Enerplus Corporation

Glycol Dehydration Pump Optimization Review

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1 Executive Summary

Enerplus Corporation engaged in an agreement with the Petroleum Technology Alliance of Canada (PTAC) to assess the environmental performance (i.e., reduce methane emissions and increase energy efficiency) and economics of gas driven pumps in glycol dehydration units. This report intends to demonstrate the viability of specific measures applied to the operation of glycol dehydration units to improve environmental performance.

Glycol dehydration units (units) in Alberta commonly overcirculate glycol, which results in more energy use and emissions, with negligible reduction in dry gas water content due to the extra circulation. In addition, stripping gas is commonly employed year-round, where it may only be required seasonally or not at all to ensure adequate drying of the gas.

Optimization of the operating conditions of the units can provide an opportunity to both reduce operating expenses (i.e., recover fuel gas revenue from wasted fuel) and simultaneously reduce emissions of greenhouse gases and other air contaminants.

Three locations with glycol dehydration units were reviewed (Hanna 4-29, Pouce Coupe 13-13 and Sun Valley 2-13), with the following potential GHG reductions and fuel gas savings, as well as the corresponding recommendations. As shown in the table, two of the locations represent excellent opportunities for pump size reduction.

Location	Potential GHG Reduction (tonnes CO_2eq/y)	Potential Fuel Gas Savings ($/y)	Recommendation
Hanna 4-29	2,365	$14,142	Reduce pump size
Pouce Coupe 13-13	98	$1,086	Reduce circulation rate
Sun Valley 2-13	1,910	$9,160	Reduce pump size; reducing circulation rate can achieve 76% of the benefit

Based on these recommendations, the pump at Hanna 4-29 was successfully replaced on March 2, 2016. Details of the pump changeover are detailed in ***Section 5.7: Glycol Pump Replacement***.

A spreadsheet-based Glycol Circulation Estimator (GCE) Tool was developed to quickly assess energy and GHG Emission optimization opportunities for TEG dehydrators, without the need to run more complex simulation models. The GCE Tool is included and described in this report.

Following completion of the initial stage, a similar review for three additional facilities was completed. This study was based on rigorous calculations supported by process simulation, and compared to results of the GCE Tool. Results of this review are shown in the table on the following page.

Location	Potential GHG Reduction (tonnes CO_2eq/y)	Potential Fuel Gas Savings ($/y)	Recommendation
Cramersburg 13-18	2,226	$13,410	Prioritize to replace pump with Kimray 1715PV / 1720PV
Lacadena 04-10	212	$2,538	Replace pump with Kimray 1715PV / 1720PV
Miry Bay 16-24	990	$5,916	Replace pump with Kimray 1715PV / 1720PV

There is an opportunity in industry to economically reduce methane emissions by replacing pumps in dehydration facilities, as evidenced in this and other projects[1]. The largest potential GHG reductions will be for those facilities which:

- Overcirculate glycol
- Use an energy exchange (Kimray) pump
- Do not recover fuel gas in a flash tank
- Vent still gas overheads
- Use stripping gas

[1] CCEMC / ConocoPhillips GHG reduction workshop, December 4, 2015

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3 Objective and Background

Process Ecology Inc. was contracted to review the opportunity for optimization (i.e., estimation of emission reduction and cost savings) of three glycol dehydrators operated by Enerplus Corporation. Aspects of the analysis include triethylene glycol (TEG) circulation rate reduction, stripping gas elimination/reduction, TEG pump evaluation, and contactor hydraulic verification.

The opportunity for GHG reduction in dehydration units can be better understood by examining the sources of methane in the process, as well as the key venting/combustion emission points, as shown in Figure 1.

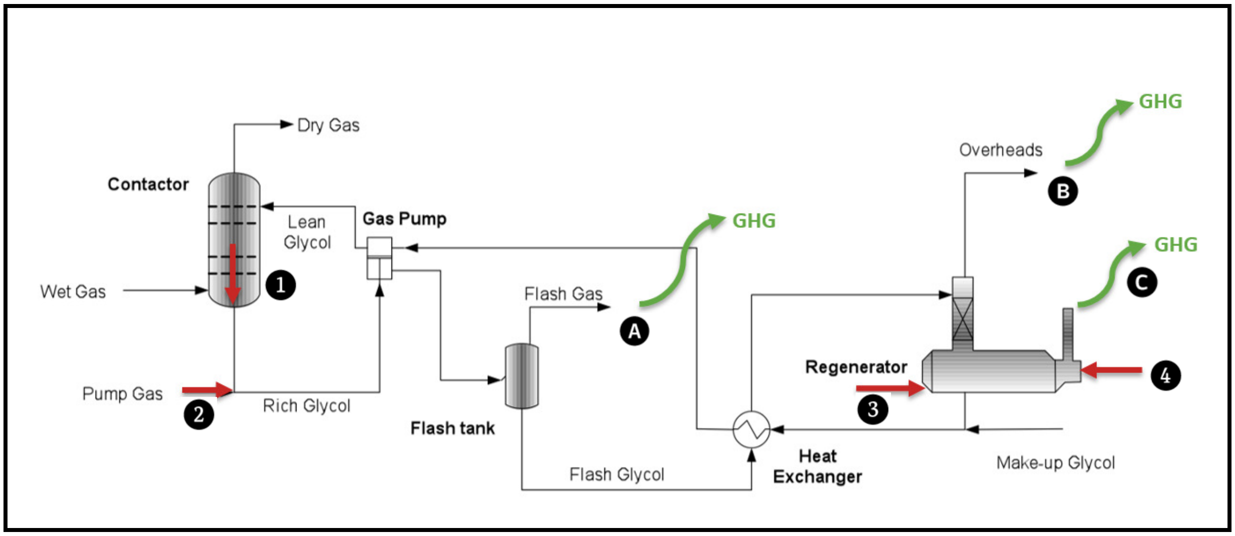


Figure 1: Sources of GHG emissions in a dehydration facility

In the dehydration process, Carbon Dioxide Equivalent (CO_2e) sources (red arrows) are:

1. Methane and CO_2 absorption by the lean glycol, in the contactor
2. Supplemental pump gas required by the energy exchange (Kimray) pump
3. Stripping gas used in the regenerator
4. Fuel gas combustion in the regenerator burner

Of these, #2 (energy exchange gas) and #3 (stripping gas) typically represent the largest methane sources.

The main potential Carbon Dioxide Equivalent (CO_2e) emission points (green arrows) are:

A. Flash tank (not always present)
B. Still vent overhead
C. Regenerator burner stack

Of these, A (flash tank) and B (still vent) are the most significant methane emission points. There are other potential methane emissions not considered here (e.g., fugitives, instrument gas).

An energy exchange pump replacement (to a lower glycol circulation rate) will reduce:

- CO_2e absorption in the contactor,

- supplemental gas used by the energy exchange pump, and
- fuel gas combustion in the regenerator burner.

Further, if stripping gas is not required, this will eliminate another significant source of methane emissions.

3.1 CCEMC / ConocoPhillips GHG reduction workshop

On December 4, 2015, a public workshop was held in Calgary which shared several GHG reduction projects implemented by ConocoPhillips for various technologies; these projects were funded by the Climate Change & Emissions Management Corporation (CCEMC).

One presentation focused on the results of projects associated with dehydration facilities. For dehydration facilities, 14 different projects in six technology areas were completed, with the majority focussed on energy exchange pump reduction. With successful results, energy exchange pump reduction was identified as the most cost-efficient GHG reduction opportunity of all the reviewed dehydration technologies for potential widespread adoption in industry.

Key learnings included the following:

- Pump rate reduction can be employed at facilities that are over-circulating glycol. The majority of dehydration units may be over-circulating; with circulation rates higher than optimal, there are no additional dehydration benefits. Depending on the pump characteristics, circulation rate can be lowered or pump replacement would be required.
- Emissions are usually linearly proportional to glycol rates.
- It is necessary to ensure that the contactor trays perform adequately at lower glycol circulation rates. It was noted that no contactor hydraulic issues were associated with downsizing the pumps in any of the projects.
- It is possible to operate energy exchange pumps lower than the manufacturer (Kimray) recommended minimums, with some potential risk for pump stalling.
- There is an opportunity to turn down electric pumps, although the greenhouse gas reduction benefits is not as significant as for reducing the demand of energy exchange pumps.
- The greenhouse gas reduction per installation was in the range of 100-1000 tCO_2e/year, which depended on facility characteristics such as still overhead control and presence of a flash tank.
- The average pump replacement project cost was $8,000, which resulted in a cost abatement of just over $1/$tCO_2e$ (taken over 20 years).

4 Assumptions and Optimization Methodology

The methodology followed during the course of this optimization review is outlined in Figure 2.

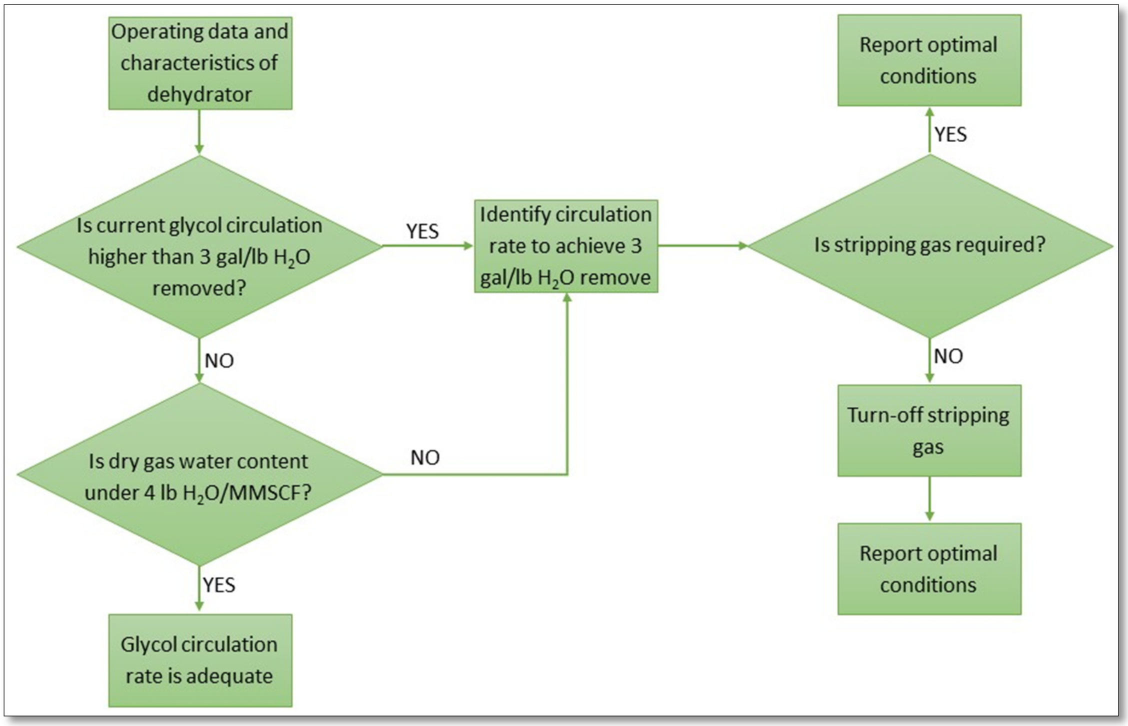


Figure 2: Optimization Methodology

Once the relevant glycol dehydration unit data was collected, a series of process simulation calculations was performed to evaluate the operational limits of each system and determine the optimal conditions for each dehydrator.

The following main assumptions were used for the calculations:

- Recorded operating data was accurate and representative of dehydrator operation.
- The dehydration objective was to reach consistently a maximum dry gas water content of 4 lb H_2O/MMSCF.
- Generally accepted TEG circulation rates range from 2 to 4 gal TEG/lb H_2O removed. In this analysis, 3 gal TEG/lb H_2O removed was used.
- Optimal reboiler temperature (for TEG) is 200°C.
- The wet gas was conservatively assumed to be water saturated at the contactor temperature.
- Aspentech HYSYS® was used for all calculations.
- Gas price was assigned a value of $2/GJ.
- Potential savings were determined based on the fuel gas use reduction in the dehydration process in three key areas:

- Burner: fuel gas consumed as a heat source in the regenerator reboiler. Fuel gas consumption increases with increasing glycol circulation rates.
- Glycol Pump: gas used to supplement rich glycol motive force in energy exchange pump. Fuel gas use in the energy exchange pump increases with increasing glycol circulation rate. Also, more CO_2 and methane is absorbed by the glycol in the contactor with increasing glycol circulation rate.
- Stripping Gas: gas used in the still column to reach higher glycol purity. This was only used when the sales gas water content specification could not be achieved by glycol circulation rate alone.

