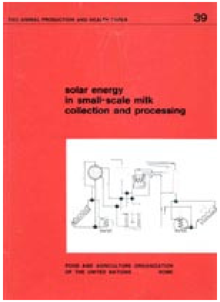

FAO ANIMAL PRODUCTION AND HEALTH PAPER 39

solar energy in small-scale milk collection and processing

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PREFACE

In most developing countries nutrition of the human population is a problem of great concern. In many cases it is a problem which is becoming more difficult because populations are increasing for various social and medical reasons. Milk is fundamental in human nutrition. It is the neonatal food of all mammal species and man is fortunate in that the milk of many domesticated animals can be used as an important part of his diet throughout life.

Milk is a perishable foodstuff because it is an excellent medium for the growth of microorganisms which cause spoilage. This can be countered by various conservation processes, some traditional, and some developed by modern technology. Even at a very modest scale of operations these processes need energy. Energy from conventional sources is becoming increasingly expensive, adding to the difficulty of promoting milk collection and processing projects in developing countries. Such countries, however, usually have a wealth of solar energy which is free and inexhaustible. The cost of such energy is that required only for the apparatus necessary to collect and transform it.

This book explores the possibilities of applying solar energy to small-scale milk projects. It suggests simple processing technologies which will readily be understood by those who may have social or administrative responsibilities for the well-being of a less affluent population. It also outlines the problems of harnessing solar energy and provides the necessary background information for those expert in this field. These problems are such that the schemes suggested must be limited to a maximum of 1 600 litres per day and thus would be applicable primarily to village communities. It is probable that this is the scale where new effort is needed and can be of the greatest benefit to the country concerned.

It is hoped that this publication will interest those concerned with promoting milk production, collection and processing schemes in developing countries and that the information presented will help in

establishing pilot development projects, possibly with external financial and technical assistance.

CHAPTER 1

INTRODUCTION

Of the many problems which a new project for milk collection and processing faces in a developing country, the most important are the shortage of the necessary capital and the difficulty in keeping all costs at a sufficiently low level. The specific costs of collection, transport and processing are usually abnormally high because supplies of milk are inadequate to utilize fully the installed machinery. Small quantities of milk delivered by individual producers, long distances between the production areas and the markets, bad road conditions and high ambient temperatures make the development of a dairy industry a particularly difficult task.

Dairy development policies in such countries are most often based on foreign patterns. They include establishment of a number of collecting centres and processing plants whose basic feature is the technology prevailing in industrialized countries. That technology is marked by processing costs often too high for markets in developing countries and machinery often too complicated for locally available skills. The capacity of equipment normally available often greatly exceeds the quantity of milk which can be obtained, particularly in the early stages of development.

In recent years new trends are becoming evident in applying technology to food processing in developing countries. This involves simple processes better adapted to the special needs of these markets. These ideas now need study and applied research, primarily by establishing pilot schemes in which feasible projects are tested. Consistent with these trends is the examination of the feasibility of using solar energy for small-scale operations.

The well-known world energy crisis justifies active search for alternative energy sources of which solar energy is a particularly attractive choice in countries situated in the sunnier parts of the world. If utilization of this energy is feasible and could be combined with simple technologies, the aim of reducing capital inputs and processing costs might well be met.

Conventional fossil fuels from known resources are estimated to last, at present consumption trends, for:

liquid fuels	-	20 years
gas fuels	-	40 years
coal	-	250 years

While these estimates may be conservative because future discoveries and more efficient methods of utilization may extend them, such resources are finite and their cost must steadily increase. The technology of nuclear energy is still in its early stages but where it is based on naturally occurring elements such as uranium it is subject to similar limitations.

The solar energy reaching the world's surface is practically inexhaustible and, in 1980, was about 20 000 times greater than all the manconverted energy from all fuels. Technologies for trapping solar energy and converting it into industrially useful forms are undergoing development, and research and development work on this subject enjoys high priority all over the world. Modern processing industries, however, including food processing require a continuous energy supply. This presents serious problems in the application of solar energy systems which, by their nature, can accumulate energy only during daylight. Difficulties in resolving the problem of storage of the accumulated energy and making this continuously available in the required quantities at the necessary levels are the main reasons why solar systems have not yet become an attractive proposition in modern industry. However, there is a chance that small-scale industries will adapt themselves much more quickly to energy supply from solar systems than would be possible for large-scale operations.

Small-scale industries already have difficulty in applying modern technologies due mostly to complicated and expensive equipment with capacities far exceeding those required by small plants. The latter need new and better adapted designs. Their energy requirements are relatively small and can be compared to those for domestic use such as water heating and air conditioning where application of solar energy has already begun.

No attempt has been made to present an exhaustive survey of the solar systems currently available or of research and development work currently in progress. The relevant literature is very rich indeed and it seems unnecessary to repeat it in this study. However, a bibliography is included. The survey of solar systems given in Chapter 3 is therefore limited to basic principles and information related to their feasibility in smallscale milk schemes.

Chapters 4 and 5 provide suggestions for pilot projects which could be successful for schemes up to 1 600 litres of milk per day. There is no single ideal solution and only by pursuing projects such as those suggested can real progress be achieved.

CHAPTER 2

ENERGY IN ESTABLISHED MILK COLLECTION AND PROCESSING

2.1 General

The consumption of energy in food processing plants is usually characterized by specific consumption

and peak-hour requirements, separately for each type of service. In milk plants data are usually presented for steam, refrigeration, well water, compressed air and electric power.

There are no standards for service requirements in the dairy industry applicable to all plant capacities or to specific products. Such requirements depend not only on the overall capacity and the type of the plant but also on the source of energy utilized.

An artisanal cheese-maker heats milk on simple wood-fired stoves in which not more than about 10 percent of the energy of the wood is used for milk heating and 90 percent is lost. In modern gas-fired steam raising plants 90 percent of the gas energy can be transferred into steam and finally over 80 percent of the energy in gas will increase the temperature of milk or, in condensing and drying processes, will cause evaporation of water. In modern milk plants plate heat exchangers with regeneration can reduce the nominal heat requirements to one fifth or even one tenth; modern multistage milk condensing plants require not more than 20 to 40 percent of the nominal heat requirement per kg of evaporated water. Thus, taking the example of milk pasteurization, the furnace fuel energy required in a small-scale artisanal plant per unit of product can be about 40 times that in a large-scale modern milk plant.

On the other hand the specific consumption of electric power may be nil or negligible in artisanal plants and relatively high in modern factories. Even within a given class of milk processing plants, the service requirements may differ substantially. Fuel consumption for drying processes depends very much on the inlet air temperatures which are kept usually on the high side when oil or gas heaters are used for air heating in spray driers but on the low side with steam heaters. Water consumption for chilling and condensing depends very much on the initial well water temperature and the humidity of the ambient air. It in turn affects the refrigeration requirements. The energy requirement figures quoted in this study are therefore of indicatory nature only.

2.2 Collection

2.2.1 Modern industries

The prevailing pattern of milk collection systems includes milk chilling directly after milking and tanker collection from the farm gate using tanker-mounted meters for measuring milk quantity. Several cooling systems are in use. The milk may be cooled in a bulk tank by a chilled water jacket containing an icebank or by a direct expansion refrigeration system. It may be precooled in a plate heat exchanger using mains water and chilled water or glycol, and then stored in bulk with or without direct expansion refrigeration to counter subsequent heat gains. The use of chilled water generally increases the total energy required in kWh/t [1] but decreases the demand in kW and so is usually preferred for larger installations. Water requirements for cleaning are small and can be estimated at about 0.15 m^3/t of chilled milk or less. For bulk tanks cold in-place cleaning is often used and is particularly suitable for icebank chilling systems.

The total energy requirements for milk chilling prior to transportation to milk plants can be estimated at 25 to 30 kWh/t net or 85 to 105 kWh/t gross respectively. This total requirement refers to electric power and includes the refrigeration unit, milk agitator, power requirement for water supply and heating or pumping in cold cleaning-in-place (CIP) systems.

Apart from the well-known fact that immediate milk chilling is one of the main factors in manufacturing quality products, it also necessitates a low energy input in milk processing in the plant. Chilling, either directly after milking or during processing if the milk is unchilled, requires as mentioned above, an estimated 25 to 30 kWh/t energy net input forming part of the milk processing operation.

[1] t= metric ton (this measurement is used throughout the publication)

2.2.2 Small-scale industries

The main feature of small-scale milk collection systems is the collection centre where milk is delivered by producers in small vessels in quantities depending on farm yield. This may vary from about 0.5 l to as much as 100 l and as a rule, the milk arrives at little below milking temperature.

In the most simple systems there is only quantity measuring and bulking into cans which are washed in the central plant. There is thus no energy consumption for milk treatment in such centres. A milk chilling system by means of refrigeration machinery installed in the milk collection centre is usually the next development step in small-scale milk collection systems, sometimes accompanied by simple milk separation equipment. In centres where cans are washed in the central plant, the energy consumption is similar to that in modern systems though available data show that it is about one third higher because of lower capacity utilization and higher heat losses. It can be estimated at 35 to 40 kWh/t net and 105 to 135 kWh/t gross, respectively.

In many countries long distances from production areas to milk plants make two-stage milk collection systems necessary. In such systems the producer delivers the milk to a simple collecting point from where, with no initial handling, the milk is transported in cans to the second stage collection centres equipped with chilling machinery and can washing facilities. Such centres are usually equipped with steam boilers and can washers and sometimes with milk tanks from which the chilled product is pumped to road tankers.

The net electric power requirement for chilling in such centres, together with stirring and pumping, can be estimated at about 40 kWh/t. In addition there is the energy requirement for cleaning which includes water supply and heating. It may vary very widely but for the majority of centres belonging to this sub-group, the specific requirement of steam could be estimated at about 10 kg/t which is equivalent to about 7 kWh energy in steam per l t of milk. Total water requirements may rise to 0.3 m^3/t. The total net specific energy requirement could be thus estimated at about 47 kWh/t of collected milk. The corresponding figures for gross requirement can be estimated at about 15 kWh/t in furnace fuel and about 140 kWh/t in electric generator engine fuel which brings the total to about 155 kWh/t. These figures are no doubt surprisingly high but the early protection of fresh milk quality is a necessary precaution if quality products are to be manufactured in the milk plant.

It should be mentioned that in some countries, increasing the temperature of milk or cream to about 60°C and keeping it at that temperature during transportation to the milk processing centre or the

customer was traditionally a way of preserving milk quality. This system still prevails in some African countries such as Mali. Although objections could be raised concerning the suitability of such milk for the manufacture of some products, this system should not be disregarded when considering cheap methods of milk marketing since it does not require high capital inputs. The respective energy requirement, even if relatively high, can be covered by locally available cheap fuels.

2.3 Processing

2.3.1 Modern industries

Modern large-scale milk processing plants prevail in industrialized countries. The daily processing capacity per plant usually exceeds 100 t of milk intake but even smaller plants with a daily intake of about 30 t are generally equipped with modern machinery. Their specific energy requirements are similar to those of large-scale factories though usually slightly higher since they do not benefit from the effects of scale.

To provide a background for the later consideration of small-scale operations, data from about 30 European plants have been analyzed. From these, typical energy requirements have been estimated for nine groups of products and are presented in Table 1 and Figs. 1 to 6. In calculating these figures certain basic assumptions were made, viz.

i. **Specific water requirements were estimated at 3 m^3t of processed milk, independent of plant capacity or processing programme.**

   This consumption is expressed as an equivalent electric power requirement of 6.4 kWh/m^3 and is included in the total electric power consumption. The relatively low energy requirement for compressed air consumption is also included.

ii. **All heat requirements for large-scale milk processing were calculated as steam condensed and the** coefficient of 0.66 kWh effective heat from 1 kg standard steam was used in all calculations. For all cleaning processes the total heat requirement was increased by about one third and the equivalent electric power consumption by one tenth.

iii. Refrigeration plays a very significant role in the overall energy requirements of a modern milk plant, often constituting above 40 percent of the total electric power consumption. In the specific energy consumption estimates, data concerning refrigeration are presented separately: (a) as total energy equivalent (heat removed from the product during processing and from the air in cold stores) and (b) electric power consumption by refrigeration machinery.

It has been necessary to ignore factors such as purchasing water from municipal mains, producing electric power from the plant's own generator, covering part of the heat requirements by direct fuel heating and running machines of different efficiency. All estimates have been made in “net requirements” and “gross requirements”. The first include figures representing the increase of enthalpy in the heated milk or the energy obtained by steam condensing in the processing machines or energy produced by electric motors moving the processing machines. The “gross requirements” represent the amount of energy in furnace fuels and engine fuels used to produce the equivalents of the respective “net requirements”.

For all milk plants with modern equipment (both large and small-scale) the efficiency coefficient for steam-raising plants was taken to be about 0.8 and about 0.5 for all other plants with steam boilers. The efficiency of milk heating with no use of steam as the intermediate medium was estimated at 0.1. In order to estimate the “gross requirement” was equivalent for electric power consumption, the “net requirement” was multiplied by the factor of 3.5 which illustrates the energy input/output ration in medium capacity electric generators. It should be borne in mind, however, that the application of this factor reflects better the “gross requirement” of electric power for small-scale plants than for modern industry which usually draw power from more effective systems.

All consumption figures are expressed in kWh (1 kWh= 3.6×10^3 kJ= 860 kcal).

Table 1. Specific energy requirement in modern milk processing plants

Type of service	Unit	Requirement-including CIP for one ton of milk processed into:								
		Liquid products in bottles		Liquid products in one-way containers		Skim milk powder and butter	Full cream milk powder	Ripened cheeses		Evaporate and condense milk
		pasteurized	sterilized	pasterurized	UHT			Without whey processing	with whey processing	
Net requirement										
Steam	kg/t	250	300	100	150	880	830	190	700	440
Refrigeration total energy equivalent	kWh/t	50	40	50	40	60	45	70	70	45
Refrigeration electric power requirement	kWh/t	20	16	20	16	24	18	28	28	18
Heating	kWh/t	165	200	70	100	585	530	125	460	295
Electric power (total requirement)	kWh/t	55	70	50	90	90	80	75	100	60
TOTAL NET REQUIREMENT	kWh/t	220	270	120	190	675	610	200	560	355
Gross energy requirement										
For heating (furnace fuel)	kWh/t	205	250	90	125	730	660	155	575	370
For electric										

power generator fuel)	kWh/t	195	250	180	315	315	280	265	350	210
TOTAL GROSS REQUIREMENT	kWh/t	400	500	270	440	1,045	940	420	925	580
% of energy in steam in total requirement	%	75	74	58	53	87	84	63	82	83
% of energy in furnace fuel in total gross requirement	%	51	50	33	28	70	70	37	62	64

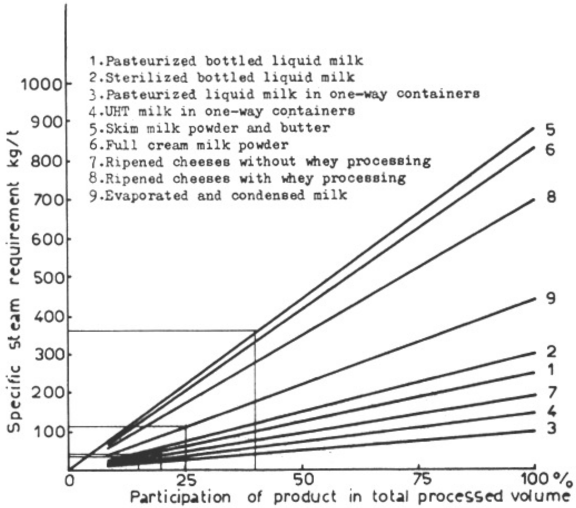


FIG 1. SPECIFIC NET STEAM REQUIREMENT

FIG 1. SPECIFIC NET STEAM REQUIREMENT

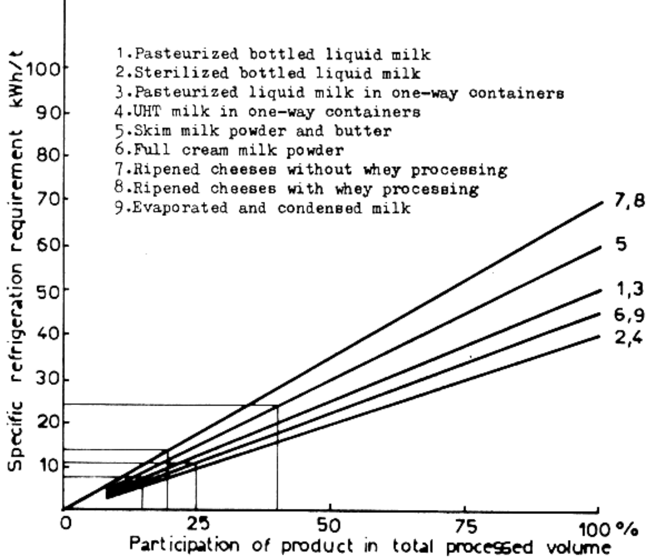


FIG.2. SPECIFIC NET REFRIGERATION REQUIREMENT

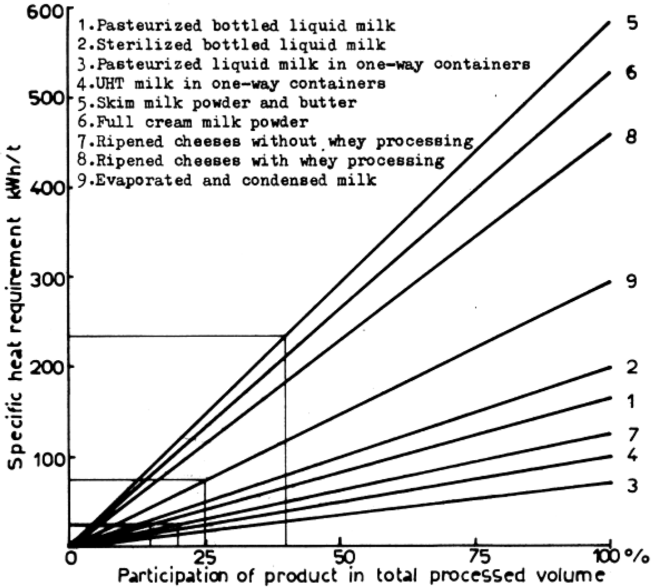


FIG.3. SPECIFIC NET HEAT REQUIREMENT

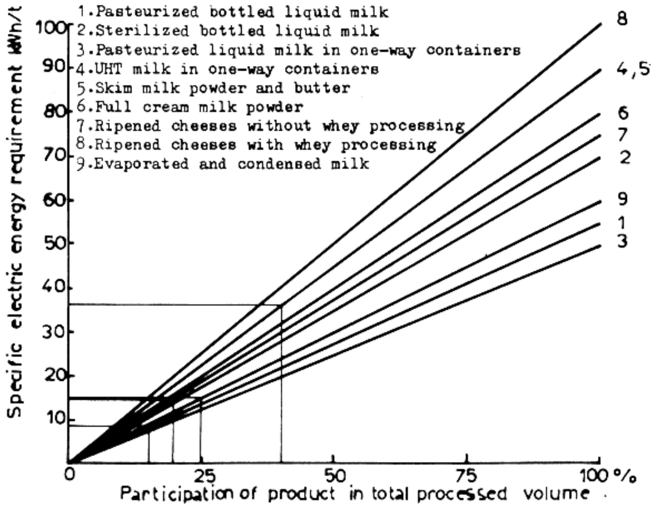


FIG.4. SPECIFIC NET ELECTRIC ENERGY REQUIREMENT

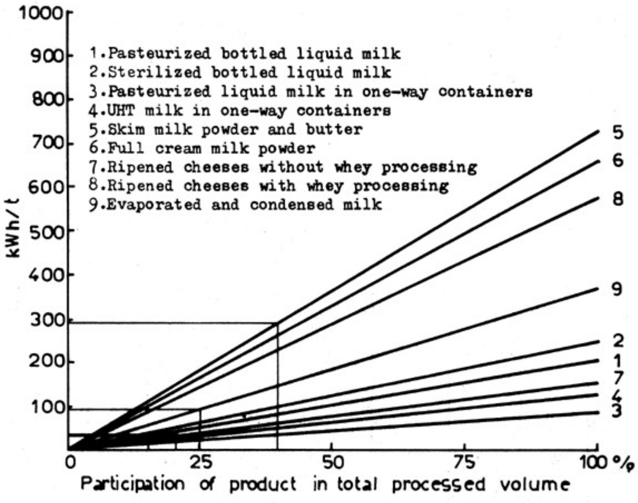


FIG 5.SPECIFIC GROSS HEAT REQUIREMENT (FURNACE FUEL)

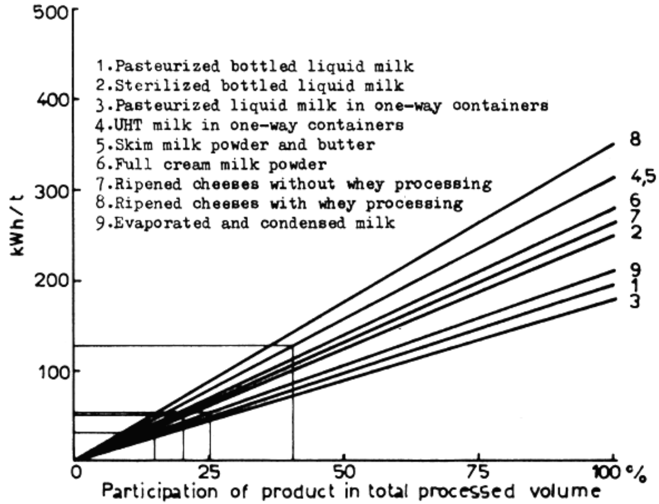


FIG 6. SPECIFIC GROSS ELECTRIC ENERGY REQUIREMENT (GENERATOR FUEL)

Figs. 1 to 6 have been compiled to facilitate estimates of energy requirements for processing programmes including any or all of the nine product groups specified in Table 1. An example for a plant processing a total of 160 t of milk per day into four products is given in Table 2.

Table 2

Estimate of specific energy requirement for a selected processing programme

Milk processed daily into:	t/day	Part of total	REQUIREMENT							
			NET				GROSS kWh/t			
			Steam kg/t	Refrigeration total energy equ. k Wh/t	heating kWh/t	electric power	grand total	heating	electric power	total

						kWh/t	kWh/t			
Pasteurized liquid milk in bottles	24	0.15	37.5	7.5	24.8	8.3	33.1	30.8	29.2	60.0
Cheese without whey processing	32	0.20	38.0	14.0	25.0	15.0	40.0	31.0	53.0	84.0
Skim milk powder and butter	64	0.40	352.0	24.0	234.0	36.0	270.0	292.0	126.0	418.0
Condensed milk	40	0.25	110.0	11.3	73.8	15.0	88.8	92.5	52.5	145.0
Total	160	1.00	547.0	56.8	537.6	74.3	431.9	446.3	260.7	707.0

The trend of development indicates that in most modern plants the total energy requirement is increasing, mainly due to the increase in electric power consumption, whereas the specific heat consumption remains substantially unchanged. Such trends are the result of increasing mechanization and automation which requires more equipment in processing lines and particularly in stores. This tendency can be exemplified by comparing methods of equipping milk tanks with valves. In a plant with manually operated valves a milk tank is equipped with 5 to 7 valves whereas automatic operation of a similar tank needs 12 to 15 pneumatic valves, requiring compressed air for their operation.

2.3.2 Small-scale industries

Data concerning energy usage in small-scale milk processing plants having a capacity from 1.0 to several tons per day have been collected in various developing countries. These plants can be considered in three groups.

(1) Shops with neither electric power nor steam. These include artisanal processing shops equipped with the simplest locally made equipment, comprising cans, vats, pots, tables, moulds, simple cheese presses, etc. Such milk processing stations are often found in the Near and Middle East where yoghurt

and cheese are manufactured, the former basically in urban and the latter in rural areas. In these shops energy is used only for heating to bring the temperature of milk to the level required for fermentation (yoghurt) or renetting (cheese). Wood, coal, gas or liquid fossil fuels are used, usually in simple stoves with an energy conversion efficiency between 10 and 15 percent.

Cheese manufacture of a similar kind can also be found in some Latin American countries. In the Far East sweetened condensed milk is produced under primitive conditions in rural areas where milk with sugar is kept at boiling temperature, or close to it, with constant manual stirring to evaporate part of the water.

It is difficult to calculate precisely the energy requirements for such processes particularly as little attention is given to cleaning and general hygiene problems. For yoghurt and cheese the net requirement could be estimated at about 60 kWh/t of processed milk (heat only) and the gross requirement at about 400 to 600 kWh/t. For sweetened condensed milk the corresponding figures would be about 580 kWh/t and 3 900 to 5 800 kWh/t respectively. It should be mentioned, however, that in this group of plants daily processing is rarely greater than 50 to 100 1 of milk.

(2) Stations with electric power but without steam. These plants are usually equipped with some modern facilities. The simplest are farm dairies manufacturing unpasteurized packaged liquid milk. This type of milk processing can be seen in a number of countries all over the world, usually for small daily quantities of less than 0.3 t. In such farms fresh milk is packaged immediately after milking in bottles or single service plastic or paper cartons, stored overnight under refrigeration and sold the next day directly to customers. The energy requirement of this type of small-scale milk processing is usually limited to electric power since electric heaters are used even for water heating. The net requirement could be estimated at about 35 kWh/t of packaged milk. The gross requirement is about 120 kWh/t.

(3) Plants with simple mechanization using electric power and steam. These plants operate a similar system of packaged liquid milk production but include pasteurization directly after milking. They are mainly found on larger farms with daily processing capacities exceeding 0.3 t. Such plants are equipped

with low pressure steam boilers, pumps, simple filling and sealing machines and pasteurizers usually of batch type, though plate heat exchangers with regeneration sections are slowly being introduced. The energy requirement in these plants is divided into furnace fuels for steam raising and electric power for water supply, refrigeration and mechanical operation of machines. The requirement for heating could be estimated at about 50 kWh/t net and about 100 kWh/t gross (batch pasteurization system) and for electric power at about 25 kWh/t net and 90 kWh/t gross which brings the total to 75 kWh/t and 190 kWh/t, respectively. These figures may be taken as reflecting the energy consumption in cheese and yoghurt manufacture in plants in this group.

