Energy Audit Report: Amul Fed dairy-Gandhinagar

Conducting activities of energy audit & dissemination activities in Gujarat dairy cluster under GEF-UNIDO-BEE project

March 2016

pwc

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List of Abbreviations and Acronyms

A.C.	Air Conditioning
BTU	British Thermal Unit
CFL	Compact Fluorescent Lamp
CFM	Cubic Feet per Minute
COP	Coefficient of Performance
CO_2	Carbon dioxide
DG	Diesel Generator
ECM	Energy Conservation Measure
EE	Energy Efficient
EER	Energy Efficiency Ratio
EPC	Engineering Procurement Construction
FAD	Free Air Delivery
FTL	Fluorescent Tube Light
GWh	Gigawatt Hour
IGEA	Investment Grade Energy Audit
kWh	Kilowatt Hour
LPG	Liquefied Petroleum Gas
LPM	Litre Per Minute
LT	Low Tension
Mkcal	Million Kilo Calories
Mt	Million Tonnes
M&E	Monitoring and Evaluation
O&M	Operation and Maintenance
PV	Photo Voltaic
RE	Renewable Energy
SEC	Specific Energy Consumption
SFC	Specific Fuel Consumption
SPC	Specific Power Consumption
SSE	Solar System Exploration
TOD	Time of Day
TR	Ton of refrigeration

Conversion Table

Unit	Conversion factor
1 kWh	860 kcal
1 Joule	0.24 Calorie
1 m^3	1,000 liters
1 TR	12,000 Btu
1 kWh	0.64 kg CO_2
1 Liter (Diesel)	2.7 kg CO_2
1 Liter (Furnace Oil)	2.9 kg CO_2
1 Liter (Kerosene)	2.5 kg CO_2
1 Kg (CNG)	2.8 kg CO_2

Acknowledgement

PwC sincerely thank GEF-UNIDO-BEE for associating us in its prestigious project “Energy efficiency and renewable energy in MSMEs” which involves developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India. Gujarat dairy cluster is also one of these 12 clusters.

We express our sincere gratitude to all concerned officials of PMU of the project for their valuable support and guidance during execution of the project.

Our special thanks to following persons:

- Mr. Milind Deore, Energy Economist, BEE
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- Mr. Ashish Sharma, Project Engineer, GEF-UNIDO-BEE Project, BEE

PwC is thankful to Gujarat Cooperative Milk Marketing Federation Limited (GCMMF) for extending support for this assignment. We are also thankful to Mr. P. K. Sarkar and his team for giving full support during the energy audit. We would like to thank Mr. Falgun Pandya, Cluster Leader - Gujarat, GEF-UNIDO-BEE Project for providing on-field support during energy audit.

We would also like to acknowledge the support, valuable inputs, co-operation and guidance provided by Mr. Prashant Sheth (Sr. Manager - Utilities) during field measurements at Amul Fed dairy, Gandhinagar - Gujarat.

1. Executive Summary

1.1 Introduction

GEF-UNIDO-BEE is developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India. Gujarat dairy cluster is one of them. The overall motive of this assignment is to improve the productivity and competitiveness of units as well as to reduce overall carbon emissions and improve the local environment. PwC was appointed by GEF-UNIDO-BEE for conducting activities under this assignment in the Gujarat Dairy cluster. The activities to be executed include conducting detailed energy audit in 6 plants under GCMMF. Amul Fed dairy - Gandhinagar was one of the plant where in detailed energy audit was conducted.

1.2 Objective of the energy audit study

The objective of detailed energy audit is to review present energy consumption scenario, monitoring and analysis of use of energy and explore various energy conservation options. It includes submission of five best operating practices & common monitorable parameters in Gujarat dairy cluster. The project also includes submission of detailed energy audit report containing recommendations for improving energy efficiency with cost benefit analysis and technical specifications for any retrofit options, with list of suppliers/manufacturers of recommended energy efficient technologies. Extensive attention was given to understanding not only operating characteristics of all energy consuming systems but also situations which cause load profile variations on both annual and daily basis.

1.3 About Amul Fed dairy

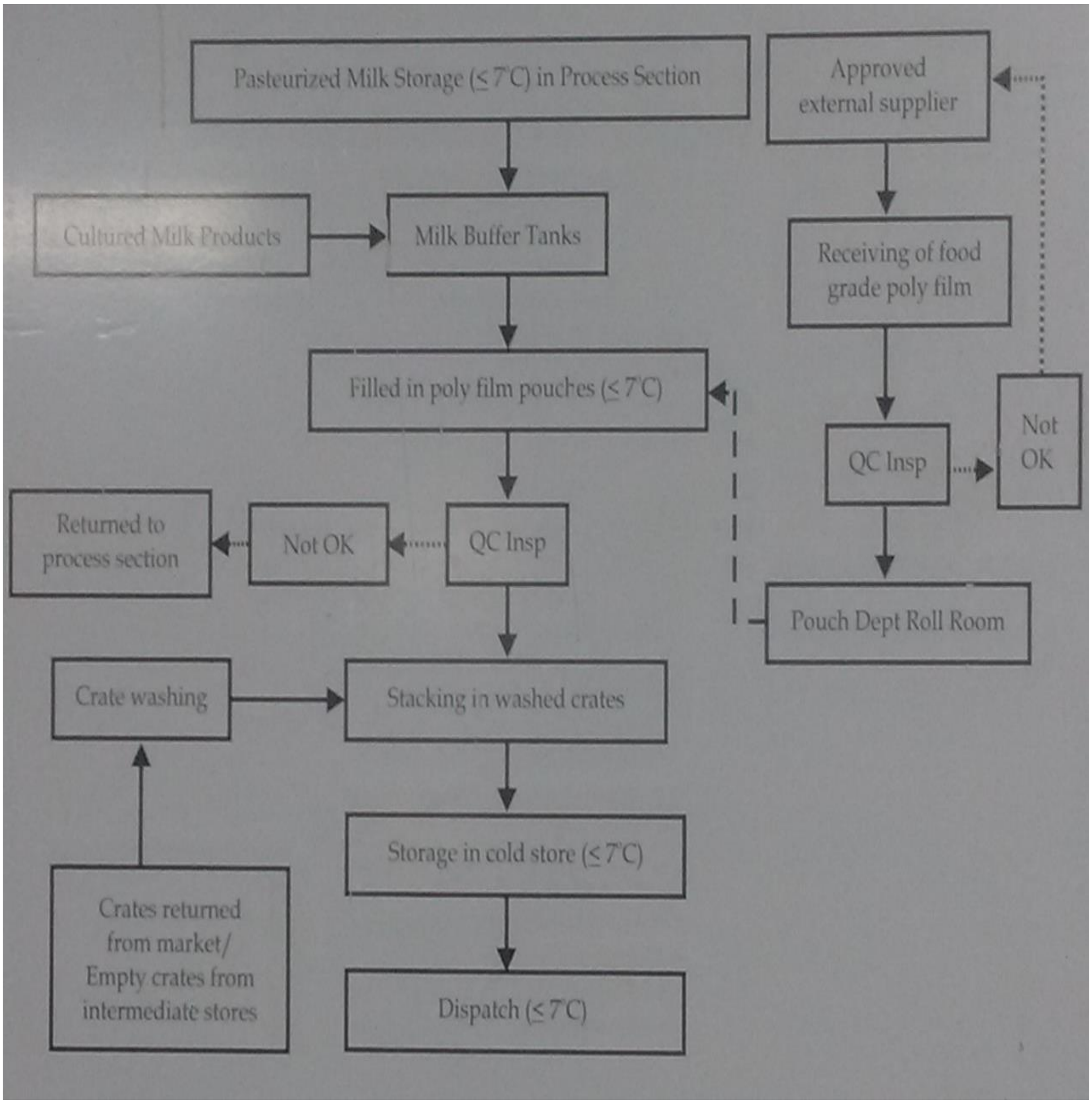
Amul Fed dairy located in Gandhinagar city of Gujarat state. Dairy is having the capacity of processing 32 lakhs liter of milk every day, which make this dairy as the Asia's largest dairy plant. Dairy manufactures different types of milk and milk products. Along with every day consuming milk, plant also manufactures milk products like yogurt, buttermilk, sweets, ice cream and milk powder.

Process flow:

Milk is received from tanker in dairy plant, tankers are collecting milk from chilling centres located at nearby places of Gandhinagar. Milk received from tanker to dairy usually will have temperature more than 4 ^{o}C. Received milk is cooled to temperature up to 4 ^{o}C in raw milk chillers and stored in raw milk silos. Milk from raw milk silos are taken to pasteurization process, wherein milk is heated up to a temperature of 78 ^{o}C and again cooled to a temperature of 4 ^{o}C and stored in to pasteurized milk storage tank. Depending on the everyday market demand, milk is packed in packing section in different quantity from half liter pouches to 5 liter pouches. Extra milk left after pasteurization process is sent to other sections like yogurt, butter milk, ice cream plants for milk product production. Milk left even after manufacturing milk products, is sent to powder plant for making milk powder.

The detailed process flow diagram for the milk processing in Amul Fed dairy is provided below.

Figure 1: Process flow diagram



1.4 *Present energy consumption scenario & specific energy consumption*

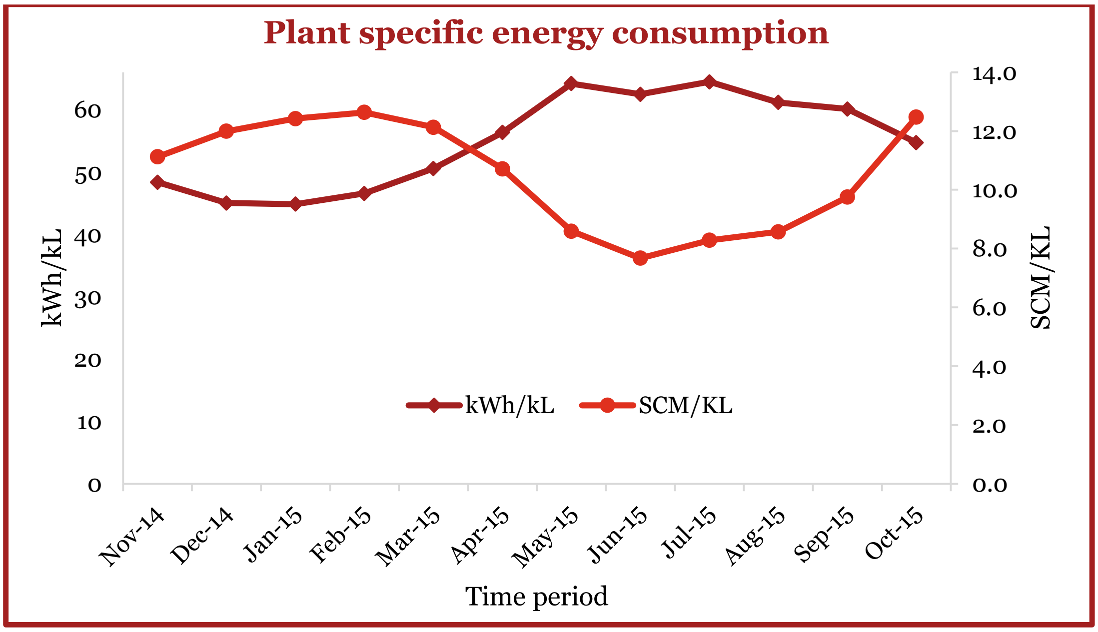
Amul Fed dairy plant uses electricity and natural gas as its main energy input for operation. Electricity and natural gas consumption of entire plant is tabulated and compared with quantity of milk processed in the same month to estimate electricity consumption and gas consumption for manufacturing each kilo liter of milk processed. These findings are tabulated below.

Table 1 : Present energy scenario and specific energy consumption

Description	Milk handled	Electricity Consumption	Electricity bill	Gas consumption	Gas consumption bill	Plant total energy bill	Specific energy consumption	
	kL/month	kWh/month	Rs. Lakhs/month	SCM/month	Rs. Lakhs/month	Rs. Lakhs/month	kWh/kL	SCM/kL
Nov-14	89,672	4,335,300	326	997,458	467	793	48.35	11.1
Dec-14	100,110	4,506,400	338	1,200,452	516	854	45.01	12.0
Jan-15	103,926	4,660,900	350	1,291,101	542	892	44.85	12.4
Feb-15	92,385	4,301,200	343	1,167,291	489	832	46.56	12.6
Mar-15	100,451	5,078,100	402	1,218,231	514	916	50.55	12.1
Apr-15	82,550	4,651,000	370	884,432	345	715	56.34	10.7
May-15	65,846	4,225,900	345	565,711	207	552	64.18	8.6
Jun-15	59,955	3,745,300	309	460,057	154	463	62.47	7.7
Jul-15	56,252	3,626,800	302	466,061	156	458	64.47	8.3
Aug-15	59,216	3,620,700	292	507,575	174	466	61.14	8.6
Sep-15	66,622	4,004,869	320	649,839	227	547	60.11	9.8
Oct-15	88,010	4,815,969	384	1,097,419	389	773	54.72	12.5
Average	**80,416**	**4,297,703**	**341**	**875,469**	**348**	**689**	**55**	**10.9**
Total	**964,994**	**51,572,438**	**4,080**	**10,505,627**	**4,181**	**8,261**		

The following figure captures variation in specific energy consumption in the plant.

Figure 2: Plant specific energy consumption variation



- The average specific electrical energy consumption for milk processing is 55 kWh/kL.
- The average specific natural gas consumption for milk processing is 10.9 SCM/kL.
- Due to seasonal variation, the milk received in the plant is decreased after April – 15, due to this specific energy consumption (kWh/kL) is increased.
- Due to seasonal variation the milk received in the plant is decreased after April – 15 due to this specific gas consumption (SCM /kL) is decreased.

1.5 Plant energy consumption and energy savings

A summary of plant energy consumption as well as savings is provided in the following table.

Table 2: Summary of plant energy consumption and energy savings

Particulars	Unit	Values
Annual electricity consumption	kWh/annum	**51,572,438**
Annual electricity cost	Rs. Lakhs	**4,080**
Annual natural gas consumption	SCM/annum	**10,505,627**
Annual expense on natural gas	Rs. Lakhs	**4,181**
Annual plant energy cost	Rs. Lakhs	**8,261**
Proposed annual electricity consumption saved	kWh/annum	**2,274,856**
Proposed annual gas consumption saved	SCM/annum	**260,602**
Proposed annual energy cost saved	Rs. Lakhs	**198.53**
Proposed investment	Rs. Lakhs	**205.75**
Payback period	Months	**12.5**
Proposed percentage of electricity saved annually	%	**4.41**
Proposed percentage of gas consumption saved annually	%	**2.48**
Proposed percentage of plant total energy cost saved annually	%	**2.4**

1.6 Summary of proposed energy conservation measures

Table 3: Summary of proposed energy conservation measures

S. No.	Suggested measure	Annual energy savings	Annual cost saving	Investment	Payback period
		kWh/annum kg/annum	Rs. Lakhs	Rs. Lakhs	Months
1	Operate one out of two HT substation 12.5 MVA transformers to optimize loading and losses.	35,321	2.03	Nil	Immediate
2	Replace captive power plant cooling water pumps with new energy efficient pump	593,880	34.14	8	2.8
3	Reduce discharge pressure of R -3 refrigeration system chilled water pumps by increasing chilled water pipelines size	245,952	14.14	10	8.5
4	Recover heat from captive power plant engines HT cooling water to pre heat any available nearby process or utility water	207,900	54.05	50	11
5	Install economizers in 6 TPH boiler to recover heat from flue gas to pre heat feed water	35,700	9.28	10	13
6	Install blowdown heat recovery system in 6 TPH and 10 TPH boilers to recover heat from blowdown water to pre heat feed water	17,002	4.43	5	13
7	Install back pressure turbine on low pressure main steam header to generate electricity and reduce steam pressure	1,184,663	68.11	120	21
8	Install VFD on 6 TPH & 10 TPH boiler feed water pumps to save the pump power consumption	116,640	6.7	10	18
9	Install VFD on 100 TPD condenser cooling water pump to avoid throttling	7,680	0.44	0.75	20.5
10	Install compressed air recovery system to recover compressed air from blow molding machine	90,720	5.21	15	34.5
Total		**2,274,856/ 260,602**	**198.53**	**205.75**	**12.50**

2 Introduction

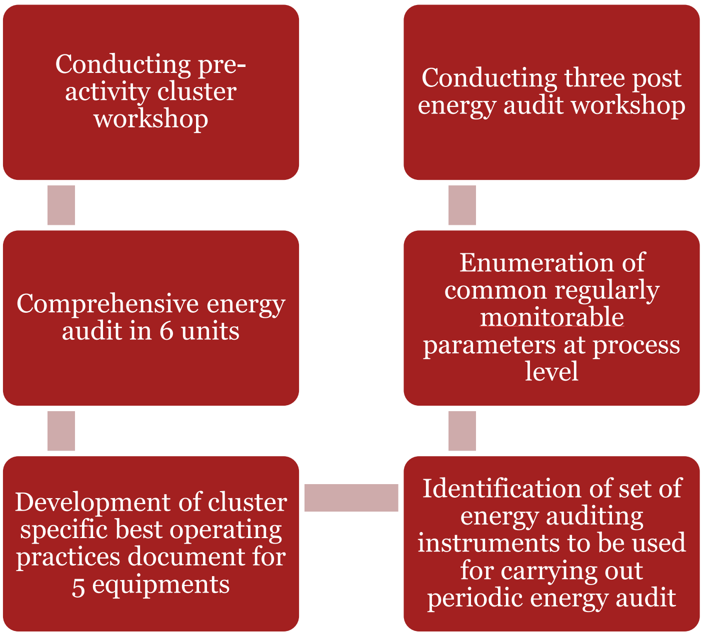
2.1 Introduction

GEF-UNIDO-BEE is developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India. Gujarat dairy cluster is one of them. The overall motive of this assignment is to improve the productivity and competitiveness of units as well as to reduce overall carbon emissions and improve the local environment. PwC was appointed by GEF-UNIDO-BEE for conducting activities under this assignment in the Gujarat Dairy cluster. Carrying out energy audit in 6 dairy plants is one of the activities of the assignment. Energy audit of Amul fed dairy - Gandhinagar was one of these 6 audits.

2.2 Scope of services

The scope of this assignment is shown at **Error! Reference source not found.**.

Figure 3: Scope of services



This report has been prepared under the task 2 of our scope of services, which involves conducting comprehensive energy audits in six units in the cluster, where Amul Fed dairy plant has been selected one of these six.

2.3. Energy audit scope and approach

A detailed energy audit was undertaken at Amul Fed dairy– Gandhinagar from 16 to 28 November 2015. The energy audit team from PwC comprised of thermal and electrical energy experts. During energy audit, a range of portable energy audit instruments were used to take various measurements of all energy consuming equipment/systems of the plant. In addition, design and operational data was collected from logbooks and equipment manuals. Also, discussions were held with technical personnel at the plant to fully understand its operations and energy requirements. The energy audit was focused on the study of Amul Fed dairy plant and evaluation of operational efficiency/performance of each equipment from energy conservation point of view.

The following areas were covered during the study:

- ***Process plant***
    - Process & New process
    - Butter plant
    - Ice cream plant
    - Old powder plant (60 TPD)
    - New powder plant (100 TPD)
    - Pizza plant
    - Yogurt plant
    - Butter milk plant
    - Sweets plant
- ***Utilities***
    - Refrigeration system (R-1,2 & 3)
    - Air compressors
    - Cooling water system
    - Boiler and steam distribution (6 TPH*3 Nos & 10 TPH*1 Nos)
    - Water pumping system
- ***Renewable Energy***
    - ✓ Opportunities were identified for use of renewable energy

The study focused on identifying the energy saving measures in the dairy plant. The analyses included estimation of investment requirement, payback period and Internal Rate of Return (IRR) calculations to ascertain financial viability of investment intensive energy conservation measures. The energy audit involved carrying out various measurements and analysis, to assess losses and potential for energy savings in different sections of the plant. A wide array of latest, sophisticated, portable measuring instruments were used to obtain primary information for energy audit investigations and analyses. The specialized instruments that were used during the energy audit included:

- Power analyzers (Three Phase and Single Phase)
- Digital manometer
- Digital hygrometers
- Temperature loggers
- Ultrasonic flow meter
- Digital pressure gauge
- Others

During the audit, the team maintained continuous interaction with plant personnel to ensure that the recommendations made were realistic, practical and implementable. On the last day of the energy audit, discussion was held with plant management on site observations and preliminary findings, to enable the management to take immediate action to conserve energy.

This report presents the field measurements, design and operational data, data analysis, key observations and recommendations to achieve energy savings in each of the major areas that consumed energy and equipment.

The recommendations are followed by cost-benefit analysis. Major emphasis is laid on short and medium-term measures. The ultimate aim of this exercise is to help the plant management to understand and prioritize energy efficiency opportunities identified through the study.

3 Observation and Analysis

Amul Fed dairy located in Gandhinagar city of Gujarat state. The dairy is having processing capacity of 32 lakhs liter milk every day, which make this dairy as the **Asia's largest dairy plant**. Dairy manufactures different types of milk and milk products. Detailed energy audit was conducted in Amul Fed dairy plant – Gandhinagar to find energy saving opportunities.

