Table 8: Preparation for shutdown and removal from service for gas dew point control systems (refrigeration) (continued)

Step no.	Step/objective	Good practice	Notes
3.	Refrigerant removal and N_2 replacement	– Refrigerant removal – Should be performed under strict control and refrigerant system displaced by N_2 – Stored refrigerant cylinders – Must always be protected from temperature extremes and in an area with appropriate fire protection and cooling – System isolation – The refrigeration system should be isolated in accordance with OEM procedures and in such a manner that there are no trapped zones that are not protected by appropriate pressure relief devices – Prime mover mothballing – The refrigeration compressor prime mover should be prepared for mothballing in accordance with the appropriate section in 4.11 depending on the driver (electric motor or gas turbine) The requirement for coupling removal will depend much on OEM recommendations and general industry guidelines for that size of refrigerant compressor/driver (see 4.11).	1. Safety notes – Liquefied refrigerant gas under pressure is hazardous sudden release of pressurised refrigerant may result in personal injury: – Frostbite. Liquid refrigerant suddenly released from high pressure to atmospheric pressure will flash and boil to vapour creating a frost zone. If touched with bare skin frostbite may be caused – Protective clothing, gloves and eye protection are effective at preventing frostbite by keeping liquid refrigerant away from the skin 2. N_2 does not support life. Appropriate precautions must be taken during purging operations. (COMAH Regulations) (HSE, HSG 253)

Table 8: Preparation for shutdown and removal from service for gas dew point control systems (refrigeration) (continued)

Step no.	Step/objective	Good practice	Notes
4.	Internal and external preservation	Internal preservation (refrigeration system) – This preferred medium for the preservation of the internals of the refrigeration circuit is high quality (99.9 % pure) N_2. This should be maintained at a positive pressure throughout the out-of-service period. – Where F-gases or similar refrigerants are used, the lubricating oil should be left in the system (ideally changed first) and no other preservative should be used External preservation (refrigeration system) The piping and heat exchangers on refrigeration systems can be widely different depending upon the refrigerant in service, the environment in which the system is operating as well as the OEM Additionally, the coating on vessels and pipework as well as the insulation specification affect the level of external preservation and monitoring required Correspondingly, the actual materials used on the plant being mothballed need to be fully understood to avoid such corrosion mechanisms as: – galvanic action – chloride stress corrosion Each material has specific risks associated with it; from chloride stress corrosion with austenitic stainless steels to SRB for low carbon steels Facility operators should research the corrosion mechanisms for the material of the specific system Keeping the systems and equipment dry is the most effective method. This can present challenges in achieving where a vessel is exposed to the elements or in an area covered by salt water deluge fire protection systems	1. Corrosion mechanisms for stainless steels are complex. Information and guidance on control measures may be obtained from the British Stainless Steel Association Important note – Refrigerant compressor oil should not have had corrosion inhibitor added, as refrigerant oils are formulated to provide good oxidation and rust inhibition

Table 8: Preparation for shutdown and removal from service for gas dew point control systems (refrigeration) (continued)

Step no.	Step/objective	Good practice	Notes
5.	Monitoring and maintaining the preservation	– Internal conditions monitoring – The internal N_2 blanket should be monitored for pressure and quality at appropriate intervals A higher frequency may be appropriate in the early stages of the preservation which may then be able to be relaxed once the stability of the N_2 preservation blanket is fully understood – External conditions monitoring – The accessible areas of the exterior of the system vessels, heat exchangers and other critical equipment should be monitored for condition stability Where the pipework, heat exchangers and critical equipment are lagged, the lagging in suspect zones should be periodically removed in order to check for any indication of deterioration of the material or coating surface	

Table 8: Preparation for shutdown and removal from service for gas dew point control systems (refrigeration) (continued)