The small-scale milk processing industry also includes milk plants equipped with the relative modern standard dairy machines, steam boilers, piped water and electric power supply. Their capacity may be in the order of 3 to 10 t/day or even more and their manufacturing programme may vary from a single product, such as liquid milk or cheese, to a combination of products, very often changing with the season. Manufacture of dried and condensed milks is, however, very expensive in small plants because of high capital inputs required for modern equipment. These products are, therefore, rarely included in the processing programmes of modern plants with low daily throughputs. The net energy needs of the modernly equipped small-scale plant differ from those of modern large-scale plants as they are less in heat requirements but substantially more in consumption of electric power for refrigeration. The majority of plants in small-scale dairying receives unchilled milk. As a result their heat exchangers have a regeneration effect seldom higher than 60 percent which increases the specific net steam requirement by 7 kg/t or about 5 kWh/t for every product manufactured. The requirement for refrigeration is however almost doubled, as the temperature sequence in their exchangers will be, for example, 30-57-75-48-38-4°C (with a water chilling section 48°–38°C) as compared to 4-61-75-18-4°C with chilled milk intake.

This substantial increase in electric power requirement for refrigeration is partly compensated by the reduced consumption in other sections of the plants since they are much less mechanized. The overall requirement figures for steam and total electric power from Table 1 are applicable also to this group of plants.

2.4 Summary

The indicatory figures calculated and collected in previous parts of this chapter illustrate the wide range of energy requirements in milk collection and processing systems and their dependence on the major factors affecting the specific energy consumption. Of particular interest are comparisons between modern large-scale dairy industries and small-scale collection and processing systems. A selection of figures concerning products manufactured in these groups is presented in Table 3 and Fig. 7.

It can be seen that energy requirements for milk collection and processing are the complex result of many factors.

In milk collection with chilling the effect of high milk intake results in slightly lower energy requirements, net and gross, for modern collection systems.

In liquid milk processing the high quality standards established in modern dairy industries and the high degree of mechanization lead to higher net and gross energy demands. A similar situation can be seen in cheese and yoghurt manufacture although it is less evident in gross energy requirements. In the simplest milk processing systems applicances used for milk heating are of such low efficiency that a great majority of the energy requirement of the furnace fuels is wasted resulting in a higher gross energy requirement even though more manual labour is needed and the final product is often of low quality.

Manufacture of condensed milk is an example of a high energy requirement for a product demanding a substantial heat input. Such inputs are dependent on the nature of the product and the process. The differences between modern and simple plants are, therefore, much more pronounced in gross requirements where the impact of the efficiency of heat producing equipment becomes so dramatically evident. Objections could be raised to comparing manually bottled unpasteurized liquid milk processed without sanitary control with bottled pasteurized liquid milk processed in modern plants and meeting all the highest quality standard demands. Similar objections could be raised to comparing condensed milk manufactured under primitive conditions and sold in 20 kg gasoline tins with high quality products of

world brands sold in 400 g tins.

Table 3
Specific energy requirement in milk collection and processing

Type of requirement	Specific requirement in kWh/t of milk collected and processed											
	Milk collection			Milk processing								
	A	B	C	Liquid milk in bottles			Cheese and yoghurt, no whey processing			Condensed milk	
				D	F[1]	G	D	E	G	D	E
Net requirement											
Heat	-	-	7	165	-	50	125	60[2]	50	295	580[1]
Electric power	30	40	40	55	35	25	75		25	60	-
Total net requirement	30	40	47	220	35	75	200	60	75	355	580
Gross requirement											
Furnance fuel for heating	-	-	15	205	-	100	155	600	100	370	5 800
Engine fuel for electric generator	105	135	140	195	120	90	265	-	90	210	-
Total gross requirement	105	135	155	400	120	190	420	600	190	580	5 800

[1] **Unpasteurized**

[2] **Figure indicating the heat absorbed by milk components during direct heatingon simple stoves**

Legend

Milk collection: A - large scale milk farms

B - collecting centres with chiiling only

C - collecting centres with chilling and can washing

Milk processing: D - plants, large or small, with modern equipment

E - centres with neither electric power nor steam

F - centres with electric power but without steam

G - plants with a varying degree of simple mechanization using electric power and steam.

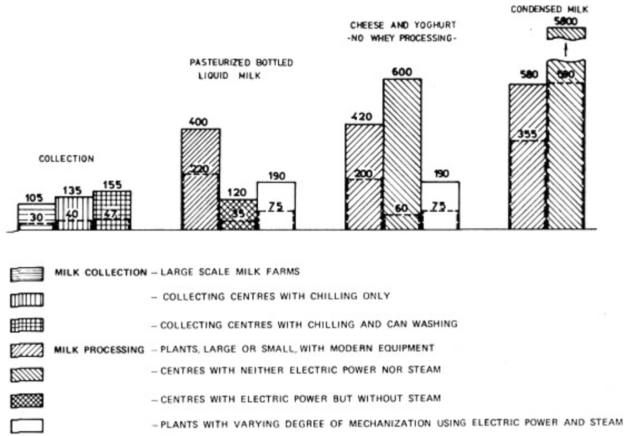


FIG 7. SPECIFIC NET (---) AND GROSS (—) ENERGY REQUIREMENT (kWh/t)

On the other hand such comparisons are justified bearing in mind that traditional ways of milk processing in developing countries cannot be replaced at one time by modern methods. Neither the producer nor the consumer could afford such a change since it would result in an enormous increase in costs. Furthermore, the required capital input needed for such rapid modernization is not available - exceptions confirm the rule only. It, therefore, seems justified to compare the order of magnitude of specific energy requirements in different milk collection and processing systems for products of a

similar nature though of different quality standard.

Apart from the quantities of energy required for milk collecting and processing, of paramount significance are the physical parameters of energy carrying media.

Heating of milk in vats placed on simple furnace stoves is an example of a heat transfer process where the temperature difference between the heating medium (burning gases) and milk is very high, very often a few hundred degrees. Heating by means of steam is an example of medium temperature difference between condensing steam and milk. Steam is the most common thermal energy carrier in the dairy industry. High pressure steam of 7 to 20 bar is used in condensing and drying plants and in some types of sterilizers. Low pressure steam (1.5 to 3.0 bar) is used in heat exchangers for heating processes up to required temperatures and for CIP. Steam is mostly used in those processes to elevate the temperature of water which, in turn, exchanges its heat with milk. Hence, except for condensing, drying and sterilization, the most common heating medium in heat exchangers for milk is hot water.

The inlet temperature is usually a few degrees above the required milk temperature which means, for the majority of processes with hot water utilization, that the highest water inlet temperature is below 100°C. This fact is paramount when considering further alternative energy sources for milk collection and processing. Except for sterilization condensing and drying, milk processing following relatively modern technologies is feasible with hot water as the heat carrying medium, provided the equipment is adapted accordingly.

Refrigeration in modern milk processing is based on ammonia or Freon condensing units whose effective operation requires electric power for compressors, fans, agitators and pumps.

In most cases, particularly in large-scale ammonia plants, water is required for compressed gas condensing and compressor chilling. Ammonia refrigeration systems are usually run at condensing temperatures of 35°C to 45°C and evaporating at -10°C. In cold stores the refrigerant evaporators are placed in the store area where heat is removed from the ambient air. For milk cooling in heat exchangers chilled water is used.

In modern systems refrigeration in milk collecting and processing requires electric power and usually also water. Absorption refrigeration has so far not gained any significance in the dairy industry.

Electric power is rarely used for heating purposes. Its main application is in driving motors by means of which all remaining processes including water supply and refrigeration are performed. In milk processing, as in the majority of other industries, alternating current (AC) at 110V or 220V is used for single-phase appliances and 220/360V or 380/640V for three-phase appliances, mainly electric motors above 5 kW.

Direct current (DC) is mainly confined to low-voltage battery-driven fork lift trucks or other wheeled vehicles.

For all practical purposes there is little alternative to electric power in any processing industry, including dairying, if mechanical energy is required. A man can develop for a short while a power equivalent to about 0.3 kW but working continuously he can only develop about 0.075 kW; obviously manual handling of processes is confined to low energy requirements.

Two basic conclusions concerning energy requirements result from the analysis presented above:

i. **There is little room for economizing on energy consumption in milk processing industries, as long as a consumption-oriented society demands products of present standards and as long as it will be able to afford them. Modern milk plants might become interested in using alternative economic energy sources provided the supply from such sources can meet at least a substantial proportion of the demand. Harnessing new energy sources for large-scale industrial application, including the dairy industry, depends entirely on future development.**

ii. **Small-scale milk collection and processing systems are likely to be sufficiently flexible to adapt technologies and equipment suitable for utilizing cheap energy from unconventional sources.**

CHAPTER 3

SUN POWER AS AN ENERGY SOURCE

“Solar constant” is the term used to define the solar flux at the outer fringes of the earth's atmosphere. Its value is defined at 1.35 kW/m^2. Due to the depletion of this energy through the earth's atmosphere, by the time the direct-beam solar radiation has reached the globe's surface it has been reduced in magnitude. Global solar radiation G which reaches the ground, comprises direct radiation I and diffuse radiation D. Direct radiation I is the flux associated with the direct solar beam on a plane perpendicular to the beam. Diffuse radiation reaches the ground from the rest of the sky's hemisphere from which it has been scattered in passing through the atmosphere. The relationship between C, I and D is given by G = D + I sin γ where γ is the solar altitude above the horizon (sin γ = 1 when the sun is in zenith).

The peak radiation received on earth is about 1.0 kW/m^2 of which the I component reaches about 90 percent on clear days. The total energy received on a horizontal surface, called insolation, is not uniform throughout the world; the respective values depend on the location and on the climate. The highest insolation values computed as annual totals are found between the two 35° latitude parallels, North and South. In that area there are regions with over 3 000 hours of sunshine per year with direct radiation reaching 90 percent of the annual global. In regions with high humidity and frequent cloud cover, the share of direct radiation falls considerably though the total number of hours of sunshine may be as high as 2 500. In some regions of this area there is little seasonal variation in insolation but there are some with marked variations even though the value of total annual insolation is high. In Fig. 8 the direct solar radiation on a horizontal plane in the northern hemisphere at various latitudes is shown.

Similar values are found in the southern hemisphere where the high latitude peak appears in December.

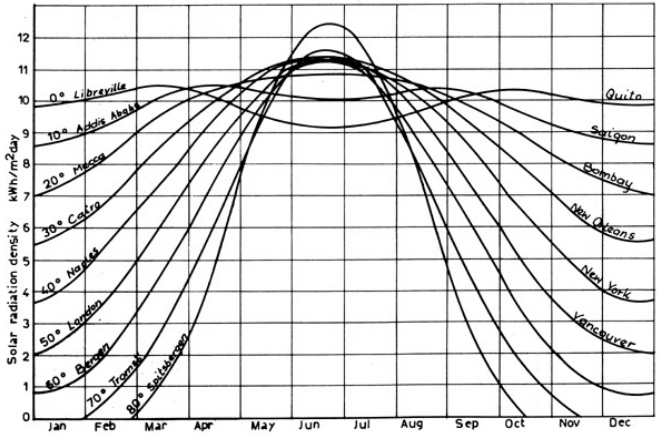


FIG.8. SOLAR RADIATION DENSITY DEPENDENCE ON SEASON IN THE NORTHERN HEMISPHERE

To be able to calculate the yield of a solar energy conversion system it is necessary to know the amount of radiation available at the location of the system, its variation in time and the ratios of diffuse and direct parts. The solar energy systems, or in other words, plants in which solar radiation is converted into other forms of energy, can be divided into thermal and non-thermal systems.

Thermal systems. The thermal systems include transformation of solar radiation into heating, into cooling or into mechanical energy. In all thermal systems solar radiation is first transformed into heat on surfaces exposed to this radiation. The surfaces on which sunlight is absorbed and transformed into heat in solar systems are called solar collectors. If a heat transfer fluid like air or water is allowed to flow over the collector it will extract the absorbed heat. It will further convey the heat to a designated place which could be a heater, a refrigeration generator or a machine in which the heat is converted into

mechanical energy. The required temperatures of the heat-carrying media depend on the application of the solar system. Domestic water heating requires 60°C, transformation of heat into mechanical energy in a Rankine cycle heat engine needs at least 120°C but a turbo-electric generator requires superheated steam above 500°C.

Higher temperatures are achievable only by concentrating collectors: linear focusing collectors up to 300°C and point focusing collectors at about 600°C. (Special designs of point focusing collectors achieve temperatures as high as 3 500°C). The flat plate collector is non-concentrating and is able to raise the temperature of the heat-carrying media to 130°C although with the majority of commercially available designs only temperatures below 100°C are obtainable. Concentrating collectors need to be equipped with sun-tracking devices since they are able to concentrate only direct radiation on the heat absorber. Flat plate collectors are able to accept both direct and diffuse radiation. No sun-tracking device is needed.

The use of solar radiation by concentrating and flat plate collectors is illustrated in Fig. 9. In Fig. 10 a schematic illustration of a flat plate collector is given. In Fig. 11 the working principles of both types of concentrating collectors are illustrated.

The most common flat plate collector is a blackened plate behind single, or double glazing. The heat absorbed by the black plate passes to the liquid (or gas) flowing along the plate, usually through a number of pipes connected with the plate in order to secure the best achievable heat transfer. An insulation layer reduces thermal losses. A protective casing is always a part of the collector. There are several designs of flat plate collectors differing particularly in the shape, number and construction materials of the liquid channels. In water-heating plants the fluid channels form the primary circuit. The liquid flowing in the primary circuit passes through a heat exchanger in which the heat is transferred from the primary to the secondary circuit. The required heat storage is usually a part of the secondary circuit. Both heat convection and forced pumping assist liquid circulation (see Fig. 12).

The net amount of heat absorbed by a collector is given by

$$Q_n = (1-g)aQ - Q_{rad} - \frac{Q_{cond}}{A}$$

Q - where solar radiation density normal to the collector plate (W/m^2)

Q_n - net heat absorption (W/m^2)

g - reflection and absorption loss in the cover plate

a - absorption coefficient for solar radiation of a black body

Q_{cond} - conduction heat losses (W)

Q_{rad} - radiation heat losses (W/m^2)

$Q_{rad} \approx \sigma \varepsilon p_T{}^4{}_{pl} - T^4{}_{gl}$

A - where absorption surface (m^2)

σ - 5.76 × 10^{-8} Boltzmann constant (W/m^2K^4)

ε_p - emissivity of the plate

T_{pl} - absorber surface/black plate temperature (K)

T_{gl} - surrounding air/glass cover temperature (K)

Considering the relation

$$\frac{Q_{cond}}{A} - Qrad = c\Delta T$$

the efficiency of the collector may be expressed as

$$\eta = \frac{Q_n}{Q} = a(1-g) - c\,\frac{\Delta T}{Q}$$

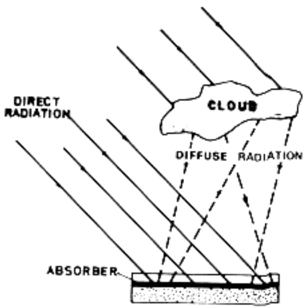
With the values for the parameters of the above equations

$g = 0.15$; $a=0.09$; $\varepsilon_p = 0.03$; and $\frac{Q_{cond}}{A} = 6.5$ to 7.0 (W)

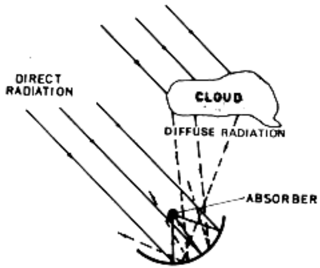
a reference equation could be formulated for the estimated value of c = 4.15

$\eta = 0.765 - 4.15 \frac{\Delta T}{Q}$

The above equation is applicable for $\frac{\Delta T}{Q}$ values from 0.05 to 0.10 and gives an indication of the efficiency of a number of commercially available collectors. As can be seen, the efficiency of the collector is a function of the temperature difference δT between the collector and the ambient as well as of the insolation. The efficiency rises with the drop of δT and increases with the increase of the density Q of solar radiation. With water as the primary circuit fluid, an ambient temperature of 35°C, insolation Q = 600 W/m^2 and an expected hot water mean temperature of 65°C, the efficiency would be about ε = 0.540 but this would drop to ε = 0.35 with an expected hot water mean temperature of 95°C.



FLAT PLATE COLLECTOR



CONCENTRATING COLLECTOR

FIG 9. THE USE OF SOLAR RADIATION BY FLAT PLATE AND CONCENTRATING COLLECTORS.

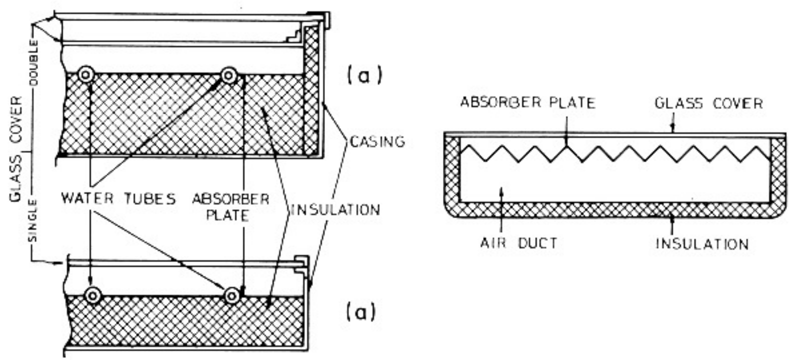


FIG 10. CONSTRUCTION OF FLAT PLATE COLLECTORS (a) WATER HEATING,(b) AIR HEATING.

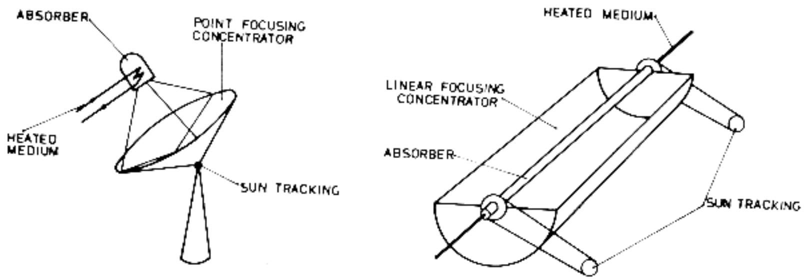


FIG 11. WORKING PRINCIPLES OF CONCENTRATING COLLECTORS.

Due to daily and seasonal variations in insolation, nearly all solar systems need storage for continuity of energy supply. Heat storage is expensive and, in practice, its high costs preclude long-term seasonal

storage, particularly in areas where summer/winter insolation ration is high and the low insolation season is long. Short-term storage is a necessity and, for practical reasons, in solar energy utilization systems with low and medium primary circuit temperatures, heat storage as the sensible heating of water is the most common.

Seasonal changes in sun radiation in most regions of the world and prohibitive costs of energy storage make solar systems unsuitable for practical application as the only source of energy, hence they are usually applied in combination with conventional systems. Data from a water-heating plant in California illustrate the problem (see Fig. 12). The plant supplies 3 m^3/day of hot (60°C) water to 32 apartments. On days with a clear sky in summer the insolation reaches 1 100 W/m^2 and then the plant provides 90 percent of the required heat from the solar system. In winter the insolation falls to 650 W/m^2 on cloudy days and the solar system of the plant provides only 10 percent of the heat requirement due to a considerable drop of efficiency with the fall of insolation. Of the annual heat requirement of the plant 70 percent is met by solar energy but the plant has to be equipped with a conventional heat supply system of a capacity matching almost the daily heat requirement. Integration of solar and conventional heating systems in one plant has became a characteristic feature in domestic application in many countries, particularly in USA and Australia. Forced circulation of the heat carrying media by electric pumps is a common solution.

Integrated solar/conventional systems are being installed also in combined space heating and cooling plants. The diagram in Fig. 13 shows the working principle of such a plant installed in a school building in Morton Grove in USA by the Bell and Gosset Co. The plant is equipped with absorption refrigeration for air cooling. In the first year of operation of the plant about 40 percent of the energy requirement for space heating and cooling was extracted from solar radiation. A similar installation advertised by Yazaki Australia, (Seaford, Victoria) is shown in Fig. 14 in which the integration of the solar and the conventional systems is particularly well shown.

In all space cooling with solar thermal systems utilization, absorption refrigeration is applied. The

principles of an intermittent absorption refrigerator are illustrated in Fig. 15.

The equipment consists essentially of two containers connected by a tube. The full process cycle comprises regeneration and refrigeration. Container A is filled with a composition comprising absorbent and refrigerant. Absorption of the refrigerant on the absorbent is exothermic, whereas desorption is endothermic. When heat is supplied to container A, called "generator", during the heating (generating) phase, the refrigerant is vaporized, leaving behind a "weak" mixture of refrigerant and absorbent. The vaporized refrigerant passes to container B where it condenses by losing the latent heat. During the generation phase container B operates as a condenser. The latent heat is usually removed by chilling the condenser with circulating or stagnant water or circulating air. The desorbed refrigerant condenses without reduction of pressure. In the refrigeration phase the generator (container A) operates as absorber and the condenser (container B) as evaporator. During this phase the absorber is cooled by the ambient fluid which results in the fall of pressure. Under reduced pressure in the evaporator the liquid refrigerant evaporates and is absorbed again by the absorbent. Evaporation of the refrigerant requires that latent heat be provided from outside, which may be by air, water or other cooled fluids. In all systems in which the generator operates consecutively as absorber the thermal efficiency of the installation is very low since substantial heat losses have to occur when the same part of equipment has first to be heated (generation) and subsequently cooled (absorption). The principles of an absorption refrigerator with the absorber separated from the generator and used for continuous operation are shown in Fig. 16. As can be seen the transfer of the "strong" mixture from absorber to generator requires external power although with some compositions of the mixtures gravity or thermosiphoning can be used for this purpose. Various components are used in absorbent/refrigerant compositions. Those most often used are:

Lithium bromide/water

Water/ammonia

Sodium thiocyanate/ammonia

Lithium nitrate/ammonia

Calcium chloride/ammonia

Strontium chloride/ammonia

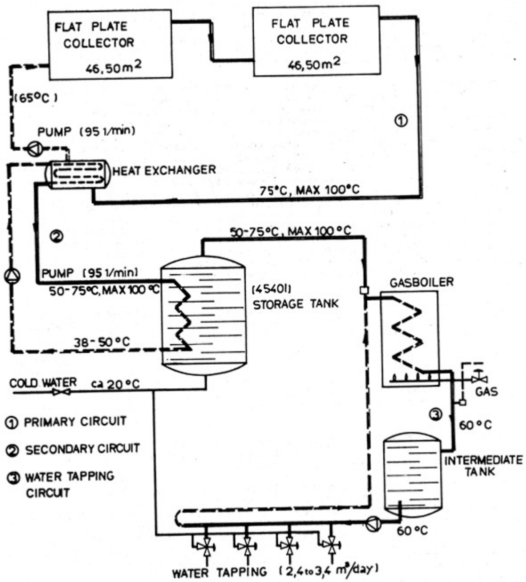


FIG 12. DIAGRAM OF A SOLAR WATER HEATING SYSTEM (SAGE,L.A.,USA)

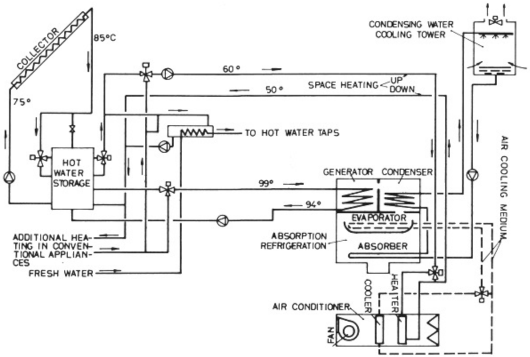
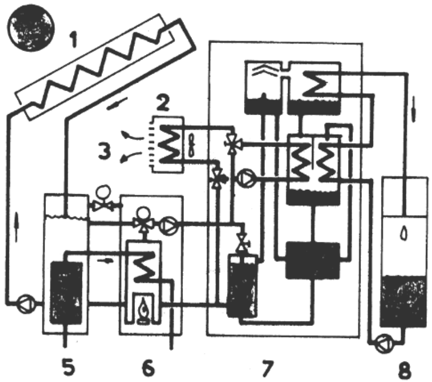


FIG 13. SPACE EATING AND COOLING WITH SOLAR ENERGY APPLICATION

COOLING OPERATION



HEATING OPERATION

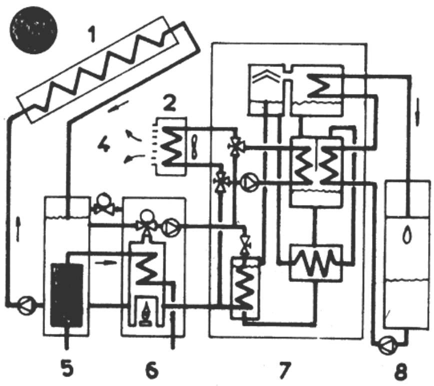


FIG 14. SPACE HEATING AND COOLING WITH SOLAR ENERGY

1. **FLAT PLATE SOLAR COLLECTOR**
2. **FAN-COIL UNIT**
3. **COOL AIR**
4. **WARM AIR**
5. **STORAGE TANK**
6. **BACK-UP BOILER**
7. **WATER CHILLER**
8. **COOLING TOWER**

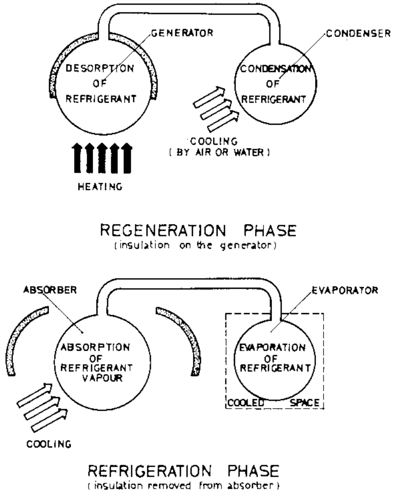


FIG 15. DIAGRAM OF AN INTERMITTENT ABSORPTION COOLING UNIT

Of the above, calcium and strontium chlorides are solid absorbents: the remaining four are liquid absorbents.

