Dynamic Evaluation: Centrifugal Compressor's Operation in Determining Anti-Surge Controller

[1]Tri Partono Adhi, [1]Tanti S Rosyid, [1]Yusrin Ramli & [1,2]Antonius Indarto*)

[1] Department of Chemical Engineering, Faculty of Industrial Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia

[2] Department of Bioenergy and Chemurgical Engineering, Faculty of Industrial Technology, Institut Teknologi Bandung, Bandung 40132, Indonesia

*) *antonius.indarto@che.itb.ac.id*

Abstract

Anti-surging is developed for a compressor system consisting of a booster compressor and a high-pressure compressor in a serial circuit. This evaluation presented 6 options of anti-surge systems with variations of the number of Anti-surge Valve (ASV) and its combination with the addition of a Hot Gas Bypass Valve (HGBV) and Cold Gas Bypass Valve (CGBV). From the model evaluation, the option that involves a special ASV (dedicated) for each compressor and coupled with a dedicated CGBV or HGBV is the best because the compressor can be back to normal in less than 1 second (maximum time to return to normal condition is 3 seconds. Referring to these options, a dedicated ASV for each compressor provides more benefits to the security of compressor operation. However, the most appropriate option in the field will return to the issue of cost or ease of modification. For facilities that are running (brownfield), the use of tools that already exist in the field and do a little modification is the most appropriate option, while for the new facility (grassroots project), the single ASV for a compressor circuit is the most optimum as it only involves minimum equipment and configuration as simple as possible piping/instrumentation.

Keywords: Centrifugal, Compressor, Dynamic evaluation, HYSYS, Surging.

1 Introduction

The addition of a centrifugal-type booster compressor in the offshore gas XX processing field is required to increase the pressure of the gas feed from the well to the existing compressor [1], [2]. At the beginning of the operation, the gas wells are still high pressure so the gas-receiving pressure at the facility is about 400–600 psig, but with the old age well the gas pressure-receiving at the facility is only 150–200 psig. By adding a booster compressor, the existing compressor feed pressure can return to the starting point of about 400–600 psig.

The common problem faced in the operation of the centrifugal-type compressor is the minimum flow constraint [3]–[5] into the compressor which must be maintained so that the compressor does not undergo surging, a condition of backflow from the compressor output to the internal compressor which can destroy the inside of the compressor [6], [7]. To overcome surging a compressor needs to be installed in an anti-surging system [8]–[12]. Anti-surging system is a system consisting of anti-surge controller system (PLC/Programmable Logic Control) and also a faucet (valve) as a follow-up tool [12], [13]. With the addition of a booster compressor, it is necessary to evaluate the most optimum anti-surging system, in terms of reliability and also the cost of its procurement.

2 Methodology

The quantitative analysis was initiated by the construction of the process system model using HYSYS V73 software since it is compatible to handle oil and gas problems [14], [15]. The established process models that have been made were then validated by data literature or actual data from the field. This step is necessary to allow the model to be correct and could be used for the next step of the simulation which is a dynamic simulation with the schematic method as shown in figure 1.

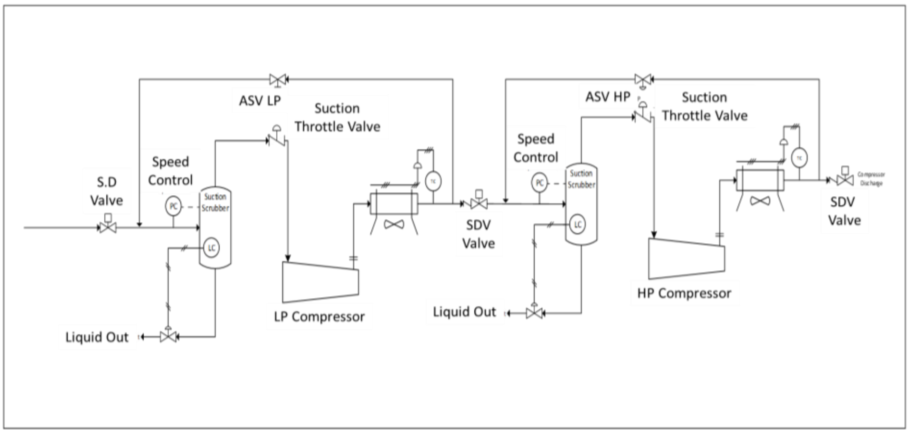


Figure 1. Schematic of LP and HP Compressor.

2.1 Model Simulation Validation

Using the software and compared to plant data and technical specifications, the simulated model of the compression process was validated in steady state mode. This state mode is required to validate the field data. If there is a difference it will be made changes in technical parameters and taking assumptions that meet the logic of process and operation. Tables 1 and 2 show actual data of LP (low pressure) and HP (high pressure) compressors, the gas composition from wells as feed to the compressors, meanwhile, the graphs show the head curve of LP and HP compressors based on HYSYS simulation and actual data (vendor data) as shown in figures 2 and 3.

