveying, and can do extensive field work. Often they can search for water in several widely scattered areas. The farmer, with no more than his individual resources and limited to the confines of his own property, can almost never make use of such methods. His search is limited to a few fundamental inquiries.

The first course open to him is to find out what kind of wells his neighbours have, or which he himself may have on his own property. This involves getting three basic facts about each well—namely, the depth of the well, the depth of water in the well, and the yield of the well during the worst season of the year. Each of these items involves a certain complexity.

The depth of the well is subject to measurement, and it is usually best simply to measure it, rather than to search about for someone who may or may not have a clear memory of what its depth is supposed to be. The measurement of the depth is of importance in locating the aquifer, or the underground stratum which bears water. This measurement can be considered as the thickness of the material (earth, rock, sand or gravel) which overlies the aquifer. This thickness varies according to the elevation of the aquifer and the elevation of the ground surface. It is important, therefore, when measuring the depth of the well to take note of the terrain—for example, whether the well is on high ground or low ground, and the relation of this to the area proposed for the new well. By doing so, a better estimation can be made of the depth to which the new well must go to penetrate the aquifer.

The depth of water in the well can also be measured, and it is convenient to do this when measuring the total depth of the well, simply by marking and measuring the wetted portion of the plumb rod or line. The depth of water in a well is subject to great changes, however; in a well at rest, from which little or no water has been drawn for several days, the water surface accurately indicates the level of the ground water table; whereas when a well is in use, and relatively large volumes are being withdrawn, the level in the well is drawn down, creating a cone of depression in the ground water table. It is important, therefore, to know what use has been made of the well at about the time of measurement, for it is perfectly possible for a well to be drawn down to the very bottom, even though the general ground water level is unchanged.

If possible, a series of measurements should be made at different seasons, but it is most important to make measurements at the season of the year when the water table is lowest. If there are wells in the neighbourhood which, according to hearsay, " never go dry ", or which " did not go dry in a year when everyone else was out of water ", measurements should certainly be made of their depth, for if a new well is carried down deep enough to provide the same depth of water it will almost certainly be below the lowest seasonal level of the ground water.

The estimation of the yield of a well is not particularly difficult, although it does call for certain care. In the first place, when dealing with an individual farm supply, the yield of a well is not important so long as there is plenty of water. If neighbours are making about the same use of water as the dairy farmer would make, and if their wells yield the amount they need without excessive drawdown or other difficulties, then it is only common sense to conclude that the same kind of well in the same kind of formation will provide the same kind of satisfactory yield. If, however, there have been difficulties, it is useful to know specifically the yield of existing wells.

Measurement of yield can be made by pumping at a constant rate until a stable condition is established, often from 12 to 24 hours, and then measuring the drawdown. The mathematical theory underlying the relationship of yield to drawdown is fully developed by Fair & Geyer (1954). To get the yield figure the rate of pumping is divided by the final drawdown, the result being the specific capacity—that is, a certain number of litres per minute per metre of drawdown. Within practical limits, the yield is directly proportional to the drawdown. Thus, if a well yields a certain amount of water with a drawdown of 1 m, the same well, or a similar one in the same formation, may be expected to yield twice as much water with a 2-m drawdown.

Drawdown and recovery rates may be very greatly influenced by restriction of flow where the water enters the well. This condition is probably most serious where the well consists simply of a pipe driven into the ground with a strainer on the bottom. When the strainer becomes corroded and encrusted it offers very strong resistance to water flow, and drawdown data on such wells may be of questionable value in predicting yields.

From information gained on neighbouring wells, and from any other sources, some decisions can be made relative to the probable location and depth of sub-surface water. If possible, this estimate should be verified by sinking one or more test holes. If the water lies deep and an expensive operation is required to drill down to it, test holes are probably out of the question, but if it can be managed, such drilling will usually prove to be a good investment.

Well construction

There are many excellent texts on the construction of wells. Particular mention is made of the book by Wagner & Lanoix (1959), which contains information gained from and applicable to virtually all parts of the world. From the practical point of view, which is usually the point of view of the farmer, local experience should be taken strongly into account. Very often improvements can be made in the types of well in local use, but the general style of local wells reflects the local needs, resources, and skills or methods of work.

Regardless of the kind of well used, one of the most important points to keep in mind is that contamination must be kept from leaking in from the surface. It is useful to consider how surface wash, carrying harmful bacteria, can find its way into a well. It can leak in through the upper 2 m of the well lining; the ground immediately surrounding a well is often saturated with water which has been wasted or spilled, for it is not uncommon for people to wash their faces and hands and to splash water over their bodies while standing at the well. The saturated soil encourages leakage through stone, brick, or other linings into the well. To correct this fault, there should be a watertight platform all round every well, extending away from it for a distance of 1.5 to 2 m, set on a built-up mound above the level of the surrounding area, and sloping away from the well in all directions. By this means, spilled water is directed away, and the earth in contact with the lining is not perpetually saturated. At the same time, at least 2 m of the lining immediately below the ground surface, and any part of the lining above the ground surface, should be absolutely watertight.