The demands on solar systems for absorption refrigeration are complex. The required generation temperatures depend on the combination of the absorbent and refrigerant. The lithium bromide/water mixture can be desorbed with temperatures of about 80° to 95°C whereas lithium bromide with water, ammonia and hydrogen operate effectively with desorption at about 150 to 160°C. In water/ammonia systems the desired temperature is about 120 to 150°C. With solid absorbents the temperature for strontium chloride/ammonia and calcium chloride/ammonia mixtures are about 90°C and 120°C respectively. The installations become more complicated with volatile absorbents such as water in the water/ammonia system since a rectifying device is needed to separate absorbent from refrigerant to

prevent water entering the evaporator where it could freeze. A simple installation has to operate at relatively low desorption temperatures. Such systems include the water/ammonia and lithium bromide/water mixtures in the liquid absorbents group and the strontium or calcium chloride/ ammonia system in the solid absorbents group.

Even the lower generation temperatures as required by the absorption refrigerators can only be obtained with particular types of flat plate collectors, either the non-tracking reflecting and moderately concentrating, or the evacuated types. Examples of both types are shown in Fig. 17.

The concept of the concentrating parabolic collector and trapezoidal reflecting collector can be seen from the cross sections. In the tubular collector under vacuum the space under vacuum is between the absorber surface and the glass cover which reduces substantially the conduction and natural convection losses. With the increase of the difference ΔT of temperatures between the heated medium [1] and the ambient [2], the efficiency of the collector falls considerably and values of about ε = 0.25 to 0.30 can only be achieved under high insolation. The curves in Fig. 18 show an example of a daily insolation in an area in southern Europe on a sunny summer day and the efficiency by Δ T = 50°C of a good quality flat plate collector of standard design.

[1] i.e. the collector

[2] i.e. with the increase of the outlet temperature of the medium

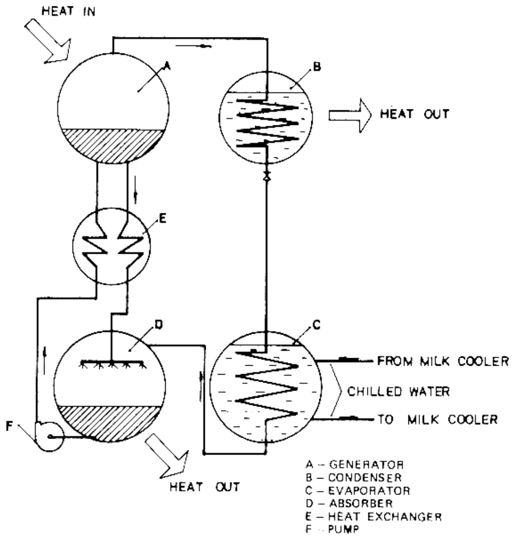


FIG 16. PRINCIPLES OF ABSORPTION REFRIGERATION (NON-VOLATILE ABSORBENT) WITH SEPARATED GENERATOR AND ABSORBER.

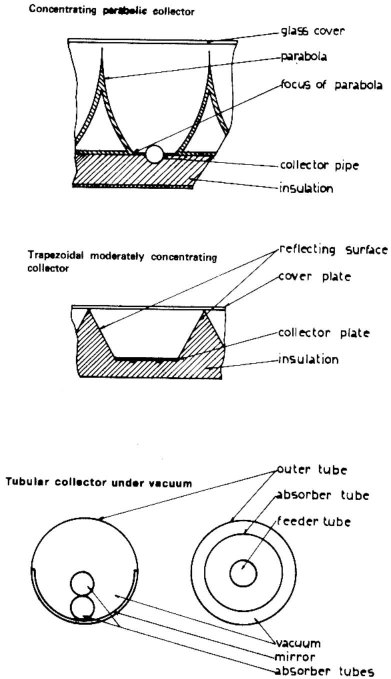


FIG 17. NON - TRACKING REFLECTING & CONCENTRATING COLLECTORS AND EVACUATED COLLECTORS.

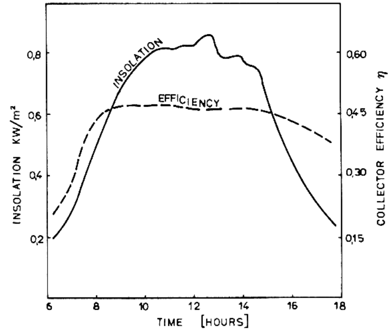


FIG 18. EXAMPLE OF DAILY INSOLATION CURVE AND RELATED SOLAR COLLECTOR EFFICIENCY.

In order to collect the solar energy at ΔT nearing 100°C the process could be performed in practice by moderately concentrating or evacuated collectors during four to five hours of highest radiation only, and even then with efficiences not exceeding ε= 0.25 to 0.30. The theoretical value of the coefficient of performance (COP) ε_r of an absorption refrigerator is given by

$$\eta_r = \frac{Qe}{Qh} = \frac{Te}{Th} \frac{(Th - Ta)}{(Ta - Te)}$$

where Qe - heat removed from the cooled medium (W)
Qh - input heat from solar collector or other (W)
Te - temperature of evaporating refrigerant (K)
Th - temperature at which Qe is supplied (K)
Ta - ambient temperature (K)

In small-scale refrigeration plants the COP achievable in practice is two to four fold smaller than in

theory and seldom exceeds v_r = 0.25 to 0.30. The overall efficiency ε_o of the solar absorption refrigerator, i.e. the ration of heat removed from the cooled medium to the solar radiation, seldom exceeds ε_0 = 0.10. One of the ways to reduce heat losses and increase the COP values in absorption refrigerators with solar systems is to fill the primary solar circuit with the absorbent/refrigerant mixture. Most of the pilot or research plants used for ice-making in absorption refrigerators with solar heating are designed in that way.

The generation phase of the refrigeration cycle is a quick process compared to absorption. With solar heating the generation phase can be completed within four to five hours. The absorption (or refrigeration) phase of the cycle can last 20 hours or more depending on the absorbent, chilling system and speed.

The first larger-scale pilot thermal solar system in the world which converts solar radiation into electric energy was commissioned in May 1981 in Italy with a rated capacity of about 1 MW. The heat-carrying medium in the plant is steam at 510°C generating heat from 128 point focusing collectors covering an area of 6 km^2 and contating solar radiation on an absorber located on a tower 63 m in height. The invested capital exceeded US$ 20 million equivalent. A schematic diagram of such a station is shown in Fig. 19.

Transformation of solar radiation into mechanical energy for water pumping in irrigation systems is under intensive research with flat plate collectors as a heat generating device. However, solar-powered water pumps, although technically feasible and on trial, particularly in India and in francophone Africa, have not yet become an economically viable proposition. A solar pump of 1 kW operating with a flat plate collector on trial in Central Africa is said to have cost in 1977 about US$ 70 000.

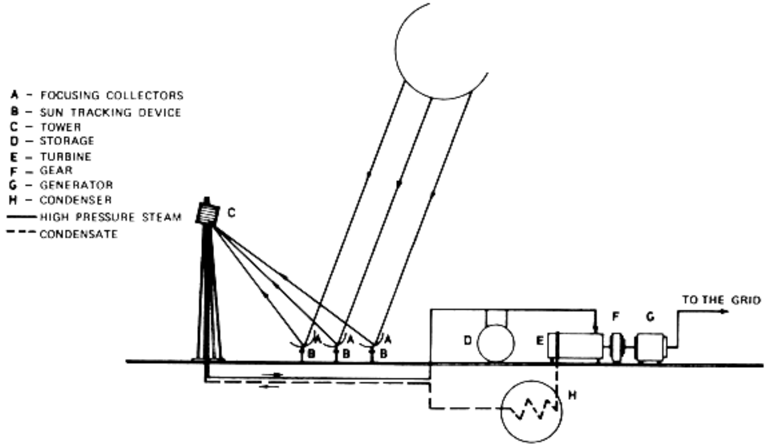


FIG 19. DIAGRAM OF A SOLAR THERMAL ELECTRIC POWER STATION.

In order to operate heat engines with a reasonable efficiency temperatures of heat-carrying media have to be much above those achievable through flat plate collectors. It has been estimated that a 1 kW system (24 kWh/ day) would require, in a solar electrical power plant with flat plate collectors, a Rankine cycle engine and a suitable heat storage unit, a collector area of 320 m^2 with air cooling (efficiency 3.5%) or 160 m^2 with water cooling (7% efficiency). The generated temperature would be about 120°C.

<u>Non-thermal solar systems</u>. In these systems the electro-magnetic radiation energy is converted directly into electric energy. This is done in adevice called a "photovoltaic power generator" or "photovoltaic cell". Photovoltaic cells absorb photons from sunlight, create an electric field and act as a semiconductor to produce electric current. The use of solar cells in space research application is well known. Solar-powered photovoltaic systems on the earth are subject to increasing research. They have already found practical application in some fields such as flashing lights on buoys, lighthouses and off-

shore oil rigs.

The very high costs of the photovoltaic energy conversion systems will retard their application in small-scale industries for many years to come.

<u>Solar systems in the food processing industry</u>. Such systems have not yet reached a noteworthy level of application. In a number of countries research work in this field is being continued but there are not many instances of industrial or semi-industrial trials, not to mention wider applications. In the milk processing industry trials are reported on application of solar heating in cheese manufacture and solar cooling in milk collection. The reports indicate the research character of the work done and/or in progress. There are also several experiments reported in ice manufacture by the use of absorption cooling machines powered by solar energy only.

The research work on milk heating for cheese manufacture currently performed in Italy concerns a conventionally powered cheese factory with a maximum daily throughput of about 1 500 kg milk per day. The experiment was carried out on a 500 litre copper cheese vat, jacketed, with hot water passing through the jacket at a rate of 1 500 litres/h.

With a hot water temperature of 80–82°C entering the cheese vat jacket, 25 minutes were required to reach a milk temperature of about 45°C. Heat energy requirements varied from about 45 to 90 kWh/t of processed milk, depending on several process conditions not directly connected with solar energy conversion and accumulation. Up to 70–80 percent of the total heat demand of the process was covered by solar energy on clear days with high insolation and with the collectors having a surface of 21.6 m^2. The experiment is an example of using solar energy as an auxiliary source to conventional fuels which implies eventual savings in fuel costs by not the avoidance or reduction of capital expenditures on machinery required for energy supply. Trials on ice-making machines powered partly, or only, by solar energy, are reported from several countries, recently from India concerning a sodium sulphocyanide/ ammonia absorption refrigerator for 20 kg/day ice production. In the USA a sizeable (52.8 kW) absorption refrigeraition unit for water cooling to about 7°C has been built with a lithium bromide/water

mixture and a flat plate collector. In that case also electric power from outside the solar plant had to be applied.

<u>Costs</u>. The economic installation of solar systems for milk cooling and/or pasteurization must be justified by savings in furnace fuel only since full capital input for installation of conventional heaters parallel to the solar system is required. Estimates of eventual savings in fuel consumption could be calculated only for a given site for which data concerning insolation and duration of sunshine are known. However, it should be borne in mind that there is no direct correlation between hours of sunshine and heat absorption. All calculations must always be made separately for heating to the moderate (90°C) and to the higher (say 120°C) temperature for water heating for pasteurization and for water chilling to cool milk, respectively.

In order to provide an example of the order of magnitude of cost savings by installation of solar systems Fig. 18 presents a simple calculation for insolation conditions.

<u>Heating</u>. The daily average insolation is estimated at 580 W/m^2 during 12 hours which gives a daily radiation equivalent of 6.96 kWh. With the average collector efficiency of ε = 0.4 the absorbed heat is equivalent to 2.78 kWh/m^2 per day. In an area with about 200 days of similar sunshine per annum, the annual heat collection could reach 556 kWh. This amount of heat requires about 120 l of furnace fuel in an oil-fired conventional water heater operating with 50 percent efficiency. Should all costs of fuel procurement be estimated at a price equivalent to US$ 0.30 to US$ 0.50 per litre, the annual fuel costs saved would be about US$ 36 to US$ 60. As solar flat plate collectors of good quality and of a relatively simple type for water heating to about 90°C could be obtained (1981) for about US$ 150 per one square meter, the installation of a solar heating system for hot water could be depreciated in about three to four years.

<u>Refrigeration</u>. Of about 4 kWh/m^2 intensive insolation between 10.00 and 15.00 hours (see Fig. 18) only about 1.0 kWh/m^2 can be absorbed by the absorbent/refrigerant mixture during generation at 120°C.

Finally the daily equivalent of heat removed from chilled water amounts to 0.4 kWh/m^2, equivalent to 80 kWh/m^2 annually. The same effect could be obtained from a conventional heater with about 52 l of furnace fuel per year costing about US$ 16 to US$ 26. The estimated price (1981) of a reflecting and moderately concentrating collector is about US$ 250 per m^2 which means a depreciation time of 10 to 15 years. The estimates presented above cannot be considered as meaningful indications in general since they are based on assumed data on insolation efficiencies etc. However, they serve to show possible orders of magnitude of the figures.

The development of solar collectors in recent years shows and encouraging tendency: the costs are decreasing if calculated per unit of harnessed solar energy. With the permanent increase of conventional fuel costs, solar systems may soon become a competitive proposition, particularly in small-scale industries. They therefore deserve attention and active applied research.

CHAPTER 4

PROSPECTIVE SMALL-SCALE SYSTEMS

4.1 Capacities, processing programmes and technologies

The daily milk throughput in the small-scale operations discussed in this study is limited mainly through energy considerations to about 1.6 t.

Within this limit seven daily capacities have been chosen for detailed consideration: 100 l, 160 l, 250 l,

400 l, 630 l, 1 000 l, 1 600 l.

They reflect the "0.2" interval in the logarithmic sequence of numbers: 10^{2} = 100, 102.2 = 160, $10^{2.4}$ = 250, $10^{2.6}$ = 400, $10^{2.8}$ = 630, $10^{3.0}$ = 1 000, $10^{3.2}$ = 1 600.

Six processing programmes are analysed for the above range of capacities and these form the basis for the project proposals given in Chapter 5.

I - II Milk collection with dispatch in cans at elevated (I) or reduced (II) temperatures.

III - Liquid flavoured milk, pasteurized, sold in cans at reduced temperatures.

IV - Liquid milk, pasteurized, sold in bottles at reduced temperatures.

V - Fermented milk, bottled, manufactured from pasteurized milk.

VI - Cheese and butter manufactured from pasteurized milk or cream.

I - II <u>Milk collection</u>

In the collecting centre a pretreatment is given to the milk to preserve its quality until it reaches the processing plant. This pretreatment may include either heating to 65°C and transporting in hot condition, or chilling to about 4°C with efforts to maintain this temperature during transportation to the processing plant. Milk cooling is the commonly recognized milk preservation system in collecting centres, whereas hot milk reception is not regarded as a recommended system in contemporary dairying. The formation of milk skim and fat separation are the most important objections. However, this "hot system" is a traditional milk preservation method in some countries and considering its simplicity, it may become useful in some areas.

Reception of hot milk at the dock of the processing plant may imply some changes in the processing

procedures such as additional chilling or separate reception of this milk for manufacturing selected products.

Heat treatment of small quantities of milk, either heating or cooling, can be done directly in transportation cans by immersing them in an insulated tank containing hot or chilled water. In such collecting centres milk handling is therefore limited to measuring the quantities of the incoming milk and bulking it into clean milk cans. The necessary agitation of the water in the tank and the milk in the cans limits the number of cans handled. The upper capacity limit of such collecting centres seems to be five 50–1 cans, equivalent to 250 l per day. The diagram in Fig. 20 illustrates the basic outline of such a system. Higher milk quantities require heat treatment in an insulated, jacketed vat emptied by gravity into transportation cans.

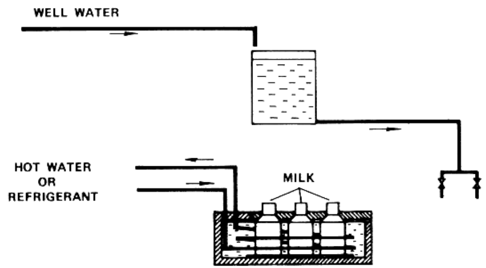


FIG 20. HEAT TREATMENT OF MILK IN TRANSPORTATION CANS

III. Liquid flavoured pasteurized milk sold in cans

Any small-scale milk processing could be a great advantage to dairy development in areas with no access to central processing plants or in areas where potential markets could offer more benefit to the producer than collaboration with central plants.

Sales in cans carry well-known risks and disadvantages but on the other hand they have been, and in many areas still are, a cheap and effective marketing system.

The processing technology of liquid flavoured pasteurized milk would need to be based on a low temperature (65°C) and on long (20–30 minutes) pasteurization in batch pasteurizers. Since cooling has to be applied, a two - stage temperature reduction is needed: the first step by well water (assumed inlet temperature about 30°C) and the second by chilled water.

The heat treatment is performed in a jacketed, insulated vat or vats suited to the planned daily throughput of the plant. The vat is a multi-purpose equipment in which all heat exchange takes place as well as mixing with other ingredients or even curd forming, cutting and drying in cheese manufacture. A general flow diagram of heat treatment of milk in a plant with one processing vat is shown in Fig. 21. Manual can washing and filling facilities need to be included in the equipment of the plant. Organization of marketing must depend on local conditions. Doorstep delivery immediately after processing is the most effective system considering the relatively small quantities of the product. Dispatch immediately after processing may allow operation of the plants without cold storage. As long as chilled or hot milk remains in the processing vat the temperature can be kept practically constant for hours. Speedy filling prior to dispatch is feasible with the small quantities of milk involved.

IV. <u>Liquid flavoured pasteurized milk in bottles</u>

Except for bottle filling and washing there is no difference in milk handling for sale in cans.

V. <u>Bottled fermented milk beverages manufactured from pasteurized milk</u>

This product, or group of products, can be considered for manufacture in some areas where the dietary habits of the population would indicate a good market, such as yoghurt in the Middle East and lhassi in India, etc. The technology applied, particularly the starters and the fermentation process as well as the precise timing of processing and sales, would need to be locally adjusted. In traditional processes no refrigeration is applied. The process proposed in this study is milk pasteurization, cooling to the

fermentation temperature, addition of starters, filling of bottles and then following the traditional ways of processing and marketing typical for the product, area and market concerned. Discussion on the proposed chilling systems is presented in section 5.3.5.

VI. Cheese and butter

Markets for cheese in developing countries vary greatly from area to area, from practically nil as in rural India, to very good as in rural and urban areas in the Near and the Middle East.

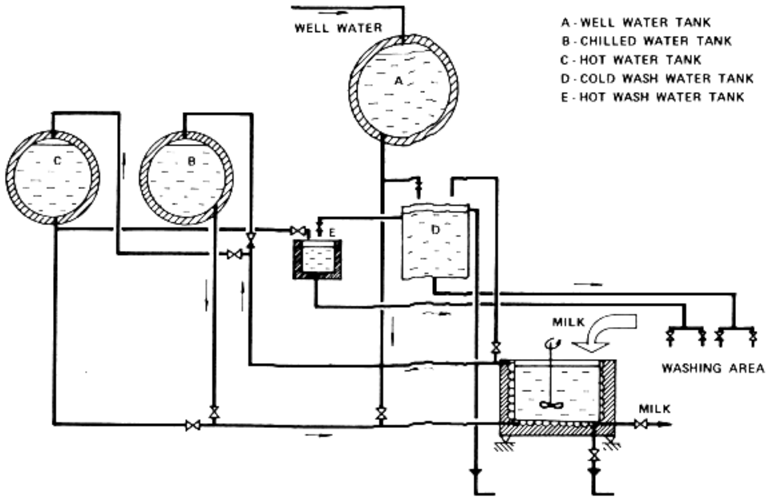


FIG 21. HEAT TREATMENT OF MILK IN ONE JACKETED VAT

Only the simplest technologies, without strictly controlled ripening, are considered in this study.

An example of such manufacture is the white cheese sold in brine - a typical product in many countries in the Near and Middle East. The technology discussed includes milk pasteurization and cooling by means of well water. The partly separated milk is cooled to renetting temperature (with or without addition of starters) and processed according to the selected technology. Cream is churned manually.

Fat separation must be done prior to milk pasteurization. Assuming that the fat content of freshmilk is 4.5 percent, the milk standarization is set for 2.5 percent and the fat content in cream is about 30 percent, the proportion of milk skimmed to the total milk will be about one third. The volume of cream will be about 7 percent of the total volume of milk supplied. The small quantities of cream make butter manufacture feasible only in plants with a more sizeable daily throughput, such as 630 l/day or more. For manufacturing cheese and butter with standardization of the fat content in the milk for cheese at 2.5 percent, the simplest is to separate fully about one third of the milk, to add the skimmed milk to the two thirds in the milk handling vat and give the required heat treatment to the milk and cream in separate vats. Fig. 22 shows the flow diagram of a plant with separate heat treatment of milk and cream.

Cheese in brine does not need immediate chilling. Butter could be put, after manual packaging, into insulated containers filled with chilled water at a temperature below 10°C.

4.2 Energy

Simplicity in milk handling technologies chosen for small-scale collecting and processing centres must be matched with similarly unsophisticated systems in service procurement.

Modern milk plants need the supply of water, heat and electric energy, the latter providing power for motion of machines, including refrigeration equipment. All four basic components of the engineering services (heat, refrigeration, water, power) needed in modern dairy industries are also required in small-scale systems. However, the latter need to be established in developing countries in remote village areas with no local facilities for water and power procurement. In such areas the installed equipment and applied technologies should be the simplest, so as to minimize the need for sophisticated skills, spare parts and careful, regular maintenance. It has to be borne in mind that simplicity according to standards

prevailing in an industrialized area does not necessarily mean the same according to the standards of a village community in a developing region.

It could be said that milk processing could be organized at any place with availability of milk and a water source. Provision of energy is a question of equipment. However, in areas with no electric power supply from a national or local grid, special attention has to be given to the means by which the power requirements of the plant could be met. Only limited needs can be met by manpower. Combustion engines for direct supply of mechanical power or for electric power provision through generator sets require regular inspection and maintenance. Neither facilities nor skills needed for such work are commonly available in rural areas in developing countries.

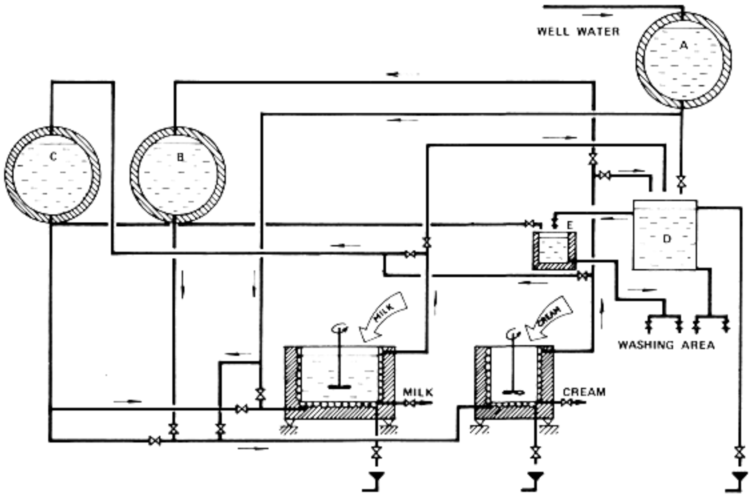


FIG 22. SEPARATE HEAT TREATMENT OF MILK AND CREAM IN TWO JACKETED VATS (CHILLED

WATER ONLY IN CREAM VAT JACKET). A - WELL WATER TANK, B - CHILLED WATER TANK, C - HOT WATER TANK, D - COLD WASH WATER TANK, E - HOT WASH WATER TANK

As combustion engines for mechanical/electric power supply to the plants proposed in this study have not been taken into account and as it to the intention to apply solar energy as an alternative energy source, this has led to limiting the considerations on energy requirements and procurement to batch processes with hot water (no steam) heating, absorption refrigeration and mechanical power provided either by man labour only or by man labour combined with non-conventional power sources, whenever feasible.

4.2.1 Requirements

4.2.1.1 Heating and cooling

The required changes of milk or cream temperatures and the respective net energy requirements for heating and for cooling by means of chilled water are presented in Table 4. Requirements for chilling by means of well water are expressed in terms of well water quantity for chilling in section 4.2.1.2.

Heat treatment in batch processes lasts longer than in continuous processes. The processing time τ of each of the three heat exchange processes (heating, cooling by means of well water and cooling by means of chilled water) in milk processing vats is given by

$$\tau = \frac{C}{C-1} \cdot \frac{-i}{i_A} \cdot \ln \frac{t_k - t_A}{t_p - t_A} \quad (s)$$

where

$$C = e^{\frac{kF}{i_A}}$$

k - overall heat transfer coefficient (W/m^{2}K)

F - heat exchange surface (m^2)

i - heat content of milk in the vat (J/K)

i_A - heat stream of water (J/sK)

t_k, t_p - final and initial milk temperatures (°C)

t_A - medium water inlet temperature (°C)

The value t_A of medium water temperature is related to the circulation of hot water or chilled water from and to the respective tanks.