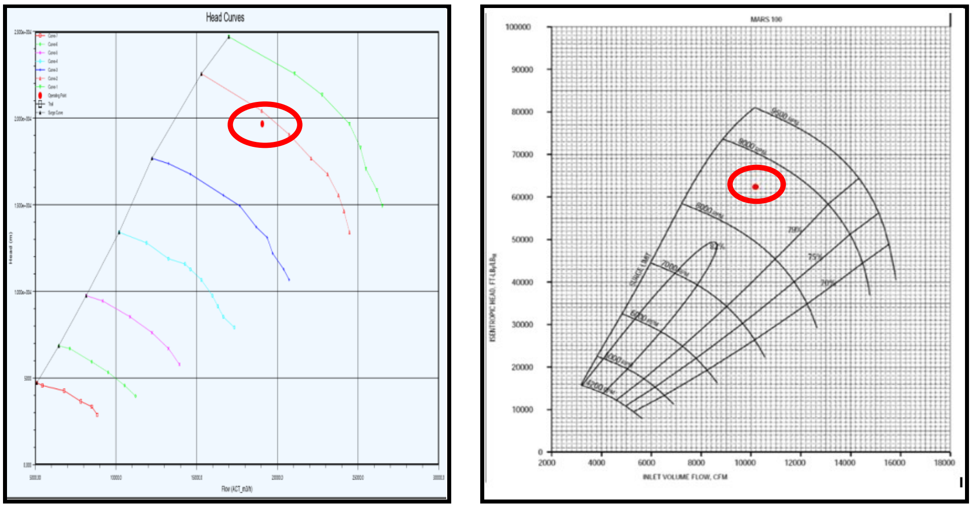
Table 1. LP and HP compressor performance curve (actual data) in March 2013

Parameter	LP Compressor	HP Compressor
Q (MMSCFD)/(ACFM)	170/11,247	170/3,588
Temp suction/discharge (°C)	21.1/124.4	21.4/125.2
Press suction/discharge (bar)	10.6/33.5	32.0/93.3
Head Isentropic, % or Head (lbf/lbm)	81.4/61,245	76.4/57,935

Table 2. Gas composition of well gas field XX

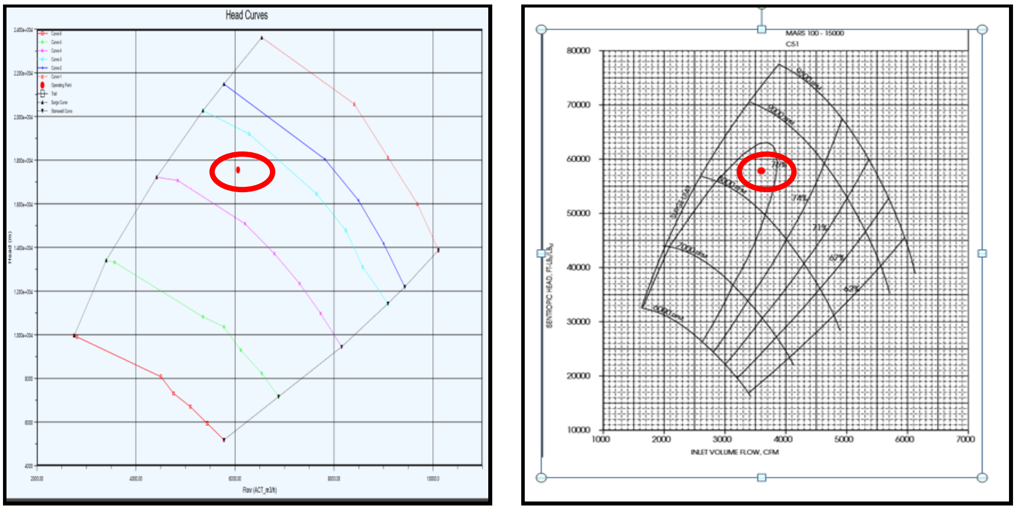
Component	Well 1	Well 2a	Well 3
H_2S	0.000	0.000	0.000
CO_2	0.001	0.001	0.000
N_2	0.003	0.003	0.004
C1	0.988	0.990	0.995
C2	0.005	0.003	0.001
C3	0.002	0.002	0.000
i-C4	0.001	0.001	0.000
n-C4	0.000	0.000	0.000
i-C5	0.000	0.000	0.000
n-C5	0.000	0.000	0.000
n-C6	0.000	0.000	0.000
Gas gravity (air=1.0)	0.56	0.56	0.56
Gross Heating value (Btu/scf)	1,012	1,010	1,010

Note: For infield gathering lines gas composition, a maximum of 10 bbl of water per MMScf of dry gas is added to dry gas composition above.



