Refrigeration Plant Review - Basis for Future Plant Upgrade

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1 Executive Summary

This report is based upon our survey of the Queensland Beef plant’s ammonia refrigeration unit carried out by the author during July 1-4 2014. This plant presently uses all installed compressors operating at extremely low LP suction pressure to meet current carton and carcase freezing requirements. These freezing requirements combined with the current plant configuration, which has relatively large booster compressors and undersized separator vessels and pipework, has created extremely large system pressure drops that result in the actual evaporating temperatures at the freezers being excessively higher than the compressor suction temperatures. Correction of the restrictions that cause the large pressure differences between compressor suctions and evaporators is the primary item that must be addressed in order to significantly improve plant performance and realise additional capacity. Improvement in operation procedures will also provide opportunities for improvement.

The following report identifies current plant operating parameters and capacities and recommends improvements that should be made to improve both current and future freezing performance.
2 Project Description

A Queensland Beef processor was implementing a whole of business approach to improving systems, processes and operations to enhance profitability to remain competitive. The initial focus area for improvement will be the review and optimisation of plant operations. Refrigeration at the Queensland Beef processing plant is responsible for the bulk of the electric power consumption. The aim of the current project was to evaluate the existing ammonia refrigeration plant to establish a baseline of current plant load status. This proposed work will compare the current status with the sizing of installed refrigeration plant and piping. A preliminary review of Queensland Beef processor’s compressors will also be undertaken as part of the assessment of the refrigeration plant. The outcome of the project will be a review of current capability and capacity of the existing refrigeration plant at a Queensland Beef processing plant. A refrigeration improvement management plan will be developed and documented in a final report with the findings and recommendations to be reported to operations management and project group via a site visit presentation.

The aim of the project was to apply methodologies to the Queensland Beef processing plant in order to determine the level of efficiencies of refrigeration, and consequently estimate the energy and cost savings that would result from optimisation of the refrigeration. The outcome of this proposed work would be a refrigeration management plan including detailed recommendations and estimated cost-savings for implementation of activities for refrigeration improvement and optimisation. This management plan would be used to assist a Queensland Beef processor and the wider industry in quantifying the cost savings associated with the recommended changes and developing the required internal company capability to design routine service and maintenance programs.
3 Objectives

The objectives of the project were to:

- Investigate existing ammonia refrigeration plant to establish the current plant load status
- Compare the current refrigeration plant load with the sizing of installed refrigeration plant and piping
- Preliminary review of compressor equipment, existing plant data and preliminary observations during a plant visit and provide a compressor improvement and management plan
- Update refrigeration engine room and layout drawings to bring these to current as built status
- To develop company and industry capability in the approach for reviewing refrigeration status and document a refrigeration management plan

The expected outcomes were:

- Evaluation of the current capability and capacity existing ammonia refrigeration plant to establish the current plant load status and enable increased efficiency of energy consumed
- Preliminary evaluation of the compressor configuration and capacity and from historical plant data provide recommendations for improvement in the form of management plans
- Provide a Queensland Beef processor with a comprehensive assessment that will enable design & implementation of the most efficient operating and asset management plan of their refrigeration plant.
4 Methodology / Scope of Work

The following approach was applied:

1) Preliminary plant meeting to review and design scope of work
   • Scope of works and detailed work schedule
   • Project group formed consisting of managers and technicians.

2) Chiller measurement data and monitoring results
   • Collation of existing data and drawings of the ammonia refrigeration plant.
   • Site visit for refrigeration consulting engineer.
   • On site investigation and audit of existing ammonia refrigeration plant.
   • Checking of plant records to assess operating conditions.
   • Discussions with staff to further assess existing plant status and capability.
   • Preliminary compressor measurement and monitoring of results

3) Data analysis, develop drawing and specifications with proposed refrigeration improvements
   • Upgrade of current engine room P+I drawing to current as built status.
   • Addition of engine room plant on overall plant layout drawing.
   • Engineering design work to establish current duty and capacities of existing plant equipment as a basis for establishing where spare capacity may exist.