5 Results - Hanna 4-29 (04-29-032-14W4M)

5.1 Unit Summary

The operating conditions at Hanna 4-29 Compressor Station are presented in Table 1:

Table 1: Hanna 4-29 Current Operating Conditions

	Reported Condition
Normal Gas Flowrate (E^3m^3/d)	115.0
Normal Contactor Pressure (kPa)	6,550
Normal Contactor Temperature (°C)	36.0
Normal TEG Circulation Rate (USGPM)	1.10
Number of Contactor Trays	8 / Bubble Cap
Glycol Pump	Kimray / 210-15 / Gas Driven
Flash Tank	No
Stripping Gas Option	Dry Gas
Stripping Gas Flow (SCFM)	7.13[2]

5.2 Ideal Operating Conditions Analysis

Based on the parameters shown in Table 1, and the available inlet gas composition supplied by Enerplus Corporation (analysis sampled on August 9th, 2015), the process simulation study was performed.

Figure 3 shows the dry gas water content as a function of TEG circulation rate at current stripping gas rate and without using stripping gas.

Current and Ideal (3 gal TEG/lb H_2O removed) TEG circulation rates are indicated in Figure 3. For each case, performance indicators, including gas use and GHG emissions, are shown in Table 2 and Table 3, respectively.

These results reveal that operating at 0.37 USGPPM with no stripping gas and a 200°C reboiler temperature would result in dry gas water content of 3.7 lb H_2O/MMSCF while achieving further fuel gas savings equivalent to $14,142 per year and a 2,365 CO_2eq/y reduction.

[2] Estimated based on stripping gas valve sizing and operating conditions.

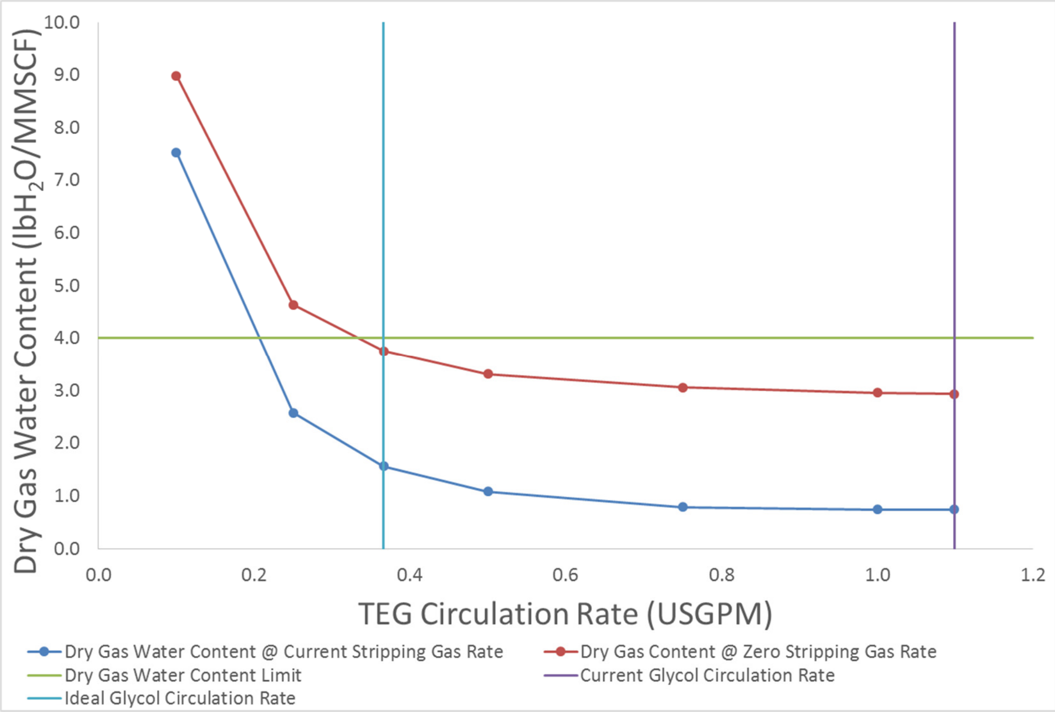


Figure 3: Dry Gas Water Content as a function of Glycol Circulation Rate of Hanna 4-29

Table 2: Hanna 4-29 Performance Indicators at Current Operating Conditions

Dry Gas Water Content (lb H_2O/MMSCF)	0.8
Burner Gas use (GJ/y)	1,837
Stripping Gas use (GJ/y)	3,949
Pump Gas use (GJ/y)	3,019
GHG Emissions (tonnes CO_2eq/y)	2,801

Table 3: Hanna 4-29 Performance Indicators at Ideal Operating Conditions

Glycol Circulation Rate (USGPM)	0.37
Stripping Gas Rate (SCFM)	0
Dry Gas Water Content (lb H_2O/MMSCF)	3.7
Burner Gas use (GJ/y)	728
Stripping Gas use (GJ/y)	0
Pump Gas use (GJ/y)	1,006
GHG Emissions (tonnes CO_2eq/y)	436
Potential Saving ($/y)	14,142

5.3 Pump Comments

This unit was originally equipped with a Kimray 210-15 glycol pump which the operators had been running at the current rate of 1.1 USGPM. To capture the identified fuel gas savings, a pump replacement was considered necessary since the Kimray 210-15 minimum rate is 1.10 USGPM.

5.4 Stripping Gas

Based on simulation results, it has been calculated that the maximum temperature at which the contactor may operate without the need for stripping gas is 36.5 °C, which is slightly above the reported temperature of 36 °C; therefore the use of stripping gas is not required at the current conditions.

5.5 Contactor Hydraulics Analysis

Based on simplified column hydraulics performance calculations, the TEG contactor gas capacity may be as low as 41 E^3m^3/d (based on an assumed 9:1 turndown ratio for bubble cap trays). For the TEG circulation rate, minimum values may be as low as 0.13 USGPM, which is lower than the recommended TEG circulation rate. A more rigorous contactor hydraulic validation based on actual column internal drawings would need to be performed to more accurately determine the minimum gas and TEG flowrates. Enerplus and Process Ecology contacted the manufacturer (Propak) to obtain contactor internal drawings but these files were not located in manufacturer archives.

5.6 Unit Optimization Summary

The Hanna 4-29 dehydrator can be operated with a lower TEG circulation rate of 0.37 USGPM and the stripping gas eliminated for approximately 80% reduction in fuel gas use equivalent to $14,142/y (16% corresponds to burner gas reduction, 56% due to stripping gas elimination, and 28% to pump gas reduction). Additionally, there will be over 84% reduction in GHG emissions (equivalent to 2,365 tonnes CO_2eq/y). Operating the Hanna 4-29 dehydrator at the recommended TEG circulation rate will require pump replacement since the current pump minimum flow is 1.1 USGPM. A recommended pump model for this facility is the Kimray 1715PV/1720PV (0.13 - 0.67 USGPM).

5.7 Glycol Pump Replacement

Based on these recommendations, Enerplus carried out the glycol pump replacement at this location on March 2nd, 2016. The unit was equipped with a Kimray 210-15 and it was replaced by a Kimray 1720 PV. The pump replacement job was performed during a scheduled dehydration facility maintenance shutdown. This procedure was carried out as expected: it started at 7:00 am with plant shutdown depressurization and cooldown, at 10:00 am the previous pump was removed and the new pump was installed, and the fitting connections and pump base were successfully completed by the end of the day. Other maintenance activities were performed simultaneously during this time.

Figure 4 shows the original pump in place (Kimray 210-15 in red color), with the new Kimray 1720 PV pump (blue color) purchased by Enerplus. Figure 5 shows the new pump as installed at the Hanna 4-29 facility.

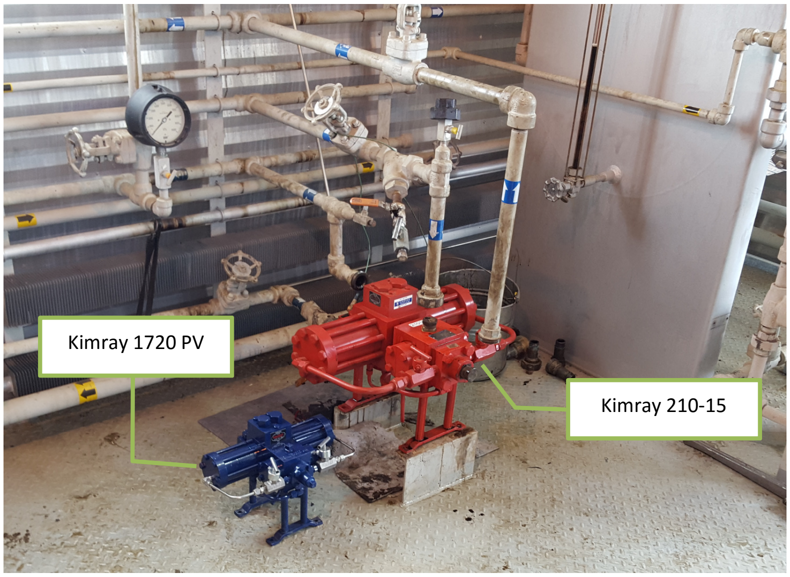


Figure 4: Hanna 4-29 pump replacement job

Figure 5: Kimray 1720PV pump as installed in Hanna 4-29

The old Kimray 210-15 pump was stored at the facility and it is recommended to keep it with the dehydrator package in case an increase in throughput is required in the future. Also, there is an opportunity to have both pumps connected to the spare connections as indicated in Figure 6. This arrangement would allow the dehydrator to have a wider range of operation without being in the scenario of glycol over circulation which causes excess methane emissions and lower energy efficiency, or under circulation which may cause out-of-spec gas production.

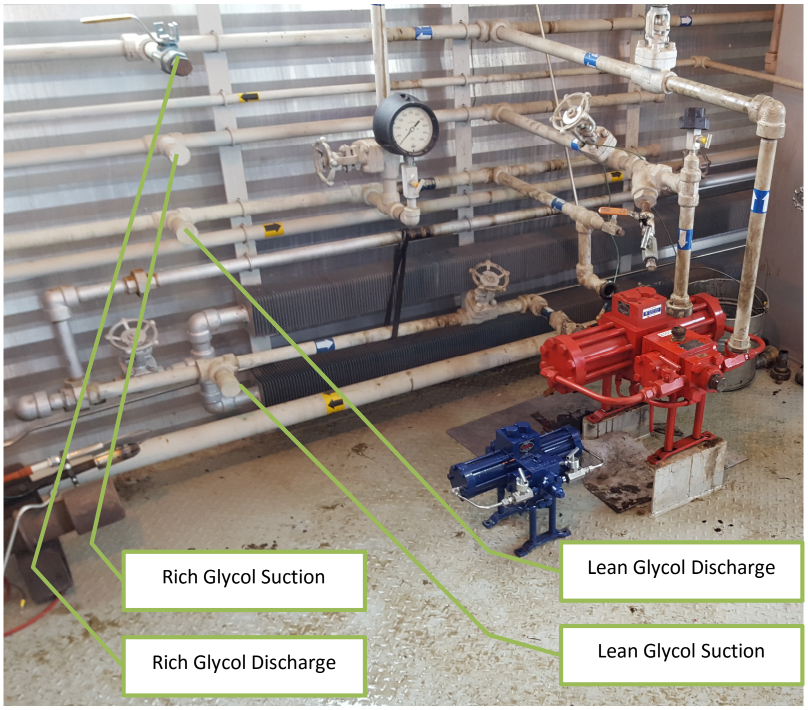


Figure 6: Spare glycol pump connections

The environmental and economic assessment presented in report was based on the usage of stripping gas as shown in Table 1; however plant personnel mentioned that stripping gas was not used regularly. However, this could not be verified since Process Ecology engineers arrived at the facility when it was already shutdown. The use of stripping gas as reflected in this report is a significant contributor to methane emissions from glycol regenerators, so its use in this dehydrator is only recommended when contactor operating temperature is higher than 36.5 °C.

Process Ecology recommends adjusting glycol circulation rate according to significant changes in dehydrator gas rate and contactor conditions to avoid unnecessary methane emissions or out-of-spec produced gas. Well known best practices suggest circulating glycol based on 3 gal TEG/lb H_2O removed. Based on the new pump model and the facility operating conditions, this pump must be operated at 22 strokes/min to deliver the optimal circulation rate proposed in this study. The Hanna 4-29 Piping & Instrumentation Diagram (P&ID), with notes, is shown in Appendix A, and Appendix B is the Glycol Pump Product Bulletin provided by Kimray Inc.

