

## Maintenance systems for the dairy plant

### CONTENTS

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## **FOREWORD**

In most developing countries dairy equipment is imported, spare parts procurement is troublesome and specialized dairy machinery servicing from outside the milk plant is either scarce or non-existent. Under such conditions the successful operation of the milk

Maintenance systems for the dairy plant  
plant depends largely on the performance of the engineering staff employed. This publication attempts to provide the dairy engineers in milk plants in developing countries with information and guidelines on methods used and means required to successfully accomplish their difficult tasks.

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## **CONTENTS**

### **INTRODUCTION**

### **CHAPTER I**

### **PREVENTIVE MAINTENANCE**

1. [Principales](#)
2. [Equipment records](#)
3. [Inspection schedules](#)
  - A. [Inspection based on log book entries](#)
  - B. [Scheduled inspection combined with schedule servicing](#)

C. Scheduled inspection of non-standard items

D. Inspection schedules recording

E. Lubrication schedules

4. Spare parts programme

5. Maintenance action

6. Maintenance workshops and equipment

CHAPTER II.

TRAINING OF DAIRY INDUSTRY ENGINEERS

1. Training Needs Analysis (TNA)

2. Skills training

CHAPTER III.

MAINTENANCE OF SERVICE EQUIPMENT

1. Piping systems

2. Centrifugal pumps, fans, air compressors

3. Ventilating and exhaust fans

4. Air compressors

5. Power transmission

6. Gears

7. V-belt drives

8. Chain drives

9. Refrigeration

10. Steam raising equipment

CHAPTER IV.

MAINTENANCE OF PROCESS EQUIPMENT

1. Pumps and piping

2. Heat exchangers

A. Plate

B. Swept surface heat exchangers

C. Tubular heat exchangers

3. Filters

4. [Milk storage and process tanks](#)
5. [Agitators and mixers](#)
6. [Homogenizers](#)
7. [Plant instrumentation](#)
  - A. [Temperature controllers and recorders](#)
  - B. [Flow controllers](#)
  - C. [Flow meters](#)
  - D. [Diversion valves](#)
8. [Evaporators and spray driers](#)
  - A. [Evaporators](#)
  - B. [Spray driers](#)
9. [In-place cleaning equipment](#)

CHAPTER V.

MAINTENANCE OPERATIONS

1. [Safety at work](#)
2. [Hygienic working practices](#)
3. [Fault diagnosis](#)
4. [Examples of routine maintenance procedures](#)

**LIST OF ILLUSTRATIONS**

- Figure1 [Equipment record card \(example\)](#)
- 2 [Flow diagram of pasteurization plant as log book recording guide \(example\)](#)
- 3 [Example of log book page with recorded entries](#)
- 4 [Maintenance inspection schedule card \(example\)](#)
- 5 [Creamery engineering management structure](#)
- 6 [Example of training analysis - Sheet A](#)
- 7 [Example of training analysis - Sheet B](#)
- 8 [Training needs analysis](#)

- 9 [Piston packings and rings - dismantling and assembly](#)
- 10 [Wear pattern - homogenizing or pressure control valve or seat](#)
- 11 [General arrangement of pressure lubrication system for homogenizer drive gears and bearings](#)
- 12 [Protective clothing](#)
- 13A [Hazard warning signs in U.K.](#)
- 13B [Hazard warning signs and safety colours in U.K.](#)
- 14 [Six-step approach to diagnosis of faults](#)
- 15 [Guide to fault-finding in the system](#)
- 16 [Half-split approach to fault diagnosis](#)
- 17 [Types of screwheads](#)
- 18 [Types of nuts](#)
- 19 [Types of washers](#)
- 20 [Shims used as packing](#)
- 21A [Types of bearings](#)
- 21B [Types of bearings](#)
- 22A [Fitting bearings](#)
- 22B [Fitting bearings](#)
- 22C [Fitting bearings](#)
- 23A [Bearing pullers](#)
- 23B [Bearing removal screws](#)

## INTRODUCTION

As soon as a milk plant is established and commissioned the need for an effective system of maintenance begins in order to maintain output at the desired level. Such a system must be planned in detail in advance and the need must be foreseen in the original planning of the plant.

The spacing of equipment items must be adequate for replacement of components as well as for operation. The

building must be designed so that any item of equipment can be removed at some future date. Experience may reveal that these objectives have not been met: if so modifications to the layout of equipment or to the building should be made at the earliest opportunity before a breakdown makes the work necessary so increasing the problem of repair, and delaying operations to restore normal output. The principles of preventive maintenance are discussed in detail in Chapter One.

The primary objective of a planned maintenance system is to prevent breakdowns. While every failure cannot be anticipated, regular inspection and servicing are the best means of preventing failure during operation of the equipment. Renewable components such as joint rings or rubber seals are replaced routinely according to a predetermined schedule. The necessary supply of spare parts is thus known in advance, and this simplifies the procedure of stores control.

However comprehensive the system of preventive maintenance, occasional breakdowns inevitably occur. They may be due to faulty components, incorrect assembly, failure to observe correct operating procedures or some other unforeseen cause. When such a break-down occurs the product line must be stopped with consequent loss of output. In some cases duplicate equipment is already installed, for example clarifiers and cream separators are often duplicated to facilitate interim cleaning. Packaging is often divided into several parallel lines so that failure of one line merely reduces output. Heat exchangers are usually not duplicated so that breakdown inevitably brings most processes to a stand-still.

The maintenance section must therefore include immediate repair facilities covering a wider range of skills and resources than otherwise would be necessary for routine preventive maintenance. The needs are discussed more fully in Chapters 1 and 2. Breakdowns inevitably mean loss of product and therefore income. Substantial wastage may result, and if the breakdown cannot be rectified within a few hours the following day's operations are jeopardized. Diversion of the incoming milk to another plant may become a necessity, with all the complications and possibly wastage, that this entails.

Milk and most milk products are highly perishable because they are excellent nutritive media for micro-organisms, which inevitably gain access and cause spoilage through souring. It is virtually impossible to prevent contamination in the process of milking and handling, but spoilage can be delayed by cooling at the farm or at

reception in the milk plant to 4°C within two or three hours of milking. This requires refrigeration, and therefore effective maintenance of the refrigeration equipment becomes a vital factor at an early stage. Cooling delays the growth of most micro-organisms for one or two days, after which heat treatment to kill most of the organisms present becomes necessary to extend the life of the milk for liquid consumption or for processing into milk products. This treatment is known as 'pasteurization'. Hence maintenance of the heat treatment equipment and the steam supply is essential to ensure product quality.

In the case of milk for liquid consumption and most fresh milk products such as cream, yoghurt and soft cheese, further cooling to 4°C is essential after processing and they must be maintained at this temperature after packaging until the point of sale. Effective maintenance of the refrigeration equipment is again essential to ensure a high product quality. Only in the case of milk for liquid consumption (treated by the ultra-high temperature (UHT) process and packaged aseptically), ghee and milk powder, is subsequent re-refrigeration unnecessary. Butter must be stored at low temperature - at 0-4°C for short-term or at up to 22°C for long-term storage. Hard cheese requires a storage temperature of about 10°C, necessitating refrigeration in most climates.

The continuous supply of steam for heat treatment during process operations and of constant refrigeration are so vital to the operation of the milk plant that at least one steam boiler and one refrigeration compressor are normally installed surplus to maximum operational requirements. This provides the opportunity for routine cleaning and maintenance and periodical inspections which may be required by law or for insurance purposes, and which require more time than is available between daily operations. In the case of unforeseen breakdowns, this space capacity minimizes the delay in restarting process operations.

Cooling delays the growth of micro-organisms which gain access to the milk up to the time of pasteurization. This heat treatment kills all pathogenic organisms and a high proportion of others but there are some which can form spores and survive the treatment. These can subsequently grow to cause spoilage. Thus there is good reason at every stage from milking to packaging to minimize contamination. Most contamination comes from equipment surfaces as a result of inadequate cleaning after previous use. This is the responsibility of the processing staff and may be caused by bad design. If so it should be reported and rectified. Nevertheless a guiding principle in all maintenance operations involving milk contact surfaces should be to work in the most hygienic conditions possible.





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## CHAPTER I

### PREVENTIVE MAINTENANCE

#### 1. Principles

The determination of plant efficiency at all essential points of the process is the first step in creating a preventive maintenance system which is fundamental to achieving optimal performance in any milk plant.

The precise meaning of the term “preventive maintenance” depends on the concept of the organization of the plant, of its capacity and processing and manufacturing programme as well as on the availability of, and accessibility to specialized services of machinery manufacturers or their agents, who are usually equipped with an ample supply of spare parts.

According to Newcomer <sup>1</sup> preventive maintenance in developing countries is a procedure involving:

1. Planning and scheduling
2. Proper installation
3. Periodic inspection
4. Planned lubrication
5. Adjustment of machines and instruments
6. Replacement of worn and damaged parts
7. Recording and reporting observations, adjustments, repairs, and replacements.
8. Periodically reviewing records on inspection, lubrication, repairs and performance of equipment
9. Keeping an adequate supply of spare parts
10. Determining maintenance costs
11. Cleaning and painting equipment and buildings

12. Inspection and maintenance of all emergency, personnel and plant protective equipment
13. Maintaining full serviceability of all utilities

The obvious benefits of preventive maintenance include:

1. Less production interruptions
2. Fewer large-scale repairs
3. Less raw material and product spoilage
4. Increased life expectancy of equipment
5. Less standby equipment needed
6. Identification of items with high maintenance costs leading to investigation and correction of causes, such as misapplications, operator abuse or obsolescence
7. Better spare parts control, greater work safety and lower manufacturing costs.

These benefits are the objectives of preventive maintenance. Although the objectives and principles of preventive maintenance programmes (PMP) are the same for any processing industry and for any plant within an industry, the actual programme of preventive maintenance procedures is an adaption of general rules to the needs of a given plant. Since there are no identical plants, there cannot be identical preventive maintenance programmes. However, the establishment of such an individual programme for any milk plant could be facilitated by giving the dairy engineer and his staff a general guide on the list of issues of which good PMP is composed, on the meaning of these issues and on the methods by which general rules can be transformed into practice. In this chapter an attempt is made to provide such a general guide.

<sup>1</sup> Newcomer, J.L., 1969. Indian Dairyman, vo1. XXI, No. 1 to 6.

Before discussing PMP procedures in more detail, it should be emphasized that the dairy engineer's group usually forms a separate unit within the organizational structure of the milk plant. This unit may take the form of an engineering department in large-scale plants, or the form of a section in smaller enterprises, but in all well-organized milk plants it is a relatively autonomous unit. Its head has the status of a senior executive officer, similar to the position of the heads of the processing group, quality control group, or sales and procurement

managers. To perform its duty the dairy engineer's group needs a programme of work, staff, and resources.

The preventive maintenance programme is the most essential part of the programme of work of the dairy engineer's group. It is divided into several parts. The first comprises collecting and recording all basic information on machines and installations: the Equipment Records of the plant. This may be classified as the preparatory part of the PMP. The second comprises identification of inspection objectives, frequency and location, and is known as the Inspection Schedule. This includes lubrication schedules, and routine spare parts replacement programmes and may be classified as the plan of operations in which also the recording and reporting systems are defined. The third part of the PMP procedure is the action which starts with the analysis of the records and is followed by decisions on what must be done, by whom, when and by what means. It also includes decisions on who inspects and accepts the completion of the action ordered. The last component of the action part of the PMP is the maintenance cost estimate.

The application of PMP depends on well-equipped workshop facilities and trained staff. The variety of skills needed for performing all the duties specified above implies that training in the dairy engineer's group is an essential requisite of success. These problems of resources and staff training are dealt with in Chapters 3 and 6.

## **2. Equipment records**

All plant performance studies require that the rated performance parameters are known, that appropriate instruments are installed to measure those actually achieved and that both are recorded and compared. As a result of this comparison all malfunctions can be detected, the reasons for their occurrence examined and steps taken in order to re-establish proper functioning of the plant. The essential elements to introducing performance studies can be listed as follows:

1. All manufacturers' literature such as manuals, drawings and spare parts specifications should be collected, filed according to a selected system and kept under strict control of the engineering department of the plant.
2. Flow diagrams of the whole plant and its sections should be prepared with performance check points clearly indicated.

3. A recording and reporting system of performance inspections and studies should be introduced and strictly observed so as to make sure that action can be taken immediately after a deviation from the expected performance has occurred.

Manufacturers' literature contains essential technical data for the dairy engineer's use, but it is impracticable to use this in daily routine work. First of all it comprises bulky volumes, from which only parts are of interest for maintenance procedures. Besides it will not allow for recording all changes, major repairs, utilization of spare parts and similar entries essential in the dairy engineer's work. Therefore a method of recording basic information for each piece of equipment of the entire plant has to be adopted. Such a method, or a system, should be simple and, prior to introduction, should be carefully checked on its suitability to the needs of maintenance procedures. Usually card files are used for equipment records. Printed on a suitable format they allow for convenient entries of data and retrieval for future reference. Codes applied for easy reference are another essential part of a recording system. There is no use in a time-consuming preparation of a card file of equipment recording without simultaneously introducing a simple method of identifying the card quickly in the file whenever needed. Cards with perforations on the card edges, termed 'needle cards', are probably the most efficient way of solving this problem. They are widely used in storage registration systems and can be also recommended for equipment recording. The technique is described below.

An example of a machine record card is given in Fig. 1. As can be seen the record comprises three distinctly different parts. The first gives the identity of the machine and its origin and the second contains information relevant to maintenance procedures and operations. In both parts the information is derived from the manufacturer's literature except for the inventory number which is arbitrarily assigned by the plant. The third part, which is simply the space on the reverse, contains entries made by the plant engineer, and concerns major changes and repairs which the machine has undergone during its life. It is the "health record book" of the machine.

### **3. Inspection schedules**

Milk processing or milk products manufacture requires machines and installations by the use of which the raw material is transformed into a product. Each and every piece of equipment of which the plant is assembled must

perform its duty. Achieving the exact performance objectives of the plant as a whole requires maximizing the efficiency of all equipment. The term “efficiency” is used in this context as a comparison between the designed and the actual performance. Should, for instance, the set holding temperature in a pasteurization plant be 72°C ( $\pm 1^\circ\text{C}$ ), the efficiency of the process is determined by checking whether, in the course of pasteurization of the product, any deviation from the wanted temperature levels occurs. In other words determining the efficiency requires collecting data concerning the actual performances and comparing them with those expected.

Any equipment is subjected to wear and tear and its efficiency and performance decrease with time. Keeping the plant performance at the required level is the responsibility of the dairy engineer and his staff. To fulfil this responsibility he needs to know what the actual performance is. By detecting a drop in performance he can take corrective action. But his first duty is to prevent any drop in efficiency by taking care of the equipment in a rational way or in other words by servicing the machine. This servicing procedure will be structured according to the needs of the plant but it will always be based on:

- inspection of performance based on log book entries
- scheduled inspection combined with scheduled servicing at selected points considered crucial for plant efficiency
- scheduled inspection of all other sections of the plant aiming at detection of faults not detectable by other routine procedures.

The practice of plant performance inspection and servicing of machines should be carried out with sufficient simplicity and thoroughness to yield the best results. The creation of a routine system in this respect is the first step in establishing good habits of proper care of all items of equipment.

It is essential to determine what should be inspected, how often and how to leave out of the procedure any collection of information which does not serve the main purpose. On the other hand the system must be beared toward prompt discovery of each and every deviation from normal in the plant or in the machine operation and also toward immediate action aiming at corrections at the detected sources of the deviation.

### A. Inspection based on log book entries

Log books contain the record of the equipment performance and usually also instructions to and from the operator. They are basically designed to keep records of the daily processing runs and their recording elements are often replaced - at least partly by automatic recording charts.

The log books are usually kept by the operators of various sections of the plant. Some or even most of them, may not belong to the engineering group but to the processing group. This should not prevent the engineering staff from inspecting the entries and from drawing conclusions from the figures and remarks recorded. In some cases it may be an advantage to include in the log book recorded observations which are particularly useful for engineering work even when the recorded are basically meant for the processing manager's inspection. Such cooperation between the departments of the plant is essential in many areas. Inspection based on log book entries permits discovery of performance faults occurring during processing and manufacturing operations of the plant. In other words such inspection is based on actual daily performance records. It is a good practice to attach to the log book a simplified sectional flow diagram of the process concerned with all check spots clearly shown and marked in the same order as they are on the recording pages. Examples of a sectional flow diagram and a corresponding performance record are shown in Figs. 2 and 3. As can be seen in the example of the performance record there is an instance of an unusually high milk outlet temperature. Simultaneously a high outlet temperature of the ice water was recorded. Inlet temperatures of milk and ice water were at the normal level. This deviation from normal will be noticed by the inspecting engineer (if not called earlier by the operator) and will make him analyse the trouble and identify the cause. The indication is that the flow of ice water was reduced either within the heat exchanger or in the ice water line. An immediate check on the ice water installation performance record should enable the engineer to locate the trouble either in the heat exchanger (choking, leakage) or in the ice water supply (pump defect, high pressure drop in the pipe, leakage). Corrective actions should follow immediately.

It is obvious that any instrument used to measure the actual value of a parameter of a process needs to be frequently checked so as to ensure that the readings illustrate the true value of the recorded item.

Inspection of log books provides the engineer with invaluable information on the actual performance of the plant,

but it cannot indicate whether the equipment is in sufficiently good condition for high performance in the immediate future. Such conclusions require another type of inspection based on different considerations.

### **B. Scheduled inspection combined with scheduled servicing**

Inspection-cum-servicing schedules are the most crucial task for the engineering team responsible for preventive maintenance. There are three sources of know-how on which these schedules are based and they may be listed as follows:

- Manufacturers' manuals
- Equipment records
- Plant experience.

There is one special category of equipment to which special inspection, servicing and maintenance criteria are applicable and to which strict adherence to special regulations is imposed by law. These include fire protection and safety equipment (fire extinguishers, vacuum and pressure safety valves, emergency relief equipment, emergency alarm devices, etc.). In many countries this type of equipment is periodically inspected by the representatives of official institutions and their recommendations need to be followed strictly and precisely for legal reasons. The manufacturers' manual is an invaluable guide on how to install, how to service, what, and how often to inspect, what and when to replace. The equipment record contains the most essential data deriving from the manufacturers' manual, but it also contains a record of the machine's history during its use in the plant. The records show the age of the machine, major repairs it has undergone and subsequent notifications. By looking at the record the engineer is able to analyse the machine's condition, its ability to continue performing safely and to introduce changes in inspection and servicing schedules concerning any particular piece of equipment.

The experience gathered in the plant by the operators and the engineering staff can be an additional but very valuable source of information on which the inspection and servicing schedules can be designed. Even the most common machines in a milk plant are subjected in each plant to different working conditions. These conditions vary for many reasons arising from differences in climate to the difference in operators' ability to handle

machines. All this cannot be foreseen by the manufacturer and his manuals will refer to normal operating conditions only. Unavoidable deviations from what the manufacturer considered as normal conditions are known only to the staff of the plant and their experience should be carefully gathered and considered when drawing up a maintenance schedule.

DESCRIPTION	(NAME OF PLANT)	MODEL	CAPACITY	SERIAL NO.	INVENTORY NO.
NAMES ADDRESSES TELEPHONES TELEXES CONTACTS CONTRACTS					
MANUFACTURER			SERVICE CONTRACT COMPANIES		
DRAWING No.		SPARE PARTS SHEET No.		SERVICING MANUAL No.	
LAYOUT DRAWING No.		MAINTENANCE INSPECTION SCHEDULE No.		LUBRICATION SCHEDULE No.	
STATUTORY INSPECTIONS					
GOVERNMENT		INSURANCE		OTHERS	
ORDER No.		RECEIVED (DATE)	INSTALLED (DATE)	COMMISSIONED (DATE)	COST
DETAILS RELEVANT TO MAINTENANCE PROCEDURES					
MECHANICAL		ELECTRICAL		GENERAL	
DRIVES		MOTORS		SPECIAL TOOLS	
GEARS					
BELTS/CHAINS					
BEARINGS		OTHER APPLIANCES		LUBRICANTS	



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Maintenance systems for the dairy plant

RECORD ON THE REVERSE ALL CHANGES, ADDITIONS, MODIFICATIONS, MAJOR REPAIRS & OTHER RELEVANT INFORMATION					

FIG. 1 EQUIPMENT RECORD CARD (EXAMPLE)

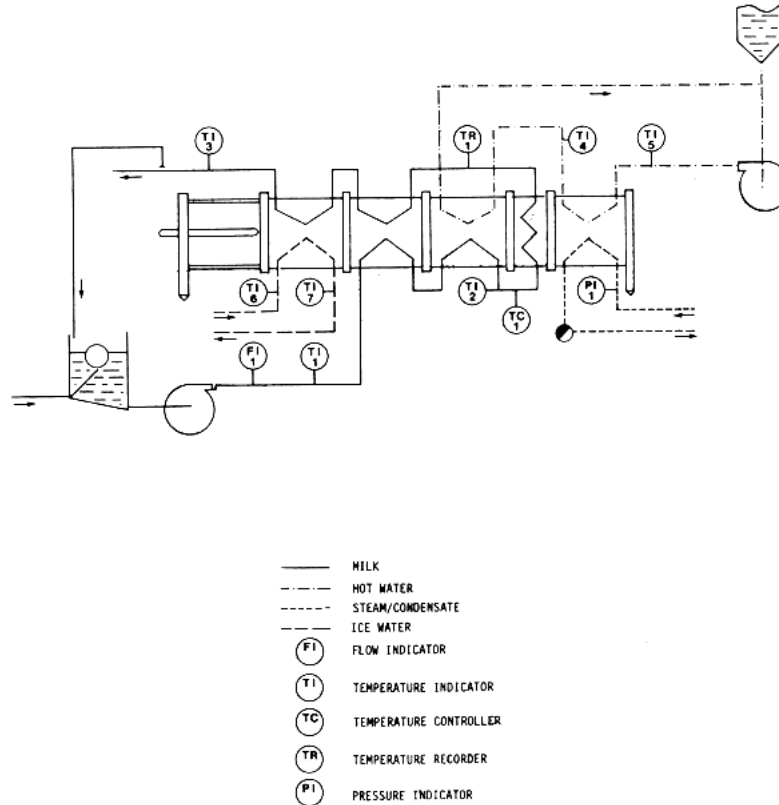


FIG. 2 FLOW DIAGRAM OF PASTEURIZATION PLANT AS LOG BOOK RECORDING GUIDE (EXAMPLE)

ASTEURIZATION PLANT No. \_\_\_\_\_

DATE	OPERATOR - SHIFT HOURS	OPERATION	TIME	VALUES SET FOR THE DAY											OPERATOR'S RECORDS ON ABNORMALITIES AND DEMANDS ON ASSISTANCE	ENGIN RECORDS CARRIE ESSE FIND RECOMME
				FI1	TI1	TI2	TR1	TI3	TI4	TI5	TI6	TI7	PI1			
28.2.1983	W.SMITH 14.00 - 22.0 R. JAMES 07.00-15.00			10	4	72	72	4	78	74	1	3	0.1	MILK OUTLET TEMPERATURE INCREASE FROM 13.00 HOURS ENGINEER ON DUTY NOTIFIED AT 14.00 HOURS	ICE WATER FAILURE F REPAIRED HOURS	
				<b>VALUES RECORDED</b>												
				FI1	TI1	TI2	TR1	TI3	TI4	TI5	TI6	TI7	PI1			
		HEATING UP	7.15	11	73	73			75	74			0.10			
			8.30													
		STERILIZATION	8.30	10	85	90			93	90			0.10			
			8.50													
		PROCESSING START	8.50	10	4	72	72	4	78	74	1	3	0.11			
		PROCESSING	9.00	10	4	72	73	4	78	74	1	3	0.11			
		"	10.00	10	4	72	73	4	78	74	1	3	0.11			
		"	11.00	10	4	72	72	4	78	74	1	3	0.11			
		"	12.00	10	4	72	72	4	78	73	1	3	0.11			
		"	13.00	10	5	72	72	8	78	74	1	6	0.11			
		"	14.00	10	5	72	72	12	78	74	1	8	0.10			
FLUSHING	14.30	10	14	76	76		78	75			0.10					
	15.00															
PROCESSING START	15.10	10	5	72	72	12	79	75	1	8	0.12					

PROCESSING	16.00	10	5	72	73	12	79	75	1	8	0.10
"	17.00	10	5	72	72	12	78	74	1	8	0.10
"	18.00	10	5	72	72	12	78	74	1	8	0.10
CLEANING	18.15	11	14	70	-	-	75	72	-	-	0.10
PLANT STOPPED	19.15	-	-	-	-	-	-	-	-	-	-

FIG.3 EXAMPLE OF A LOG BOOK PAGE WITH RECORDED ENTIRES

### C. Scheduled inspection of non-standard items

The third group of inspection schedules concerns parts of the plant assets which are not covered by the foregoing two groups and is also based mainly on experience. These schedules cover inspection of civil structures, ducts and pipelines between distant section or buildings, underground structures and mains, water storage tanks, wells, and many other parts of the plant not described in manufacturers' manuals. In this group the inspection of the sanitation of the whole plant is also included which contains anything from painting to insect and rodent control. Neatness and orderliness are important, both inside and outside the plant.

### D. Inspection schedules recording

All inspection schedules must contain information concerning what to inspect, when and how often. This information needs to be recorded either on overall charts on which equipment is listed in a selected order and the necessary functions of the inspections and servicing, including servicing instructions, are specified, or on individual cards for each section of a machine. An inspection schedules card file is widely considered as advantageous, particularly in larger scale plants. An example of an individual inspection schedule card is given in Fig. 4.