4) Final report including refrigeration management plan with estimated efficiencies and cost savings
   • Submission of a report summarising observations and measurements from the site visit, capacities of main plant items, recommendations for improvement and upgrade pathway to deal with increasing refrigeration demand.
   • Management plan with preliminary savings
   • Site visit and presentation to operations management group
   • Industry report produced by the provider to include the general process of reviewing plant refrigeration and developing a management improvement plan for plant refrigeration.
5 Observations and Measurements

The Queensland beef processing plant operates as a single shift chilled boning operation with additional freezing of carcasses. Running of a second shift is currently not possible as carton freezing capacity is fully utilised. Plant throughput is generally constant throughout the year so the only significant changes to the running conditions of the refrigeration plant are due to seasonal changes in ambient temperatures and humidity.

The refrigeration plant is a two stage booster intercooled pump recirculation ammonia system which is currently operating at the following main compressor suction pressure set points:

- LP -45kPa (-45°C)
- IP 160kPa (-12°C)
- HP 1050kPa (30°C)

The LP set point is very low for a plant which freezes 27.2kg beef cartons using 24 hour plate freezing cycles and 48 hour cycle air blast freezing. This plant is also freezing sides of beef in a 48 hour cycle using side chillers that have been reconnected to the LP system for this purpose. It is the opinion of the refrigeration plant operators that the current set point is required to meet required freezing times across all of the various freezers.

The IP set point is lower than normal but is a reasonable match for the low stage to avoid too much compression for the booster compressors. It is set to primarily meet the requirement of the chill tunnel which runs with -4°C air temperature and a short residence time (approx. 7.5 hours). The HP set point is a suitable pressure to achieve economical low stress operation of the high stage compressors while delivering hot gas for defrosting.

The plant is operating with four dedicated booster compressors as follows:

- B3 Mycom 200VLD at 2950rpm
- B4 Mycom 250VLD at 2950rpm
- B5 Mycom 250VLD at 2950rpm
- C8 Mycom 250VLD at up to 3550rpm (via VSD)

During the survey period all booster compressors were operating and achieving the LP set point except for Tuesday when B3 was off. For most of the time, particularly in the afternoons, all boosters were running fully loaded with the exception being C8 which would slow to around 3200rpm for short periods. There may also have been some unloading of compressors at night as would be expected when peak freezing loads are past. Such logged data is presently not available for B5 and C8 on the plant SCADA.

The plant is operating with six dedicated high stage compressors as follows:

- C6 Mycom 200VLD at 2950rpm
- C7 Mycom 250VLD at 2950rpm
- C1 Budge 6TYA at 980rpm (assumed – belt drive)
- C2 Budge 6TYA at 980rpm (assumed – belt drive)
- C3 Budge 12TXA at 980rpm
- C4 Budge 12TXA at 980rpm
During the survey period C7 was always running fully loaded, C6 was always running but at varying load, and compressors C1-C4 were cycling on and off as IP loads increased (particularly boning room and chillers in afternoons). At times all compressors would run fully loaded for short periods and IP set point was always achieved. It is expected that these compressors would run at higher loadings (and for longer) during higher ambient temperatures.

During the survey period all compressors were simultaneously being run at times, particularly during the afternoons when the boning room was working and chiller loads were high. Compressors C6, C7 and C8 are all arranged to operate as swing compressors able to work on booster or high stage duty. However with the current plant production requirements all are required to run for extended periods so there is no standby capacity available. If one of the Mycom screw compressors is unable to run then freezing times and temperatures will be affected (in the current plant arrangement) unless production is reduced.

The plant is operating with three evaporative condensers as follows:

- BAC CXV-296
- BAC VXCS-504
- BAC VXCS-680

During the survey period all condensers were on line and working as required, although the VXCS-504 has corrosion of the framework and fan cowls that may necessitate replacement in the medium term. The plant was easily achieving HP set point with condenser fans cycling. It was noted that all fans run and the pressure increases to 1200 – 1300kPa during warmer and more humid conditions as expected. The liquid outlets appeared to be colder than the condensing temperature which suggests some foul gas, needing purging. The active purger was working on the newer VXCS-680 only (due to a leaking valve on the older purger) and comment was made that this seemed to be where foul gas accumulated most. The older purger has been returned to service since the site inspection. Given the low suction pressure (vacuum) of this system, foul gas (air) ingress is expected and will need constant vigilance as does water which is sucked in with air but not purged.