These water temperatures change during the heat exchange processes. For the purpose of calculating the τ values it was assumed that at any given moment the water temperature in the respective water tank is uniform throughout the volume, although changing during the process. The k value - constant throughout the heat exchange process - is given by

$$k = \frac{1}{\frac{1}{\alpha 2} + \frac{1}{\alpha 2} + \frac{s}{\lambda}}$$

where α1 α2 - heat penetration coefficients on the milk and water sides respectively (W/m^{2}K)

λ - thermal conductivity of the wall separating milk from water (W/m K)

s - thickness of the wall (m)

Table 4. NET ENERGY REQUIREMENTS [1] FOR HEATING AND FOR COOLING WITH CHILLED WATER

		Change of milk/cream	Energy Requirement (kWh/day)

		temperature				for heating							for cooling						
						Daily throughput (litres)													
		30–65°	65–35°	35–45°	35–4°	100	160	250	400	630	1000	1600	100	160	250	400	630	1000	1600
Collection - hot dispatch		+				5	7	11	17	26	41	66	0	0	0	0	0	0	0
Collection - cold dispatch					+	0	0	0	3	5	7	9	4	6	10	15	23	36	58
Pasteurized - dispatch		+	+		+	5	7	11	17	26	41	66	4	6	10	15	23	36	58
in cans																			
Pasteurized - bottled		+	+		+	5	7	11	17	26	41	66	4	6	10	15	23	36	58
Fermented - bottled		+	+			5	7	11	17	26	41	66	4	6	10	15	23	36	58
Cheese and Butter	Cheese	+	+	+		6	9	14	21	31	49	78	-	-	-	-	0	0	0
	Butter	+	+		+	-	-	-	-	2	3	5	-	-	-	-	3	4	6

[1] **Figures rounded up to full digits**

The α_1 and α_2 values are determined by

$$\alpha = \frac{Nu \cdot \lambda}{d}$$

where Nu - Nusselt number (Nu_1 and Nu_2 are related to α_1 and α_2 respectively)

d - diameter of the channel of the flow of the fluid (m)

The d value for the product side of the heat exchange surface is given by the diameter d_1 of the milk

container; for the water side the corresponding values is given by the diameter d_2 of the channel of the water flow (assumed d_2 = 0.03 m)

$$Nu_1 = 1.01\left(\frac{D}{d_1}\right)^{0.13}\left(\frac{h}{d_1}\right)^{0.12} Re^{0.66}\ Pr^{0.33}$$

$$Nu_2 = 0.023\ Re_2^{0.8}\ Pr^{0.33}$$

$$Re_1 = \frac{n \cdot D^2}{\eta \cdot \nu}$$

$$Re_2 = \frac{w \cdot d_2}{\nu}$$

$$Pr = \frac{Cp \cdot \nu \cdot \varrho}{\lambda}$$

where D - diameter of the agitator (m)

h - distance between the agitator blade and the container bottom (m)

n - speed of the agitator (rev/s) (assumed n=0.25)

v - kinematic viscosity (m^2/s)

ε - mechanical efficiency coefficient of the agitator (assumed ε= 0.4)

w - water velocity in heat exchange channel (m/s) (assumed w=0.71m/s)

C_p - specific heat (J/kg.K)

ρ - density (kg/m^3)

The processing time τ of heat exchange in the milk-in-can heat treatment is given by

$$\tau = \frac{M \cdot c}{F} \left[\frac{(x+1)}{B \cdot m}^{m+1} \left(\frac{1}{\theta k^{m}} - \frac{1}{\theta p^{m}} \right) - \frac{s}{\lambda} \ln \frac{\theta k}{\theta p} \right] \text{ (s)}$$

where M - quantity of milk (kg)

c - specific heat of milk (J/kg . K)

F - heat exchange surface (m^2)

λ - thermal conductivity of the can wall (W/m . k)

$\theta_k = t_k - t_o$

$\theta_p = t_p - t_o$

t_k - final milk temperature

t_p - initial milk temperature

t_o - ambient temperature

x = $\frac{\alpha_1}{\alpha_2}$

B = $\frac{\alpha_1}{\Delta t^m}$

m - exponent depending on the heat convection conditions

As can be seen, the calculation of τ according to this equation requires that the water temperature t_o in the basin is uniform throughout its volume and is constant during τ. Such conditions are rarely achievable, since t_o depends much on the intensity of agitatin of the water surrounding the cans. Therefore, even with frequent manual agitation of the water, the practical heating or cooling time is likely to be longer than the theoretically calculated τ.

On the other hand in the milk-in-can system the total volume of milk undergoing heat treatment is divided in 50–1 portions which shortens the heat exchange time as compared to heating or cooling time of the total volume in one container.

Heat exchange is slow with only natural convection; therefore agitation (or forced motion) on both sides of the exchange surface is required. Manual sporadic agitation of milk and water in the milk-in-can system should be such as to keep the duration of the process within practical limits. A suggestion for a coupled mechanism for milk agitation and water circulation in the milk-in-vat system is shown in Fig. 23. The mechanism can be operated by one person or by one prime mover.

The duration of heat exchange processes in the cans and in the vats is given in Table 5. Figures concerning milk-in-vat treatment are based on the assumption that the height of the vat is equal to its diameter, that there is no heat exchange through the bottom and that four removable speed-breaking blades are immersed in milk in order to intensify the agitation.

Diagrams illustrating the increase of the overall heat transfer coefficient k and the process time τ with the increase of the processed volume in the vat are shown in Figs. 24 and 25.

Important implications result from the diagram in Fig. 25 and Table 5. First of all milk pasteurization is the shortest of the three heat exchange processes and deep cooling is the longest.

The estimated τt value does not include time required for keeping the milk at pasteurization temperature

for 20 to 30 minutes which adds about 0.4 to 0.5 hours to the total duration of the processes. The time for all heat exchange processes needs to be kept within a limit of about three hours since otherwise the quality of the product may be adversely affected. Moreover, the organization of the work in the plant requires that all processing or manufacturing processes do not last too long. Therefore, in plants with throughputs higher than about 630 l/day and with processing programmes requiring pasteurization and deep cooling, the heat treatment must be performed in two vats of a capacity not exceeding about 630 to 800 l.

4.2.1.2 Well water

The well water requirements in plants under consideration can be divided into those for (a) cleaning and (b) chilling.

Daily quantities Q_1 of cleaning water may be estimated by taking

Q_1 = 0.5C + 0.2 (m^3day) in plants without washing of either cans or bottles

Q_1 = 0.8C + 0.2 (m^3/day) in plants with can washing

Q_1 = 1.5C + 0.2 (m^3/day) in plants with bottle washing and cheese manufacturing plants

where C - daily milk throughput in thousand litres.

About $0.25Q_1$ needs to be heated to about 60°C for cleaning purposes.

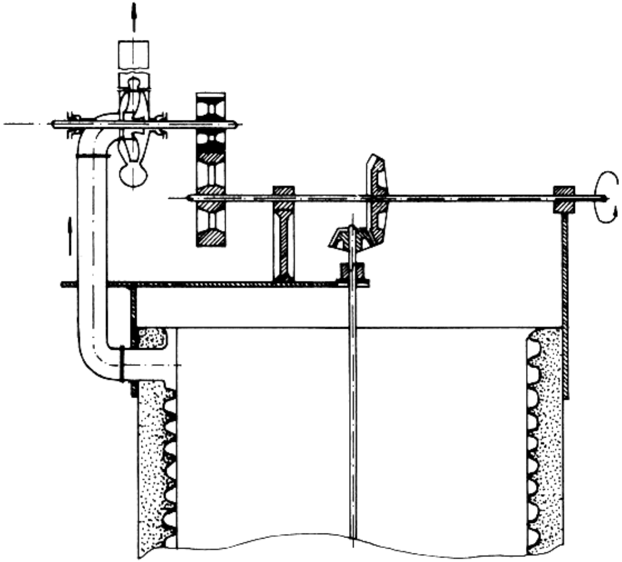


FIG 23. MILK AGITATOR COUPLED WITH WATER CIRCULATION PUMP

Table 5. DURATION OF MILK HEAT TREATMENT

Treatment	Duration of heat exchange processes (hours) τ_1 - pasteurization from 30°C to 65°C τ_2 - well water chilling from 65°C to 35°C τ_3 - chilled water cooling from 35°C to 40°C $\tau_t - \tau_1 + \tau_2 + \tau_3$			

Milk-in-cans up to 250 l	τ_1	τ_2	τ_3	τ_t
heating	above 1	-	-	above 1
cooling	-	-	above 3	above 3
Milk-in-vat full heat treatment[1]				
100 l	0.16	0.34	0.60	1.10
160 l	0.19	0.41	0.70	1.30
250 l	0.25	0.50	0.85	1.60
400 l	0.32	0.66	1.08	2.06
630 l	0.43	0.88	1.39	2.70
1 000 l	0.61	1.21	1.84	3.66
1 600 l	0.90	1.78	2.59	5.27

1 Based on the following assumptions:hot water temperatures: initial 90°C, final 80°Cwell water inlet temperature: 30°Cchilled water inlet temperature: 1.5°C

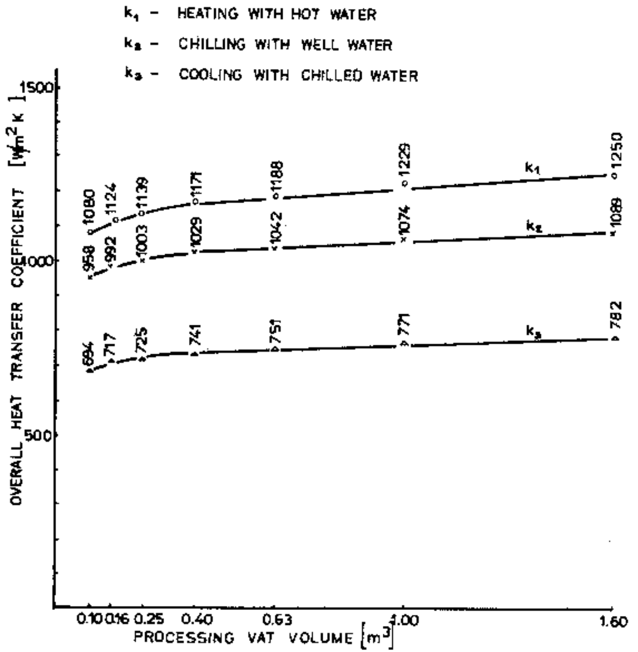


FIG 24. OVERALL HEAT EXCHANGE COEFFICIENT k.

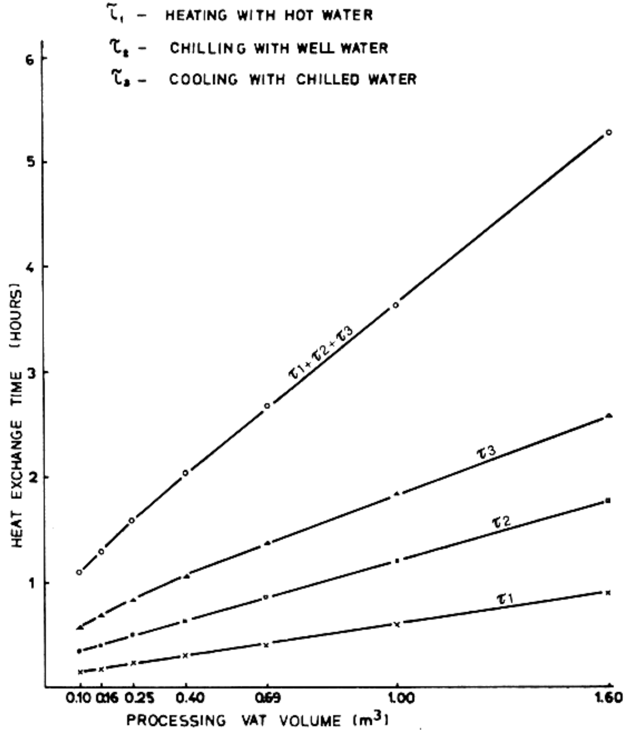


FIG 25. DURATION OF HEAT EXCHANGE PROCESSES.

Daily well water requirement Q_2 for milk chilling depends on heat transfer conditions in the processing vat and may be given by

$Q_2 = 0.785\ d_2 \cdot w \cdot \tau_2$ (m^3/day)

(legend of symbols as in equations in section 4.2.1.1).

In plants with milk chilling by means of well water the required quantities for chilling (Q_2) exceed those for cleaning (Q_1). By re-using water passing through the heat exchange channels (see Figs. 21 and 22), the total water requirement is equal to the sum of the quantities for water for chilling and the quantity Q_3 of hot water needed for mixing in the hot wash water tank in order to obtain the final hot wash water temperature of about 60°C.

$$Q_3 = Q_1 \frac{15-0.25\ t_1}{t_2 - t_1} \quad (m^3/day)$$

where t_1 - temperature of well water or water flowing from heat exchangers

t_2 - temperature of water flowing from hot water tank

The values of t_1 may vary from about 41°C to above 60°C depending on the capacity of the milk processing vat and on the period of the heat exchange at which the water for re-use is tapped.

4.2.1.3 Power

Mechanical power, provided either by manual labour or through energy converting machines, is required for milk handling and service procurement. In small-scale plants most of the power is dissipated, particularly in milk handling processes. Reception for all capacities and programmes does not necessitate mechanization considering the small quantities of milk supplied by an individual producer. Of all other milk handling processes bottle washing and filling is the most time consuming if performed manually but for quantities considered in this study, no standard machines are available on the world

markets. Similarly, there are no standard butter churns for such small capacities.

The balance for mechanical energy requirements in milk handling given in this section is for milk agitation and heating/cooling water circulation only. Sporadic manual agitation of milk and water in the milk-in-can handling systems requires negligible energy inputs only.

On the service procurement side the highest single power requirement is in well water pumping which depends on the total pumping head from the source to the well water tank, the outlet of which must be placed above the highest tapping point. This pumping head will differ from site to site. In order to make an indicative estimate for the purpose of this study, the total pumping head H_W equivalent was assumed to be 20 m. Heating of water and refrigerant/absorber mixtures in conventional heaters may be resolved without mechanical motion of the heated media, although the heat exchange coefficients fall considerably and the heat exchange processes last longer without forced motion of the media. The same applies to the heat exchange in solar collectors. However, considering that preference should be given to simplicity of equipment, natural convection in water heating and in desorption in refrigeration processes should be considered as the best solution.

Table 6. DAILY WATER REQUIREMENT (m^3) [1]

	All wash water							**Hot wash water (60°C)**							**Total for all purposes**						
	Daily throughput (litres)																				
	100	**160**	**250**	**400**	**630**	**1000**	**1600**	**100**	**160**	**250**	**400**	**630**	**1000**	**1600**	**100**	**160**	**250**	**400**	**630**	**1000**	**1600**
Collection - hot or cold dispatch	0.3	0.3	0.4	0.4	0.5	0.7	1.0	0	0	0	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.7	1.0
Pasteurized - dispatch in cans	0.3	0.4	0.4	0.6	0.8	1.0	1.5	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.7	0.8	1.0	1.3	1.7	2.3	3.4
Pasteurized - bottled	0.4	0.5	0.6	0.8	1.2	1.7	2.6	0.1	0.2	0.2	0.2	0.3	0.5	0.7	0.7	0.8	1.0	1.3	1.7	2.3	3.4

Fermented - bottled	0.4	0.5	0.6	0.8	1.2	1.7	2.6	0.1	0.2	0.2	0.2	0.3	0.5	0.7	0.7	0.8	1.0	1.3	1.7	2.3	3.4
Cheese and butter	-	-	-	-	1.2	1.7	2.6	-	-	-	-	0.3	0.5	0.7	-	-	-	-	1.8	2.4	3.5

[1] Figures rounded up to 0.1 m^3

The highest concentrated mechanical energy inputs can be thus considered as related to milk agitation and water motion in the milk processing vats and to well water procurement.

Mechanical energy requirement E_a for milk agitation in the vat can be estimated by

$E_a = N_a \cdot \tau_t$ (kWh)

where $N_a = \rho n^3 D^5 \cdot f\left(\frac{D^2 n}{v}\right)$

N_a - power required for milk agitation (kW)

τ_t - total agitation (h)

other symbols as in section 4.2.1.1.

The function $f\left(\frac{D^2 n}{v}\right)$ is based on experimental data and can be found in respective manuals.

Mechanical energy requirement E_c for water circulation in the jacket is given by

$$E_c = \frac{Q_c \cdot H_c \cdot \varrho \cdot g}{3.6 \cdot 10^6 \, \eta_c} \quad (kWh)$$

where Q_c - quantity of circulated water (m^3)

H_c - average pumping head for water return (m)

ρ - water density (kg/m^3)

g - gravity constant (m/s^2)

ηc - efficiency coefficient of the circulation pump

The Q_c value can be estimated by

$Q_c = 0.785 \cdot d_2^2 \cdot w \cdot (\tau_1 + \tau_2 + \tau_3)$ (m^3)

or by applying $d_2 = 0.03$ m w = 0.71 m/s

$Q_c = 0.0005 \cdot (\tau_1 + \tau_2 + \tau_3)$ (m^3)

with τ_1, τ_2, τ_3 values (in seconds) taken from Table 5.

With the assumed average H_c value of 2.0 m, $\varepsilon_c = 0.25$ and average water density ρ = 1 000 kg/m^3, the mechanical energy requirement E_c is given by

$E_c = 0.040 . (\tau_1 + \tau_2 + \tau_3)$ (kWh)

with all values expressed in hours. As can be seen from the equation, the respective power requirement $N_a = 0.040$ kW.

Mechanical energy requirement E_W for well water procurement is given by

$$E_w = \frac{Q_w . H_w . \varrho . g}{3.6 . 10^6 \eta_w} \quad \text{(kWh)}$$

where Q_W - total well water requirement (m^3) - to be taken from Table 6

H_W - total pumping head equivalent (m) - assumed $H_W = 20$ m

ρ - water density (kg/m^3)

g - gravity constant (m/s^2)

ε_W - efficiency coefficient of the well water pump - assumed = 0.35 with those assumed values E_W can be estimated as

$E_W = 0.16 . Q_W$ (kWh)

The respective power requirement N_W will depend on pumping time τ_W (h)

$$N_w = \frac{E_w}{\tau_w} \quad \text{(kW)}$$

In Table 7 the mechanical energy requirements E_a, E_c and E_w are grouped according to capacities and processing programmes.

4.2.2 Procurement

4.2.2.1 Thermal energy

Thermal energy is required for milk and wash water heating and for generation in absorption refrigerators. As already mentioned the lack of continuity of solar energy supply requires that conventional heaters fired with furnace fuels need to be installed for meeting the full thermal energy requirements of the plant.

This implies that plants under consideration are operational on conventional heating systems only. Solar thermal systems may be installed in addition to conventional heaters, both constituting parts of a combined heating system.

The combined space heating and cooling solar systems shown in Figs. 13 and 14 differ from those eventually applicable in milk processing. The systems shown in these figures are used at a time either for heating or for cooling. They are designed for relatively high cooling temperatures.

In milk processing the solar energy must be simultanously collected for milk heating and cooling to relatively low temperatures. The temperature of the heat-carrying medium (water) in milk pasteurization is about 90°C and is achievable with relatively simple flat plate collectors. For generation (desorption) in absorption refrigerators the temperature of the generator must exceed 90°C which requires collectors of a special design. With the absorber/refrigerant mixture flowing through the primary circuit in the solar collectors, the collectors operate as parts of generators. Should the generator operate subsequently as absorber, as is the case in typical intermittent systems, the insulation of the collectors should be removed for the absorption phase and put back for generation. In a well-insulated collector temperature fall in the circuit at night is limited in spite of the drop of the ambient temperature. In order to make the absorption of the refrigerant effective, the absorbent must be cooled during the absorption phase as

intensively as feasible. These demands imply removal of the insulation from the collectors at night and replacing it during the day. Such an operation does not seem to be a practical proposition in industrial application. Cooling 100 l, i.e. the smallest milk quantity considered in this study, requires about 4 kWh net energy in refrigeration. In solar absorption refrigeration this may mean about 9 m^2 of special flat plate collectors.

Table 7. MECHANICAL ENERGY REQUIREMENTS FOR MILK AGITATION (E_a), CIRCULATION OF WATER IN THE JACKET OF THE PROCESSING VAT (E_c) AND FOR WELL WATER PUMPING (E_w) - (kWh) [1]

		$N_a + N_c$ (W)						
		41	**41**	**42**	**44**	**48**	**58**	**77**
		Daily throughput (litres)						
		100	**160**	**250**	**400**	**630**	**1 000**	**1 600**
Collection - hot dispatch	$E_a + E_c$	sporadic demands			0.02	0.02	0.04	0.07
	E_w	0.05	0.05	0.07	0.07	0.08	0.11	0.16
	Total	0.05	0.05	0.07	0.09	0.10	0.15	0.23
Collection - cold dispatch	$E_a + E_c$	sporadic demands			0.05	0.07	0.11	0.20
	E_w	0.05	0.05	0.07	0.07	0.08	0.11	0.16
	Total	0.05	0.05	0.07	0.12	0.15	0.22	0.36
Pasteurized - dispatch in cans	$E_a + E_c$	0.05	0.06	0.07	0.09	0.13	0.22	0.35
	E_w	0.11	0.13	0.16	0.21	0.27	0.37	0.54
	Total	0.16	0.19	0.23	0.30	0.40	0.59	0.89
Pasteurized - bottled	$E_a + E_c$	0.05	0.06	0.07	0.09	0.13	0.22	0.35
	E_w	0.11	0.13	0.16	0.21	0.27	0.37	0.54
	Total	0.16	0.19	0.23	0.30	0.40	0.59	0.89
Fermented - bottled	$E_a + E_c$	[illegible]	[illegible]	0.04	0.05	0.07	0.11	0.21

Fermented - bottled	$E_a + E_c$	0.02	0.03	0.04	0.05	0.07	0.11	0.21
	E_w	0.11	0.13	0.16	0.21	0.27	0.37	0.54
	Total	0.13	0.16	0.20	0.26	0.34	0.48	0.75
Cheese and butter	$E_a + E_c$	-	-	-	-	0.13	0.15	0.27
	E_w	-	-	-	-	0.29	0.38	0.56
	Total	-	-	-	-	0.42	0.53	0.83

[1] Rounded up to 0.01 kWh. Values of $E_a + E_c$ for pasteurized milk incans and bottles calculated for two and three parallel vats forcapacities of 1 000 1 and 1 600 1 respectively.

Daily removal of the insulation from collectors even having this surface may result in its damage and in a rapid drop of the overall efficiency of the system. Unsurmountable problems will arise with the removal and replacement of the insulation when the surface of the collector increases due to the increase of refrigeration requirements. At the present stage, the more feasible solution seems to be the separation of the four main components of the absorption refrigerator: the generator, the condenser the evaporator and the absorber. This not only implies that there is no need to remove the insulation from the generator but also that the “weak mixture” or the pure absorbent has to be transferred to the absorber and the “strong mixture” from the absorber to the generator.

No attempt is made in this study to provide final suggestions for the choice of the solar absorption refrigeration system: at the time of project implementation the supplier concerned must decide. However, it should be noted that intermittent absorption refrigerators are space consuming compared to compressor plants. This becomes evident when analysing some of the engineering aspects of the process, taking the water/ ammonia absorption refrigerators as an example. With ice accumulation the evaporation temperature is usually kept at about -10°C corresponding to a pressure of about 3 bar. The condensation temperature is likely to be about 35°C and the ammonia pressure in the condenser about 11 bar. The latent heat of ammonia at -10°C is about 0.36 kWh/kg which means that in order to obtain the cooling effect of 1 kWh, about 2.8 kg of ammonia have to be evaporated. In intermittent systems

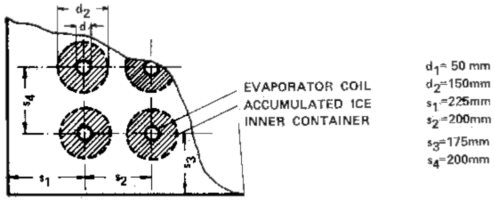
with generation temperatures not higher than 100°C to 120°C and with initial ammonia concentration in the solution of about 46 percent, only about one fifth of the refrigerant can be distilled. This, in turn, indicates that the required ammonia quantity in the initial solution must be about 14 kg in about 30.4 kg or 0.038 m^3 solution per 1 kWh cooling effect. The respective volumes of relative plant components must be in the order of 0.075 m^3 per kWh cooling effect.

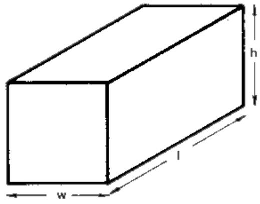
In addition, the volume of the stagnant water condenser substantially increases space requirements. The water quantity in the condenser may be estimated at 0.15 m^3 per 1 kWh cooling effect taking 5°C as the average rise of the water temperature in the condenser. Water evaporation may reduce the required water volume in the condenser but the respective values cannot be calculated until the climatic conditions at the site of the plant are known.

The necessary application of gravity flow between several parts of the refrigerator affect also the required height of the supporting structures of the equipment.

The volume of the chilled water tank in which the evaporator is immersed depends on the amount of heat removed from the milk by one kilogram of chilled water and on the heat content in the chilled water storage tank. Formation of ice on evaporator coils creates refrigeration storage known as an icebank, so that the volume of the tank can be reduced by virtue of the latent heat of fusion of ice. An indication of the icebank volumes for six accumulation capacities from 5 kWh/day to 6 kWh/day corresponding to the range of requirements considered in this study is shown in Fig. 26.

A schematic flow chart of thermal energy procurement in plants requiring hot and chilled water for the heat generation circuits consists of conventional heaters and solar heaters but, as already mentioned, the hot water circuit and the circuit of the refrigerant/absorber mixture have to be separated. In the absorption refrigerator the space in which the absorbent and the refrigerant are kept forms a sealed primary circuit as a whole and with water/ammonia mixtures it is exposed to relatively high pressures during generation. The hot water circuit is filled with water at atmospheric pressure.





REFRIGERATION CAPACITY (kWh/day)	5	10	15	25	45	60
TOTAL COIL LENGTH (m)	4	8	12	20	36	48
NUMBER OF VERTICAL ROWS OF COIL	1	2	3	5	3	4
INNER CONTAINER - WIDTH (m)	0.45	0.65	0.85	1.25	0.85	1.05
- LENGTH (m)	1.5	1.5	1.5	1.5	2.5	2.5
- HEIGHT (m)	1.0	1.0	1.0	1.0	1.5	1.5
- VOLUME (m^3)	0.7	1.0	1.3	1.9	3.2	4.0

FIG.26 INDICATIVE ICEBANK DIMENSIONS FOR AMMONIA AS REFRIGERANT

The hot water container from which water is drawn on one side to the heaters and on the other side to the jacket of the milk processing vat has to be filled with water which has received a suitable water treatment so as to avoid deposit formation on all heating surfaces. This requires particular attention

when planning the respective installations since changing liquids in the jacket of the milk vat (hot water, well water and chilled water) will certainly cause losses and result in frequent additions of make-up water to the hot water storage tank. Further, some of the hot water will be drawn in some plants to the hot wash water container increasing the necessary addition of fresh water. Since the quality of water flowing through the heating circuits is a crucial parameter affecting the efficiency of the system, the water treatment system needs to be planned very carefully. Preference should be given to systems with all water undergoing water treatment processes although in plants with higher daily water consumption, the water treatment could be limited to quantities required for feeding the hot water container.