This contains three parts. The first part gives the name and the identification data of the machine, but its basic component is the check list of items to be inspected. The inspection items are grouped according to the inspection frequency into five sections, A to E. The list should ensure uniform and complete inspection regardless of who does the job. The second part of the inspection card is the confirmation of routine work carried out: the

third, on the reverse, is a record of non-routine observations and works.

An essential feature of the maintenance inspection schedule cards is the system which ensures that they are pulled out from the file at scheduled periods and that they are distributed to the persons instructed to do the inspection. As already mentioned, coding on perforated edges of the cards is one of the simplest and most convenient to use. The example in Fig. 4 shows an inspection schedule card with perforations on the top edge only. The right hand top corner of each card is cut off to make sure that when placing cards in the file box they will all face the same side of the box. In the example there are 35 holes on the top edge of the card. Perforations for coding purposes could continue along all four edges of the card. The perforations in the example are used for coding the inspection dates and frequencies, the type of the scheduled inspection and the group of machines inspected. The legend of the coding applied is as follows:

#### Days of the week

- 1 Monday
- 2 Tuesday
- 3 Wednesday
- 4 Thursday
- 5 Friday
- 6 Saturday
- 7 Sunday

#### Decades of the month

- 8 First
- 9 Second
- 10 Third

Months of the year

11 January

12 February

13 March

14 April

15 May

16 June

17 July

18 August

20 October

19 September

21 November

22 December

Type of inspection

23 General performance

24 Mechanical

25 Electrical

26 Lubrication

27 Civil and auxiliary

28 Fire protection and work safety

Plant Department

- 29 Processing
- 30 Steam raising
- 31 Refrigeration
- 32 Water supply and distribution
- 33 Compressed air and air conditioning
- 34 Buildings and other civil engineering structures
- 35 Miscellaneous

DESCRIPTION (NAME) OF MACHINE		MODEL	CAPACITY	SERIAL NO.	INVENTORY NO.																					
CHECK LIST ON INSPECTIONS AND ROUTINE SERVICING																										
GROUP A - EVERY WEEK		10		19																						
1		11		GROUP E - ONCE A YEAR																						
2		GROUP C - EVERY 3 MONTHS		20																						
3		12		21																						
4		13		22																						
5		GROUP D - EVERY 6 MONTHS		23																						
6		14		24																						
GROUP B - EVERY MONTH		15		25																						
7		16		26																						
8		17		27																						
9		18		28																						
REPORT ON ROUTINE MAINTENANCE INSPECTION AND SERVICING WORKS																										
LAST ANNUAL INSPECTION CARRIED OUT ON																										
MONTH	JANUARY				FEBRUARY				MARCH				APRIL				MAY				JUNE					
WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

GROUP CODE	A	A	AB	A	A	A	AB	AB	A	A	A	ABC	A																																
INITIAL	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC																																
MONTH	JULY				AUGUST					SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER																							
WEEK	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52																			
GROUP																																													
CODE																																													
INITIAL																																													
RECORD ON THE REVERSE ALL NON-ROUTINE OBSERVATION AND DETAILS OF NON-ROUTINE WORKS CARRIED OUT																																													

FIG. 4 MAINTENANCE INSPECTION SCHEDULE CARD (EXAMPLE)

By cutting out the space between the perforation and the edge, the card receives a code. Pushing a thin rod or needle through a selected perforation in a pack of cards and lifting the cards on the rod will result in separating all cards coded on this particular perforation (cards not lifted) from those not coded (lifted on the rod). The code specification chosen in the example concerns a maintenance schedule card system in which several (up to six) cards are used for one inspection subject. The check list on each card contains only works referring to one out of the possible six types of inspection works marked on holes 23 to 28. The philosophy of the coding system may be best illustrated by analysing the example in Fig. 4. The cut-outs on Nos 31 and 24 indicate that the card concerns the refrigeration plant or a component part and refers to mechanical maintenance inspection. Cut-outs Nos 11 to 22 indicate that there are items requiring monthly inspection. The cut-out No 9 shows that the monthly inspection for this machine is scheduled for the second decade of each month. The cut-out in No. 3 position shows that weekly inspections are performed on wednesdays.

The coding system presented above is simple and helps in the organization of the work, provided it is systematically applied. Every day of the week, cards marked with that day's code should be sorted out from the total by lifting on the rod all those not carrying that code. The next step is putting the rod through holes 23 to 28 - one by one - and distributing the work according to the indications on the cards to mechanics, electricians, lubricators, etc.



The cards - if kept in transparent plastic envelopes - can be handed out for easy reference to the inspecting crews, but all entries except initialling should be done by the officer to whom the workmen report after completing the job, otherwise the cards would not last long. It should be noticed that the selection or the day of the week on which the weekly inspection is done as well as the selection of the decade for monthly inspections are the result of work planning. The preventive maintenance staff inspect the equipment and do the routine servicing by going from one group of the machines to another throughout the day and the week, spending as much time on a job as required but basically changing their place of work and returning to it after a specified time. Only operators spend all their time on performing the same job every day.

Cards for monthly inspections are selected on the first, eleventh and twenty-first day of the month concerned. After selecting all cards relating to a given month, those sorted out concern the current decade. The work is then distributed in the same way as for weekly inspections.

In the recording part of the card - in the group code register - symbols A, B, C, and D are recorded depending on the type of work done, as illustrated in Fig 4. It is the duty of the officer-in-charge to see that the C and D works are done according to the schedule by analysing the recordings in the past periods. The same applies to the annual inspection by checking the date of the last one recorded at the top of the recording table.

On cards of machines not requiring weekly inspections none of the first seven perforations will have the space between the edge of the card cut out. Similarly, when there are no monthly inspections, the perforations 11 to 22 will be coded only for three monthly or semi-annual inspections.

One of the important advantages of the card-file system is the fact that the order in which the cards are put back into the file box is immaterial since the uncoded cards will be pulled out by the rod irrespective of the location of the card in the file.

Special attention should be given to electric prime movers and other electrical appliances attached to the machine when considering the preventive maintenance recording system. It often happens that electric motors are moved from one piece of equipment to another. If the motor data is kept on the equipment card, this could lead in such cases to misinformation. Therefore it is advisable to keep motor data on a separate card attached to the main equipment card, removable and exchangeable whenever required.

### E. Lubrication schedules

These are an integral part of preventive maintenance schedules. Most machines have some elements requiring lubrication, such as gears, bearings, cylinders, chains, etc. Lubrication reduces wear in the lubricated elements. Correct lubrication practices can reduce the overall machine maintenance costs by as much as 20 percent although the costs of lubricants may represent as much as 10 percent of the maintenance costs of a plant. The term lubrication includes lubrication oiling and greasing and the indication on costs swings given above covers all three. Lubrication is such an essential part of the dairy engineer's activities that in larger scale plants one staff member is employed only to take care of this activity, selecting lubricants, teaching mechanics and operators and supervising their work in this respect.

Selection of proper lubricants is a very important and difficult task. It is usually done by first recording the recommendations given in manufacturers' manuals for each machine and its components. Next comes the analysis of the recommended list with a view to reducing the variety to a minimum. At this stage an expert opinion from an oil supplying company might be of help and is strongly recommended. Lubrication and selection of proper lubricants are highly specialized fields. Seldom has the dairy plant engineer the opportunity to acquire the necessary background in this field. Calling in a qualified lubrication expert should not be restricted to requests for help in selecting the list of lubricants. He should also be involved in training lubrication personnel in the fundamentals of the work, methods of lubrication, utilization of lubrication tools, methods of marking lubrication points, methods of purification of lubricants and in applying criteria for re-using purified lubricants. In many instances there are good reasons for establishing a separate card file for lubrication schedules. Designing a lubrication programme requires deciding who is going to do the actual lubrication work. In some plants this work is done by the machine operators, in others by specially trained lubrication staff. In the first case proper supervision has to be introduced, particularly in order to train people in keeping the oil clean and in detecting reasons for quick deterioration of oil quality in gearboxes or other lubricated devices. Finally training is needed in application of properly selected lubricants and in proper marking and recording of lubrication jobs performed.

In plants where a lubricator is employed and lubrication schedule cards are used, the routine steps of the lubricator are as follows:

1. Collecting the schedule cards for the day
2. Examining the lubrication programme for the day
3. Collecting necessary lubrication tools and lubricants
4. Lubricating and tagging the machines after completing the job
5. Recording the job on card - adding notes on essential observations
6. Returning the cards to the engineer in charge or to the clerk.

#### **4. Spare parts programme**

The spare parts programme is a particularly intricate task for a dairy engineer in a plant in a developing country. In most cases the plants were designed abroad and almost all equipment imported. The supplying companies seldom had sufficient information, not only on the local technical resources from which some parts of the plant could be procured, but even on the legal standards of the recipient country. In many of the developing countries more than one milk plant had been imported and very often each of them purchased from a different supplier, from a different country, sometimes even from a different continent. As a result there is often practically no standardization of equipment in milk plants in developing countries, except where the complete plant has been installed on a turn key basis. Moreover, even such simple items as bolts, screws and nuts used on a machine imported from the USA differ from the ones used by companies from the European continent, which in turn differ from those purchased in the UK. This variety applies to also to stainless steel pipes and fittings used in milk ducts, where at least five or six standards are in use. In some developing countries they are all represented in one milk plant.

With the absence of standardization, with difficulties in acquiring import licences for spare parts and in communication with the suppliers and absence of local specialized servicing agents, the continuous operation of a milk plant and its good performance will depend heavily on the spare parts stock available in the plant for immediate use. It is the dairy engineer's duty to decide on what spares and supplies to keep, on how much should be kept, on how to store and how to register.

The engineering stores should contain consumable items such as gaskets, standard lubricants and paints and three basic groups of engineering accessories:

- equipment spare parts
- complete components
- pipes and fittings, bolts, nuts and washers, bars and plates of different metals, electric components and other general types of engineering accessories.

The total number of items stored often amounts to thousands, of which a negligible part or sometimes even the majority may be imported. The selection of spare parts kept in the store is based on the manufacturers' recommendations and on the plants own experience of local operating conditions. In many plants there are several machines of the same type, capacity and make. This must be considered when deciding on the spare parts store, since, although the number of items stored will not be reduced, the quantity of each item may. Moreover such situations may make it convenient and economic to keep in the store complete components as spares, such as pumps for bottle and can washers, milk pumps, gears for tank agitators, electric motors, etc. Such components kept in the store could serve as emergency replacements for a number of machines or functions. The quantities to be kept should ensure regular and trouble-free plant performance without overstocking the stores.

In the spare parts lists there are items which are on relatively steady demand such as rubber gaskets for milk pipes, plate gaskets for heat exchangers, graphite and rubber sealings for pumps, electric relays and special bulbs, selected bearings, springs and automatic switches, etc. Also some consumable items may be listed in this group, such as automatic recorder charts and inks, special lubrication components and even packaging materials to which packaging machines are particularly sensitive, such as aluminium capping foils for bottling. It is relatively easy to establish a list of items and of required quantities contained in this group.

It is much more difficult to decide on items which are used sporadically. The demand for them is erratic and only experience can tell what deserves to be stored in the plant. This could involve parts of machines which theoretically last for the lifetime of the machine, such as shafts carrying spray discs in milk driers, plates in heat exchangers and pressure and temperature indicators. There are instances when they need quick replacement and should be available in the store.

On the other hand large spare parts stores absorb a considerable portion of the capital and may adversely affect

the economic situation of the plant. Finding a correct balance between these two aspects of the problem may be facilitated by considering whether local supplies could replace costly and time consuming imports, whether there are components which could be locally reconditioned by removing worn-out parts and replacing them with parts which are locally made or even fabricated in the plant's own workshop. It may be of advantage to the milk plant to make or to purchase tools for spare parts fabrication and to use them when required. This may be illustrated by an example. The local rubber parts manufacturing company may have the skills and facilities to produce rubber parts of required quality, but it may not be interested in undertaking such jobs for the milk plant because of high tool manufacturing costs and of low demand.

The rubber moulding tools are the key to the solution of the problem. Making them or paying for their manufacture and keeping for the next order may seem to be an expensive venture, but it may be the safest and cheapest solution in the long run. However, at least one original sample of each spare part should always be kept in the store under special care so that a critical comparison between the original and locally made items is possible and corrections of the latter feasible. Certain spare parts will always have to be imported due to lack of know-how, to the need for special materials, or to high manufacturing costs. A careful survey of the stock position of the relevant items, of their condition on the machines and of their anticipated life should be made with sufficient frequency so as to ensure that ample time is given for the procurement of spare parts before the last pieces are used. It is a well known fact that procurement of spare parts takes often more time than the procurement of a new machine. Sometimes it may take a year or even more to replenish the stocks. Lowest quantity limits on particularly crucial items kept in the store need to be defined in order to avoid the risk of running out of stock before new supplies arrive.

The registration system of spare parts is an essential component of a good preventive maintenance programme. Needle cards may also be of use here.

## **5. Maintenance action**

The preparatory part of the PMP as well as the plan of action presented in the foregoing leads to the correct performance of the physical maintenance of the whole plant and each of its components. As it has been shown, the inspection schedules - including lubrication - are the guidelines for routine servicing of the machines and in this

respect the plan of operation includes an essential part of maintenance: routine servicing during scheduled inspections. However, any routine activity implies action during normal situations in which no deviation from normal has been spotted. But daily review of the inspection records will certainly also reveal that in some of the machines the performance does not meet expectations. In such instances remedial action needs to be taken before the performance decreases further since there is likelihood of reduced output, serious damage to the machine or the situation may develop to a stage at which it becomes hazardous to personnel.

The examination of the situation will lead to findings upon which the decision will be taken on further action. Such examinations must be done by members of the engineering staff who are best qualified in the field in which the trouble occurred or by the person actually on duty. The degree of seriousness and the urgency for a solution will influence the way in which the problem is analysed and decision taken. The most dramatic conclusion would be taking the machine out of service because of the hazards in its further operation. This seldom happens and when it does it is most often limited to particularly sensitive machines such as milk centrifuges and refrigeration compressors, of which standby items are usually included in the plant design from the very beginning of the plant's operation.

In the majority of instances the decision-making engineer must consider whether:

- the work can be done during the operation of the machine
- the work can be done after normal operation hours without disrupting the normal processing schedules
- the work requires time, skills and resources available in the plant or it is necessary to call in other specialized companies or people.

The decision is followed by work orders. Should the work be carried out by the plant's own crews, the maintenance craftsman or foreman receives a work order which gives details of the work to be done. Usually it will refer to a particular maintenance schedule and will be given together with requisition documents to the stores for issuing materials and spare parts required for carrying out the job. Only in very urgent instances should the craftsmen work to verbal instructions, although discussions on how best to perform the job are of great value to the quality of the work and to the overall working atmosphere in the engineering group. After the completion of the job a Job Report should be submitted in which confirmation of completion is given, and the time and materials

used are recorded and recommendations for any further action are specified.

The Job Reports are one of the main sources for preparing accounts of the actual costs of machinery maintenance. They may be prepared either within the engineering department of the plant, by the accounts department or in cooperation between both, depending on the organizational system of the factory management. Independent of the organization structure of the plant, it is the dairy engineer's duty to keep his own records on maintenance costs, to review them frequently and to draw conclusions on ways and means by which all necessary expenses on plant maintenance are made.

In spite of all the efforts in taking care of the machines, equipment and other assets of the plants, the time will come when overhauling becomes unavoidable. Damage caused by faulty operations, maladjustments and misuse of machines can be minimized under proper management, but deterioration caused by wear and tear of moving parts, by corrosion or by entry of foreign materials between moving parts cannot.

Overhauling machines at planned regular intervals is a means to avoid sudden breakdowns. The intervals between planned overhauling of each and every part of the plant's equipment can usually be found in the technical documentation of the plant, including manufacturers' manuals. Here again the plant's own experience may be of even greater value in establishing overhauling schedules of machines. Such schedules are based on the anticipation of breakdowns after a given number of hours of the machine's operation. Most often the planned intervals become shorter when the machine advances in age and in wear and tear. However, a planned schedule cannot be the only indication with respect to the need of major repairs of a machine. During the preventive maintenance inspections the readings of the instruments together with other observations can also indicate the danger of immediate breakdowns. Well trained staff will make it clear in their inspection reporting, but it is for the supervisory staff to spot such dangers in their routine analysis of the reports and to take appropriate actions. It is a good habit to spend 30 minutes each day and to have the written reports of the machinery inspection staff supported by verbal descriptions of the observations. In the long run it will always result in real time saving and also in a better diagnosis of the actual condition of all parts of the entire plant.

The time available in a milk plant for overhauling works is usually limited and in well-managed plants the engineering group aims at the reliance on its own resources of which the maintenance workshop is the most

essential. The reasons for such an approach become drastically evident when assistance is sought from outside facilities in case of emergency.

## **6. Maintenance workshops and equipment**

Before planning the accommodation and equipment needed for maintenance the external resources available such as spare parts stocklists within the country and the existence of specialist firms which can undertake engineering fabrication, building maintenance or vehicle servicing, should be surveyed and evaluated. If the milk plant is situated in an existing urban community it is likely that builders, motor vehicle agents and probably refrigeration engineers will already be established as these services are needed by so many other enterprises. However comprehensive these outside resources appear to be, it is still essential for the milk plant to include its own maintenance section to operate a preventive maintenance scheme and to cope with emergencies.

Although most of the work of inspection and maintenance of the equipment, both service and process, will be carried out in-situ, a base workshop and record office are necessary even in small plants. In large plants this may extend to several workshops each devoted to a particular branch of engineering service work. For example if the plant has to maintain its own vehicles because outside facilities are inadequate, a special workshop suited to this particular requirement may be needed.

In small milk plants a single general-purpose workshop should be adequate and this might be sited adjacent to the process area with direct access outside, possibly associated with the refrigeration compressor room, the records office and the spare parts stores. In large plants where more than one workshop may be appropriate a separate building may be needed, possibly in conjunction with the boilerhouse or garage.

The workshop should be supplied with the main services including compressed air and should be equipped with benches and a full complement of hand tools appropriate to the various engineering trades, together with special tools required for dismantling specific items of equipment. The latter is especially important in vehicle maintenance. Where repair work or the manufacture of special items of equipment is contemplated, electric and gas welding equipment must be included and, perhaps, basic machine tools, such as lathe, pillar drill and metal working machines.





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## CHAPTER II

### TRAINING OF DAIRY INDUSTRY ENGINEERS

A well-trained, well-managed team of engineers is vital to the running of a milk plant. If training or management is lacking then the equipment will break down or not work effectively. With short life products such as milk, shortage, stoppages or ineffective machinery can mean disaster.

In an ideal world the engineers would be required to be a well-organized, methodical, highly-condensed team devoted to indepth planned maintenance. However, in reality what is in fact often required is a highly reactive force that can respond quickly to the unknown with the minimum of delay.

The engineering department needs to contain three teams; engineers, electricians and support team. Each team should be independent in structure but capable of inter-dependence with the other enquiry teams and other working groups within the milk plant. For example, in a creamery receiving 100 000 litres per day, there will be variants depending on the exact produce mix. Assuming that two shifts are worked, the expected manning levels would be six to eight working engineers and electricians per shift. The age and complexity of the milk plant would determine the exact engineer/electrician mix. The structure would probably look as Fig. 5.

For a three-shift operation an increase in establishment of four per section per shift would be seen. The extra requirement would cover the rota implications of the extra shift. As with modern equipment there would be a requirement for instrumentation skills. This could be part of the duties of the electrical section, or a separate section altogether, depending on two factors:

- a. the amount of electronic control in the plant, and

- b. whether or not there is a recognition of electronic/instrumentation skills as separate from those of an electrician.

In a highly modern plant separation would probably be an advantage.

### **1. Training Needs Analysis (TNA)**

If a new plant is to be built or a major expansion is to be carried out then before recruitment or training commences an indepth Training Needs Analysis should be executed. This should also be carried out on existing sites as a review exercise.

Training Needs Analysis for an engineering purpose has some major differences from a normal TNA as carried out on a production unit. The first difference is that there are fewer day-to-day tasks on which to base the analysis. Secondly there will exist a number of one-off tasks which must be taken into account regardless of their probability. These will be hard to foresee as information from the manufacturers of equipment will be non-existent.

The first step in the TNA is to list the basic skill requirements that will be needed for any particular operation (see Fig. 6). Once a matrix of basic skills has been formed then the operation is repeated for the higher level skills required. These skills matrices should be carried out for each area, i.e. mechanical, electrical, etc. Once they have been carried out they will then form the basis of a manpower inventory, a skills requirement for an engineer and a training format.

The difference between a new development and a redevelopment is that on new projects new recruits must be imported to cover all the skills identified. On redevelopment it may be that by expanding the existing workforce the personnel can be successfully upgraded to the standards required.

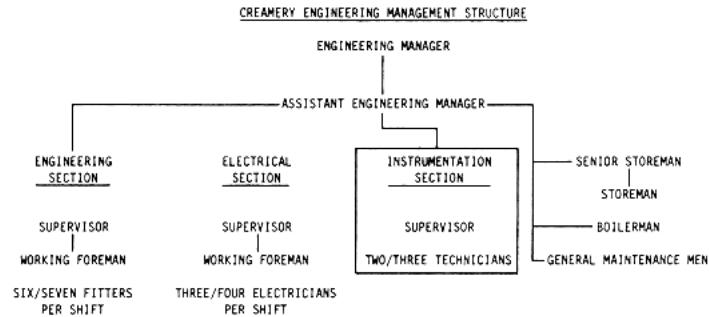


FIG. 5 CREAMERY ENGINEERING MANAGEMENT STRUCTURE

	Correct use of Hand Tools	Recording and Work from Engineering Drawing	Use of Measuring Equipment	Correct use of Tower Tools	Cutting, Bending, Threading Pipe	Etc.	Etc.	Remarks
Area of Static Requirement	✓				✓			
Area of Increasing Requirement		✓	✓	✓				
Area of Decreasing Requirement								

P. ADAMS	X	X	/	X	X			
L. BROWN	X	X	X	X	X			
F. WALKER	X	X	/	/	/			
I. ZIMMER	X	X	/	X	/			
Numbers Available	1	1	1	1	1			
Numbers Required	3	3	4	4	4			

CODE:

/ Not Trained

x Training

x Proficient under supervision

x Proficient

FIG. 6 EXAMPLE OF TRAINING ANALYSIS - SHEET A

After a skills analysis has been carried out an equipment analysis is then necessary. Each piece of major plant is broken down into its known requirements under the headings of skill, theory and plant specific knowledge (see Fig. 7). From this plant analysis the skill requirements can be calculated in terms of loading, the general theory that will be required for the understanding of processes and equipment, and the amount of indepth specific plant knowledge the engineer must acquire or have at hand. The transfer of this last part must be monitored, as it will show the effectiveness of the commissioning engineer at passing on his knowledge to the work force. This must be tested during the installation and before the commissioning engineer leaves the site.

The analysis as explained will require a considerable amount of time, but will in the end save time by ensuring that during recruitment an excellent picture will be formed of what is required. By having the training objectives built in, training plans and scheduling will be easier to control and monitor. This will also provide an excellent vehicle through which to judge when and where the training inputs have been effective. By doing such an analysis it will be possible to foresee problem areas and provide a basis for a planned maintenance schedule.

Recruitment. It is essential to establish a centre core of highly-skilled trouble shooters at an early stage both in the mechanical and electrical areas. The ability to fault-find is not present in all engineers; it is however a skill that can be learnt. This is time-consuming and needs good examples to follow. In demonstrating effective fault-finding skills simple logic is not all that is required. Good fault-finders need to be happy with the theoretical as well as the practical aspects of systems, and demonstrations of this will be required.

Management. The person specification when recruiting Management should include, apart from a good technical background and dairy industry experience, some ostensible indication of high motivation, organizational skills, good communicative ability, a strong training background and a high awareness of production needs and attitudes. It is the human-relations skills rather than the engineering qualifications that should be considered. The Engineering Manager must be consulted when recruiting other engineering management staff. Disharmony within the engineering structure is to be avoided. Also the engineering team must be able to cooperate effectively with other management teams within the unit.

Engineering staff. When recruiting engineers, reference should be made to the skills requirement as defined in the Training Need Analysis. Reliability and the ability to work unsupervised once directed are important factors, as many jobs will require the engineer to work on his own initiative away from the workshop. If recruiting raw beginners such as apprentices, tests for numeracy, spatial ability and mechanical comprehension are very valuable.

Providing training expertise. The training of engineers is time-consuming and requires a large input of skill. This may be available on site. However, time could well be a problem, so training must be carefully planned and use made of all the available resources. These are likely to be:

- Own skilled staff on site
- Local college or skill centre
- Local college operating on site
- Specialist training organizations
- Own specialist trainers.

A great deal will depend on the size of the task, the number to be trained, time constraints and available funding.

Using on-site staff for training. The main constraint is time. It is more than probable that only a limited number of people skilled enough to perform such a task will have been recruited and that they will be fully engaged in their normal tasks. Their instructional ability must also be examined. It is likely that a highly skilled fitter or electrician may not be very good at passing on his own skill and indeed may not want to. Working with a skilled man therefore, although a very valuable experience, must be regarded as only part of the answer. Its success rate can be considerably improved by ensuring that all engineers used as work guides have some form of training in instructional techniques. This will help them understand the learning process. It is essential that supervisory staff have a good understanding of instructional techniques, as they will not only have to instruct, but also test and make judgements on the development of the ability of each individual.

If skilled staff are under pressure, or there are a number of personnel who must reach a required standard before working with a skilled man, then there may be justification for an on-site training specialist. Given sufficient numbers this may be the most speedy and effective way of training these personnel to such a standard of skill and knowledge. The advantages over training at a local training centre, i.e. technical college, or bringing in a specialist training company are that it is more flexible in having complete control over input, timing and cost, as well as being geared to the specific plant requirements in skills and detailed knowledge.