HYSYS Simulation for LP Compressor Actual Data (Vendor Data)

Figure 2. Performance head curve resulted by HYSYS vs actual (vendor) data for LP Compressor, at 170 MMSCFD, 10.60 bar suction to 33.50 bar discharge.



HYSYS Simulation for HP Compressor Actual Data (Vendor Data)

Figure 3. Performance head curve resulted by HYSYS vs actual (vendor) data for HP Compressor, at 170 MMSCFD.

As presented in Figures 2 and 3, the results obtained from the HYSYS simulation are closed to the results achieved through the soft map of the compressor vendor. So simultaneously, HYSYS can represent the compressor performance. The next validation shows the overall validation with the actual conditions in the field, based on field data as listed in Table 3. The results obtained from the HYSYS simulation and field data are close enough for the compressor speed data or the compressor output temperature. Hence, it can be concluded that simulation using the HYSYS method is quite accurate to map the actual compression condition in the field.

Table 3. Comparison of field data vs HYSYS simulation data for discharge temperature and %NPT

Date	Discharge Temperature (°C)		Speed, %NPT	
	Plant Data	HYSYS	Plant Data	HYSYS
28-May-12	84.1	85.49	68.4	68.4
29-May-12	81.0	80.83	65.2	64.7
30-May-12	81.5	84.30	65.2	66.3
31-May-12	64.7	64.92	59.0	60.0
1-Jun-12	65.6	65.56	59.0	60.0
2-Jun-12	77.1	77.48	66.0	66.8

2.2 Model Simulation Validation

There are two general categories of anti-surging system which are dedicated anti-surging systems for each compressor (LP and HP compressor) and the other one is a single anti-surging system for overall compressors [16], [17]. From those 2 categories, six different simulation models were built to evaluate the most optimum anti-surging system for compressors as presented in table 4 and figure 4.

Table 4. Options for anti-surging system

Option	Remark
Option 1	**Dedicated Anti-surging system for each compressor**
A	Dedicated Anti-surging for each compressor (LP and HP) without CGBV/HGBV. CV ASV for LP Compressor (booster) is 3399 and for HP Compressor about 640.
B	Dedicated Anti-surging for each compressor (LP and HP) plus dedicated CGBV. CV-CGBV LP Compressor 229.4, CV-CGBV HP Compressor about 69.9.
C	Dedicated Anti-surging for each compressor (LP and HP) plus dedicated HGBV. CV- HGBV LP Compressor 200, CV-HGBV LP Compressor about 100.
D	Dedicated Anti-surging for each compressor (LP and HP) plus single CGBV. CV- Single CGBV about 200.
Option 2	**Single Anti-surging System for LP-HP Compressor**
A	Single anti-surging for LP-HP compressors with data input from *LP compressor*. CV Single ASV about 750.
B	Single anti-surging for LP-HP compressors with data input from *HP compressor*. CV Single ASV about 750.