6 Results – Pouce Coupe 13-13 (13-13-078-11W6M)

6.1 Unit Summary

The operating conditions at Pouce Coupe 13-13 Compressor Station are presented in Table 4:

Table 4: Pouce Coupe 13-13 Current Operating Conditions

	Reported Condition
Normal Gas Flowrate (E^3m^3/d)	80.0
Normal Contactor Pressure (kPa)	3,355
Normal Contactor Temperature (°C)	30.0
Normal Glycol Circulation Rate (USGPM)	0.76
Number of Contactor Trays	8 / Bubble Cap
Glycol Pump	Bruin / 90-15 / Gas Driven
Flash Tank	No
Stripping Gas Option	No
Stripping Gas Flow (SCFM)	0.0

6.2 Ideal Operating Conditions

Based on the parameters shown in Table 4 and the available inlet gas composition supplied by Enerplus Corporation (analysis sampled on December 15th, 2014), the process simulation study was performed.

Figure 7 shows the dry gas water content as a function of TEG circulation rate at current stripping gas and without using stripping gas.

Three TEG circulation rates are indicated in Figure 7: Current, Ideal (3 gal TEG / lb H_2O removed), and 0.6 USGPM. Performance indicators, including gas use, GHG and benzene emissions are shown in Table 5, Table 6, and Table 7, respectively. Note that for the ideal circulation rate case, the use of stripping gas was required to meet water content specifications. At lower contactor pressures (in this case, less than 3,500 kPag), it is more difficult to meet the dry gas water content specification.

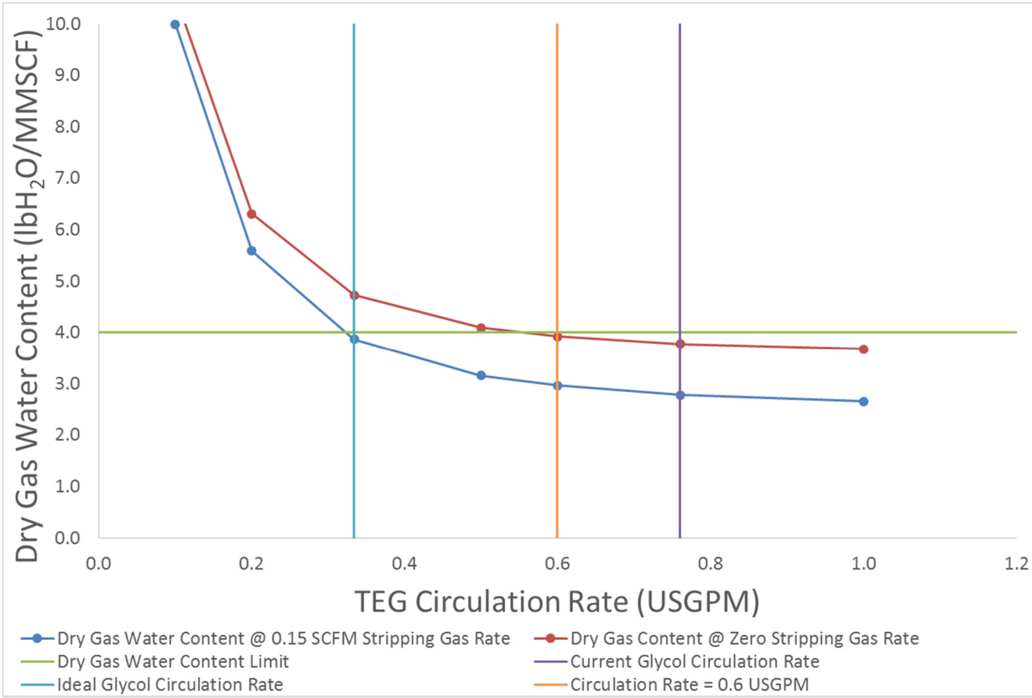


Figure 7: Dry Gas Water Content as a function of Glycol Circulation Rate of Pouce Coupe 13-13

Table 5: Pouce Coupe 13-13 Performance Indicators at Current Operating Conditions

Dry Gas Water Content (lbH_2O/MMSCF)	3.8
Burner Gas use (GJ/y)	1,423
Stripping Gas use (GJ/y)	0
Pump Gas use (GJ/y)	1,252
GHG Emissions (tonnes CO_2eq/y)	452
Benzene Emissions (tonnes/y)	1,086

Table 6: Pouce Coupe 13-13 Performance Indicators at Ideal Operating Conditions

Glycol Circulation Rate (USGPM)	0.33
Stripping Gas Rate (SCFM)	0.15
Dry Gas Water Content (lbH_2O/MMSCF)	3.9
Burner Gas use (GJ/y)	676
Stripping Gas use (GJ/y)	94
Pump Gas use (GJ/y)	550
GHG Emissions (tonnes CO_2eq/y)	222
Benzene Emissions (tonnes/y)	0.611
Potential Saving ($/y)	2,710

Table 7: Pouce Coupe 13-13 Performance Indicators at 0.6 USGPM

Glycol Circulation Rate (USGPM)	0.6
Stripping Gas Rate (SCFM)	0.0
Dry Gas Water Content (lbH_2O/MMSCF)	3.9
Burner Gas use (GJ/y)	1,145
Stripping Gas use (GJ/y)	0

Pump Gas use (GJ/y)	987
GHG Emissions (tonnes CO_2eq/y)	354
Benzene Emissions (tonnes/y)	1.239
Potential Saving ($/y)	1,086

6.3 Pump Comments

This unit is equipped with a Bruin 90-15 glycol pump, which is currently circulating 0.76 USGPM TEG. To capture the identified fuel gas savings for the ideal case (using stripping gas) a pump replacement would be necessary since the minimum flowrate for this pump is 0.45 USGPM. Alternatively, operating at 0.6 USGPM will allow for some fuel gas saving without replacing the TEG pump.

6.4 Stripping Gas

In the first case, a 0.45 USGPM glycol circulation rate will require a small amount of stripping gas to ensure the 4 lb/MMSCF dry gas water content specification is met. At 0.6 USGPM, no stripping gas is required; however, an increase in gas temperature to the contactor (above 31 C) will necessitate the use of stripping gas to ensure the dry gas water content specification is met. This temperature is relatively low due to the lower than typical pressure in the contactor.

6.5 Contactor Hydraulics Analysis

Based on simplified column hydraulics performance calculations, the TEG contactor gas capacity may be as low as 31 E^3m^3/d (based on an assumed 9:1 turndown ratio for bubble cap trays). For the TEG circulation rate, minimum values may be as low as 0.17 USGPM, which is lower than the recommended TEG circulation rate. A more rigorous contactor hydraulic validation based on actual column internal drawings would need to be performed to determine more accurately the minimum gas and TEG flowrates. Enerplus Corporation and Process Ecology contacted the manufacturer (Propak) to obtain contactor internal drawings but these files were not located in manufacturer archives.

6.6 Unit Optimization Summary

Pouce Coupe 13-13 dehydrator can be operated with a lower TEG circulation rate of 0.6 USGPM with no stripping gas, providing a 20% reduction in fuel gas use equivalent to $1,086/y (52% corresponds to burner gas reduction and 48% to pump gas reduction). Additionally, there will be a 22% reduction in GHG emissions (equivalent to 98 tonnes CO_2eq/y), and a 15% reduction in Benzene emissions. Alternatively, if the current pump is replaced, this dehydrator can be operated at 0.34 USGPM and 0.15 SFCM providing 51% reduction in fuel gas use equivalent to $2,710/y (52% corresponds to burner gas reduction and 48% to pump gas reduction). Additionally, there will be a 51% reduction in GHG emissions (equivalent to 230 CO_2eq/y), and a 62% reduction in Benzene emissions. A recommended pump model for this facility is the Kimray 1715PV/1720PV (0.13 - 0.67 USGPM). However, given the inability to accurately set the stripping gas rate, the more modest decrease in GHG emissions, and the requirement to change the pump to circulate at 0.34 USGPM, this is not considered to be a strong candidate for pump replacement. Some savings ($1,086/y) can be achieved simply by operating at a lower circulation rate (0.6 USGPM).

7 Results – Sun Valley 2-13 (02-13-013-04W4M)

7.1 Unit Summary

The operating conditions at Sun Valley 2-13 Compressor Station are presented in Table 8:

Table 8: Sun Valley 2-13 Current Operating Conditions

	Reported Condition
Normal Gas Flowrate (E^3m^3/d)	82.0
Normal Contactor Pressure (kPa)	6,033
Normal Contactor Temperature (°C)	28.0
Normal Glycol Circulation Rate (USGPM)	1.32
Number of Contactor Trays	8 / Bubble Cap[3]
Glycol Pump	Kimray / 90-15 / Gas Driven
Flash Tank	No
Stripping Gas Option	Dry Gas
Stripping Gas Flow (SCFM)	2.71

7.2 Ideal Operating Conditions

Based on the parameters shown in Table 8 and the available inlet gas composition supplied by Enerplus Corporation (analysis sampled on October 16th, 2015) the process simulation study was performed. Figure 8 shows the dry gas water content as a function of TEG circulation rate at current stripping gas and without using stripping gas.

The current and ideal (3 gal TEG / lb H_2O removed) TEG circulation rate is indicated in Figure 8. For each case, performance indicators, including gas use and GHG emissions, are shown in Table 9 and Table 10 respectively.

These results reveal that operating at 0.17 USGPM with no stripping gas and a 200°C reboiler temperature would result in dry gas water content of 2.5 lb H_2O/MMSCF while achieving further fuel gas savings ($9,160/y).

[3] To be confirmed by Enerplus Corp.

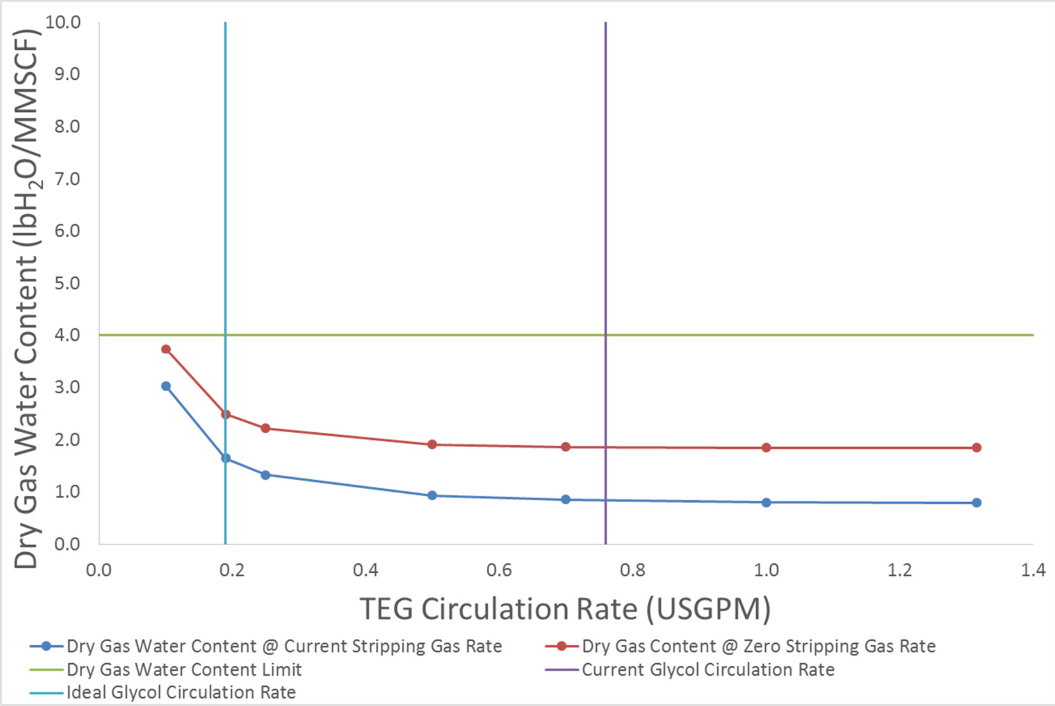


Figure 8: Dry Gas Water Content as a function of Glycol Circulation Rate of Sun Valley 2-13

Table 9: Sun Valley 2-13 Performance Indicators at Current Operating Conditions

Dry Gas Water Content (lbH$_2$O/MMSCF)	0.8
Burner Gas use (GJ/y)	2,265
Stripping Gas use (GJ/y)	1,442
Pump Gas use (GJ/y)	3,362
GHG Emissions (tonnes CO$_2$eq/y)	2,115

Table 10: Sun Valley 2-13 Performance Indicators at Ideal Operating Conditions

Glycol Circulation Rate (USGPM)	0.17
Stripping Gas Rate (SCFM)	0.0
Dry Gas Water Content (lbH$_2$O/MMSCF)	2.5
Burner Gas use (GJ/y)	369
Stripping Gas use (GJ/y)	0
Pump Gas use (GJ/y)	486
GHG Emissions (tonnes CO$_2$eq/y)	205
Potential Saving ($/y)	9,160

7.3 Pump Comments

This unit is equipped with a Kimray 90-15 glycol pump which is running at the current rate of 1.32 USGPM. To capture the identified fuel gas savings, a pump replacement is necessary since the pump minimum rate is 0.45 USGPM. However, significant benefit could be achieved by reducing the rate to the pump minimum. A reduction from 1.32 USGPM to 0.45 USGPM is 76% of the full proposed reduction from 1.32 USGPM to 0.17 USGPM.

