"OPTIMUM COMPRESSOR CONTROLS FOR CLOSED LOOP REFRIGERATION", or

"AVOID THESE MISTAKES IN MR COMPRESSOR CONTROL"

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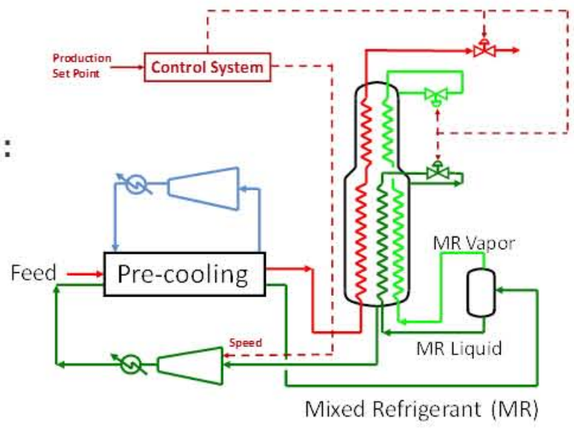
Introduction

This poster identifies 3 mistakes sometimes made in controlling the mixed refrigerant (MR) compressor in an LNG Precooled Liquefaction Process (Fig 1 below) and how to avoid them.

Fig 1:

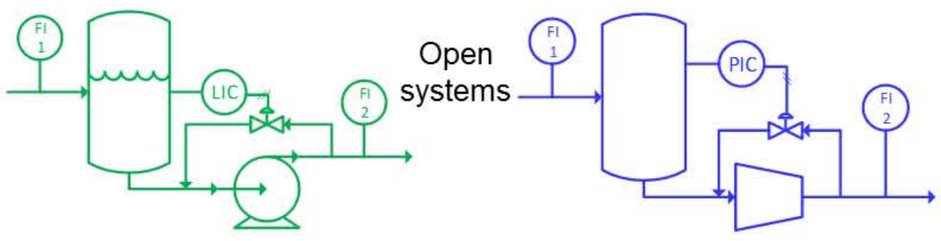


1 Avoid Using Open System Controls on a Closed System

Consider a simple system consisting of a vessel and a pump or compressor which withdraws fluid from the vessel. The question is how best to control the machine flow. In an open system at steady state with the feedrate set by outside factors, the machine flow is adjusted to hold a constant mass inventory in the system. For a liquid, inventory is measured by level. For a vapor, inventory is measured with pressure (Fig 2 & 3).

Fig 2: Liquid – controls outlet flow w/ level

Fig 3: Vapor – controls outlet flow w/ pressure

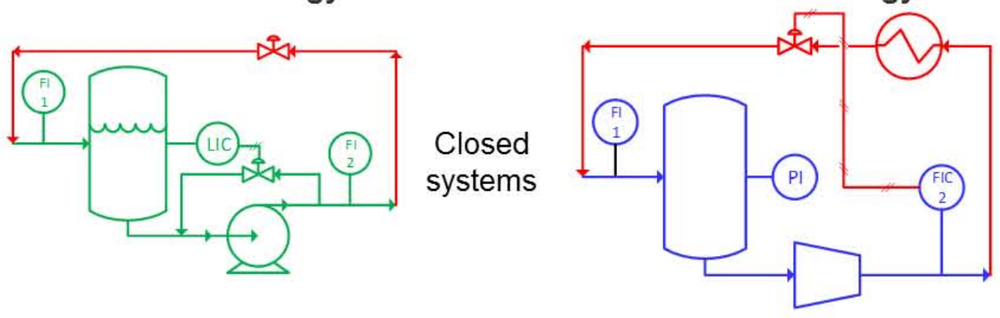


Consider now a closed system, which has a fixed mass inventory, circulating at a given rate. (See Fig 4 and 5, with the red lines converting from open to closed systems.)

Fig 4 attempts to use the open loop strategy of varying pump flow to hold a level setpoint; however, the level is fixed by the inventory, so this control strategy will drive the recycle valve to either fully open or fully closed. In Fig 5, the compressor flow is controlled effectively by discharge throttling.

Fig 4: Liquid system w/ invalid control strategy

Fig 5: Vapor system w/ valid control strategy



This illustrates a key difference between open and closed systems; they must use different strategies to control flowrates.

Steady State Differences Between Open and Closed System Control

	Open System	Closed System
Inventory	Many	Fixed
Flowrates at Steady State	Fixed (Outlet =Inlet)	Many

The first mistake to avoid is to use open loop strategies for the closed loop MR system.

#2 – "Mind the Head": Speed Impacts More Than Flow

In LNG processes, the MR compressor type is centrifugal or axial, which both have a relationship between volumetric flowrate and head. (The pressure ratio is determined from the head.)