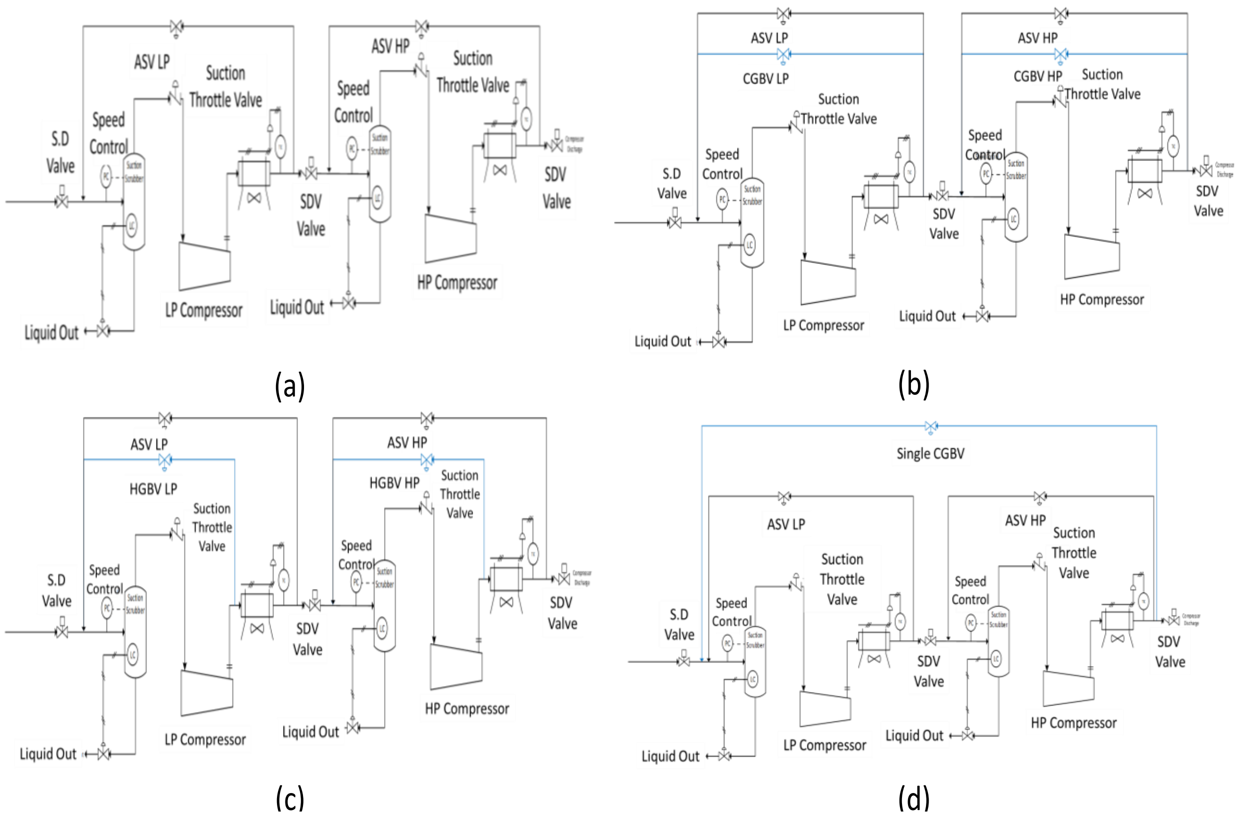
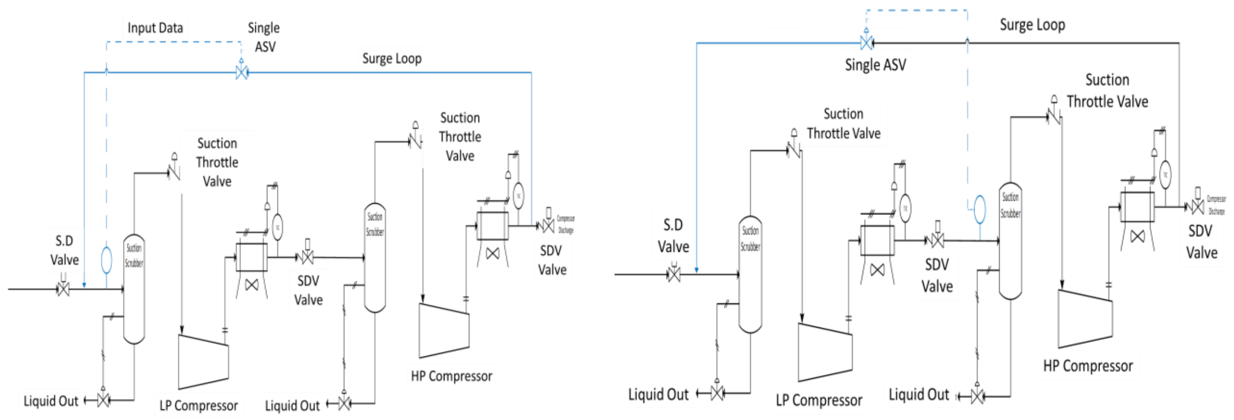


Figure 4. The schematic figure for: (a) option 1A; (b) option 1B; (c) option 1C; (d) option 1D; (e) option 2A; (f) option 2B



(e) (f)

Figure 4. (continue) The schematic figure for: (a) option 1A; (b) option 1B; (c) option 1C; (d) option 1D; (e) option 2A; (f) option 2B

Table 5. Detail data for each option

Opt.	LP Compressor			HP Compressor			Remarks
	ASV	**CGBV**	**HGBV**	**ASV**	**CGBV**	**HGBV**	
1A	CV = 5,000	No CGBV	No HGBV	CV = 800	No CGBV	No HGBV	Dedicated ASV for each compressor
	CV = 8,000	No CGBV	No HGBV	CV= 1.500	No CGBV	No HGBV	
1B	CV = 3,399	229.4	No HGBV	CV = 640	69.9	No HGBV	
1C	CV = 3,399	No CGBV	CV=200	CV = 640	No CGBV	CV=100	
1D	CV = 3,399	200	No HGBV	CV = 640	200	No HGBV	
	CV = 5,000	200	No HGBV	CV= 640	200	No HGBV	
	CV = 3,399	200(+500)	No HGBV	CV = 640	200	No HGBV	
2A	CV= 750	No CGBV	No HGBV	CV= 750	No CGBV	No HGBV	Input data from suction LP Compressor
2B	CV= 750	No CGBV	No HGBV	CV= 750	No CGBV	No HGBV	Input data from suction HP Compressor
2B*	CV= 750	600	No HGBV	CV= 750	150	No HGBV	

Table 6. Result data for each option

Opt.	CV-ASV	Operation condition after Surging
1A	LP = 5,000; HP = 800	Not return to normal condition
	LP = 8,000; HP = 1,500	Not return to normal condition
1B	LP = 3,399; HP = 640; CGBV LP = 229.4; CGBV HP = 9.9	Returned to normal condition less than 1 second.
1C	LP = 3,399; HP = 640; HGBV LP = 200; HGBV HP = 100	Returned to normal condition less than 1 second.