Checking of records from last summer showed periods where all plant was running, LP suction was up to -20kPa, IP suction up to 235kPa and HP up above 1300kPa. However these seemed to be peaks, probably due to extreme ambient conditions, rather than sustained loads that the plant could not cope with.

The main LP and IP separator vessels and mains piping appeared to be very small given the size of the connected compressors. In particular the low stage compressors are all sucking from a single 150NB line and three are discharging into a common 100NB line. These are sizes normally associated with one of these boosters alone. This has arisen to this extreme state due to the requirement to run compressor C8 as a booster to meet current freezing requirements when this compressor was originally installed to primarily operate on high stage duty and standby booster only if either B4 or B5 was unavailable. Now all three run together fully loaded through the same suction and discharge piping, which was likely to have initially been sized for one booster compressor.
Under-sizing of piping is confirmed by large pressure differences on the LP wet suction mains and booster discharges. The LP wet suction pressure measured around 0 to -10kPa in the chiller ceiling space and was around -38°C equivalent (-22kPa) in the plate freezer separator (based on liquid temperature). This indicates excessive pressure drops caused by overloading of the mains piping and means that the evaporating temperatures at the freezer evaporators are a lot higher than the compressor suction pressures. This has been made worse in some areas by sections of wet suction mains in the ceiling space which have un-trapped rising sections to accommodate walkways. Sections in the carcass freezer mains have recently been corrected but others still remain in the ceiling space above the air blast freezers. The booster compressors had discharge pressures (at the compressors) up to 230kPa while the IP dry suction was around 160kPa which confirms the under-sizing of the booster discharge piping.

The requirement to run all compressors, in particular to run C8 as a booster has recently arisen due to the plant deciding to produce frozen carcasses for further processing overseas. It was explained that this has allowed spare capacity to be utilised in the slaughter area while existing carton freezing capacity is fully committed. Currently carcass freezing is being carried out in side chillers which have been connected to the LP pumped liquid and wet suction (via new submains) to achieve the required temperatures. No other changes have been made to the chillers, i.e. room construction, evaporators, fans and internal refrigeration piping for the freezing duty. Carcasses are frozen as sides in a nominal 48 hour cycle before being cut into quarters and loaded directly into freezer containers. The freezing cycle is compromised further as follows:

- There is an initial 6 hour spray chilling regime before temperatures are lowered to freezing levels.
- Regular defrosting is needed to be carried out during the cycle. This would be due to the combination of moist carcasses and low evaporating temperatures while using evaporators designed for chilling duty.
- Existing suction control valves are causing back pressure and increase of evaporating temperature at the evaporators. Chiller 7 pressure upstream of the suction valve was around 25kPa (-29°C), while the wet suction main was between 0 to -10kPa.
- Chillers are highly loaded (overloaded at times) which will compromise air flow past carcasses and overload evaporators.
- Actual time in the freezer is only 39-41 hours due to load out, wash down and warming and reloading requirements.

The refrigeration plant operators consider that presently the low suction pressure set point is required as much for the carcass freezing time requirements as it is for plate freezing.

The existing plate freezers struggle to meet expected freeze times and as such are only used for chilled boneless meat, not hot offal cartons. Performance of the plate freezers is being compromised by two main issues which are resulting in the plate freezer evaporating temperature being significantly higher than the LP compressor saturated suction temperature. Based on the measured liquid temperature the saturated temperature at the plate freezer LP accumulator vessel is around -38°C. Compared to -45°C at the engine room LP dry suction, this is an extremely large difference. The dry suction from this vessel is piped into the common wet suction return from the air blast freezers and cold stores (which now
also has the carcase freezer wet suction added further downstream) which was probably done to keep original installation costs down by avoiding running a separate dry suction line. There is no need for this dry suction to be connected into the wet return for reason of liquid and gas separation. All that it is doing now is adding unnecessary load and pressure drop to the LP suction system. Additionally to this the wet suction return from the plate freezers into the LP accumulator has another large pressure difference due to accumulation of liquid creating significant static head in the vertical rising section as this line rises from ground level into this vessel. Pressure readings at the bottom of this riser of approximately -32°C confirm this.