The diagram in Fig. 27 has been proposed under the assumption that both hot and chilled water must have the required temperatures at the time of milk reception in the morning. Since only limited automatic control systems can be used the installation should be designed basically for operator supervision. If by afternoon the hot water temperature has not reached the required 90°C, the operator should switch on the conventional heater. With oil or gas as furnace fuel, a simple automatic switch-off system with thermostatic control could be used to prevent heating above desired levels. The capacity of the heater should be such as to raise the temperature of water to the required level in two to three hours.

The refrigeration circuits could be controlled in a similar way. If by afternoon the temperature (or the pressure) has not reached the required level in the generator, the conventional heater should be switched on manually by the operator.

The proposed system may be operated either by conventional heating only, by solar energy only or by both, with one of them serving as an auxiliary system. However, the installation of conventional heaters is necessary if regular service supplies are to be secured.

4.2.2.2 Mechanical energy

The mechanical energy requirements shown in Table 7 are related to two different places at which energy is used and power needed, namely the milk agitator/water circulation pump and the well water pump. The two processes can be performed at different times. As can be seen the power requirement

for milk agitation and water circulation varies from 41W to 77W. Most adult humans can continuously sustain a power output of about 75W which means, that in all capacities and processing programmes considered in this study, milk agitation and water circulatin could be done manually. In Table 8 indications are given for the working time spent on milk agitation water circulation and on well water pumping. Data in Table 8 are based on figures from Table 5 and on the assumption that power applied to the well water pump is N_W = 0.075 Kw. Table 8 shows that in all types and capacities of collection centres, the total time needed for manual operation at the milk vat and at well water pumping does not exceed five hours. It is within the abilities of one man to perform the work and since it is fair to assume that in most developing countries not less than two men will be employed, even in centres and plants with very low capacities, there should be no problem with manual operation of the heat treatment and well water procurement in collecting centres. The same applies to the processing plants with daily milk throughputs of up to 630 1 in which this part of the work can be performed by two men in about one third of their shift time. In plants where the total time requirement for agitation/circulation and pumping exceeds 5.3 hours, the total number of hours is presented in Table 8 in two or three separate figures, indicating that the work is to be performed by more than one man.

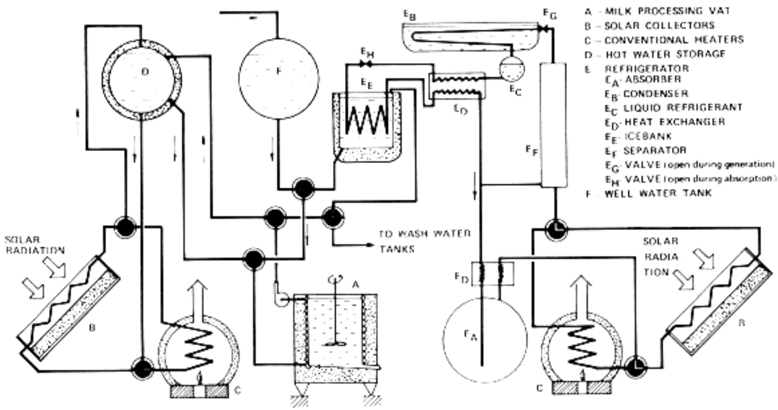


FIG 27. FLOW CHART OF THE ENERGY PROCUREMENT FOR THE HEAT TREATEMENT OF MILK

Table 8. TIME REQUIREMENTS FOR MILK AGITATION/WATER CIRCULATION (τac) AND FOR WELL WATER PUMPING (τw) - (hours)

		Daily throughput (litres)						
		100	**160**	**250**	**400**	**630**	**1 000**	**1 600**
Collection - hot dispatch	τac	-	-	-	0.32	0.43	0.61	0.90
	τw	0.67	0.67	0.93	0.93	1.07	1.47	2.13
	Total	0.67	0.67	0.93	1.25	1.50	2.08	3.03
Collection - cold dispatch	τac				1.08	1.39	1.84	2.59
	τw	0.67	0.67	0.93	0.93	1.07	1.47	2.13
	Total	0.67	0.67	0.93	2.01	2.46	2.31	4.72
Pasteurized - dispatch in cans	τac	1.10	1.30	1.60	2.06	2.70	2.33 + 2.33	3.13 + 3.13

	τ	1.47	1.73	2.13	2.80	3.60	4.93	7.20
						2.70	2.33	3.13
	Total	2.57	3.03	3.73	4.86	+ 3.60	+ 2.33	+ 2.13
							+ 4.93	+ 7.20
Pasteurized - bottled	τac	1.10	1.30	1.60	2.06	2.70	2.33	3.13
							+ 2.33	+ 3.13
	τ_w	1.47	1.73	2.13	2.80	3.60	4.93	7.20
	Total	2.57	3.03	3.73	4.86	2.70	2.33	3.13
						+ 3.60	+ 2.33	+ 3.13
							+ 4.93	+ 7.20
Fermented - bottled	τ_{ac}	0.50	0.60	0.75	0.98	1.31	1.82	2.68
	τ_w	1.47	1.73	2.13	2.8	3.60	4.93	7.20
	Total	1.97	2.33	2.88	3.78	1.31	1.82	2.68
						+ 3.60	+ 4.93	+ 7.20
Cheese and butter	τ_{ac}	-	-	-	-	1.31	1.82	2.68
						+ 0.60	+ 0.90	+ 1.20
	τ_w	-	-	-	-	3.87	5.06	7.47
	Total	-	-	-	-	1.31	1.82	2.68
						+4.47	+ 0.90	+ 1.20
							+ 5.06	+ 7.47

The problem becomes more difficult in plants of 1 000 1 and 1 600 1 daily capacity and concerns all processing programmes. In plants of 1 000 1/day capacity, well water pumping lasts about five hours and it is unlikely that the same person could do the water pumping and the milk agitation/water circulation at one of the milk or cream processing vats. Heat treatment in two parallel vats makes it

necessary for two persons to be simultanously employed at this job.

However, even in plants with capacities of 1 000 1/day the work under consideration requires about 9.3 hours and could be done as a part of the work of three employees. Applying the same philosophy to the 1 600 1/day plants would mean the employment of four persons, two of them would be engaged in water pumping. Although not impossible, such an organization does not seem recommendable or even feasible. Processing plants with a capacity of about 1 000 1/day and more cannot be efficiently operated with mechanical energy requirements provided by human muscle power only. A combustion engine coupled with an electric generator is the most common solution for providing mechanical power. However, as already mentioned there are several drawbacks to their application.

The utilization of wind energy is well worth considering either for directly driving the water pump and milk agitators or by producing wind generated electricity. Unfortunately, the feasibility of such solutions depends on climatic and topographical features of the area in question. The lowest average wind velocity required to operate a wind machine is 3 m/s. The inconstant power supply from a windmill, caused by the fact that winds are erratic, make wind-produced electricity a more promising proposition for application in small-scale milk plants than direct mechanical energy output since batteries can be charged and serve as energy storage. Wind-generated electricity has a relatively long tradition in small-scale domestic use but recently wind-powered electric power stations up to 2 MW have been developed and are already operational in several countries, the best known being in the USA and Denmark. Similar stations are under development in Fed. Rep. of Germany, Sweden and Canada. Small plants with outputs of 1 kW are being widely installed for water pumping with direct conversion of the rotary motin of the windmill into the reciprocating movements of a pump piston.

In small-scale wind-powered electric generators, horizontal rotors are most common. Their axis must be parallel to the wind direction which necessitates a tail rudder in order to make the propeller of the machine face the wind. The electric generator is coupled with the axis of the wind rotor. With a two-blade or three-blade wind rotor and wind speeds of 4 m/s to 8 m/s the windmill axis rotates at 300 to 500 rev/min which makes it necessary either to use low-speed electric generators need to be equipped with

braking devices in order to regulate the speed and to prevent damage at excessive speeds. They are mounted on elevated structures, either on special towers or on a roof exposed to the wind. The electric power output P_W of a wind machine can be estimated by taking

$$P_W = 0.513 .d^2. u_W^3. \simeq_W (w)$$

where d - diameter of the useful rotor area (m)

u_W - wind velocity (m/s)

εw - efficiency coefficient - (indicatory value: for small horizontal rotors εw ≃ 0.25)

As can be seen with a wind velocity of about 2.8 m/s (10 km/h) the output is $P_W \simeq 10$ W but with wind velocity increasing three times to about 8.4 m/s (30 km/h) the output increases to more than 290 W. Wind-powered electric generators require voltage regulation particularly for battery charging. It might be argued that the equipment needed with wind-powered electric systems makes the whole arrangement too complicated, contrary to the idea of simplicity expressed as one of the basic assumptions of the concept of small-scale milk plants. Electric equipment certainly introduces complications but this is also the case with power drawn from a combustion engine generator.

The use of batteries could be avoided when the inconstancy of wind could be replaced by a regular power source. On the other hand application of truck generators (about 80 W) and commercial truck or automobile leadacid batteries could make the problem of repairs, replacement and maintenance easier in developing countries, compared with imported combustion engines not common in these countries. Wind energy, of course, is free. Inverters could be applied and current drawn directly from the output of the wind machine when the wind is blowing during the operation of the milk plant, or for water pumping. This could reduce the required capacity of the batteries. No detailed specifications can be made for the equipment of a wind-powered electric power station until the situation at the selected site is known. A wind generator of 80 W will replace the muscle power of a man for as long as a wind velocity of 5 to 6

m/s is maintained. High-discharge (traction) batteries could give a better performance than normal commercial car batteries which are usually built for about 50 to 200 Ah, that is, a current of about 1 A can be drawn from a fully-charged battery for about 50 to 200 hours. Operations of absorption refrigerators and all kinds of solar systems, particularly with higher capacities, may require controls and regulators for which an electric power supply may be needed. This, of course, could be provided from wind-powered systems but in places where such systems are not available, a relatively simple conversion of human labour into electricity could be considered. In such a system a man operates a bicycle-type generator, partly for direct use and partly for battery charging. With an assumed power output of a man of about 0.35 kwh in 5 hours daily and conversation efficiency ε of about 0.55, the daily man-produced electric energy could be estimated at about 0.2 kwh per man. Capital inputs required for a man-powered electric installation are (1981) in the range of US$ 300 per unit of about 0.2 KWh/day or US$ 1 500 per 1 per day. This includes a bicycle-type dynamo drive, a dynamo of about 40 W and a battery of about 30 to 40 Ah.

Wind-powered small electric generators up to 3 kw are (1981) calculated at US$ 1 000 to 2 000 per kw, depending on the conditions under which the plant is installed and is to operate.

For smaller capacities the capital per unit input will be higher.

CHAPTER 5

PILOT PROJECT PROPOSALS

5.1 General

Project proposals in this Chapter include the six milk collection and processing programmes described in Chapter 4. The presentation attempts to give technical indicatons concerning equipment of the plants and the size and type of buildings required. In the short description of each of the six groups of plants labour requirements and time schedules are discussed. Since most of the equipment proposed in each of the plants is suitable for all groups, standard equipment specifications have been prepared and are given in section 5.2. The selection of the equipment needed for a particular processing programme and a particular capacity is given in the respective parts of section 5.3. Standardization of equipment may not be of interest to those establishing a single plant but it may help in comparing the various proposals included in this study. It may also help to reduce capital costs in cases where equipment for several pilot plants with various processing programmes is to be purchased. Indicatory cost estimates, based on 1981 prices, are given in section 5.4.

Section 5.3 indicates that milk processing in all types of plants is relatively simple compared to service procurement. It is evident, particularly from the isometric layouts, that the "milk system" is only one of three or four combined "systems": the "well water system", the "hot water system" and the "chilled water system". The refrigerant piping is not shown since the absorption refrigeration system will depend on the design of the selected supplier.

In all groups of plants the same concept for buildings has been assumed. In this, only milk handing is located indoors in the processing building. All services equipment is proposed for outdoor installation on supporting structures adequate for the purpose. Such structures should be a part of the specification for outdoor equipment, whereas the milk handling building could be built of local materials by local companies or craftsmen. In the proposed layouts there are no load bearing floors or walls (except for the ground floor), so that neither special building structures nor construction materials are needed. Usually the most difficult problem in dairy building construction is the finish of walls and floors. Glazed ceramic tiles are an expensive finish for walls. Some resinbased or silicate paints applied to hard wall plaster are a cheaper and acceptable solution, although not as durable as ceramic tiles. Floors are

the most difficult problem in milk processing buildings. Hard-burned bricks or tiles jointed with special mortars are the common solution in modern plants. Cast iron tiles are successfully used for floor finish, particularly when cans are in operation. As small building areas are being considered, imported suitable floor finish materials should not increase greatly the overall capital inputs. However, the work must be done by highly specialized craftsmen.

The layouts proposed do not include auxiliary space needed for changing rooms, toilets, stores, offices, mechanical/electric energy procurement area etc. This is subject to local conditions and may be included in the plants of a selected plant on a chosen site only. All pilot project proposals presented in this study could have an indicatory character only since local factors will greatly affect the final shape of the building or buildings and the specification of equipment, particularly regarding non-conventional energy sources. It is, therefore, of paramount importance that no physical action concerning construction be taken until all plans are clarified with the suppliers of equipment and materials who very often undertake the job on a turn-key basis.

5.2 Standard equipment specifications

5.2.1 Milk reception and measuring equipment

Function Milk is supplied by small-scale producers who deliver it in their own vessels in quantities averaging about 5 1 at a time. The milk is poured through a cloth filtre into a standard bucket. A sample is taken from the bucket for quality testing, the bucket is placed on the hook of a spring balance and weighed again after emptying into a milk can or into the milk processing vat. The intake of milk is recorded.

Capacity. The reception capacity depends on the average supply of milk by individual producers and the efficacy of the personnel employed in the reception section. With two buckets and one spring balance the capacity will depend mainly on the weighing and emptying time of the bucket. Assuming about one minute per operation and two hours effective daily reception, the capacity of a reception section with one spring balance and two buckets can be estimated at 300 1/hour or 600 1/day. In plants with higher

capacities two lines should be able to receive up to 1 600 1/day since most likely the average supply per producer would increase.

<u>Specification</u>. All components of the equipment should be easy to clean and suitable for operations in. hot, humid climates.

1. **One spring balance of 25 kg capacity, weighing accuracy not less than 0.05 kg, legalized in the country of origin.**
2. **Two stainless steel buckets of 15 1 capacity and of hygienic design, equipped with one handle for placing the bucket on the hook of the spring balance.**
3. **Two milk cloth filtres composed of a 15 1 conical stainless steel vessel with a 150 mm outlet and a supporting structure suitable for positioning the vessel outlet above the weighing bucket.**
4. **One platform weighing machine having a capacity of 100 kg may be needed in plants dispatching pasteurized liquid milk in cans.**

5.2.2 Milk can

A standard aluminium alloy milk can with mushroom lid, capacity 50 1, to be used for milk transportation. Occasionally the can may also be used as a container in which milk is heat treated.

5.2.3 Milk-in-can heat treatment tank

<u>Function</u>. Milk received from the producer is filtered, measured and collected in a standard 50 1 milk can. The filled can is then placed in a rectangular, insulated water container equipped with a divided lid with openings for the can necks. The neck of the can protrudes above the lid of the tank, so as to permit agitation of milk in the can. The water in the tank is heated or cooled, depending on the milk treatment programme and the equipment of the tank. During the heat treatment process water in the

tank is agitated manually.

Capacities. The heat treatment tank should be suitable for simultaneous heat treatment of milk either in two or in five cans. The tank for five cans should be such that the cans can be placed in one line.

Specification. The tank should be made of corrosion-protected mild steel sheets. It should be insulated so as to guarantee a temperature change of the water in the tank of not more than 3°C in 24 hours in an ambient/water temperature difference of 30°C. The outer cover of the insultation should allow the operation of filled milk cans without damage either to the cans or to the tank components. A manual propeller agitator with a vertical shaft and suitable gear should be such that the water in the tank is kept in motion. For heating, the tank must be equipped either with a heat exchange coil in which hot (80°C to 90°C) water circulates by natural conversation and causes the rise of the temperature of the water in the filled tank (without cans) from 30°C to 70°C in not more than one to one and a half hours, with sporadic water agitation lasting altogether not more than half an hour.

For cooling, an ice accumulation coil provide an icebank of not less than 20 kg ice for each milk can to be immersed in the tank is required. The design of the coil needs to be coordinated with the design of the refrigerator.

5.2.4 Manual milk-in-can agitator

The agitator consists of a stainless steel shaft to one end of which a perforated, round plate is welded, the other end being formed into a handle. It should be of standard dairy design.

5.2.5 Milk processing vat

Function. In the insulated, jacketed processing vat, milk delivered by the producers is heat treated by means of hot water, well water, and/or chilled water depending on the requirements of the process. The milk is manually agitated and the heat treatment media are kept in motion by a manually-operated pump. The arrangements of the heat treatment channels, milk agitator and media pump are described in

Chapter 4 and shown in Fig. 23. In plants for cheese manufacture the milk agitator should be replaceable by curd cutting and agitating tools, suitable for manual operation through the same gear as the agitator. The reference number for vats equipped for cheese manufacture is marked by the index C. The vat would be equipped with a divided lid, removeable if required.

Capacities. (in litres effective volume): 50, 100, 160, 250, 400, 630, 800, 1 000, 1 600

Description. The inner vessel of the vat, the lid and all agitating tools must be made of stainless steel. All parts of the vat welded to the stainless steel vessel must also be made of stainless steel. Insulation of the vat should guarantee a temperature change of the milk in the vat of not more than 2°C in 24 hours by an ambient/milk temperature difference of 30°C.

The outer cover of the insulation should be corrosion proof. The vat must be equipped with a stainless steel outlet cock of a suitable diameter designed according to standards applied in the dairy industry. A stainless steel connecting piece must be attached to the outlet valve.

5.2.6 Milk quality testing equipment

Function. Milk supplied by the producers must be checked for cleanliness, acidity, specific gravity and fat content. Product testing is limited to temperature measurement in all products, specific gravity in liquid producers and brine in cheese production, acidity in fermented products and finally water content in butter. Microbiological tests must be limited to methylene blue or resazuring tests. Acidity tests of the incoming milk include quick alizarol alcohol test performed on each delivery.

Sampling bottles (40 bottles per 100 1 daily capacity) are used for milk samples taken daily for weekly or fortnightly fat testing. The laboratory must be equipped with facilities for water testing on hardness (soap tests).

Specification. The quality testing equipment includes the laboratory table, stools, shelves, glassware, a manually-operated Gerber centrifuge, water baths equipped with simple liquid fuel heaters, chemicals

for one-year operations and all auxiliaries required to perform quality control tests as described above. The testing equipment should be suitable for use without availability of electric power or piped water.

Since no separate room is foreseen for the laboratory equipment the arrangement of the testing table, shelves and sampling cupboards should be such that all equipment and glassware, after completing daily work, can be locked.

5.2.7 Wash trough

Function. Manual washing of cans, bottles and small equipment takes place in wash troughs. The troughs should not only be used for washing under running water by means of suitable brushes but also as containers for detergent solutions in which bottles or parts of equipment are soaked in order to soften the deposits collected on surfaces to be cleaned afterwards.

Capacity. The dimensions of the troughs should suit convenient manual operation and permit full immersion of a 50 1 milk can.

Specification. The wash trough should consist of a rectangular container resting on four legs. All parts should be made of corrosion-protected or non-corrodible materials. Sturdy construction is required as pieces weighing about 10 kg, such as cans, may be washed in the trough. One overflow pipe and one outlet plug should be fitted.

5.2.8 Water container (water tank)

Function. Water containers are required for storing

- **well water**
- **unheated wash water**
- **heated wash water**

- **hot water for milk pasteurization**

__Description__. The water containers can be most conveniently installed when designed as closed horizontal cylindrical vessels with standardized inner dimensions. Insulation is required on the hot water container for milk pasteurization and on the hot wash water container. The well water container may not be insulated provided it is protected against direct insolation in plants where well water is used for milk chilling after pasteurization.

__Capacities__. All requirements for water storing in the plants under consideration can be met by standardizing the dimensions of the tanks so that the containers' total volumes in m^3 are as follows: 0.17, 0.28, 0.42, 0.66, 1.06, 1.70, 2.65, 4.42 and 6.38.

The total volumes of the containers have to exceed the nominal require ment by about 20 percent because the highest water level should be kept at about 0.9 diameter and the king outlet of the tank should be positioned at about the 0.1 diameter level since, except for the hot water container for milk pasteurization, untreated water might be kept in all containers and deposits may tend to collect on the bottom. The working outlet in the hot water container is positioned slightly above the bottom level.

__Specification__. The water tanks should be made of corrosion-protected or non-corrodible materials, designed as closed horizontal cylinders with suitable supporting legs or plates. The front wall should be either screwed to the cylinder or, in all welded constructions the tank should be equipped with a manhole. Four pipe connections are required in all tanks (inlet, outlet, overflow and drainage) all positioned in the front wall of the tank. The hot water tanks need an additional connection in the rear wall for the circulation inlet from heaters. All tanks should be equipped with water level indicators. The hot water containers and hot wash water containers should be insulated.

5.2.9 __Water treatment plant__

__Function__. All plants considered in this study are designed under the assumption that the hygienic standard of water supplied to the plant is acceptable for milk plant operations and household use. Such

water may contain minerals tending to create deposits on heat exchange surfaces, particularly at elevated temperatures (water hardness). The function of the water treatment plant is to soften water used as a heating medium in all pasteurization processes.

Capacity. Capacities in the range of 0.1 to 0.3 m^3 per hour are sufficient for softening the daily quantities of make-up water to replace water lost or drained from hot wash water tanks. Daily quantities of water which need softening will amount to 0.05 to 0.5 m^3, depending on the type and capacity of the plant.

Specification. The water treatment plant should be of the ion exchange type, its particulars depending on the composition of minerals contained in the water. It should be suitable for continuous operation under pressure not exceeding 1 m to 2 m water column since it will be fed by gravity. No electric power should be needed to operate the plant.

5.2.10 Milk can roller conveyor

The standard milk can roller conveyor should have rollers fixed on ball bearings, of a length according to the needs of the plant, with can intake and dispatch tables and with or without 90°bends. It should be free-standing.

5.2.11 Well water pump

The pump should be suitable for supplying water from the water source to the well water container in the plant. Since the pump must be selected according to the water procurement conditions at site, no standard specification can be given.

Assuming that the total pumping head will not exceed 20m, the pump should be suitable for manual operation in plants with daily milk throughputs of up to 630 l. In plants of higher capacities the manual power must be replaced by means selected for a particular site.

5.2.12 Pipes and fittings

The interconnection of all machines and equipment with suitable pipes, fittings and supports must be done according to the final layouts and specifications.

Apart from the refrigerant/absorber interconnections in the absorption refrigerator, the majority of pipe work to be done comprises water lines. The water temperature varies from about 0°C for ice water up to 90°C for hot water for pasteurization. The water pressure does not exceed the few metres water column. Galvanized steel or plastic pipes of suitable quality may be used for water lines. There is little pipe work needed for milk transportation, limited to the interconnection of the processing vats and bottle-filling equipment. This part of piping must be made of stainless steel according to dairy standards. For water temperatures below that of the ambient the pipes must be insulated.

5.2.13 Supporting structures for outdoor installations

According to the general concept of the plant designs, only the milk processing part is located in a regular building, whereas service equipment is located outside this building on structures suiting the complex needs of a particular plant. Their specification, design and materials used for their construction must depend on the final specification and the layout of the plant and must create a well-coordinated unit together with the processing building.

Should the equipment be completely imported, the outdoor equipment together with all supporting structures could be supplied in a prefabricated form in transportation containers to simplify the erection of the plants. A properly prepared cost comparison should be the deciding factor in selecting either individual items erected on the site or prefabricated deliveries.

5.2.14 Oil-fired water heater

Function. The water heater is used to increase from about 80°C to about 90°C the temperature of water used as the heating medium in milk pasteurization processes. It becomes operational only when, by

afternoon, the temperature of the sun-heated water does not reach the required level.

Capacity. The water heater can have six capacities to meet the heat requirements of the plants proposed: 2.5 kW, 4.0 kW, 6.0 kW, 10.0 kW, 16.0 kW and 25.0 kW. Its daily operation is expected for two to three hours only.

Specification. Water heaters commonly used for space central heating and domestic hot water in countries with moderate or cold climates, are considered suitable for the requirements of the plants under consideration. Oil is suggested as the standard furnace fuel, but gas, coal or wood-fired heaters may be applied if and when they suit better the conditions prevailing at particular sites. The heater must be complete with fuel containers, burners, controls, indicators and alarms, and operational without additional energy supply from outside the heater.

5.2.15 Absorption refrigerator with ice accumulation

Function. In most of the milk collection systems milk must be cooled to about 4°C. Processing of pasteurized liquid milk and manufacture of a number of milk products also require cooling of milk or cream to about 4°C. In order to reduce the temperature of milk to 4°C (usually from about 35°C), water at a temperature of about 1°C is moved over a heat exchange surface separating the water from the milk. The function of the refrigerator is to provide chilled water for milk cooling. Since there can be only a small temperature difference between milk and water particularly at the end of the heat exchange and, since cooling of milk has to be completed within 0.6 to about 1.4 hours (depending on daily quantity), “storage of cold” is required. This is best achieved by freezing a part of the water when there is no milk cooling but the refrigerator is operating. The latent heat of fusion (0.093 kWh/kg) is about 80 times higher than the specific heat of water (0.00116 kWh/kg) and therefore accumulation of cold in icebanks permits reduction of the volume of chilled water containers.