Local training centres are a good source for providing theory on a general basis and may even have good basic skills programmes at low cost. They need to be carefully examined however to ensure that their practices are not counter to those required on site. It should also be remembered that in many cases their methods are probably not as up-to-date as those used in a new plant.

Bringing in a specialist training organization on a short-term basis is both costly and not very effective for basic skills training, but it may be a very good means of quickly upgrading a number of skilled staff in new or more advanced methods. An example may well be the upgrading of skilled welders to stainless steel welding.

## **2. Skills training**

The best means of ensuring that the basic skills content of any training programme is complete in detail is to use, as a guide, such publications as the Modular Practices published by the Engineering Industry Training Board in the U.K. As an example, their Module J3 Maintenance Factory Services skill specification would include on

completion of training that the individual should be capable of the following:

- Applying statutory and safety regulations
- The safe and efficient use of both hand and portable power tools
- The safe and efficient use of test and measuring equipment
- The use of factory recording procedures associated with maintenance and breakdowns
- Working to sketches, engineering drawings
- The cutting, bending and joining of piping and tubing
- Installing, servicing, testing and replacement of factory services pipework and ancillaries
- Applying various methods of securing and fixing components.

This list goes on to include servicing of boilers, the use of lubricants and servicing of air compressors.

The module books break down all the necessary skills into their component parts so that any skilled engineer with an instructional background should be able, following the modular pattern, to provide training tasks and theoretical input sufficient to develop a trainee to a good standard of basic skills. Other modules dealing with the basic skills are J1 Mechanical Maintenance and J2 Electrical Maintenance. For a higher skill level, the same system applies using more advanced modules. These are:

- J21 Mechanical Maintenance II
- J22 Electrical Maintenance II
- J4 Electronic Maintenance
- J23 Maintenance Factory Services II
- J28 Instrument Maintenance.

Providing the selection of trainees has been carried out correctly, the modular programmes should provide sufficient information to avoid difficulties and will provide a complete guide to the training of engineering skills.

	Gas Cutting Equipment	Gas Welding Equipment	Electric Welding Equipemnt	Maintenance of Hydraulic	Maintenance of Pneumatic	Etc.	Etc.	Remarks
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				System	System			
Area of Static Requirement	✓				✓			
Area of Increasing Requirement		✓	✓	✓				
Area of Decreasing Requirement								
P. ADAMS	✗	✗	/	✗	✗			
L. BROWN	✗	✗	✗	✗	✗			
F. WALKER	✗	✗	/	/	/			
I. ZIMMER	✗	✗	/	X	/			
Numbers Available	1	1	1	1	1			
Numbers Required	3	3	4	4	4			

CODE:

/ Not Trained

× Training

× Proficient under supervision

× Proficient

FIG. 7 EXAMPLE OF TRAINING ANALYSIS - SHEET B

Dairy product training. It is often not appreciated that an engineer working in a dairy produce environment needs to understand the nature of the products or the processes being applied. That he can repair any individual item of plant is not sufficient. A lack of knowledge in the dairy produce and processing field leads to misunderstanding of the importance of hygiene and clean working practices, usually a major criticism of the engineer by production



staff. This can manifest itself in the deposit of foreign matter into produce, e.g. grease streaks in butter, nuts and bolts in cheese blocks and even, more important, it may lead to dangerous practices such as welding in areas where dry milk powder is present. The engineer, who has no knowledge of the processes involved, cannot assist the production staff in trouble shooting process problems and will be at a disadvantage in locating possible defects in modern complex equipment.

Knowledge of the dairy produce and the processing methods will already exist on site and the use of production staff in this type of training is to be encouraged, being both cost-effective and valuable in assisting the development of good relations between production and engineering departments. The areas that need to be covered are milk and its treatments, pasteurization, separation and effects of mishandling, and a brief explanation of test procedure and the microbiological implications would be useful. Buttermaking and cheesemaking processes should be treated in the same way in their basic make-up, outline of the process involved and problem areas. Engineers should also have a good knowledge of packaging, with emphasis of the effects of poor packaging on the product and any legal demands. The production departments may well organize training of this type for their own operators. If so, this would be an excellent opportunity to combine forces.

Health and Safety. In any engineering environment health and safety must be a high priority and, as such, must be included in any training programme. There are special areas within the dairy industry environment which need emphasis. The introduction to health and safety must be during the general induction training and should cover responsibilities and safe working practices. This should be followed up by not only talking about the safety aspects, but also ensuring that trainees follow safe working practices in everything they do. The areas where particular attention should be paid are:

- Electrical supply
- Steam supply
- Acid tanks and supply lines
- Powder areas and equipment.

If there is no permit to work system operating within the milk plant, then there should be some safeguards for engineers working on equipment to prevent the power supply being momentarily turned on. The engineer must be

drilled into the habit of checking the electrical and/or steam supply lines before attempting any repairs.

Care in the use of strong acids in storage, or in use for cleaning must be emphasized. The engineer must know the routing of acid, and when and where it is being used. The treatment of acid spillage should be included at an early stage of training as well as part of any training directly connected with acid holding equipment.

Dried milk powder is highly explosive and a considerable live risk. This fact must be known to any engineer who is liable to work within a powder area, especially if the work should include welding in any form.

The use of safe working practices and the wearing of safety equipment cannot be stressed enough. Safety is an area with major training implications.

A systematic approach is as always the key to success. By first carefully analysing both the available resources and plant requirements a clear picture of the final objective may be drawn, and only then can a training plan be formulated and effectively implemented. The early training of supervisory and skilled staff in instructional techniques and the integration of background theory to complement the practical aspects of the training programme are vital in ensuring success.

A major failing of many training programmes is the lack of maintaining momentum. The day-to-day pressure of work takes over all scheduling and effectively destroys any semblance of order. To avoid the problem of work pressure the training programme must be carefully integrated with the development plans and expected day-to-day operation. It is safer to err on the side of caution when scheduling training sections and the use of the TNA sheets (Figs. 6 and 7) will be valuable in maintaining control of progress of the programme. The effectiveness of the milk plant is dependent upon the engineer, and his effectiveness is dependent upon his training (Fig. 8).

### Maintenance systems for the dairy plant

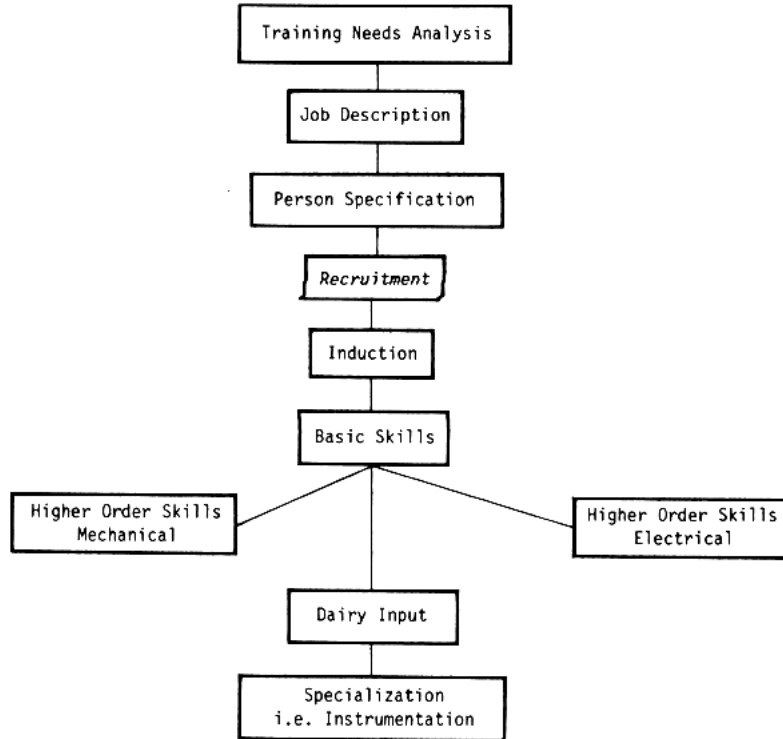


FIG. 8 TRAINING NEEDS ANALYSIS





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## CHAPTER III

### MAINTENANCE OF SERVICE EQUIPMENT

#### 1. Piping systems

In any milk plant, milk needs to be transported from one part of the plant to another, and this transportation is done in piping systems. Fluids comprise gases, vapours and liquids. Gases and vapours may be transported under increased or reduced pressure. Liquids are transported almost exclusively under pressure higher than that prevailing in the ambient, i.e. atmospheric. Depending on the pressure of the medium transported in the pipe the occurrence of leaks will demonstrate itself either by the fluid coming out the pipe (fluids under increased pressure) or by the ambient air being sucked into the pipe (fluids under reduced pressure). In the majority of instances in the dairy industry the pressure inside pipe systems is higher than that in the ambient although there are exceptions such as milk evaporators (vapour ducts) and spray driers (air in the driers, in the cyclones and in the interconnecting components). Milk and liquid products are also transported within the milk plant in piping systems under increased pressure. However, the milk pipes need to meet special requirements not applicable to other fluid pipes in the milk plant and therefore they are discussed together with milk processing equipment in Chapter 4.

Pressures under which fluids are transported in piping systems in a milk plant are classified by industrial standards as low and medium. To the highest belong steam pressure which in milk powder factories may exceed 2.0 MPa (atmospheric pressure equals about 0.1 MPa) and compressed ammonia in refrigeration plants reaching about 1.2 MPa in single-stage compressors. Compressed air pressure for pneumatic devices may reach about 0.8 MPa, but air used in all air conditioning systems may be transported in air ducts either under slightly increased, or slightly reduced pressure as compared to the ambient. The pressure in water pipes usually does not exceed 0.3 to 0.5 MPa.

Depending on the type of fluid transported in the pipe and on its pressure, the design engineer selects the suitable type of piping and fittings. Pipelines may be flexible (plastic, rubber) or rigid (usually metallic). Various types of fitting are used to interconnect pipes or to connect pipes to machines. Obviously only flexible pipes can be connected to moving components. Worm drive clips and snap-on connector unions are in common use to secure flexible hose to metal pieces and adaptors. Screwed joints, flange joints and welded joints are most commonly used on mild steel piping, but in the case where galvanized pipes (zinc coated) are used - usually for water lines no welding should be applied since it removes the zinc coat and exposes the fluid and the steel to corrosive interactions. Soldered joints are used when lengths of thinwalled copper piping have to be connected and this is very often met in internal connections of automatic controls. Contrary to a frequent attitude, piping systems require the meticulous attention of the engineering staff of the milk plant. This attention should be given not only to the valves, traps, reducers, filters and other more complicated parts of a piping system, but also to the pipelines themselves. They need their share of scheduled inspection, care and maintenance.

The trouble most often met in piping systems is the deterioration of the flow of the fluid. Preventive maintenance should be aimed at preventing this from happening. This deterioration is caused by scale accumulation, by condensation inside the system or by leaks. The term "scaling" means depositing solids inside the pipe by which the free way for the passing fluid may be reduced and sometimes completely blocked. This occurs particularly often in water pipes transporting untreated water at elevated temperatures: if the water hardness caused by bicarbonates is high, the scale accumulation is rapid and the deposits are hard like stone. Condensation can occur in vapour (mainly steam) lines and gas (mainly air) piping systems. It always happens when the temperature of the fluid inside the pipe drops below a given value. Leaks are caused by corrosion or by distress cracks, which in turn may be the result of liquid hammer, faulty drainage or faulty pipe installation, particularly in anchoring, supporting and in designing the expansion couplings.

Securing high performance of a piping system begins with the proper layout in which all piping elements are well selected and properly assembled into a system. First of all allowance must be made for the fact that all dimensions of the pipeline change with a change of the temperature, increasing when heated and decreasing when cooled. As a result of this expansion the whole system moves and all hangers and supports have to be designed in such a way that they either move together with the pipe (roll or slide) or that they can swing without exposing any stress either on the pipe or on the part of the supporting anchoring structure. Expansion pipe bends

are not often used in a milk plant since the "spring effect" of an expansion bend is usually achieved through the frequent change of the direction of the line. However, expansion joints are often in use on steam lines. In vertical runs that the expansion of the pipe may cause the even distribution of the weight of the cold pipe on all rigid hangers will change in such a way that the entire load will be shifted to the bottom hanger. Should, during preventive maintenance inspection, distress cracks on walls and footings near the pipe anchors be detected, the fault diagnosis will indicate improper layout with regard to thermal expansion.

Liquid hammer occurs when a moving column of liquid is rapidly stopped. It exposes the whole piping system to mechanical stresses which may cause serious damage and result in leaks. Slow moving valves do not cause hammering, but pneumatically operated spring loaded valves may. Air chambers are one of the common methods by which the hammer shocks are relieved. Condensate from the steam lines needs to be removed in order to avoid water hammer, but keeping traps in operating condition may not be sufficient when pipes are sagging and creating pockets where condensate can collect. The whole system should be adequately pitched. Condensate will tend to collect above closed valves in vertical lines and in the back of globe valves in horizontal lines. Draining the condensate from all such spots prior to admitting steam to cold pipes is one of the ways of preventing water hammer in steam pipes. Condensation in air pipes leads to rapid corrosion, but first of all it is dangerous because of the introduction of water in a part of equipment in which dry air only is wanted. For instance, air distribution valves for automatics are usually activated by solenoids; when air is discharged from the valve outlet together with water, short circuits in the solenoid wiring systems are unavoidable. Air drying is a must in most milk plants. It is done directly after compression and usually achieved by condensation of the water through cooling the air in a pipe heat exchanger.

Prevention from scaling depends much on whether the general technical standard of operations in the entire plant meets the requirements. A water treatment plant, filters and oil separators are the common components of the equipment, permitting fluids to flow smoothly in the pipes without scale formation. They all need proper care and maintenance.

The most difficult task in maintaining piping systems at expected levels of performance is the prevention of corrosion. Corrosion is unavoidable, but it can be slowed down by proper operation procedures and proper maintenance. Well-maintained mild steel piping systems may last 12 to 15 years or even longer, but instances of

a complete breakdown in 3 to 4 years after commissioning are known. Corrosion can be caused by many factors but they are all of electro-chemical nature. Corrosion is generally caused by atmospheric oxygen dissolved in aqueous liquids, or by dissolved salts such as brines and detergent solution and finally some gases like carbon dioxide and sulphur hydroxide or dioxide dissolved in water. The internal corrosion in the pipes can be reduced by strictly observing all rules in handling the fluids prior to their entering the piping system. Such rules must be introduced after a thorough analysis of the fluids, by drawing conclusions from the analytical results and by applying appropriate measures. Most typical in this respect is water treatment, not only for the steam raising plant, but also for general use. If aggressive solutions are transported in the pipes, corrosion can be slowed down by adding to the liquid certain selected chemicals such as sodium silicates. Scale formation and corrosion can be often reduced, particularly in water pipes, by adding up to 20 ppm sodium hexametaphosphate to the water. Basically corrosion is slower in liquids with pH values exceeding 7.0, or in other words in alkaline solutions, as compared to the acidic ones.

External corrosion on pipes is always increased on sweating pipes if the pipe is colder than the ambient dew point at which the air moisture condenses on the cold surface. Air and other gases dissolve in the condensate, and cause corrosion. A practical solution to the problem is to prevent the pipe from sweating. Watertight covering applied directly to the pipe (asphaltic coats, thermal insulation, spiral wrapping of strong fabrics) is the simplest remedy.

The layout of the piping and the selection of all components should depend on the parameters of the transported fluids and on the wanted capacities. The fluid velocity in a pipe is limited and depends on the type of the fluid: for water usually 2 m/s, for steam up to 50 m/s at pressures reaching 2.0 MPa but only 35 m/s for reduced pressures ranging between 0.2 to 0.6 MPa. The liquid velocity in milk pipes does not usually exceed 1 m/s, except during cleaning.

There are several technical rules guiding the installation, operation, care and maintenance of valves, and other components of a piping system. They are a part of the art of proper installation but, particularly concerning care and maintenance, they depend on the design of the component for which a good manufacturer always issues appropriate manuals. Globe-type valves cause higher pressure drops than gate valves, but they are useful for throttling service, and are easier to maintain tight and easier to repair. It is advisable to install whenever possible

globe-type valves in such a way that the pressure is above the disc - this prevents vibrations. Automatic drainage needs to be provided in all places in which condensate could accumulate, particularly above valves in vertical lines, and above the discs on stop-check valves. All accessible points of friction of the piping system components, especially valves, should be frequently lubricated (steam threads, yoke sleeves, etc). Any leak discovered in the pipe system should be stopped without delay: stuffing boxes tightened, misalignments corrected, packings replaced, supports repaired or changed if they do not support their share of the load. Any repair on an insulated pipe may adversely affect the insulation. The insulation must be repaired immediately not only to prevent excessive heat exchange with the ambient, but also to prevent rapid outer corrosion.

## **2. Centrifugal pumps, fans, air compressors**

Fluids move in a pipeline when there is a pressure difference between the ends of the line. This difference, if not caused by thermal convection, is usually created by pumps when the moving medium is a liquid and by compressors and fans when the moving medium is a gas. In many respects compressors and fans can be considered as gas pumps and there are several similarities in their mechanical design, installation and care. Therefore they could be considered as one group of machines supplying pipelines with fluids. In a milk plant, apart from milk, the most common liquids transported through pipelines are water and water solutions and air is the most common gas. (Gases used in refrigeration circuits are dealt with in section 9 below; milk pumps are dealt with in Chapter 4). Service pumps in a milk plant are nowadays almost exclusively of the centrifugal type and so are ventilating and exhaust fans used for building ventilation, for supplying air to burners in steam boilers, for air supply in spray driers, can washers, etc. Air compressors used in milk plants are commonly of the small and medium size and are built as single or multi-cylinder piston pumps. Air tanks are standard parts of the machine. In smaller machines the motor and the compressor are usually mounted on the air tank.

Centrifugal pumps. There are several types of centrifugal pumps used in a milk plant of which the simplest are those with motor and pump rotor built on a single shaft. Their care and maintenance is similar to milk pumps which are dealt with in another section below. In all other types of centrifugal pumps, the motor and the pump are joined by a coupling, flexible or rigid. The majority of centrifugal pumps are supplied by the manufacturers with bed-plates which need either to be grouted on a pump foundation or to be fixed on other types of rigid structures.



Misalignment is one of the most common sources of pump troubles. Proper alignment should be secured during pump installation and checked frequently throughout the pump's life. It should be noticed that neither a flexible coupling nor delivery of the pump on the manufacturer's bed-plate can be considered as guarantees for proper alignment. Therefore the pump must be checked for alignment - angular and paralleled - and necessary corrections must be done several times during installation: on the bed-plate prior to fixing this to its foundation, after fixing but prior to securing piping and finally after the pipes have been attached to the pump.

Absence of air, particularly in suction piping, is the next requisite for satisfactory pump performance. The capacity of a centrifugal pump is reduced by almost half when only 4 percent of free air is present in the pumped liquid. It leads in extreme cases to cavitation and to damage of the pump. The suction side of the pump is the most sensitive to entrained air and proper attention must be given to the following rules guiding the correct installation and operation of a pump:

- The size of the section pipe should never be smaller than that of the discharge pipe; usually it is one size larger.
- As far as feasible valves, filters, excessive fittings, horizontal bends, ells and tees should be avoided on the suction side of the pump but if their installation is necessary, they should not be mounted close to the suction inlet of the pump.
- Air can enter into the pump when liquid is falling directly above the surface close to the pump suction connection: any return line should be brought under the surface of the liquid and as far from the suction connection of the pump as feasible.
- Vapours in hot liquid pipes shorten considerably the life of rotating elements of a pump, particularly in multi-stage centrifugal pumps used commonly in boiler feed systems; vapours can also be created within the pumping system due to many reasons - most often due to operating a pump continuously near the lowest capacity without appropriate installation and operation of by-pass orifices. The by-pass should never be connected straight to the suction pipe.

Proper care of glands is most important during the operation of centrifugal pumps. The main function of a gland on centrifugal pumps is to hold in place a soft packing preventing the liquid from leaking or air from entering the pump casing. Glands may serve also as a device for removing heat from the shaft - they are then called quench

glands. They have a hollow portion adjacent to the shaft, through which cooling liquids pass and lower the temperature of the shaft, thus protecting bearings mounted on the shaft. Quench glands must fit the shaft close to the outboard ends. The clearance between shaft and gland has to be kept at the correct tolerance, otherwise the pumped liquid will leak along the shaft. Glands may be treated as replaceable spare parts as a whole, but the necessary clearance may also be re-established by replaceable bushings or auxiliary packings. A normal packed-type stuffing box requires lubrication and cooling. Usually 40 to 60 drops per minute of the cooling/lubricating liquid (which most often is water) flowing out of the stuffing box are considered sufficient for the safe operation of the pump. The maintenance procedures for pumps must be guided - as they are with any other machine - by manufacturers' manuals, and experience, but a few indications may serve as a useful illustration of the work involved:

- the temperature of the moving parts and the general condition of the pump must be inspected weekly or every fortnight; lubricants should be changed every three months;
- alignment must be checked every six months, which is also the most common frequency for replacing packing;
- a thorough inspection on general wear of all major components must be done once a year and the performance of the pump should be checked after the post maintenance reassembly.

### **3. Ventilating and exhaust fans**

Most of the fans used in a milk plant are of much larger dimensions than the pumps and in addition their housings, ducts and blades are built out of relatively thin metal sheets. Because of this they are much more exposed to damage during shipment and installation. They require thorough inspection upon delivery, careful storage prior to installation and extra care in handling, particularly when lifted with a hoist. The installation of larger size fans means reassembling in the milk plant since they are usually disassembled by the manufacturer prior to shipment. The assembly has to be done with proper care being given to match the markings of the manufacturer. Exceptional importance should be attached to the correct direction of rotation. Many of the principles of a correct installation, care and maintenance of centrifugal pumps apply also to fans, particularly concerning alignment, foundations, lubrication of bearings, etc. However, there is a number of installation problems typical for fans only - one of them concerns vibration. Vibration-isolating bases are used in fan installations to reduce the transmission

of sound and vibration from a fan to other areas of the plant. The isolating elements consist of resilient material and steel springs which deflect under the weight of the vibrating element and absorb structure-borne sounds and vibration. The isolating elements should support the rigid base on which the motor and the fan are mounted. They should be adequate in number and properly spaced. Flexible connections should be provided between air ducts and the fan. Large fans are usually belt driven and the efficiency of the drive depends on friction adjustable by the V-belt tension. Correct tension is attained when the belts just do not slip when operating at full speed and load. The initial run of a large-scale fan must start under reduced load: outlet dampers and variable inlet vanes should be partially - not completely - closed. Vibration can be measured by instruments indicating displacement: well-running fans will show displacement ranging from 0.05 mm for fans with low (600 rpm) rotation speed to 0.02 mm for those with high (1900 rpm) speed. The maintenance inspection procedures and inspection frequencies for fans are similar to those for centrifugal pumps: in addition isolation of the vibration bases and inspection of V-belts need to be included in the preventive maintenance programmes. Fans also need more devices to protect personnel from contact with rotating elements: protective screens, belt guards and coupling guards.

#### **4. Air compressors**

In many instances air compressors are assembled by the manufacturer as a unit together with the air tank. Since the highest permitted pressure in the tank is limited to a value declared by the manufacturer and in most countries it is also subject to inspection by legal authorities, the tank is provided with a safety valve and the compressor's operations are automatically controlled by an on-off regulator. The compressor is driven by an electric motor through a V-belt drive. Air filters are installed on the suction side of the compressor. A pressure unloader prevents the machine from starting with air pressure in the compressor's head. The crank case contains oil necessary for lubricating the main drive of the pistons. In many plants the compressed air should contain a very low level of moisture which requires an air cooling and water condensing device mounted between the compressor and the air tank. Moisture-free air is very difficult to obtain and for most purposes the reduction of the compressed air humidity serves the purpose. Even with air cooling installed, some water may condense in the air tank and therefore a drain valve at the bottom of the tank is necessary - preferably automatically operated. Oil separators are mounted on the compressed air pipe, but oil-free air used for milk agitation in large tanks is obtainable only from special type compressors in which the cylinder lubrication is achieved by application of self-lubricating rings. The inspection and maintenance of air compressors include:-

- weekly cleaning of air filters
- weekly check of lubricant level in crank case
- weekly check of the performance of the on-off regulator
- weekly check of condensate level and drainage
- weekly check of the pressure unloader
- monthly cleaning of oil separators
- monthly check and adjustment of V-belt tension
- monthly check of the performance of the compressor by measuring time needed to load the tank from the lowest to the highest pressure.

## **5. Power transmission**

The electric motor is practically the exclusive prime-mover for powering all machines in a milk plant. The transmission of the power from the electric motor to the main shaft of the machine is performed by means of a drive. The most commonly used types of drives are gears, belts and chains. The acting part of the driven machine is sometimes mounted directly on the shaft of the electric motor, as in some of the most common types of milk pumps and in some designs of spraying discs in spray driers. Power can also be transmitted from a motor to a main shaft directly by means of couplings. Gears are most commonly used for driving dairy process equipment, belts - almost exclusively V-belts - are widely applied on auxiliary machinery like ammonia compressors, air compressors and fans, whereas chain drives are met in bottle and crate washers and in crate and package transportation equipment.

## **6. Gears**

Those in most common use are plain spur, helical spur, bevel and worm and worm wheel gears. Plain spur gears transmit power between parallel shafts only. They are becoming less used in milk plant equipment, since helical gears are able to perform similar duties, are quieter in operation and have a higher transmitting capacity. Bevel gears transmit power between shafts meeting at an angle. They are called mitre gears when the angle is 90°. Worm and worm wheel gears provide a high reduction in speed; they operate very quietly and are commonly used as dairy machinery drives. They usually run in an oil bath enclosed in a gear box. Normally the drive can be

transmitted only from the worm to the worm wheel.