Step no.	Step/objective	Good practice	Notes
6.	Return to service 1	Preparations for RTS: – Refrigerant recharging compliance review Before the previously evacuated refrigeration system can be recharged, the responsible person must verify that the task conforms to current legislation for the specific refrigerant This is especially important for F gases and ODSs It must also be recognised that a supplementary charge of refrigerant may be required due to minor losses during the recovery and recharge operations and that this may be restricted by additional regulations – Condition assessment – refrigeration compressor and circuit (internal) – Given that the preservation monitoring has been correctly performed, the condition of the system should be reasonably well known but as a function of the recharging operation additional checks must be made (see RTS 2) – Condition assessment – refrigeration compressor and circuit (external) – Correct undamaged insulation is vital to the function of any refrigeration plant. The whole system should be checked for removed or damaged sections. All sections should be replaced before RTS Pipe mountings and pipe runs should also be carefully examined as any change to the specified fall angle of the refrigeration circuit pipework will affect the efficiency of operation	

Table 8: Preparation for shutdown and removal from service for gas dew point control systems (refrigeration) (continued)

Step no.	Step/objective	Good practice	Notes
6.	Return to service 1 (continued)	– Condition assessment, associated equipment – All associated equipment critical to the operation of the conditioning system (e.g. Refrigerant pressure and vacuum gauges) should all be in place and undamaged. Level and pressure instrumentation, PSVs and unloading valves) should be checked or serviced ready for operation This is particularly important for SCE/SRE items such as ESD and PSD valves as well as unit controllers – Lubricating oil systems should all have the quality checked Important note – Refrigerant compressor oil should not have had corrosion inhibitor added as refrigerant oils are formulated to provide good oxidation and rust inhibition All oil filters should also be changed – Prime mover checks – The refrigeration compressor prime mover should be prepared for operation in accordance with the appropriate section in 4.11. depending on the driver (electric motor or gas turbine)	
7.	Return to service 2	Refrigerant system testing and charging for RTS – The recommissioning of a refrigeration system is a specialised task and should only be performed by personnel with the correct level of competence and in accordance with OEM and the host facility procedures In summary, the following basic steps will be taken: – N_2 purge will take place to refresh the gas and to check there is no residual moisture – The refrigeration circuit will be pressure tested with N_2 and checked for leakage	1. All de-isolations and recharging operations must be performed in accordance with the facility isolations policy and PTW 2. Inert gas does not support life. Appropriate precautions must be taken during purging operations. (COMAH Regulations)

Table 8: Preparation for shutdown and removal from service for gas dew point control systems (refrigeration) (continued)

Step no.	Step/objective	Good practice	Notes
7.	Return to service 2 (continued)	– The refrigeration circuit will be evacuated (by vacuum) in stages to allow all residual moisture to flash off and then be extracted – Recharged with the recovered refrigerant (during mothballing) plus any supplementary requirements – Final leak checks – Consider the competency and experience of personnel prior to assigning the task of the equipment restart	3. Industry experience has demonstrated that the refrigeration systems that have not been properly pressure tested, leak checked evacuated will have maintenance problems and leaks when RTS. These are likely to be situations such as ice forming in expansion valves, wax build-up in the system and acid in the oil 4. For HSE requirements for pressure testing of pressure equipment being returned to service (HSE, *Safety requirements for pressure testing*)
8.	Return to service 3	Monitoring on RTS – During the initial period of RTS it is important to provision for additional monitoring of the full refrigeration circuit as well as the refrigerant compressor and the associated prime mover as well as the associated refrigeration control system for: – Early indication of leakage from joints, flanges and PSV devices (these may be bursting discs) – Performance of the associated equipment critical to the operation of the system (e.g. level and pressure instrumentation and PSVs). This is particularly important for SCE/SRE items such as ESD, PSD and loading valves	1. For leak checking, a special refrigerant detector will be required that matches the type of refrigerant

4.8.4 Glycol regeneration system (in association with dew-point control)

4.8.4.1 General

In order to assess a glycol regeneration system for potential mothballing it is important to understand the interrelationship with the gas processing plant and gas pipeline operations.