Capacity. There are eight capacities of the absorption refrigerators which can meet the cooling requirements of the proposed plants (expressed in kWh/day): 3, 4, 6, 10, 15, 23, 36 and 58. The same capacities expressed as kilograms of ice accumulated in the icebanks are as follows: 32, 43, 65, 108,

161, 247, 387 and 624.

Specification. Basically intermittent absorption refrigerators with one cycle per day, operating without electric or mechanical energy supply and with desorption temperatures not exceeding 100°C to 120°C are considered for the suggested plants. The concept of pilot plants indicates the experimental character of the enterprise which means that the refrigerator can be operated either with furnace fuel desorption heaters or with solar desorption heaters. The need to make the system work with thermal energy provided either from conventional sources or from solar radiation explains the demands described above. Should application of mechanical or electric energy be necessary, particularly in larger machines to obtain the required process parameters, the power applied should not exceed a fraction of 1/kW per prime mover and the total daily energy requirement for all prime movers should not exceed the capacity of a 200 Ah battery. Should controls require electric power, even in smaller plants, the total requirements should be kept within the limits achieved by a man-driven bicycle-type dynamo of 40 W charging a suitable battery.

The lack of mechanical/electric power in the plants with the exceptions mentioned above, necessitates the consideration of stagnant water condensers with well water temperatures of about 30°C for refrigerant condensation. No limitations are made concerning absorbent/refrigerant mixtures or other details of the absorption refrigerator, provided they can meet the requirements of the plants under consideration.

5.2.16 Solar wash water heating system

Function. In milk collection centres with milk-in-vat cooling of 400 to 1 600 1/day, hot water is needed only for cleaning and disinfection of equipment coming in contact with milk.

The desirable hot wash water temperature is about 60°C of which well water of about 30°C is to be heated in a solar water heating system.

Capacity. There are four capacities of the water heating system which can meet the requirements of all

the proposed plants: 3, 5, 7, and 9 kWh/day.

Specification. A solar heating system with flat plate collectors suiting the insolation conditions prevailing at site, with natural convection of water heated from 30°C to 60°C. Water is softened in treatment plants prior to entering the heating system. It is drawn for washing purposes directly from the primary circuit.

If a design with divided primary and secondary circuits is considered advantageous because of reasons of improved economy or operational safety, the supplier should be encouraged to suggest such a solution.

All controls and safety devices must operate on thermal energy provided by the system since no outside energy supply is planned.

5.2.17 Solar water heating system

Function. In all plants in which milk treatment requires raising the temperature of milk, hot water is used as the heating medium.

The heat exchange processes are so designed that the initial inlet temperature of hot water is 90°C and at the end of the process it may drop to 80°C. Hot water creates the primary circuit of the system; milk should be considered as the secondary circuit except for milk-in-can heating in collection centres where there are three circuits, milk being the third. The second circuit consists of the water in the tank in which cans with milk are immersed. Hot water of the primary circuit circulates in a heat exchange coil immersed in the water in the tank.

In all plants requiring hot water for milk heating conventional fuel heaters are installed. The solar water heating system must be considered as an alternative energy source and the conventional heater used only when by sunset the water temperature does not reach the required level of 90°C.

Capacity. There are 16 capacities of the solar water heating system which can meet the requirements of

the proposed plants (expressed in kWh/day): 2, 3, 5, 6, 7, 9, 11, 14, 17, 21, 26, 31, 41, 49, 66 and 78.

Specification. A solar heating system with flat plate collectors suiting the insolation conditions prevailing at the site, with natural convection of water heated from 80°C to 90°C. Water is softened in treatment plants prior to entering the heating system.

Water losses during circulation in the heat exchange system in milk processing vats, as well as the need to use a part of this hot water for washing purposes, necessitate the daily addition of make-up water to the primary circuits in all milk-in-vat milk heating systems. Should a design with a separate circuit passing the solar collectors be advantageous, for reasons of improved economy or operational safety, the supplier should be encouraged to suggest suitable solutions.

All controls and safety devices must operate on thermal energy provided by the system itself since no outside energy supply is planned.

5.2.18 Solar desorption heater in absorption refrigerators

Function. In all plants in which milk treatment requires deep cooling to 4°C, chilled water is used as the cooling medium. Absorption refrigerators are designed to accumulate ice on evaporator coils. By melting the ice, heat is removed from water serving as the milk cooling medium. Conventional fuel heaters provide the heat needed for desorption. Solar desorption heaters must be considered as an alternative energy source and the conventional heater is used only when by sunset the pressure in the refrigerant circuits does not reach the required level.

Capacity. There are eight capacities of absorption refrigerators to which the solar desorption heaters need to be adjusted. The capacities are expressed in kilograms of ice accumulated daily on evaporator coils: 32, 43, 65, 108, 161, 247, 387 and 624.

Specification. Solar heating systems with moderately concentrating collectors suitable for application as desorption heaters in absorption refrigerators. The specification of the system depends closely on the

design of the absorption refrigerator. The system should be offered together with the absorption refrigerator.

5.2.19 Mechanical/electric power source

Function. Milk processing plants with a capacity of about 1 000 1/day and more require mechanical energy in quantities exceeding rational employment of manual power. Water pumping and milk agitation with heating media circulation are the processes where power requirements are the highest. Circulation of media in the absorption refrigerators and in the solar heaters may be intensified with pumps if ample mechanical energy is available. In addition, mechanization of bottle washing and filling systems could also be introduced.

Capacity. In line with the basic concept of the pilot plants under consideration, electric generators driven by combustion engines should only be installed in exceptional cases. Windmills providing mechanical power directly or generating electric energy, drawn directly or from batteries charged by wind generators, are recommended in areas with sufficient wind energy available.

The capacity of the power station cannot be defined since, depending on local conditions for power generation, the mechanization of the plant may take various forms and levels. The minimum requirements for power are estimated at above 75 W and for daily energy production at above 0.56 kWh.

Specification. A windmill with dynamo, batteries, alternators and all mechanical and electrical applicances suitable to the requirements of the plants and adapted to local wind conditions. Only in specific cases a combustion engine-driven electric generator should be considered as an appropriate solution for the mechanical/electric power supply.

5.2.20 Man-operated electric generator with battery

Function. In specific cases operation of solar water heaters and absorption refrigerators may be facilitated by introducing controls, safety devices and small prime movers requiring small amounts of

electric energy. In such cases, if no other solution is available, man-driven electric generators could meet the requirements. This may be particularly useful in plants where all other mechanical energy requirements could be relatively easily covered by manual power and where installation of wind-mills could not be feasible or justified.

Capacity. Considering the limited output of manual power a 40 W generator operated over about five to six hours could generate about 0.25 kWh of electric energy, either in direct supply or through battery charging.

Specification. A bicycle type, man-operated rotating wheel, propelling a 40W dynamo, with a battery of about 50 Ah and all electric installation is required.

5.2.21 Milk reception funnel

Function. In some of the milk plants - in particular in those with milk separation - the milk processing vat may be not accessible from the reception floor. In such instances the received milk can be poured into a reception funnel from which it will flow by gravity into the processing vat.

Description. A stainless steel funnel of about 50 1 volume, with an outlet and connecting pipe to the processing vat, supported on a suitable structure at a convenient working level.

5.2.22 Manually-operated milk separator

A manually-operated milk separator of standard design and capacities of about 160 1/h and 250 1/h milk intake.

5.2.23. Butter churn

Function. To make butter out of cream with about 30 percent fat content, by turning the churn around its horizontal axis.

Description. The butter churn should be suitable for filling with cream from 35 to 55 percent of its total volume. Required total volumes: 100 1 and 200 1. The churn is rotated about a horizontal axis by a crank handle for manual operation. If an electric motor can be provided a belt reduction drive is required.

Internal kneading rollers are not required if a separate kneading machine is provided for further processing of the butter.

5.2.24 Butter container

A stainless steel container of about 50 1 for butter storage in ice water before kneading/packaging. The container should be equipped with a stainless steel lid.

5.2.25 Butter-handling table

A rectangular table with a washable surface of about 1 m^2, with all four legs equipped with wheels. The table is to be used as an auxiliary surface during kneading and packaging.

5.2.26 Butter-kneading machine

A circular manually-operated butter-kneading machine with a rotating kneading table and one roller, capacity up to 15 kg/h.

5.2.27 Butter-packaging machine

A manually-operated butter portioning machine equipped with facilities for manual wrapping of the product in waxed paper or aluminium foil. Capacity up to 15 kg/h in 100 g or 250 g packages.

5.2.28 Curd-handling trolley

The curd-handling trolley is used as auxiliary equipment during the process of filling cheese moulds with curd. It should consist of a sturdy stainless steel tray suitable for containing about 20 cheese moulds

and 20 lids and should be positioned on four legs equipped with wheels permitting easy transfer of the filled moulds to the appropriate area of the processing hall.

5.2.29 Cheese moulds

Standard cheese moulds (wooden or of perforated stainless steel sheets or plastic cylinders) suitable for blocks of about 5 kg soft cheese.

5.2.30 Cheese presses

Manually-operated cheese presses with 20 single-arm levers suitable for 20 cheese moulds positioned at a time.

5.2.31 Brine container

A rectangular plastic container with 40 mm outlet with one outlet cock, equipped with a suitable supporting frame protected against corrosion. Capacity about 0.25 m^3.

5.2.32 Rack for cheese moulds

A sturdy rack for cheese moulds to be dried after washing, suitable for up to 60 moulds with lids.

5.2.33 Bottle washing and filling equipment

Function. Pasteurized liquid milk, stirred fermented milk beverages and unstirred fermented milk products are to be packaged in returnable glass bottles of standard volume, varying from 0.25 to 1.0 1. The bottles are collected in crates containing 30 bottles of 0.25 1, 20 bottles of 0.5 1 or 15 bottles of 1.0 1. Preferably only one size of bottles and crates should be handled in one plant.

Empty bottles from crates returned from the market need to be soaked in a hot alkaline solution for at

least 20 minutes and afterwards, brushed manually and rinsed. Cleaned bottles should be positioned upside down in cleaned crates and stored until the filling starts.

The product for filling is kept in the processing vat, from which it will flow by gravity to an intermediate container equipped with spring loaded outlet valves, connected to the container by flexible hose-pipes. The volume of the intermediate container and the number of filling valves attached depend on the required filling capacity. Bottles for filling are put on a table above which the intermediate container is positioned.

Capacity. From 100 bottles/day to 1 600 bottles/day with two to ten filling valves.

Description. (a) A complete set of soaking, brushing and rinsing troughs adequately equipped with necessary pipes and fittings, protected against corrosion, suitable for manual washing of bottles and crates.

(b) A complete set of manual bottle filling valves with intermediate containers, pipes, fittings and necessary tools, tables and supporting structures. All parts coming in contact with milk are to be made of stainless steel and flexible hose-pipes out of food-quality rubber or plastic.

5.3 Project proposals

5.3.1 Milk collecting centres with milk heating

The centres are equipped to dispatch hot (60°C) milk in 50 1 cans. The specifications and layouts are based on the assumption that clean cans are supplied by the processing plants. In centres receiving up to 250 1 milk daily, the milk-in-can heating system is proposed. For daily throughputs above 250 1 up to 1 600 1, the milk-in-vat heating system is planned.

The description of milk handling processes, reception techniques, scope of the quality control and of the concept of service procurement can be found in Chapter 4 (“Prospective small-scale systems”) and

in section 5.2 ("Standard equipment specifications").

In Figs. 28 to 33 the general outline of the concepts of the centres is illustrated. In all centres solar water heaters are proposed as an alternative energy source in addition to the conventional heater. No layouts for the solar system could be proposed since they will depend on local conditions at the site.

As can be seen from the figures, hot wash water is planned only for centres equipped with processing vats.

The duration of processes and the labour requirements may be estimated as follows:

- reception	- up to 3 hours	- two men
- milk heating	- up to 1 hour	- one man
- can filling	- up to 1 hour	- one man
- truck loading/unloading	- up to 0.5 hours	- two men
- washing	- up to 1 hour	- one man
- service procurement	- up to 4 hours	- one man

Under the assumption that milk is received in the centre once a day and that it is dispatched immediately after the temperature of the milk has reached 60°C, the work can be completed within one 8-hour shift with only two men employed even in centres handling 1 600 1 per day.

5.3.2 Milk collecting centres with milk cooling

The centres are equipped to dispatch chilled (4°C) milk in 50 1 cans. The specifications and layouts are based on the assumption that clean cans are supplied by the processing plants. In centres receiving up to 250 1 milk daily the milk-in-can cooling system is proposed. For daily throughputs above 250 1 up to 1 600 1 the milk-in-vat cooling system is planned.

The description of milk handling processes, reception rechniques, scope of the quality control and of the concept of service procurement can be found in Chapter 4 ("Prospective small-scale systems") and in section 5.2 ("Standard equipment specification").

In Figs. 34 to 39 the general outline of the concepts of the centres is illustrated. In all centres solar heaters are proposed as an alternative energy source for absorption refrigeration generators in addition to conventional heaters. Hot wash water is planned only for centres equipped with processing vats. Solar collectors are planned as the only energy source for wash water heating.

No layouts for the solar systems could be proposed since they will depend on local conditions at the site.

Table 9. Equipment specification - Milk collecting centres with milk heating

Equipment	Standard specification reference (in text)	Requirement (numbers)						
		Daily throughput (litres)						
		100	160	250	400	630	1 000	1 600
1. Milk reception and measuring equipment	5.2.1	1	1	1	1	1	2	2
2. Milk can 50 1	5.2.2	2	4	5	8	13	20	32
3. Milk-in-can heat treatment rank with water heating coil - for 2 cans	5.2.3	1	-	-	-	-	-	-
-for 5 cans	5.2.3	-	1	1	-	-	-	-
4. Manual milk-in-can agitator	5.2.4	2	4	5	-	-	-	-
5. Milk processing vat 400 1	5.2.5	-	-	-	1	-	-	-
630 1	5.2.5	-	-	-	-	1	-	-
1 000 1	5.2.5	-	-	-	-	-	1	-
1 600 1	5.2.5	-	-	-	-	-	-	1
6. Quality testing set	5.2.6	1	1	1	1	1	1	1

7. Wash trough	5.2.7	1	1	1	1	1	1	1
8. Well water tank 0.28 m^3	5.2.8	1	-	-	-	-	-	-
0.42 m^3	5.2.8	-	1	1	-	-	-	-
0.66 m^3	5.2.8	-	-	-	1	1	-	-
1.06 m^3	5.2.8	-	-	-	-	-	1	-
1.70 m^3	5.2.8	-	-	-	-	-	-	1
9. Hot wash water tank - 0.17 m^3	5.2.8	1	1	1	1	1	-	-
- 0.28 m^3	5.2.8	-	-	-	-	-	1	1
10. Water treatment plant	5.2.9	1	1	1	1	1	1	1
11. Milk can roller conveyor with one bend - 5 m length	5.2.10	-	-	-	1	1	1	1
12. Manual well water pump	5.2.11	1	1	1	1	1	1	1
13. Pipes and fittings - set	5.2.12	1	1	1	1	1	1	1
14. Supporting and protecting structures								
for outdoor installations - set	5.2.13	1	1	1	1	1	1	1
15. Hot water tank 0.42 m^3	5.2.8	1	-	-	-	-	-	-
0.66 m^3	5.2.8	-	1	-	-	-	-	-
1.06 m^3	5.2.8	-	-	1	-	-	-	-
1.70 m^3	5.2.8	-	-	-	1	-	-	-
2.65 m^3	5.2.8	-	-	-	-	1	-	-
4.42 m^3	5.2.8	-	-	-	-	-	1	-
6.38 m^3	5.2.8							1
16. Oil fired water heater 2.5 kW	5.2.14	1	-	-	-	-	-	-

16. Oil fired water heater 2.0 kW	5.2.14	1						
4.0 kW	5.2.14	-	1	1	-	-	-	-
6 kW	5.2.14	-	-	-	1	-	-	-
10 kW	5.2.14	-	-	-	-	1	-	-
16 kW	5.2.14	-	-	-	-	-	1	-
25 kW	5.2.14	-	-	-	-	-	-	1
<u>OPTIONAL</u>								
17. Solar water heating system - 5 kWh/day	5.2.17	1	-	-	-	-	-	-
- 7 kWh/day	5.2.17	-	1	-	-	-	-	-
- 11 kWh/day	5.2.17	-	-	1	-	-	-	-
- 17 kWh/day	5.2.17	-	-	-	1	-	-	-
- 20 kWh/day	5.2.17	-	-	-	-	1	-	-
- 41 kWh/day	5.2.17	-	-	-	-	-	1	-
- 66 kWh/day	5.2.17	-	-	-	-	-	-	1

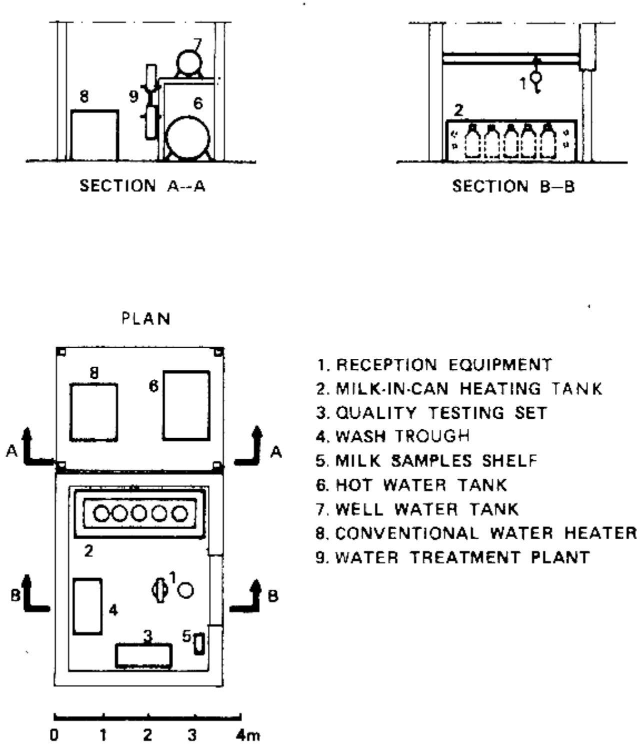


FIG 28. MILK COLLECTION CENTRE 100 l/day TO 250 l/day - MILK-IN-CAN HEATING.

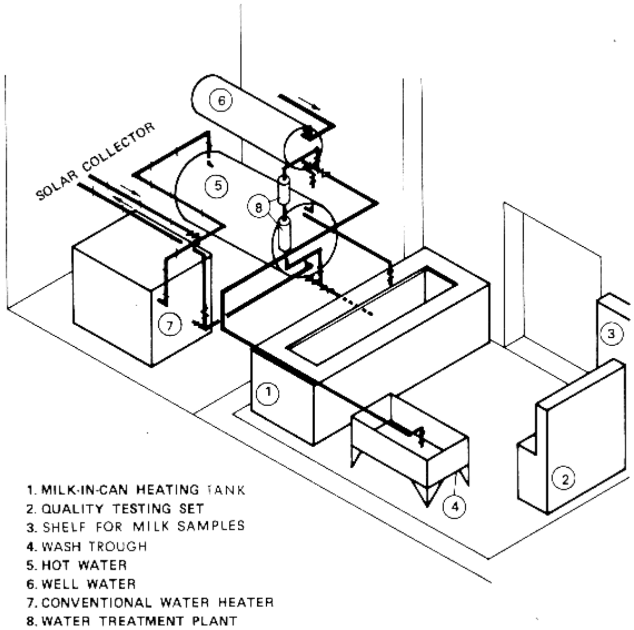


FIG 29. MILK COLLECTION CENTRE 100 l/day TO 250 l/day - MILK-IN-CAN HEATING

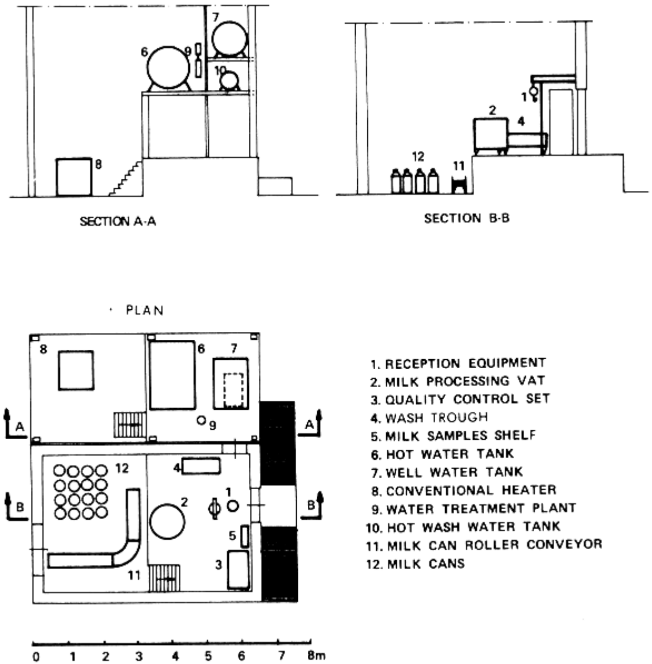


FIG 30. MILK COLLECTION CENTRE 400 l/day TO 630 l/day. MILK-IN-VAT HEATING'.

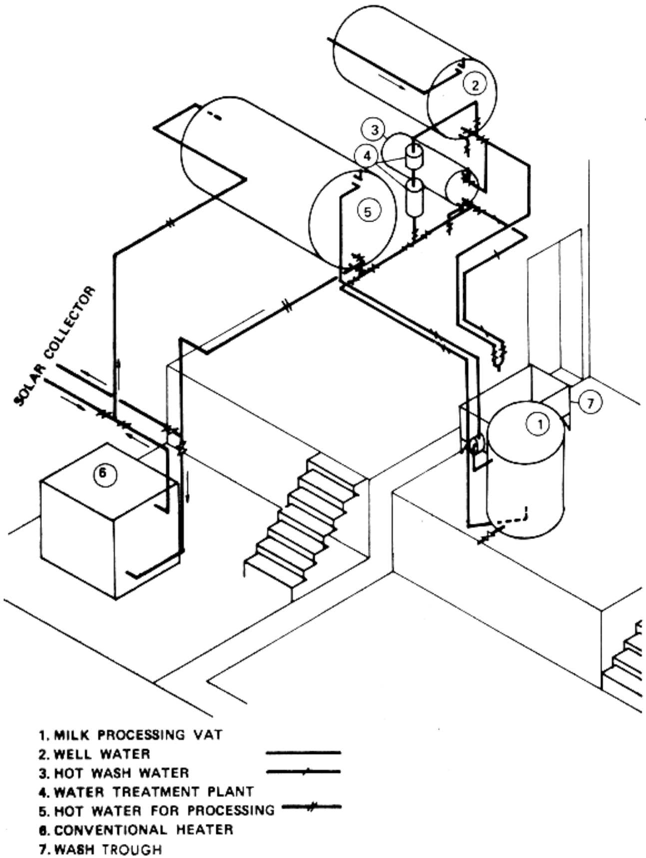


FIG 31. MILK COLLECTION CENTRE 400 l/day TO 630 l/day. MILK-IN-VAT HEATING

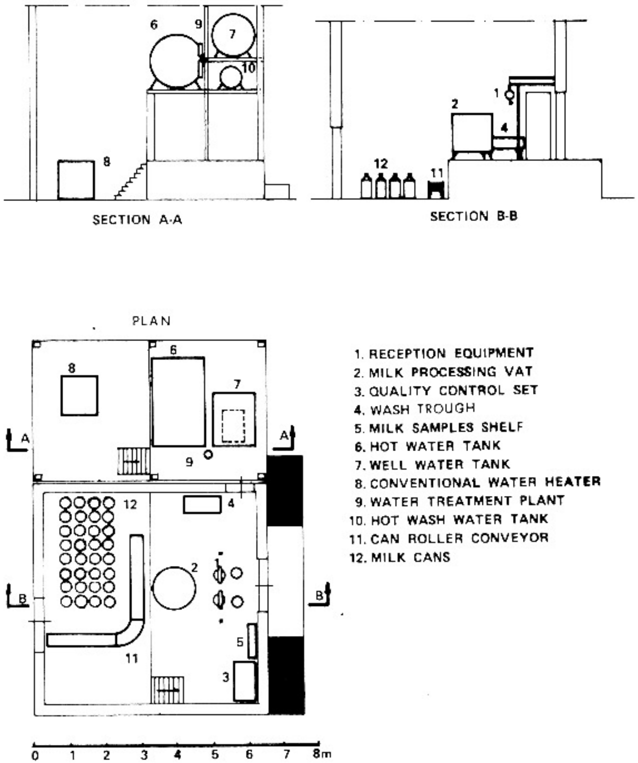


FIG 32. MILK COLLECTION CENTRE 1000 l/day TO 1600 l/day. MILK-IN-VAT HEATING.