As in any rotating part of a machine, correct alignment is the most crucial requisite of proper performance of a gear drive. It is of paramount importance that the gears mesh correctly. Excessive wear will occur very soon when the shafts of the gears are misaligned, or when the gears are too tight or too loose in mesh. In worm and worm wheel gears there is a heavy load on the worm shaft and adequate thrust bearings are incorporated in the design. They must be checked regularly for wear as should all gearbox bearings.

As with all other critical mechanical parts ball and roller bearings should be handled with greatest care to avoid mechanical abuse and corrosion damage. They should be constantly protected from all forms of dirt or foreign matter that might dent or wear the highly polished surfaces of the balls, rollers and races. Dirt causes 90 percent of early bearing failure. The services required on gears - including lubrication - are always described in manufacturers' manuals but local operating conditions may indicate additional sources of trouble and spots to which particular care needs to be given. Experience is a valuable source of information on how to maintain a gear at its optimal performance level.

## **7. V- belt drives**

These occupy an important place in the service section of a milk plant. The driving power of the motor can be transmitted by the belts when drive wheels (pulleys) are located on the shafts. V-belt pulleys are held in position by keys or by tapered locking bushes. Before installing belts the tension adjustment should be slackened completely, the driving surfaces of the pulley should be cleaned and the alignment of the pulley checked. Prior to installing a set of V-belts, the belts should be checked that they are a matched set. Standard V-belts are marked with a letter indicating their width across the tip and a number indicating their length. Widths are marked with letters A to E, lengths are stamped with a number which indicates the precisely measured length. A nominal pitch length will be marked, for example, (50), other figures (49, 51) will indicate the deviation from the nominal length. A matched set of V-belts is a set with the same stamped markings. Mismatched V-belts put on a drive will have a short life since the shorter belt will carry all the load whereas the longer ones will remain idle. Belts stretch on the drive, never shorten. Replacing V-belts one at a time (when wear is detected on one only) is a risky operation since the new one - being shorter - is likely to carry most of the load. For this reason it is always better to install

a complete new matched set. The used belts can often be put on less demanding services in machines requiring a smaller number of V-belts.

Belts must be tensioned correctly to transfer the drive and prevent unnecessary wear. As they stretch in use, their tension must be regularly checked and adjusted. Testing the V-belt installation on tension is done when it is stopped or when running. The following are suggestions on how to do a simplified testing during routine maintenance inspection. When stopped, a correctly tensioned V-belt should, if pressed firmly with the thumb near the mid-point (half way from centre to centre), depress 3/4 of its own thickness for each one metre centre to centre distance. With belts running at full speed the sag on the slack side of the drive should be checked. Correctly tensioned belts will show a sag equal to the depression shown during stop testing, i.e. about 3/4 of its thickness for each one metre centre to centre distance. It should be noted that the adjustment of the tension of new belts needs checking and rechecking several times during the first 48 hours of operation since new V-belts stretch slightly and settle into the pulley grooves before reaching their working lengths.

## **8. Chain drives**

These are subject to wear even when properly selected for installation, properly installed and adequately lubricated. They wear and stretch unevenly during use and checking chain wear means inspecting the complete length and all sprockets. Worn chains or sprockets will cause the chain to jump and possibly come off the sprockets which may mean damage to the machine. Proper alignment of sprockets minimizes chain wear but does not affect chain stretching which stresses the need for checking chain tension frequently and adjusting regularly. Chains need to be adjusted at the tightness tension as they stretch unevenly. The correct selection of the chain drive is given in manufacturers' manuals. Worn sprockets will also adversely affect the performance of a chain driven even with new chains. They should be replaced to ensure proper chain fit on the sprockets. In some cases the life of a worn sprocket may be extended by reversing it on the shaft to bring a new set of working tooth surfaces into use. Properly lubricated chains will not show discolouring at the joints and the connecting link pins will be brightly polished with a very high lustre. Frequent clearing of the chains and sprockets can greatly contribute to extending the life of a chain drive.

## **9. Refrigeration**

Any refrigeration system forms two circuits. In the primary circuit the refrigerant in the form of low-pressure vapour is compressed in a compressor and the compressed gas is liquified by cooling with air or water in a condenser, from where it passes to the liquid receiver. From the receiver the liquid passes under high pressure to a regulator or expansion valve where the pressure is reduced at its entry into the evaporator coils. In the coils the liquid evaporates by taking heat from the secondary circuit medium in which the coils are immersed. The refrigerant vapours return to the compressor.

The secondary circuit can be air in a cold store and brine or water in a container. In most modern milk plants there are usually two secondary circuits in which two sets of evaporator coils are installed: one for evaporation in the air of the cold stores and the second for evaporation in water used for cooling milk or liquid milk products in plate heat exchangers or in jacketed vats. In ice-cream plants, refrigerant evaporation takes place directly in a processing machine (freezer) but then the circuit is usually fed by a separate refrigeration system. There are numerous types of refrigerants, those in most common use are ammonia (R 717), R 12, R 22 and R 502 - the last three known under the trade names "Freon" or "Arcton". They are supplied in cylinders marked with identification colours: R 717 in black cylinders with red and yellow bands, R 12 in grey cylinders with white markings, R 22 in grey cylinders with green markings and R 502 in grey cylinders with orchid markings.

Of the four refrigerants listed above ammonia (R 717) is extremely toxic and must be handled under strict controlled conditions. The remaining three are not toxic but they are gases heavier than air and any leak will tend to accumulate at ground level. In poorly ventilated rooms it may cause health hazards such as unconsciousness and suffocation. Before cylinders are returned for recharging they should be completely emptied by venting in an open space.

Refrigeration has become in the last few decades a very specialized subject in the engineering field. In many milk plants refrigeration specialists are employed to look after this essential part of a dairy enterprise. Their main responsibility is to maintain the performance of the refrigeration plant at its optimum level and to make it meet the respective requirements.

In many milk plants, even in those not manufacturing ice cream, the installed electric power of the refrigeration plant represents one third of the total electric power installed and often even more. The electric power

consumption of the refrigeration equipment may come up to half of the total plant's consumption. Therefore the operation of the refrigeration equipment may greatly affect the total energy costs of the plant. A continuous performance checking of the refrigeration system is a requisite of the plant's good overall functioning.

The characteristics of the functioning of a refrigeration plant make it necessary to adjust pressures, flows, temperatures, etc. more frequently than in any other part of the milk plant. False readings caused by wear of the gauges and indicators lead to false adjustments. It is of paramount importance to make sure that all of them are checked for accuracy and kept in perfect mechanical condition. Thermostatic expansion valves require checking every month. If they open too wide, through wear or dirt, flooding may cause a frost back to the compressor. Gas leak to the bulbs may cause reduction of the flow to the evaporator and subsequent reduction of the overall capacity of the evaporator.

Cartridges in float controls need changing every three months. The float control valve is responsible for the refrigerant level in the evaporator. When closed too much, it reduces the capacity of the evaporator. If it is open too much the compressor may receive liquid on the suction side and get damaged.

Back -pressure regulating valves need checking every month. They are responsible for keeping the temperature of the gas within limits in the evaporator. If the temperature falls too low, frost accumulation on the blower units in the cold stores may occur leading to clogging of the units. Solenoid valves are used to stop the flow of either gas or liquid at different points in the system. Their functioning needs occasional checking. The trouble with the solenoid valves occurring most often is the burning of the coil: it should be warm when energized. Scale traps with screens ahead of all controls are important. They should be cleaned every six months. Only stainless steel screens should be allowed in ammonia circuits.

Thermostats, which automatically control the system, require checking on proper functioning by comparing the set and the true temperatures. Faulty thermostats can seldom be repaired and they usually have to be replaced with new ones. Relief valves need to be checked frequently on re-seating in order to avoid excessive loss of refrigerant.

Items requiring the major attention of maintenance staff in a refrigeration plant may be listed as follows:



1. Purging non-condensable gases, including air. The presence of these gases is checked by comparing the temperature of the vapour with its corresponding pressure, preferably near the expansion valve. Excessive pressure indicates the need for purging. The installation should be shut down during the check.
2. Draining oil traps on the refrigerant discharge side as frequently as indicated by experience.
3. Purging oil out of evaporators and receivers. Oil traps are not always sufficiently effective to prevent oil from the compressor travelling through the condenser pipes, the receiver and the evaporator coils. Oil reaching the evaporator may solidify and obstruct the flow of the refrigerant; in addition even the thinnest oil film on the heat exchange surface reduces the energy transfer.
4. Evaporative condensers are the most common in use in modern refrigeration systems in milk plants. They are usually located outdoors and there is a tendency for dirt accumulation and for growth of algae and fungi on the surfaces and in water basins. The unit needs cleaning with the frequency depending on local conditions under which the condenser operates. Fungicides and algicides are often added to the water basins which also help to keep the outer surfaces of the cooling pipes free of slime deposits.
5. Evaporator coils in cold stores need to be kept free of frost. Defrosting may be achieved by several methods of which passing hot compressed gas from the compressor's discharge side is the most common. Depending on the defrosting arrangements the frost accumulation needs frequent checking in order to keep heat exchange on the evaporator coils as effective as possible. Evaporator coils in brine basins seldom accumulate frost or ice, but in the ice-bank system the equipment is designed to accumulate ice on the evaporator coils. The heat transfer is reduced when ice grows on the pipes but up to a given thickness this reduction is allowed for in the design. The ice-water requirements of the plant vary in the course of the day and are usually nil during the night hours. This makes the thickness of the ice layer on the pipes grow. The plant should be shut down when the thickness of the ice layer reaches the highest calculated value. In many plants automatic switch-off devices are used; their efficiency needs frequent checking in order to operate the refrigeration plant at the lowest possible cost.
6. Compressor stuffing boxes need repacking at regular intervals. The condition of the compressor requires checking at least once a year. Refrigeration compressors are usually supplied with very comprehensive

manuals, maintenance instructions and spare parts lists. They should be carefully studied and all instructions followed precisely. Refrigeration equipment - particularly that operating with ammonia as refrigerant - is long-lasting if well maintained, but any negligence in care and maintenance may lead to drastic accidents and to health hazards to the staff.

The check list on maintenance inspection schedule cards is particularly long for refrigeration equipment. This is also a long list of items for recording in the refrigeration log books. Their contents and mode of preparation are very often suggested by the manufacturers in their manuals. Additional assistance from a reputed refrigeration engineer may be of great help in establishing a preventive maintenance system for the refrigeration plant and will pay for its cost in the long run.

### **10. Steam raising equipment**

There is a great diversity of steam boilers utilized in milk plants. They differ in size from about 100 kg/h steam capacity to tens of metric tons per hour. They differ in the level of pressure of the produced steam, they use different fuels (coal, gas, oil, sometimes electricity) and they may be fully hand operated or fully automatic. The thermal efficiency of the boiler plant may be as low as 40 percent in small coal-fired plants and as high as above 90 percent in large-scale oil or gas-fired boilers. Depending on the type of processing equipment installed and on the layout of the milk plant, the condensate recovery may be nil but it may also exceed 80 percent of the total steam output.

Because of this diversity, it is not possible to draw up a universal standard maintenance programme for a steam raising installation. The operation of steam boilers is in most countries subject to official control of legal bodies which also set steam boiler regulations and standards. The diversity of boiler plants is taken into account in these standards and they are considered in the regulations accordingly. They are the first source of guidelines concerning care and maintenance of the plant. The second is the manufacturer's manual. The third could be the standard handbooks' advice on fuel burning, heat transfer in boiler plants, water treatment methods and requirements, feed water handling, etc. Experience of the plant in boiler operations is of course the last but not least important source of indications concerning plant care and maintenance.

Only few indications of general nature can be given as a list of first steps to be taken when establishing a

preventive maintenance system in the steam boiler section. Periodical checking of the thermal efficiency of the plant will give the most crucial information on the overall performance of the boiler. The thermal efficiency may be considered as the ratio of energy obtained in steam to the energy supplied in the fuel and feed water. Estimating the efficiency requires data on the quantity of produced steam and on its parameters, the parameters of the feed water and the quantity and the calorific value of the fuel used. In large-scale installations instruments for recording most of the values needed for making the heat balance and for calculating efficiency are included. It is particularly easy to calculate the efficiency in boilers utilizing liquid fuels or gas since their calorific values once determined remain relatively constant for the given type of fuel. The situation is more complicated with coal which is difficult to weigh and for which the calorific value may change considerably from one supply to another. Besides, coal is normally stored in the open and is subjected to rain and snow which obviously change its moisture content and subsequently the calorific value. Milk plants seldom possess laboratory facilities for fuel analysis. Such analyses need to be done by specialized laboratories. The problems become even more difficult in small-scale plants in which the team quantity cannot be measured directly and indirect calculations may not give sufficiently accurate results. A common practice is to hire the services of a specialized engineering company or of an individual specialist in this field. The efficiency check should be repeated every year.

A useful indication - but indication only - on the overall performance of the boiler plant can be obtained by checking the composition and the temperature of the chimney gases. This can be done by the milk plant staff by means of relatively simple gas analysers and suitable thermometers. Excessive quantities of oxygen or carbon dioxide will indicate incorrect air supply; high temperatures may indicate scale accumulation on the heating surfaces.

Scale accumulation is one of the most commonly met reasons for poor boiler performance. It may reduce considerably the steam output and in extreme instances lead to damage of the boiler and be a health hazard to personnel. Scaling on the inner boiler surfaces is caused by improper quality of water which contains calcium, magnesium, iron and other salts. The quantity of these salts is expressed as water hardness. Hard water deposits scale very quickly reducing the heat transfer from the burning gases to boiling water. Feed water needs treatment prior to entering the boiler and the degree by which the original hardness must be reduced depends on the type of the boiler, although the ideal water for any boiler should be completely free of compounds causing scale deposits. There are many water treatment plants for boiler feed water. The most common in use are

continuous ion-exchange water softeners. They are cheap in price and reliable in operations, but the resins need periodical regeneration and general care as instructed in the manuals. Gases dissolved in water such as oxygen and carbon dioxide should also be removed from feed water: suitable equipment is usually included as a component of the feed water treatment plants. It is a very good practice for the laboratory of the milk plant to analyse the feed water quality every day and inform the plant engineer on results. The analyses are very simple and can be carried out in a few minutes. They give essential information on boiler performance evaluation and for maintenance operations.

Feed water temperature should be as high as feasible in working installations. The amount of further heating with steam depends on the quantity of condensate collected from the processing sections of the plant and eventually from central heating and air conditioning installations. A very considerable energy saving can be made by collecting the maximum of available condensate: unfortunately this possibility is often neglected. All steam boilers require periodical internal inspection. Daily blowdown and periodic descaling are essential. The relevant instructions given in the manufacturers' manual must be followed strictly.

Steam distribution is a system which begins in the boilerhouse and continues through the entire plant. Saturated steam is most suitable for heating processes. Superheated steam is generally used for energizing steam prime movers such as turbines in electric power stations. However, saturated steam becomes superheated in the process of pressure reduction. For economic reasons the pressure in the boiler should be kept at the highest permissible level which in most plants not manufacturing milk powder is about 0.5 MPa to 1.0 Mpa. On the other hand the pressure permitted in most of the dairy machines does not exceed 0.2 MPa to 0.3 MPa, sometimes even lower. Steam pressure reducing valves are therefore installed at several points of the plant to ensure that steam reaches the machine at required pressure levels. The laws of thermo-dynamics must be followed when planning a pressure reduction and steam distribution system. One of the essential principles is to reduce the pressure step-wise when the ratio of high pressure to low pressure required after the reducing valve exceeds the value 1:83. In order to avoid supplying processing equipment with superheated steam (which might happen when the reduction valve is relatively close to the equipment receiving steam) the final length of the team supplying pipe should be left uninsulated. This system allows for cooling the superheated steam and saturating it prior to entering the equipment.



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## CHAPTER IV

### MAINTENANCE OF PROCESS EQUIPMENT

#### 1. Pumps and piping

##### i. Centrifugal pumps

This type of pump requires little maintenance, which is usually confined to disassembly and cleaning, replacement of seals, seal plate and joints.

The product seal will obviously in time show signs of wear. The life of a seal depends so much upon its duty and to the product being pumped that it is difficult to generalize. It is however, possible to say that a product seal being used with hot sticky liquids may only give good service for three months. The examination period therefore should be adjusted to suit the conditions, e.g. six monthly intervals for light duties or six weeks for more arduous duties.

Premature seal failure or leakage can be caused by numerous means but the most common are:

- a. Foreign matter between seal running faces.
- b. Cracked carbon seal ring, usually caused by damaging during installation or thermal shock.
- c. Excessive wear on seals due to abrasive in-product.
- d. Inorrect installation and setting of product seals.
- e. If water-coiled seal arrangements fitted, then starvation of water to the seal.

The impellor should be examined for blockage in the tangential holes. This problem is usually indicated by the loss of pumping pressure or flow rate.

The motors mainly associated with a centrifugal pump require little maintenance but the following points should be noted. For specific requirements, the manufacturers' handbook should be consulted.

- a. Ball and roller bearings should have their grease renewed every 12 months, to ensure that a film of grease is in the rolling elements and that the housing is almost filled with grease in close contact with the bearing faces.
- b. Bearings should be checked each month for temperature and smooth running.
- c. Motor drive shaft for end float should be checked. Evidence of end float would normally indicate bearing wear.
- d. Monthly inspection of cooling fans, ventilation holes and ducts is recommended, cleaning as necessary.
- e. Terminal box connections should be periodically checked for tightness and insulation of leads for hardening, cracking or chafing. Overheating, from whatever cause, is a serious fault. High temperatures can cause deterioration of the motor insulation. The temperature of the motor should be tested by using an open bulb-type thermometer located as close as possible to the motor windings.

ii. Positive displacement pumps

A typical pump comprises a motor, which could be electric, air or hydraulic drive, to which is coupled a gear case assembly which has two rotor shafts. These rotor shafts protrude through the pump body and located on each will be the rotors.

The complete assembly is then clamped together via front cap and cap nuts. It is particularly important in handling this type of pump that methods are used which will not allow rotors or housings to become nicked, dented or scratched. The use of rubber mats on which to lay the pump components during disassembling is

often practised.

The maintenance required on this type of pump is greater than that for centrifugal pumps in that the gear case has many moving parts, bearings and oil seal. The manufacturers's recommendations for specific maintenance requirements for the gearbox must be consulted but a guideline is as follows:

Lubricants will be required in the gear case and on the bearings; the gear case should be regularly checked for correct levels. It will also be required, usually daily, to drain condensate from the gear case. The shafts should be checked for looseness and adjusted on the bearings as necessary. Oil seals will require replacement as will various 'O' rings located in the gearboxes. Within the pump body, gaskets, 'O' rings and the product seals will require replacing but, as with centrifugal pumps, the nature of the product being pumped will determine their safe working lives.

The rotors, which are usually rubber coated, will require replacing periodically. Excessive rotor wear could be due to one or more of the following: if the discharge pressure is too high, the pump speed may be excessive or an incorrect rotor material used. Abrasive products can also be a major factor. The incorrect use of the pump, e.g. running the pump dry or pumping foreign objects should be considered. Other factors are abnormalities in the actual pump, such as drive shafts out of line, shafts worn, loose bearings and worn hubs. All of these can cause rapid rotor wear.

The product seal, if wearing excessively, could be due to a too high discharge pressure, or product temperature. If the pump is mishandled, such as by the use of sharp instruments when installing, or damaged mating parts, problems with seal life will occur. A worn seal housing, loose pump shafts or shaft alignment with the pump body are all mechanical abnormalities within the pump, which will affect seal life. Excessive wear in the gear case may be the result of incorrect oil being used, the failure to drain condensate or failure to change oil. It could also be the result of failure to replace product seals allowing product/cleaning solutions to enter the gear case. Mechanical damage within the pump such as drive alignment, bearing adjustment, or using worn rotors on new shafts, will all contribute to wear in the gear case.

Finally, poor pumping performance is usually the result of a low pump speed, a 'starved' pump suction

condition, or air leaks in the suction line. Product seal condition is obviously also a major factor.

### iii. Valves and cocks

Various types of valves and valve configurations can be used for product routing. In the main they are pneumatically operated with an exhaust route, internal spring operation being then used to reverse the movement.

Valves should be checked as part of a planned maintenance scheme. Factors to be considered for the production of a scheme are the frequency of operation, nature of product, temperature of product, etc. Obviously the product seals should be changed if there are signs of wear or cracking. In conjunction with this, the valve seats should be examined. If they are metal seats they should be refaced if worn; if rubber seats then replacement is necessary. Valves will have an air cylinder of some nature which incorporates the valve return spring, air piston, valve spindle, 'O' rings, etc. As the cylinder may have to hold internal pressures of around 350 to 700 KPa obviously all components within must be in good order. Valves may be operated via a control box, which houses solenoid valves that control the flow of air to the valve. The sealing of these control boxes is important to stop the ingress of moisture; therefore the seals must be regularly inspected. In conjunction with this the air supplying the valve should be dry and oil free to eliminate possible problems with electrical equipment and valve internals.

Feedback on the valve position is a common feature and is usually achieved via micro-limit switches that are activated from the valve shaft. These switches should be inspected and adjusted at regular intervals. For specific assembly/dismantling instructions, reference should be made to manufacturers' instructions.

Valve cocks are manually operated valves that can either have a straight through or three-way port configuration. A typical cock will comprise a full bore plug, top and bottom sealing rings, top retaining cap and a handle for operation. Maintenance requirements will include the inspection of the sealing rings together with the valve plug and valve body. When dismantling a cock, great care must be taken not to allow any nicks, scratches or dents to occur in the mating faces of plug and body; these could cause leakage. If any damage is evident then plug and body should be "lapped" to eliminate leakage. When reassembling the cock, a suitable edible vegetable grease should be smeared on plug and body mating faces to ease



operation. It should never be necessary to hammer the cock handle to turn the valve.

#### iv. Pipework

Interconnecting product piping between various items of plant generally fall into the expanded or welded fabrication categories.

An increasing preference is being shown for the welding of pipes and fittings utilizing orbital welding or inert gas purge to reduce the number of pipe unions employed and so minimize potential crevice areas which may prove difficult to clean. Where skilled welders are not available, the expanded type pipe union may be employed utilizing semi-skilled labour.

When using the expanding method, it is essential that the correct gauge of tube is used to suit the expanding tool. The tube must be held square with the clamping block and the correct load setting used as appropriate to size of fitting. Use of an incorrect setting for the torque may result in failure; on a low setting, in fittings becoming loose under operational pressure and vibration; on a high setting, in a stretching of the fittings resulting in difficulty in attaining a leakproof union.

Plant layout is an important factor with respect to pipework. For ease of support and for an overall pleasing appearance it is usually desirable to run pipework parallel with or at right angles to the enclosing walls. Adequate falls must be arranged to pump suctions and drain points. As a general guide the amount of fall required is 1:120. 'Dead legs' or pockets in pipe layout should be eliminated wherever possible. If unavoidable, they should be positioned so that they are self-draining or in line with the flow. Pipework should be periodically inspected for damage or corrosion/erosion.

## 2. Heat exchangers

### A. Plate

By virtue of its passive nature in operation, the plate heat exchanger tends to receive a low priority in terms of maintenance programmes with the result that engineering attendance becomes one to cover emergency or

breakdown situations. This is obviously not good practice and logically denies the aims of good maintenance in taking preventive action at an early date to avoid the onset of serious problems. This tendency arises in particular in the food processing industries, where the heat exchanger forms part of a larger plant, the operational control of which is the responsibility of others ranging through production, quality assurance and cleaning and disinfecting. Whilst each of these management areas are required to commit themselves to specific actions to overcome their particular problems, the maintenance engineer must be sure, by means of programmed examination, that actions taken by others in their own disciplines are not detrimental to the well-being of the heat exchanger.

The planned maintenance job specification for individual heat exchangers will vary in line with the variety of applications to which they operate. It is, however, recommended that such maintenance specifications be based upon a framework embodying the following ideas, with additional matters being incorporated to deal with the manufacturers' more specific recommendations.

i. Frame

Where the frame is clad in stainless steel, apply a thin coating of vegetable oil to protect the finish. At the same time this will ease the removal of inadvertent splash markings from product material or cleaning solutions. The plate carrying strip or slots of the top carrying bar should be kept greased with an appropriate agent to minimize drag during plate movement and so reduce risk of damage to the plate hanging eyes. The plate pack tightening device should also be protected against environmental conditions with special attention being given to exposed threads of tie-bars which may be accidentally damaged.

ii. Plates and gaskets

Examine plate pack to determine whether any signs of damage are present of either a mechanical or corrosive nature. Mechanical damage may result from:

- a. Damage to the plate hanging eyes resulting in misalignment and gasket damage.
- b. Overtightening of the plate pack to overcome leakage problems due to high pressures or poor gasket

condition.

- c. High pressure loads or repeated pressure reversals of great magnitude may emanate from high pressure pumps or centrifuges. Such operational conditions may also lead to the movement and subsequent damage of the plate gasket.

Chemical damage may result from:

- a. The use of aggressive acid solutions during in-place cleaning activities, or from more specialized actions to remove hard scale on product or service sides of plates. Gasket damage may also be present.
- b. The misuse of hypochlorite sterilizing solutions. In this connection the strength of the solution, contact time and temperature are interactive and require close control of their use.
- c. Where calcium chloride brine coolants are used, care must be taken to ensure that the correct pH value is maintained and that any scale build-up on plates is removed frequently. Inadequate draining out of brine solutions and flushing out/neutralizing of residuals will lead to the onset of corrosion during application of high temperatures required for the cleaning and disinfecting activities.
- d. The continued use of high temperatures in excess of those specified for the particular gasket in use will hasten deterioration due to thermal ageing and subsequent loss of elasticity.