7.4 Stripping Gas

Based on simulation results, it has been calculated that the maximum temperature at which the contactor may operate without the need for stripping gas is 33.0 °C.

7.5 Contactor Hydraulics Analysis

Based on simplified column hydraulics performance calculations, the TEG contactor gas capacity may be as low as 41 E^3m^3/d (based on an assumed 9:1 turndown ratio for bubble cap trays). For the TEG circulation rate, minimum values may be as low as 0.10 USGPM, which is lower than the recommended TEG circulation rate. A more rigorous contactor hydraulic validation based on actual column internal drawings would need to be performed in order to determine more accurately the minimum gas and TEG flowrates. Enerplus and Process Ecology contacted the manufacturer (Cessco) to obtain contactor internal drawings but these files were not located in manufacturer archives.

7.6 Unit Optimization Summary

The Sun Valley 2-13 dehydrator can be operated with a lower TEG circulation rate of 0.17 USGPM and the stripping gas eliminated for approximately 88% reduction in fuel gas use equivalent to $9,160/y (18% corresponds to burner gas reduction, 55% due to stripping gas, and 27% to pump gas reduction). Additionally, there will be a 90% reduction in GHG emissions (equivalent to 1,910 tonnes CO_2eq/y). Operating the Sun Valley 2-13 dehydrator at the recommended TEG circulation rate will require pump replacement since the current pump minimum flow is 0.45 USGPM. A recommended pump model for this facility is the Kimray 1715PV/1720PV (0.13 - 0.67 USGPM).

8 Stage 2: Additional Dehydrator Study

Following the first stage of the project, which included the analysis of three units as outlined earlier in this report, and pump replacement of the best candidate (Hanna 4-29), a similar review for three additional facilities was completed. In addition, a spreadsheet-based Glycol Circulation Estimator (GCE) Tool was developed (refer to ***Section 9: Glycol Circulation Estimator (GCE) Tool Spreadsheet***), as a way to quickly assess energy and GHG Emission optimization opportunities for TEG dehydrators. An objective of the project was to evaluate the performance of the GCE Tool for analysis of the three additional glycol dehydration units.

For the three additional units, this study was based on rigorous calculations supported by process simulation. Table 11 shows the current operating conditions and relevant information used to perform the energy and GHG optimization calculations for the additional units.

Table 11: Current Operating condition for the additional dehydrators

	Dehy 1	**Dehy 2**	**Dehy 3**
Name	Cramersburg 13-18 Compressor: Dehy 1	Lacadena 04-10 North Compressor: Dehy 1	Miry Bay 16-24 Compressor: Dehy 1
Location	13-18-022-20W3	04-10-023-18W3	16-24-021-19W3
Normal Gas Flowrate (E^3m^3/d)	115.0	110.0	67.0
Normal Contactor Pressure (kPa)	6,101	6,501	6,301
Normal Contactor Temperature (°C)	22	22	30
Glycol Pump	Kimray 21015 PV	Kimray 9015 PV	Kimray 21015 PV
Normal Pump Speed	16	12	8
Normal Glycol Circulation Rate (USGPM)	1.78*	0.46*	0.89*
Flash Tank	No	No	No
Stripping Gas Used?	No	No	No
Still Control Option	No Control	No Control	No Control

*Calculated based on normal pump speed as reported by Enerplus Corporation

Table 12 shows the results of the rigorous energy and GHG emission optimization analysis of these additional units. Analysis indicates that all three units are circulating more glycol than required. Based on the fuel gas cost savings associated with glycol circulation reduction, the best candidate for pump replacement is "Cramersburg 13-18 Compressor: Dehy 1". This unit has the largest savings, and potential to provide a project payout time in less than a year.

Table 12: Energy and GHG emission optimization results for additional units

	Dehy 1	Dehy 2	Dehy 3
Name	Cramersburg 13-18 Compressor: Dehy 1	Lacadena 04-10 North Compressor: Dehy 1	Miry Bay 16-24 Compressor: Dehy 1
Wet Gas Water Content (lbH2O/MMSCF)	24.4	23.5	37.9
Optimal Circulation Rate (USGPM)*	0.17	0.17	0.17
Glycol Circulation Reduction (%)	90.3	64.2	81.2
GHG Emissions Reduction (tonnes CO_2eq/y)	2,226	212	990
Potential Saving ($/y)	13,410	2,538	5,916
Recommended Pump Model	Kimray 1715PV/1720PV	Kimray 1715PV/1720PV	Kimray 1715PV/1720PV

* Coincidentally, the optimal circulation rate for all three units was 0.17 USGPM

Reducing the glycol circulation rate at “Cramersburg 13-18 Compressor: Dehy 1” to the optimal level will reduce GHG emissions by approximately 2,200 tonnes CO_2eq per year, with a potential savings of $13,410/yr.

9 Glycol Circulation Estimator (GCE) Tool Spreadsheet

A spreadsheet-based GCE Tool was developed to quickly assess energy and GHG Emission optimization opportunities for TEG dehydrators, without the need to run more complex simulation models. This tool provides the ability to:

- evaluate different Kimray pump models to determine the most appropriate size required
- evaluate the potential GHG emission reductions associated with a pump replacement
- determine the potential savings which can be accomplished by replacing the pump

The GCE Tool contains the basic calculations to evaluate potential energy and GHG emissions reductions for TEG dehydrators. It is comprised of three tabs:

- User Guide: this tab provides documentation regarding the use of the spreadsheet, summarizes the minimum information required to run the calculations, and outlines the possible warnings, assumptions, relevant information, and references used in the development of this tool.
- Glycol (TEG) Rate Optimization: this tab contains all of the input data, calculations and results related to the energy and GHG emissions optimization. This tab is displayed in Figure 9, and is divided into five sections:
    1. **Site Operating Conditions:** here the user specifies contactor pressure and temperature, gas specific gravity, dehydrator gas flow rate and gas price. Wet gas water content and target circulation rate are calculated here.
    2. **Model Selection/Comparison:** in this section the user specifies the Kimray pump model and pump speed. The spreadsheet automatically calculates glycol circulation rate, among other pump parameters.
    3. **Emissions:** this section displays results related to gas consumption and GHG emissions.
    4. **Economics:** this section displays a brief economic evaluation for the selected pump options.
    5. **Recommendations:** provides a location for the user to write down some comments and recommendations based on the results.
- Lookup Tables: this tab contains the lookup tables for the Kimray pumps; it is kept visible because it is considered to be a useful reference, and includes some explanation of the Kimray pump parameters.

Project LSD:	13-18-022-20W3		Date:	2016-03-23
Site Operating Conditions				
Contactor Pressure		6000	kPag	
Contactor Temperature		22	C	
Gas Gravity		0.5785		
Normal Gas Flow Rate		115	e^3m^3/d	
Water Content (Calculated)		31.9	lb/mmscf	
Gas Price		2	$CAD/GJ	
Target Circulation Rate		0.24	USGPM	
Model Selection/Comparison				
	Units	**Current**	**Option 1**	**Option 2**
Kimray Pump Model		21015PV	9015PV	4015PV
Kimray Pump Speed	SPM	16	12	14
Glycol Circ. Rate	USGPM	1.78	0.46	0.24
Gal Glycol/lb H2O removed	Gal/lb	22.5	5.8	3.0
Pump Range	USGPM	1.11 - 3.55	0.46 - 1.52	0.2 - 0.68
Max Gas Flow Rate at Max Pump Rate	e3m3/d	1511	647	289
Emissions				
Gas used for Energy Exchange	mscf/d	12.42	3.19	1.66
Gas absorbed by glycol	mscf/d	2.56	0.66	0.34
FG used to regen glycol	mscf/d	5.11	1.31	0.69
GHG Potentially emitted	tCO2eq/yr	2725	700	365
GHG Potential emission savings	tCO2eq/yr	n/a	2025	2360
Economics				
Cost to Implement	$	n/a	5000	5000
Savings	$/yr	n/a	$ 11,501	$ 13,400
Simple Payout	months	n/a	5	4
Recommendation				
Based on the evaluation above, there is an opportunity to reduce the glycol pump by 1 or 2 sizes. The option with the most flexibility is changing to a 9020PV as this gives room for throughput increases if an adjacent facility goes down and There will also be associated benzene emission reductions.This will optimize the glycol flow rate at the facility, reducing greenhouse gas emissions in half.the gas is routed to this station.				

Figure 9: Glycol Circulation Estimator Tool preview: Glycol (TEG) Rate Optimization tab

Table 13 shows a comparison of wet gas water content, optimal circulation rate, potential savings, and GHG emission reduction calculated using a commercial process simulator (Aspen HYSYS) and the spreadsheet developed in this project. The table shows that wet gas water content and optimal circulation rate values are within 30% of the rigorous calculation, which provides a reasonable estimation of dehydrator performance. Based on potential savings and GHG emission reduction “Dehy 1” (Cramersburg 13-18) is the best candidate for pump replacement.

Table 13: HYSYS Calculation and Glycol Rate Optimization Spreadsheet Calculator

	Wet Gas Water Content (lbH2O/MMSCF)		Optimal Circulation Rate (USGPM)		Potential Saving ($/y)		GHG Emissions Reduction (tonnes CO_2eq/y)	
	Process Simulation	Spreadsheet	Process Simulation	Spreadsheet	Process Simulation	Spreadsheet	Process Simulation	Spreadsheet
Dehy 1	24.4	31.9	0.17	0.24	13,410	13,400	2,226	2,360
Dehy 2	23.5	30.7	0.17	0.22	2,538	2,100	212	380
Dehy 3	37.9	48.2	0.17	0.22	5,916	5,900	990	1,050

It is important to emphasise that the GCE Tool is not intended to replace the use of a rigorous process simulator; it provides the user with a quick assessment of dehydrator pump replacement candidates. An initial assessment can be done using the GCE Tool to identify the candidates, and using a commercial process simulator, more accurate studies can then be carried out.

10 Conclusions and Recommendations

Based on the foregoing analysis, the key conclusions are summarized below.

Hanna 4-29 Compressor Station:

- overcirculating TEG by a factor of 3.0 times the ideal circulation rate determined in this study.
- currently using stripping gas when the process simulation shows that is not required. However, stripping gas will be required when the gas temperature to the contactor is higher than 36.5 °C.
- If pump is replaced at this facility, it can be operated with a lower TEG circulation rate of 0.37 USGPM and the stripping gas eliminated. This will produce approximately 80% reduction in fuel gas use and 84% reduction in GHG emissions.
- This unit is a candidate for pump replacement (e.g., 1715PV/1720PV).

It is noted that based on these recommendations, the pump at Hanna 4-29 was successfully replaced on March 2, 2016. Details of the pump changeover are detailed in ***Section 5.7: Glycol Pump Replacement***.

Pouce Coupe 13-13 Compressor Station:

- overcirculating TEG by a factor of 2.27 times the ideal circulation rate determined in this study.
- not currently using stripping gas which is not required at current circulation rate. However, it will be necessary to use stripping gas if the unit is operated at the “ideal circulation rate”.
- can be operated with a lower TEG circulation rate of 0.6 USGPM with no stripping gas providing 20% reduction in fuel gas use, 22% reduction in GHG emissions, and 15% reduction in Benzene emissions. For this option, the circulation rate can be reduced with the current pump.
- Alternatively, it can be also be operated at 0.34 USG and 0.15 SFCM providing 51% reduction in fuel gas use, 51% reduction in GHG emissions, and 62% reduction in Benzene emissions. For this option, which is not recommended, the pump would need to be replaced.
- Modest potential savings are achievable without pump replacement.

Sun Valley 2-13 Compressors Station:

- overcirculating TEG by a factor of 6.95 times the ideal circulation rate determined in this study.
- currently using stripping gas when the process simulation shows that is not required. Stripping gas will be only required when the contactor temperature is higher than 33.0 °C.
- If the pump is replaced at this facility, it can be operated with a lower TEG circulation rate of 0.17 USGPM and the stripping gas eliminated. This will produce approximately 88% reduction in fuel gas use, and 90% reduction in GHG emissions.
- pump replacement would be required for this option (e.g., 1715PV/1720PV). However, there would still be significant benefit with a reduction in circulation rate to 0.45 USGPM.

Stage 2 Analysis:

Following completion of the initial stage, a similar review for three additional facilities was completed. This study was based on rigorous calculations supported by process simulation.