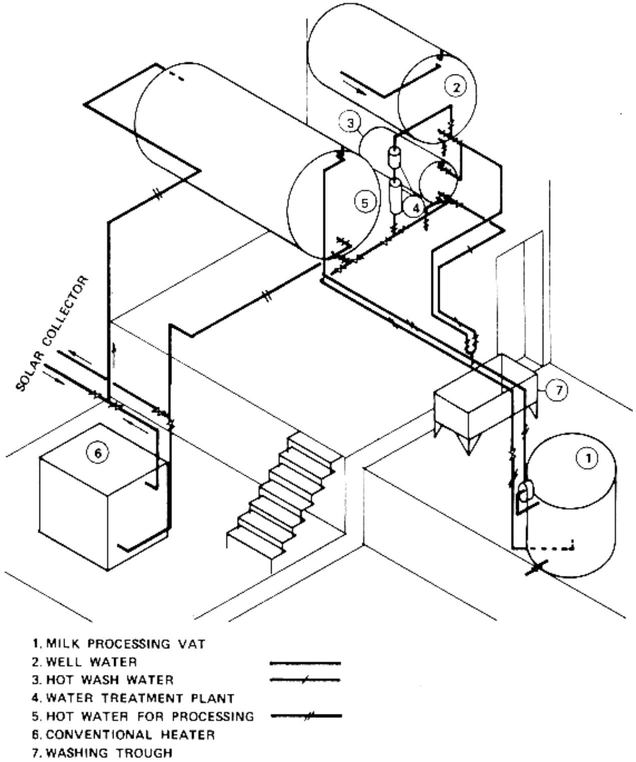


FIG 33. MILK COLLECT ION CENTRE 1000 l/day TO 1600 l/day. MILK-iN-VAT HEATING

The duration of processes and the labour requirements may be estimated as follows:

- reception	- up to 3 hours	- two men
- milk chilling	- up to about 3 hours	- one man
- can filling	- up to 1 hour	- one man
- truck loading/unloading	- up to 0.5 hour	- two men
- washing	- up to 1 hour	- one man
- service procurement	- up to 4 hours	- one man

Assuming that milk is received in the centre once a day and that cans can be dispatched immediately after the temperature of milk has fallen to about 4°C, the work can be completed within one 8-hour shift with only two men employed in centres handling up to 1 000 1 per day. In centres handling 1 600 1 per day the work can be completed in one 8-hour shift under favourable conditions. Ten hours from the starting of reception seems to be a more realistic assumption.

5.3.3 Pasteurized liquid milk processing plants - dispatch in cans

The plants are equipped to process pasteurized liquid milk dispatched at a temperature of approximately 4°C. The milk is transported to the customer in cans containing 50 1 each. Empty cans are washed after return and kept clean until the next filling. Up to a 630 1 daily throughput all milk processing is done in one jacketed vat. In plants of higher capacities the processing needs to be done in two parallel vats of a suitable capacity.

The description of milk handling processes, reception techniques, scope of the quality control and of the concept of service procurement can be round in Chapter 4 ("Prospective small-scale system") and in section 5.2 ("Standard equipment specifications"). Filling of cans up to the 50 l mark is the proposed quantity measuring system. Cans not fully filled should be weighed on a platform weighing machine.

In Figs. 40 to 45 the general outline of the concept of the plants is illustrated. In all centres solar heaters are proposed as alternative energy sources to absorption refrigeration generators and to water systems, in addition to conventional heating systems. No layouts for solar systems are presented since

they will depend on local conditions on the site .

Plants of a capacity exceeding about 630 1 daily need to be equipped with a mechanical/electric power source since manual operations of all mechanisms may prove to be impractical due to the relatively high level of total mechanical energy requirement. Wind-powered electric generators are proposed in such instances for all plants located where local weather conditions would make such a solution practical.

In plants of up to 400 1 capacity two men are able to complete milk reception, processing, plant: cleaning, water pumping and service equipment servicing within one 8-hour shift. In plants processing 630 1 per day the labour requirement increases to three men. An additional mechanical/electric power source is required in plants of a capacity exceeding 630 1 up to 1 600 l, and the labour requirerent rises to four men.

Table 10. Equipment specification - Milk co11ecting centres with mi1k coo1ing

Equipment	**Standard specification reference (in text)**	**Requirement (numbers)**						
		Daily throughput (litres)						
		100	**160**	**250**	**400**	**630**	**1 000**	**1 600**
1. Milk reception and measuring equipment	5.2.1	1	1	1	1	1	2	2
2. Milk can 50 l	5.2.2	2	4	5	8	13	20	32
3. Milk-in-can heat treatment tank with ice accumulation coil for 2 cans	5.2.3	1	-	-	-	-	-	-
- for 5 cans	5.2.3	-	1	1	-	-	-	-
4. Manual milk-in-can agitator	5.2.4	2	4	5	-	-	-	-
5. Milk processing vat 400 1	5.2.5	-	-	-	1	-	-	-
630 1	5.2.5	-	-	-	-	1	-	-
1 000 1	5.2.5	-	-	-	-	-	1	-
1 600 1	5.2.5	-	-	-	-	-	-	1

1 000 l	5.2.5	-	-	-	-	-	-	1
6. Quality testing set	5.2.6	1	1	1	1	1	1	1
7. Wash trough	5.2.7	1	1	1	1	1	1	1
8. Well water tank 0.28 m^3	5.2.8	1	-	-	-	-	-	-
0.42 m^3	5.2.8	-	1	1	-	-	-	-
0.66 m^3	5.2.8	-	-	-	1	1	-	-
1.06 m^3	5.2.8	-	-	-	-	-	1	-
1.70 m^3	5.2.8	-	-	-	-	-	-	1
9. Hot wash water tank 0.17 m^3	5.2.8	1	1	1	1	1	-	-
0.28 m^3	5.2.8	-	-	-	-	-	1	1
10. Water treatment plant	5.2.9	1	1	1	1	1	1	1
11. Milk can roller conveyor with one bend -5 m length	5.2.10	-	-	-	1	1	1	1
12. Manual well water pump	5.2.11	1	1	1	1	1	1	1
13. Pipes and fittings - set	5.2.12	1	1	1	1	1	1	1
14. Supporting and protecting structures for outdoor installations - set	5.2.13	1	1	1	1	1	1	1
15. Absorption refrigerator with ice accumulation - 4 kWh/day	5.2.15	1	-	-	-	-	-	-
- 6 kWh/day	5.2.15	-	1	-	-	-	-	-
- 10 kWh/day	5.2.15	-	-	1	-	-	-	-
- 15 kWh/day	5.2.15	-	-	-	1	-	-	-
- 23 kWh/day	5.2.15	-	-	-	-	1	-	-
- 36 kWh/day	5.2.15	-	-	-	-	-	1	-
- 58 kWh/day	5.2.15	-	-	-	-	-	-	1

- 58 kWh/day	5.2.15	-	-	-	-	-	-	1
16. Solar wash water heating system								
- 3 kWh/day	5.2.16	-	-	-	1	-	-	-
- 5 kWh/day	5.2.16	-	-	-	-	1	-	-
- 6 solar wash water heating system								
- 7 kWh/day	5.2.16	-	-	-	-	-	1	-
- 9 kWh/day	5.2.16	-	-	-	-	-	-	1
<u>OPTIONAL</u>								
17. Solar desorption heater in absorption refrigerators for - 4 kWh/day	5.2.18	1	-	-	-	-	-	-
- 6 kWh/day	5.2.18	-	1	-	-	-	-	-
- 10 kWh/day	5.2.18	-	-	1	-	-	-	-
- 15 kWh/day	5.2.18	-	-	-	1	-	-	-
- 23 kWh/day	5.2.18	-	-	-	-	1	-	-
- 36 kWh/day	5.2.18	-	-	-	-	-	1	-
- 58 kWh/day	5.2.18	-	-	-	-	-	-	1
18. Man-operated electric generator with battery - 40 W	5.2.20	1	1	1	1	1	1	1

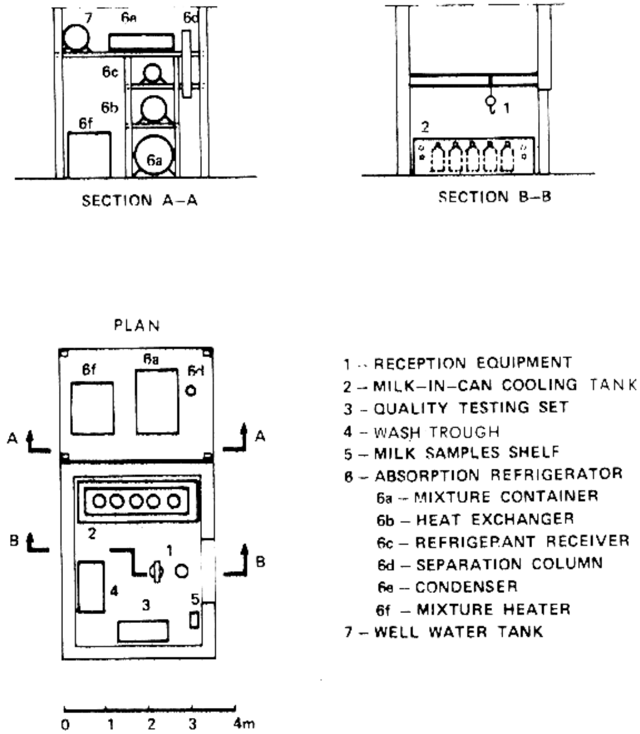


FIG 34. MILK COLLECTION CENTRE 100 l/day TO 250 l/day - MILK-IN-CAN COOLING

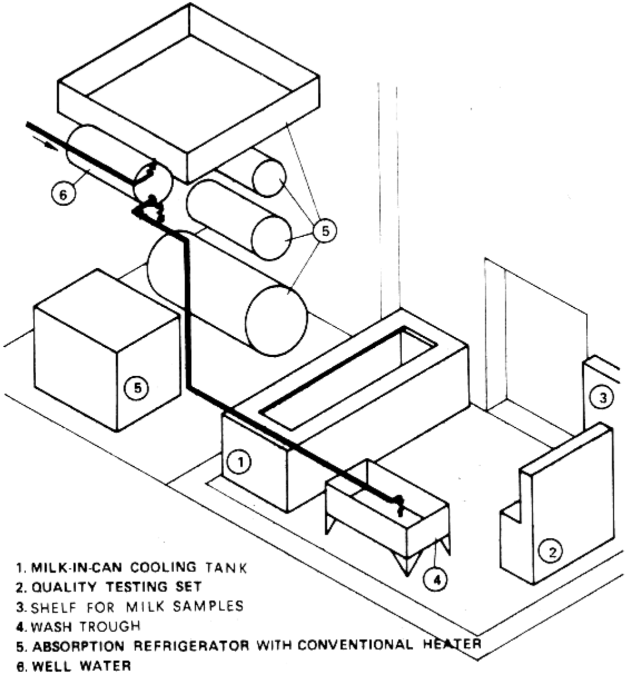


FIG 35. MILK COLLECTION CENTRE 100 l/day TO 250 l/day -MILK-IN-CAN COOLING

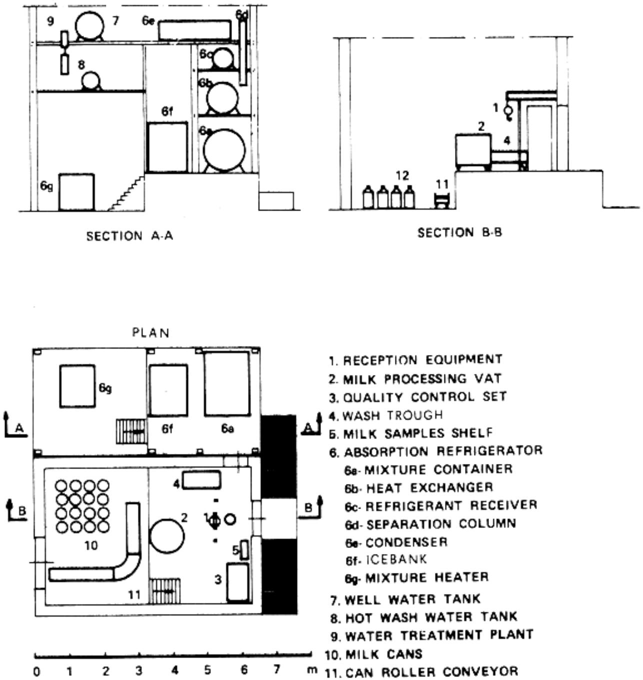


FIG 36. MILK COLLECTION CENTRE 400 l/day TO 630 l/day. MILK-IN-VAT COOLING.

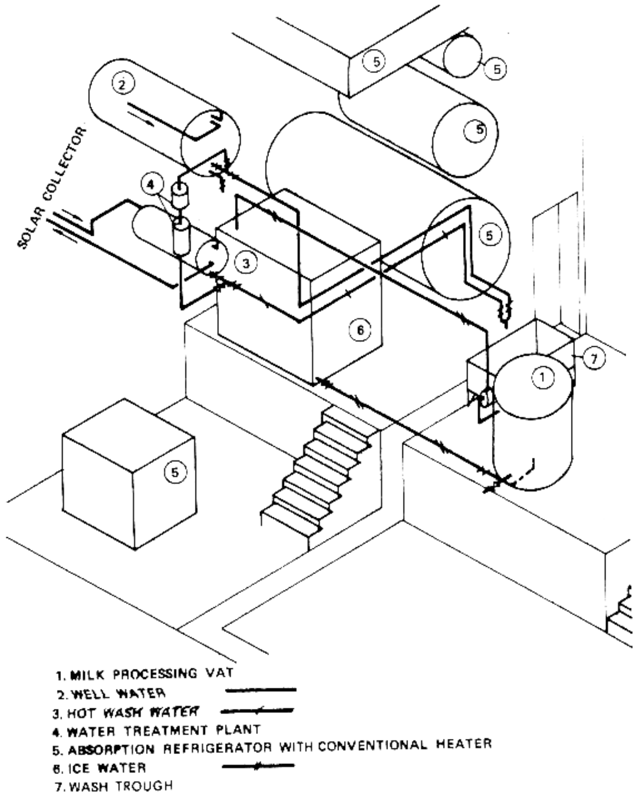


FIG 37. MILK COLLECTION CENTRE 400 l/day TO 630 l/day. MILK-IN-VAT COOLING

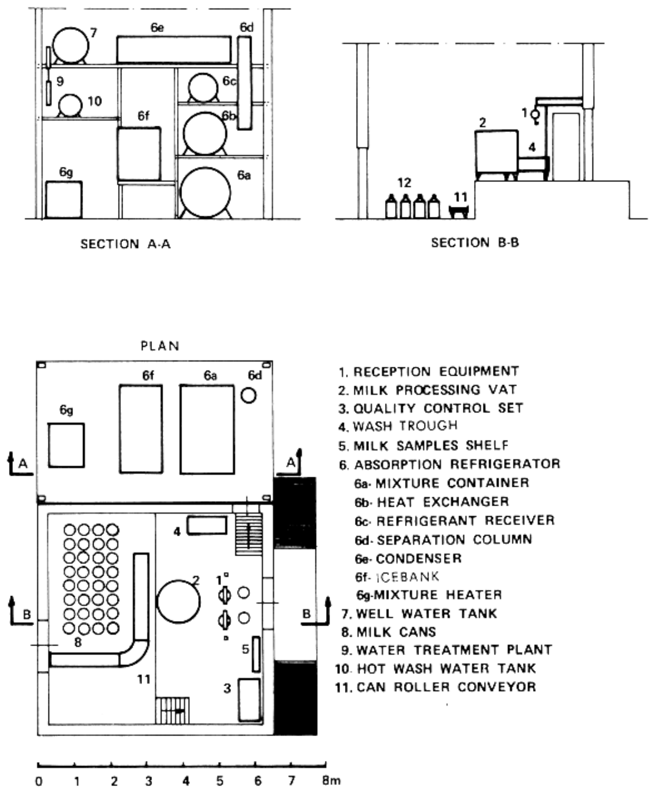


FIG 38. MILK COLLECTION CENTRE 1000 l/day TO 1600 l/day. MILK-IN-VAT COOLING.

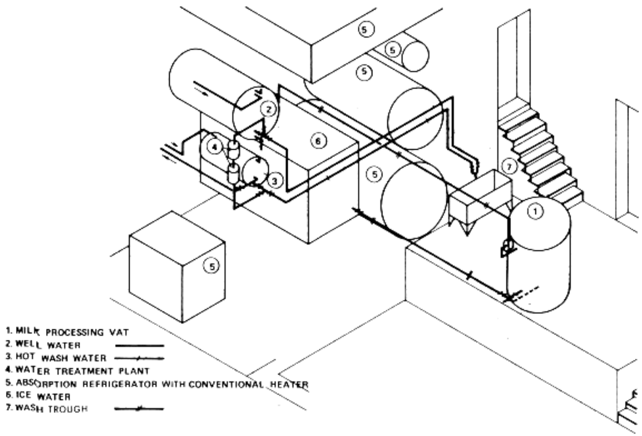


FIG 39. MILK COLLECTION CENTRE 1000 l/day TO 1600 l/day. MILK-IN-VAT COOLING

Table 11. Equipment specification - Pasteurized liquid milk processing - despatch in cans

Equipment	Standard specification reference (in text)	Requirement (numbers) Daily throughput (litres)						
		100	160	250	400	630	1 000	1 600
1. Milk reception and measuring equipment	5.2.1	1	1	1	1	1	2	2
2. Milk can -50 1	5.2.2	2	4	5	8	13	20	32
3. Milk processing vat - 100 l	5.2.5	1	-	-	-	-	-	-
- 160 1	5.2.5	-	1	-	-	-	-	-
- 250 1	5.2.5	-	-	1	-	-	-	-
- 400 1	5.2.5	-	-	-	1	-	1	-

- 630 1	5.2.5	-	-	-	-	1	1	-
- 800 1	5.2.5	-	-	-	-	-	-	2
4. Quality testing set	5.2.6	1	1	1	1	1	1	1
5. Wash trough	5.2.7	1	1	1	1	1	2	2
6. Milk can roller conveyor without bends - 3 m length	5.2.10	1	1	1	-	-	-	-
with one bend - 5 m length	5.2.10	-	-	-	1	1	1	1
7. Well water tank - 1.06 m^3	5.2.8	1	1	1	-	-	-	-
- 1.70 m^3	5.2.8	-	-	-	I	-	-	-
- 2.65 m^3	5.2.8	-	-	-	-	1	1	-
- 4.42 m^3	5.2.8	-	-	-	-	-	-	1
8. Hot water tanks - 0.42 m^3	5.2.8	1	-	-	-	-	-	-
- 0.66 m^3	5.2.8	-	1	-	-	-	-	-
- 1.06 m^3	5.2.8	-	-	1	-	-	-	-
- 1.70 m^3	5.2.8	-	-	-	1	-	-	-
- 2.65 m^3	5.2.8	-	-	-	-	1	-	-
- 4.42 m^3	5.2.8	-	-	-	-	-	1	-
- 6.38 m^3	5.2.8	-	-	-	-	-	-	1
9. Wash water tanks - 0.28 m^3	5.2.8	1	1	-	-	-	-	-
- 0.42 m^3	5.2.8	-	-	1	-	-	-	-
- 0.66 m^3	5.2.8	-	-	-	1	1	-	-
- 1.06 m^3	5.2.8	-	-	-	-	-	1	-

- 1.69 m^3	5.2.8	-	-	-	-	-	-	1
10. Hot wash water tanks - 0.17 m^3	5.2.8	1	1	1	1	-	-	-
- 0.28 m^3	5.2.8	-	-	-	-	1	-	-
- 0.42 m^3	5.2.8	-	-	-	-	-	1	-
- 0.66 m^3	5.2.8	-	-	-	-	-	-	1
11. Water treatment plant	5.2.9	1	1	1	1	1	1	1
12. Well water pump	5.2.11	1	1	1	1	1	1	1
13. Pipes and fittings - set	5.2.12	1	1	1	1	1	1	1
14. Supporting and protecting structures for outdoor installations - set	5.2.13	1	1	1	1	1	1	1
15. Oil-fired water heater - 2.5 kW	5.2.14	1	-	-	-	-	-	-
- 4.0 kW	5.2.14	-	1	1	-	-	-	-
- 6.0 kW	5.2.14	-	-	-	1	-	-	-
- 10.0 kW	5.2.14	-	-	-	-	1	-	-
- 16.0 kW	5.2.14	-	-	-	-	-	1	-
- 25.0 kW	5.2.14	-	-	-	-	-	-	1
16. Absorption refrigerator with ice accumulation - 4 kWh/day	5.2.15	1	-	-	-	-	-	-
- 6 kWh/day	5.2.15	-	1	-	-	-	-	-
- 10 kWh/day	5.2.15	-	-	-	-	-	-	-
- 15 kWh/day	5.2.15	-	-	-	1	-	-	-
- 23 kWh/day	5.2.15	-	-	-	-	1	-	-
- 36 kWh/day	5.2.15	-	-	-	-	-	1	-
- 58 kWh/day	5.2.15	-	-	-	-	-	-	1
17. Mechnical/electric power source capacity 75	5.2.10						1	1

W, output 0.56 kWh/day	5.2.19	-	-	-	-	-	1	1
OPTIONAL								
18. Solar water heating system - 5 kWh/day	5.2.17	1	-	-	-	-	-	-
- 7 kWh/day	5.2.17	-	1	-	-	-	-	-
- 11 kWh/day	5.2.17	-	-	1	-	-	-	-
- 17 kWh/day	5.2.17	-	-	-	1	-	-	-
- 26 kWh/day	5.2.17	-	-	-	-	1	-	-
- 41 kWh/day	5.2.17	-	-	-	-	-	1	-
- 66 kWh/day	5.2.17	-	-	-	-	-	-	1
19. Solar desorption heater in absorption refrigerator - 4 kWh/day	5.2.18	1	-	-	-	-	-	-
- 6 kWh/day	5.2.18	-	1	-	-	-	-	-
- 10 kWh/day	5.2.18	-	-	1	-	-	-	-
- 15 kWh/day	5.2.18	-	-	-	1	-	-	-
- 23 kWh/day	5.2.18	-	-	-	-	1	-	-
- 36 kWh/day	5.2.18	-	-	-	-	-	1	-
- 58 kWh/day	5.2.18	-	-	-	-	-	-	1
20. Man-driven electric power source	5.2.20	1	1	1	1	1	-	-

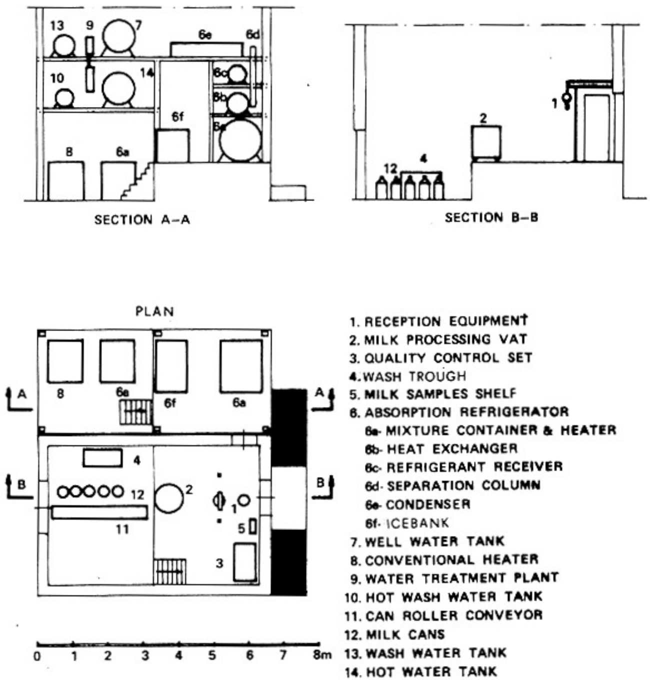


FIG 40. PASTEURIZED LIQUID MILK PROCESSING 100 l/day TO 250 l/day-DISPATCH IN CANS.

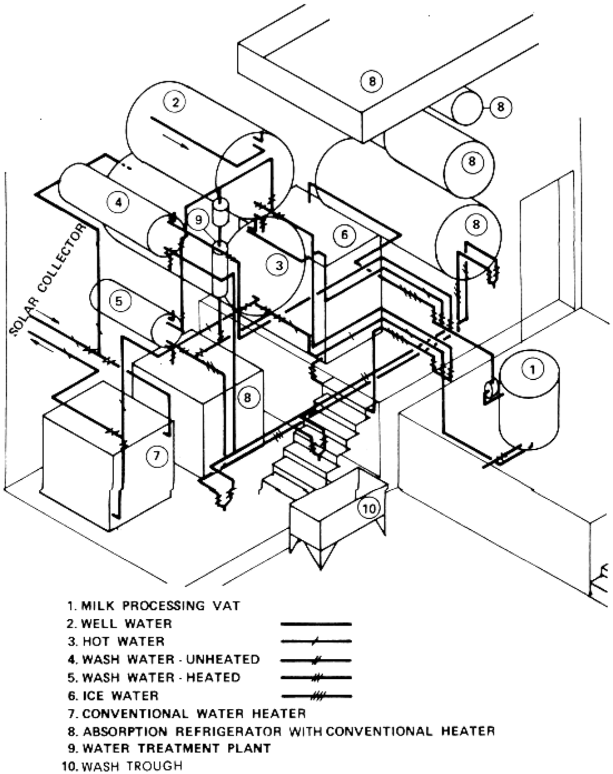


FIG 41. PASTEURIZED LIQUID MILK PROCESSING 100 1/day TO 250 l/day -DISPATCH IN CANS.

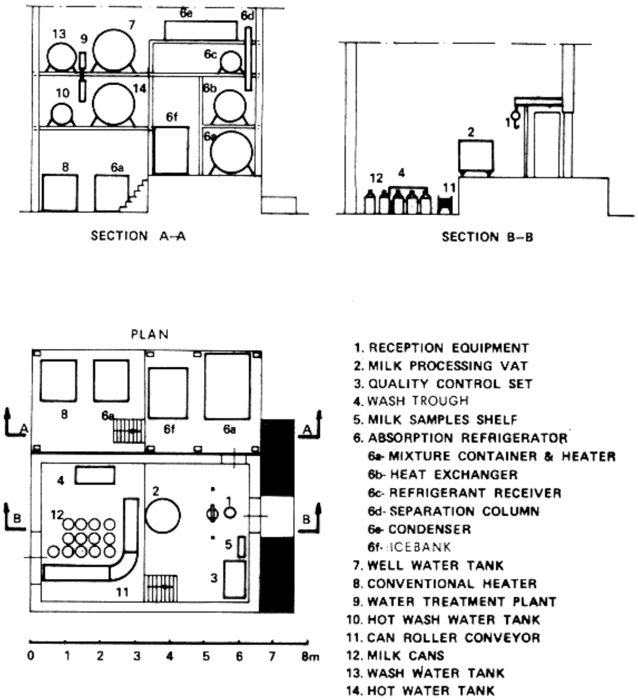
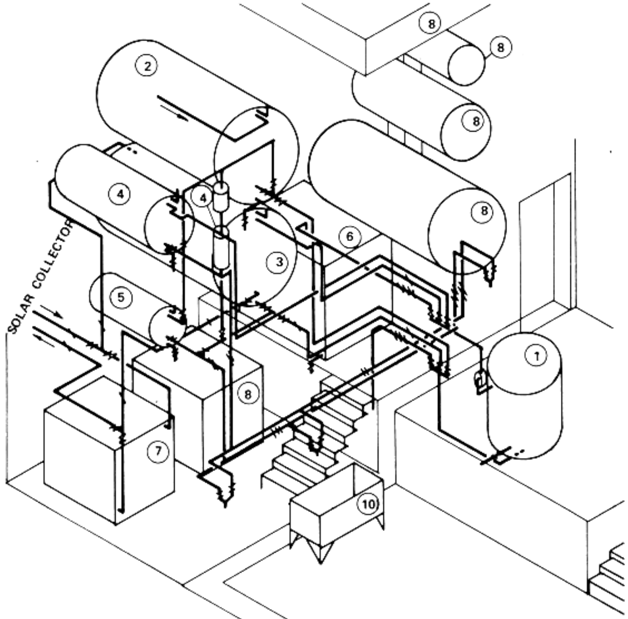


FIG 42. PASTEURIZED LIQUID MILK PROCESSING 400 l/day TO 630 l/day -DISPATCH IN CANS.