### iii. Thermal performance

When problems of loss of thermal performance arise, the maintenance engineer should always consider the institution of heat balance/heat transfer calculations to enable him to identify the source of the problem.

Areas having a detrimental effect on performance are:

- a. Product debris on plates.
- b. Formation of tenacious scale.

- c. Product throughput not under control at specified rate.
- d. Incoming product temperature not to specification.
- e. Process product temperature too high.
- f. Heating/cooling services not to specification in throughput or temperature.
- g. Inspect thermometry.
- h. Arrangement of platage changed - possibly by error.

#### iv. Corrosion

Stainless steel plates should undergo detailed examination at frequent intervals to determine whether the improper use of chemical sterilizing solutions of the hypochlorite range or calcium chloride brine cooling liquids has created conditions leading to corrosion attack.

Pitting corrosion may be seen at random areas of the plate as dark individual spots which are not removed during the cleaning process.

Crevice corrosion, if present, will occur at any plate to plate contact point throughout the surface of the plate in the flow path.

Where calcium chloride brine cooling solutions are in use the problem of scale formation is always present, if allowed to remain on the plate. Such scale may harbour residual brine leading to pitting and crevice corrosion.

#### v. Regasketing of plates

The replacement of gaskets for heat exchanger plates is a relatively simple and straightforward operation providing due note is taken of the manufacturers' instructions relative to the type of gasket elastomer being used and the adhesive appropriate for the particular gasket material. Whatever the adhesive system recommended, it is essential that care is exercised in the removal of the worn or damaged gaskets, not only to avoid damage to the gasket retention groove, but to ensure that all old gasket debris is removed easily, prior to cleaning and degreasing of the groove area in preparation for the application of the approved

adhesive.

Most adhesives produce a satisfactory gasket-to-plate bond strength either by chemical reaction or solvent evaporation provided sufficient plant down time is available. To counter this time factor the application of heat to the completed plate pack may be recommended to ensure that a satisfactory adhesive bond is attained to suit plant operating temperatures and pressures.

### **B. Swept surface heat exchangers**

A swept surface heat exchanger consists of a rotating dasher, with affixed scraper blades totally enclosed with a cylinder. The continual sweep of the blades cleans the cylinder surface of product. Heat transfer is through the cylinder wall. Inlet and outlet product ports are situated at each end of the product cylinders. Individual drives for the dashers may be hydraulic or electric. For specific maintenance requirements of the drive assembly, reference to manufacturers' manuals is recommended. The heat exchanger will normally have a product rotary seal; this seal must be inspected at regular intervals for damage or excessive wear. The dasher should be removed from the cylinder so that examination of the dasher blades together with the upper bearing and seals can be examined. Extreme care must be taken when removing the dasher to eliminate the possibility of damaging cylinder bore or dasher blades. After inspection of all parts, the upper bearing will require lubrication with a sanitary lubricant. The motor/dasher shaft should be checked for alignment at regular intervals. This procedure is explained in detail in the manufacturer's maintenance handbook.

### **C. Tubular heat exchangers**

As the name implies the tubular heat exchanger consists of a coil of tubes which is totally enclosed within a larger tube. The product flows through the coil of tubes with the heating cooling medium flowing over the tubes within the larger tube. On most tubular heat exchangers very little maintenance can be carried out as they are of completely welded construction. If the heat exchanger has removable end caps, then the inspection of the smaller coil of these can and should be carried out at regular intervals. Gaskets on the end caps should be replaced if worn or twisted.

### **3. Filters**

A typical continuous cloth type milk filter will consist of two cylindrical filtration chambers joined to a common inlet via a three-way changeover cock. Both chambers could be mounted on a length of horizontal outlet pipe, which would have non-return valves fitted in the junction points. The non-return valves are to prevent filtered milk feeding back through the chamber not in service. Milk would be directed to either of the two filtration chambers by the three-way cock. Continuous flow through the filter is achieved by alternating the flow between the two chambers. Before starting up, a filter cloth should be fitted to each filtration chamber. Generally, a filter cloth should be removed and washed when the back pressure on the filter increases by 0.14 bar, and replaced with a clean cloth in the chamber.

Maintenance of the filter would include stripping down the complete filter and inspection of all joint rings, changing if twisted, nicked or flattened. Attention must be paid to the non-return valves, checking the valve/valve seat for damage, spring tensions and correct alignment of valves. The valves should then be tested to ensure they only allow flow through one way. The three-way cock should be stripped and inspected as described in paragraph (iii), "Valves and cocks", and any inner screens or wire mesh components examined for damage. Milk filters will have drain and vent plugs fitted to enable continuous running of filters during production. These plugs should also be inspected to make sure that their respective seats are clean and seals are in good order.

#### **4. Milk storage and process tanks**

All milk plants have the need for tanks for storing either raw or finished milk. These tanks can come in a variety of shapes and sizes. They may be of the square or rectangular type, particularly in the small sizes, or they could be of the vertical or horizontal cylindrical type. Tanks vary from hundred litres up to about 150 000 litres.

Most milk storage tanks have an inner and outer skin with up to 5.08 cm of insulation inbetween. The insulating material is usually cork. The inner skin would be of stainless steel although some tanks are glass lined. Milk storage tanks are designed to withstand a certain amount of pressure or vacuum and can be equipped to be filled by vacuum or emptied by pressure. These types of tanks should have a safety device which will prevent excessive pressure or vacuum. If this type of device is fitted, then regular inspection should be carried out to ensure its effectiveness. Tanks may also be fitted with an air vent which must be of sufficient size to prevent any build-up of excessive pressure or vacuum. It is important therefore not only from a sanitary point of view, but also

from a safety aspect, that the air vent should not become restricted or blocked. Regular inspection of this vent is therefore required. If the tank is fitted with a thermometer this should be checked against a known standard thermometer for accuracy. The tank will be fitted with a manhole which opens inwardly to minimize danger of leakage. The manhole will have a gasket for sealing which should be checked and replaced if damaged or badly worn.

Most milk storage tanks will be fitted with an observation glass. The glass is usually of about 150 mm diameter and situated near the top of the tank. Gaskets sealing this glass should be inspected and replaced if damaged. Finally, the tank should be inspected internally and externally for any defects (cleaning effectiveness, corrosion, etc.). It should be stressed that when internal inspection is taking place all necessary safety precautions should be taken and that rubber-soled boots/shoes worn to prevent damage to surface of tank. Transport tanks will be fitted with top manholes which open outwards.

### **5. Agitators and mixers**

High quality standards of design and manufacture are maintained to ensure that this type of equipment gives trouble-free service. Nevertheless, recommended precautions and procedures must be observed in the handling, installation and servicing of all rotating equipment and accessories. Careful application of the manufacturer's recommendations will ensure an optimum performance. Errors or carelessness during installation can often lead to problems or even failure at a later date.

At installation, it is therefore necessary that the following points receive consideration:

- a. The manufacturer's instruction and maintenance manual must be made available to all personnel involved with the installation, operation and maintenance of the mixing equipment.
- b. On receipt, all equipment should be carefully checked to ensure that no parts are missing and that no damage has occurred during transport from the factory to the user.
- c. Any discrepancy or damage must be immediately reported to both the carrier and the supplier.

- d. The installation of most standard mixer drives and in-tank mixing equipment can normally be carried out without the presence of the manufacturer's representative. However, it is advised that only experienced tradesmen should be used to install agitators or any rotating equipment.
- e. Care must be taken to ensure that the mounting location of a mixer must be rigid and strong enough to support the mixer drive. This applies equally to direct flange, fabricated stool or structure and concrete flooring. If the unit is to be mounted on a surface which is not horizontal, the manufacturer should be consulted to ensure that the mixer will receive adequate lubrication when mounted in the desired position.
- f. At the start-up of a newly installed agitator, it is sensible to proceed with caution. Regardless of how well an installation is carried out, it is possible for errors or omissions to occur.
- g. Before running the unit, electrical requirements should be checked thoroughly. The voltage range on the motor nameplate should correspond to the supply voltage. The wiring of the unit should be carefully confirmed in accordance with the diagram provided. The direction of rotation must be checked and, if necessary, altered by interchanging the supply leads.
- h. The gearbox should be checked to ensure that it is filled with lubricant to the recommended level. The correct grade of oil as specified in the manual must be used.
- i. On units with mechanical seals, it is necessary to ensure the seal is adjusted in accordance with manufacturer's instructions and that the seal lubrication system is correctly selected and pressurized normally to 1 bar above the vessel pressure before rotation of the unit takes place.
- j. It is of great benefit if the mixer unit can be run under light load conditions for a short period. This permits the gears to be run in. (Instruction manuals cover this point.) The unit can then be operated at normal load conditions.
- k. During service, regular oil changes are essential to ensure efficient performance of the agitator. The following factors should be used to determine the frequency of these oil changes:



- i. oil temperature - unit operating under load
- ii. type of oil - plain or containing additive
- iii. the environment - humidity, dust, etc.
- iv. operating conditions - shock, loading, etc.

Finally, it should be noted that great care has been taken in the design and manufacture of all agitation equipment. If this care is continued by the user through regular checks and recommended maintenance, many years of trouble-free service will be the reward.

## **6. Homogenizers**

The homogenizer is essentially a reciprocating pump capable of producing very high pressures of up to more than 200 atmospheres. It has a multi-piston cylinder block to minimize cyclical variation of flow and produce the high pressure to force the product between the mating faces of the preloaded homogenizing valve. The homogenizing valve is supplied either as single or two-stage according to the product to be processed or the degree of homogenization control required. The base of the machine carrying the drive end consists of an electric motor connected to the drive shaft by pulley and belts. Further reduction to the eccentric shaft can be by pulleys or gear ratio, which in turn provides the reciprocating motion to the pistons through the connecting rods.

The maintenance of a homogenizer should be carried out on a regular basis. A daily inspection should be made of the oil level visible through the sightglass at the rear of the machine. After draining off any condensate from the oil sump through the pet cock, oil should be added if required, before starting up the homogenizer. The oil pressure should be checked to ensure it is above the recommended minimum when the machine is running. Finally, the water lubrication to the pistons and through the oil cooler should be checked to ensure that it is sufficient.

More detailed inspection and maintenance is required after each month in addition to the daily inspection. The drive belts should be checked for tightness and condition. Nuts, bolts and fittings within the drive chamber should

be tightened and/or checked to torque specification. Connector rod ends and tightness of the crosshead should be inspected and adjusted if necessary. Oil leakage from the piston adaptor oil seals can occur and packings must be tightened or replaced. The piston cylinder block is disassembled by removing the front caps, the piston and packing assemblies, care being taken in the handling of each item and checking for signs of wear and damage, especially in the piston packings. These should be replaced if there is product leakage from the rear of the cylinder block. After removal of the top caps and the inlet and discharge valves, the valve seats within the cylinder block should be carefully inspected for signs of wear and erosion, which will also be seen on the mating valve. Poor condition of these faces can have a marked effect on the product rate and cause erratic homogenizing pressure. Early maintenance and relapping of the valves can avoid a costly recutting exercise.

The cap gaskets must be replaced if they become too thin or extruded to a point of leakage at high pressure. This will also apply to the homogenizing pressure gauge and block. The homogenizer valve unit can either be activated by a spring-loaded handwheel or by hydraulic pressure. The handwheel must be manually set on each start-up of the homogenizer whereas the hydraulic unit can be pre-set and will automatically come up to the correct pressure at the push of a button.

In each case they must be removed and the valve push rod inspected for signs of wear and damage together with the valve rod seal. This seal is important in keeping a true and steady alignment of the push rod and if worn will cause erratic valve action. The handwheel thread and the valve rod spring must be checked and lubricated. It is sufficient to check that there is no hydraulic oil leakage from the push rod chamber and adjacent pipework and that the oil level in the main reservoir is correct.

The homogenizer valve assembly block or blocks can now be removed and stripped down to show the valve, valve seat and impact ring. The faces of the valve and valve seat must be kept in good serviceable condition to retain an efficient homogenization of the product. This can be recognized by the amount of wear that initiates at the bore of the valve and radiates out across the face. If the wear is up to two-thirds of the surface area, relapping of the valve with carborundum paste between faces can rectify this but further wear will allow erosion grooves to appear, recognized by straight lines radiating outward, and loss of homogenization will rapidly occur.

The impact ring is also an essential part of the homogenizing process and must be carefully examined. Wear of

the impact ring will occur on the internal face of the ring in the form of a groove. The erosion of the groove will be acceptable to a depth of 1 mm, when the ring should be replaced to maintain efficient homogenization. Two external factors to the machine should be checked during this maintenance period. Firstly, that the feed pump pressure is retained as recommended and does not fluctuate and secondly, that the pressure relief valve in the discharge pipeline, adjacent to the homogenizer, is set to relieve at the correct pressure. Finally, after six months or 1 000 hours of service, the crankcase should be drained, cleaned and replaced with fresh oil and the oil filter cartridge renewed. The motor bearings should be lubricated according to the manufacturer's instructions.

## **7. Plant instrumentation**

### **A. Temperature controllers and recorders**

have historically relied upon pneumatic signalling and drive for bellows and linkages, coupled to a mercury filled system comprising a temperature sensing bulb and bourdon tube. The mercury filled system is sealed for life and no maintenance is possible. Operational failure will be due to damage to the capillary between the sensing bulb and bourdon tube or fatigue failure of the material. In both cases the complete system will require replacement. Lubrication of the metal bearings of the linkage mechanism should be carried out at 6-monthly intervals using a good quality clock oil. At the same time the pneumatic control system should be inspected and any contamination due to dirty, wet or oily air supplies should be removed with paraffin or suitable solvent.

In more recent years, the tendency has been to design instrumentation embodying solid state techniques, printed circuit boards, etc. with the result that maintenance work has been reduced to the checking of instrument calibration against known standards or, in the event of trouble shooting, the use of diagnostic instruments and subsequent replacement of the failed module or printed circuit board. Inking systems for the temperature recorder pens require inspection at monthly intervals. Various inking systems are employed by instrument manufacturers. Generally these fall into the categories of direct charging of the pen nib using a small ink dropper, or alternatively a capillary feed arrangement from an ink reservoir housed within the instrument. Having ensured that the system is charged with ink, the pen nib should be cleaned to remove dried ink. Where the design of recorder pen permits some manufacturers to utilize ink cartridges with a fibre tip nib, it is only necessary to replace the cartridge when exhausted.

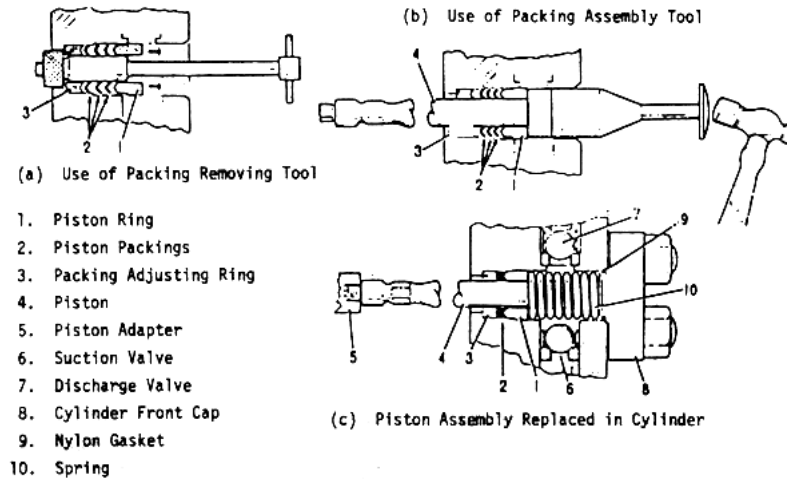


Fig. 9 PISTON PACKINGS AND RINGS - DISMANTLING AND ASSEMBLY

(By courtesy of APV International Limited)

## Maintenance systems for the dairy plant

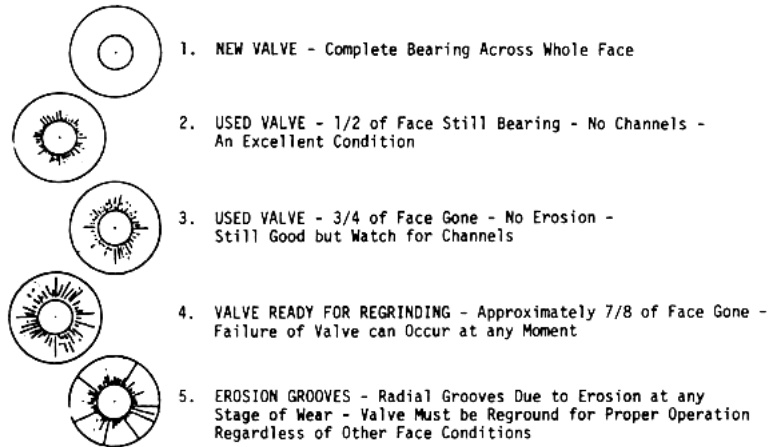


Fig. 10 WEAR PATTERN IN HOMOGENIZING OR PRESSURE CONTROL VALVE OR SEAT

(By courtesy of APN International Limited)

## Maintenance systems for the dairy plant

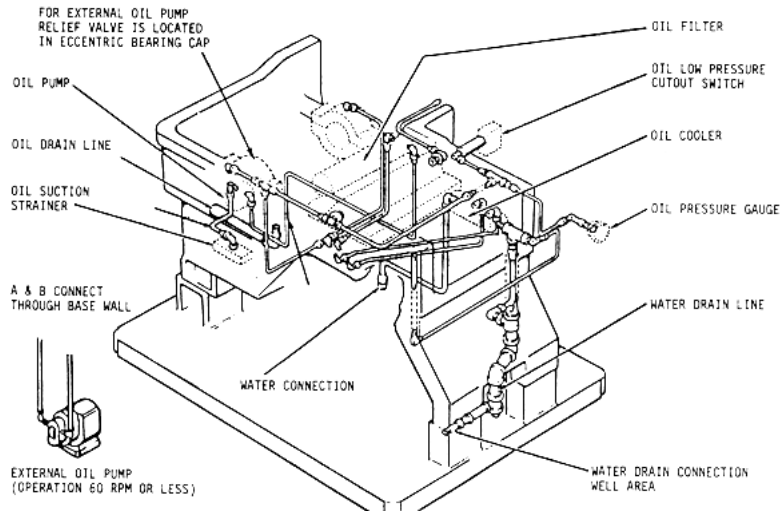


FIG. 11 GENERAL ARRANGEMENT OF PRESSURE LUBRICATION SYSTEM FOR HOMOGENIZER DRIVE GEARS AND BEARINGS

(By courtesy of APV International Limited)

### **B. Flow controllers**

for process liquids may take the form of:

- i. A device comprising basically a vertical tube with liquid flowing upwards into which is suspended a free piston attached by means of a spindle to a specifically machined disc of a predetermined diameter. This mechanical device has very close tolerances and it is essential to ensure, when taken down daily for cleaning, that no damage occurs by scoring or bruising to the stainless steel components. Due to the close fit of the free piston to the inner tube, a strainer will be fitted either internally as part of the assembly or in

Maintenance systems for the dairy plant  
the pipeline to the controller. This strainer must be cleaned daily.

- ii. A positive displacement pump usually of the rotary type design. When this type of pump is utilized for control of throughput of a pasteurizer it is more generally referred to as a “timing” pump. Construction and maintenance requirements are the same as for similar pumps referred to in Section 1, “Pumps and piping”.

### **C. Flow meters**

may be of the mechanical positive displacement, turbine or magnetic design.

- i. The mechanical meter utilizes the energy present as a result of the velocity of fluids passing through the rotor housing to transmit a driving force via linkages to a mechanical counting device. Such meters are of robust construction and require maintenance in respect of moving parts and any lubrication recommended by the supplier. Air entrainment with the product fluid must be avoided as its presence will not be detected by the rotor.
- ii. A turbine device where a multi-blade rotor is housed within a section of tube in the pipeline. Fluid flowing through the tube causes the rotor to rotate and a magnetic pick-up attached to the body registers pulses as the rotor blade interrupts the magnetic flux. The turbine must also be protected by a strainer at its inlet and periodic examination is required to ensure that no damage has occurred to the special bearings supporting the rotor. Cleaning of the whole assembly should be carried out upon conclusion of each process batch to ensure that coagulation of process material around the rotor and bearings is avoided.
- iii. Magnetic flowmeter comprising a tube of non-magnetic materials housing electrodes which create a magnetic field through which a conductive liquid creates small voltages proportional to the flow.

The magnetic type of flowmeter is basically simple in construction and, apart from the associated electronics, care should be taken to ensure that fouling of the electrodes does not occur.

In the case of items (ii) and (iii), additional field instruments will be employed, such as converters and amplifiers, which pass pulses or signals to a control unit. Apart from calibration activity, it is unlikely that the

maintenance engineer will be able to take preventive action.

#### **D. Diversion valves**

on process plant will invariably be pneumatically operated in the forward flow mode against a tensioned spring fitted into the air cylinder to effect a fail-safe valve position in the event of air failure. This feature is used to achieve the diversion or recirculation mode of process plant by means of a pre-set alarm setting in the recorder/controller instrument which, in the presence of a temperature condition at variance in either direction of the desired value, will energize/deenergize a solenoid valve situated in the air line or air supply connection of the particular process valve.

Maintenance requirements for the diversion valves will be as explained earlier in basic instrument action or Section 1, "Pumps and piping" insofar as the type of product valve is concerned.

### **8. Evaporators and spray driers**

#### **A. Evaporators**

##### **i. Low vacuum/high temperature**

Should the situation arise where the vacuum is low and the temperature is too high, attention should be paid to the possibility of air entering the effects or being contained in the product or cooling water where a spray condenser is installed. Air leakage may be located at manholes, pumps, covers and seals where joints are installed.

This problem may also be related to lack of cooling water when stuffing boxes and suction pipes should be examined for air leakage, and the water level in the cooling tower checked to ensure sufficient is available in the sump.

Inadequate supplies of product may also be associated with low vacuum and high temperature, and pump stuffing boxes and suction pipes should be checked and distributor plates examined for blocked holes. It is



essential that sufficient supplies of product are available at the balance tank.

ii. Rising levels in separators

Rising levels in the separators may be associated with air leakage at pump seals and joints, low steam pressure, fouling of the evaporator tubes, or increased product flow.

iii. Solids percentage not constant

Failure to maintain the solids percentage in the concentrate may be due to a fluctuation in the steam pressure, the supply or temperature of the cooling water not being constant, or temperature of feed not to specification. The level in the balance tank should also be checked to ensure it is being maintained.

Variation in solids percentage may also be associated with increased steam supply in which case the steam controller should be checked, or with a decrease in the vacuum pump efficiency in which case the temperature or supply of the operation water should be investigated. If the cooling water inlet temperature is too high, and a cooling tower is installed, a check should be made of its proper operation and the water flow increased. If the cooling water outlet temperature is too high, the cooling tower should be checked as above. Where a surface condenser is used a check should be made for fouling of the tubes, too high a condensate level and air pockets. The condensate and vacuum pumps should also be examined. In the case of a spray condenser the strainer may be clogged and should be cleaned.

iv. Closing of steam control valve

If the steam control valve closes, it may be due to the boiling temperature in the first effect rising above the safety limit, a pump stopping, or an air/electrical failure. In all these cases some fouling of the tubes may have been caused and it is therefore advisable to empty the evaporator of product and clean the plant before production.

v. Hints for location of air leakage

All the manholes, etc., which have been opened since the last run should be checked. If the source of the leak cannot be located by putting the plant under vacuum and the sealing water in the pumps, it may be possible to find the air leak by listening. If not, connections may be checked by means of smoke or soapy water. If the separators are filled and the ducting flooded, air leakage will be indicated by small air bubbles in the separator. Alternatively, with the plant at atmospheric pressure and no sealing water to the pumps, the separator should be filled with water and the connections and seals of pumps checked for leaking water.

## **B. Spray driers**

- i. Rising outlet temperature may be due to failure of feedstock supply to atomizer owing to pump stoppage, fouling or leakage from delivery line to drier, blockage of distributor or deposit on outlet sensor.
- ii. Falling outlet temperature may be caused by a large increase in the supply of feedstock to the atomizer, but failure of the outlet sensor should also be checked.
- iii. Fluctuating outlet temperature may be due to erratic feedstocks supply to the atomizer due to low level in feed tanks, or failure of the automatic controls of feed pumps.
- iv. Falling inlet temperature may be the result of loss of control of steam pressure, failure of the temperature sensor, blocking of the condensate outlet, rising inlet temperature, increasing steam temperature or fouling of air filters.
- v. Fluctuating atomizer power consumption may be due to inadequate drive belt tension, damaged atomizer bearings, incorrect setting of the atomizer disc or fluctuating feed stock supply.
- vi. Fluctuating discharger power consumption may be due to mechanical failure of the discharge drive transmission, powder deposits in the chamber, or physical contact between the discharger and the chamber.
- vii. Fouling of cyclones is caused by high water content in the powder and a cold air stream around the cyclone or blockage of the outlet rotary valve.

- viii. Abnormal deposits of powder in the chamber are due to low outlet temperature creating high water content in the powder, which can be due to a fluctuating product supply to the atomizer or incorrect adjustment of the air distributor.
- ix. V-Belts. In order for V-belts to have a long life it is important that they are kept so tight that they hardly slide on the V-belt pulleys. New V-belts must be tightened after 2, 8 and 24 hours and again after 3 days. When changing belts the whole set must be replaced at any one time, and V-belts of exactly the same length must be chosen.
- x. Lubricating. Every month the oil level in the gearboxes is controlled, and is changed once a year. The ball bearings of the motors do not have to be greased.
- xi. General. The capacity of evaporation is dependent on and proportional to the weight of the drying air. Therefore, the air cleaning filter should be changed when the resistance through it has increased to 200 mm W.C., as an increased resistance will have a reducing effect on the air quantity, which means a reduced capacity. Moistening the drying air and the transport air with steam or hot water should be avoided. Cold draughts on the cyclones should also be avoided as cooling these will cause powder deposits on the cold walls. The specific gravity of the product should be kept as uniform as possible.
- xii. Fire in chamber. Theoretically, fire may occur in cases where moist powder deposits are found in the chamber and these deposits are exposed to abnormally high temperatures.