If an upstream oil and gas facility is exporting gas, it will have one of two basic pipeline options:

- A wet pipeline – where entrained condensate and water flow with the gas to shore with an added hydrate inhibitor (e.g. methanol). This method is commonly used for Offshore gas production facilities. The liquid products are then separated and recovered at the Onshore terminal.
- A dry pipeline – the entrained condensate and water carried forward with the produced gas is extracted on the offshore facility by chilling the gas stream, removing the fluids and then reheating the dried gas; this is known as a dew-point control system.

For this process to function, a hydrate suppression system needs to be used in the chiller and heat exchangers otherwise they would choke with hydrates and stop the gas flow.

Glycol is commonly used for this purpose (usually triethylene glycol (TEG)). The TEG is injected into the gas chiller and upstream heat exchangers in a water lean state (about 80 % TEG) and is recovered, after the hydrocarbons have been separated, in a water rich state (about 20 % TEG) where the TEG is reprocessed to drive off the water and is reused.

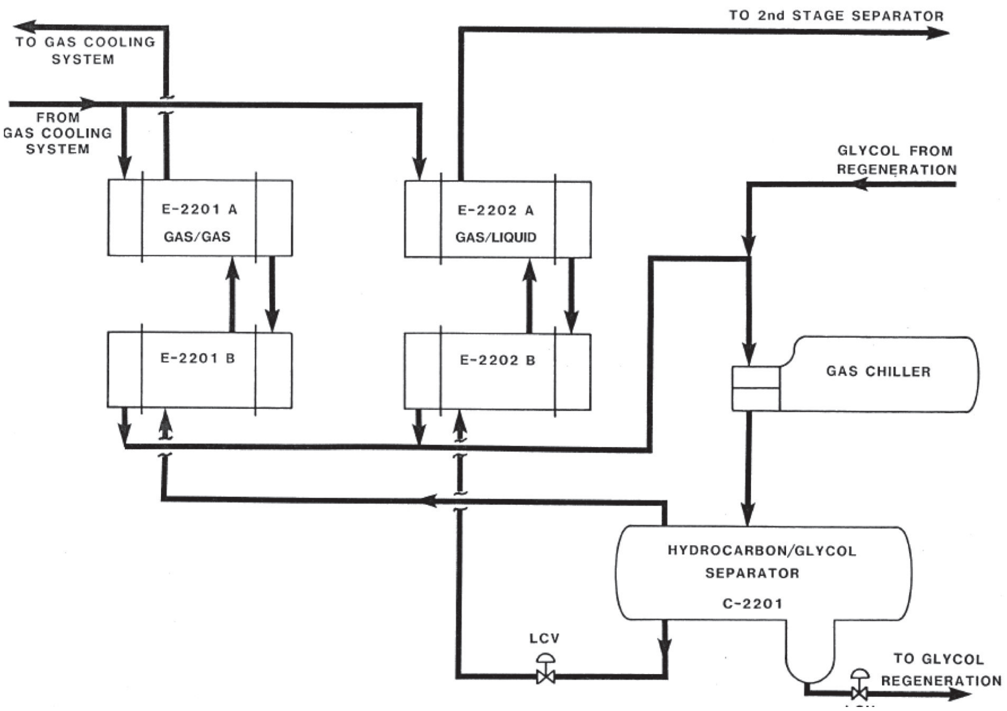

Figure 15: Simplified flow diagram for condensate recovery (courtesy of Optima/ WMT)