3.1 Annual electrical energy consumption

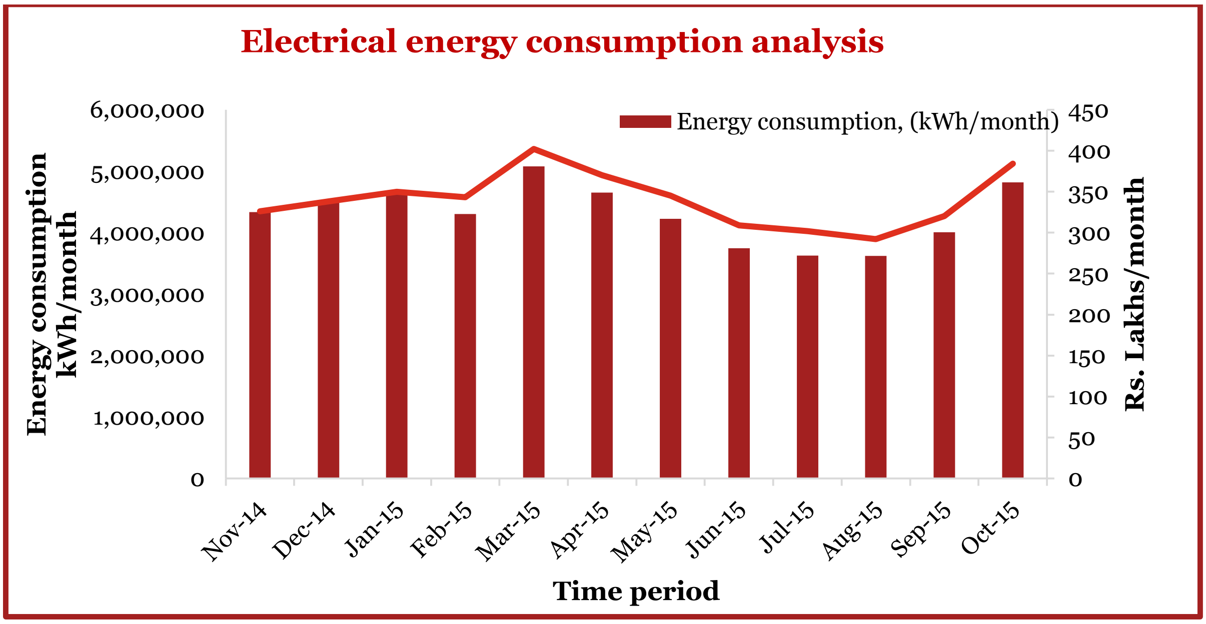
Plant receives power from Uttar Gujarat Vij company limited at 66 kV HT line. There are two transformer of capacity 12,500 kVA each operating to step-down voltage from 66 KV to 11 kV near HT substation. The details of the plant electricity consumption for last one year is tabulated and presented below.

Table 4: Annual electrical energy consumption of plant

Description	Energy consumption, (kWh/month)	Electricity bill (Rs. Lakhs/ month)	Milk handled (kL/month)	Specific energy consumption (kWh/kL)
Nov-14	4,335,300	326	89,672	48.35
Dec-14	4,506,400	338	100,110	45.01
Jan-15	4,660,900	350	103,926	44.85
Feb-15	4,301,200	343	92,385	46.56
Mar-15	5,078,100	402	100,451	50.55
Apr-15	4,651,000	370	82,550	56.34
May-15	4,225,900	345	65,846	64.18
Jun-15	3,745,300	309	59,955	62.47
Jul-15	3,626,800	302	56,252	64.47
Aug-15	3,620,700	292	59,216	61.14
Sep-15	4,004,869	320	66,622	60.11
Oct-15	4,815,969	384	88,010	54.72
Average	**4,297,703**	**341**	**80,416**	**55**
Total	**51,572,438**	**4,080**	**964,994**	

The following figure captures variation in electricity consumption and electricity cost in the plant.

Figure 4: Electrical energy consumption analysis



- Average electricity consumption of the plant per month is 4,297,703 kWh/month with average electricity costs of 341 lakhs/month.
- Annual electricity consumption of the plant is 51,572,438 kWh/annum, which costs about 4,080 lakhs/annum.

3.2 *Annual natural gas consumption*

Plant consumes natural gas as a fuel for generating thermal energy for its heating application in dairy process. Month wise natural gas consumption, milk produced is tabulated below.

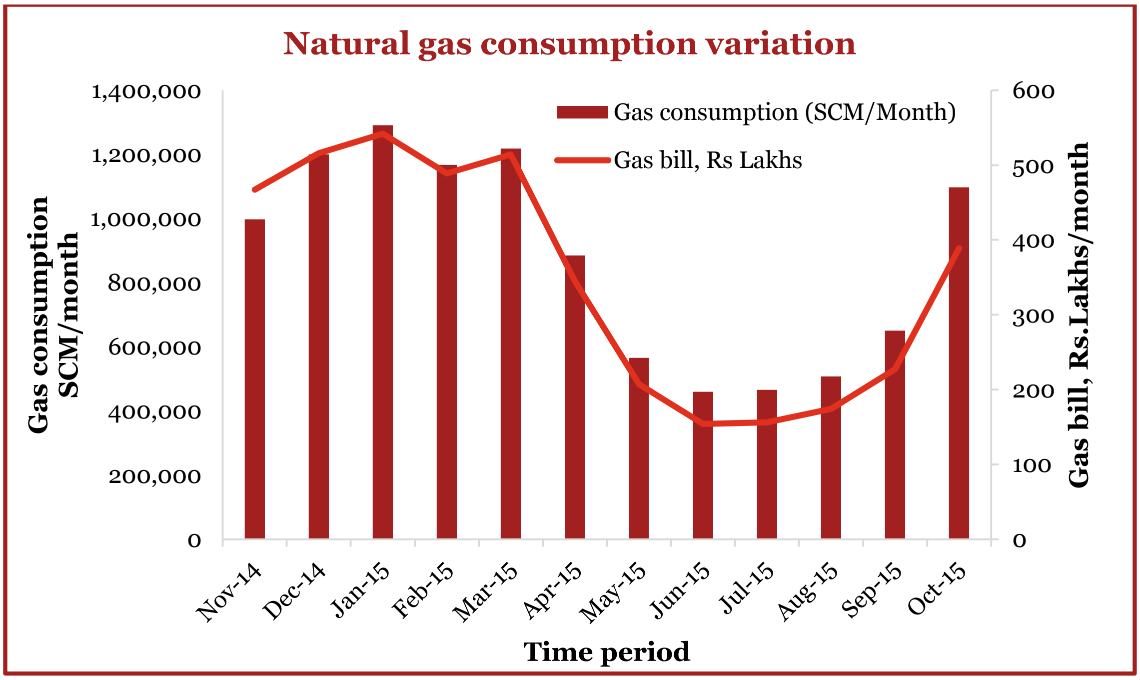
Table 5: Annual natural gas consumption of plant

Description	Gas consumption (SCM/month)	Gas consumption bill (Rs. Lakhs/month)	Milk handled (kL/month)	Specific gas consumption (SCM/kL)
Nov-14	997,458	467	89,672	11.1
Dec-14	1,200,452	516	100,110	12
Jan-15	1,291,101	542	103,926	12.4
Feb-15	1,167,291	489	92,385	12.6
Mar-15	1,218,231	514	100,451	12.1
Apr-15	884,432	345	82,550	10.7
May-15	565,711	207	65,846	8.6
Jun-15	460,057	154	59,955	7.7
Jul-15	466,061	156	56,252	8.3
Aug-15	507,575	174	59,216	8.6
Sep-15	649,839	227	66,622	9.8
Oct-15	1,097,419	389	88,010	12.5

Average	**875,469**	**348**	**80,416**	**10.9**
Total	**10,505,627**	**4,181**	**964,994**	

The following figure captures monthly variation in gas consumption and cost in the plant.

Figure 5: Natural gas consumption analysis



- Average natural gas consumption of the plant per month is 875,469 kWh/month with average gas costs of 348 Lakhs/month.
- Annual gas consumption of the plant is 10,505,627 kWh/month, which total costs about 4,181 Lakhs/annum

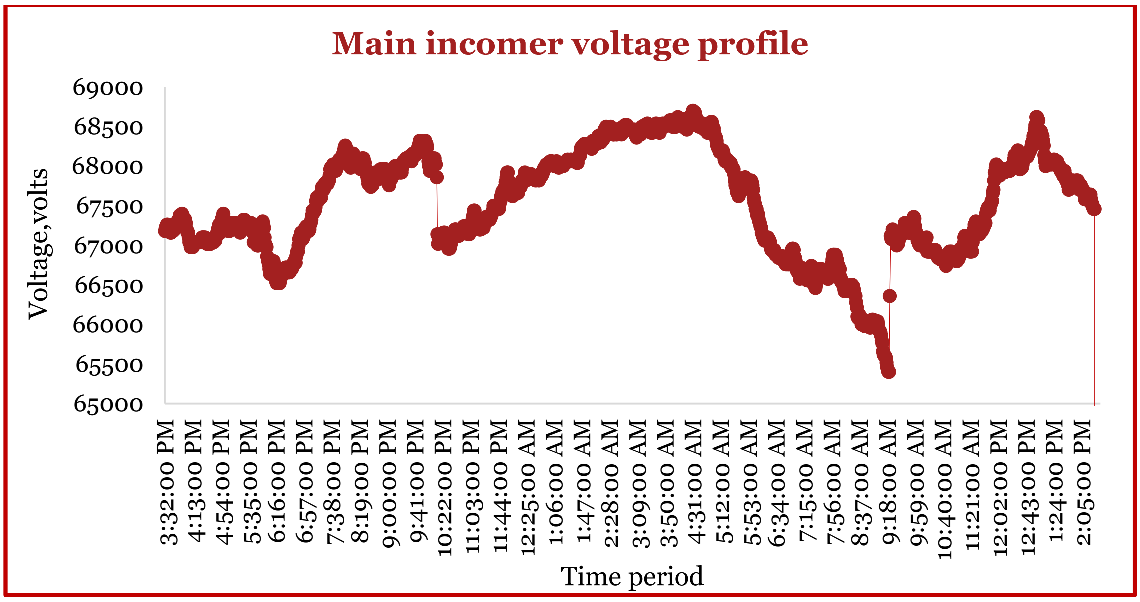
3.3 Main incomer profile

Amul fed dairy getting electrical power from Uttar Gujarat vij company limited (UGVCL) through 66kV express feeder. There are two transformer of capacity 12.5 MVA operating at HT substation to step down voltage from 66 kV to 11 kV. The detailed power consumption profile is recorded at 66kV HT line for a complete day during the audit and same given below.

Voltage profile:

The voltage profile recorded for the main incomer at the 66 kV HT side from 16-11-2015 @03:30 pm to 17-11-2015 @ 2:00 pm is presented below.

Figure 6 : Main incomer - voltage profile

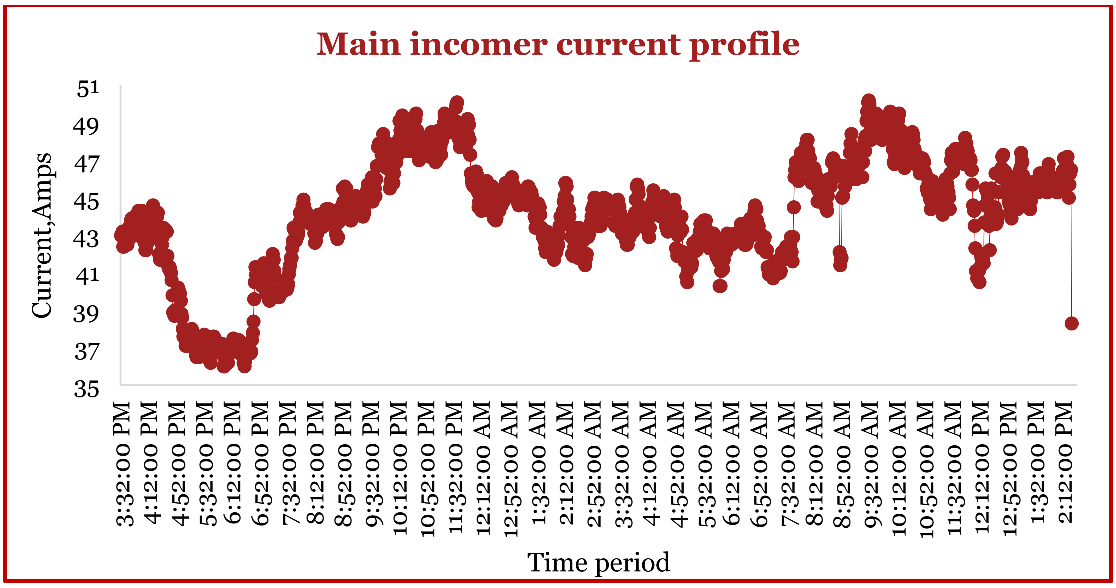


The maximum voltage recorded during this period	=	68,500 volts
The minimum voltage recorded during this period	=	65,500 volts

Current profile:

The current profile recorded for the main incomer at the 66 kV HT side from 16-11-15 @03:30 pm to 17-11-15 @ 2:00 pm is presented below.

Figure 7 : Main incomer - current profile

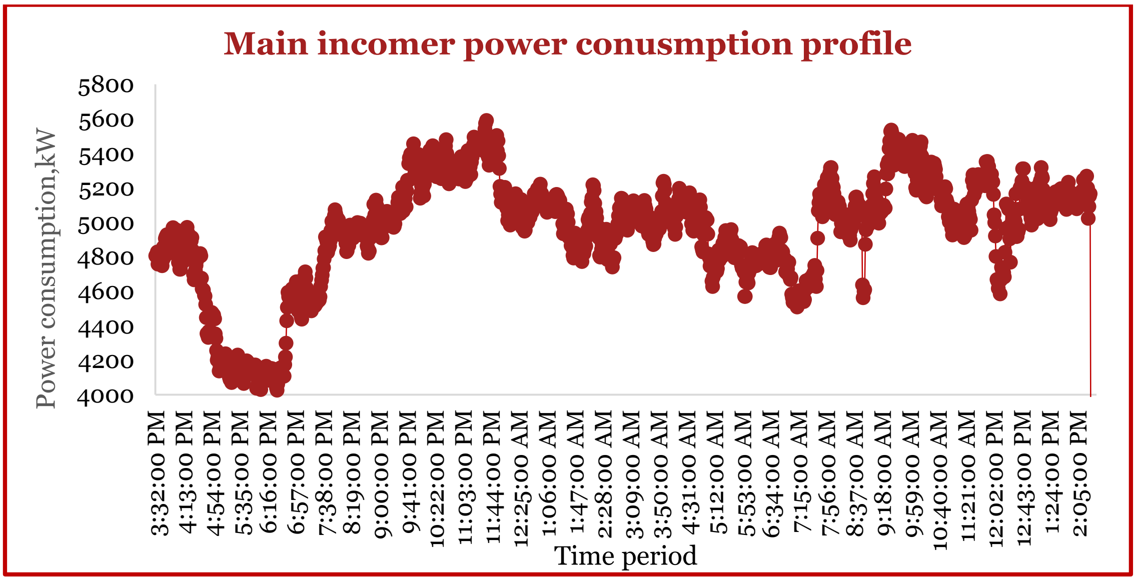


The maximum current recorded during this period	=	52 Amps
The minimum current recorded during this period	=	36 Amps

Power consumption profile:

The power consumption profile recorded for the main incomer at the 66 kV HT side from 16-11-15 @03:30 pm to 17-11-15 @ 2:00 pm is presented below.

Figure 8 : Main incomer - power consumption profile

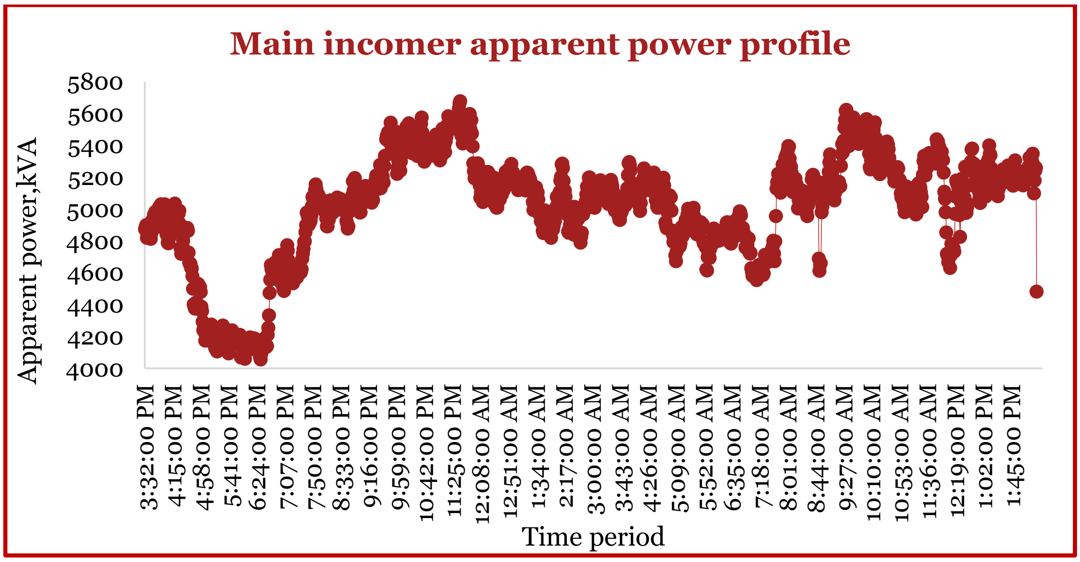


The maximum power consumption recorded during this period	=	5 600 kW
The minimum power consumption recorded during this period	=	4000 kW

Apparent power profile:

The apparent power consumption profile recorded for the main incomer at the 66 kV HT side from 16-11-15 @03:30 pm to 17-11-15 @ 2:00 pm is presented below.

Figure 9 : Main incomer - apparent power profile

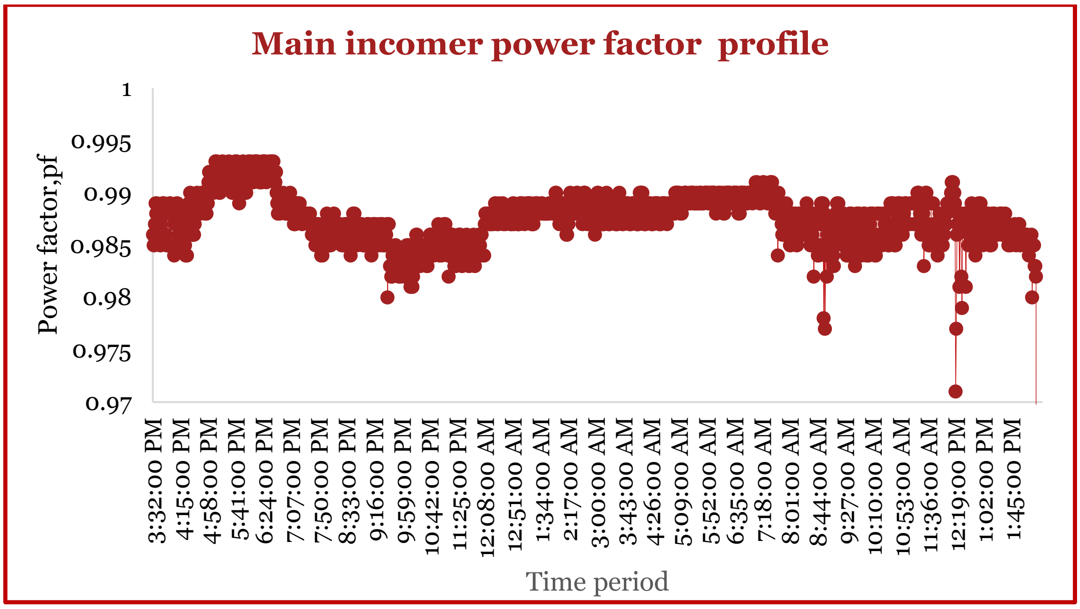


The maximum power consumption recorded during this period	=	5650 kVA
The minimum power consumption recorded during this period	=	4000 kVA

Power factor profile:

The power factor profile recorded for the main incomer at the 66 kV HT side from 16-11-15 @03:30 pm to 17-11-15 @ 2:00 pm is presented below.

Figure 10 : Main incomer - power factor profile



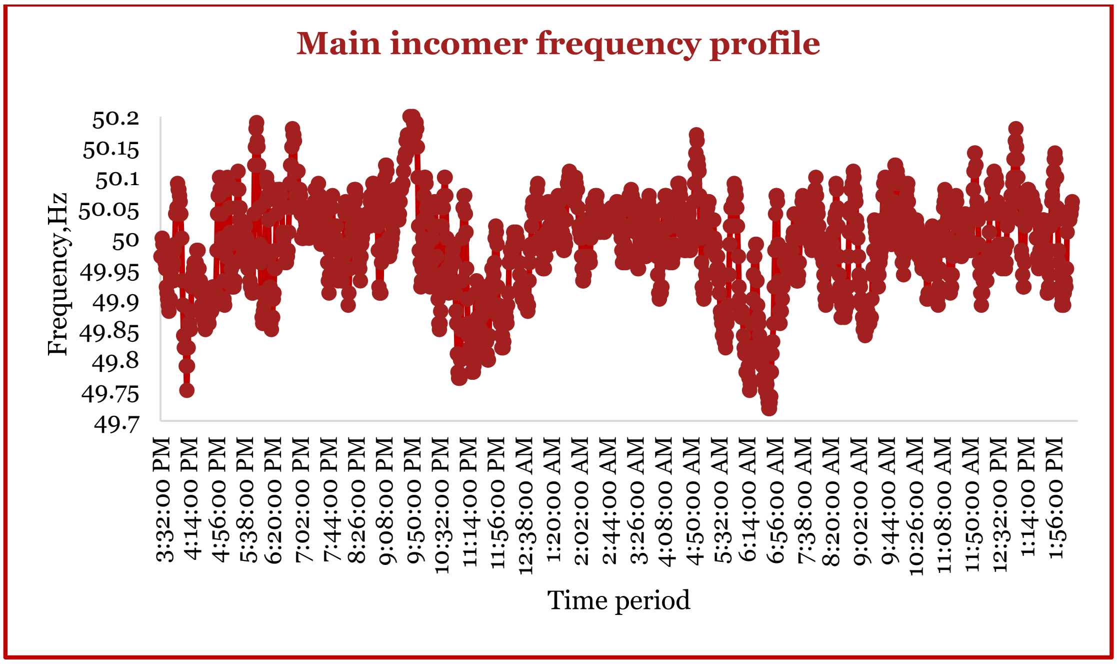
The maximum power factor recorded during this period = 0.994 lagging

The minimum power factor recorded during this period = 0.97 lagging

Frequency profile:

The frequency profile recorded for the main incomer at the 66 kV HT side from 16-11-15 @03:30 pm to 17-11-15 @ 2:00 pm is presented below.