1D	LP = 3,399; HP = 640; CGBV = 200,	LP did not return to normal condition, and HP returned to normal
	LP = 5,000; HP = 640; CGBV = 200	LP did not return to normal condition, HP returned to normal
	LP = 3,399; HP = 640; CGBV = 200, plus dedicated CGBV for LP = 500	LP and HP returned to normal condition, less than 1 sec
2A	LP = 750; HP = 750, Data Input from suction LP compressor	Return to normal condition less than 1 second.
2B	LP = 750; HP = 750; Data Input from Suction HP Compressor plus Additional Dedicated CGBVs	Not return to Normal Condition (Still surging)
2B*	LP = 750; HP = 750; CGBV LP = 600; CGBV HP = 150; Data Input from Suction HP Compressor plus Additional Dedicated CGBVs	Return to Normal Condition

3 Simulation and Result

Option 1A has a dedicated ASV for each compressor is not adequate to avoid surging while transient happened (compressor shutdown or gas supply stopped). It is understood that considering ASV is a control valve its response is slower compared to CGBV/HGBV. The phenomenon is shown different while dedicated CGBV or HGBV is added for each compressor as in options 1B and 1C. CGBV/HGBV can react faster so that surging can be eliminated [18], [19], and the condition returns to normal in less than 1 second. However only adding a single CGBV or HGBV to LP and HP compressors, instead of a dedicated one only gives affects to the HP compressor. This is further observed in option 1D as shown in figure 8, it is most likely because of single CGBV response for LP compressors reacts slowly so that surging condition is unavoidable, while for HP compressors it seems that the timing of adding flow rate sufficiently works so that the HP compressor condition can return to normal.

On the other hand, option 2A shows a fairly stable performance. It takes 2.5 seconds for the LP compressor to return to normal condition, while for the HP compressor 0.1 seconds. It is observed because one compressor train (LP and HP) is basically one unit of the compressor, ASC (Anti-surge Controller) determination by using data input flow rate from LP Compressor is the most appropriate to get a fast response on the LP compressor during surging occurs. With a fast response on the LP compressor then normal conditions will soon be achieved, while HP Compressor will follow the next condition of the prior compressor (LP). On contrary, option 2B indicates that the operating conditions cannot return to normal during surging conditions. It is observed that at the time of surging condition detected in the suction section of HP compressor, gas supply rate to LP Compressor is already much lower than HP Compressor so once surging detected at HP, the condition at LP is worse. Because the LP compressor is worse, the following compressor (HP compressor) will get worsen. The detailed condition for each option is presented in table 5 and a brief explanation of each option is shown in table 6.

In addition, the most optimum conditions to be installed on the compressor system are options 1B and 1C because seen from the time required to be normal is very short (< 0.1 seconds), but option 1B is more reliable. With the precooling, the compressor performance will be much better by using option 1B. Option 1C is commonly used at start-up conditions after shutdown. Additionally, referring to recovering time of return to normal condition, options 1B and 1C are preferable. However, if referring to investment cost option 2A is basically the simplest and relatively cheaper, because it involves only 1 ASV single with an ASC system. In terms of plant conditions, option 2A is more appropriate if applied to the grass-root project, a project not for refurbishing/modification. Option 1B / 1C may be more suitable for the brownfield plant, for modification activity of the plant that is running. Generally, a brown plant will prefer to use the existing equipment rather than buy a new single ASV (control valve). Removing an old control valve will also be considered a waste/design error in a plant. The illustrations of the compressor curve for each option are presented in Figures 5–10.

4 Conclusion

Dynamic evaluation of centrifugal compressor's operation in determining anti-surge controller has been completely simulated. This study showed that the best option for recovering time is options 1B and 1C since they just need less than a second to recover. However, on the economical side, option 2A is quite reliable because it only uses one ASC system although it needs 2.5 seconds to recover. Hence, option 2A is more suitable for grass-root plants and 1B and 1C are preferable for brownfield plants. In addition, this study revealed some options that can be used to combat surging phenomena in compressors as shown in compressors' curves. Therefore, this study can be referenced to solve anti-surge controller problems for centrifugal compressor's operation.

