Maintenance Strategy Development in the UK Food and Drink Industry

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Introduction

The penetration of maintenance engineering "Best Practice" within the United Kingdom (UK) food and drink are weak and inconsistent. In general, UK food and drink production facilities are secretive with regard to dissemination of maintenance strategies, are unaware of advances in engineering and maintenance methods and are reluctant to embrace new methods and technologies to improve their production process and thus increase their share of the world market. As a consequence, any novel technology or process needs to be well proven before becoming adopted by food companies.

Since 1990, several studies have been completed in the UK that has identified the need for the implementation of better maintenance practices. While there is no doubt that some organisations have taken this on board and achieved significant measurable benefits, the following conclusions are applicable to the majority of organisations (including the food sector). It costs approximately £20 billion per annum to maintain plant and equipment in the UK alone. Even small improvement should result in significant benefits. In the UK the food and drink sector employs approximately 900,000 people and has a manufacturing turnover of £20 billion a year. Recent surveys have shown that approximately **70% of food and drink industry still operates a breakdown maintenance system** and that the available technologies are not being used as effectively as they should be. Organisations claiming to have a "planned" maintenance programme seldom meet their targets, usually because of unexpected breakdowns. While some organisations have successfully implemented some of the available tools and technologies, they are not in common use, and methods need to be devised to assist with the process of implementation. One of the major problems is the difficulty of recording and passing on intellectual capital of the workforce.

Designing and implementing a correct maintenance strategy is essential for a company's competitiveness. Large companies take advantage of modern maintenance practices and technologies to improve their production responsiveness and flexibility. SMEs, especially in the food-processing sector, have been largely unable to implement such strategies. In response to the problems outlined above the main objective from the University of Sunderland is to **assess the effectiveness of existing maintenance practices and to develop appropriate maintenance strategies, which will help, reduce the cost of production and maintenance and improve productivity.** The new strategy will stimulate the development and application of more energy efficient technologies and business practices for use throughout the company whilst not compromising food safety and quality.

Key Objectives

- To identify critical equipment which effect system performance and availability.
- To identify the range of maintenance practices which organisations are using to maintain their refrigeration equipment.
- To assess the effectiveness of existing maintenance practices thorough relevant maintenance related metrics.
- To identify a range of modern maintenance strategies which will increase the performance/availability of refrigeration equipment.

Analysis

The objectives have been divided into seven work packages. The following section describe each work package, the data collection and analysis.

WP1. Develop relevant maintenance related metrics for the refrigeration context, i.e. OEE

Overall Equipment Effectiveness (OEE) is used to target the major losses associated with poor maintenance practices. The maintenance performance indicators are a measure of equipment availability, performance rate and quality rate. OEE addresses all losses caused by equipment faults, and many companies recognize the important role OEE plays in determining bottom-line results. The OEE calculation (see table one) is used as an index for measuring maintenance performance. The model is organized in a structured and systematic way because it starts with the general elements such as quality, productivity and availability then examines the low-level maintenance losses such as reduced speed and defects. An advantage of OEE is that it provides a benchmark from which to start a maintenance initiative by providing one simple figure from three functional and important areas.

However, OEE, on its own, is not comparable for the food industry as it is difficult to examine slow running equipment or idling time within the refrigeration context. Therefore, a derivative of OEE was used to determine “availability and performance”. Also, in order to provide a “true cost” the energy consumption, where possible, was collected using Hawk Meters were used to monitor electricity supply and consumption by means of safe, non-contact current transformers.