Figure 11 : Main incomer - frequency profile



The maximum frequency recorded during this period = 50.2 Hz

The minimum frequency recorded during this period = 49.75 Hz

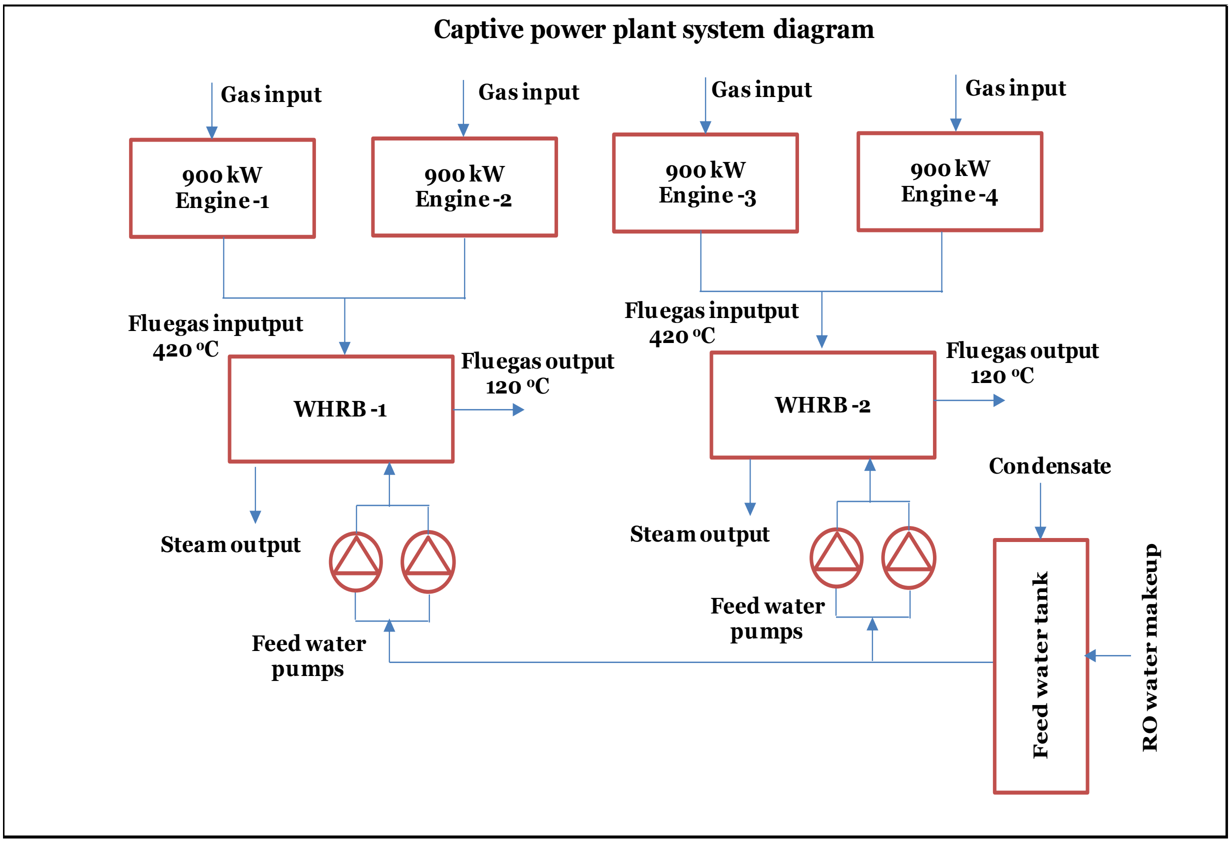
The analysis of various power parameters given above indicates that the overall quality of power received by the plant is good and most of the parameters are within the desired range.

3.4 Captive power plant

There is a captive power plant in dairy to supply electricity along with grid supply for plant operation. Captive power plant is having four gas engines, out of which two or three will be working to meet electricity demand during normal working hours. Gas engines using natural gas as fuel and having WHRB boilers at the flue gas exhaust to recover heat from flue gas to generate steam. In gas engine, plant generates both electricity and steam and these are used in dairy operations. Operating and design parameters collected and detailed analysis done on CPP during audit and is discussed below.

The detailed captive power plant system diagram is as follows.

Figure 12 : CPP plant system diagram



During the audit, three engines and both WHRBs were running. The various parameters measured at CPP during the audit is as follows.

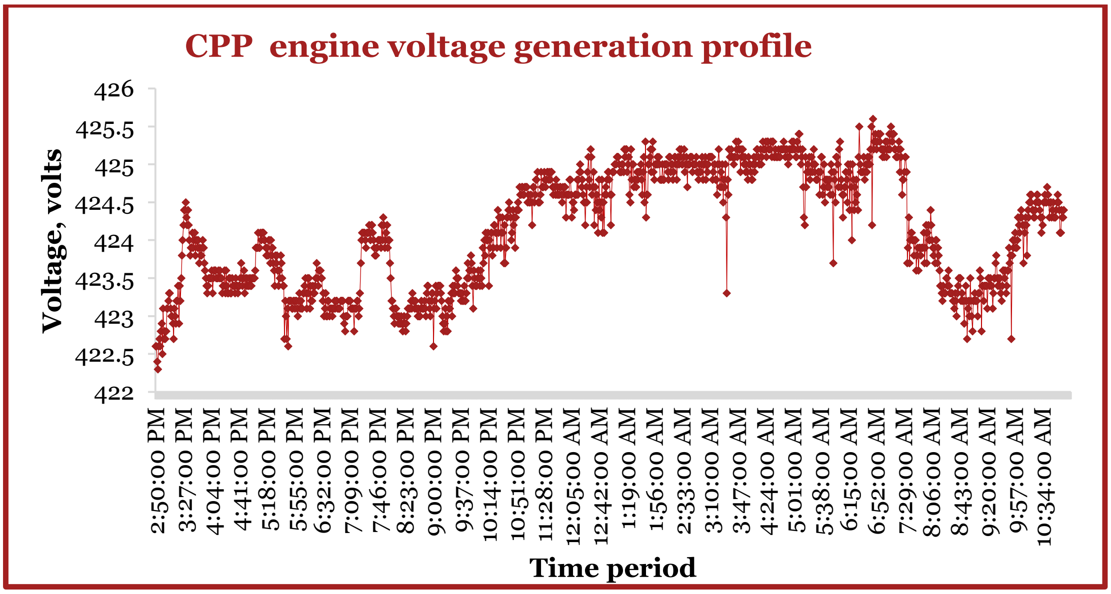
Number of gas engines running	=	3 Numbers
Number of WHRB running	=	2 Numbers
Flue gas out let at engine outlet	=	420 °C
Flue gas outlet at WHRB outlet	=	120 °C
Feed water temperature	=	70 °C

Power consumption profile recorded at CPP gas engines main incomer during the audit to find the total electrical energy generation and details are discussed below.

Voltage profile:

The voltage profile recorded for the CPP main incomer from 17-11-15 @02:50 pm to 18-11-15 @ 10:40 am is presented below.

Figure 13 : CPP main incomer voltage profile

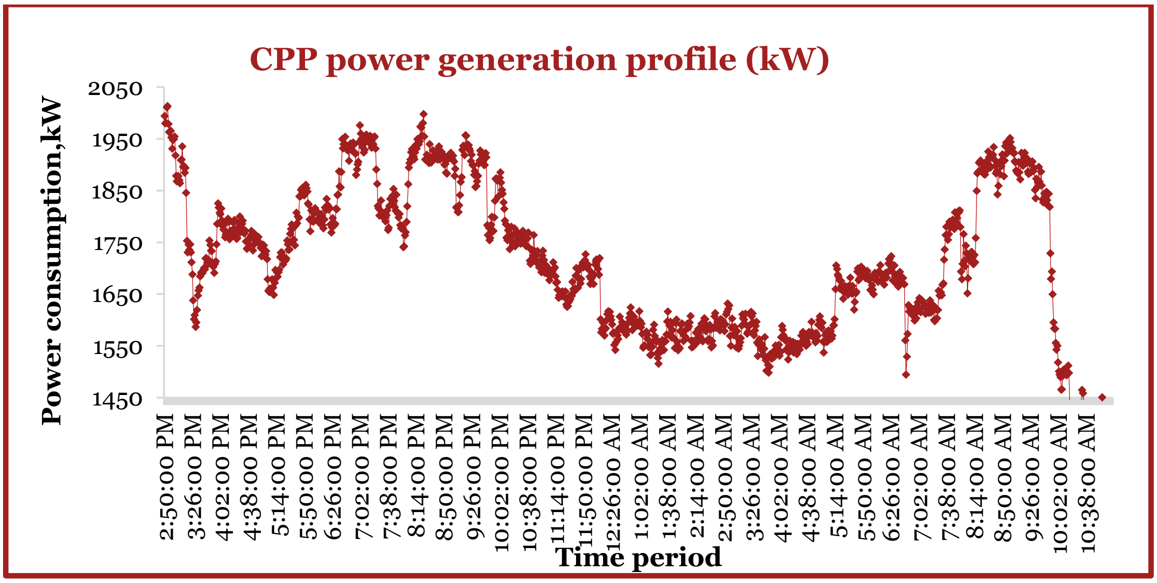


The maximum voltage recorded during this period	=	425 volts
The minimum voltage recorded during this period	=	423 volts

Power generation profile:

The power generation profile recorded for the CPP main incomer from 17-11-15 @02:50 pm to 18-11-15 @ 10:40 am is presented below.

Figure 14 : CPP total power generation profile



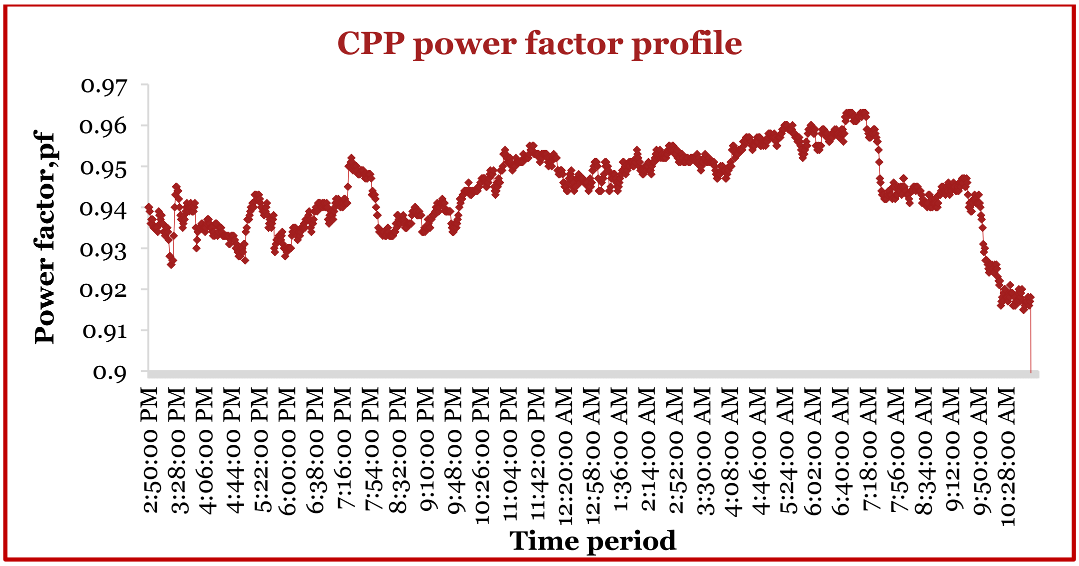
The maximum power generation recorded during this period = 2,000 kW

The minimum power generation recorded during this period = 1,450 kW

Power factor profile:

The power factor profile recorded for the CPP main incomer from 17-11-15 @02:50 pm to 18-11-15 @ 10:40 am is presented below.

Figure 15 : CPP main incomer power factor profile



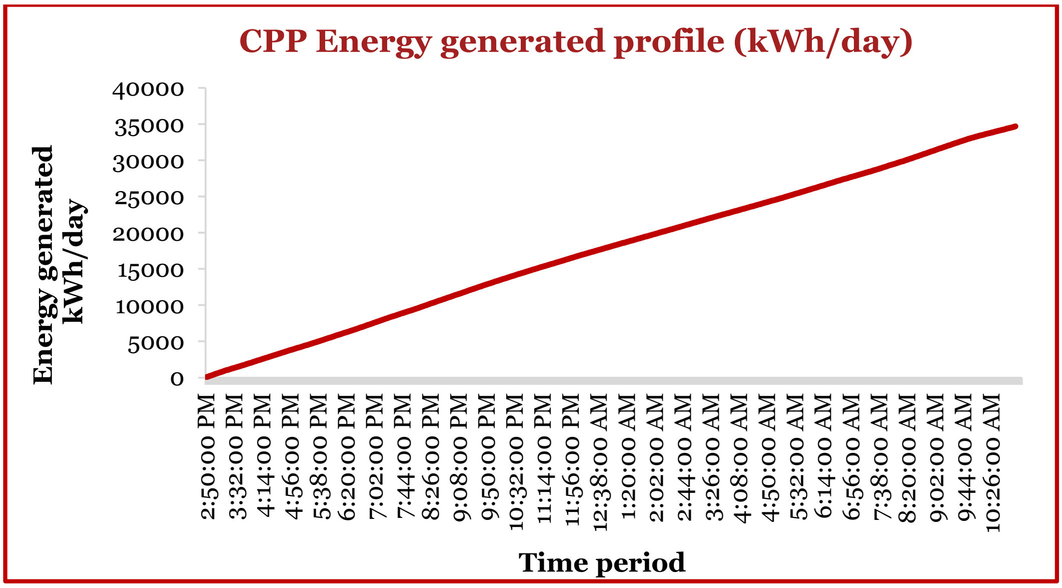
The maximum power factor recorded during this period = 0.96 lagging

The minimum power factor recorded during this period = 0.92 lagging

Energy generation profile:

The energy generated profile recorded for the CPP main incomer from 17-11-15 @02:50 pm to 18-11-15 @ 10:40 am is presented below.

Figure 16 : CPP main incomer energy generation profile



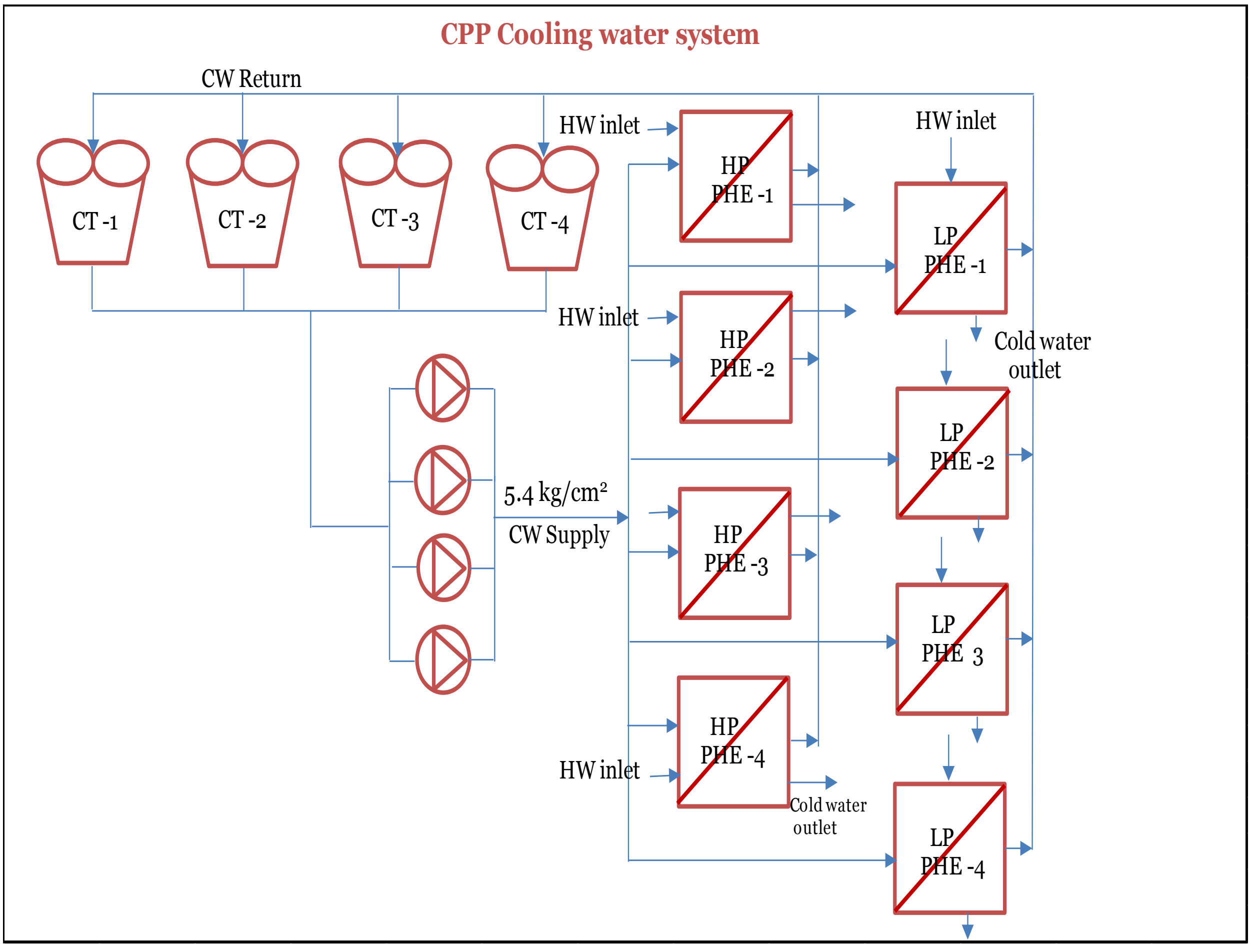
The electrical energy generated by gas engine during the measurement period is 34,660 kWh/day

3.4.1 CPP cooling water system:

CPP is has separate cooling water system to cool the engine and its auxiliaries during operation. Main engine cooling is called as HP cooling and auxiliary cooling is called as LP cooling. For both HP and LP cooling, separate PHEs are installed for each gas engine.

The detailed cooling water system diagram is as follows.

Figure 17 : CPP cooling water system diagram



In cooling water system, three cooling towers and two cooling water pumps will be running during the normal working day. The temperature, flow parameters measured and analysis done on cooling water system is as follows.

Table 6 : Cooling water system analysis

Description	Units	Parameters
Cooling tower basin water temperature	ºC	30
Cooling tower return water temperature	ºC	33
Delta T across CT	ºC	3
HT PHE -1 engine water return temperature	ºC	102.5
HT PHE -1 engine water supply temperature	ºC	50.4
HT PHE -1 cooling water return temperature	ºC	36
HT PHE -1 cooling water supply temperature	ºC	32.5

Description	Units	Parameters
CW water flow to HP PHE -1	m3/h	65
Heat rejected by hot water in PHE	kCal/h	227,500
HT PHE -1 engine water return temperature	oC	54.8
LT PHE -1 engine water return temperature	oC	54.8
LT PHE -1 engine water supply temperature	oC	35.9
LT PHE -1 cooling water return temperature	oC	32
LT PHE -1 cooling water supply temperature	oC	35.5
CW water flow to LT PHE -1	m3/h	15
Heat rejected by hot water in PHE -2	kCal/h	52,500
HT PHE -2 engine water return temperature	oC	103.6
HT PHE -2 engine water supply temperature	oC	52.5
HT PHE -2 cooling water return temperature	oC	34.5
HT PHE -2 cooling water supply temperature	oC	31
CW water flow to HP PHE -2	m3/h	65
Heat rejected by hot water in PHE -2	kCal/h	227,500
LT PHE -2 engine water return temperature	oC	52.1
LT PHE -2 engine water return temperature	oC	37.3
LT PHE -2 engine water supply temperature	oC	31.8
LT PHE -2 cooling water return temperature	oC	34
CW water flow to LT PHE -2	m3/h	15
Heat rejected by hot water in PHE -2	kCal/h	33,000
HT PHE -4 engine water return temperature	oC	107
HT PHE -4 engine water supply temperature	oC	56.6
HT PHE -4 cooling water return temperature	oC	35
HT PHE -4 cooling water supply temperature	oC	32
CW water flow to HP PHE -4	m3/h	65
Heat rejected by hot water in PHE -4	kCal/hr	195,000
LT PHE -4 engine water return temperature	oC	58.3
LT PHE -4 engine water return temperature	oC	37.9
LT PHE -4 engine water supply temperature	oC	35
LT PHE -4 cooling water return temperature	oC	32.7
CW water flow to LT PHE -4	m3/h	15
Heat rejected by hot water in PHE -4	kCal/h	34,500

The rated heat capacity of HP PHE is 400,000 kCal/h and actual heat rejection in HP PHE -1, and 2 is 227,500 kCal/h and in HP PHE -4 it is 195,000 kCal/h, which is much less than the rated capacity.

Decrease in heat transfer capacity of the PHE is may be due to the deposition at its inside plates. Due to decrease in the heat transfer capacity, PHEs will not cool the engine to its required temperature there by decrease the engine electrical energy generation capacity. It is recommended to clean these PHEs at regular intervals for better heat transfer.

Cooling water pumps:

There are four cooling water pumps installed at CPP cooling water system. CW pumps supplies cooling water for CPP engine and its auxiliary cooling application. Out of four pumps installed, two pumps work during normal working hours to meet the demand. The detailed parameters measured and analysis done on the cooling water pumps is as follows.