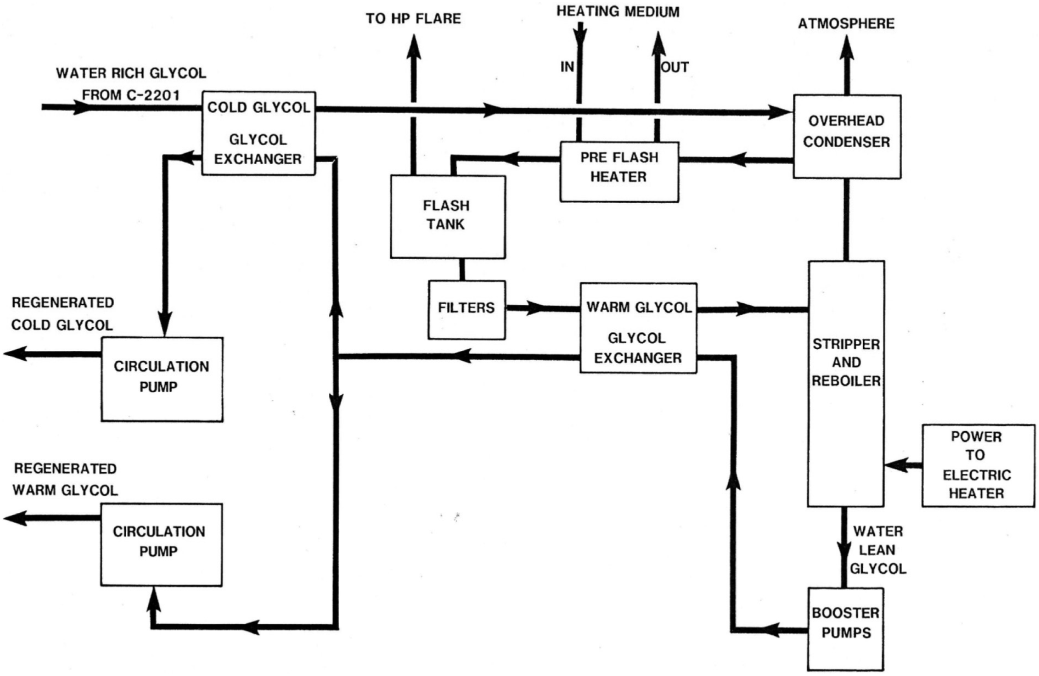

Figure 16: Block flow diagram for glycol regeneration (courtesy of Optima/WMT)

For an upstream oil and gas facility to consider mothballing a TEG unit it would essentially have to have two systems. Additionally, the produced gas would need to have a correspondingly dry and low condensate flow such that if the remaining glycol regeneration unit failed then production could continue or that the risk to production losses would be acceptable.

It is therefore considered unlikely that there would be an opportunity to mothball a glycol regeneration system.

However, circumstances could occur; for example, if upstream facilities were required to be modified and with that the need may arise to mothball the glycol regeneration facilities for the duration of the modifications.

4.8.4.2 Guidance steps for removal from service and mothballing of glycol regeneration

Table 9 contains a 'step/objective' with 'good practice' approach which should be used as guidance for these steps.

The stages in the table are for high level guidance. In practice, more detailed production operations procedures would be expected to be used. These would normally be drawn from the specific POPM held by the host facility.

Alternatively, these may need to be specifically developed for the task of withdrawing equipment from service and mothballing it.

For this section it should be noted that the glycol regeneration package is not a closed circuit and has a direct interface with hydrocarbons; this can and does lead to hydrocarbon contamination of the circulating glycol.

Note: this table must be used in conjunction with the established procedures of the facility.

Table 9: Preparation for shutdown and removal from service for glycol regeneration system