- Cramersburg 13-18 Compressor: Estimated to be overcirculating glycol by 90%, with an optimal TEG circulation rate of 0.17 USGPM. Potential GHG Emissions reduction is 2,226 tonnes CO_2eq/y, with potential savings of $13,410/y.
- Lacadena 04-10 North Compressor: Estimated to be overcirculating glycol by 64%, with an optimal TEG circulation rate of 0.17 USGPM. Potential GHG Emissions reduction is 212 tonnes CO_2eq/y, with potential savings of $2,538/y.
- Miry Bay 16-24 Compressor: Estimated to be overcirculating glycol by 81%, with an optimal TEG circulation rate of 0.17 USGPM. Potential GHG Emissions reduction is 990 tonnes CO_2eq/y, with potential savings of $5,916/y.

Glycol Circulation Estimator (GCE) Tool Spreadsheet:

A spreadsheet-based GCE Tool was developed to quickly assess energy and GHG Emission optimization opportunities for TEG dehydrators, without the need to run more complex simulation models. The GCE Tool is described in this report and provided with the project deliverables.

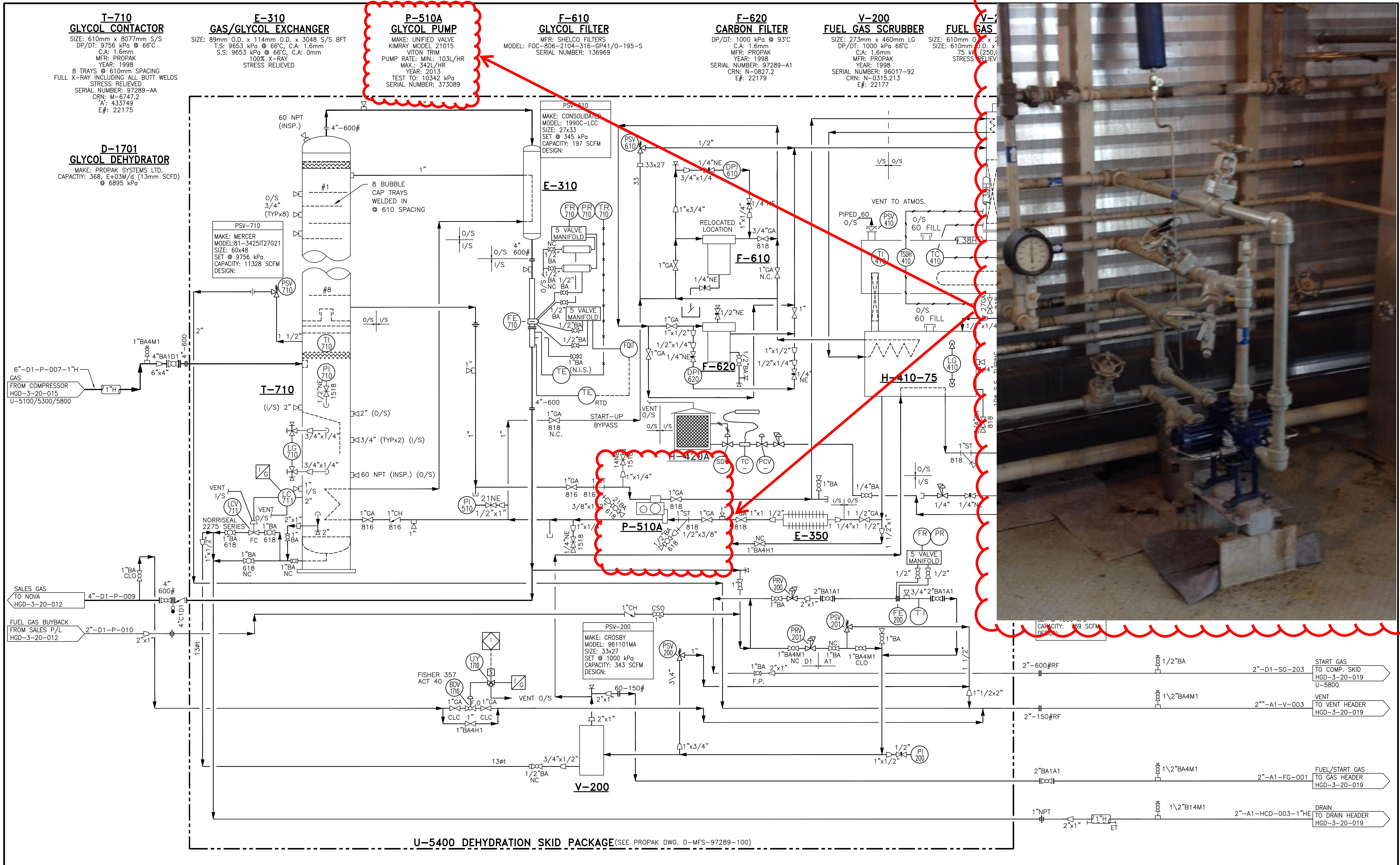
Economics, GHG Reduction and Abatement Cost:

Potential savings and GHG Reduction for each location is outlined in this report. The Hanna 4-29 pump replacement cost was approximately $6,300. This is consistent with the findings of the CCEMC / ConocoPhillips GHG reduction workshop (refer to Section 3.1), which budgeted roughly $8,000 for pump replacement projects. For expected annual savings of $10,000, a Kimray pump replacement project should pay out in less than 1 year.

Potential GHG reductions vary significantly, depending primarily on the amount of glycol overcirculation, as well as stripping gas use. In this project, the GHG reductions varied from 100-2400 tonnes CO_2eq/y, with an average of 1300 tonnes CO_2eq/y.

The abatement potential for 1 year (based on an average of 1300 tonnes CO_2eq/y, and $6300 budget) is calculated to be $5 per tonnes CO_2eq/y. For the CCEMC ConocoPhillips GHG reduction workshop, the abatement potential was found to be closer to $23 per tonne CO_2eq/y, due to the smaller average GHG reduction for each opportunity.

Appendix A: Notated Piping & Instrumentation Diagram



DWG. NO.	DESCRIPTION	REV	DESCRIPTION	DATE	BY	APRD
		5	AS-BUILT	01/05/24	DMM	
		6	AS-BUILT (STANTEC PROJECT #110616903)	14/05/02	MO	
		C	FOR BOILERS BRANCH APPROVAL	98/02/27	BD	CS
		0	ISSUED FOR CONTRUCTION	98/03/09	RN	CS
		1	REVISED AS-BUILT	98/04/30	BD	CS
		2	ISSUED FOR REFERENCE (1998 GULF COMP. ADDITION)	98/07/13	BY	CS
		3	FOR BOILERS BRANCH APPROVAL	98/07/07	BD	CS
		4	ISSUED FOR CONSTRUCTION (GLE JOB#01038)	01/03/16	CW	JMR

REFERENCE DRAWINGS — REVISIONS

DRN BY: R. NG — DATE: 98/01/02
CHKD BY: E. ABAD — DATE: 98/02/03
APVD BY: C. STANG — DATE: 98/02/24

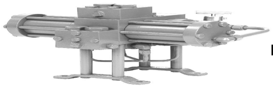
enerPLUS

HANNA GARDENS 04-29 COMPR. STN. 2014 AS-BUILT
LSD 04-29-032-14 W4M
04-29 DEHYDRATION SKID AREA P & I D

Stantec

SCALE: NONE | E+ PROJECT No: 1400060 | DWG Size: A1 | DRAWING No: HGD-3-20-018 | REV: 6

Appendix B: Kimray Pump Specifications



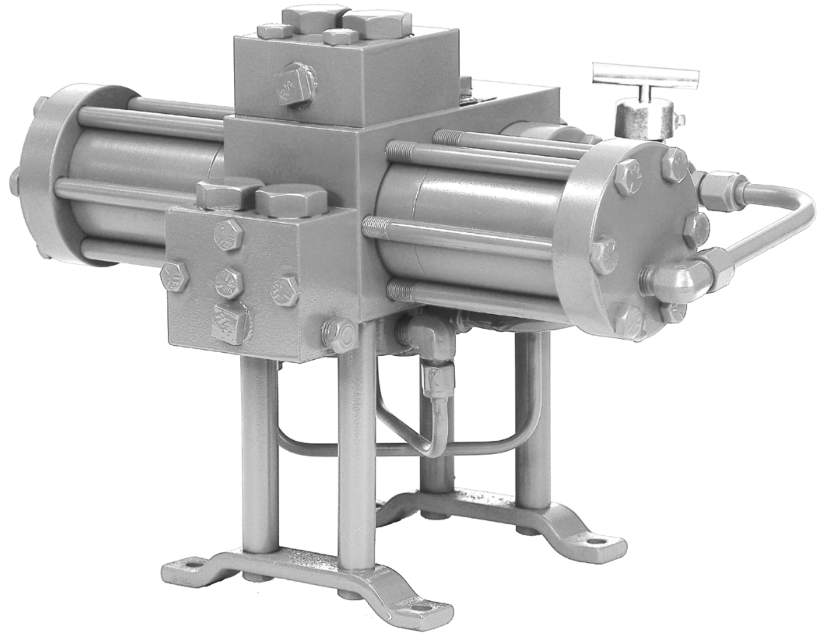
Glycol Pumps

Models PV, SC

Product Bulletin

PB0004

July 2011



Glycol Pump

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NOTE

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Kimray reserves the right to modify or improve the designs or specifications of such products at any time without prior notice.

Introduction

The Glycol Pump utilizes the energy of wet glycol at absorber pressure as a source of power to circulate the glycol in a gas dehydrator. The pump transfers the energy available from the wet glycol, at absorber pressure, to an "equivalent" volume of dry glycol at reboiler pressure. In order to circulate the glycol, additional energy is needed to overcome friction losses within the pump and connecting piping. This additional energy is supplied by gas at absorber pressure.

Summary:	
Pump Description	Energy Exchange
Normal Service	Glycol
Connection Size:	See table 4, page 6
Connection Type:	NPT
Operating Range:	300 - 2000 psi for PV 100 - 500 psi for SC
Temperature:	Standard -30º to 200º

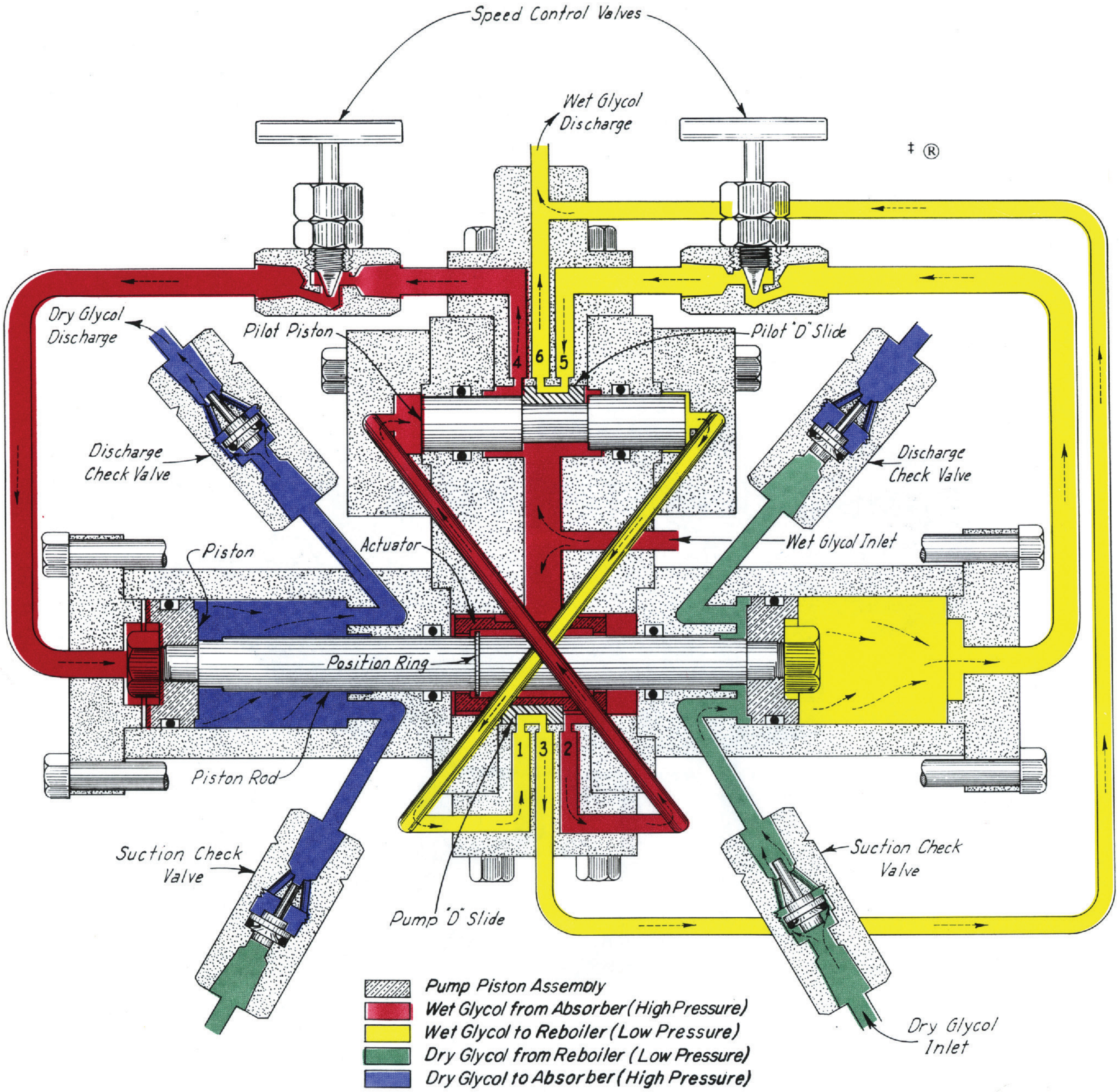


Figure 1

Principles of Operation

The Kimray glycol pump is double acting, powered by wet glycol and a small quantity of gas at absorber pressure (Red). Yellow denotes wet glycol (Blue) is being pumped to the absorber. Green is dry glycol suction from the reboiler.