The combined effect is that the evaporating temperature at the plate freezer is up to 13°C higher than the compressor suction which is an extraordinary difference given that 2-3°C is a normal design difference. It was also noted that both liquid pumps are run to service the two plate freezers, rather than having these arranged as worker and standby as is more common. We would question whether running of two pumps is necessary given that running one may reduce (but not eliminate) the static head issue.

The air blast freezers are arranged for a 48 hour freezing cycle, which with allowance for loading and unloading should allow for approx. 42 hour freeze time to achieve freezing to -18°C. This should be achieved easily given the LP system suction pressure but it does not seem to be so. This appears to be for the following reasons:

- High pressure drops in LP suction lines will mean that evaporating temperatures at the blast freezers are significantly higher than the compressor suction temperatures.
- Blast freezers are having fresh unfrozen product added in with partially frozen product during the second day of freezing. This will reduce freezing times (due to refrigeration being suspended when doors are open), compromise freezing temperatures and add frost to evaporators which reduces performance.
- Blast freezers are being emptied early (36 hours) in order to allow more fresh cartons to be frozen.

The result of all of this is that the air blasts are also struggling to perform to meet required frozen product temperature. This seems to be confirmed by the freezer store struggling to hold temperature, despite a recent evaporator upgrade, as it will be accepting significant product freezing load rather than equalisation and storage only.

The carton chilling tunnel is currently run with -4°C air temperature and residence time of around 7.5 hours. It is fully emptied by 9pm due to production requirements and reloaded the next morning with freshly produced cartons. The duty requirement of this tunnel appears to be the main driver for the IP set point of 160kPa (-12°C SST). If the residence time of cartons in the tunnel can be increased, this would allow for air temperature and suction pressure to be increased accordingly and this heat load to be spread across non-production periods to better utilize the centralized refrigeration plant. Additionally carton tunnels generally work more efficiently when full of product rather than being partly empty due to circulating air not being able to bypass the cartons.

The spray chilling water chiller has it’s dry suction connected to the IP wet suction main and IP pumped liquid. There is no need to connect this dry suction into the wet return for reason of liquid and gas separation. All that it is doing is adding unnecessary load and pressure drop to the IP suction and pumped liquid system. It is noted that this was probably done to
reduce installation costs for this water chiller and the pressure drop on the IP system is currently at an acceptable level that is not creating a significant capacity or running cost penalty.

Despite the pipe sizing issues, the engine room plant appeared to run as intended with required compressor operating parameters within specification and liquid level set points being maintained. Compressor oil and discharge temperatures were as expected with C6 and B3 possibly being a bit low (although this may be related to instrument calibration). Drawn currents were also as expected with B5 possibly being a bit low – again check calibration first. During highest load periods B3 appeared to frost over more than the other booster compressors. This along with the low discharge temperature could indicate some liquid carryover from the LP vessel affecting this compressor first which seems feasible given the LP dry suction piping configuration.

The plant SCADA and compressor sequencing control does not include compressors B5 and C8. As such these compressors operate on their own local controllers rather than being sequenced from the central control system and their operational data is not stored for inspection. Settings and transducer readings have been adjusted to attempt to keep these compressors fully loaded as though they were part of the sequence. However it was noted that C8 in particular was unloading (by reducing speed) at times. Having these two compressors fully integrated into the central system will provide better assurance of efficient plant utilisation and allow for any problems relating to these compressors to be seen earlier or investigated more thoroughly.

There are significant sections of redundant piping around the engine room area that are still live. These are generally from compressors in the old part of the engine room that are no longer in service. Having these pipes still in place has no benefit. Instead they are just potential for unnecessary refrigerant accumulation and leakage and create confusion when trying to follow the piping systems.
6 Design Review of Plant and Equipment

At current LP and IP set point pressures and 35°C condensing temperature the rated refrigeration capacities and drawn shaft powers of the compressors are as follows:

<table>
<thead>
<tr>
<th>Booster Compressors at -45/-12°C</th>
<th>Q (kWR)</th>
<th>P(kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B3 Mycom 200VLD</td>
<td>184</td>
<td>54.3</td>
</tr>
<tr>
<td>B4 Mycom 250VLD</td>
<td>364</td>
<td>105.4</td>
</tr>
<tr>
<td>B5 Mycom 250VLD</td>
<td>364</td>
<td>105.4</td>
</tr>
<tr>
<td>C8 Mycom 250VLD</td>
<td>443</td>
<td>126.9</td>
</tr>
</tbody>
</table>

**Totals**: 1355 392  COP=3.46

Note that actual drawn powers will be higher than this due to back pressure in undersized booster discharge piping. Actual capacities may also be a little lower due to pressure drop difference between system pressure transducer position and actual compressor position.