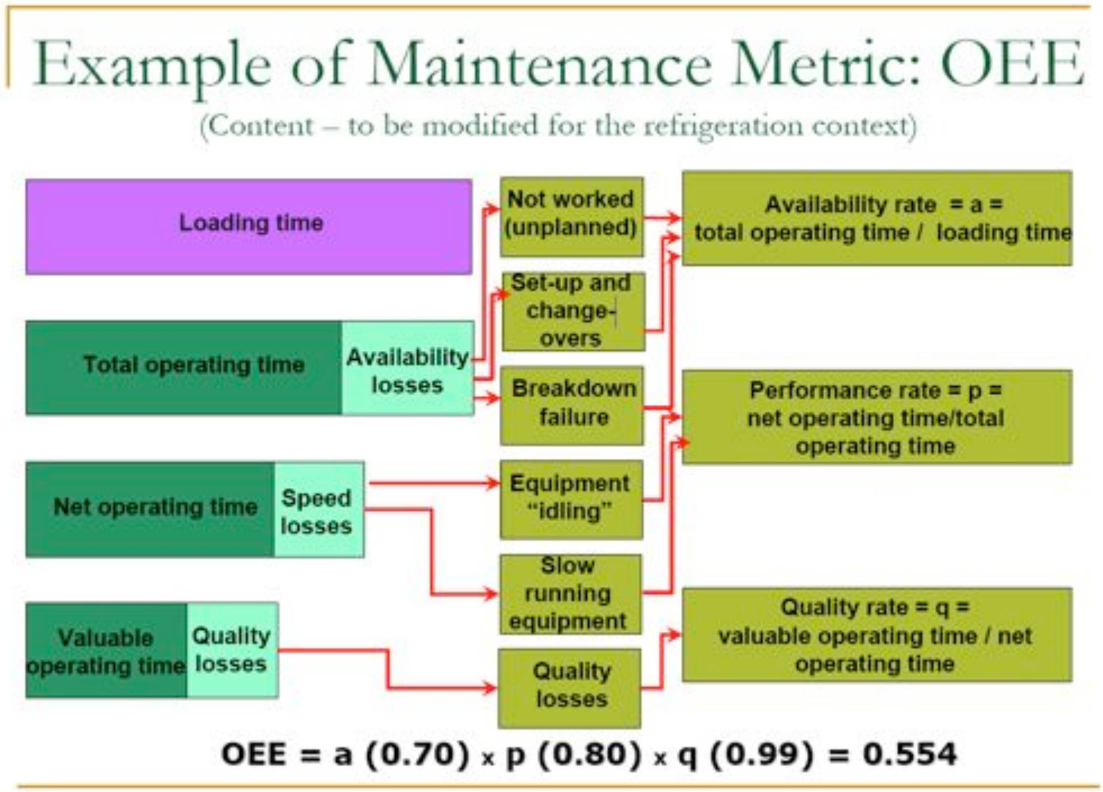


Table one. Example of an OEE calculation

WP2. *Identify two companies who are currently using each of the 10 ranked processes (identified by Bristol University). Collect data from these organisations using (1) the developed metrics to assess equipment criticality and performance/availability and (2) questionnaires and interviews with key respondents to identify existing issues/practices and the barriers to the development and implementation of new maintenance strategies.*

Initially a target group of five companies comprising of nine sites were identified. These companies were in Bristol, Cambridge and Northern Ireland. To obtain background information questionnaires were distributed to 120 staff within the chosen companies. Eighty two completed questionnaires were returned. The aim of the questionnaire was to identify, but not be restricted to, the following:

- What is the company maintenance strategy?
- Are equipment records kept, used and updated?
- Does management believe this approach to maintenance is the most appropriate method?
- What are the factors that influence the company when deciding upon implementing or not implementing maintenance improvement initiatives?
- What would be the impact upon the culture, workforce and management by the adoption of a new maintenance strategy?

- Is the management aware of modern maintenance practices such as TPM?

To support (or not support) the questionnaire findings interviews were carried out with 8 senior managers from each company (one person managed two sites). The interviews followed a similar structure in that the same questions were asked to interviewees but additions were included from previous interviews.

WP3. *Data Analysis Phase- assess the suitability of existing maintenance practices: and identify areas for improvement which contribute to increased equipment performance and availability.*

The findings confirmed what was largely expected in that the majority of SMEs operated a reactive maintenance system, which was largely configured to respond to breakdowns. Although a reactive approach was the dominant maintenance system, several companies did have a mixture of reactive, planned and condition based. Table two identifies the respondents approach to maintenance; the figures indicate the main method of maintenance.

Size	Reactive	Planned	Condition Monitoring (Predictive)
Small	**(86%)**	**(9%)**	**(5%)**
Medium	**(73%)**	**(20%)**	**(7%)**

Table 2 Respondents approach to maintenance

The majority of the respondents believed that their maintenance practices did not have a direct impact upon their profitability. Additionally, many also believed that production schedules and performance would be adversely affected by the introduction of a new maintenance initiative. The lack of maintenance planning, or identifying areas where maintenance is important, has produced maintenance system which neither optimize the maintenance tasks or find an optimum balance between the costs and benefits of maintenance, therefore resulting in an ad hoc maintenance system which is a mixture of reactive, preventive and condition based.