Fig 6

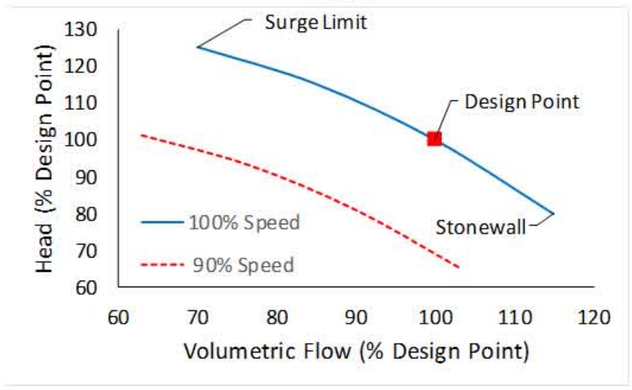


Fig 6 illustrates how speed affects performance. By the fan laws, the volumetric flowrate increases linearly with speed, but head increases with the ***square*** of speed. Because the amount of refrigeration supplied depends on the pressure ratio, small changes in speed can greatly affect refrigeration supplied. Therefore, in closed loop MR systems, it is more accurate to think of speed primarily affecting head, not flowrate.

#3 Avoid Suction Pressure Control for MR Compressors

One parameter of interest is the MR compressor suction pressure. In an open system, the compressor suction pressure can be held constant by adjusting the compressor flowrate (Fig 3). However, in a closed system, the MR compressor suction pressure is a function of many things: inventory, compressor speed, the overall LNG process operation and compressor flow. Therefore, it is difficult to control suction pressure based on a single parameter. In particular for LNG liquefaction, attempting to control MR compressor suction pressure with just speed is not effective.

MR Compressor Controls

These learnings can be applied to the MR system of an LNG liquefaction process. The closed MR system is defined by 3 inputs. Once these are determined, all other operating parameters are fixed.

Input	Set by
Inventory	Fixed by operator
Circulating MR flowrate	Determined by LNG production; set with JT valves
Compressor Speed	Industrial Gas Turbine – fixed Aeroderivative Gas Turbine – possible to vary

Optimum Conditions – Constant Inventory

Dynamic simulations were performed to rigorously model a constant inventory system. Three cases were run: base (DS-1), turndown at constant speed (DS-2) and turndown with reduced speed (DS-3).

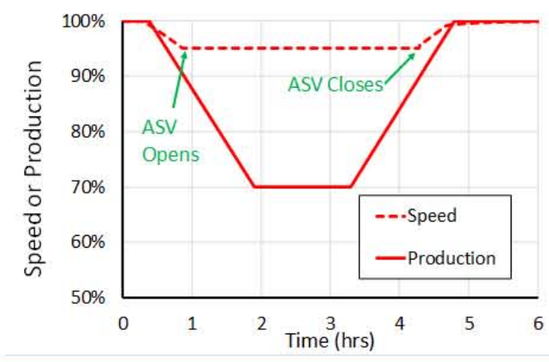
Case		DS-1	DS-2	DS-3
Inputs	LNG Production	100%	85%	85%
	Speed	100%	100%	95%
	Inventory	Same	Same	Same
Results	Suction Pressure (bara)	4.28	3.79	4.45
	Discharge Pressure (bara)	44.8	45.7	43.9
	Compression Ratio	10.5	12.1	9.88
	Power to recycle	0.0%	4.5%	2.7%
	MR Spec Power (relative)	100%	106.8%	103.8%

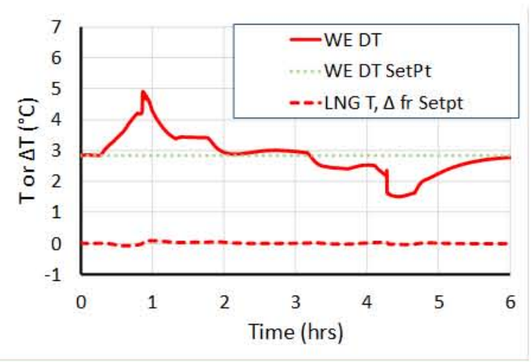
Key results of this study:

- In DS-2 and DS-3, the MR compressor recycles to prevent surge, which increases power consumption.
- Lower speed decreases turndown power consumption (compare DS-2 and DS-3)
  - Speed decreases only ~1/3 as much as production
  - Even with the small speed reduction, the head (as indicated by compression ratio) decreased significantly.

Automatically Adjusting Speed With Production

Modern LNG plants have control systems, such as the Air Products Enhanced Control Scheme (AP-ECS), that automatically optimize performance and move the plant between different operating modes. A dynamic simulation was run, with AP-ECS automatically ramping plant production from 100% to 70% and back. The AP-ECS was modified to ratio the speed with the refrigeration flowrate. When the anti-surge valves open, the speed setpoint is held constant. AP-ECS automatically adjusted the JT valves and speed to keep the key operating parameters within the desired range: production, LNG temperature and MCHE warm end ΔT (efficiency measurement). These dynamic simulations confirm that it is possible to avoid the 3 common mistakes and also automatically adjust speed and control the process when varying production.





Conclusions

- Three facts must be considered to effectively control the MR system:
  - The MR system is closed; control concepts for an open system may not apply.
  - Varying speed affects head (and refrigeration) much more than it affects flow.
  - MR suction pressure cannot be controlled with a single parameter, such as speed.
- At turndown, slightly reducing MR compressor speed consumes less power by partially or completely closing the ASVs.
- ***In the LNG liquefaction process, if the MR compressor speed is varied, then adjust the speed based on supplied refrigeration.***

For Further Information

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