<table>
<thead>
<tr>
<th>High Stage Compressors at -12/35°C</th>
<th>Q(kWR)</th>
<th>P(kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C6 Mycom 200VLD</td>
<td>751</td>
<td>199</td>
</tr>
<tr>
<td>C7 Mycom 250VLD</td>
<td>1467</td>
<td>382</td>
</tr>
<tr>
<td>C1 Budge 6TYA</td>
<td>146</td>
<td>39.5</td>
</tr>
<tr>
<td>C2 Budge 6TYA</td>
<td>146</td>
<td>39.5</td>
</tr>
<tr>
<td>C3 Budge 12TXA</td>
<td>292</td>
<td>78</td>
</tr>
<tr>
<td>C4 Budge 12TXA</td>
<td>292</td>
<td>78</td>
</tr>
</tbody>
</table>

**Totals**: 3096 816  COP=3.79

This total load consists of transferred LP load of approximately 1600kW and dedicated IP load of 1500kW. At these full load conditions, the heat rejected to the condensers is approximately 4050kW.

The design ratings of the condensers at 35°C condensing temperature and 25°C ambient wet bulb temperature is

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CXV-296</td>
<td>1275kW</td>
</tr>
<tr>
<td>VXCS-504</td>
<td>1551kW</td>
</tr>
<tr>
<td>VXCS-680</td>
<td>2093kW</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4919kW</strong></td>
</tr>
</tbody>
</table>

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The condensers are therefore well sized for the current plant with 21% theoretical additional capacity. Any problems maintaining discharge pressure will be most likely related to plant maintenance issues (such as deteriorating condition of VXCS-504) or extremely hot and high humidity conditions.

The above loads appear to be a reliable indication of actual plant loadings given that all compressors are needed to run fully loaded for prolonged periods. This is higher than theoretical load calculations indicate that freezing loads should be, however there was no obvious indication of gas bypassing that would lead to compressors being unnecessarily loaded. Instead it seems more likely that the additional load is more due to product throughput being higher than the assumed levels.

If the plant were to be modified in such a way that LP suction could run at -40°C and IP suction could run at -10°C (as should normally be expected for a plant like this), then the compressor refrigeration capacities will be as follows:

**Booster compressors at -40/-10°C**

<table>
<thead>
<tr>
<th>Compressor</th>
<th>Q (kWR)</th>
<th>P (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B3 Mycom 200VLD</td>
<td>243</td>
<td>57.9</td>
</tr>
<tr>
<td>B4 Mycom 250VLD</td>
<td>480</td>
<td>112.4</td>
</tr>
<tr>
<td>B5 Mycom 250VLD</td>
<td>480</td>
<td>112.4</td>
</tr>
<tr>
<td>C8 Mycom 250VLD</td>
<td>584</td>
<td>135.3</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>1787</strong></td>
<td><strong>418</strong></td>
</tr>
</tbody>
</table>

**COP=4.28**

**High Stage Compressors at -10/35°C**

<table>
<thead>
<tr>
<th>Compressor</th>
<th>Q (kWR)</th>
<th>P (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C6 Mycom 200VLD</td>
<td>899</td>
<td>207.5</td>
</tr>
<tr>
<td>C7 Mycom 250VLD</td>
<td>1580</td>
<td>399</td>
</tr>
<tr>
<td>C1 Budge 6TYA</td>
<td>165</td>
<td>45</td>
</tr>
<tr>
<td>C2 Budge 6TYA</td>
<td>165</td>
<td>45</td>
</tr>
<tr>
<td>C3 Budge 12TXA</td>
<td>337</td>
<td>89</td>
</tr>
<tr>
<td>C4 Budge 12TXA</td>
<td>337</td>
<td>89</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>3393</strong></td>
<td><strong>875</strong></td>
</tr>
</tbody>
</table>