There would appear to be a strongly held perception amongst the majority of the respondents, that the reactive paradigm is acceptable as it ensures that the only time spent on maintenance is when faulty equipment is being repaired and this is considered as beneficial to production. Knowledge of the central argument which is used to justify a planned/preventative maintenance approach and which advocates that the frequency of breakdowns be reduced because of its adoption would appear to be missing from the responses. The case study respondents, who employ a purely reactive system believe the cost of maintenance is kept relatively low because costs, work force and finances, are only incurred when something breaks

At this stage Diagnostic Solutions (DSL) were appointed to assess a variety of methods for monitoring refrigeration plant condition and reliability and thereby increase the amount of “live” data.

Two companies were chosen as candidates for the assessment process, both within the dairy processing manufacturing sector.

In addition to the above 2 sites, DSL were already monitoring a number of Chilled Distribution Centres (CDC) as part of an on-going commercial refrigeration monitoring service. DSL have installed and fitted 12 on-line monitoring systems within a number of sites under sub-contract to STAR Refrigeration of Glasgow; this monitoring project has been on-going for 2 years.

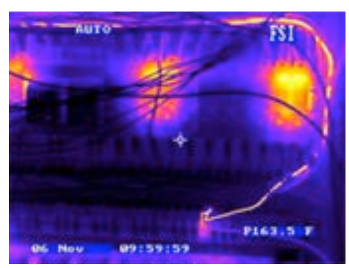
Methods and Technologies Considered

CbM methods were tried in two distinct technology blocks. The first attempted to use very basic and low cost methods to predict food manufacturing plant health. The second phase involved advanced CbM methods and technologies.

Basic Technologies

- Hand Held Meter (ISO 10816 Velocity and Enveloped acceleration overall levels)
- Laser sighted temperature gun
- Some oil sampling.

Advanced Technologies



- Vibration Spectral methods (Velocity, acceleration, ESP, Acoustic Emission)
- Electrical panel thermography
- Full spectrographic Oil analysis
- Fixed sensors to measure the vibration levels from inaccessible plant

Vibration Analysis overview

Vibration measurement systems fall into the following categories:

Single Value Methods	Time Frequency Methods
• Hand Held meters	• Hand Held Data-collectors
• SPM Units	• Spectrum Analysers
• Acoustic Emission Units	• PC Analysers

• Vibration Pens	• On line systems
• 4-20mA sensors	

Single Value Measurements

The variety of single value measurements is endless, from the ISO filtered levels mentioned in ISO 10816 [1] to the 'magic numbers' offered by some of the technology vendors; promising to solve all of your plant condition problems within one simple solution.

Please note single value methods are either 'generic' or 'specific'. The generic case is where a value will indicate the presence of 'a problem' but cannot categorise the problem into a specific fault (e.g. Unbalance, looseness, misalignment, cavitation, etc.). The specific methods concentrate on issues such as bearing faults and try to eliminate the influence of 'other' faults through the use of algorithms and electronic design.

Table 3 outlines the more common types of measurement with comments on applications and a brief technical description of the method.

Single Value Method Summary		
Method	**Description**	**Applications**
ISO Filtered Velocity	2Hz – 1kHz filtered Velocity	Works as a general condition indicator.
SPM	Carpet and Peak related to the demodulation of a sensor resonance around 30kHz.	One of the better single value bearing indicator methods. Some problems on larger bearings and gear units.
Acoustic Emission	Distress & dB, demodulates a 100kHz carrier which is sensitive to stress waves.	Better general indicator than ISO velocity, without the ISO comfort zone.
Vibration Meters / pens	Combine velocity, bearing, acceleration, temperature and occasionally speed.	Look for ISO Velocity, envelope & enveloped acceleration.
4-20mA sensors	Filtered data converted to DCS/PLC compatible signal.	ISO velocity, g's envelope Can be used to 'home in' on specific problems by filter selection.

Table 3 Single Value Method Summary

Single value vibration methods have two major advantages and only one real disadvantage; these are low cost, simple interpretation and lack of accuracy respectively. The overall CM system implications of single value methods are discussed within the later sections of this text.

Single value data are easy to trend and interpret as shown by Figure 4 below.