Wet glycol (Red) from the absorber flows through port #4 and of the pump piston assembly, moving this assembly from left to right. Dry glycol (Blue) is being pumped from the left cylinder to the absorber while the right cylinder is being filled with dry glycol (Green) from the reboiler.

At the same time wet glycol (Yellow) is discharging from the right end of the pump piston assembly to a low pressure or atmospheric system. As the pump piston assembly nears the end of its stroke, the position ring on the piston rod contacts the right end of the actuator. Further movement to the right moves the actuator and pump "D" slide to uncover port number one and communicate ports two and three. This exhausts wet glycol (Red) to the right end of the pilot position. this causes the pilot piston and pilot "D" slide to be driven from right to left.

In it's new position, the pilot "D"slide uncovers port number five and communicate ports number four and six. This exhausts wet glycol (Red) from the left end of the pump piston assembly through ports four and six to the low pressure wet glycol (Yellow) system. Ports number 5 (which was communicated with port number 6) now admits wet glycol (Red) through the right hand speed control valve to the right end of the pump piston assembly. The pump piston assmbly now starst the stroke from right to left. Follow above procedure reversing directions of flow.

Actions of each of the two basic pumps are completely dependent upon the other. The pilor "D" slide actuated by the pilot piston alternately feeds, and exhausts absorber pressure to the power cylinders at opposite ends of the piston rod assembly. Likewise, the pump "D" slide actuated by the piston rod assembly alternately feeds and exhausts absorber pressure to opposite ends of the pilot piston.

The force to circulate glycol within the dehydration system is supplied by absorber pressure acting on the area of the piston rod at its o-ring seals. The area of the piston rod is approximately 20 percent of that of the pressure acting on the area of the piston. Neglecting pump frection and line losses, the resultant force is sufficient to produce a theoretical discharge pressure 25 percent greater than absorber pressure. The theoretical discharge pressure, for example, at 1500 psig absorber pressure would be 1875 psig. This theoretical "over-pressure" would develop against a block discharge line but is not sufficient to cause damage or create a hazzard.

Approximately 25 to 30 psig pressure is required to overcome pump friction leaving the additional "over pressure" for the losses and circulation. It is recommended that these losses be held to approximately 10 percent of the absorber pressure or as noted in catalog.

Two speed control values are provided to regulate the flow of wet glycol and gas to and from the power cylinders. Reversing the direction of flow through the speed control valves provides a flushing action which cleans the valve orfices.

If the wet glycol, returning to the pump from the absorber were to be completely fill the cylinder, no additional gas would be needed. However, the wet glycol will only occupy approximately 65 percent of the total volume of the cylinder and connecting tubing leaving 35 percent to be filled by gas from the absorber. This gas volume amounts to 1.7S.C.F. per gallon of dry glycol at 300 psig absorber pressure and 8.3S.C.F. at 1500 psig and may be considered as continuing power cost for pump operation. This gas can be utilized in the regeneration process of the dehydrator for "rolling" and "stripping" purposes. It may also be recovered in a low pressure glycol gas separator and used to fire the reboiler.

By supplying some absorber gas to the cylinders, the wet glycol level is maintained at the wet glycol outlet connection on the absorber and eliminates the need of a liquid level controller and its attendant problems.

Excess liquids such as hydrocarbons are removed from the absorber at approximately 55 percent of the pump rate, reducing the hazard of dumping a large volume of hydrocarbons into the reboiler as would be the case with a liquid level controller.

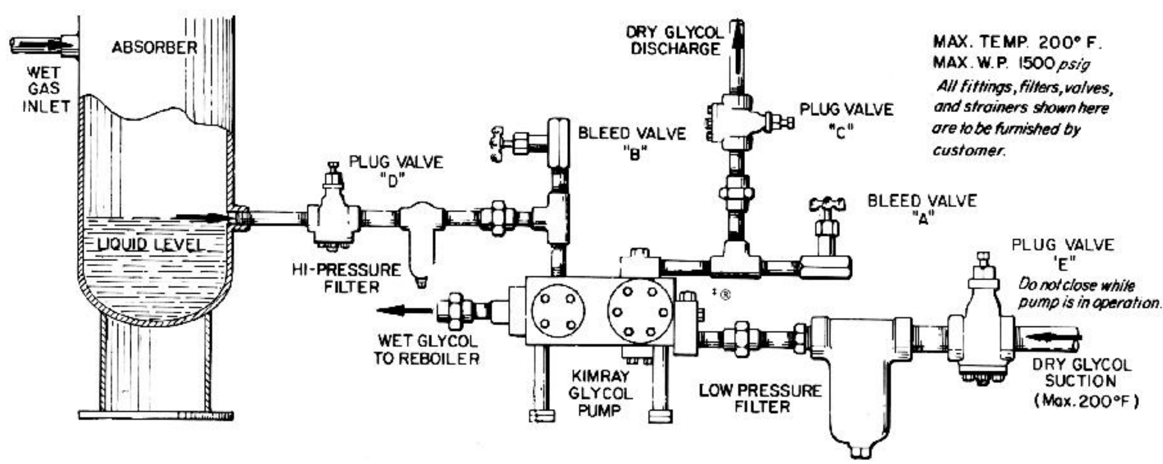


Figure 2

SYSTEM SHUTDOWN

1. Close plug valve "D" Allow pump to stop running.
2. Close plug valve "C" and "E".
3. Bleed pressure from bleed valve "A" and "B".

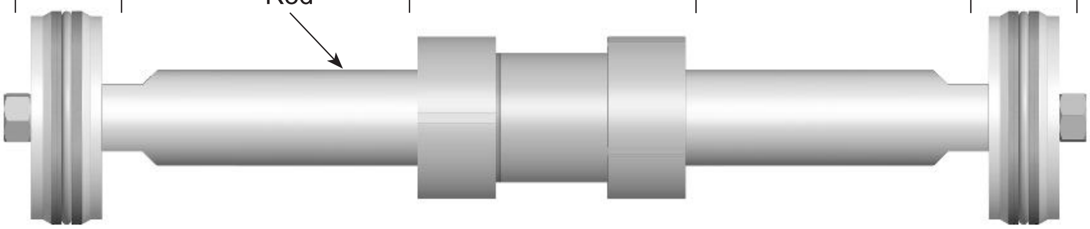


Figure 3

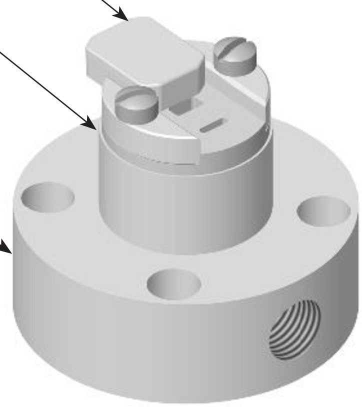
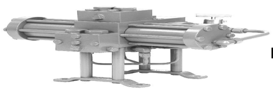


Figure 4

Table 1 - PV & SC Series Glycol Pumps						
Model Number	Capacity Gal. / Hr. (Liters / Hr.)		Rate Strokes / Minutes		Operating Pressure psig (bar)	
	Min.	Max.	Min.	Max.	Min.	Max.
1720PV	8 (30.3)	40 (151)	12	40	300 (20.6)	2000 (137)
4020PV	12 (45.4)	40 (151)	12	40	300 (20.6)	2000 (137)
9020PV	27 (102)	90 (340)	12	40	300 (20.6)	2000 (137)
21020PV	66 (250)	210 (795)	10	32	400 (27.5)	2000 (137)
45020PV	166 (628)	450 (1700)	10	28	400 (27.5)	2000 (137)
2015SC	8 (30.3)	20 (75.7)	5	55	100 (8.9)	500 (34.4)
5015SC	12 (45.4)	50 (189)	10	50	100 (8.9)	500 (34.4)
10015SC	22 (83.3)	100 (379)	10	48	100 (8.9)	500 (34.4)
20015SC	60 (227)	200 (757)	10	40	100 (8.9)	500 (34.4)

Maximum design pressure for P.V. is 2000 psig and S.C. Model is 1500 psig.



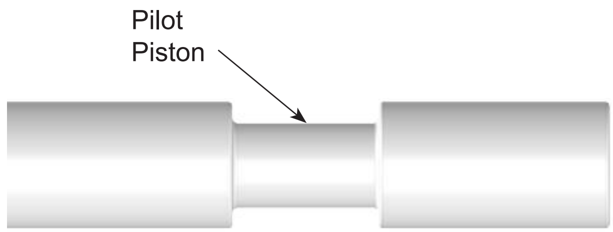


Figure 5

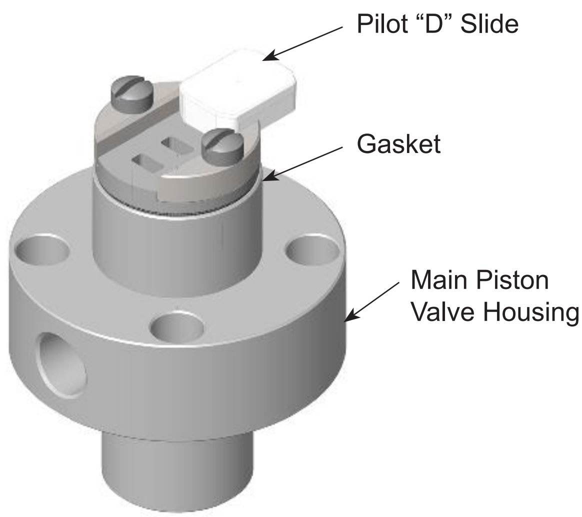


Figure 6

Table 2 - Pressure Rating		
Pressure Volume PV & SC Pump		
Type	**Max. Gallons Per Hour**	**Operating Pressure**
1720 PV	40	300 to 2000 psig Max
4020 PV	40	300 to 2000 psig Max.
9020 PV	90	300 to 2000 psig Max.
21020 PV	210	400 to 2000 psig Max.
45020 PV	450	400 to 2000 psig Max.
2015 SC	20	100 to 500 psig Max
5015 SC	50	100 to 500 psig Max
10015 SC	100	100 to 500 psig Max
20015 SC	200	100 to 500 psig Max

Circulating pump for gas glycol dehydrators.
Circulating pump for gas amine desulphurizers.