**COP=3.88**

As can be seen if you were able to run at -40°C LP suction, your booster compressors would have 432kWR or 32% additional capacity compared to now. This would create immediate standby capacity if your loads were to remain the same or capacity that could be used for additional freezing equipment. Running at -10°C IP suction would create 297kW or 10% additional capacity from your present high stage compressors which could be utilized. The existing condensers should cope with this additional high stage load.
Based upon the same refrigeration load and running 24/7, 52 weeks per year and an average electricity tariff of $0.05 per kWhr, the annual compressor power saving equates to $45,000. The loadings may be a little overstated but the higher booster discharge pressures have not been accounted for so this gives a good idea of the potential savings. Plant maintenance should also be lower due to needing to run lower compressors and lower compression ratios.

We have checked sizing of vessels and piping mains and comment as follows:

**LP Suction Separator 1200mm dia vertical – current duty 1350kWR at -45°C**

This vessel seems to be well undersized based on ability to separate liquid and gas. It currently has double the internal velocity that we would recommend as a maximum. Milmeq would only consider this size for this duty if it has an internal demist pad which we cannot confirm or deny. There is some evidence of liquid carryover as seen at compressor B3 at full booster load.

**LP Wet Suction main 200NB – current duty 1350kWR at -45°C**

This line is currently handling between 2-3 times the duty of what is recommended as maximum for this size. The gas and liquid will still pass through but at very high pressure drops as observed.

**LP Dry Suction main 150NB – current duty 1350kWR at -45/-12°C**

This line is currently handling almost 3 times the gas velocity of what is recommended. The recommended maximum velocity is 30m/s. This line has a velocity of 115m/s which is extreme. The velocity drops as each compressor take off is passed but is only acceptable size to serve one Mycom 250VL booster – not effectively 3.5 of these. The gas will still pass through but at very high pressure drops as observed.

**IP booster discharge 100NB shared line from B4, B5 and C8, 125NB shared line for all boosters**

These lines are currently handling between 2-3 times the duty of what is recommended. The discharge gas does still pass through but at very high pressure drops as observed by large pressure differences between booster compressors and IP dry suction.

**IP Intercooler 760mm dia vertical – current duty 1600kWR at -12°C**

This vessel is very undersized based on ability to separate liquid and gas. It currently has more than double the internal velocity that we would recommend as a maximum. Milmeq would only consider this size of vessel for this open flash intercooling duty if it has an internal demist pad which we cannot confirm or deny. We would think probably not based upon the connecting line sizes which are suited to lower capacity.

**IP Separator 1200mm dia vertical – current duty 1500kWR at -12°C**

This vessel is adequately sized for the current duty but should not have additional load added.
IP Dry Suction 250NB header – current duty 3100kWR at -12/35°C, 150NB lines to each Mycom 250VLD compressor

These lines are suitably sized for current duty but should not have additional load added.

IP Wet Suction 200NB – current duty 1500kWR at -12°C

This line is suitably sized for the current duty.

HP Discharge 125NB and 100NB – current duty 3100kWR at 35°C condensing

This network appears to be adequately sized given that it is fed from several different points and distributes to the three condensers so there should not be sections of unacceptable high velocity while all condensers are operating.

In summary the lines and vessels that are most undersized are those on the LP side and booster discharge, i.e. LP Separator, Intercooler, LP Wet Suction, LP Dry Suction and Booster Discharge. All are grossly undersized for the current duty. It would appear that these vessels and mains were probably designed and constructed when the design freezing load was less than half of what it is now and the system has since been gradually added to with additional refrigeration load and compression capacity. None of these vessels and pipes should have additional duty added; instead any plant upgrade should strongly consider removing load from these sections in order to reduce pressure losses to allow evaporating temperatures to drop or compressor suctions to be increased (or a combination of both).

The plate freezer system requires attention in two areas, both of which will realise large gains by allowing plate freezer evaporating temperatures to closely approach booster compressor saturated suction temperature as follows:

a. Remove vessel dry suction connection into existing LP wet suction main and instead redirect this into LP dry suction network. This will greatly reduce this pressure drop from the plate freezers and also reduce pressure drop affecting the air blast freezers and carcase freezers.

b. Add an additional separator vessel at low level to eliminate the static liquid head that is occurring in the vertical rising sections of wet suction between the plate freezers and the separator vessel. The new vessel would allow separation of gas and liquid before the riser, allowing dry gas to flow unimpeded into the existing vessel (or directly into the LP dry suction network) and provide for liquid to be pumped back into the existing vessel.