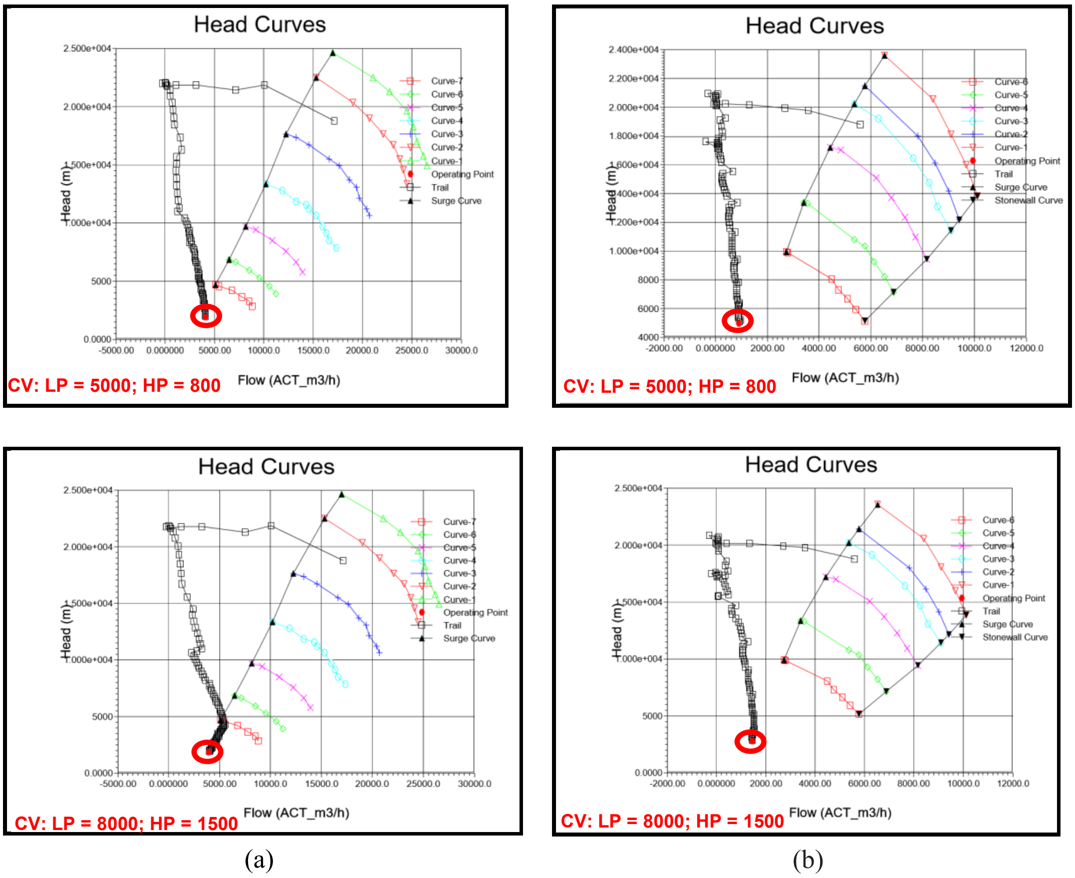


Figure 5. Compressor curve for option 1A: (a) LP compressor; (b) HP compressor.

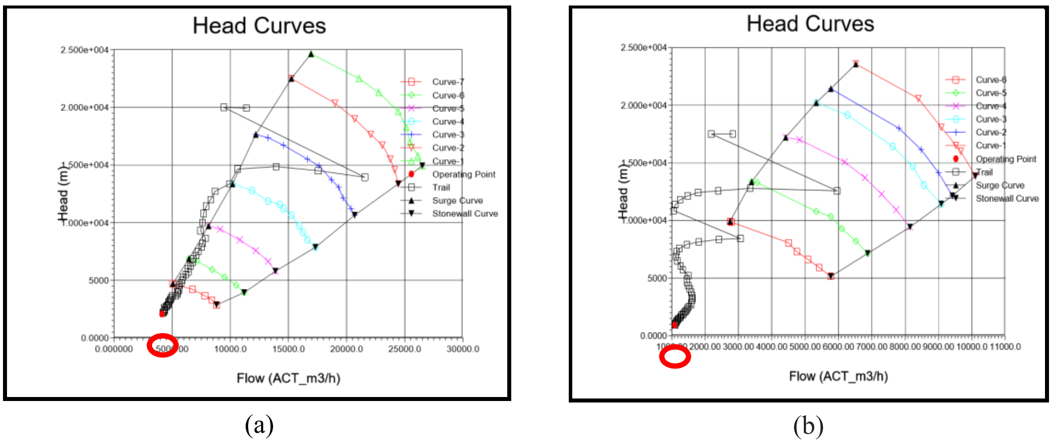


Figure 6. Compressor curve for option 1B: (a) LP compressor; (b) HP compressor.