Table 7 : Cooling water pump analysis

Description	Units	Parameters
Design details		
Number of pumps installed	Number	4
Number of pumps operating	Number	2
Design water flow rate of pump	m^3/h	250
Design head	m	50
Rated power consumption	kW	50
Operating parameters		
Number of pumps working	Numbers	2
Pump suction pressure	kg/cm^2	0
Pump discharge pressure	kg/cm^2	5.4
Water flow delivered (2 pumps)	m^3/h	240
Percentage of opening of suction valve	%	100
Percentage of closing of suction valve	%	0
Percentage of opening of discharge valve	%	50
Percentage of closing of discharge valve	%	50
Water pressure before throttling	kg/cm^2	5.4
Water pressure after throttling valve	kg/cm^2	1.8
Pressure drop across control valve	kg/cm^2	3.6
Power consumption of pump -1	kW	50
Power consumption of pump -2	kW	52
Total power consumption of both pump	kW	102
Overall efficiency	**%**	**35%**
Combined pump efficiency @95% of motor efficiency	**%**	**36%**

- Both pumps are operating with discharge valve throttling (discharge valve closed by 50%) to control pump flow and pressure due to over sizing. The actual head required is around 20 m but these pumps are designed with 50 m which is very high compared to actual requirement.
- Combined efficiency of both pumps is 36 % only, which found to be very less.

3.5 Refrigeration system

There are three separate refrigeration system in dairy to serve cooling requirement of the entire plant. These refrigeration systems called as R -1, R -2 and R -3. All three refrigeration systems were working during audit to meet the cooling requirement of the plant. All three plants are catering to different area/sections of the plant. Plant wise cooling load distribution is listed below.

Refrigeration plant -1 (R-1)

- Milk cold rooms

- Pizza section

Refrigeration plant -2 (R-2)

- Ice cream mix room
- Old powder plant
- New powder plant
- RTF
- Cold rooms for butter
- Deep freezer
  - Ice cream
  - Butter

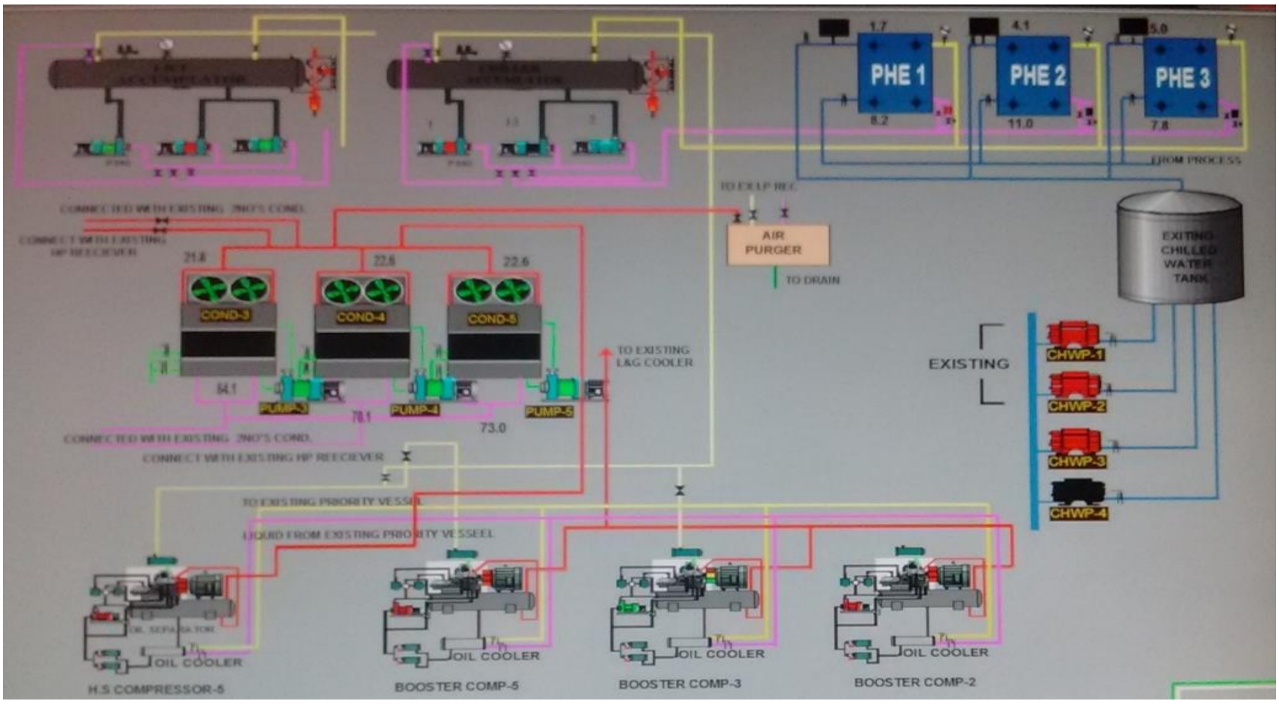
Refrigeration plant -3 (R-3)

- New pre – process
- Process
- Pet bottling building
- Butter plant
- New Ice cream milk (New)

3.5.1 R – 1 Refrigeration system

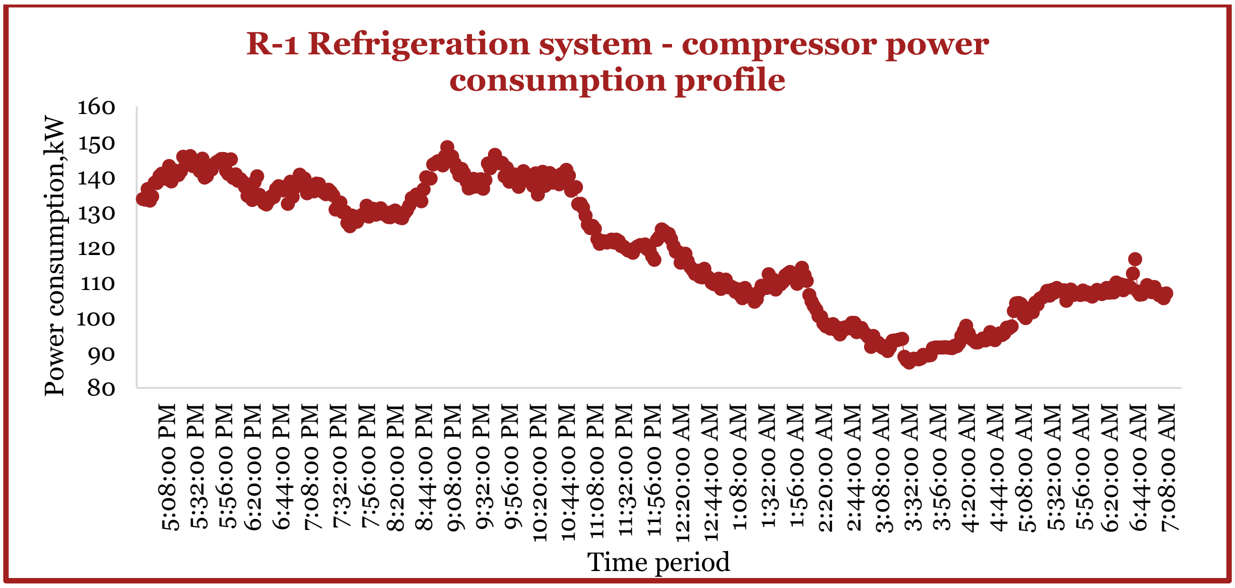
R -1 refrigeration system serves refrigeration requirement for milk cold rooms. Out of four compressor installed in R-1 refrigeration system one will be working during normal working hours. R -1 refrigeration system is old compared to R -2 and R -3. R-1 refrigeration system is having cooling water system to cool hot refrigerant after compression, but R -2 and R -3 are having evaporative condensers. R -1 refrigeration system diagram collected from plant SCADA is as follows.

Figure 18 : R -1 refrigeration system diagram



Power consumption measurement done on the operating compressor in R -1 refrigeration system is as follows.

Figure 19 : R -1 refrigeration system - compressor power consumption profile



The maximum power consumption recorded during this period	=	150 kW
The minimum power consumption recorded during this period	=	90 kW

Condenser water Pumps:

Condenser water pumps are pumping condenser water from cooling tower to condenser PHEs. There are four pumps installed out of which two pumps will be working to meet the water requirement of condenser PHEs connected under R -1 refrigeration system. The operating parameters measured and detailed analysis is done on these pumps to find operating efficiency and is presented below.

Table 8 : R -1 refrigeration system - CW pump efficiency estimation.

Description	Units	Parameters
Design details		
Make		KSB
Flow rate	m^3/h	300
Head developed	M	20
Speed	Rpm	2,910
Actual parameters		
Number of pumps running	Numbers	2
Flow rate delivered	m^3/h	428
Head developed	M	44
Power consumption	kW	80
Combined efficiency	**%**	**64%**
Pump efficiency at 95 % of motor efficiency	**%**	**67%**

- Efficiency of these water pumps are found to be good and are operating as per the rated efficiency.

Since R-1 refrigeration system serves the cold refrigerant requirement, it is not possible to calculate the actual specific energy consumption and TR generated as these parameters are possible to calculate only when refrigeration system serves chilled water to its users.

3.5.2 R – 2 Refrigeration system

R – 2 refrigeration system serves both chilled water and cold refrigerant to process applications. Chilled water and refrigerant in R-2 system is generated by two stage of cooling. The major user for R -2-refrigeration system is ice cream plant. In ice cream plant, cold refrigerant is used for ice cream making process and in ice cream cold rooms.

In R -2-refrigeration plant, during normal operation two HP compressor and two booster compressors will be working along with five evaporative condenser and two chilled water pumps. Design and operating details of the R-2 refrigeration compressor & its auxiliaries are tabulated and compared with each other and is presented below.

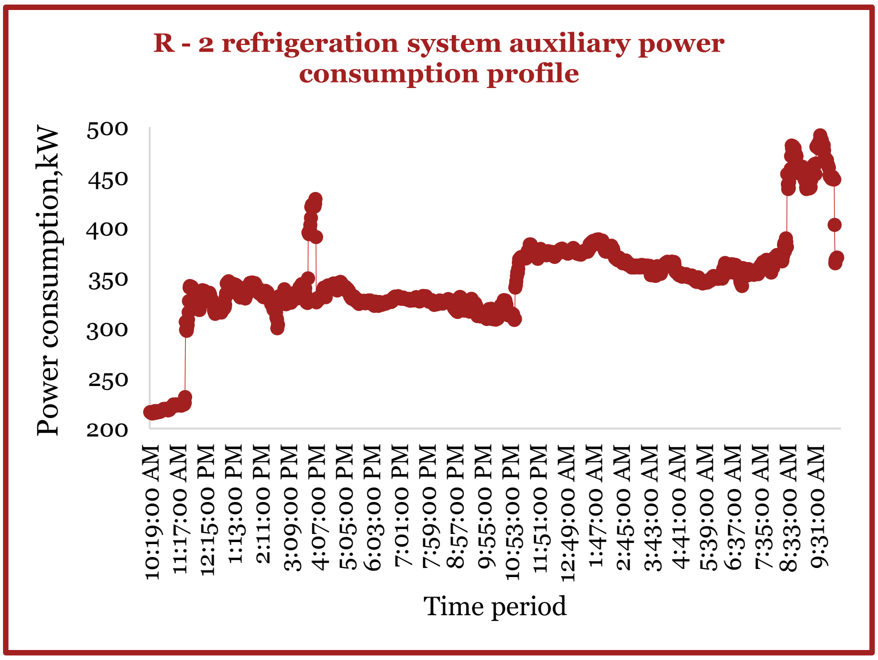
Table 9 : R -2 refrigeration system - compressor design and operating parameters analysis

Description	Units	Parameters
LP screw compressor		
Make		Grasso
Model		XAR - XA30B-28
Capacity	kCal/h	54,4320
Saturated suction temperature	^oC	-40
Condensing temperature	^oC	-5
Power consumption	kW	171
Speed	rpm	2940
Superheated considered		5K
Number of compressor installed	Numbers	5
Compressor motor power consumption	kW	200
HP screw compressor		

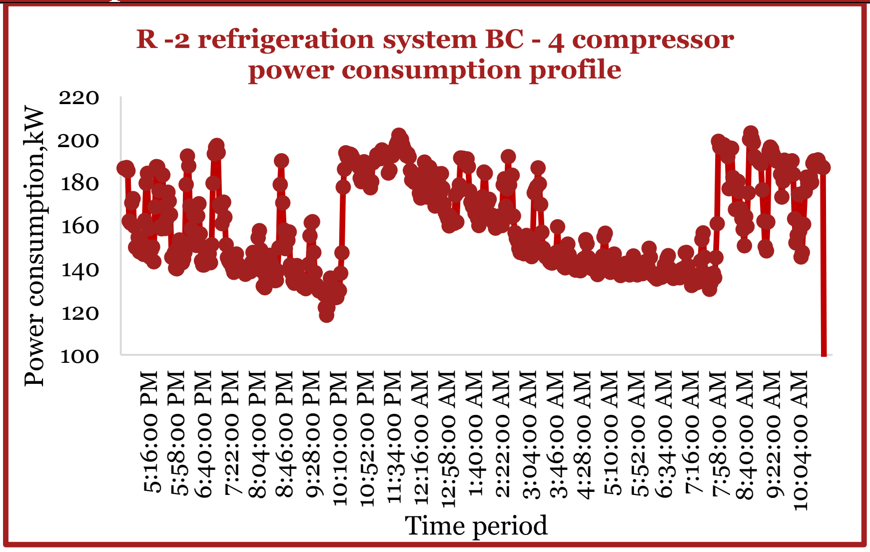
Description	Units	Parameters
Make		Grasso
Model		RR - R305-28
Capacity	kCal/h	75,600
Saturated suction temperature	^oC	-5
Condensing temperature	^oC	40
Power consumption	kW	220.4
Speed	rpm	2940
Number of compressor installed	Numbers	5
Compressor motor power consumption	kW	250
Operating parameters		
Number of LP compressor operating	Numbers	2
Number of HP compressor operating	Numbers	2
Average power consumption of LP -1 compressor	kW	180
Average power consumption of LP -2 compressor	kW	190
Average power consumption of HP -1 compressor	kW	220
Average power consumption of HP -2 compressor	kW	230
Average power consumption of R -2 system auxiliaries	kW	300

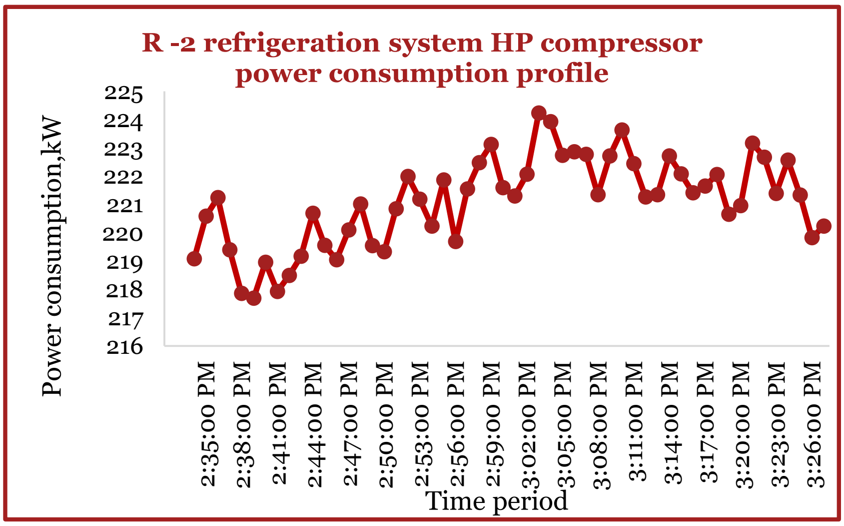
Power consumption measurement done on the operating compressor and auxiliaries during audit is as follows.

Figure 20 : R -2-refrigeration system - power consumption profile

<table>
<tr><th>Power profile</th><th>Observation</th></tr>
<tr><td>
</td><td>R -2 refrigeration system auxiliary panel maximum power consumption = 420 kW

R -2 refrigeration system auxiliary panel minimum power consumption = 220 kW</td></tr>
<tr><td></td><td>R -2 refrigeration system BC -4 compressor maximum power consumption = 200 kW</td></tr>
</table>

<table>
<tr><th>Power profile</th><th>Observation</th></tr>
<tr><td>


</td><td>R -2 refrigeration system BC -4 compressor minimum power consumption = 120 kW</td></tr>
<tr><td>


</td><td>R -2 refrigeration system HP-1 compressor maximum power consumption = 224 kW

R -2 refrigeration system HP -1 compressor minimum power consumption = 218 kW</td></tr>
</table>

Note: Due to lack of provision for power measurement in electrical panels, power measurement for one HP and one LP compressors are not carried out during audit.

Since R-2 refrigeration system serves the cold refrigerant requirement, it is not possible to calculate the actual specific energy consumption and TR generated as these parameters are possible to calculate only when refrigeration system serves chilled water to its users.

Chilled water pumps:

Chilled water pumps are pumping chilled water from ice tank to user end for process cooling applications. There are four pumps installed out of which one pump will be working to meet the chilled water requirement of plant sections connected under R -2 refrigeration system. The detailed analysis is done on these pumps to find operating efficiency and is presented below.

Table 10 : R -2 refrigeration system - chilled water pump efficiency evaluation

Description	Units	Set -1	Set -2
Design details			
Make		Grundfos	Lubi
Flow rate	m^3/h	125	146

Description	Units	Set -1	Set -2
Head developed	m	35	32
Speed	rpm	2910	2900
Rated current	A	32	29.5
Actual parameters			
Flow rate delivered	m^3/h		117.3
Head developed	m		34
Power consumption	kW		16.5
Combined efficiency	**%**		**66%**
Pump efficiency at 92 % of motor efficiency	**%**		**72%**

- Efficiency of Set -2 lubi pump is found to be good and it is operating as per the rated efficiency.

Evaporative condenser:

There are six evaporative condensers installed dedicatedly for R -2-refrigeration system, out of which five will be working during normal working day. Design and operating details of the evaporative condensers is tabulated and compared with each other in following table.

Table 11 : R -2 refrigeration system – Evaporative condenser performance evaluation

Description	Units	Parameters
Design details		
Quantity	Numbers	6
Make		Baltimore air coil
Model		CXV – 309
Condensing temperature	^oC	40
Wet bulb temperature	^oC	28
Capacity	kCal/h	1,209,600
Fan motor rating	kW	18.5
Air flow rate	m^3/sec	41.5
Circulating water flow rate	lps	45
Operating details		
Water flow in evaporative condenser -1	m^3/h	183.3
Water flow in evaporative condenser -2	m^3/h	181.5
Water flow in evaporative condenser -4	m^3/h	174
Water flow in evaporative condenser -5	m^3/h	188
Water inlet temperature to evaporative condenser -1	^oC	33.5
Water outlet temperature to evaporative condenser -1	^oC	31
Water inlet temperature to evaporative condenser -2	^oC	34
Water outlet temperature to evaporative condenser -2	^oC	31.5
Water inlet temperature to evaporative condenser -4	^oC	35
Water outlet temperature to evaporative condenser -4	^oC	32
Water inlet temperature to evaporative condenser -5	^oC	36
Water outlet temperature to evaporative condenser -5	^oC	32.8
Range for evaporative condenser -1	^oC	3

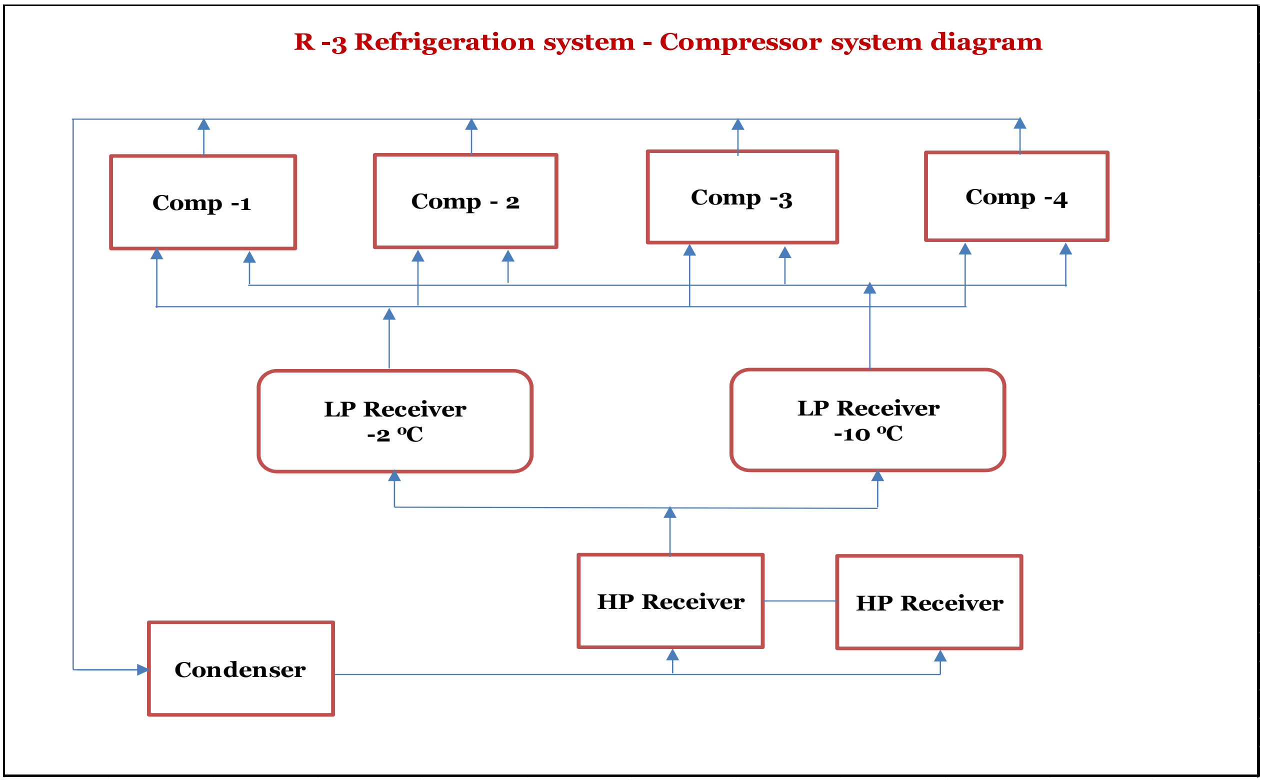
Description	Units	Parameters
Range for evaporative condenser -3	^oC	2.5
Range for evaporative condenser -4	^oC	3
Range for evaporative condenser -5	^oC	3.2
Approach for evaporative condenser -1	^oC	3
Approach for evaporative condenser -3	^oC	3.5
Approach for evaporative condenser -4	^oC	4
Approach for evaporative condenser -5	^oC	4.8
Effectiveness for condenser evaporator -1	%	50%
Effectiveness for condenser evaporator -3	%	42%
Effectiveness for condenser evaporator -4	%	43%
Effectiveness for condenser evaporator -5	%	40%

- Water flow and temperature across the all-evaporative condenser are found to be good and these condensers are working to best of their efficiency.