The carcase freezing system would ideally be set up as a purpose built quarter (not side) freezing system with its own dedicated separator vessel and pumped recirculation mains. Having this in place along with the recommended improvements to the plate freezer system (as above) would also optimise evaporating temperatures to the air blast freezers. Alternatively the existing LP Separator could serve the carcase freezers and a new separator vessel and pumps would be installed for the blast freezers and cold store with the existing wet suction main converted and redirected at the engine room to be a dry suction. This would provide similar benefits to the air blasts and be beneficial for the carcase freezers compared to the current arrangement (but not as good as a purpose built system).
If the above suggestions are not considered to be feasible then the following improvements should be considered to improve the carcase freezer operation.

- Add valves and controls so that spray chilling part of freezing cycle is handled by IP system.
- Replace suction control valves so that pressure drop through these is minimised while freezing.
- Consider replacing evaporators and fans to be more suited for freezing operation.

Air blast freezing performance will be improved by filling the cabinets once and then closing the doors and refrigerating until the end of the cycle; i.e. not to add fresh cartons mid cycle.
7 Recommendations for Improvement

The following are our recommendations to improve freezing performance and refrigeration plant efficiency with the existing loads and engine room equipment.

1. Reduce excessive pressure drops from LP side of plant.
   Re-pipe plate freezer dry suction directly into LP dry suction piping network.
   Modify LP dry suction and IP discharge piping to reduce high velocities and pressure drops.
2. Reconfigure plate freezer wet suction line and LP separator arrangement to remove current liquid static head penalty by installation of a separator vessel below the level of the wet suction main.

3. Improve efficiency of carcase freezing operation.
   - Upgrade valves and controls to allow chill part of cycle to be on IP system and freeze section to be on LP system with low pressure drop suction valves.
   - Consider replacing evaporators with new units designed specifically for freezing operation.
   - Consider freezing carcasses as quarters, not sides.

4. Change air blast freezing procedures by allowing full cycle to be completed without loading additional fresh cartons mid cycle.
5. Increase chill tunnel residence time and air temperature to reduce peak loads and increase IP pressure.
6. Continue to remove unnecessary rising sections of wet suction piping.
7. Remove sections of redundant piping to reduce leak risk and improve plant safety.
8. Include all compressors in centralised sequencing control system and SCADA.
9. Install an automatic purge system with automatic cycling of purge points to ensure that foul gas accumulation is minimised.
10. Regularly check for water level in refrigerant to avoid build up and contamination of refrigerant that can create harmful compounds and compromise refrigerant properties.
8 Recommended Requirements for Plant Expansion

The following are our recommendations for increasing the capacity of the refrigeration system when new freezing and chilling equipment is added.

1. Remove sections of existing large pressure drops by reconfiguring existing piping and/or addition of new vessels to allow upgraded plant to run at -40°C saturated suction pressure or higher – as also described in the section above.

2. Plant improvements must achieve sustainable lower evaporating temperatures for all types of remaining freezers, i.e. plate freezing, carcase freezing and air blast freezing, so that all can perform required freezing duty at -40°C saturated suction pressure or higher.

3. No new load should be added to the existing vertical LP separator vessel. Instead possibilities of reducing load from this vessel should be investigated. This could include diverting the air blast freezer mains to a purpose built separator vessel that would be required if additional plate freezers are being installed.

4. No new load can be added to the existing intercooler. Addition of any new booster compressors must also include a new LP Separator vessel and suitably sized intercooler.

5. If new chilling load is being added, then the spray chilling water chiller suction line should be removed from the IP wet suction main and tied into the IP dry suction before adding load to the existing pumped IP system.

6. Additional high stage compressor capacity should allow for retirement of existing Budge compressors which are approaching the end of their economical service life.

7. Provision of standby capacity should be considered to allow single compressors to be removed from service for maintenance or breakdown without affecting capability of plant to meet overall refrigeration requirements.

8. If additional condensing capacity is required consider the economics of taking the oil cooling load from the existing condensers and including this load on a new dedicated cooling tower. This will free up condensing capacity and may preclude the requirement for a new condenser.