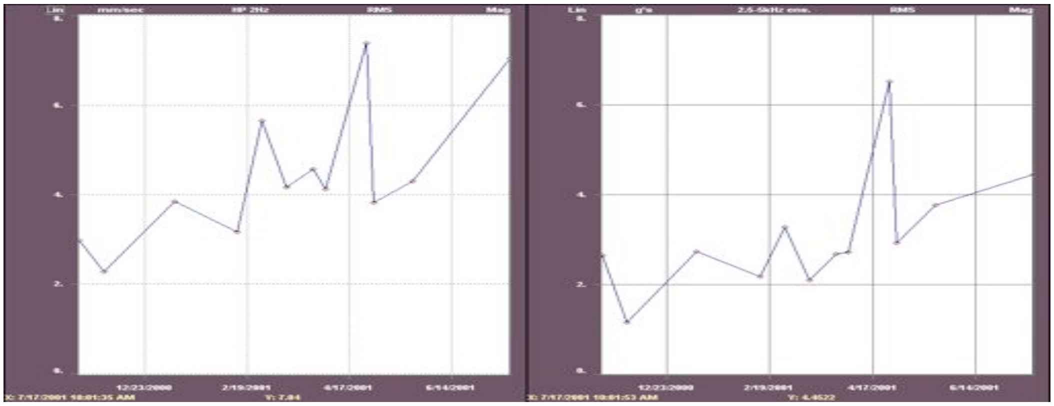


Figure 4 – Example overall trend plots

Spectral vibration measurements

This type of measurement involves the detection and display of specific components of a time history sensor output. The use of specific frequency components lends itself to the detection of faults down to a single mechanical component (e.g. bearing, gear, and impeller). Once again, various methods, techniques and signal conditioning systems are used to detect specific components of the raw time history data.

Velocity (Mid Frequency)

The most commonly used method for fault identification, mainly due to the scalar consistency of the method (i.e. 25mm/s is high almost irrespective of the machine type). Used to detect signs of mechanical problems in the frequency range 20Hz – 2000Hz. Detection capabilities cover the following fault conditions.

Unbalance, Misalignment, Looseness, Resonance, Cavitation, Blade problems, Turbulence

Acceleration (High Frequency)

Amplitude Demodulation Methods (often called enveloped acceleration or ESP)

Used to extract impacts from the standard acceleration spectra, through the extraction of amplitude-modulated components and the display of those demodulated components on an FFT plot. This process is illustrated within Figure 5.

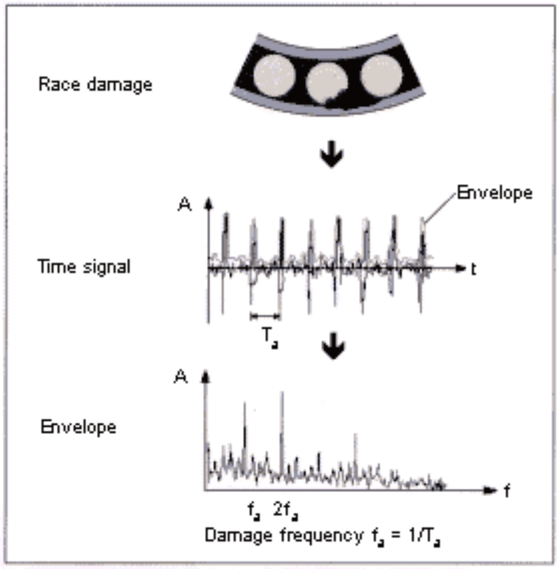


Figure 5 Enveloping Diagram

Impacts are created as a rolling element collides with a damaged area.

These impacts show as transients within the time domain. The Demodulator extracts these transients.

Extracted impact frequencies are then displayed on an envelope spectrum (shown opposite)

Discussion of Results

Between 3 and 4 visits were made to each of the 2 evaluation sites and the associated data summary spreadsheets are shown as Appendices 1 and 2 to this text.

A number of problems were observed within company 1 relating to the freeze drier unit fans in particular, however the problems were not severe enough to warrant immediate maintenance intervention during the course of the CbM assessment within this facility.

The main problem observed within company 2 related to a blower unit that went from 'high bearing levels' to replace the bearing. An overhaul of this blower showed badly damaged motor bearings. In both of the above cases when discussing assets with the companies; the assets in question were critical and would cause serious downtime if they failed in service.

Most of the 1st line refrigeration system comprises circulation/cooling pumps and refrigeration compressors. The only observed problem during the assessment period related to misalignment on one of the company 1 Chillers. This is supported by the data collected by DSL over the last 24 months from STAR refrigeration (CDC sites). In short the compressor assemblies themselves all demonstrate a high level of reliability.

The Table 6 below shows the number of faults rectified within the 24 months of monitoring the CDC sites compressor sets every 2 hours.