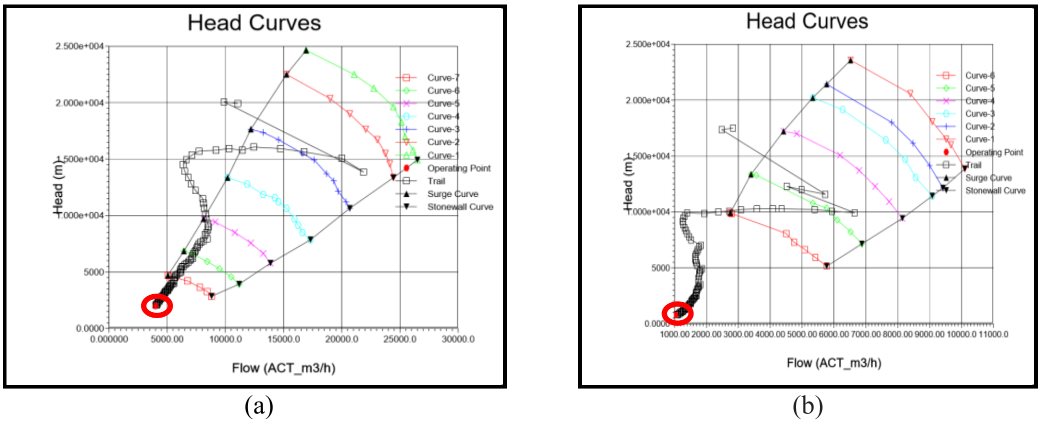


Figure 7. Compressor curve for option 1C: (a) LP compressor; (b) HP compressor.