Step no.	Step/objective	Good practice	Notes
1.	Final period of running	– Gather performance data of the system in the pre-mothballed condition as a reference base if/when the unit is returned to service. Retain the data securely – TEG management – It should be recognised that the TEG may have to be removed from the system. Accordingly, the system should be set up to achieve the leanest water content possible – Execute a controlled shutdown – This task needs to be coordinated with the shutdown of the gas compression system if the glycol regeneration systems are not duplicated	1. Depending upon the process facilities, the associated gas compression train and the dew point control system may need to be shut down ahead of the glycol regeneration system 2. Retain sampling/analysis data and performance data securely, as a considerable time may elapse before the unit is RTS
2.	Planning for two levels of mothballing 1) Medium term (up to 12 months) and 2) Indefinite	Options The designs of glycol regeneration systems vary but generally speaking, the issues that affect the decision on how to approach withdrawal from service are common to most designs; amongst these are those related to the condition of the glycol. (TEG) The condition of the TEG will then affect the decision as to which mothballing approach should be taken 1. Medium-term – up to nine months An effective low cost, short-term option is to leave the TEG in place in the system with a continuous low rate circulation ongoing via an appropriate recycle line An N_2 gas blanket should also be applied. This approach is, however, only really effective if the TEG is known to be in good condition and worth keeping. If the system is suffering from any of the following issues then making efforts to retain the TEG in the system for an extended period is less likely to be worthwhile	1. TEG disposal should always be to an approved outlet and COSHH precautions should always be taken. It should also be noted that TEG that has been in circulation against the process may also contain hazardous contaminants 2. BIs must achieve a safe level of isolation from live process (HSE, HSG 253*)*

Table 9: Preparation for shutdown and removal from service for glycol regeneration system (continued)

Step no.	Step/objective	Good practice	Notes
2.	Planning for two levels of mothballing 1) Medium term (up to 12 months) and 2) Indefinite (continued)	1. Glycol losses – These are most often caused by ineffective temperature control in the reboiler but if they have been ongoing for a period then the TEG may have already thermally degraded 2. Foaming – Will cause poor heat exchange and localised thermal degrading of the TEG. It may also be caused by poor filtration If foam has been a problem in the system for a period then the TEG is probably not worth keeping 3. Glycol pH control – The corrosion rate of the system will increase dramatically if the pH has been allowed to drift from the desired level of 7.5 to 8.0. If it has been greater than that for a period, corrosion products may already be in solution or deposited as sludge and the system is probably not worth saving. If, however, the pH is greater than 9.0 then that may have caused emulsions or contributed to foaming issues 4. Salt contamination – Should be removed by correct filtration but if not cannot easily be corrected by regeneration. If the TEG has a history of high salt content then it is most likely not worth saving as a part of a medium term mothballing period 5. Glycol oxidisation – If the TEG has been allowed to oxidise through contact with oxygen (e.g. as a result of poor blanket gas on storage tanks) it will form corrosive organic acids. This can be corrected with the use of oxygen scavenging chemical (e.g. hydrazine) but the damage may have already been done	

Table 9: Preparation for shutdown and removal from service for glycol regeneration system (continued)

Step no.	Step/objective	Good practice	Notes
2.	Planning for two levels of mothballing 1) Medium term (up to 12 months) and 2) Indefinite (continued)	6. Sludge – Accumulations of solid particles and tarry hydrocarbons can occur in the TEG. The sludge, when the particles become large enough, will drop out of solution and settle out. The result is a gooey black gum that interferes with the functionality of the system. This is usually managed by good filtration but if the TEG has already deteriorated to the point that this is occurring then it is probably not worth saving 2. Long-term mothballing – greater than about nine months If the period is going to be longer than about nine months or the TEG is suspect as described in 1) then the best approach is to dispose of the TEG, then blow all the system clear with nitrogen from all possible drain and vent points. This will give the opportunity to clean the heat exchangers, reboiler, flash tank and filters on the system ready for long-term mothballing under a blanket of N_2 System pumps should be preserved in accordance with guidance in 4.16.2 The BI for both of these scenarios should reflect the need to work on the components of the system while maintaining a secure isolation from live processes	
3.	Internal and external preservation	Internal preservation (glycol regeneration system) – The preferred medium for the preservation of the internals of the glycol regeneration system is high quality N_2. This should be maintained at a positive pressure throughout the out-of-service period In order to achieve a sealed system the stripping column and other vents/ flare outlets will need to be spaded at the vents to atmosphere	1. Corrosion mechanisms for stainless steels are complex. Information and guidance on control measures may be obtained from the British Stainless Steel Association