Major Motor Faults	Minor Motor Faults	Compressor Faults
4	9	0

Table 6 24 month on-line monitoring summary

The core of any refrigeration plant is the chiller compressor set, this also constitutes the most expensive and safety critical element in the refrigeration chain. Experience within this DEFRA project and throughout the last 24 months of on-line monitoring has resulted in the following conclusions from a reliability viewpoint:-

- Motor bearing and coupling problems cater for 100% of the problems observed
- Compressor data should be collected close to 100% load

The following recommendations are made based on the assessment completed within this project and the experience DSL have gained over the last 2 years of monitoring refrigeration compressor related equipment:-

- Low cost on-line monitoring is ideal to ensure compressor data are measured under load
- It would be more efficient to log compressor process and energy data at the same time as vibration such that all pertinent data elements could be compared and analysed
- Spectral vibration is required to adequately categorise the failure modes, hence at the very least a monthly walk around vibration assessment would be required.

Final observations

The cost of surveillance systems through the use of wireless data transmission and battery power has changed the condition assessment and energy monitoring market place. DSL believe that further developments in low-cost surveillance and web based monitoring software represents the best possible method for determining reliability and efficiency of refrigeration plant. Therefore, a new approach to maintenance is required which is developed from the maintenance needs of the equipment and the limited available resources. Due to the aforementioned barriers the new methodology must be:

- Simple in structure.
- Outline clear links between the processes.
- Systematic and easily understood.

Ongoing work

WP4. *Identify and develop appropriate maintenance strategies for the processes/equipment which offer the greatest potential to increase equipment performance and availability using a combination of modern maintenance practices and appropriate technology.*

WP5. *Develop a structured implementation process map for each of the selected processes.*

WP6. *Implement and evaluate the feasibility of the two new strategies within each case study. However, the extent of the implementation phase will be dependent upon company agreement to implement change and the equipment costs involved. i.e. no money has been allocated for the CBM equipment in the budget as the exact* *requirements are unknown at this stage. It may be that separate funding is required and this could be sought within stage 3.*

WP7. *Feasibility Report*.

Conclusion

The data collection exercise and the data collected by Diagnostic Solutions Ltd has shown that a new approach to maintenance is required. This new approach will need to embrace new and relatively inexpensive technologies, outlined above. The use of Condition Bases Maintenance (CBM) techniques such as vibration analysis, thermal cameras or oil analysis can be used to determine objectively the condition of machines and can predict failures. However their application is dependent upon cost to purchase, the ease of use (intrusive or non-intrusive) and the ability of the company to collect, analyse and determine maintenance. However, the diagnostic capabilities of predictive maintenance technologies have increased in recent years with advances made in sensor technologies. These advances in component sensitivities, size reductions, and most importantly reduced cost, have opened up an entirely new area of diagnostics to the maintenance engineer and equipment operator.

Two case studies are being carried out. Initially a benchmarking exercise will be undertaken to determine:

- Current OEE data
- Current Energy consumption data per one or two critical components
- Map new maintenance strategy

Finally a new approach will be implemented using available technologies to record equipment effectiveness, the data collected will be used provide OEE figures to determine if the new technologies are successful and if maintenance, manufacturing and energy costs have decreased.

Case Study one:

PLANT CONDITION REPORT - CRIT 1		FEB 08		ALARM STATUS			
	ASSET	Reference	Note	Feb 08	Jan 08	Dec 07	Nov 07
Services Area				☐	☐	☐	☐
DX1	Motor Comp Unit DX1			☺	☺	☺	☺
DX2	Motor Comp Unit DX2			☺	☺	☺	☺
Sabro A	Sabro Pack A			☺	☒	☺	☒
Sabro B	Sabro Pack B			☺	☒	☒	☒
Sabro C	Sabro Pack C			☒	☒	☺	☒
Sabro D	Sabro Pack D			☒	☒	☒	☒
HydroV 3	Hydro Vane Motor 3			☺	☺	☺	☺
HydroV 6	Hydro Vane Motor 6			☺	☺	☺	☺
HydroV 7	Hydro Vane Motor 7			☺	☺	☺	☺
HydroV 11	Hydro Vane Motor 11			☺	☺	☺	☺
HydroV 12	Hydro Vane Motor 12			☺	☺	☺	☺
Effluent Area				☐	☐	☐	☐
Blower 1	Air Blower Unit 1			☺	☒	☒	☒
Blower 2	Air Blower Unit 2			☒	☺	☺	☺
Blower 3	Air Blower Unit 3		Mtr DE	☒	☒	☹	😐
Blower 4	Air Blower Unit 4			☺	☺	☺	☺
Blower 5	Air Blower Unit 5			☺	☺	☺	☺