3.5.3 R – 3 Refrigeration system

R – 3 refrigeration system serves only chilled water to process applications, where as other refrigeration system (R-1 & 2) serves both chilled water and cold refrigerant to user ends process applications. Chilled water in R-3 system is generated by two stage of cooling. In the first stage, return chilled water from process is cooled in pre chiller and then same chilled water is cooled in ice tank to get the temperature near to 0 ^oC. Capacity of R-3 refrigeration system is 1,500 TR, the system is having four compressors, out of four compressors, three are operating at -2 ^oC refrigerant temperature and one compressor will be operating at -10 ^oC refrigerant temperature. R-3 refrigeration compressor system arrangement is given below.

Figure 21 : R – 3 refrigeration system - compressor system diagram



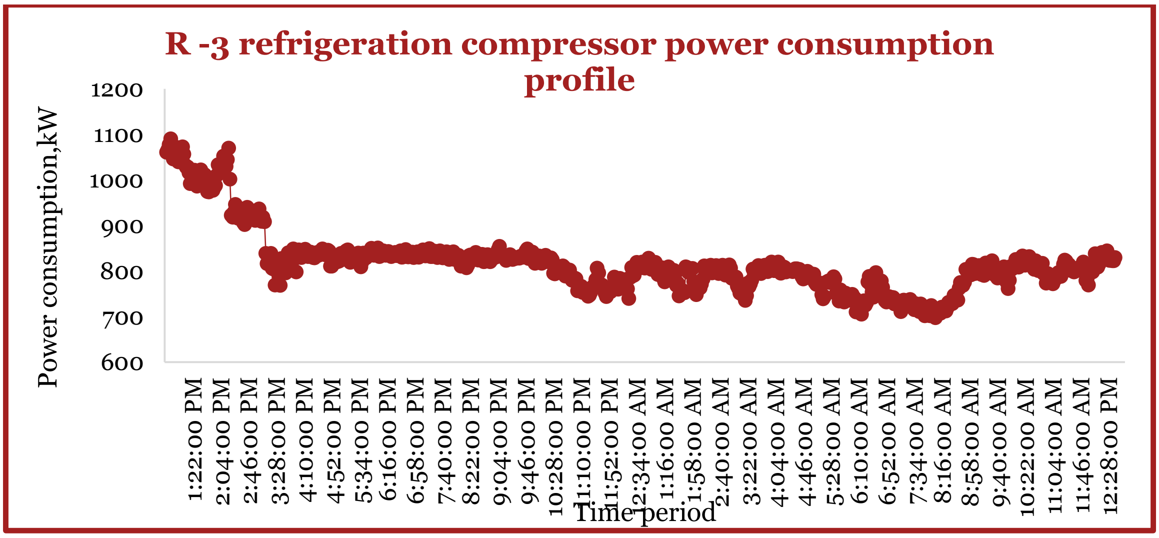
During the normal operation, compressor -1 and 2 are operating for cooling refrigerant up to -2 ºC and compressor -3 is operating for cooling refrigerant up to -10 ºC. The design details and operating parameters of the refrigeration compressors are as follows.

Table 12 : Cooling water system analysis

Description	Units	Parameters
Compressors		
Number of compressors installed	Numbers	4
Make		Mycon
Model		M 250 - VS-LE
Condensing temperature	ºC	40
Suction temperature	ºC	-5
Capacity with economizer	hp	475
Speed	rpm	2950
HP receiver		
Quantity	Numbers	2
Make		Frick
Size		1220 * 8095 long
Capacity	L	5,000
Purger		
Quantity	Numbers	2
Make		Manik
Model		SGP 2E - 8

Actual power consumption measurement done for all R -3-refrigeration system operating compressor and its auxiliaries during audit and is as follows.

Figure 22 : R -3 refrigeration system - compressors power consumption profile



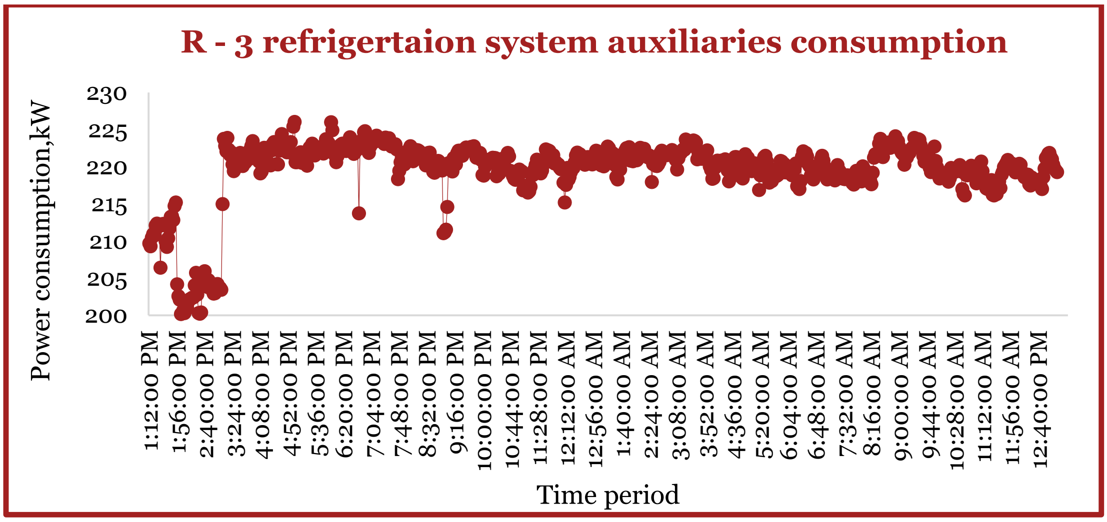
Note: Since there was no provision to measure power consumption of individual compressors, all the three operating compressor power consumption measured together at R-3 compressor main incomer panel.

The maximum power consumption recorded during this period = 1,100 kW

The minimum power consumption recorded during this period = 700 kW

Below profile represents the power consumption for the R -3-refrigeration system auxiliaries' main incomer (auxiliaries are CHW pumps, condenser fans) measured during the audit.

Figure 23 : R -3 refrigeration system – utilities power consumption profile

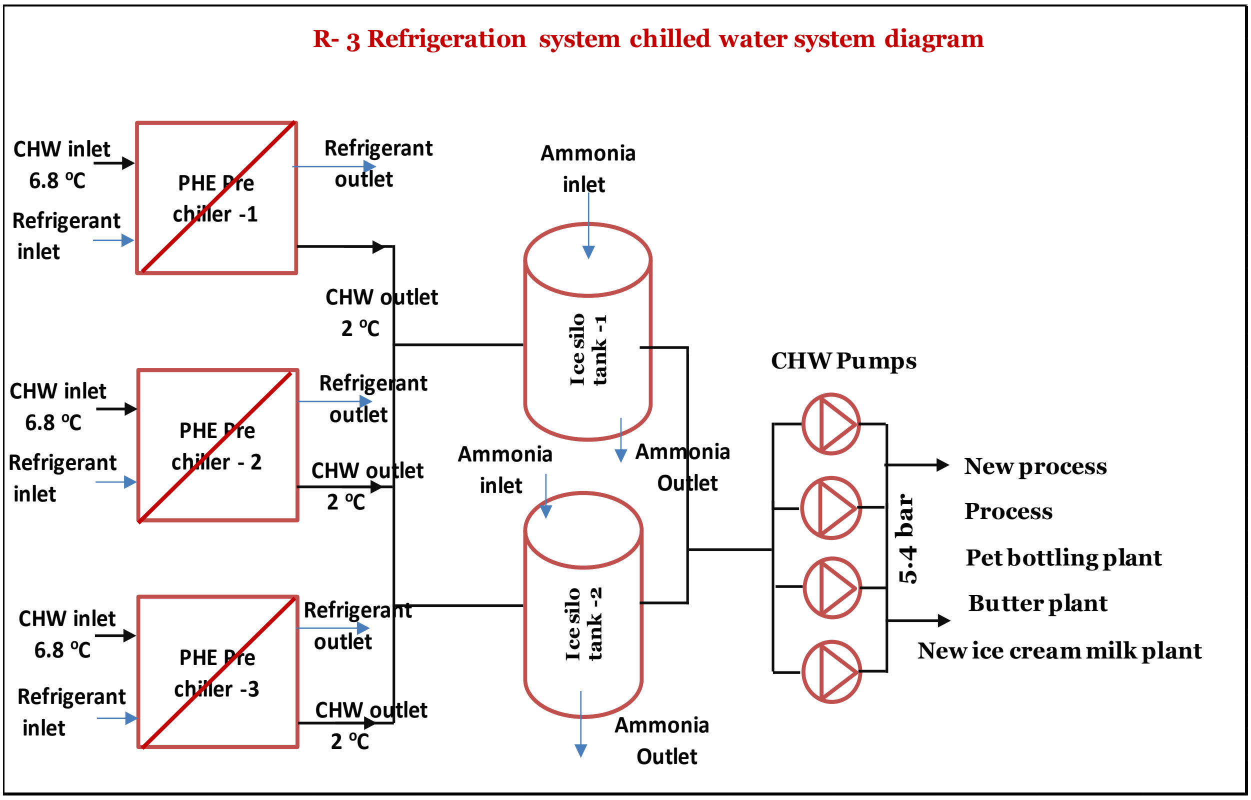


The maximum power consumption recorded during this period	=	225 kW
The minimum power consumption recorded during this period	=	200 kW

Chilled water system:

The chilled water is generated by two stages of cooling in the R-3 refrigeration system, in the first stage return water from process is cooled by -2 °C PHE chiller using the refrigerant from -2 °C compressor. In the second stage, chilled water is cooled in the ice tank by -10 °C refrigerant. In the two stage of cooling system chilled water cooled up to 0 °C. Chilled water system diagram is as follows.

Figure 24 : R – 3-refrigeration system – chilled water system diagram



The design and operating details of the chilled water system equipment are as follows.

Table 13 : R -3 refrigeration system specific energy consumption estimation

Description	Units	Parameters
PHE Chiller		
Quantity	Numbers	3
Make		SONDEX
Model		SWS8-1518-134-EVAP
Capacity	kW	1406
SST	^oC	-2
Water inlet temperature	^oC	10
Water outlet temperature	^oC	4
Water flow rate	m^3/h	200
Ice tank		
Number of ice tank	Numbers	2
Refrigerant inlet temperature	^oC	-10
Operating parameters		
Chilled water inlet temperature	^oC	6.8
Chilled water outlet temperature	^oC	0.8
Chilled water flow rate	m^3/h	703
Cooling generated by R-3 refrigeration system	**TR**	**1,394**
Power consumption of R -3 refrigeration system	**kW**	**1,073**
Specific energy consumption of R -3 refrigeration system	**kW/TR**	**0.76**

- The specific energy consumption of the R-3 refrigeration system is 0.76 kW/TR, which is found to be good and indicates that R-3 refrigeration system is operating to best of its efficiency.

Chilled water Pumps:

There are six chilled water pumps installed in the R-3 refrigeration system to pump water from generation to user end applications. Out of six pumps installed, five pumps will be working during normal working hours to meet the chilled water demand. Detailed analysis done on the chilled water pumps to find the efficiency and it is presented below.

Table 14 : R -3 refrigeration chilled water pumps efficiency estimation

Description	Units	Set -1	Set -2
Number of pumps installed	Numbers	3	3
Make		Lubi	
Model		LES - 100-4004	
Rated Power consumption of each pump	kW	29.8	37.25
Rated Flow of each pump	m^3/h	150	150
Rated Head of each pump	m	40	50
Number of pumps operating	Numbers	2	3
Operating parameters			

Description	Units	Set -1	Set -2
Head developed	m	54	54
Flow delivered	m³/h		713
Power consumption	kW	68	96
System efficiency	**%**		**64**
Pump combined efficiency @95% of motor efficiency	**%**		**67.3**

- Efficiency of chilled water pumps are found to be good and is as per rated efficiency.

Evaporative condensers:

There are six evaporative condensers installed dedicatedly for R -3-refrigeration system, out of which four will be working during normal working day. Design and operating details of the evaporative condensers are analyzed and tabulated below.

Table 15 : R -3 refrigeration evaporative condenser analysis

Description	Units	Parameters
Design details		
Quantity	Numbers	6
Make		Evapco
Model		CATC - 482
Condensing temperature	°C	40
Wet bulb temperature	°C	28
Capacity	kW	1,512
Pump motor rating	kW	4
Fan motor rating	kW	7.5
Operating details		
Water flow in evaporative condenser -1	m³/h	165
Water flow in evaporative condenser -3	m³/h	170
Water flow in evaporative condenser -4	m³/h	163
Water flow in evaporative condenser -5	m³/h	166
Water inlet temperature to evaporative condenser -1	°C	35.5
Water outlet temperature to evaporative condenser -1	°C	32
Water inlet temperature to evaporative condenser -3	°C	36
Water outlet temperature to evaporative condenser -3	°C	33.5
Water inlet temperature to evaporative condenser -4	°C	35.5
Water outlet temperature to evaporative condenser -4	°C	31
Water inlet temperature to evaporative condenser -5	°C	35.3
Water outlet temperature to evaporative condenser -5	°C	31.5
Range for evaporative condenser -1	°C	3.5
Range for evaporative condenser -3	°C	2.5
Range for evaporative condenser -4	°C	4.5
Range for evaporative condenser -5	°C	3.8
Approach for evaporative condenser -1	°C	4
Approach for evaporative condenser -3	°C	5.5

Description	Units	Parameters
Approach for evaporative condenser -4	°C	3
Approach for evaporative condenser -5	°C	3.5
Effectiveness for condenser evaporator -1	**%**	**47%**
Effectiveness for condenser evaporator -3	**%**	**31%**
Effectiveness for condenser evaporator -4	**%**	**60%**
Effectiveness for condenser evaporator -5	**%**	**52%**

- Water flow and temperature across the condenser evaporator is found to be good and it is as per the design parameters.

3.6 Boiler and steam distribution system

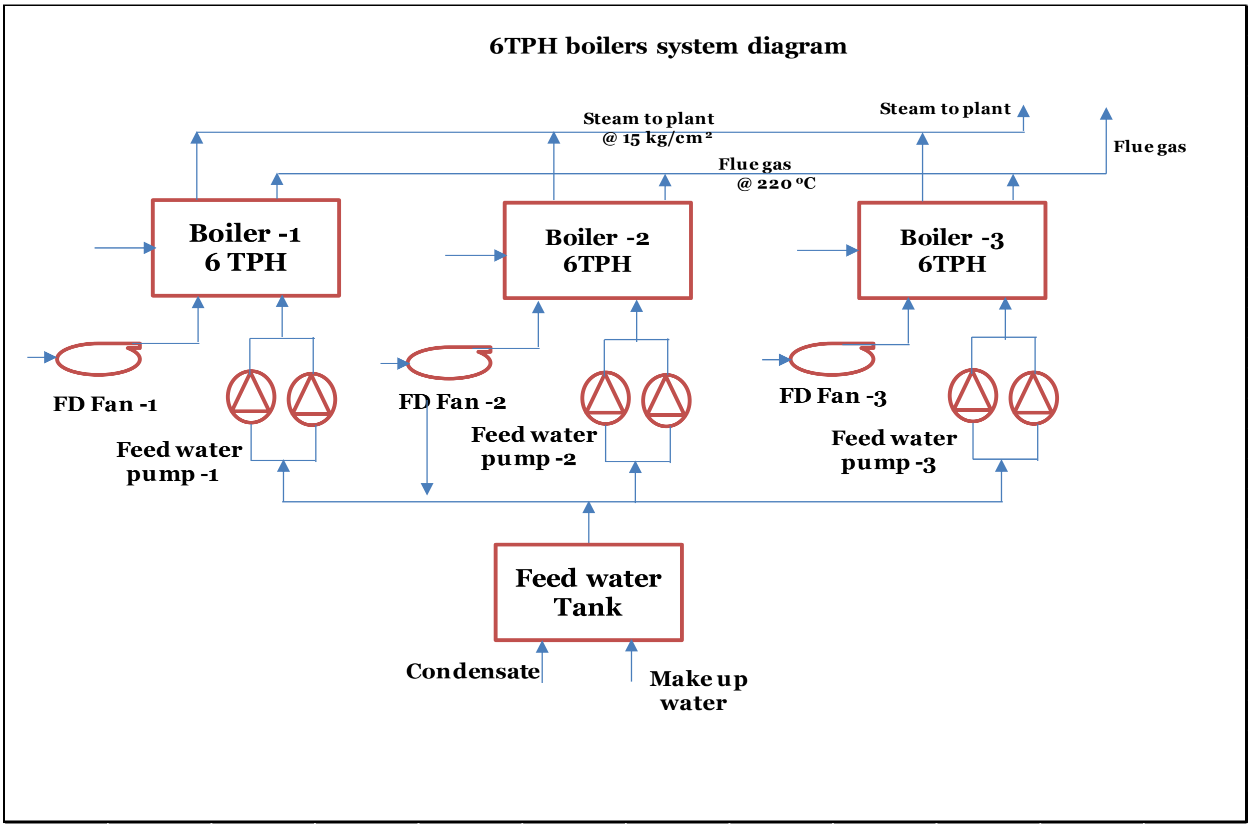
There are two separate boiler plants installed and both are working in dairy to meet the process steam demand. One boiler plant is called as old boiler, which has three boilers of capacity 6 TPH each. Other boiler plant is called as new boiler, which has one boiler of 10 TPH capacity. All the boilers in old plant and new plant along with WHRB in CPP sections are connected to a common steam header to supply steam to entire plant.

3.6.1 Old boiler plant:

Old boiler plant has three boilers of 6 TPH capacity each. Out of three boilers, two boilers are running with natural gas fuel and one boiler is running with biogas and natural gas mix fuel. These boilers are generating steam at pressure of 15 kg/cm^2.

The detailed parameters measured and analysis of old boiler section boilers with system diagram is as follows.

Figure 25 : old boiler section – system diagram



The operating parameters measured at old boiler plant -1 during the audit is as follows.

Table 16 : Old boiler section, boiler -1 operating parameters

Description	Units	Parameters
Feed water flow rate	m^3/h	2.41
Temperature of feed water measured	°C	80
Oxygen at the flue gas outlet during low flame	%	3.5
Oxygen at the flue gas outlet during high flame	%	3.0
CO level in flue gas during low flame	ppm	5
CO level in flue gas during high flame	ppm	0
Temperature of flue gas	°C	240
Actual steam generation during measurement period	TPH	2.41
Steam pressure	kg/cm^2	15

The operating parameters measured at old boiler plant -2 during the audit is as follows.

Table 17 : Old boiler section, boiler -2 operating parameters

Description	Units	Parameters
Feed water flow rate	m^3/h	3.82
Temperature of feed water measured	°C	75
Oxygen at the flue gas outlet during low flame	%	3.5
Oxygen at the flue gas outlet during high flame	%	3.0
CO level in flue gas during low flame	ppm	5
CO level in flue gas during high flame	ppm	0
Temperature of flue gas	°C	240
Actual steam generation during measurement period	TPH	3.82
Steam pressure	kg/cm^2	15

The operating parameters measured at old boiler plant -3 during the audit is as follows.

Table 18 : Old boiler section, boiler -3 operating parameters

Description	Units	Parameters
Feed water flow rate when biogas is used	m^3/h	1.52
Feed water flow rate when biogas & natural gas is used	m^3/h	1.88
Temperature of feed water measured	°C	75
Oxygen percentage in flue gas during low flame during LNG + bio gas	%	3.1
CO level in flue gas during low flame during LNG +bio gas	ppm	1215
Oxygen percentage in flue gas during low flame during only LNG running	%	9.4
CO level in flue gas during low flame during only LNG running	ppm	600
Oxygen percentage in flue gas during high flame during only LNG running	%	11.2
CO level in flue gas during high flame during only LNG running	ppm	131
Oxygen percentage in flue gas during high flame during only bio gas running	%	9.6
CO level in flue gas during high flame during only bio gas running	ppm	150

Description	Units	Parameters
Temperature of flue gas	°C	240
Steam pressure	kg/cm²	15

Note: Fuel consumption for these three boiler were not possible to record due to gas flow meters installed at these three boilers were not operating during audit. Since boiler fuel, consumption is not available, boiler efficiency for these boilers are not calculated.