For safety reasons the normal procedure to follow in case of fire in the chamber is as follows:

1. - The steam valve is closed.
2. - Change from product to water is made.
3. - The cleaning switch is changed for the atomizer.
4. - The exhaust fan is stopped.

5. - The controller is switched to “Man”.
6. - The feed pump velocity is regulated to maximum.

### **9. In-place cleaning equipment**

The main items of any in-place cleaning plant, namely, pumps, valves, piping and fittings, have been dealt with in an earlier section of this chapter. In addition to those items, numerous electrical/electronic devices may be employed for control functions, ranging from micro-computers, programmed card readers, flow indicators of either solid state or electro-mechanical design, together with conductivity meters and line probes. The maintenance details of all such equipment will be highly variable and, whilst the essence of good maintenance is to ensure correct performance by calibration, the individual supplier's maintenance notes must be consulted.

#### **i. Stages in cleaning**

The stages in cleaning comprise essentially:

- a. Removal of product residues by flushing with water.
- b. Circulation of an alkaline detergent.
- c. Flushing out alkaline detergent with water.
- d. Circulating an acid descaling agent.
- e. Flushing out acid with water.
- f. Either hot water sterilization or chemical disinfection, followed by flushing out of the disinfectant with cold clean water.

It is appreciated that in some installations one or more stages may be omitted and that many of the larger installations will have the cleaning/disinfecting schedule under automatic/computer control.

ii. Detergent cleaning

Brine sections - Heat exchangers which incorporate brine cooling sections necessitate special conditions. Before undertaking the cleaning programme it is essential that the brine section should be filled with dilute (0.25 percent) caustic soda or alkaline detergent to inhibit the corrosive action of the chloride ions at the temperature employed for cleaning.

General precautions -

- a. Detergents should always be carefully measured or dosed into the balance tank to give the desired strength of cleaning solution. If equipment to monitor the conductivity (and hence the strength) of the cleaning solution is not fitted, it is recommended that the solution strengths are checked by titrimetry.
- b. Alkalis (and acids) will attack tinned metals, gunmetal, copper, bronze and solder. If the plant is not constructed entirely in stainless steel, further advice should be sought.
- c. Rinsing must be carried out at sufficiently high flow rates to give turbulent flow in the circuit. High temperatures are not necessary for rinsing. With hard water, final rinsing should be carried out at under 38°C (100°F) and even with soft water there is no need to exceed this. Before final rinsing, detergent solutions should be cooled to this temperature or lower.
- d. Water should not be used for cleaning if it contains more than 100 ppm of chloride salts.

iii. Acid descaling

General - Under no circumstances should sulphuric or hydrochloric acid be used for this operation. The recommended acids are phosphoric acid or nitric acid. Sulphamic acid may be used. Neither nitric nor phosphoric acid is corrosive to austenitic stainless steel under the conditions recommended for cleaning. However, nitric acid can cause deterioration of some types of rubber gaskets and therefore it is strongly recommended that under no circumstances should the concentration exceed 1 percent nor the temperature exceed 85°C (185°F). No such problems exist with phosphoric acid and concentrations of up to 5 percent at

iv. Disinfecting agents

Whilst hot water is always the preferred disinfecting agent, chemical disinfection is commonly practised and among the chemicals used are the following:

Sodium hypochlorite <sup>1</sup>

Chlorinated sodium phosphate <sup>1</sup>

Organic chlorine containing compounds (e.g. dichloro dimethyl hydantoin) <sup>1</sup>

Quaternary ammonium compounds

Peracetic acid

Iodophors, etc.

It should be borne in mind by maintenance engineers that these brief notes serve only as an introduction to the chemistry of plant cleaning and for more detailed information a study should be made of appropriate publications.

<sup>1</sup> All disinfecting agents which rely on the release of chlorine are potentially corrosive to stainless steel and their use must always be under strictly controlled conditions.





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## CHAPTER V

### MAINTENANCE OPERATIONS

The preventive maintenance programme includes many sections, an essential one of which is the maintenance work done directly on the machine. It needs to be performed by skilled craftsmen and in this chapter an attempt is made to provide the engineering staff of milk plants with a guide to maintenance comprising:

1. Basic rules concerning safety at maintenance work
2. Essential information on hygiene requirements relating to milk plants
3. Diagnosis of faults
4. Examples of routine maintenance procedures

#### 1. Safety at work

Regulations concerning health and safety at work may differ from country to country in detail, but some relevant provisions are embodied in all of them. All craftsmen must adhere strictly to the regulations concerning their particular trade, together with the Company rules complying with the country regulations actually in force. It is the duty of every employee while at work to take reasonable care for the health and safety of himself and of other persons, who may be affected by his acts or omissions at work. No person shall intentionally or recklessly interfere with or misuse anything provided in the interests of health, safety or welfare in pursuance of any of the relevant statutory provisions. Every craftsman must be trained to be safety conscious and should know the correct use of protective clothing.

Overalls should be buttoned up, sleeves rolled up above the elbows or cuffs buttoned up, and a protective cap

should be worn, as illustrated in Fig. 12.

Gloves may not be worn at all times, but a suitable barrier cream should be used to protect the skin. Cotton gloves with reinforced non-slip gripping surfaces are worn when handling oil or grease covered components or materials. Heat-resistant gloves should be used to give protection against burns. Leather gloves give protection against sharp corners when handling bulky or heavy equipment. Rubber gloves are worn when using cleaning fluids and to protect the hands from skin damage due to air blast when cleaning components by means of compressed air.

Footwear worn should be reinforced safety shoes or boots with reinforced toecaps, especially at work demanding the lifting of relatively heavy components. Special care should be taken where the conditions underfoot are hazardous such as excessive water on the floor.

Goggles must be worn when a chisel, a sharpening tool or a grinder are used, and when cleaning with compressed air is performed.

Hazard warning signs, obligations and instructions should be widely displayed throughout the buildings on walls, vehicles, containers, etc. to bring these to the attention of personnel. The series of signs prepared by the British Standards Institute is shown in Figs. 13 A and B. These show the black triangle with a black-on-yellow pictogram indicating warning, the red circle with crossbar and a black-on-white pictogram denoting a prohibition and the blue circle with the pictogram imposed in white denoting obligation or instruction. A green square with the pictogram in white is for information.

Every potentially dangerous part of any machine whether power driven or not must be securely protected. Before work is started on a machine it is essential to ensure that it cannot be accidentally set in motion. The power supply system must be so disconnected that some special action is required for its reconnection. If the machine has individual drive, either the fuses should be removed with precautions to prevent accidental replacement, or the switch should be locked in the 'off' position. In some cases mechanical isolation might be necessary such as removal of belt from drive. A notice should be displayed at the machine to be worked upon to warn persons against any attempt to set the machine in motion. The power should be connected and the warning notices removed only by the maintenance craftsman after he has completed his work and made the necessary checks.



In exceptional circumstances it may be necessary to observe closely the machinery in motion with the guards removed. Such work may only be carried out by qualified persons, and only when permission to do so has been obtained from the supervisory officer on duty. Before a guard or fence is removed from machinery, warning notices should be displayed on all sides where there is access to the unguarded mechanism. Guards and fences should be replaced before the warning notices are withdrawn. This 'permit-to-work' system ensures the safety both of the craftsman and of the equipment on which he works. Certain tasks require an extra strict observance of safe working practices, e.g., when adjacent equipment may still be in use. Such tasks must not be carried out by a craftsman unless he has been issued with written authority to do so in the form of a signed 'permit-to-work'. It is essential that the correct procedures are followed and are accepted as the normal method of working. The practices of a permit-to-work system vary according to local needs, but the contents of such a permit usually include the description of the work involved, the time limits between which the equipment or the area must be made safe, the title of the issuing authority, the officer-in-charge and the necessary precautions required to make the equipment safe to work. The permit must be signed by the officer-in-charge.

General safety rules should be displayed in places where they can be easily and frequently seen by the staff concerned. It is more effective to display them as a list of what should and what should not be done in connection with particular types of jobs. An example of this, referring to safety of electrical works, could be displayed as:

- |   |   |
|---|---|
| DO- report all electrical faults              | DO NOT- use defective cables, plugs, etc.           |
| - keep loose cables off the floor             | - connect power tools to lamp sockets               |
| - keep all electrical equipment dry and clean | - attempt to repair electrical electrical equipment |
| - use compressed air carefully                | - direct compressed air at yourself or others       |

## **2. Hygienic working practices**

**Hygienic working practices include precautions concerning personal hygiene, practices during maintenance operations and finally the CIP (clearing-in-place) system involving cleaning and sterilization of equipment after completing and/or before starting processing and manufacturing operations.**

**Personal hygiene includes medical clearance for working in food processing plants, which needs to be**

renewed at pre-determined intervals. Clean protective clothing must be worn, 'no smoking' notices observed and all tools and equipment must be carried in closed tool boxes or bags.

Hygiene precautions during maintenance operations must concentrate on preventing the food from begin contaminated by extraneous material. It is therefore essential that all fastening devices are secured firmly, and that only non-corrosive fixing parts such as washers or split pins are used when in direct contact with the product or passing above the product. Further precautions to be strictly adhered to are:

- Oil grease, solvents and compounds used on food machinery must be those recommended for such use;
- All electrical equipment must be correctly waterproofed;
- Glass instruments such as thermometers must be properly encased, so that they remain in position if broken;
- There must be no leakages of services, especially refrigerants and cleaning solutions;
- Recycled water systems must be frequently treated;
- Cleaning nozzles in washing devices must not be blocked or excessively worn;
- Cold storage units must be adequately ventilated when not in use.

Once a maintenance task has been completed, all debris, tools and equipment must be removed and the plant left ready for cleaning and sterilizing operations.

Cleaning in place (CIP) consists of circulating water and various chemical solutions through assembled process equipment. In pipelines and other enclosed machines the solutions fill the equipment and each wash pushes out the previous solution. Control valves are used to control the critical operations of

**solution changes. It is of the utmost importance that the control valves are kept in faultless operating condition. Faults in control valve operation can become the source of serious damage to the products by contamination with detergents.**

### **3. Fault diagnosis**

**Skill in diagnosis involves the identification of the faults which arise in a machine or system, and the quick and accurate location of the cause of the faults. Not only should all the signs and symptoms that can indicate a fault and its cause be recognized, but also a suitable method of collecting this information should be adopted. An example of a six-step approach is illustrated in Fig. 14. A guide to fault finding is shown in Fig. 15. Whenever possible tests should be carried out to determine whether a series of components is working correctly before examining individual components. To reduce diagnosis time to a minimum the 'half split' approach to fault diagnosis should be used. For example, if there is no output from component E, by testing component C the area in which the fault could lie is halved. If C is functioning correctly, the next component to be tested would be D, as shown in Fig. 16.**

**Many machine manuals contain a section which includes fault finding or trouble shooting charts covering a number of known common faults. The information contained in these charts is based on previous experience. Predicted or anticipated faults may also be included, based on the knowledge and experience of the design engineer. The charts normally contain the fault, its cause and remedy. They are a useful aid to fault diagnosis, particularly in relation to product or process faults, and they should always be used.**

### **4. Examples of routine maintenance procedures**

**Manuals for craftsmen engaged in any given industry usually contain a selection of servicing and maintenance instructions related to the equipment most often installed in the factories concerned. They are used in conjunction with handbooks and general instruction manuals on mechanical maintenance, whose contents cover the job knowledge required by a skilled fitter. In many developing countries such manuals may not be available in the mother-tongue of the craftsman. Moreover, those available may not**

be easily understood, or may not apply to the needs of a milk plant. In this section two examples are given of the type of information with which the maintenance crew should be provided during on-the-job training. Both are taken from the Instruction Manual for dairy industry fitters, by permission of the Dairy Trade Federation of the United Kingdom, and are illustrated in Figs. 17/18. These examples deal with securing and fixing devices, and bearings, and demonstrate the preparation of training aids and the conveyance of the instructions to the trainees. The efficiency of the training and subsequently the efficiency of the performance of the maintenance work is greatly improved when each trainee is provided with a carefully prepared manual. Such manual preparation may not be an easy task, but it is continuous work and after a few years a manual of valuable information can be made available if proper attention is given to the problem by the engineering department of the plant.



GLOVES should also be used to protect the hands from skin damage due to air blast when blowing out and cleaning components by means of compressed air.

**SAFETY**

Do not direct compressed air at yourself or workmates — IT CAN KILL.



**FOOTWEAR**  
For normal duties reinforced safety shoes or boots should be worn.

**SAFETY**

## Maintenance systems for the dairy plant



Special care should be taken where the conditions underfoot are not good, e.g. excessive water.



### GOGGLES

Goggles must always be worn when there is danger to the eyes, e.g.

1. Using a chisel.
2. Operating certain machines, e.g. grinders.
3. Sharpening tools.
4. Cleaning with compressed air.

FIG. 12 PROTECTIVE CLOTHING

## FIG. 12 PROTECTIVE CLOTHING


### HAZARD WARNING SIGNS


For the safety of yourself and all other personnel any hazard warning signs displayed inside or in the vicinity of the factory should be observed. These signs may appear in areas, on walls, vehicles (tankers) or containers, e.g. drums.

The full range of these signs is illustrated in black and white only. Reference should be made to the appropriate British Standard full colour charts.

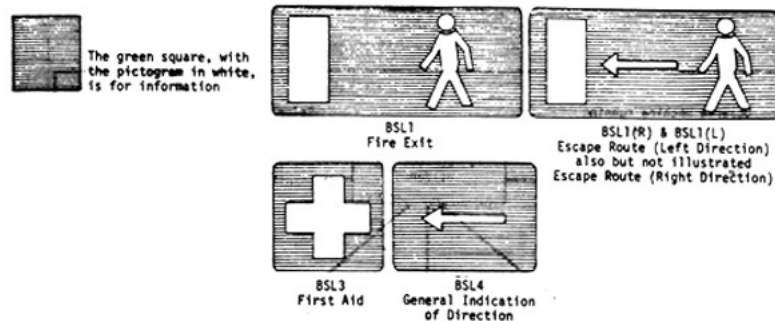
This series of signs, prepared by the British Standards Institute, is based on four standard combinations of shapes and colours, and the signs are manufactured in accordance with British Standard BS5378 - 1976.

 The black triangle, with a black-on-yellow pictogram, indicates a warning

 The red circle with crossbar and a black-on-white pictogram, denotes a prohibition

 The blue circle, with the pictogram imposed in white, denotes obligation, or instruction

BSW1 General Warning: Caution - Risk of Danger	BSW2 Caution - Risk of Fire	BSW3 Caution - Risk of Explosion	BSW4 Caution - Risk of Electric Shock
			
			
BSW5 Caution - Risk of Corrosion	BSW6 Caution - Risk of Intoxication	BSW7 Caution - Risk of Ionising Radiation	BSW8 Beware, Overhead Load
			
BSW9 Beware, Industrial Trucks		BSD1 Smoking Prohibited	BSD2 Fire, Open Light and Smoking Prohibited
			
BSD3 Water as an Extinguishing Agent Prohibited	BSD4 Not Drinking Water	BSD5 Thoroughfare Prohibited For Pedestrians	
			
BSR1 Head Protection Must Be Worn	BSR2 Hand Protection Must Be Worn	BSR3 Foot Protection Must Be Worn	BSR4 Hearing Protection Must Be Worn
			
BSR5 Eye Protection Must Be Worn	BSR6 Respiratory Protection Must Be Worn		
			

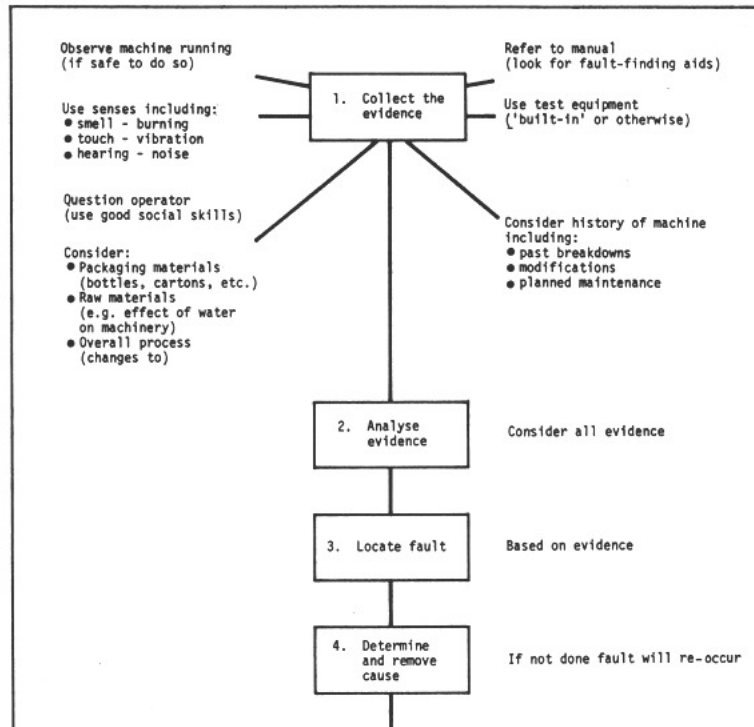
**FIG. 13A HAZARD WARNING SIGNS IN UK****SAFETY COLOURS AND CONTRASTING COLOURS**

SAFETY COLOUR	MEANING OR PURPOSE	EXAMPLES OF USE	CONTRASTING COLOUR (if required)	SYMBOL COLOUR
Red*	Stop Prohibition	Stop signs Identification and colour of emergency shutdown devices Prohibition signs	White	Black
Yellow	Caution, risk of danger	Indication of hazards (fire, explosion, radiation, chemical, etc.) Warning signs Identification of thresholds, dangerous passages, obstacles	Black	Black
Blue	Mandatory action	Obligation to wear personal safety equipment Mandatory signs	White	White
Green	Safety condition	Identification of safety showers, first-aid posts and rescue points Emergency exit signs	White	White

\* Red is also used to identify fire fighting equipment and its location.

### FIG. 13B HAZARD WARNING SIGNS AND SAFETY COLOURS IN UK

When commencing fault diagnosis do not start to strip down parts immediately, as this may destroy the evidence which will eventually lead to the cause of the fault, but apply a logical approach.





Maintenance systems for the dairy plant

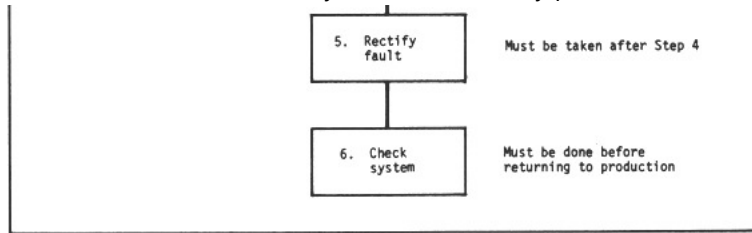
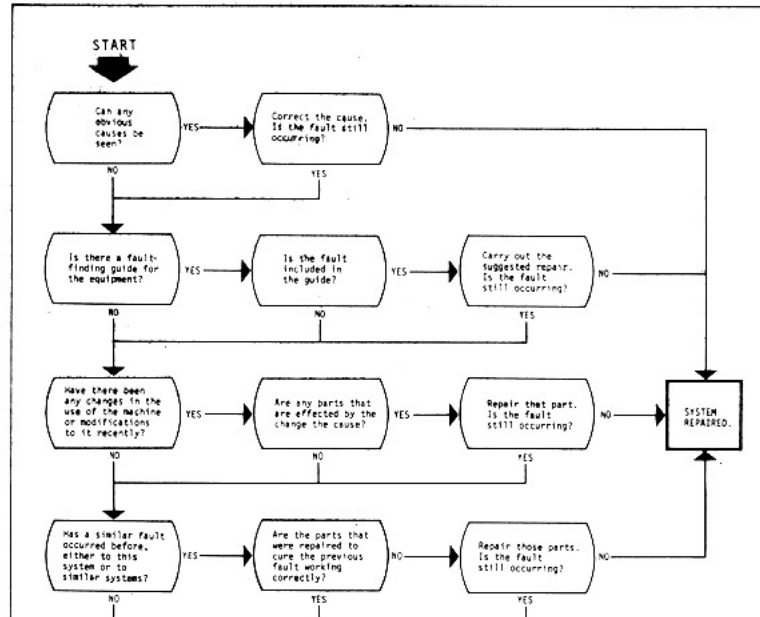
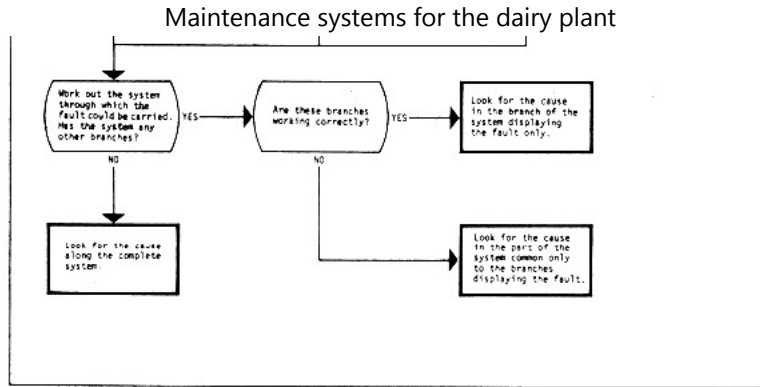
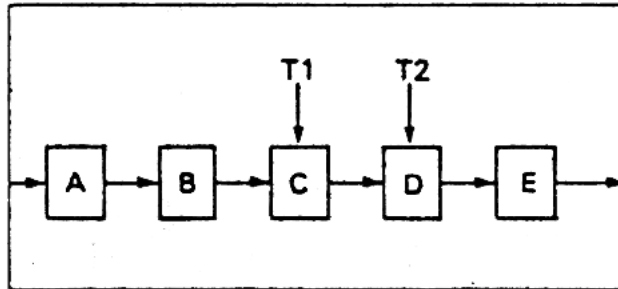


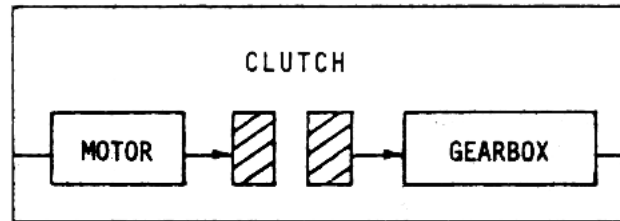
FIG. 14 SIX-STEP APPROACH TO DIAGNOSIS OF FAULTS





**FIG. 15 GUIDE TO FAULT FINDING IN THE SYSTEM**





### USING THE HALF-SPLIT APPROACH TO LOCATE THE CAUSE

Whenever possible, tests should be carried out to determine whether a series of components is working correctly before examining components individually. To reduce diagnosis is time to a minimum the half-split approach to fault diagnosis should be used.

For example, if there is no output from component E, by testing component C the area in which the fault could lie is halved. If C is functioning correctly the next component to be tested would be D.

Other considerations which should be taken into account when using this approach include accessibility

**of test points and the odds on a fault occurring in a particular component, i.e., if the odds on the fault lying in A are three times as great as for the other components the first component to be tested should be B.**

## **CHECKING FUNCTIONS/COMPONENTS**

**When checking functions or components inputs and outputs should be considered.**

**For example: Input from motor to clutch correct. No output from clutch when engaged. Fault lies in clutch.**

**NOTE: The cause may be a tight or worn bearing in the gearbox. Adjusting the clutch could temporarily remove fault but it would eventually recur. Cause must be determined and removed.**

## **FIG. 16 HALF-SPLIT APPROACH TO FAULT DIAGNOSIS**

**Securing and fixing devices. These include basically screws, nuts, washers and shims.**

**Screws are identified by the head type, length and the type of thread. The types of screw heads are shown in Fig. 17. The definition of the screw length is also shown in Fig. 17. The basic types of threads include metric, British Standard and self tapping. Except for self tapping types, screws are screwed into tapped holes or used with nuts. Blind holes should be checked to see that there is no swarf in the bottom of the hole and that the screw is not too long. The screw should be 1.5 mm shorter than the depth of the thread plus the thickness of the part being secured. The correct type of screwdriver must be used for fitting the screws. Fig. 17 illustrates the details of screws and their fitments.**

**Nuts are manufactured as standard and special purpose nuts. Standard hexagon nuts are used either singly with or without a locking washer, or as full nuts or as lock nuts to lock another nut into a fixed position on a thread. A lock nut is placed under the main nut and tightened. The main nut is run down on top of the lock nut and is tightened with one spanner, whilst a second spanner prevents the lock nut**

from turning as shown in Fig. 18. Special purpose nuts include castellated nuts for use with split pins, self-locking nuts with nylon inserts and spring steel self-locking fasteners. When using castellated nuts the bolt with nut must be assembled, a clearance hole drilled through the bolt shank in line with the slots, a split pin pushed through the hole until the head meets the nut and the ends of the split pin bent tightly around the nut as shown in Fig. 18. Split pins should be used only once.