1. MILK PROCESSING VAT
2. WELL WATER
3. HOT WATER
4. WASH WATER - UNHEATED
5. WASH WATER - HEATED
6. ICE WATER
7. CONVENTIONAL WATER HEATER
8. ABSORPTION REFRIGERATOR WITH CONVENTIONAL HEATER
9. WATER TREATMENT PLANT
10. WASH TROUGH

FIG 43. PASTEURIZED LIQUID MILK PROCESSING 400 l/day TO 630 l/day -DISPATCH IN CANS.

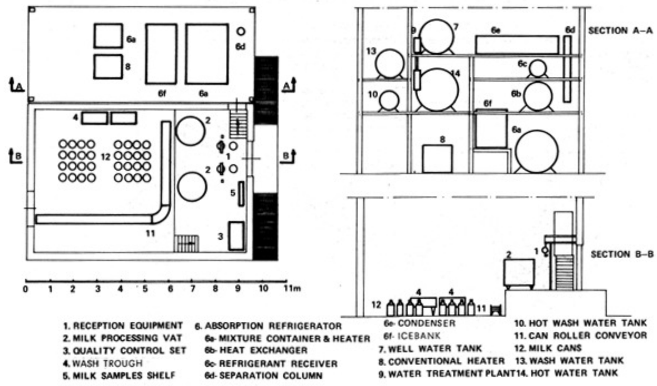


FIG 44. PASTEURIZED LIQUID MILK PROCESSING 1000 l/day TO 1600 l/day - DISPATCH IN CANS.

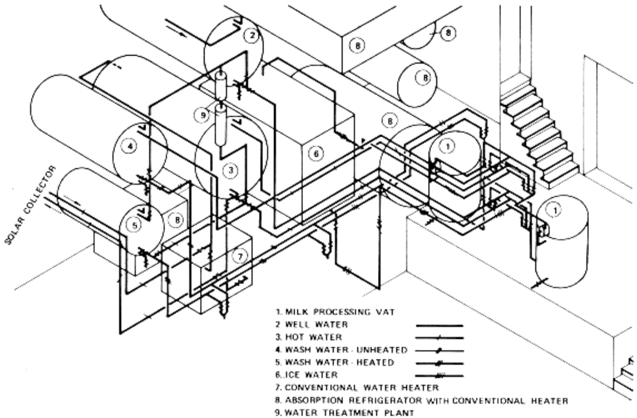


FIG 45 PASTEURIZED LIQUID MILK PROCESSING 1000 l/day TO 1600 l/day - DISPATCH IN CANS

5.3.4 Pasteurized liquid milk processing plants - dispatch in bottles

Milk handling techniques, equipment specifications and layouts for plants processing pasteurized liquid milk dispatched both in cans and in bottles do not differ much except for the packaging hall in which equipment for washing, filling and dispatch of either cans or bottles is installed.

Cold storage of packaged liquid milk, both in cans and in bottles, could be omitted provided packaging is done at the time of dispatch. Under such an assumption the bottle filling capacity must depend on the local marketing and distribution system. It could mean in extreme instances that all milk is bottled within one hour. Manual filling with spring-loaded valves takes about 20 to 25 seconds per one litre bottle. One person is able to fill about 150 l/h, which means that about ten people need to be employed to fill about 1 600 litres in one hour, plus about two persons to crate the bottles and to load the crates on the transport vehicles. Thus the totalstaff of a bottling plant of 1 600 l/day may be three times that in can filling plants. Semi-mechanical bottling machines could be an improvement in the packaging technique but they are no longer available on the standard dairy machinery market.

A general specification for manual bottle washing and filling equipment is given in section 5.2.33. Considering the similarities between the plants processing pasteurized liquid milk and the dependence of the applied packaging techniques on local marketing conditions, neither separate specifications nor layouts are suggested for plants with dispatch in bottles. They must be prepared based on the data presented in section 5.3.3 and 5.2.33 and on the analysis of sales systems most suitable for the local market.

5.3.5 Bottled fermented milk beverages manufactured from pasteurized milk

There can be no standard approach to the manufacture of fermented milk products since the applied technology depends very much on local dietary habits and local marketing conditions. All these products have in common milk pasteurization, chilling to the required fermentation temperature and

incubating with selected starters. Starter propagation techniques depend on the kind of microbiological cultures involved but for the majority of products a milk can can be used.

For stirred products, starters are added to the milk in the processing vat. Milk is left to coagulate for two to four hours, after which the curd is stirred and chilled in the processing vat. Filling may being after the product temperature is lowered to about 5°C.

For unstirred products, starters must be added shortly before filling and the setting of the coagulum occurs in the filled bottles separately. As filling is basically slow in the plants under consideration the manufacture of unstirred products requires intermediate containers between the processing vat and the filling valves. Starters are added to the milk in these intermediate containers. Their volumes must not exceed the quantity of the product bottled in about 30 minutes.

The speed of bottle filling will depend on the filling system available and on the volume of the single bottle filled. With hand filling only about 150 one-litre bottles per hour can be filled by one person but in practice only about 200 quarter-litre bottles per hour. There are practical limits to the number of bottles handled manually in one plant. A plant of 1 600 l/day processing capacity which fills fermented milk in quarter-litre bottles must handle 6 400 bottles daily. Manual washing of such a quantity, particularly in hot climates and in bottles neither washed nor rinsed by the customer immediately after emptying, will create unsurmountable problems regarding hygienic conditions of manufacture. It is difficult to set a practical limit to the number of bottles handled in a small-scale plant but 1 500 to 2 000 seems to be the maximum. Regardless of the capacity of the plant manufacturing stirred fermented products, the duration of fermentation i such that bottles can only be filled in the second shift. The filling speed has to be adjusted to the dispatch timing, as already described in section 5.3.4.

Unstirred products require keeping the incubated milk in bottles at fermentation temperature for a few hours. The temperature and timing depend on the product. In traditional artisanal manufacturing systems the ways of adjusting the starter concentration, fermentation temperature and timing are based on centuries-long experience. They do not require modern applicances for adjusting the process

parameters. Small-scale plants will have to follow these traditional methods, typical for the area and product concerned. The main difference between the artisanal enterprise and the proposed plants lies in the sales organization.

The artisan's shop is known to the customers and dealers who most often operate within walking distance from the shop. The small-scale plants described in this study may have to transport their product over a relatively long distance to the market.

Without chilling, the growth of microorganisms in the product may make its quality unacceptable to the customer. It may therefore be necessary to chill the product in bottles after fermentation. As filled bottles have to be kept in crates, the volume of the goods for chilling and dispatch will be in the order of 5 m^3 in the largest plants under consideration.

A suitable cold store for chilling the product would require electric fans for circulating the air in order to achieve effective chilling.

Problems involved with extensive installation of electric appliances were listed in section 4.2.1.3 and therefore chilling of the product through immersion in cold water is proposed in this study.

The suggested system is illustrated in Fig. 46: crates with filled bottles are immersed in an insulated trough filled with water up to a level of about 20 mm below the bottle cap. Ice water circulates by thermal convection in a piping system installed along the inner walls of the trough. The crate is immersed at one end of the trough and pushed towards the other end by the next crate entering the trough. In order to reduce friction the crates are positioned on a structure of bars or pipes which are corrosion proof such as plastic or protected against corrosion. The total area occupied by the chilling troughs depends on the type and number of crates. One hundred crates, containing fifteen one-litre bottles of product, totalling about 1 500 l, may require about 25m^2 floor area for troughs.

The milk handling techniques in this group of plants are in general terms very similar to those described

in section 5.3.3 and so are the specifications except for those concerning bottle washing and filling which replace the can filling system. Incubation and fermentation do not affect the general layout suggested in section 5.3.3 and the comments in section 5.3.4.

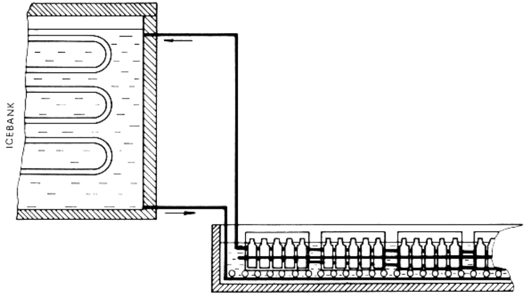


FIG. 46. IN-BOTTLE CHILLING OF UNSTRIRRED FERMENTED MILK PRODUCTS

Neither standard layouts nor standard pilot specifications can be suggested for the bottle filling and chilling part of the plant. They are so much affected by the type of the product and local marketing conditions that realistic proposals cannot be given unless these factors are analysed in detail.

5.3.6 Cheese and butter manufacture

As assumed in section 4.1 out of every 100 kg milk supplied, about 33 kg would be fully separated. The separation would result in about 26 kg skim milk and 7 kg cream with 30 percent fat. Finally, cheese would be manufactured out of 93 kg milk. The expected yields would be about 15 kg cheese, 75 kg whey, 2.0 to 2.2 kg butter and 5 kg buttermilk.

Packaging of cheese in tins containing 5 kg cheese and about 6 kg brine would result in a requirement of three tins per 100 kg milk received. Butter would be manually packaged in 100 g to 250 g packages

and kept in iced water in insulated cans. The respective figures related to the particular capacity of the plants may be presented as follows:

Table 12. Cheese and butter manufacture

Daily milk reception	kg	630	1 000	1 600
Milk for separation	kg	210	330	530
Quantity of 30 percent cream	kg	45	70	110
Quantity of butter	kg	13	20	32
Buttermilk as food or feed	kg	30	45	70
Milk for cheese manufacture	kg	585	930	1 490
Quantity of cheese	kg	100	150	240
Whey for feeding	kg	450	700	1 100
Tins containing 5 kg cheese	Nos	20	30	48
Insulated cans for butter storage	Nos	1	2	4

There are several methods of manufacturing cheese sold in brine. The equipment needs to be adjusted to the technology chosen. The technology and equipment depend on the kind of the product desired. Heat treatment prior to renneting could be done in a cylindrical vat and all other processes in rectangular or cylindrical cheese vats. There are also several methods of curd transfer, cutting, whey draining and curd pressing.

The simplest technology specified in this section seems to be the performance of heat treatment, milk clotting, curd cutting, curd drying and whey draining in one cylindrical vat. The curd is then transferred - usually through the outlet cock - to a curd handling table where it is pressed into a block and cut or put into moulds and pressed separately.

Butter obtained in the manually-operated butter churn requires kneading, to be performed on a manually-operated kneading machine. Prior to kneading, butter should be chilled which may be best

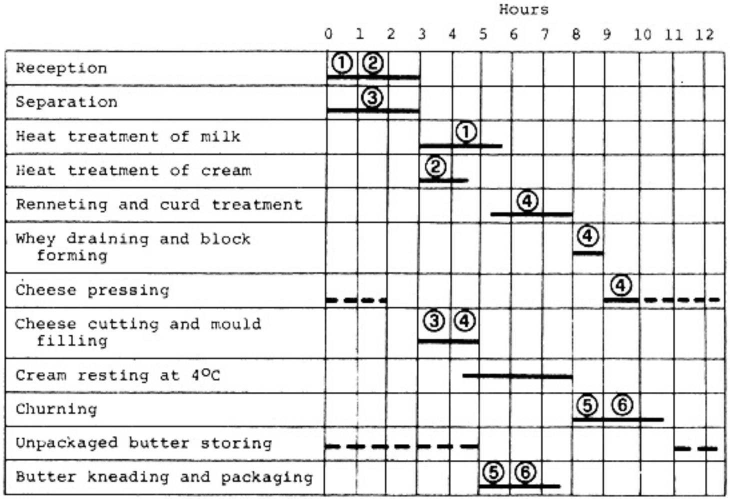
achieved by removing it from the butter churn into a stainless steel container and placing the container in the chilled water tank. After about 24 hours the butter should be ready for kneading and packaging. Packaged butter should be placed in ice-water in insulated transport boxes or cans.

Whey and buttermilk are collected in cans and sold or given away as animal feeds.

In Figs. 47 and 48 the general outline of the concept of the plants is illustrated. There is little difference in area requirement for cheese and butter manufacture when total daily intake varies from about 600 to 1 600 1. Therefore, only one preliminary layout for a 1 600 l/day plant is suggested. Staff requirements may also be considered as relatively constant for that range of capacity.

A preliminary time schedule with indications of staff employment (about 6 men for processing only) operating in two shifts may be indicated as follows:

Table 13. Process schedule for butter and cheese



Numbers in circles refer to a given staff member employed at an indicated processing section. Two more men may be required for energy procurement. The total indicated staff of eight people does not include sales, transport and procurement of packaging material.

Table 14. Equipment specification - Cheese and butter manufacture

Equipment	Standard specification reference (in text)	Requirement (number) Daily throughput (litres)		
		630	1 000	1 600
1. Milk reception and measuring equipment	5.2.1	1	1	1

2. Milk can 50 1 insulated	5.2.2	2	4	8
3. Milk processing vat - 50 1	5.2.5	1	-	-
- 100 1	5.2.5	-	1	-
- 160 1	5.2.5	-	-	1
- 630 1	5.2.5.C	1	-	-
- 1 000 1	5.2.5.C	-	1	-
- 1 600 1	5.2.5.C	-	-	1
4. Milk reception funnel	5.2.21	1	1	1
5. Manually-operated milk separator - 160 l/h	5.2.22	1	-	-
- 250 l/h	5.2.22	-	1	1
6. Quality testing set	5.2.6	1	1	1
7. Butter churn - total volume - 100 l	5.2.23	1	-	-
- 200 1	5.2.23	-	1	1
8. Butter container	5.2.24	1	1	1
9. Butter-handling table	5.2.25	1	1	1
10. Butter-kneading machine 50 kg/h	5.2.26	1	1	1
11. Butter manual-packaging machine	5.2.27	1	1	1
12. Curd handling trolley for 100 kg curd	5.2.28	2	2	3
13. Cheese moulds - (5 kg of curd/mould)	5.2.29	50	80	130
14. Cheese presses-mechanical, for 20 moulds	5.2.30	2	3	4
15. Brine container	5.2.30	1	1	1
16. Rack for cheese moulds	5.2.32	1	1	1
17. Wash trough	5.2.7	2	2	2
18. Well water tank - 1.7 m^3	5.2.8	1	-	-
- 2.65 m^3	5.2.8	-	1	-
- 4.42 m^3	5.2.8	-	-	1

19. Hot water tank - 2.65 m^3	5.2.8	1	-	-
- 4.42 m^3	5.2.8	-	1	-
- 6.38 m^3	5.2.8	-	-	1
20. Wash water tank - 1.06 m^3	5.2.8	1	-	-
- 1.70 m^3	5.2.8	-	1	-
- 2.65 m^3	5.2.8	-	-	1
21. Hot wash water tank - 0.28 m^3	5.2.8	1	-	-
- 0.42 m^3	5.2.8	-	1	-
- 0.66 m^3	5.2.8	-	-	1
22. Water treatment plant	5.2.9	1	1	1
23. Well water pump	5.2.11	1	1	1
24. Pipes and fittings - set	5.2.12	1	1	1
25. Supporting and protecting structures for outdoor installations - set	5.2.13	1	1	1
26. Oil-fired water heater - 10 kW	5.2.14	1	-	-
- 16 kW	5.2.14	-	1	-
- 25 kW	5.2.14	-	-	1
27. Absorption refrigerator with ice accumulation - 3 kW/day	5.2.15	1	-	-
- 4 kW/day	5.2.15	-	1	-
- 6 kW/day	5.2.15	-	-	1
28. Mechanical/electric power source	5.2.19	1	1	1
OPTIONAL				

29. Solar water heating system - 33 kWh/day	5.2.17	1	-	-
- 52 kWh/day	5.2.17	-	1	-
- 83 kWh/day	5.2.17	-	-	1
30. Solar desorption heater in absorption refrigerator - 3 kWh/day	5.2.18	1	-	-
- 4 kWh/day	5.2.18	-	1	-
- 6 kWh/day	5.2.18	-	-	1

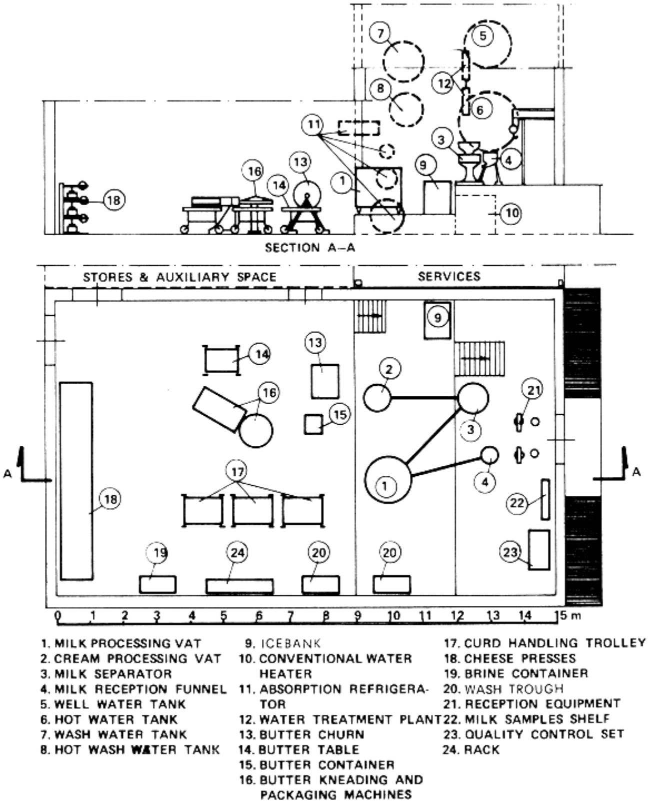


FIG. 47. CHEESE AND BUTTER MANUFACTURE 630 l/day TO 1600 l/day FRESH MILK INTAKE. - EQUIPMENT SHOWN FOR 1600 l/day.

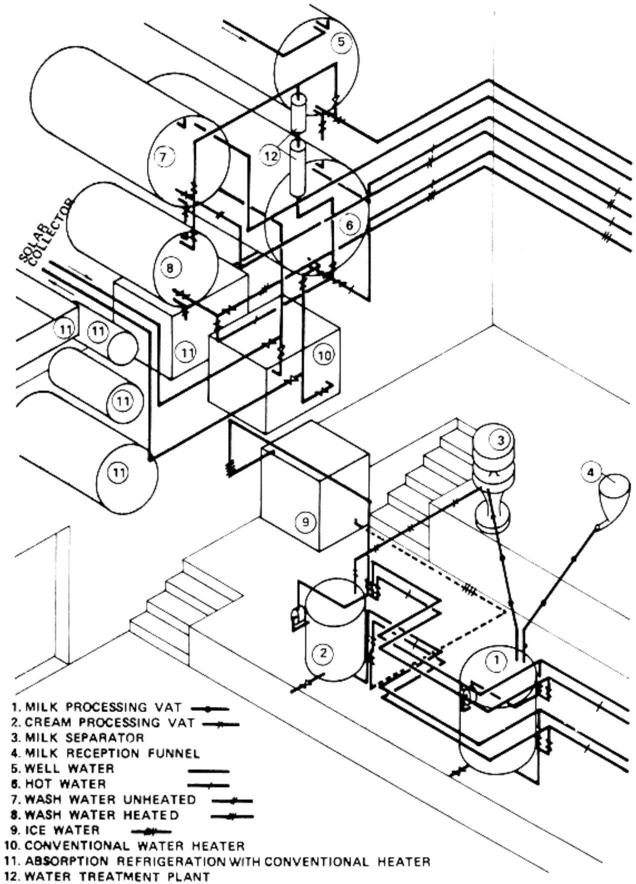


FIG 48. CHEESE AND BUTTER MANUFACTURE 630 l/day TO 1600 l/day FRESH MILK INTAKE.

5.4 Indicatory cost estimates

Figures presented in Table 15 are only an illustration of the order of magnitude of the capital inputs required. Many factors may affect the erection costs of a pilot plant described in this study. They depend mainly on local conditions and therefore an accurate cost estimate cannot be made unless all factors are known and a suitable detailed project is prepared for the selected locality.

Figures in Table 15 and in Figs. 49 and 50 are given separately for plants equipped with or without optionals. Under "optionals" basically equipment for solar energy procurement is specified. Accordingly, projects for plants without "optionals" represent simple small-scale collecting and processing centres adapted to operation without electricity supply from outside and using conventional fuels for their service procurement. Plants with "optionals" are additionally equipped with solar collectors and can procure services either from conventional or from solar heaters. The cost estimates include contingencies calculated as a lump sum which is equal for all capacities within a selected processing programme.

The margin of error in capaital input estimates is wider for plants with lower capacities. It seemed therefore to be appropriate to put in the final cost evaluation a relatively higher figure as contingencies.

As can be seen from the figures, there is little difference in the total costs between the first four capacities (up to 400 l/day) within each of the processing programmes. It is therefore suggested that the capacity of 400 l/day should be chosen as the base for planning the smallest plants.

The pilot character of all projects must be considered by those who would be making the decision concerning respective investments. The capital input should constitute only a part of a more compact project which should include the expertise and technical assistance of carefully selected advisers.

Table 15. Capital input requirements (1981 estimates in "000" US$)

	Capacity	Equipment		Building	Contingencies	Total		US$/1
		without	with			without	with	without/with

	l/day	optional	optional			optionals	optionals	optionals
Collection - hot dispatch	100	9	10	6	15	30	31	300/310
	160	10	11	6	15	31	32	194/200
	250	12	13	6	15	33	34	132/136
	400	15	16	12	15	42	43	105/108
	630	16	18	12	15	43	45	68/71
	1 000	24	26	18	15	43	45	57/59
	1 600	28	32	18	15	61	5	38/41
Collection - cold dispatch	100	11	14	6	20	37	40	370/400
	160	13	16	6	20	39	42	243/263
	250	15	20	6	20	41	46	164/184
	400	17	26	12	20	49	58	123/145
	630	19	32	12	20	51	64	81/102
	1 000	23	44	18	20	61	82	61/82
	1 600	29	60	18	20	67	98	42/61
Pasteurized - dispatch in cans	100	14	17	12	25	51	54	510/540
	160	16	20	12	25	53	57	331/356
	250	18	24	12	25	55	61	220/244
	400	24	34	12	25	61	71	153/178
	630	31	45	12	25	68	82	108/130
	1 000	42	60	28	25	95	113	95/113
	1 600	50	84	28	25	103	134	64/86
Pasteurized or	100	16	19	18	35	69	72	690/720
	160	18	22	18	35	71	75	444/469
	250	20	26	18	35	73	79	292/316
	400	27	36	24	35	86	95	215/238

fermented - bottled	630	33	47	24	35	92	106	146/168
	1 000	45	63	36	35	116	134	116/134
	1 600	56	90	36	35	27	161	79/101
Cheese and butter	630	39	43	65	40	144	148	229/233
	1 000	49	54	65	40	154	159	154/159
	1 600	58	66	65	40	163	171	102/107

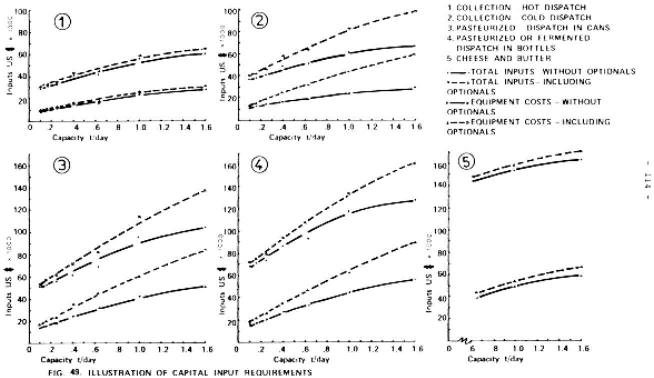


FIG. 49. ILLUSTRATION OF CAPITAL INPUT REQUIREMENTS

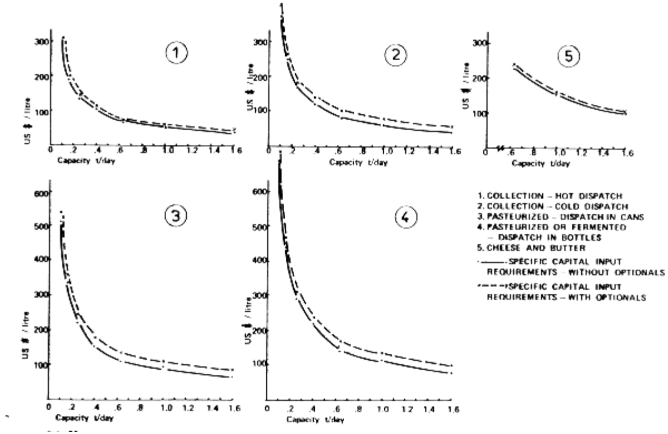


FIG. 50. ILLUSTRATION OF SPECIFIC CAPITAL INPUT REQUIREMENTS

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