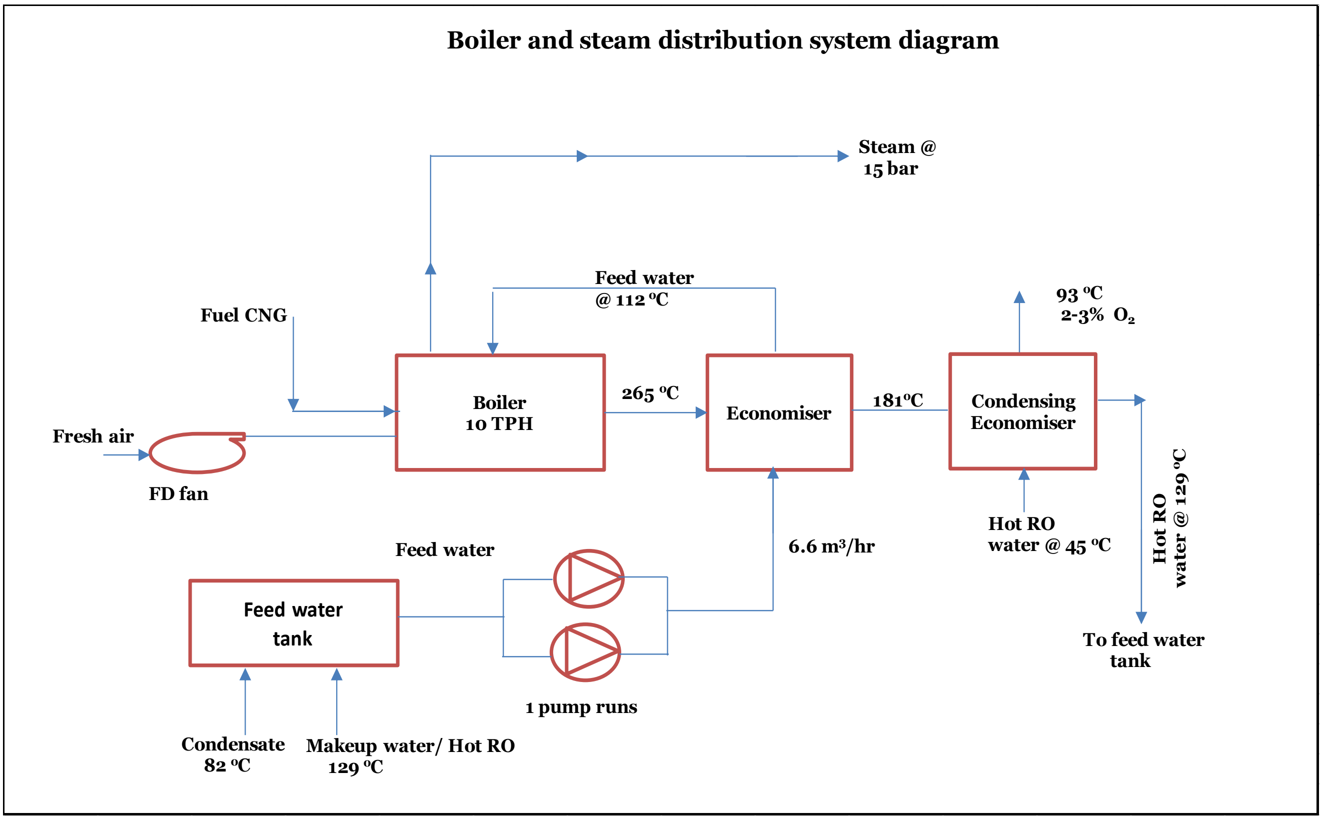
It is recommended to repair/ replace the gas flow meters installed in these boilers for gas flow monitoring and reporting.

All the three boilers put together generating the steam of 7.75 TPH during normal working hours with natural gas fuel. The oxygen percentage and CO level measured at all boilers -1 & 2 are found to be good. In boiler – 3, oxygen percentage was on higher side (Low flame - 9.4% and high flame - 11.2%) compare to standard of 3 % during all fuel conditions like natural gas + biogas, only biogas and only natural gas firing conditions.

3.6.2 *New boiler plant:*

New boiler plant has one boiler of 10 TPH capacity. This boiler is new and installed just two years back. Boiler uses natural gas as fuel. This boiler also generates steam at pressure of 15 kg/cm². The detailed parameters measured and analysis done on the new boiler section along with system diagram are as follows.

Figure 26 : New boiler section – system diagram



The operating parameters measured at new boiler during the audit is as follows.

Table 19 : New boiler section, boiler -1 operating parameters

Description	Units	Parameters
Steam generation during measurement	TPH	8.5

Description	Units	Parameters
Average steam generation per day	TPH	215,800
Temperature of feed water measured	^oC	96
Oxygen at the flue gas outlet	%	3.0
CO level in flue gas	Ppm	0
Temperature of flue gas at boiler outlet	^oC	265
Temperature of flue gas at economizer outlet	^oC	180
Temperature of flue gas at condensing economizer outlet	^oC	90
Water inlet temperature to economizer	^oC	78
Water outlet temperature from economizer	^oC	112
RO water inlet temperature to condensing economizer	^oC	45
RO water outlet temperature from condensing economizer	^oC	130
Condensate temperature to feed water tank	^oC	82
Makeup temperature to feed water tank	^oC	32
Steam pressure at boiler outlet	kg/cm^2	15
Gas flow rate to boiler during measurement period	SCM	700
Average gas flow rate per day	SCM	16770
Steam to fuel ration measured	**kg/SCM**	**12.86**
Boiler efficiency measured	**%**	**83.3**

- The efficiency of the boiler is found to be optimum and is near to the rated efficiency of 86%.

3.6.3 Steam traps, Insulation and leakage:

Detailed study is done on the steam traps, steam insulation and steam leakage in the plant during the audit, same is discussed below.

Steam traps: Plant is installed with inverted bucket type of steam traps in most of the places in steam distribution network. Detailed physical inspection survey on sample basis is done on the steam traps in plant and it is found that, steam traps are working fine and there was no leakage is observed from it.

Insulation study: Detailed study is done on the steam insulation by physical inspection and temperature measurement of steam pipeline and it is found that steam insulation was proper and there was no insulation breakage is observed during the study.

Steam Leakage: There was no steam leakage in the plant through live steam lines, steam traps or some other equipments in the plant.

3.7 Powder plant

There are two-powder plants in dairy, one has the production capacity of 60 TPD and is called as old plant. Other plant has production capacity of 100 TPD and is called as new plant. The production in both plants is highly depending on milk availability in dairy. These plants usually work to their full capacity during winter and rainy season and are under complete shut down during summer season due to less availability of milk. On an average, both plants will be working for about eight to nine months in a year.

Detailed measurement and analysis done on both plants during audit are as follows.

3.7.1 Old powder plant:

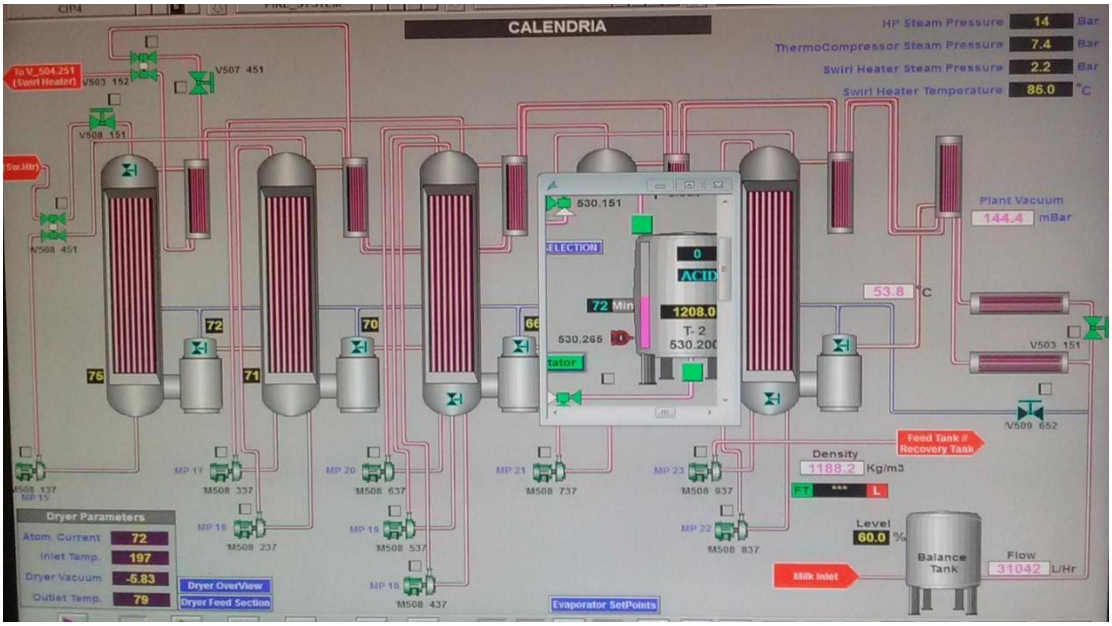
Old powder plant has the production capacity of 60 TPD and it was working to full of its capacity during audit. Milk is received at powder plant from old process and new process pasteurized milk tanks at temperature of around 4 °C and stored in to powder plant silos. Liquid milk is converted to milk powder in two stage of drying process; in the first stage, milk undergoes heat treatment in evaporators and then in spray dryer to make final powder.

Evaporators:

Evaporation is the first stage of powder making process, in evaporation process milk is heated in evaporator columns under vacuum. There is a four stage of evaporation process and vacuum is maintained by using vacuum pumps. After evaporation process, percentage of solid content in milk will be around 48 to 50%.

The evaporation process screen shot collected during audit is as follows.

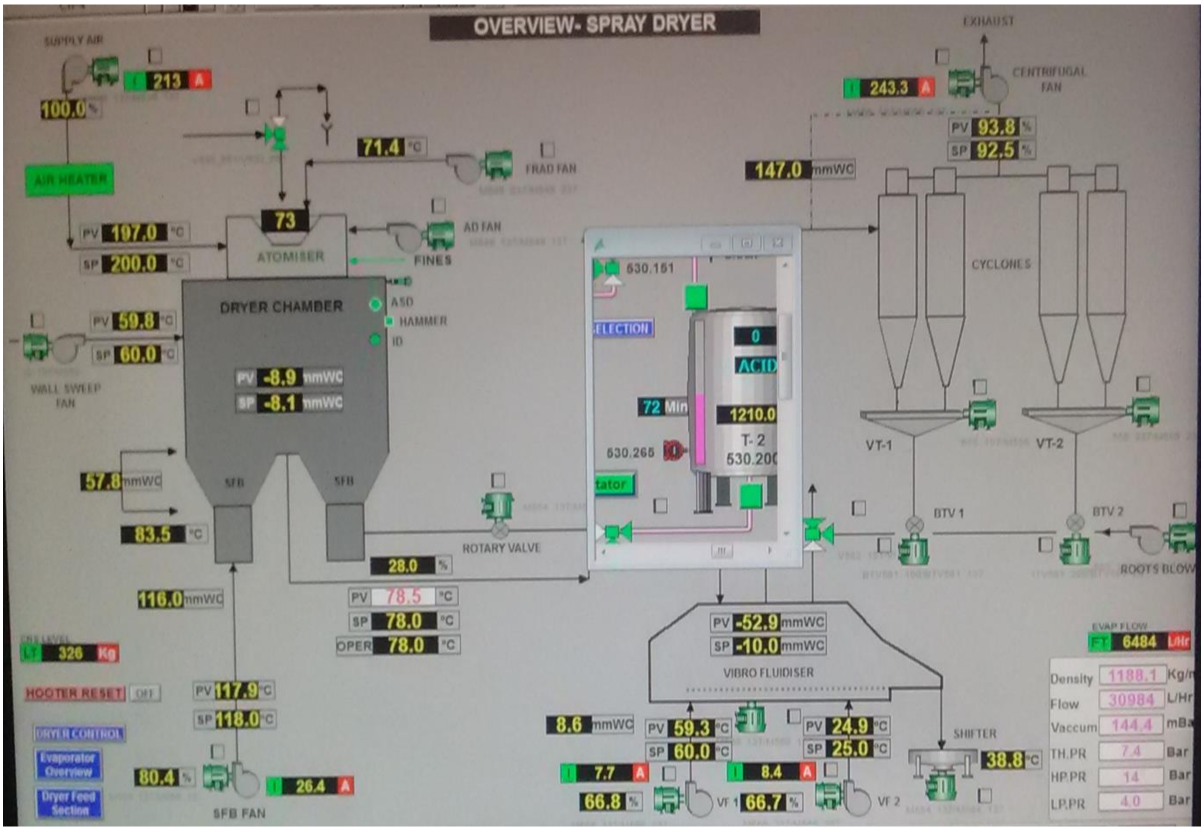
Figure 27 : Old powder plant - evaporator system diagram



Spray drier:

In spray drier 48 % to 50 % of solid content milk from evaporators are further processed to make final milk powder. In spray drier milk at 45 °C is sent to drier along with hot air at temperature of around 200 °C for heat treatment. The detailed spray drier process flow SCADA diagram collected during audit is as follows.

Figure 28 : Old powder plant spray drier system diagram



The major energy consuming equipment in drier is fans. There is supply air fan to supply air for drying process and exhaust fans to exhaust air from drier after processing. Both fans are fitted with VFD and working with variable speed as per drier requirement.

3.7.2 New powder plant:

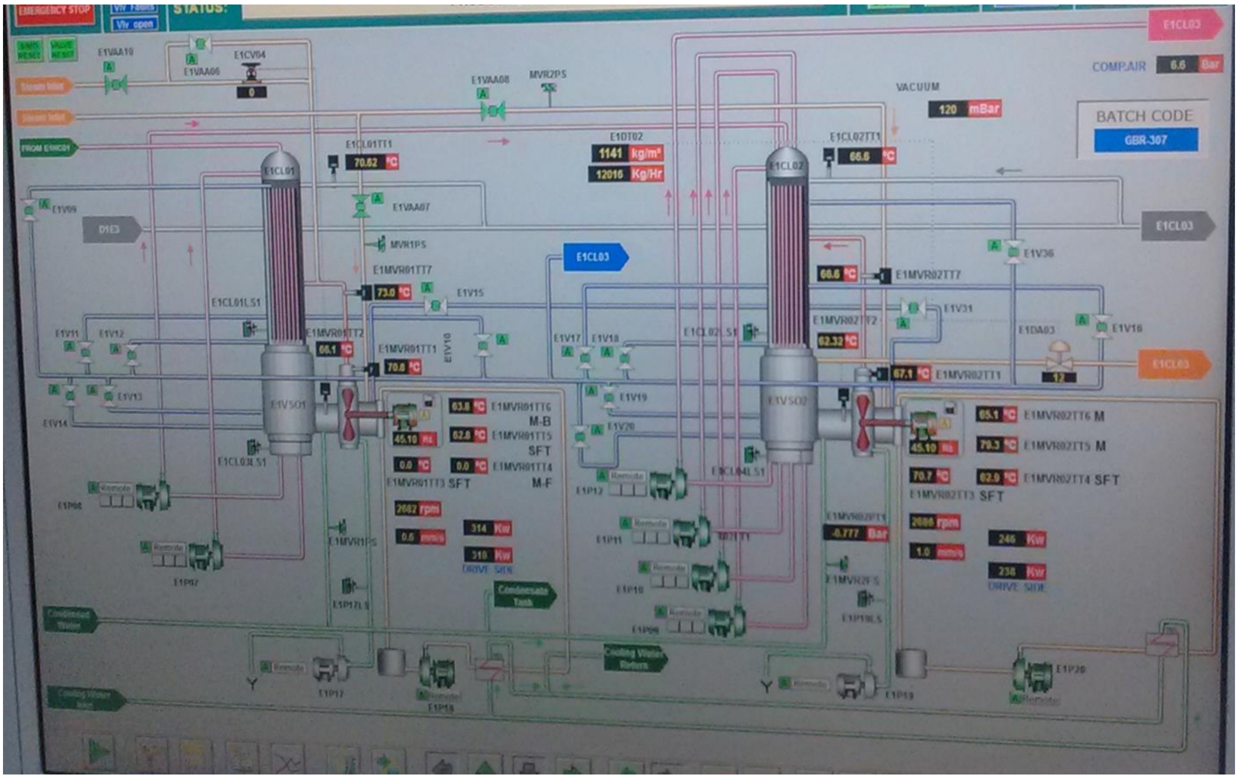
New powder plant has production capacity of 100 TPD and it was also working to full of its capacity during audit. Milk is received to powder plant from old process and new process pasteurized milk tanks at temperature of around 4 °C and stored in to powder plant silos. Liquid milk is converted to milk powder in two stage of drying process; in the first stage, milk undergoes heat treatment in evaporators and then in spray dryer to make final powder.

Evaporators:

Evaporation is the first stage of powder making process, in evaporation process milk is heated in evaporator under vacuum. There is a four stage of evaporation process and vacuum is maintained by using vacuum pumps. After evaporation process, percentage of solid content in milk will be around 48 to 50%.

The evaporation process screen shot collected during audit is as follows.

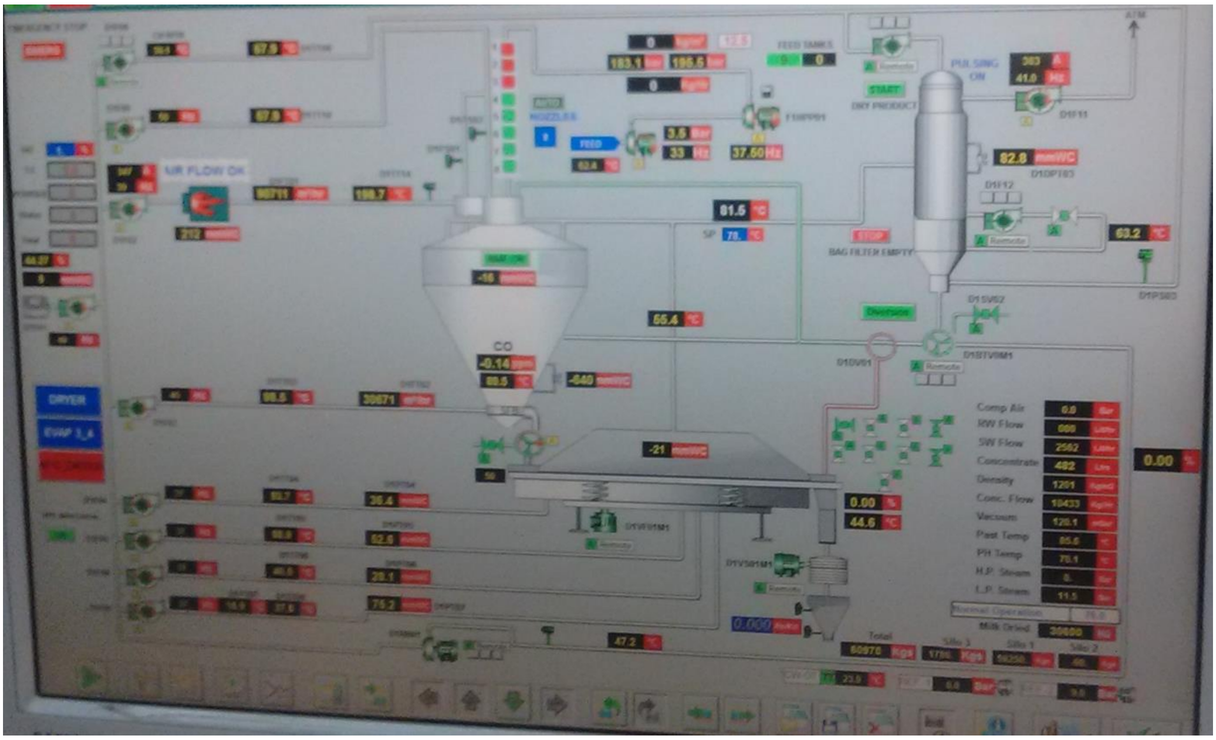
Figure 29 : New powder plant evaporator system diagram



Spray drier:

In spray drier 48 % to 50 % of solid content milk from evaporators are further processed to make final milk powder. In spray drier milk at 45 ºC is sent to drier along with hot air at temperature of around 200 ºC for heat treatment. The detailed spray drier process flow SCADA diagram collected during audit is as follows.

Figure 30 : New powder plant – spray drier system diagram



The major energy consuming equipment in drier is fans. There are supply air fan and exhaust fans to supply air for drying process and exhaust air after milk is dried. Both fans are fitted with VFD and working with variable speed as per drier requirement.

3.8 Water treatment plant

There is a water treatment plant in dairy to supply water required for plant operation. Water treatment plant produces four types of water. Types of water generated and its usage in dairy is listed below.

- RO Water - Dairy operation
- Raw water - Plant usage and for cleaning applications
- Cold soft water - Dairy operations
- Hot soft water - Dairy operations

RO water is generated in RO plants installed in the water treatment plant. Raw water is pumped through bore wells installed in plant campus and cold and hot soft water is generated in water treatment plant and also collected from both powder plants.

RO water plants:

There are three RO water plants operating in water treatment plant. All these three plants are generated RO water is used for dairy operation. The capacity of RO plant -1 is 10 kL, RO -2 is 25 kL and RO -3 is 5 kL. Details of each RO plants are discussed below.

Water handling capacity of 10 kL RO plant	=	15 kL
Accepted water quantity of 10 kL during operation	=	10 kL
Rejected water quantity of 10 kL during operation	=	5 kL
Water handling capacity of 25 kL RO plant	=	34 kL
Accepted water quantity of 25 kL during operation	=	25 kL
Rejected water quantity of 25 kL during operation	=	9 kL
Water handling capacity of 5 kL RO plant	=	8 kL
Accepted water quantity of 5 kL during operation	=	5 kL
Rejected water quantity of 5 kL during operation	=	3 kL

All the RO water plants accept and reject quantity is found to be optimum and all RO plants are working to best of their efficiency.

Raw water (Bore well) pumps:

There are two bore wells drilled in the plant campus and these two pumps enough water to meet entire plant water demand. Water flow and power measurement was done on these bore well pumps and the results are presented below.

Bore well pump -1 :

Water flow rate	=	92 m^3/h
Pump power consumption	=	25 kW

Bore well pump -2 :

Water flow rate = 88 m^3/h

Pump power consumption = 23 kW

Water flow rate and pump power consumption measured in bore well pumps are found to be as per design.

3.9 *Air compressors*

There are five air compressor installed in plant, out of which three will be working to meet plant compressed air requirement. All these compressor are screw type, water-cooled and having VFD installed in it. The design and operating details of the compressor are as follows.