Pump **PV** Working pressure of **300** - **2000 psig**.
Pump **SC** Working pressure of **100** - **500 psig**

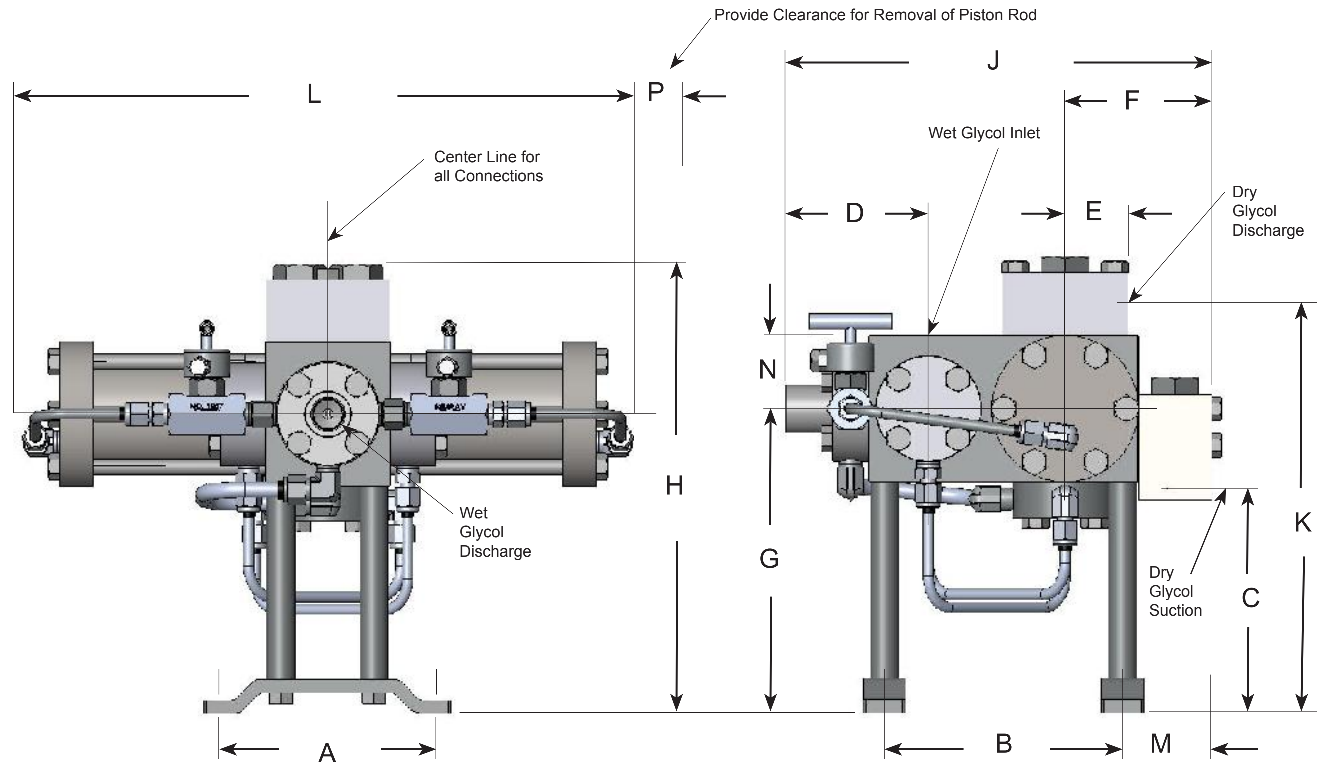


Figure 7

Table 3 - Glycol Pump Dimensions														
Model PV, SC	A	B	C	D	E	F	G	H	J	K	L	M	N	P
1720 PV	5 1/4 in. (133 mm)	5 11/16 in. (144 mm)	5 3/4 in. (146 mm)	5 7/16 in. (87 mm)	1 1/2 in. (38 mm)	3 1/2 in. (88 mm)	7 1/4 in. (184 mm)	10 7/8 in. (276 mm)	10 3/16 in. (258 mm)	9 5/8 in. (244 mm)	15 in. (381 mm)	2 1/8 in. (53 mm)	1 3/4 in. (44 mm)	3 in. (76 mm)
4020 PV & 2015 SC	5 1/4 in. (133 mm)	5 11/16 in. (144 mm)	5 3/4 in. (146 mm)	5 7/16 in. (87 mm)	1 1/2 in. (38 mm)	3 1/2 in. (88 mm)	7 1/4 in. (184 mm)	10 7/8 in. (276 mm)	10 3/16 in. (258 mm)	9 5/8 in. (244 mm)	15 in. (381 mm)	2 1/8 in. (53 mm)	1 3/4 in. (44 mm)	3 in. (76 mm)
9020 PV & 5015 SC	6 1/4 in. (158 mm)	5 11/16 in. (144 mm)	6 3/8 in. (161 mm)	5 in. (127 mm)	1 3/4 in. (44 mm)	4 1/4 in. (107 mm)	8 3/4 in. (222 mm)	13 1/4 in. (336 mm)	13 7/8 in. (352 mm)	11 3/4 in. (289 mm)	20 in. (508 mm)	2 1/2 in. (63 mm)	2 in. (50 mm)	3 in. (76 mm)
21020 PV & 10015 SC	7 5/8 in. (193 mm)	10 1/8 ± 1/8 (257 mm)	7 in. (177 mm)	5 3/8 in. (136 mm)	2 1/4 in. (57 mm)	5 3/4 in. (146 mm)	9 1/4 in. (234 mm)	14 3/4 in. (374 mm)	16 5/8 in. (422 mm)	13 in. (330 mm)	24 in. (508 mm)	3 3/16 in. (80 mm)	2 1/2 in. (63 mm)	4 in. (101 mm)
45020 PV & 20015 SC	10 3/4 in. (273 mm)	14 ± 1/8 (355 mm)	9 in. (228 mm)	6 5/8 in. (168 mm)	2 5/8 in. (66 mm)	6 1/2 in. (165 mm)	11 3/8 in. (288 mm)	19 in. (482 mm)	21 1/8 in. (536 mm)	16 3/8 in. (415 mm)	34 in. (863 mm)	3 3/4 in. (95 mm)	3 1/2 in. (88 mm)	6 in. (152 mm)

Table 4 - Glycol Pump Specifications								
Model Number	Max. Cap		Size of Pipe Connections	Mounting Bolts	Approx. Weight	Max. Strokes Per Minute	Glycol Output Strokes / Gal.	Glycol Output Gal. / Strokes
	G.P.M	G.P.H						
1720 PV	.67	40	1/2 in NPT (12 mm)	3/8 in. dia (9.42 mm)	66 lbs (29.93 kg)	40	59	0.017
4020 PV	.67	40	1/2 in NPT (12 mm)	3/8 in. dia (9.42 mm)	66 lbs (29.93 kg)	40	59	0.017
9020 PV	1.5	90	3/4 in NPT (19 mm)	1/2 in. dia (12 mm)	119 lbs (53.97 kg)	40	26.3	0.038
21020 PV	3.5	210	1 in NPT (25 mm)	1/2 in. dia (12 mm)	215 lbs (97.52 kg)	32	9	0.111
45020 PV	7.5	450	1 1/2 in NPT (38 mm)	1/2 in. dia (12 mm)	500 lbs (22.68 kg)	28	3.5	0.283
2015 SC	.33	20	1/2 in NPT (12 mm)	3/8 in. dia (9.52 mm)	66 lbs (29.93 kg)	55	147	0.0068
5015 SC	.83	50	3/4 in NPT (19 mm)	1/2 in. dia (12 mm)	119 lbs (53.97 kg)	50	52	0.019
10015 SC	1.67	100	1 in NPT (25 mm)	1/2 in. dia (12 mm)	215 lbs (97.52 kg)	48	25	0.040
20015 SC	3.33	200	1 1/2 in NPT (38 mm)	1/2 in. dia (12 mm)	500 lbs (22.68 kg)	40	8.8	0.114

Table 5 - Materials of Construction		
Valve Components	**Standard**	**Optional**
Body	Ductile, ASTM A395	
Suction Block	Ductile, ASTM A395	
Discharge Block	Ductile, ASTM A395	
Main Valve Housing	Steel	
Pilot Valve Housing	Steel	
Port Plates	Stellite 3	
Cylinder Heads	Ductile, ASTM A395	
Pilot Piston Caps	Ductile, ASTM A395	
Cylinders	Stainless Steel	
Pistons	Steel	
Pilot Pistons	17-4 PH Stainless Steel	
Piston Rod	17.4 PH Stainless Steel	
Piston Rod Glands	Ductile, ASTM A395	
Fittings	Steel	SS6
Tubing	304 Stainless Steel	SS6
O-Rings	Nitrile	Viton®, Aflas®, HSN
Backups	Glass Filled Teflon	

Table 6 - Parts Required to Convert From PV to SC Series					
Part Name	**Quantity Required**	**4020 PV to 2015 SC**	**9020 PV to 10015 SC**	**21020 PV to 10015 SC**	**45020 PV to 20015 SC**
Cylinder Liner	2	2108	2373	2412	ǂ1505
Piston	2	1506	776	1507	1508
Piston Seal Retainer	2	1509	1510	1511	1512
Piston “O” Ring	2	156	773	774	329
Back-up Ring	4	1513	1457	1458	772
“O” Ring	2	154	154	155	1107
Lock Nut (Piston)	2	*_	906	175	1140
Cylinder “O” Ring	2	773	774	329	

* The piston is the nut for this model and is furnished with a socket head set screw.
ǂFull cylinder only.
ǂModel 20015 SC only, requires 8, No. 772 Back-up rings.

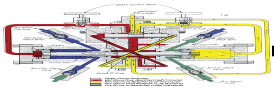


Table 7 - Elastomer Options		
Part	**Standard Material**	**Optional Material**
O-Rings	Buna	Viton®, Aflas®, HSN

Table 8 - Elastomer Specifications

		ELASTOMERS							
		AFLAS	ETHYLENE PROPYLENE	VITON	HIGHLY SATURATED NITRILE	BUNA-N	LOW TEMP. BUNA-N	POLY-ACRY-LATE	GEO-THERMAL EPDM
	Kimray Suffix	AF	EP	V	HSN	-	LTN	H	GEP
Resistance	Abrasion	GE	GE	G	G	G	G	G	GE
Resistance	Acid	E	G	E	E	F	F	P	G
Resistance	Chemical	E	E	E	FG	FG	FG	P	E
Resistance	Cold	P	GE	PF	G	G	E	P	GE
Resistance	Flame	E	P	E	P	P	P	P	P
Resistance	Heat	E	G	E	E	G	G	E	E
Resistance	Oil	E	P	E	E	E	E	E	F
Resistance	Ozone	E	E	E	G	P	P	E	E
Resistance	Set	PF	GE	E	GE	GE	GE	F	GE
Resistance	Tear	PF	GE	F	FG	FG	FG	FG	GE
Resistance	Water/Steam	GE	E	P	E	FG	FG	P	E
Resistance	Weather	E	E	E	G	F	F	E	E
Resistance	CO2	GE	GE	PG	GE	FG	FG	P	GE
Resistance	H2S	E	P	P	FG	P	P	P	F
Resistance	Methanol	PF	G	PF	P	P	P	P	G
Properties	Dynamic	GE	GE	GE	GE	GE	GE	F	GE
Properties	Electrical	E	E	F	F	F	F	F	E
Properties	Impermeability	G	G	G	G	G	G	E	G
Properties	Tensile Strength	FG	GE	GE	E	GE	GE	F	GE
Properties	Temp. Range (°F)	+30° to +500°F	-65° to +300°F	-10° to +350°F	-15° to +300°F	-30 to 200	-65 to 225	±0° to +300°F	0 to 500
Properties	Temp. Range (°C)	0° to +260°C	-54° to +148°C	-23° to +177°C	-26° to +149°C	-34 to 121	-53 to 107	-17° to 149°C	-17 to 260
Properties	Form	O	O	O	O	O	O	O	O

RATINGS: P-POOR, F-FAIR, G-GOOD, E-EXCELLENT

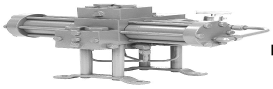


Table 9 - Glycol Pump Parameters

Pump	Bore	Rod Diameter	Stroke	Minimum Working Pressure	Maximum Working Pressure	Minimum Stroke / Minute	Maximum Stroke / Minute	Minimum Gallons / Hour	GPH Per Stroke / Minute	Glycol Output Stroke / Gallon.	Glycol Output Gallon / Stroke	Maximum Gallons / Hour
1720 PV	1.750 (44 mm)	.750 (19 mm)	2.000 (50 mm)	300 (20.6 bar)	2000 (137 bar)	8	40	8	1.00	59	0.017	40
4020 PV	1.750 (44 mm)	.750 (19 mm)	2.000 (50 mm)	300 (20.6 bar)	2000 (137 bar)	12	40	12	1.00	59	0.017	40
9020 PV	2.250 (57 mm)	1.000 (25.4 mm)	2.750 (69 mm)	300 (20.6 bar)	2000 (137 bar)	12	40	27	2.25	26.3	0.038	90
21020 PV	3.250 (82 mm)	1.375 (34 mm)	3.750 (95 mm)	400 (27.5 bar)	2000 (137 bar)	10	32	66	6.56	9	0.111	210
45020 PV	4.500 (114 mm)	2.000 (50 mm)	5.125 (130 mm)	400 (27.5 bar)	2000 (137 bar)	10	28	166	16.07	3.5	0.283	450
2015 SC	1.250 (31 mm)	.750 (19 mm)	2.000 (50 mm)	100 (6.89 bar)	500 (34.4 bar)	10	55	8	0.36	147	0.0068	20
5015 SC	1.750 (44 mm)	1.000 (25.4 mm)	2.750 (69 mm)	100 (6.89 bar)	500 (34.4 bar)	10	50	12	1.00	52	0.019	50
10015 SC	2.250 (57 mm)	1.375 (34 mm)	3.750 (95 mm)	100 (6.89 bar)	500 (34.4 bar)	10	48	22	2.08	25	0.040	100
20015 SC	3.250 (82 mm)	2.000 (50 mm)	5.125 (130 mm)	100 (6.89 bar)	500 (34.4 bar)	10	40	60	5.00	8.8	0.114	200