KEY to REPORT Icons		
	Good Condition	☺
	Alert MINOR	😐
	Action MAJOR	☹

	Not Available	☒		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PLANT CONDITION REPORT - CRIT 1		**FEB 08**		**ALARM STATUS**											
	ASSET	**Reference**	**Note**	**Feb 08**	**Jan 08**	**Dec 07**	**Nov 07**								
Cold Store Area				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 001A			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 001B			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 001C			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 002A			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 002B			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 002C			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 003A			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 003B			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 003C			☺	☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐
	Motor Chill 004A			☺	☺	☺	☺								
	Motor Chill 004B			☺	☺	☺	☺								
	Motor Chill 004C			☒	☒	☒	☺								
	Motor Chill 005A			☺	☒	☒	☒								
	Motor Chill 005B			☺	☒	☒	☺								
	Motor Chill 005C			☒	☒	☒	☒								
	Motor Chill 006A			☺	☺	☺	☺								
	Motor Chill 006B			☺	☺	☺	☺								
	Motor Chill 006C			☺	☺	☺	☺								
				☐	☐	☐									

PLANT CONDITION REPORT - CRIT 1	**FEB 08**	**ANALYSIS**		
		COMMENTS	**ACTION**	**COMPLETED**

	ASSET	Reference	STATUS			
	Blower 3	1	☹	Motor DE brg envelope g's levels are high and not affected by LUBE	Unit away for repair	
			□			
			□			
			□			

Case Study two:

PLANT CONDITION REPORT - CRIT 1		JAN 08		ALARM STATUS											
	ASSET	Reference	Note	Jan 08	Dec 07	Nov 07									
New Chill Area				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Grasso 1	Motor Comp Unit 1			☒	☒	☒	☐	☐	☐	☐	☐	☐	☐	☐	☐
Grasso 2	Motor Comp Unit 2			☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐	☐
Pump 1	Cool Wtr Pp 1			☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐	☐
Pump 2	Recirc Pump 2			☺	☺	☺	☐	☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
NB Drier				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 1			☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 2			☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 3			☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 4			☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 5			☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 6			☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 7			☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

KEY to REPORT Icons		
	Good Condition	☺
	Alert MINOR	😐
	Action MAJOR	☹
	Not Available	☒

PLANT CONDITION REPORT - CRIT 1 | JAN 08 | ALARM STATUS
n 08 | ec 07 | ov 07

	ASSET	Reference	Note												
Evaporators				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Stork Fan 1			☺	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Stork Fan 2			☺	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Nokia Fan 24A			☺	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Nokia Fan 24B	2	Fan NDE	😐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MKT Drier				☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 1			☺	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 2			☺	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 3	3	Fan NDE	☹	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	Fan 4			☺	☐	☐	☐								
	Fan 5			☺	☐	☐	☐								
	Fan 6	4	Fan NDE	😐	☐	☐	☐								
	Fan 7	5	Fan DE	😐	☐	☐	☐								
	Fan 35			☺	☐	☐	☐								
				☐	☐	☐	☐								
Milk reception				☐	☐	☐	☐								
Compr 1	Motor Comp Unit 1			☒	☒	☒	☐								
Compr 2	Motor Comp Unit 2	1	Mtr DE	☒	☹	😐	☐								
PLANT CONDITION REPORT - CRIT 1		**JAN 08**		**ANALYSIS**											

	ASSET	Reference	STATUS	COMMENTS	ACTION	COMPLETED
Milk Reception	Motor Comp Unit 2	1 (Dec 07)	☹	Axial 1x running speed component is above 16mm/s (see Plot1)	Re-align motor with compressor	**Not running in Jan 08**
Evaporators	Nokia Fan 24B	2	😐	Running with a higher than acceptable FAN NDE enveloped g's level	Lube if possible, another set of readings required in Feb before more	

					accurate diagnosis	
MKT Drier	Fan No 3	3	☹	Excessive envelope and temperature readings on FAN NDE brg	Can try lubrication **first** to see if vibration improves	
MKT Drier	Fan No 6	4	😐	Running with a higher than acceptable FAN NDE enveloped g's level	Lube if possible, another set of readings required in Feb before more accurate diagnosis	
MKT Drier	Fan No 7	5	😐	Running with a higher than acceptable FAN DE enveloped g's level	Lube if possible, another set of readings required in Feb before more accurate diagnosis	