Table 20 Air compressor-operating parameters

Description	Units	Comp -1	Comp-2	Comp-3
Design details				
Make				Atlas Copco
Model		ZR -3	ZR - 145	ZR - 160
Motor power consumption	cfm	135	145	160
Air capacity	cfm	845	900	1000
Operating details				
Loading pressure	kg/cm^2		6.7	6.7
Unloading pressure	kg/cm^2		7	7
Compressor outlet pressure				6.8
VFD installed		Yes	Yes	Yes
Compressor speed	rpm			4270
Running hours	Hours	34,890	31,059	13,296
Loading hours	Hours	31,970	30,306	9,802
Accumulated volume	m^3			1,000
Oil pressure	kg/cm^2	2.5	2.24	3.7
Temperature of compressed air at outlet	^oC	36	34	35
Cooling water inlet temperature	^oC	36	36	36
Cooling water outlet temperature	^oC	37	38.5	39

Since all compressors are working with VFD, there was no un- loading time observed in compressors. Cut in and cut off pressure set in compressor are found to be optimum and compressor are working at the best of its efficiency.

4 Energy Conservation Measures

Amul Fed dairy located in Gandhinagar city of Gujarat state. The dairy is having processing capacity of 32 lakhs liter milk every day, which make this dairy as the **Asia's largest dairy plant**. Dairy manufactures different types of milk and milk products. Detailed energy audit was conducted in Amul Fed dairy plant – Gandhinagar to find energy saving opportunities.

4.1 Electrical distribution

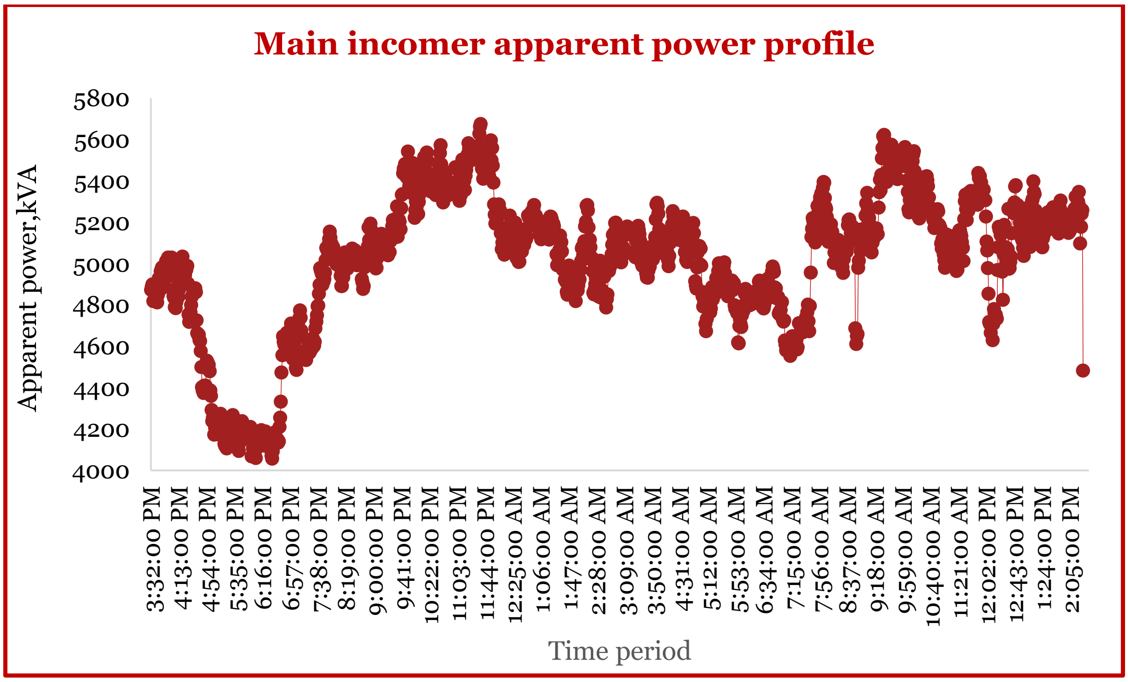
4.1.1 Operate one HT substation transformer instead of two to optimize transformer loading and reduce losses

Background

There are two transformers of 12.5 MVA operating at the HT substation to step down voltage from 66 kV to 11 kV. Power profile recorded for a complete day indicating that, average power consumption on both the transformer is 5,000 kW and average apparent power during the same time is 5,100 kVA.

Apparent power profile recorded on the 66kV main incomer during audit is as follows.

Figure 31 : Main incomer apparent power profile



Finding

An optimum loading of 40 to 60% is need to be maintained on transformers to get best efficiency and less losses. Loading transformer more than 60 % or less than 40 % will reduce the efficiency there by losses in transformer will increases.

Power consumption measurement done on both transformer indicating that, these transformers are under loaded (loading is less than 40%).

Maximum apparent power recorded during measurement time	=	5,600 kVA
Maximum loading on each of transformer	=	22.4 %

Minimum apparent power recorded during measurement time = 4,050 kVA

Minimum loading on each of transformer = 16.2 %

Recommendation

Operate one transformer instead of two to save the transformer loss in one transformer and to operate another transformer with optimum loading for better efficiency.

Note: Detailed discussions is done with plant officials during the audit for the feasibility of implementation of this recommendation. Since plant has never experienced any power quality issue, failure in HT line, HT transformers and have the gas engine backup, it is agreed to operate one HT transformer instead of two to save the transformer losses.

Energy & Financial savings

Estimated energy and financial saving for the recommendation with payback period is as follows.

Table 21 : Transformer loading optimization

Description	Units	Parameters
Present operating transformer		
Number of transformers installed in HT substation	Numbers	2
Number of transformers operating in HT substation	Numbers	2
No load losses in transformer	kW	10
Full load losses in transformer	kW	64
Maximum apparent power measured	kVA	5,600
Loading on transformer -1	%	22%
Loading on transformer -2	%	22%
Transformer -1 losses	kW	13.2
Transformer -2 losses	kW	13.2
Proposed operating transformer		
Proposed number of transformer operation	Numbers	1
Proposed loading on one transformer	%	44
Calculated losses due to one transformer operation	kW	22
Saving in transformer losses due to one transformer operation	kW	4.0
Annual operating hours	Hours	8,760
Annual energy saved	**kWh**	**35,321**
Power cost	Rs/kWh	5.75
Annual cost saved	**Rs. Lakhs**	**2.03**
Investment	**Rs. Lakhs**	**Nil**
Payback period	**Months**	**Immediate**

4.2 Captive power plant (CPP)

4.2.1 Replace CW pumps with new energy efficient pump

Background

There is a dedicated cooling water system for captive power plant. Cooling water is used for the engine and its auxiliary cooling purpose. Two CW pumps was operating in cooling water system to pump water to CPP and these pumps are throttled at discharge side to control its water flow and head. The design details of these pump collected and actual parameters measured to derive the pump efficiency is tabulated below.

Table 22 : CPP CW pump efficiency estimation

Description	Units	Parameters
Design details		
Number of pumps installed	Number	4
Number of pumps operating	Number	2
Design water flow rate of pump	m^3/h	250
Design head	m	50
Rated power consumption	kW	50
Operating parameters		
Number of pumps working	Numbers	2
Pump suction pressure	kg/cm^2	0
Pump discharge pressure	kg/cm^2	5.4
Water flow delivered (2 pumps)	m^3/h	240
Percentage of opening of suction valve	%	100
Power consumption of pump -1	kW	50
Power consumption of pump -2	kW	52
Total power consumption of both pump	kW	102
Overall efficiency	**%**	**35%**
Combined pump efficiency @95% of motor efficiency	**%**	**36%**

Finding

The efficiency of these pumps are found to be very low, due to mismatch between the design and actual parameters because of oversizing.

Recommendation

Replace present in efficient pumps with new energy efficient pumps to save the pump power consumption.

Energy & financial savings

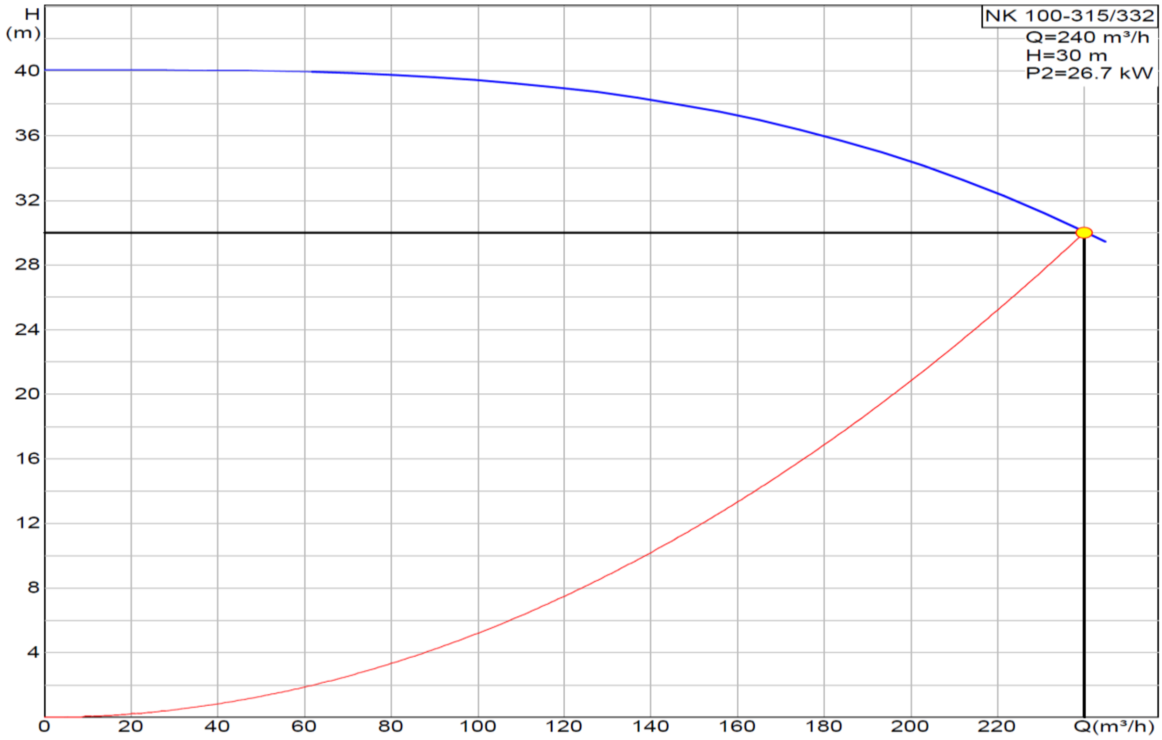
Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 23: Replacement of CPP CW pumps with new energy efficient pumps

Description	Units	Parameters
Design details		
Number of pumps installed	Number	4
Number of pumps operating	Number	2
Design water flow rate of pump	m^3/h	250
Design head	m	50

Description	Units	Parameters
Rated power consumption	kW	50
Present operating parameters		
Number of pumps working	Numbers	2
Pump suction pressure	kg/cm²	0
Pump discharge pressure	kg/cm²	5.4
Water flow delivered (2 pumps)	m³/h	240
Percentage of opening of suction valve	%	100
Percentage of closing of suction valve	%	0
Percentage of opening of discharge valve	%	50
Percentage of closing of discharge valve	%	50
Water pressure before throttling	kg/cm²	5.4
Water pressure after throttling valve	kg/cm²	1.8
Pressure drop across control valve	kg/cm²	3.6
Power consumption of pump -1	kW	50
Power consumption of pump -2	kW	52
Total power consumption of both pump	kW	102
Overall efficiency	**%**	**35%**
Combined pump efficiency @95% of motor efficiency	**%**	**36%**
Proposed parameters		
Proposed flow rate of pump	m³/h	240
Proposed head	m	30
Proposed make of new pump		Grundfos
Model		NK 100-315/332
Proposed pump power consumption	kW	26.7
Proposed efficiency of pump	**%**	**73.5**
Proposed pump motor power consumption	kW	31.3
Pump power consumption saved	kW	70.7
Annual operating hours	Hours	8,400
Annual energy saving	**kWh**	**593,880**
Power cost	Rs/kWh	5.75
Annual cost saved	**Rs Lakhs**	**34.14**
Investment for new pump	**Rs. Lakhs**	**8**
Payback period	**Months**	**2.8**

Figure 32 : CPP proposed pump performance curve



4.2.2 Recover heat from engine HT cooling water

Background

Heat is generated during operation of CPP gas engine and this heat is cooled by circulating cooling water through engine jacket. There is a separate PHE in each engine for this application. Heat rejected by engine to cooling water is estimated by water flow and temperature measurements and it is given below.

Table 24: Heat availability estimation in CPP engines

Description	Units	Parameters
Heat rejected by hot water in PHE	kCal/h	227,500
Heat rejected by hot water in PHE -2	kCal/h	227,500
Heat rejected by hot water in PHE -4	kCal/h	195,000

There is a waste heat of 650,000 kCal/h which can be used.

Finding

Waste heat is generated due to engine jacket cooling is being wasted through cooling tower without any recovery.

Recommendation

Recover heat from engine cooling water, presently it is being wasted without any recovery.

Note: There was no proper matching heat requirement application nearby CPP to give this waste heat for preheating purpose. Plant need to identify such application to recover this heat.

Note: During discussion with plant official, it is found that presently there is no application in plant that needs this waste heat. This heat can be utilized for any pre heating application in future projects if any.

Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 25: Recover waste heat from CPP engine cooling water

Description	Units	Parameters
HT PHE -1 engine hot water return temperature	°C	102.5
HT PHE -1 engine hot water supply temperature	°C	50.4
Heat rejected by hot water in PHE - 1	kCal/h	227,500
HT PHE -2 engine hot water return temperature	°C	103.6
HT PHE -2 engine hot water supply temperature	°C	52.5
Heat rejected by hot water in PHE -2	kCal/h	227,500
HT PHE -4 engine hot water return temperature	°C	107
HT PHE -4 engine hot water supply temperature	°C	56.6
Heat rejected by hot water in PHE -4	kCal/h	195,000
Total waste heat available in CPP	kCal/h	650,000
Calorific value of natural gas	kCal	8,400
Recoverable heat	kCal/h	390,000
Natural gas saved per hours	Kg	46.2
Annual operating hours	Hours	4,500
Total natural gas saving	**SCM**	**207,900**
Natural gas price	Rs/SCM	26
Annual gas cost saved	**Rs. Lakhs**	**54.05**
Investment heat recovery installation	**Rs. Lakhs**	**50**
Payback period	**Months**	**11**

4.3 Refrigeration system

4.3.1 Reduce discharge of R -3 refrigeration system chilled water pumps

Background

There are two sets of chilled water pumps installed in the R-3 refrigeration system to pump chilled water to process. The design and operating details of the pumps are as follows.

Table 26: R -3 refrigeration system chilled water pump operating parameters

Description	Units	Set -1	Set -2
Number of pumps installed	Numbers	3	3
Make		Lubi	
Model		LES - 100-4004	

Description	Units	Set -1	Set -2
Power consumption	kW	29.8	37.25
Flow delivered	m3/h	150	150
Head developed	M	40	50
Number of pumps operating	Numbers	2	2
Operating parameters			
Head developed	M	54	54
Flow delivered	**m3/h**	713	
Power consumption	kW	68	66

Finding

The discharge pressure of these chilled water pumps are found to be very high. Discharge pressure is high due to mismatch between chilled water pipe size and water flow in it. During discussion with plant officials it was found that, plant has expanded in phase manner including addition of new products every year. Due to increase in number of sections, there was an increase in chilled water flow in same pipe size. According to expansion of plants, there was no proper modification and pipe size increase done on the chilled water pipeline. Increased flow rate of chilled water with same pipe size increased in pressure drop.

The chilled water pressure measured at the pump discharge is 5.4 kg/cm², whereas chilled water pressure measured at first user in the plant is 3.5 kg/cm². The pressure measurement at pump discharge and first user end indicating, that there was a pressure drop of 1.9 kg/cm² across the chilled water pipeline in R-3 refrigeration system.

Recommendation

Replace the chilled water pipeline with new proper sized pipeline to reduce the pressure drop.

Energy & financial savings

Estimated energy and financial saving for the recommendation with payback period is as follows.

Table 27: Reduction in CHW discharge pressure recommendation saving potential

Description	Units	Set -1	Set -2
Number of pumps installed	Numbers	3	3
Make			Lubi
Model			LES - 100-4004
Power consumption	kW	29.8	37.25
Flow delivered	m3/h	150	150
Head developed	m	40	50
Number of pumps operating	Numbers	2	3
Operating parameters			
Head developed	m	54	54
Flow delivered	**m3/h**		713
Power consumption	kW	68	96
Proposed parameters			
Proposed discharge pressure	m		38

Description	Units	Set -1	Set -2
Flow rate	m^3/h		713
Reduction in head	m		16
Power consumption reduction due to reduction in head	kW		115.2
Saving in power consumption	kW		48.8
Power consumption saved considered for saving calculation	kW		29.28
Annual operating hours	Hours		8400
Annual energy saved	**kWh**		**245,952**
Power cost	Rs/kWh		5.75
Annual cost saved	**Rs. Lakhs**		**14.14**
Investment	**Rs. Lakhs**		**10**
Payback period	**Months**		**8.5**

4.4 Boiler and steam distribution

4.4.1 Install economizers in 6 TPH boiler to recover heat from flue gas to pre heat fresh air

Background

There are three 6 TPH boilers operating in the old boiler house to supply steam to dairy process. These boilers are very old and generating steam at pressure of 15 kg/cm^2. Flue gas temperature measured at the stack in each boiler is as follows.

Flue gas temperature at boiler -1 stack = 230 °C

Flue gas temperature at boiler -2 stack = 240 °C

Flue gas temperature at boiler -3 stack = 250 °C

Finding

Flue gas temperature measured at the stack is very high and it is indicating that there is a potential for waste heat recovery to preheat fresh air or boiler feed water. Since these boilers are using natural gas fuel, which is very clean in nature, flue gas temperature at stack after waste heat recovery can be up to 90 to 100 °C

Recommendation

Install economizer to recovery heat from flue gas to preheat feed water from boiler feed water pump.

Energy & Financial savings

Estimated energy and financial saving for the recommendation with payback period is as follows.

Table 28: Installation of economizer

Description	Units	Parameters		
Present system		**Boiler -1**	**Boiler -2**	**Boiler -3**
Flue gas temperature measured in boilers	°C	230	240	250
Feed water inlet temperature to boiler	°C	80	80	80
Fuel consumption per hours	SCM	120	150	140

Description	Units	Parameters		
Present steam generation	TPH	2.42	3.8	1.82
Proposed system				
Flow rate of flue gas	kg/h	12,000	11,000	10,500
Flue gas temperature	ºC	230	240	250
Expected final temperature of flue gas after heat recovery	ºC	120	120	120
Recoverable heat energy in flue gas	kCal/h	303,600	303,600	313,950
Recoverable heat considering recovery system efficiency	kCal/h	182,160	182,160	188,370
Present temperature of feed water	ºC	80	80	80
Expected final temperature of feed water	ºC	120	120	127
Fuel quantity saved per hours	SCM	14	16	12.5
Annual fuel quantity saved	SCM	11,760	13,440	10,500
Fuel cost	Rs	26	26	26
Total cost saving per year	**Rs. Lakhs**	**305,760**	**349,440**	**273,000**
Total cost saving	**Rs. Lakhs**	**9.28**		
Investment	**Rs. Lakhs**	**10**		
Simple payback period	**Months**	**13**		

4.4.2 Install VFD on 6 TPH& 10 TPH boiler feed water pumps

Background

Plant is having three number of 6 TPH & one number of 10 TPH boiler to generate steam. Steam is generated at pressure of 15 kg/cm², there is a boiler feed water pump to pump the feed water to each of the boiler for generating steam. The design and operating details of all boiler feed water pump is as below.

10 TPH boiler design details:

Make	:	Grundfos
Model	:	CR - 15-17
Power consumption	:	15 kW
Head developed	:	197 m
Flow delivered	:	17 m³/h

10 TPH boiler-operating details (During audit)

Head developed	:	200 m
Flow delivered	:	7.5 m³/h

6 TPH boilers operating details (During audit)

Head developed	:	250 m
Flow delivered by BFP -1	:	2.41 m³/h
Flow delivered by BFP -2	:	3.82 m³/h

Flow delivered by BFP -3 : 1.88 m^3/h

Finding

Boiler feed water pumps at 6 TPH boilers are working with pressure of 25 kg/cm^2, whereas the boiler steam pressure is 15 kg/cm^2.

Boiler feed water pumps in 10 TPH boilers are working with pressure of 20 kg/cm^2, whereas the boiler steam pressure is 15 kg/cm^2.

Pumps in both boilers section are operating with the higher head than required. In any medium sized boiler, the feed water pressure should be 1 to 2 kg/cm^2 more than the steam pressure. The higher pressure is required to overcome all the static and frictional loss happening in the pipe and valves. However, in this boiler, the feed water pump is generating more head and flow and it is controlled externally in the control valve installed at the discharge side of the pump.

Recommendation

The steam generation is varying in the plant throughout the day depending on the plant load. In order to match the feed water pump flow and pressure as per plant steam demand, it is recommended to install VFD on the feed water pump with header pressure feedback control to vary frequency as per steam flow and pressure.