The second way that surface wash can enter a well is through the slab or covering. Open wells are not admissible for use on dairy farms. The justification for this statement is revealed in the filth and debris that can be found at the bottom of open wells when they are drawn down for cleaning. The slab or cover should be constructed in such a way that no drops of water splashed or flushed over the surface of the cover can find entrance into the well.

The third way that contamination can enter a well is through the pump. This occurs most frequently in cases where suction-lift pumps are used which require priming. Self-priming pumps, with cylinders set below the water level in the well, are somewhat more expensive, but they afford very much better protection to the quality of the water and as a rule are freer from trouble.

The Use of Power

The use of water is facilitated and encouraged if it can be made available without great expenditure of human effort. This can be accomplished in a number of ways. A spring on a hillside can be led to the point of use through pipes, providing gravity-flow. In areas where the winds are frequent, wind-wheels can be used to advantage. Water power can be harnessed to pump water. Internal combustion engines are commonly employed for pumping in all parts of the world, and where electric power is available on a farm it offers an ideal solution to the pumping problem.

Gravity-flow from an elevated source can be used in two ways. The first is to use a pipe connecting the source to an elevated tank located near the farm buildings and farmhouse; from this tank, water can be led through pipes to the points of use. The second system is to construct a basin near the source high enough to give the desired pressure at the farm buildings or house, and to lay a pipe from this basin to the points where the water is to be used. The choice between these two systems is based entirely on the relative cost in each instance.

The following factors relate to pipe sizes, and hence to cost. Water is seldom drawn from a piped system at a uniform rate. At certain times of the day it is used for different purposes, at various rates, ranging from nothing at all during the night to relatively very high rates during washing, milk-cooling, or other operational periods. Figures have been given on the daily amount of water required for use on a dairy farm. There are 1440 minutes in a day, but if a farm uses 2880 litres per day the flow used will not be a steady 2 litres per minute, but will vary from 0 to 40 litres per minute at different periods of the day. To satisfy the peak demand, under the second condition described above, the pipe connecting the source to the outlet must be large enough to discharge the maximum rate. Furthermore, depending on the yield of the source and the daily cycle of use, the reservoir or basin constructed at the source must be large enough to supply the sudden peak demands whenever they are in excess of the yield.

In the first case, where an elevated tank is constructed near the point of use, the pipe connecting the source to the elevated tank can be operated to deliver water at a constant rate throughout the 1440 minutes of the day. A heavy draught during the day will draw down the level of water in the elevated tank, but the level is restored again during the night by the steady inflow. The elevated tank must be of sufficient size to meet the daily demand, and should generally be large enough to contain one day's supply.

It can be seen that, in the second instance, the pipe from the source must be very much larger than in the first case. If the source is some distance away the saving in piping cost effected by using the first system will offset the extra cost of an elevated tank.

Where power pumps are used, a similar consideration applies to pump sizes, and it will be found that elevated or pressure-tank storage ordinarily reduces the cost of pumping, both in terms of equipment costs and operation.

It is an odd thing that a suitable pump has not been developed for use with animal power. There have been instances of the use of treadmills or other devices to drive a proper pump, but there has been no widespread use of this method. Animals are very commonly used for lifting water, but the devices generally utilized are insanitary, and can only result in contaminating the water. Among these are the ingenious self-emptying goatskin bags used in North Africa, and the Persian wheel used in parts of Asia. There is scope here for some research and development, for animal power is the commonest source of energy on farms throughout the world.

The Human Element

In the final analysis, the production of safe water on a dairy farm depends on the human being involved, the farmer. Every farm has a water supply, and consequently, the commonest situation to be faced is its improvement, or perhaps the substitution of a new supply. Farmers as a class tend, however, to be conservative, and an individual farmer may well have a deep-seated attachment to his water supply. It is a part of his life, almost like a member of his body, and he may be resentful of criticism directed against it. His well may have been in use since ancestral times, it is a part of his tradition. To change his well may mean not only a change in his own life: it may represent to him a break with the past. In spite of these difficulties, the farmer may have to be persuaded that his water supply is not as good as it should be, and that he must take certain actions to bring it up to an acceptable standard. The burden of maintaining a farm water supply falls directly on the farmer, and if he is to keep it in good condition he must have a permanent convinction that it is worth while to put in the effort required. Different people will react differently, and the educational methods applied will vary with the circumstances. The main point is that the dairyman should be persuaded that he must give as much attention to the hygiene of his water as to that of his milk.

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