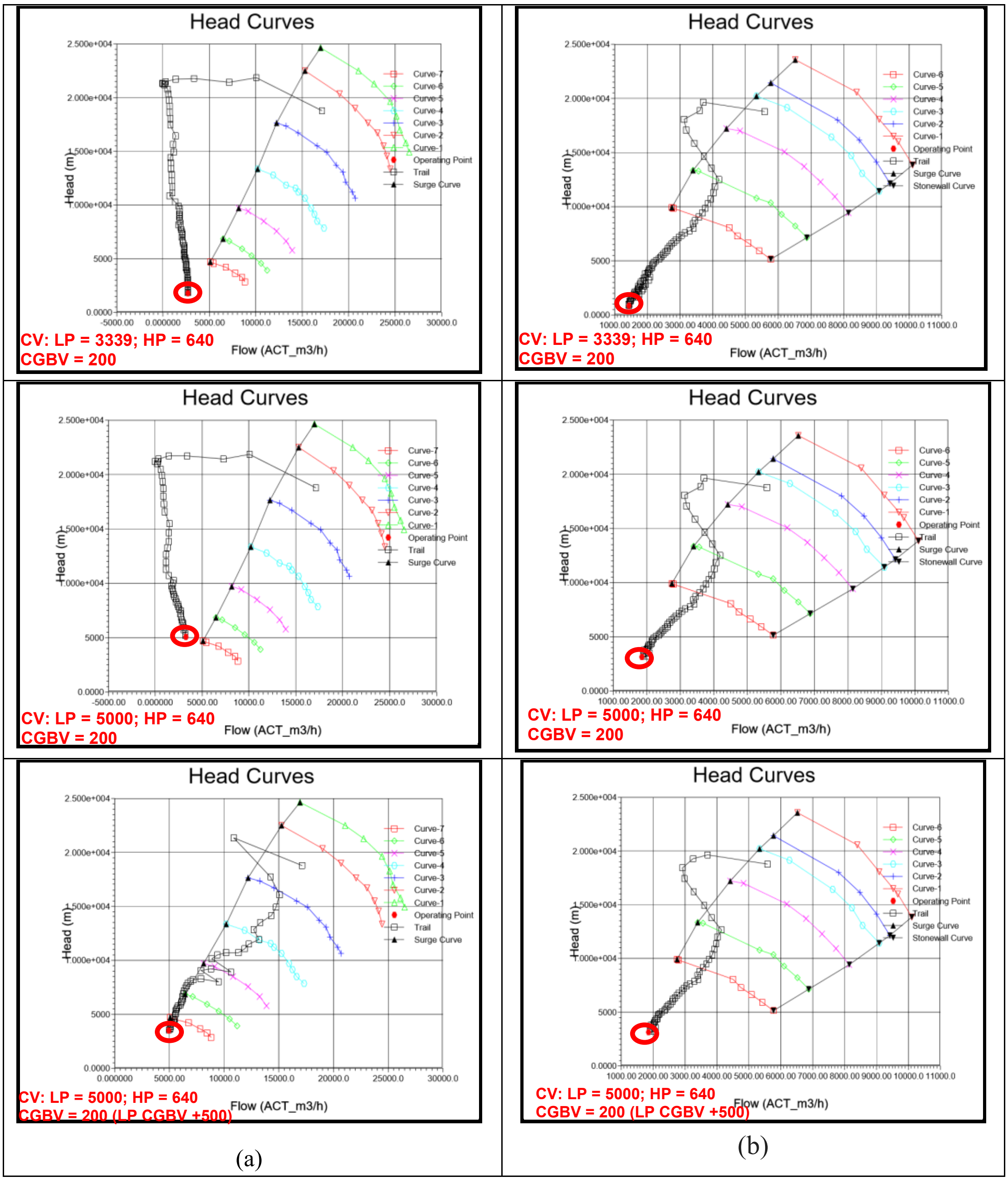
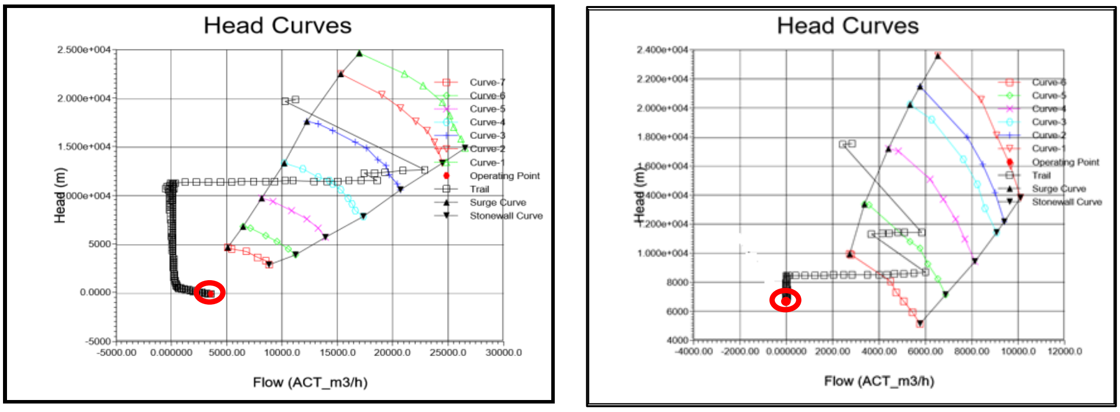
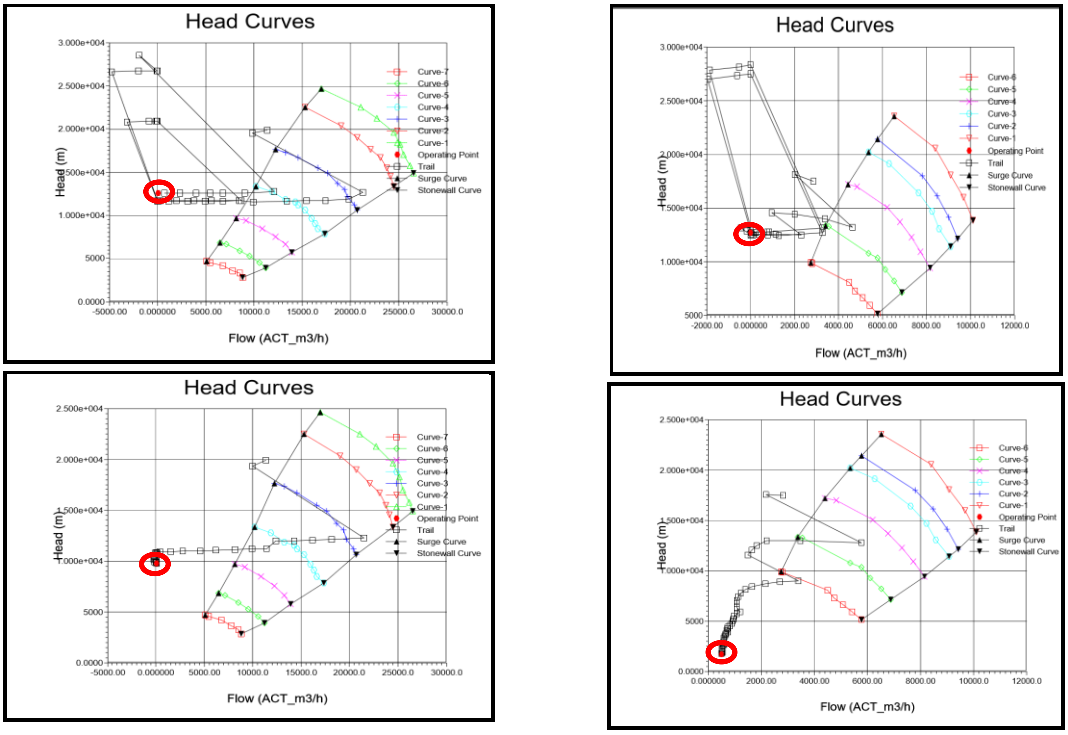


Figure 8. Compressor curve for option 1D: (a) LP compressor; (b) HP compressor.



(a) (b)

Figure 9. Compressor curve for option 2A: (a) LP compressor; (b) HP compressor



(a) (b)

Figure 10. Compressor curve for option 2B: (a) LP compressor; (b) HP compressor.

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