Energy & financial savings

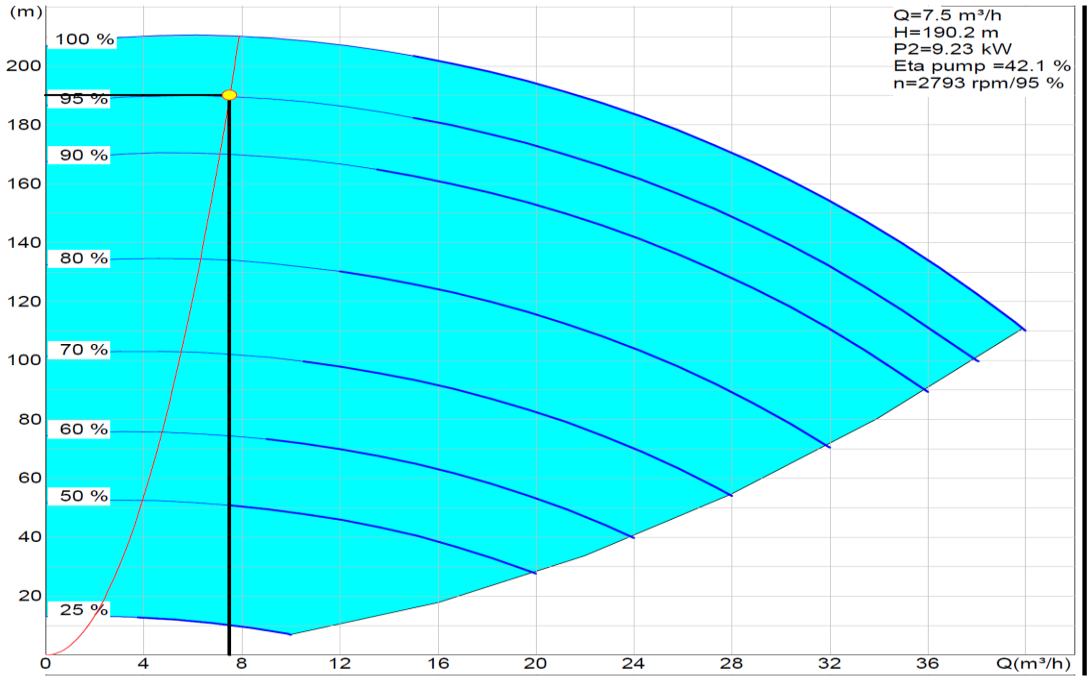
Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 29: VFD installation on 6 TPH and 10 TPH boiler feed water pump

Description	Units	10 TPH BFP	6 TPH BFP
Design parameters			
Make		Grundfos	Details are not available
Model		CR – 15-17	
Power consumption	kW	15	
Head developed	m	197	
Flow delivered	m^3/h	17	
Operating parameters			
Average head developed	m	200	250
Flow delivered by each pump -1	m^3/h	7.5	2.41
Flow delivered by each pump -2	m^3/h		3.82
Flow delivered by each pump -3	m^3/h		1.88
Pump power consumption -1	kW	12.5	11.7
Pump power consumption -2	kW		10.5
Pump power consumption -3	kW		12.1
Proposed parameters			
Head developed	m	170	170
Flow delivered by BFP-1	m^3/h	7.5	2.41
Flow delivered BFP-2	m^3/h	-	3.82
Flow delivered BFP-3	m^3/h	-	1.88
Power consumption of pump with VFD	kW	9.23	24
pump power consumption saved	kW	3.2	10.3

Description	Units	10 TPH BFP	6 TPH BFP
Annual operating hours	Hours		8,640
Annual energy consumption saved	**kWh**		**116,640**
Power cost	Rs/kWh		5.75
Annual cost saved	**Rs. Lakhs**		**6.7**
Investment for VFD and accessories	**Rs. Lakhs**		**10**
Payback period	**Months**		**17.7**

Figure 33 : 10 TPH boiler pump performance curve with VFD



4.4.3 Install blowdown heat recovery system in 6 TPH and 10 TPH boilers

Background

6 TPH and 10 TPH boiler are generating steam for process in dairy. Both boiler use RO water as feed water makeup and blow down done on these boilers once in a shift to exhaust the salt, minerals and hard water out of boiler.

TDS value of makeup water = 250 ppm

Maximum allowable TDS in both boilers = 2,500 ppm

Finding

Boiler blow down is happening once in the shift, blow water from boiler is collected in a pit and sent to ETP for water treatment then it is used for the gardening purpose. There is a considerable amount of sensible heat present in blowdown water is being wasted in present system.

Recommendation

Install blowdown recovery system, to recover heat from blowdown water to pre heat boiler feed water. Pre heating boiler feed water will further increase the temperature of feed water there by reduces the boiler fuel consumption.

Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 30: Boiler blowdown heat recovery system recommendation saving potential

Description	Units	6TPH	10 TPH
Boiler Pressure	kg/cm²	15	15
Boiler steam generation	kg/h	6610	10000
Maximum Allowable TDS in Boiler	ppm	2500	2500
Feed water TDS	ppm	250	250
Blowdown Rate	kg/shift	734.44	1111.11
Amount of Energy in each Kg of Blowdown	kJ/kg	740.0	740.0
Specific enthalpy of water at 0.2 kg/cm²	kJ/kg	440.5	440.5
Specific enthalpy of evaporation at 0.2 kg/cm²	kJ/kg	2242	2242
% of Flash Steam generated	%	13.36	13.36
Rate of Flash Steam Generation	kg/shift	98.11	148.43
Equivalent useful Energy saved by flash steam generation	kCal/shift	52,623	79,612
GCV of natural gas	kCal	8,400	8,400
Fuel savings per shift	kg/shift	6.3	9.5
Number of shifts per day	Numbers	3.00	3.00
Annual operating days	Days	360	360
Annual fuel savings	**SCM**	**6,766**	**10,236**
Cost of NG	Rs/SCM	26	26
Annual cost savings	**Rs. Lakhs**	**1.76**	**2.67**
Total savings	**Rs. Lakhs**		**4.43**
Investment	**Rs. Lakhs**		**5**
Payback	**Months**		**13**

4.4.4 Install back pressure turbine on main LP steam header

Background

Steam is generated in all the operating boilers at pressure of 15 kg/cm². Major user of steam in the process is milk plants and powder plants. The steam users in plant can be divided in to two type, one is low-pressure user, which needs steam pressure at 3 kg/cm² and high-pressure user need steam at 8 kg/cm².

Average steam generation per hour = 16.61 TPH

Estimated steam consumption of low pressure users = 7 TPH

Estimated steam consumption of low pressure users = 6.61 TPH

Note: The total steam generation, low pressure and high-pressure user consumption data is collected from plant officials for one day during the audit and these are indicative purpose only. Actual steam generation and consumption will vary depending on plant load every day.

Finding

Plant is generating steam at 15 kg/cm², but maximum steam pressure required at user end is 8 kg/cm². User end pressure is found to be very less compared to generation. Since steam is generated at higher pressure, its pressure is reduced by multiple PRVs installed at different locations of plant. Due to pressure reduction in PRVs the pressure energy in steam is lost without any use.

Recommendation

Install backpressure turbine at the main LP steam header to recover pressure energy associated with steam. Due to backpressure turbine installation, pressure energy getting lost in PRVs can be recovered in the form of electrical power and steam at required pressure can be used for LP process application.

Note: In order to install the backpressure turbine in the steam network, there may be minor steam pipeline and PRS location changes need to be done, which may need plant shutdown. If plant wishes not to change the pipelines, plant can install the small micro turbine separately in each of the steam line. Energy generated by this arrangement will be almost same but it will increase the investment.

Variation in the steam flow to the turbine is considered during the saving calculation and suggested turbine will handle the variation in steam without any problem. (As per vendor confirmation, vendor details are provided in Annexure – 5.2)

Energy & financial savings

Estimated energy and financial saving for the recommendation with payback period is as follows.

Table 31: Installation of backpressure turbine recommendation saving potential

Install Back Pressure Turbine	Units	Parameters
Description		**At 7 TPH**
Boiler Steam Pressure	Bar(g)	15
Present boilers total rating	Kg/hr.	7000
Steam Pressure required at User end	Bar (g)	3
Saturation Temperature of Steam at 15 bar	°C	201.3
Enthalpy of Inlet steam to turbine	Kcal/kg	665.58
Enthalpy of Outlet steam from turbine (Having dryness fraction of 96%), Output steam will be wet steam	Kcal/kg	641.4
Enthalpy drop across turbine	Kcal/kg	24.18
Efficiency of Turbine, gears and alternator	%	76%
Quantity of useful heat equivalent of power	Kcal/kg	18.38
specific steam consumption of turbine	kg/kWh	46.80
Estimated Power Generation	**KW**	**150**
Power generation considered for saving	%	90%
Estimated Power Generation	kW	135
Annual Operating Hours	Hours	7920
Electrical Energy Generation Annually	KWh	1,184,663
Cost of Electrical Energy	Rs/kWh	5.75
Total Annual Savings (Including variation in steam flow)	Rs Lakhs/year	68
Investment	**Rs Lakhs**	**120**
Simple Payback	**Months**	**21**

4.5 Process plants

4.5.1 Install auto control valve at refrigerant and CHW line in all process plant

Background

Plant is having good SCADA system and auto control valves to control and maintain temperature of chilled water temperature at the most of the process end. There are some plants still having a manual control valve and there is no SCADA control. The manual control valve are present at following section of plants:

Ice cream plant	-	Process equipment
Buttermilk plant PHE	-	1 Number
Old process pasteurization PHEs	-	4 Numbers

Finding

Ice cream plants process equipment uses cold refrigerant from R-2 refrigeration system for freezing ice candies. These machines will be working as per ice cream requirement and will be under CIP for four hours in 24 hours. Even though process equipment are not working or under CIP refrigerant will be flowing in to these machine without any control due to manual operating valves.

The PHE chillers installed at the buttermilk section to cool the buttermilk to the required temperature. Since there is no auto control valve at these PHEs, temperature of the buttermilk is going less than the required temperature of 8 ^{o}C, which is not required.

The PHE pasteurizers operating at the old process section to cool the milk after heating in pasteurization process. Since there is no auto control valve at these PHEs, temperature of the milk is going less than the required temperature of 4 ^{o}C, which is not required.

If there is no control on refrigerant and chilled water flow as per the product temperature requirement, chilled water and refrigerant will be flowing in PHE chiller and process equipment always at same rate irrespective of product flow rate and temperature, this will increases the plant heat load and chiller power consumption.

Recommendation

Install solenoid auto control valve at the above said plants chillers PHEs and process equipment.

Energy & Financial savings

Installation of auto control valves at the PHE's and ice cream process equipment will reduce the chilled water and refrigerant consumption and thereby reduce the compressor power consumption.

Since it is not possible to decide, the exact possible saving by theoretical calculation (which has to be realized practically). The saving potential is not calculated for this energy conservation measure.

4.5.2 Reduce pasteurization milk heating temperature from 78 ^{o}C to 74 ^{o}C

Background

Dairy is having two plants to process milk namely old plant and new plant. Both plants to gather is having milk-handling capacity of 32 lakhs liter per day. In milk processing plant milk pasteurization is done. In pasteurization process, milk is heated up to the temperature of 78 - 79 ^{o}C and kept it in hold for 20 second and cooled back to temperature of less than 4 ^{o}C.

According to food standards and Amul milk standard, pasteurization temperature of milk should be 74 ^{o}C for heating and 4 ^{o}C for cooling.

Finding

According to standards, milk is need to be heated to temperature of 74 ^{o}C and cooled to temperature of 4^{o}C. In old process and new process plants, heating temperature of milk in pasteurization process is set at 78 ^{o}C, which is very high compared to standards.

Higher heating temperature of milk leads to more steam consumption for heating and more chilled water consumption for cooling it after heating.

Recommendation

Change the heating temperature of milk in pasteurization process to 74 ^{o}C instead of 78 ^{o}C. Changing the heating set temperature of milk will reduce both steam and chilled water consumption.

Energy & Financial savings

Since there is no steam consumption data available for pasteurization process, it is not possible to calculate the saving associated with pasteurization process heating set temperature reduction from 78 ^{o}C to 74 ^{o}C.

4.5.3 Install compressed air recover system to recover HP compressed air from blow molding machines

Background

There is a blow-molding machine in the new process plant. Blow molding machine is used to blow the pre forms purchased outside to make final bottles for milk packing. Blow molding machine needs high-pressure compressed air for preform blowing application. In order to supply high-pressure compressed air, plant is operating one high-pressure compressor. Design and operating details of this compressor is as follows

Air compressor make = AF

Design pressure = 40 kg/cm^2

Model = CE 24A

FAD = 300 cfm

Power consumption = 90 kW

Capacity of blow molding machine = 200 bottles per hours

Actual compressed air pressure required to blow 200 ml bottle = 25 kg/cm^2

Actual compressed air pressure required to blow 1 liter bottle = 30 kg/cm^2

Finding

After blowing preforms in blow molding machine, high- pressure compressed air is getting escaped to ambient without any recovery in the present blow molding machine. In the blow-molding machine, there is a provision to recover the compressed air after blowing preforms in it. Plant has to install proper air recovery system to the provision provided in present blow molding machine to recover compressed air after blowing. The recovered air from this machine can be re-used for plant low-pressure application.

Expected compressed air pressure after recovery from blow molding machine is 8 to 10 kg/cm².

Recommendation

Install proper compressed air recovery system to blow-molding machine to recover compressed air after blowing preform in it.

Energy & financial savings

Estimated energy and financial saving for this recommendation with payback period is as follows.

Table 32: Installation compressed air recovery system recommendation saving potential

Description	Units	Blow molding machine
Design details		
Air compressor make		AF
Design pressure	kg/cm²	40
Model		CE 24A
FAD	cfm	300
Power consumption	kW	90
Operating details		
Capacity of blow molding machine	Bottles/Hour	200
Actual compressed air pressure required to blow 200 ml bottle	kg/cm²	25
Actual compressed air pressure required to blow 1 liter bottle	kg/cm²	30
Compressor power consumption during loading	kW	90
Compressor power consumption during un loading	kW	40
Average loading percentage of compressor when running	%	60
Average un loading percentage of compressor when running	%	40
Expected compressed air flow rate per hours	cfm	180
Proposed parameters		
Minimum compressed air pressure used for blowing application	kg/cm²	25
Expected compressed air pressure after recovery	kg/cm²	8
Quantity of air after recovery (Estimated)*	cfm	126
SEC of compressor running @ 8 kg/cm²	kW/cfm	0.15
Power consumption saved by recovery	kW	18.9
Annual operating hours	Hours	4,800
Annual energy consumption saved	**kWh**	**90,720**
Power cost	Rs/kWh	5.75
Annual cost saved	**Rs Lakhs**	**5.2**
Investment for recovery system	**Rs Lakhs**	**15**
Payback period	**Months**	**34.6**

*Note: Quantity of compressed air recovery mentioned in above calculation from blow molding machine is an estimated value based on similar system running in other plants. Actual quantity of air recovery from machine has to be realized practically after installing air recovery system.

4.6 Powder plants

4.6.1 Install VFD on 100 TPD condenser CW pump to avoid throttling

Background

There is a cooling water system in 100 TPD powder plant to serve cooling water requirement for the plant condenser. There is one cooling tower with three fans and a cooling water pump installed in this system.

The design and operating details of the cooling water pumps is given below.

Table 33: 100 TPD condenser water pump operating parameters

Description	Units	100 TPD plant
Design details		
Make		KBL
Model		CPHM 50/20
Flow rate	m^3/h	12
Head developed	m	18
Pump power consumption	kW	11
Operating parameters		
Flow delivered by pump	m^3/h	8
Percentage valve open at suction	%	100
Percentage valve closed at suction	%	0
Percentage valve open at discharge	%	25
Percentage valve closed at discharge	%	75
Discharge pressure	kg/cm^2	5.5
Suction pressure	kg/cm^2	0
Water pressure near to condenser (After valve throttling position)	kg/cm^2	3
Pressure drop across control valve	kg/cm^2	2.5
Pump power consumption	kW	9.7

Finding

Cooling water pump is operating with discharge valve throttling. Valve is throttled to control pump flow and pressure as per condenser requirement. Throttling is a bad practice of controlling pump, due to throttling there will be pressure drop across control valve, there by power consumption increases.

Pressure drop across the discharge control valve is 2.5 kg/cm^2.

Recommendation

Install VFD to cooling water pump with header pressure feedback control mechanism to vary VFD frequency as per flow and pressure requirement of powder plant condenser.

Energy & financial savings

Estimated energy and financial saving for the recommendation with payback period is as follows.

Table 34: VFD on 100 TPD powder plant CW pump recommendation saving potential

Description	Units	100 TPD plant
Design details		
Make		KBL
Model		CPHM 50/20
Flow rate	m^3/h	12
Head developed	m	18
Pump power consumption	kW	11
Operating parameters		
Flow delivered by pump	m^3/h	8
Percentage valve open at suction	%	100
Percentage valve closed at suction	%	0
Percentage valve open at discharge	%	25
Percentage valve closed at discharge	%	75
Discharge pressure	kg/cm^2	5.5
Suction pressure	kg/cm^2	0
Water pressure near to condenser (After valve throttling position)	kg/cm^2	3
Pressure drop across control valve	kg/cm^2	2.5
Pump power consumption	kW	9.7
Proposed parameters		
Flow delivered by pump	m^3/h	8
Percentage valve open at suction	%	100
Percentage valve closed at suction	%	0
Percentage valve open at discharge	%	100
Percentage valve closed at discharge	%	0
Discharge pressure	kg/cm^2	3
Power consumption of pump after VFD installation	kW	6.5
Power consumption saved	kW	3.2
Expected frequency of VFD	Hz	35
Annual operating hours	Hours	2,400
Annual energy saved	**kWh**	**7,680**
Power cost	Rs/kWh	5.75
Annual cost saved	**Rs. Lakhs**	0.44
Investment for VFD	**Rs. Lakhs**	**0.75**
Payback period	**Months**	**20.5**

5 Annexure

5.1 List of Energy Audit Instruments

PwC has multiple energy audit instruments kits. All the instruments are of have high quality, precision and are periodically calibrated. The instruments are capable to cover all electrical and thermal measurements required in the plants. A list of instruments used by PwC during the audit are shown below

Table 35: List of energy audit instruments

S. No.	Name of the Instrument	Make	Quantity
Thermal Instruments			
1	Flue Gas Analyzer (KANE 900+)	Kane (UK)	2
2	Non-contact Infrared Thermometer (Testo-845 and Extech)	Testo (USA),	3
3	Contact type Thermometer (Testo-845 and Extech)	Extech (USA)	3
4	Digital Manometer (Testo-510)	Testo (USA)	1
5	Vane Anemometer (Testo-416)	Testo (USA)	2
Electrical Instruments			
6	3-phase Power Analyzer	Krykard	3
7	1-phase Power Analyzer		3
8	Digital Tachometer (Extech-461995)	Extech (USA)	1
9	Lux Meter (Extech and Testo)	Extech and Text	5
10	Pressure Gauge	Comark (UK)	2
Others			
11	Precision Hygrometer (Testo-625)	Testo (USA)	2
12	Ultra Sonic Water Flow meter - Transit Time type	GE, Micronics	2
13	Ultra Sonic Water Flow meter - Doppler type	Micronics	1

5.2 List of Suppliers

The objective of the mapping of suppliers is to provide guidance to the factory management in understanding the supplier base for the recommended energy efficient technologies and equipment in the energy conservation measures in the report.

PwC team with their experience as well as during the fieldwork stage of the energy audits collected a very wide range of energy consumption related data and gained a thorough understanding of related technologies and practices adopted at dairy plants. These interactions enabled the PwC to understand the current level of awareness among factories about energy efficient equipment and the suppliers of such equipment.

By analyzing, the energy consumption related data collected at the fieldwork stage, the PwC team identified the appropriate energy efficient equipment for each of the audited dairy plants. Following the identification of the most appropriate energy efficient technologies and equipment, the energy audit team gathered information on the suppliers of such technologies and equipment mainly through following steps:

- Names and addresses of the suppliers, who have supplied energy efficient equipment's and technologies to the factories, which were visiting during field studies, were collected.
- Desk Research (internet search etc.) was carried out to identify the established international and local suppliers of energy efficient equipment to dairy plants.
- When additional technical and pricing information was required, the suppliers (or agents or representatives in India) were directly contacted by the PwC team, to obtain the required information.

Based on the above-mentioned approach, the following table provides insights into the composition of the current supplier base and identifies preferred suppliers of energy efficient technologies/ equipment's to the Gujarat dairy sector.

Table 36 : Vendor details for recommended saving solution

Equipment/ Technology	Product	Manufacture / Brand	Available Location
Variable Frequency Drive (VFD)	VFD	Danfos	**Danfos India Private Limited** No. 502, Abhijeet IV, Behind Pantaloon Showroom Near Law Garden Ahmedabad - 380009
	VFD	Schneider	**Schneider electric India Private Limited** No. 42A, 4th Floor, Space House, Mithakali Six Roads Opp. Sri Krishna Centre Ahmedabad - 380009
	VFD	Siemens	**Siemens Ltd** 3rd Floor, Prerna Arbour, Opp. Singapore Airlines, Nr Girish Cold drinks cross roads, Off. C. G. Road, Ahmedabad - 380009 Tel.: +91 (079) 30927600/40207600
Blowdown recovery system	Blowdown recovery system	Thermax	**Thermax India Private Limited** 403, Mihir Tower, Mani Nagar Near Jawahar Chowk, Mani Nagar Ahmedabad, Gujarat 380008
		Forbes Marshal	**Forbes Marshal India Private Limited** 35, Punitnagar Society, Old Padra Rd, Vadodara Gujarat 390015
Backpressure turbine	Turbine	Turbo Tech	**Turbo Tech Pression Engineering private limited** Survey No. 8/2, Honnasandra Village Kasab Hobli, Nelamangala Taluk Bangalore

Equipment/ Technology	Product	Manufacture / Brand	Available Location
Pumps	Pumps	Grundfos	**Grundfos India Private Limited** Shop No. 107, 1st Floor, Swapneel - 5, Near Commerce Six Roads, Drive in Rd, Sarvottam Nagar Society Navrangpura, Ahmedabad - 380009
		Kirloskar brothers	**Kirloskar Brothers Limited** 11, Mill Officer Colony, Behind La Gajjar Chamber, Ashram Road, Ashram Road 079 2657 4802
Waste heat recovery system	Economizer	Thermax India	**Thermax India Private Limited** 403, Mihir Tower, Mani Nagar Near Jawahar Chowk, Mani Nagar Ahmedabad - 380008
	CPP Engine waste heat	Thermax India	

** Please note neither PwC nor BEE recommends any particular vendor/supplier. The list provided is not comprehensive and is only suggestive to facilitate the unit. If unit has its own vendor /supplier, those can also be contacted for the same.*