Washers are of two main types, illustrated in Fig. 19. Plain washers are inserted under screw heads or nuts to provide a suitable bearing surface while tightening and to protect the component from damage due to rotation of the nut or screw head. Lock washers are used to prevent loosening due to vibrations, movement or temperature variation. Common types include:

- single coil spring washers normally made of square section spring steel, cut, twisted and chisel-edged;
- thackerey double oil spring washers made of flat section steel or phosphor bronze;
- snakeproof washers punched from spring steel;
- crinkle washers made from beryllium copper and used when a lighter spring pressure is required;
- tab washers used when a more positive locking action is required. (The tab is bent up against the nut face, thus preventing it from turning.)

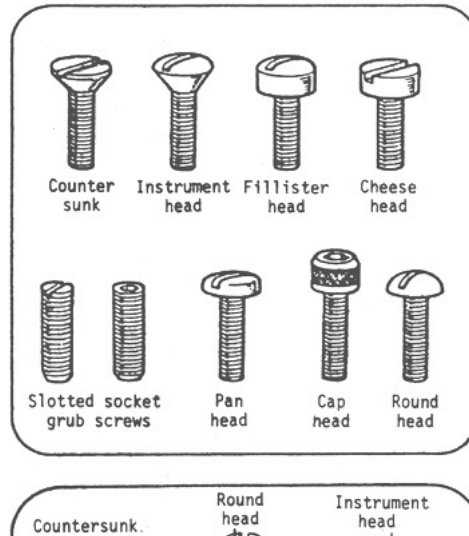
Liquid sealants are used to provide a permanent lock to a fixing point.

Shims, as illustrated in Fig. 20, are used as packing between two machine parts. Selecting shims of the appropriate thickness secures the accurate distance between the two parts. The shim must be flat. Holes can be punched in shims using a close fitting plain punch and two plates bolted and dowelled together.

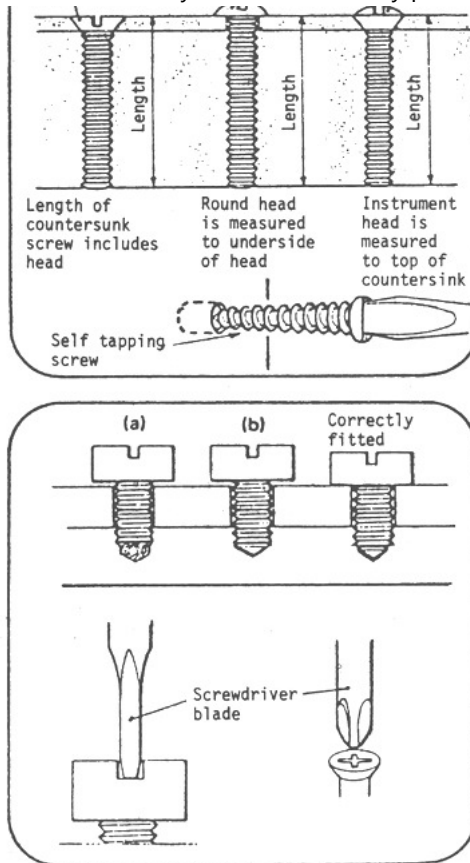
**Bearings** are illustrated in Figs. 21–27, and include plain bearings, split shell bearings and ball and roller bearings. All types are designed to reduce friction between moving and stationary machine parts. Bearings belong to the most delicate parts of machinery and are easily ruined if their surfaces are damaged. Bearings with damaged surfaces should never be used.

Plain bearings are built as shells or bushes in which shafts run. The material of the shell is always softer than the material of the shafts.

When fitting a bush a clean shouldered mandrel should be used, coated with light oil. The bush fitted on to the correct size of mandrel should be aligned with the housing. After checking that it is square with the hole it is gently pressed home with the lever. The internal dimensions must be checked after completing the fitting, as shown in Figs. 21A/21B.



# Maintenance systems for the dairy plant



## SECURING AND FIXING DEVICES

## **SCREWS**

**Screws are used for securing components and assemblies and are identified by:**

**1. Head type. Flush fitting screws are used when there is little clearance between assemblies or where protruding heads are not desirable.**

**The semi-flush type is used mainly for panel assembly or where a pleasing appearance is required.**

**The other full head types are used for general assembly work. As these heads are non-registering, some adjustment can be made to the relative positions of the workpieces by using the full clearance.**

**2. Screw length. Parts of the screw which protrude above the surface being fixed are not included when defining the length of the screw.**

**3. Thread type. Various types of thread are available such as:**

- 1. Metric**
- 2. BA (British Association)**
- 3. UNF (Unified National Fine)**
- 4. UNC (Unified National Coarse)**
- 5. Self tapping.**

**Screws will normally be screwed into tapped holes or used with nuts.**

**If the hole is blind, ensure (a) that there is no swarf in the bottom of the hole, or (b) the screw is not too long. The screw should be 0.06 inches (1.5 mm) shorter than the depth of thread plus the thickness of**

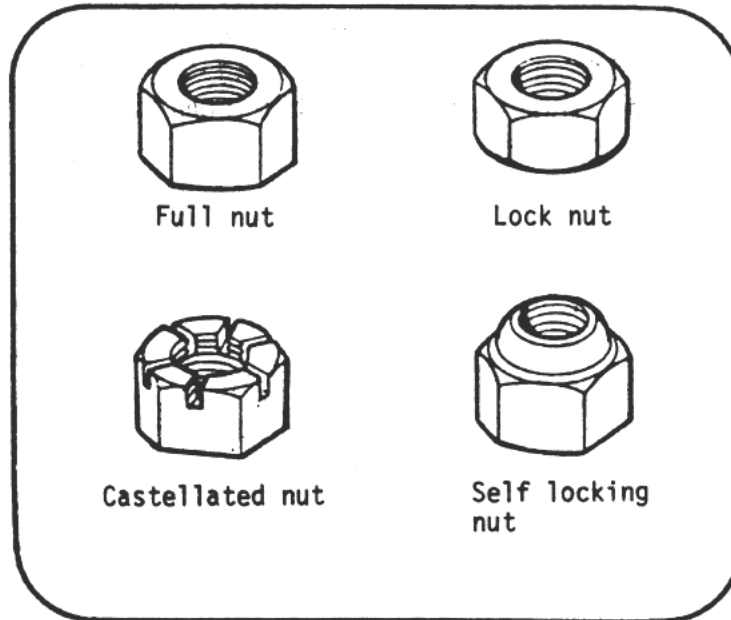


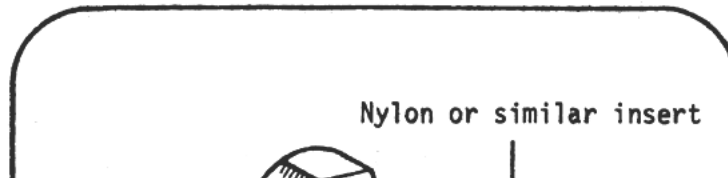
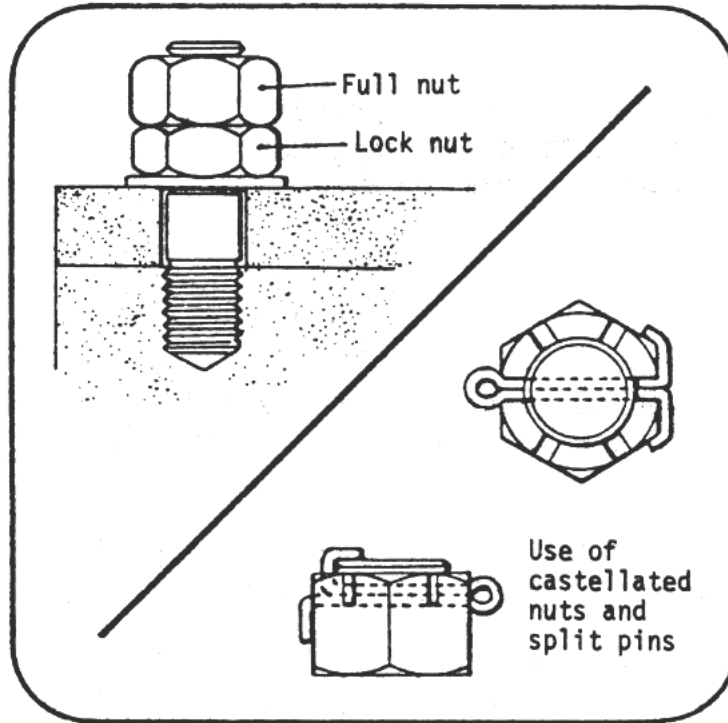
the part being secured.

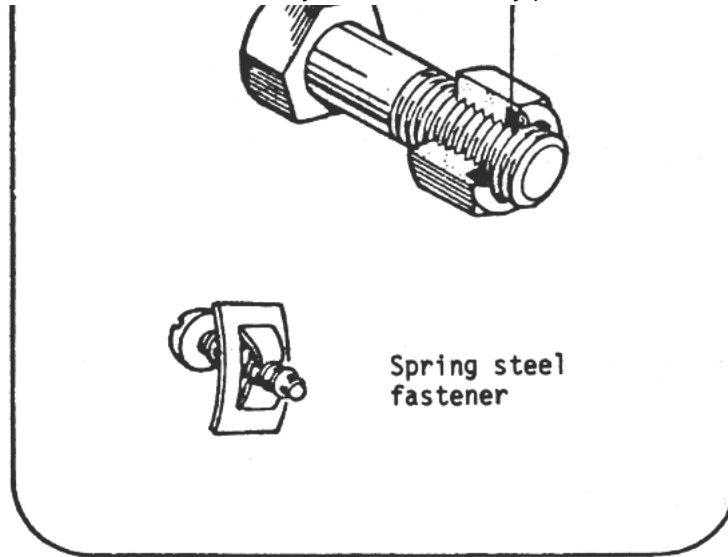
Ensure that the blade of the screwdriver is a good fit in slotted head screws or damage to the slot will result.

Ensure that the correct type of screwdriver is used when fitting hexagon socket/cruciform slotted screws.

#### FIG. 17 TYPES OF SCREWHEADS







## **NUTS**

**Standard hexagon nuts are manufactured in two thicknesses:**

- a. Full nut - used singly with or without a locking washer.**
- b. Lock nut - used to lock another nut into a fixed position on a thread.**

**Special-purpose nuts include:**

- a. Castellated nuts for use with split pins.**

- b. Self locking nuts with nylon inserts.
- c. Spring steel self locking fasteners.

### ***USE OF LOCK NUTS***

A lock nut is placed ***UNDER*** the main nut and tightened.

The main nut is run down on top of the lock nut and is tightened with one spanner while a second spanner prevents the lock nut from turning.

***NOTE:*** The practice of placing the lock nut on top of the full nut weakens the assembly as the smaller number of threads in the lock nut take the strain.

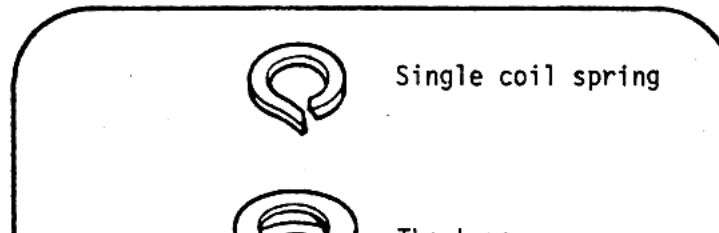
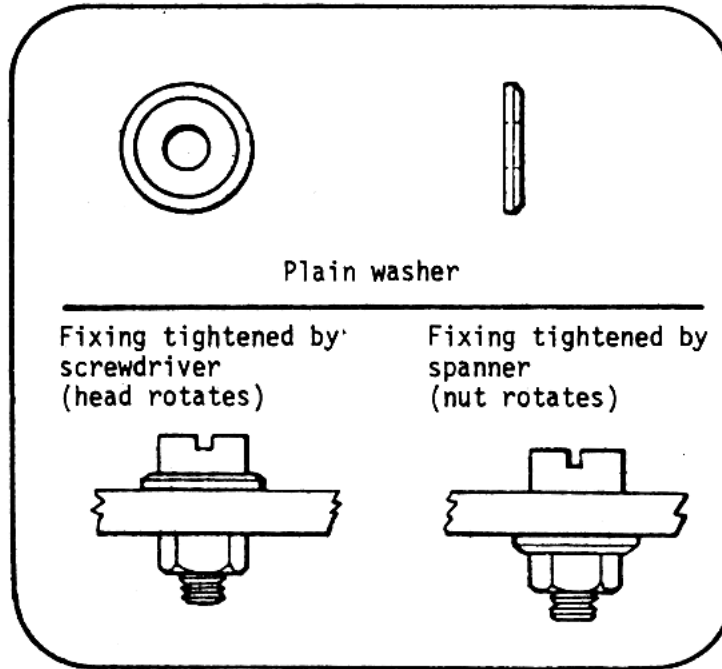
### ***USE OF CASTELLATED NUTS***

- a. Assemble bolt with castellated or slotted nut.
- b. Drill clearance hole through bolt shank in line with slots.
- c. Push split pin through hole until head meets nut.
- d. Trim split pin 'ends' to length.
- e. Bend ends tightly around nut.

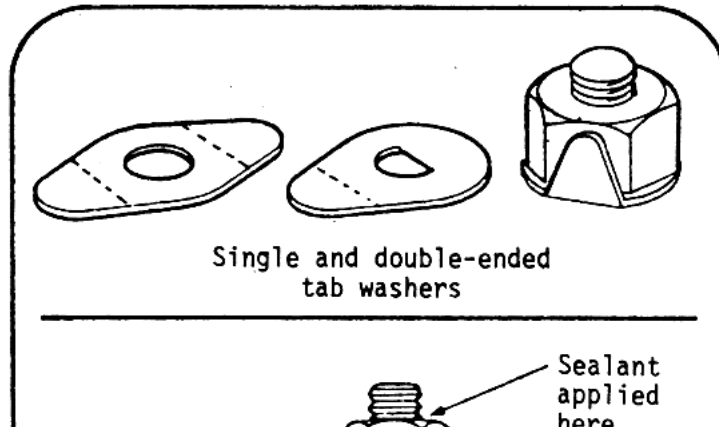
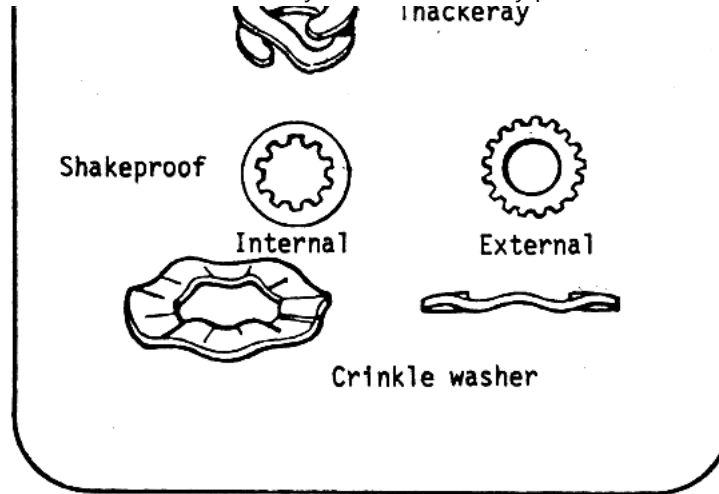
***NOTE:*** Do not use split pins more than once.

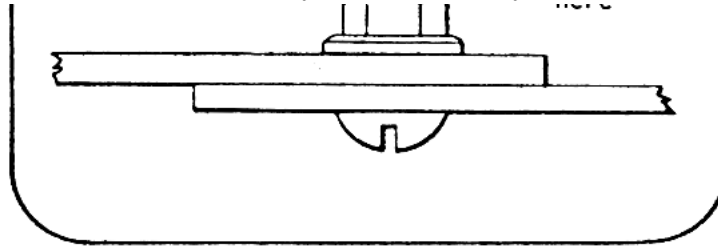
When used in conjunction with proprietary lock nuts, the screw should protrude by at least one thread.

### **FIG. 18 TYPES OF NUTS**



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## WASHERS

Plain washers are inserted under screw heads or nuts to provide a suitable bearing surface while tightening and to protect the component from damage due to rotation of the nut or screw head.

## LOCK WASHERS

Locking washers are used to prevent loosening due to vibration, movement or temperature variation. Common types include:

**SINGLE COIL** spring washers normally made of square section spring steel, cut, twisted and chisel-edged.

**THACKERAY DOUBLE COIL** spring washers made of flat section steel or phosphor bronze.

**SHAKEPROOF WASHERS** punched from spring steel. The outer or inner edge is slit radially in a number of places and the segments in between the slits are twisted so that several sharp edges bear against nut and work.

**CRINKLE WASHERS** made from beryllium copper are used where a lighter spring pressure is required.

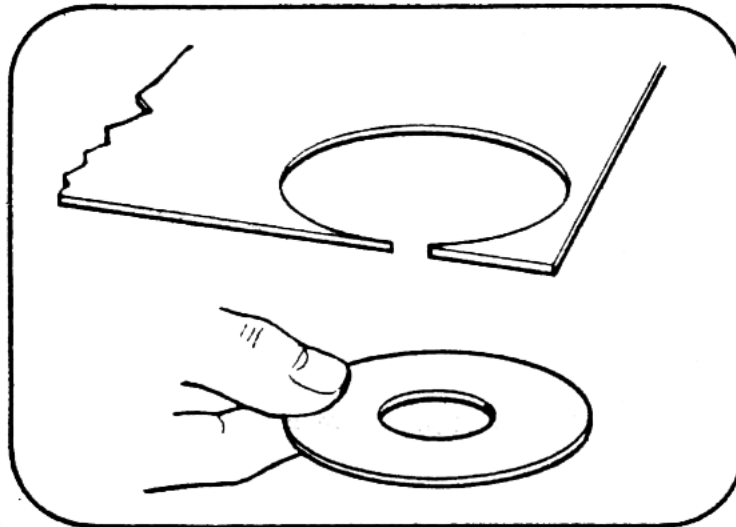
**TAB WASHERS**, used in special applications where a more positive locking action is required. The tab is bent up against the nut face, thus preventing it from turning.

### LIQUID SEALANTS

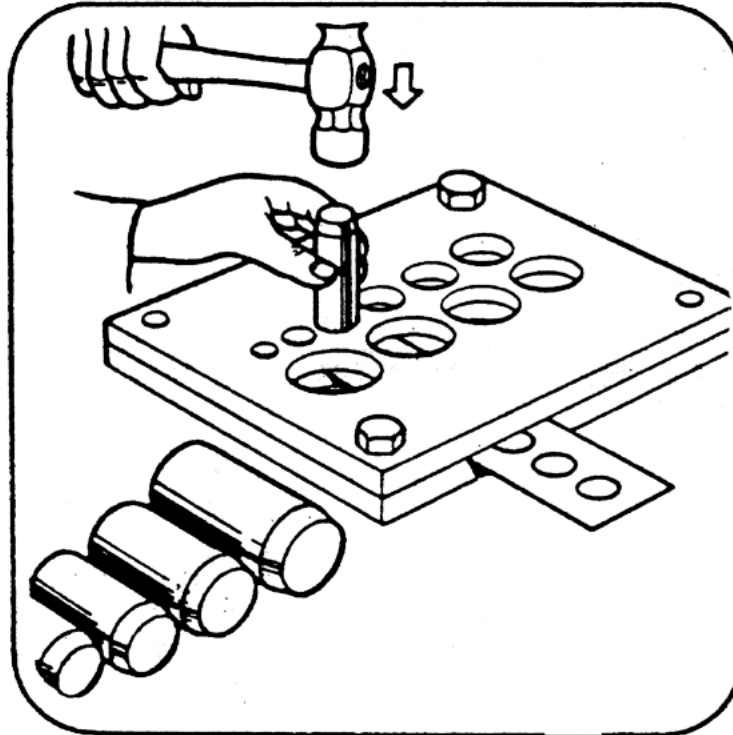
These may be used to provide a permanent lock to a fixing point.

The sealant should be applied to the point where the thread emerges from the nut, using a small brush or the nozzle of the sealant container.

### FIG. 19 TYPES OF WASHERS







**Ensure that shim is flat.**

**Holes can be punched in shim, using a close fitting plain punch and two plates bolted and dowelled**

**together.**

- a. Select a punch of the correct size.**
- b. Place shim between plates and align position of marked hole with hole in plate.**
- c. Place punch in hole and strike with hammer.**
- d. Remove punch, release plates and remove shim.**

### **FIG. 20 SHIMS USED AS PACKING**

**Bearings reduce friction between moving and stationary machine parts. They are designed for minimal wear, and by being replaceable, save wastage of expensive machine parts.**

### **HANDLING BEARINGS**

**The working surfaces of bearings are either honed or very soft; if these surfaces are damaged, the bearing is ruined, therefore:**

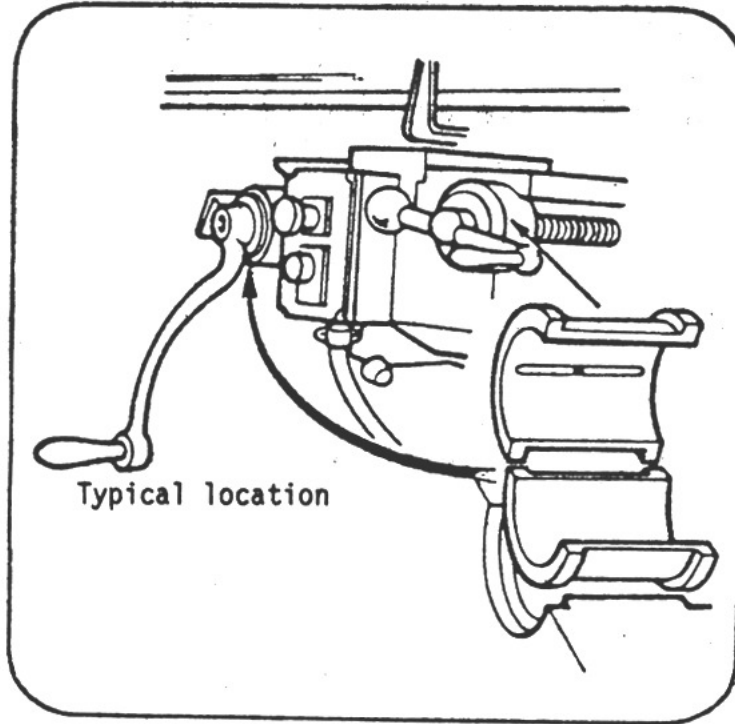
- 1. Handle bearings carefully to prevent damage.**
- 2. Keep bearings wrapped until fitted, to keep out dirt.**
- 3. Protect bearings against corrosion during storage, e.g. steel bearings must be oiled.**

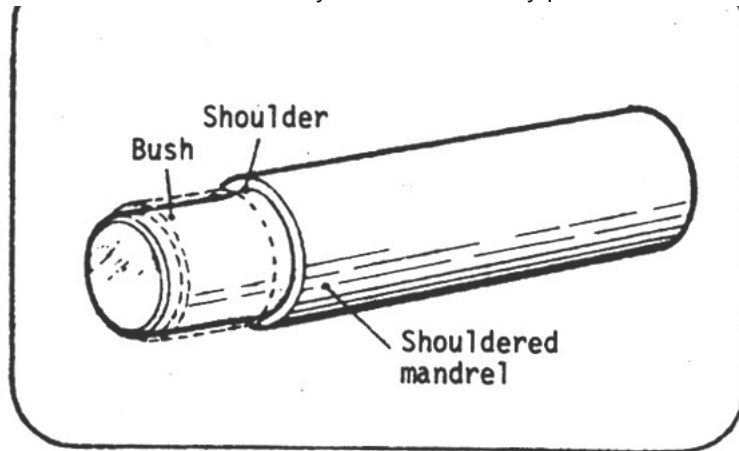
### **INSTALLING BEARINGS**

**Before any bearing is fitted:**

- 1. Clean the journal or housing thoroughly and the seatings of the locating devices.**

**2. Inspect the surfaces for damage, do not fit bearings to damaged surfaces.**





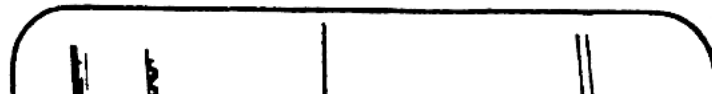
## PLAIN BEARINGS

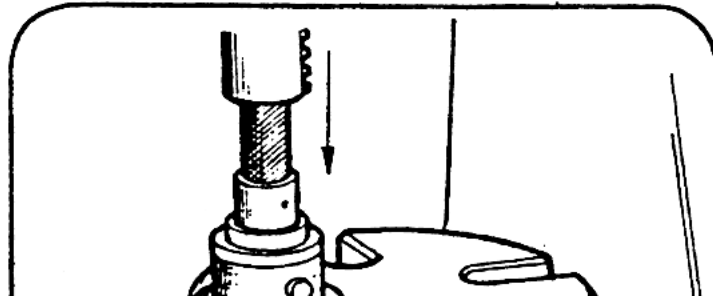
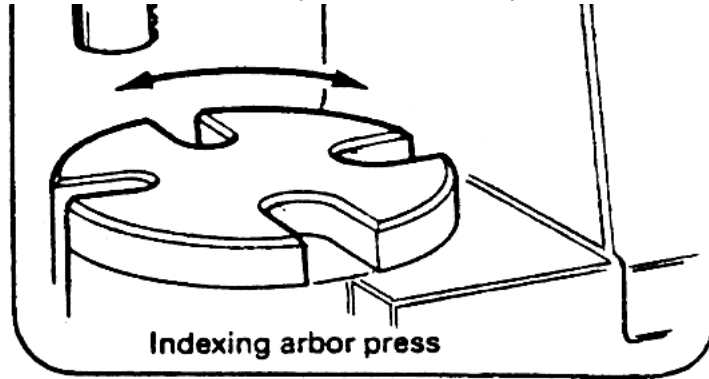
These are shells or bushes in which shafts run. They are made of different materials from the shaft.

## FITTING A BUSH USING AN ARBOR PRESS

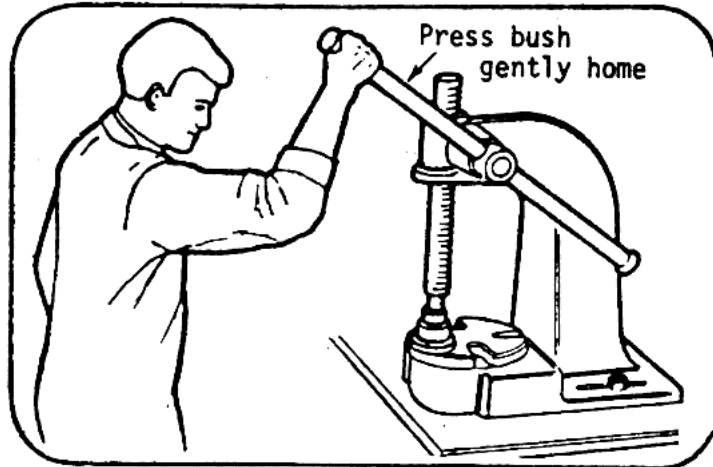
**NOTE:** A shouldered mandrel must be used when a bush is fitted, to prevent deformation. Use the correct size of mandrel.

## FIG. 21A TYPES OF BEARINGS





Maintenance systems for the dairy plant



- a. Clean the housing, the mandrel and the base of the arbor press thoroughly.
- b. Coat the housing and the mandrel with light oil.
- c. Index the base of the arbor press round to give the most suitable hole size.
- d. Fit the bush on to the mandrel.
- e. Align the bush with the housing and lower the ram on to the mandrel so that the ram holds the bush in position, above the housing.
- f. Check that the BUSH is square to the HOLE.
- g. Gently press the bush home with the lever.
- h. After fitting, check the internal dimensions.

**NOTE:** Some bushes are secured by locking compounds and only a light push fit is required. Indexing arbor press

#### **FIG. 21B TYPES OF BEARINGS**

Split shell bearings fit directly on to the shaft. A split shell bearing is fitted after removing the old shells and after cleaning the journal and the shell seatings. When putting the new shells into their housing, care should be taken for proper alignment of the oil holes. Prior to assembling, all parts must be coated with appropriate lubricants. The shaft should be running freely and the bearing should remain cool under running conditions.

Ball and roller bearings have a stationary and a revolving race between which rolling balls or rollers

**prevent sliding friction. The stationary race is usually a light push fit whereas the revolving race is a press fit; therefore it is fitted to the machine first.**

**When fitting a bearing, force is applied only to the race in contact with the housing or shaft. The race must be square to the shaft. Preferably arbor presses should be used for fitting bearings. Figs. 22A/22B/22C show the procedures used, illustrating the pressing of a bearing on to the shaft. The square machined tube should touch only the inner race.**

**Fig. 22C shows the pressing of a shaft into a bearing supported by the inner race only. The force must be applied to the outer race only when the bearing is pressed into the housing. Bearings should only be tapped into place when they cannot be pressed into position as shown in Fig. 22B.**

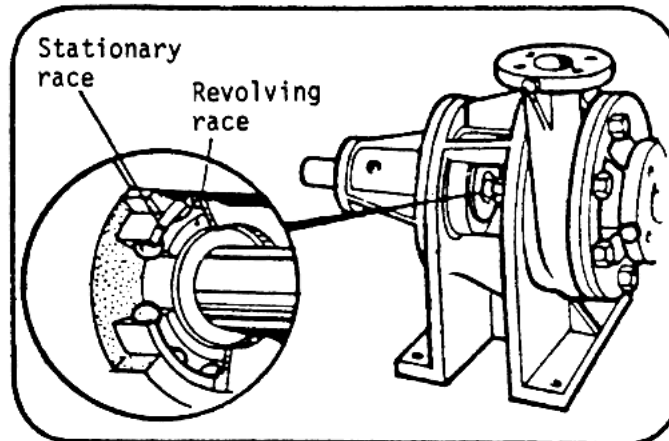
**In some instances locating devices are used to position bearings on shafts or in housings. They have to be cleaned, coated with light oil prior to use, and must only mate with the face that has to be located, holding the bearing evenly around its circumference.**

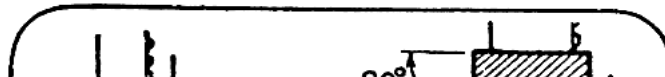
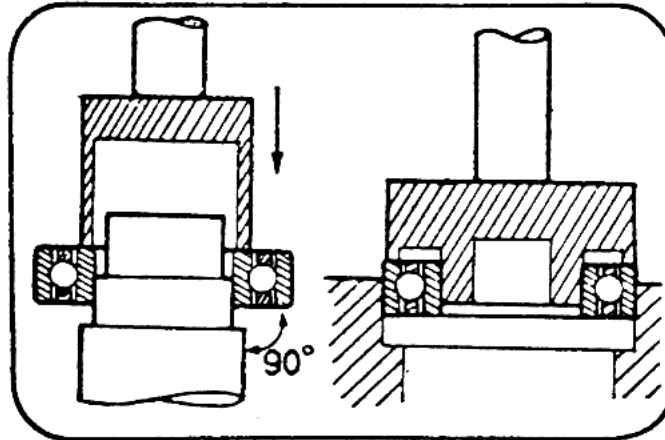
**Removal of bearings requires careful handling so that seatings and bearings for re-use are removed without being damaged. During removal force must be exerted only on the race being extracted, and pullers should never be clamped to the working surfaces of the bearings. Whenever possible arbor presses should be used for bearing removal, as when fitting bearings into position. If arbor presses cannot be used properly, selected pullers can be substituted for them, as shown in Figs. 23A/23B. Bearing removal screws are used in some housing equipped with tapped and countersunk holes behind the bearing. The holes are fitted with short screws to keep the threads clean. When removing the bearing these screws should be removed from the holes, and the same number of longer screws fitted and tightened equally by small amounts to remove the bearing slowly from its housing (Fig. 23B).**

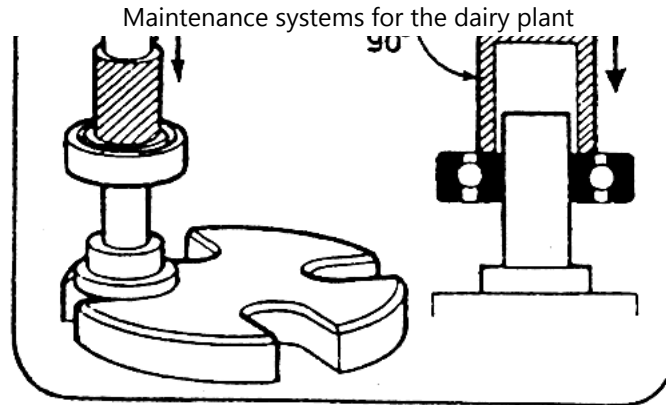
**Handling and maintenance of bearings, particularly ball and roller bearings, require the greatest possible care, as do all critical mechanical parts, mainly to avoid mechanical abuse and corrosion. As far as possible bearings should be protected against moisture. When moisture is present the selection of proper lubricants can help to run the bearings successfully under these more severe conditions.**



**Discoloration and metal smearing is an indication of a bearing operating with inadequate lubrication. Temperature is usually considered a fair indication of the condition of the bearing, although grease lubricated bearings can operate at temperatures as high as 80° to 90°C. The temperature at which the bearing can work depends mainly on the type of lubricant used. In most cases in milk processing machines the temperature of the bearings does not exceed 50°C under normal operating conditions. This can be felt by placing the hand lightly against the housing or the shell of the bearing. If it feels hot, the bearing should be inspected more closely. Wear of properly selected and properly lubricated bearings occurs only when foreign matter mixes with the lubricant and distorts the alignment of the races. Dirt causes most of the early bearing failures.**







## **BALL AND ROLLER BEARINGS**

**These bearings have balls or rollers which prevent sliding friction by rolling between the races.**

**As bearings are used between stationary and revolving machine parts, such bearings have a stationary and a revolving race.**

**Normally, the revolving race is a press fit, so it is fitted to the machine part first, and the stationary race is a light push fit, so it is assembled with the machine part.**

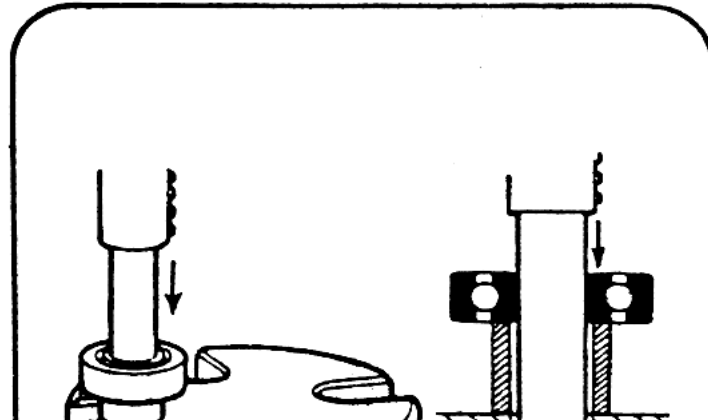
**Bearings are precision-made of hard, brittle materials. Therefore, when force is applied to fit them:**

- 1. Coat the journal or housing with clean, light oil.**
- 2. Only apply force to the race in contact with the housing or shaft.**

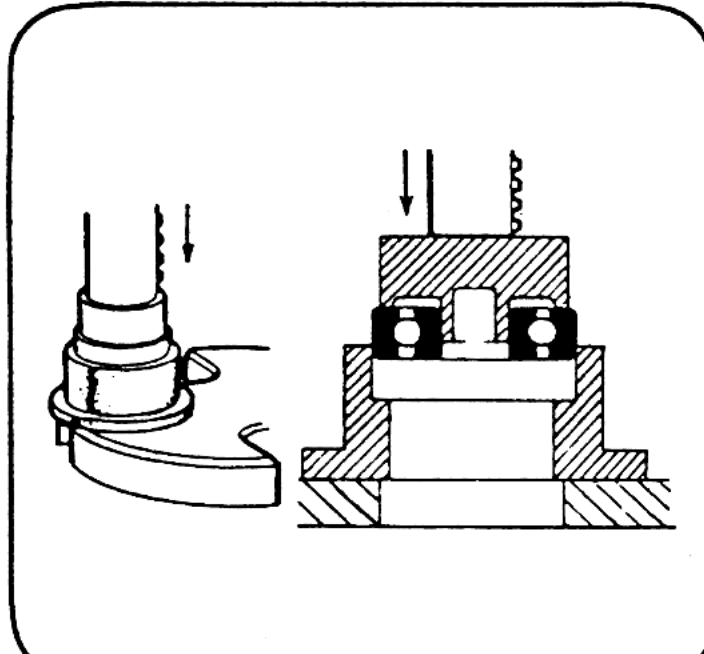
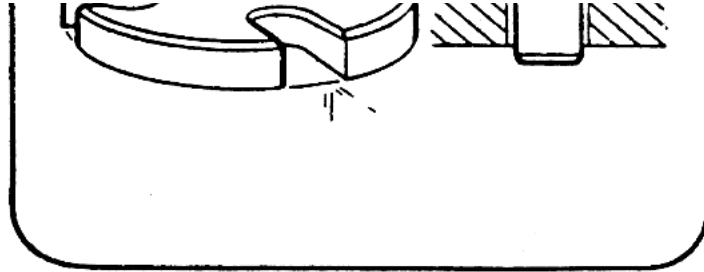
**3. Keep the bearing square to the housing or shaft.****FITTING A BEARING, USING AN ARBOR PRESS**

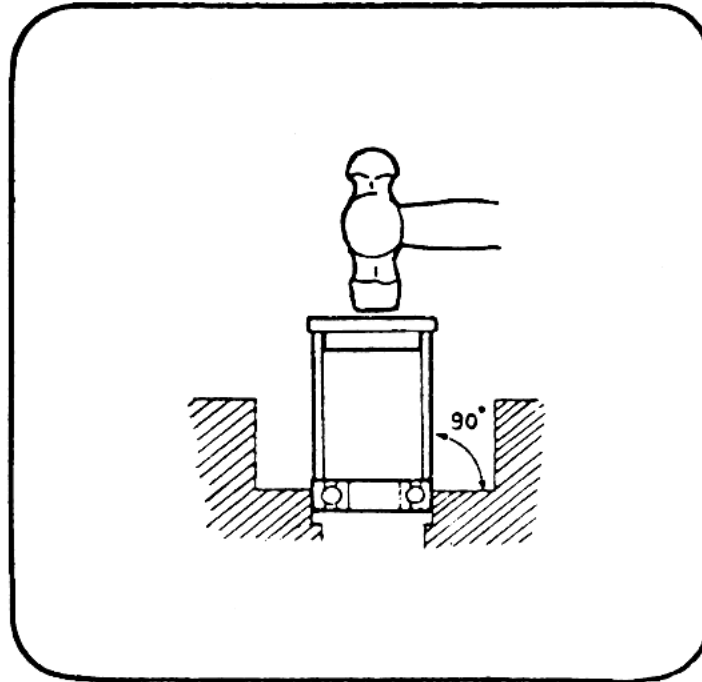
**1. Whenever possible, use an arbor press, because it keeps the bearing square to the shaft or housing. Decide which is the best way to set the job up on the press:**

- a. **Pressing a bearing onto a shaft. Use a tube to distribute the force evenly to keep the bearing square to the shaft. The tube must only touch the inner race and its ends must be machined square.**
- b. **Pressing a shaft into a bearing. The bearing must be supported by the inner race only.**
- c. **Pressing a bearing into a housing. A tube or flat block must be used so that the force is applied to the outer race only.**

**FIG. 22A FITTING BEARINGS**

Maintenance systems for the dairy plant





**2. Operating the press.**

- a. Set up the part on the base of the press.**

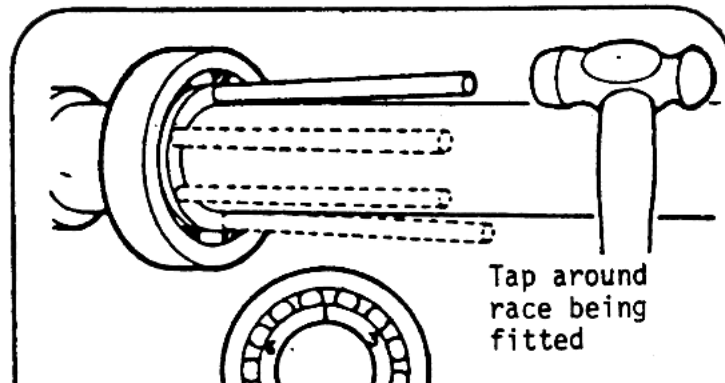
- b. **Align the part to be pressed into place and lower the ram to just hold it.**
- c. **Check that the parts are square to each other.**
- d. **Gently press the bearing home.**
- e. **Check the bearing is positioned correctly.**

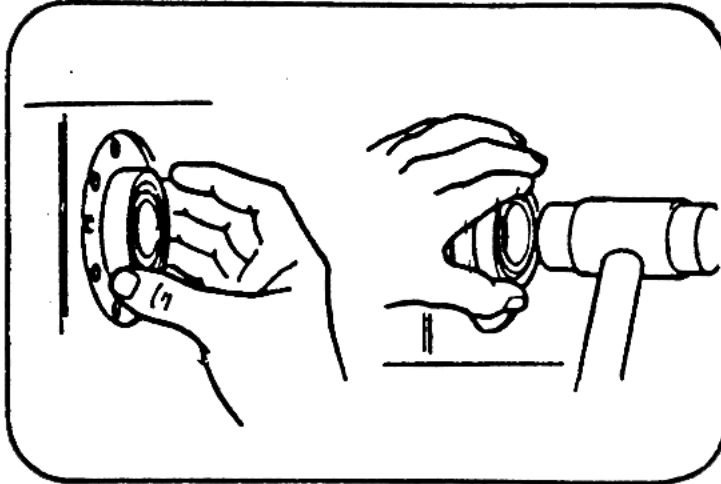
### TAPPING BEARINGS INTO PLACE

Bearings should only be tapped into place when they cannot be pressed into position. Decide which is the best method.

1. **Using the tube and striking block. This is the best method, since the bearing can more easily be kept square to its seating.**

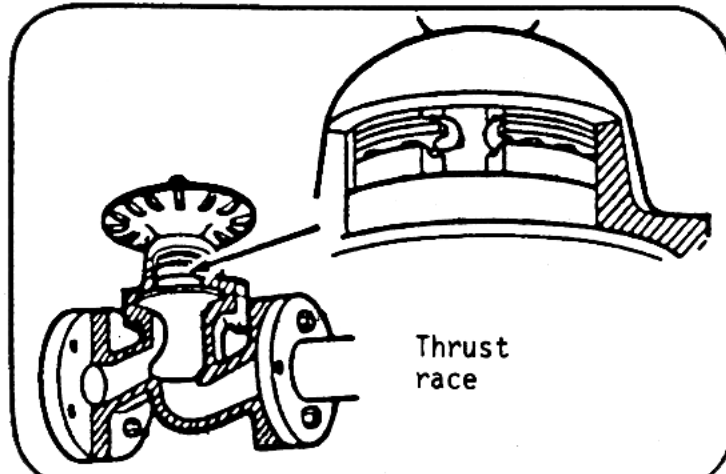
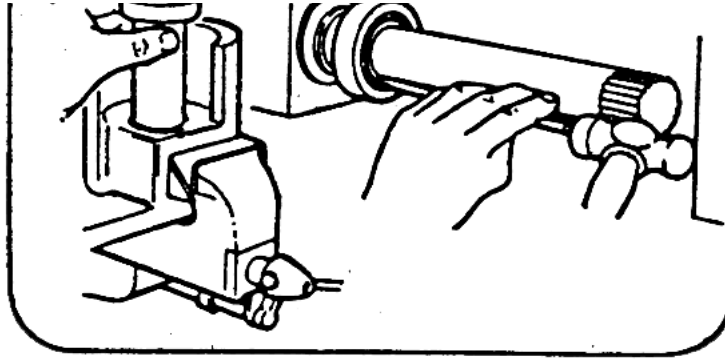
**FIG. 22B FITTING BEARINGS**







Maintenance systems for the dairy plant



**2. Using a drift. Tap evenly around the race being fitted. Take care to keep bearing square to seating.**

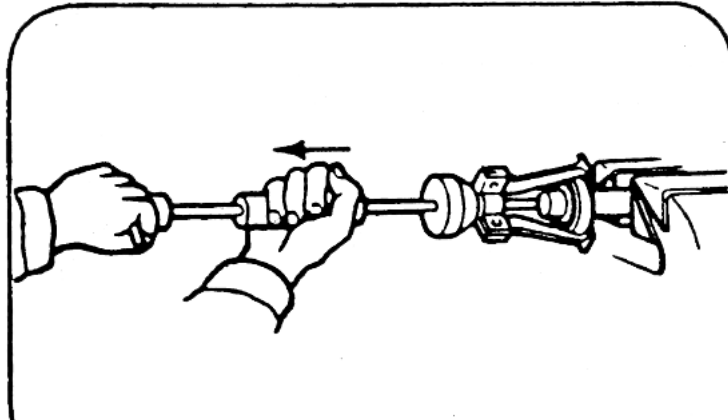
The method is useful when the seating is in an awkward situation. Take care to prevent foreign matter from entering the bearing.

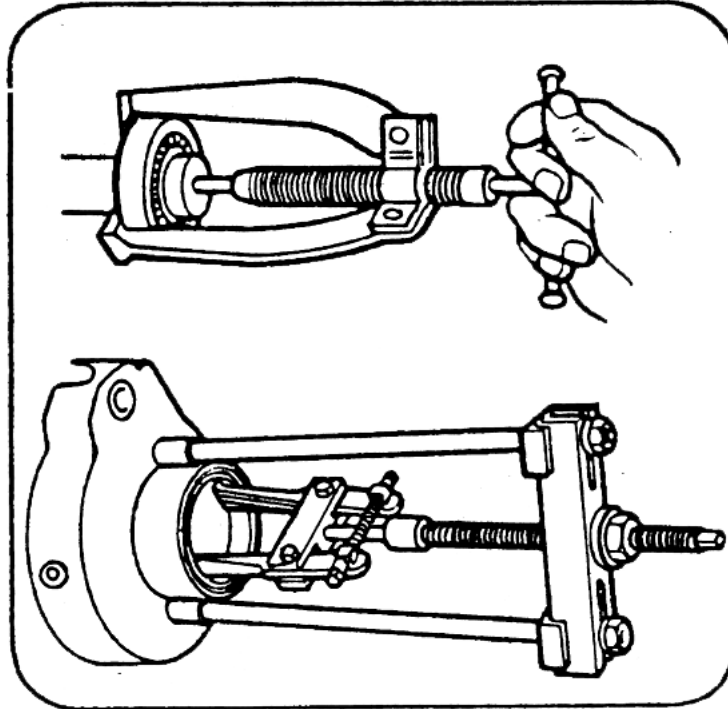
- a. Align the bearing with its seating and start to fit it by hand. A soft mallet may be used if necessary.
- b. Tap the bearing home gently, stopping frequently to check that it is square.

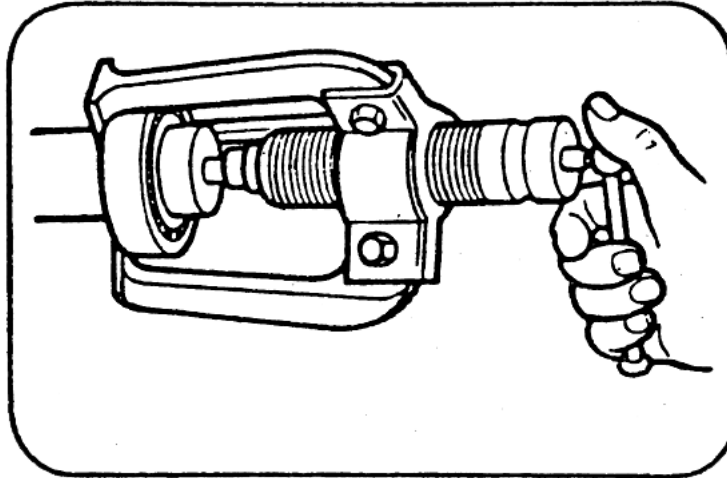
### THRUST RACES

Thrust bearings are ball or roller bearings specially designed to take end loads only.

**FIG. 22C FITTING BEARINGS**







## USING BEARING PULLERS

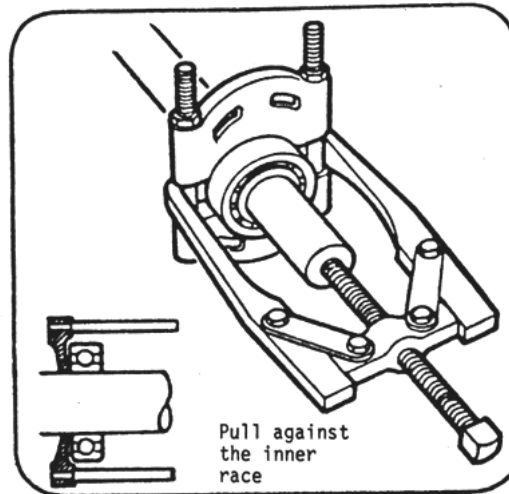
When using bearing pullers take care to keep the bearing square to the shaft.

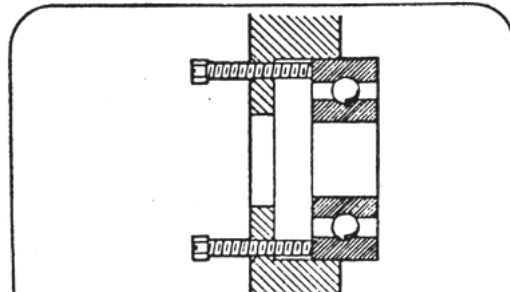
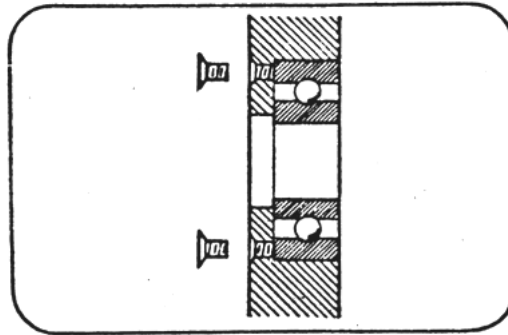
a. Select the most suitable puller:

- i. Impact pullers are only suitable for small bearings; the weight must be held when it is tapped against the stop.
- ii. Screw pullers are suitable for most purposes: take care to keep the puller square when turning the screw.

- iii. **Hydraulic pullers are to be used when a large force is required.**
- b. **Arrange the pullers inside or outside the bearing as required.**
- c. **Fit the puller and tighten it to hold it in position.**
- d. **Check that the puller is square and bearing only on the correct surfaces.**
- e. **Pull the bearing slowly. Stop frequently to check that the bearing puller is square.**

**FIG. 23A BEARING PULLERS**







## **PULLER PLATES**

**When a bearing mounted on a shaft is to be re-used, a puller plate should be used so that the force is exerted against the inner race.**

## **BEARING REMOVAL SCREWS**

**Some housings have tapped and countersunk holes behind the bearing. These holes are normally fitted with short screws to prevent the threads becoming blocked with dirt.**

**To remove the bearing:**

- a. Remove the screws from the holes.**
- b. Select the same number of screws that will fit the holes and are long enough to remove the bearing.**
- c. Fit the longer screws and tighten them equally by small amounts to remove the bearing slowly from its housing. Take care to keep the bearing square to its housing.**

## **FIG. 23B BEARING REMOVAL SCREWS**

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