Circulation Rate Graph

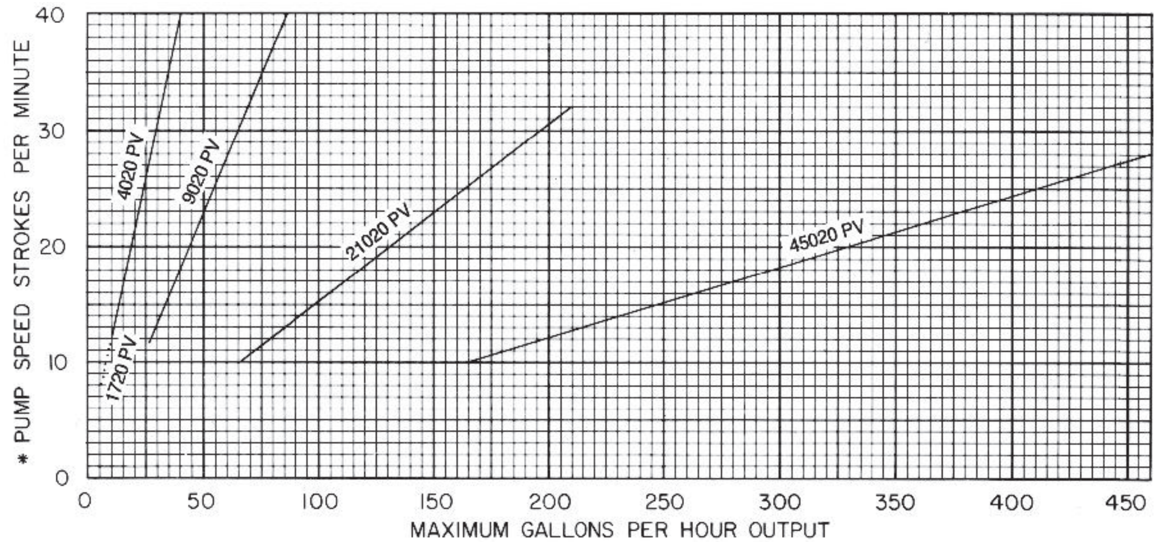


Figure 8

* It is not recommended to attempt to run pumps at speeds less than those indicated in the above graph.

Table 10 - PV Glycol Pumps													
Operating Pressure psig	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
Cut. Ft./Gallon @ 14.4 & 60˚F	1.7	2.3	2.8	3.4	3.9	4.5	5.0	5.6	6.7	6.7	7.2	7.9	8.3

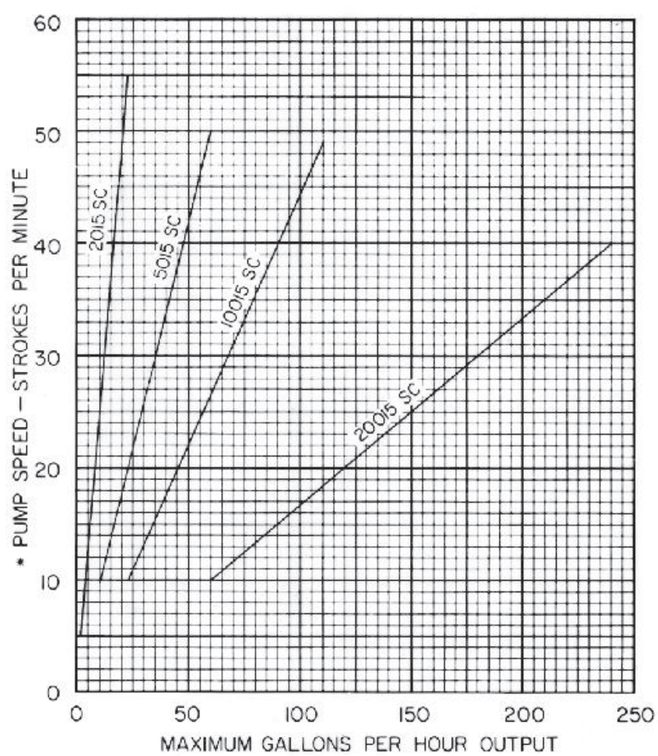
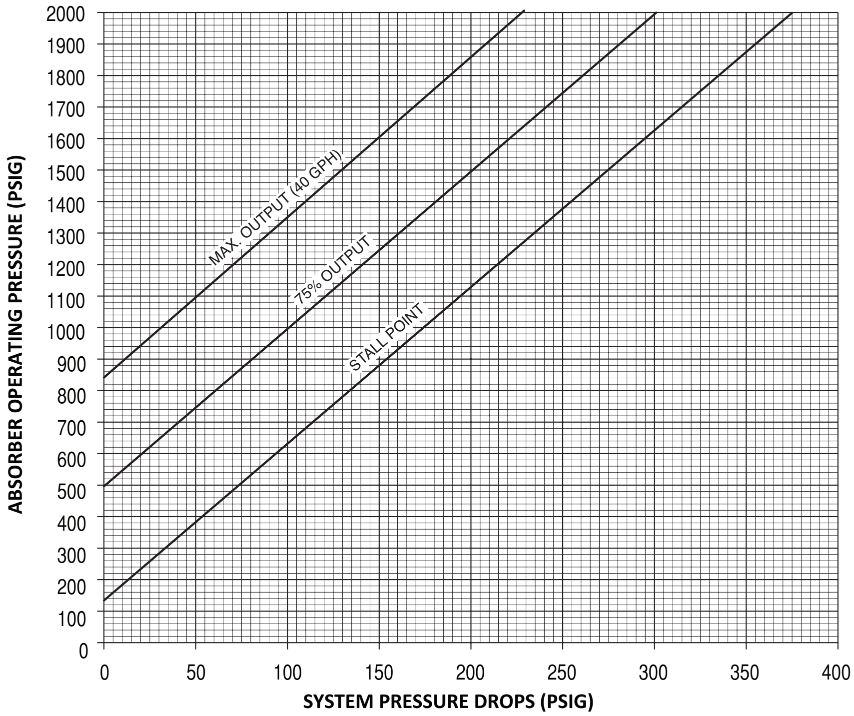


Figure 9

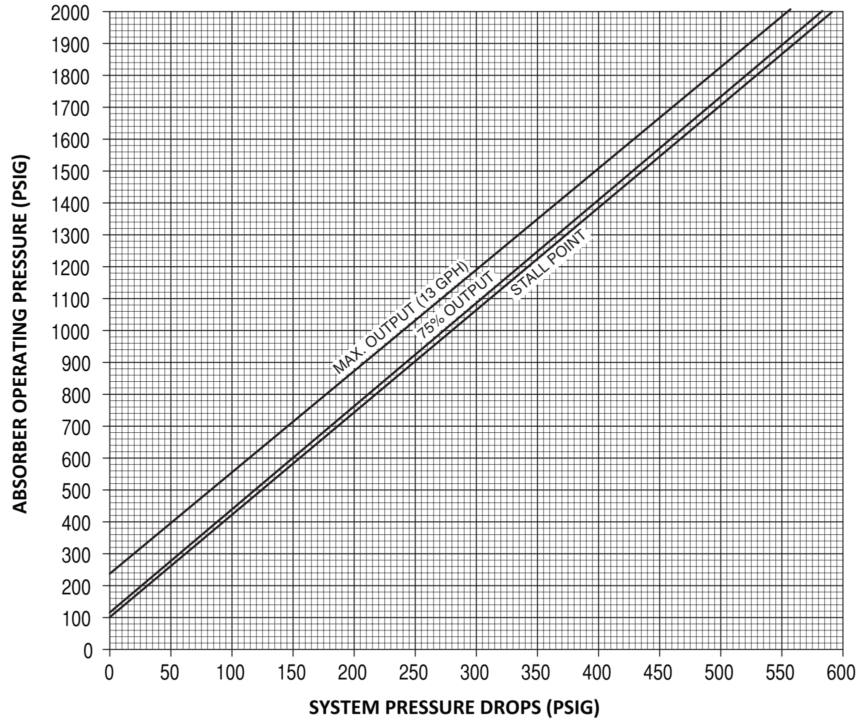
* It is not recommended to attempt to run pumps at speeds less than those indicated in the above graph..

Table 11 - PV Glycol Pumps				
Operating Pressure psig	100	200	300	400
Cut. Ft./Gallon @ 14.4 & 60˚F	1.7	2.3	2.8	3.4

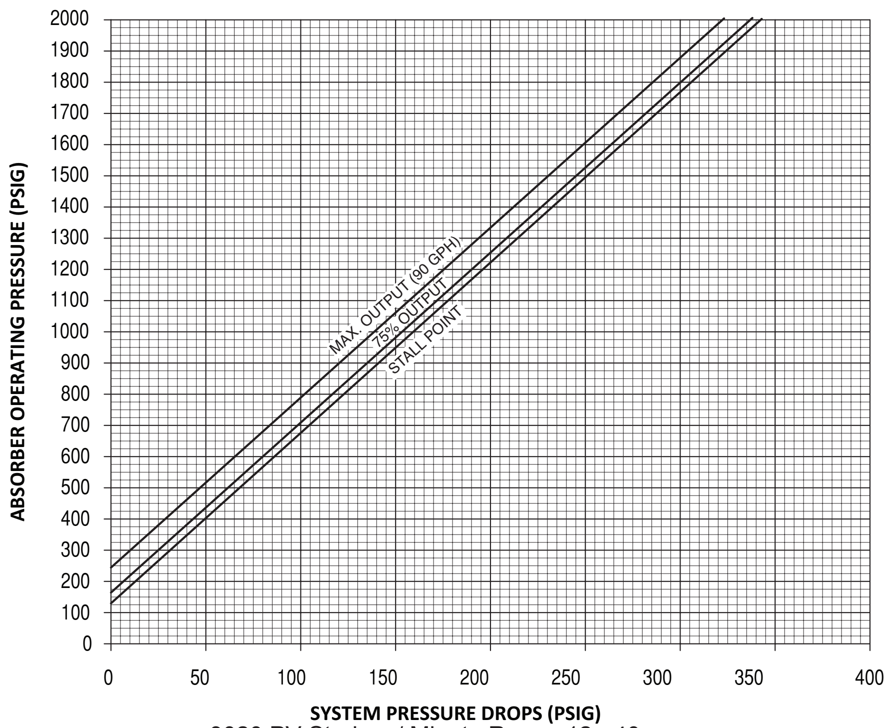


1720 PV Strokes / Minute Range 8 - 40

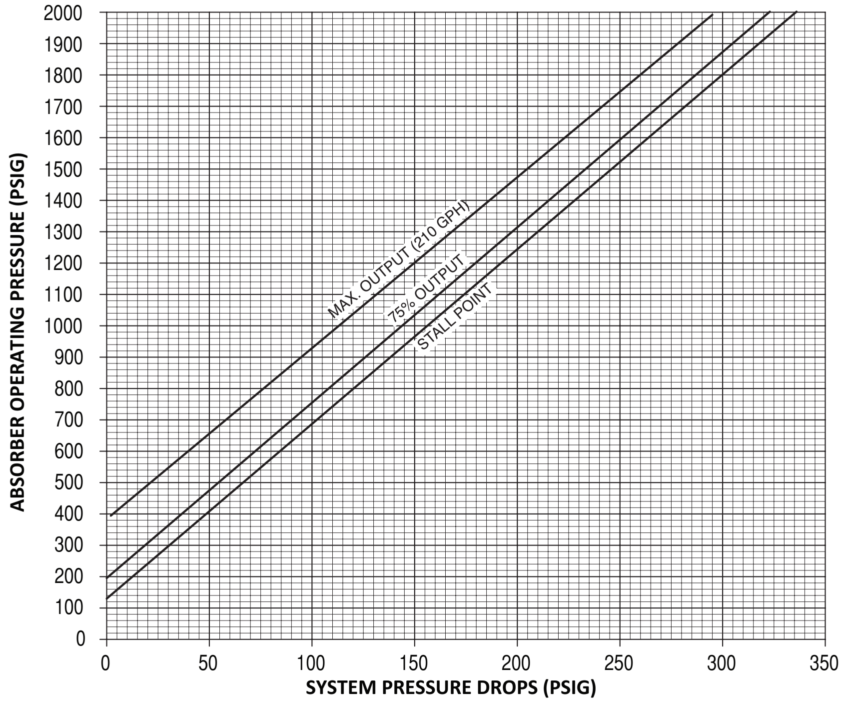
Figure 10



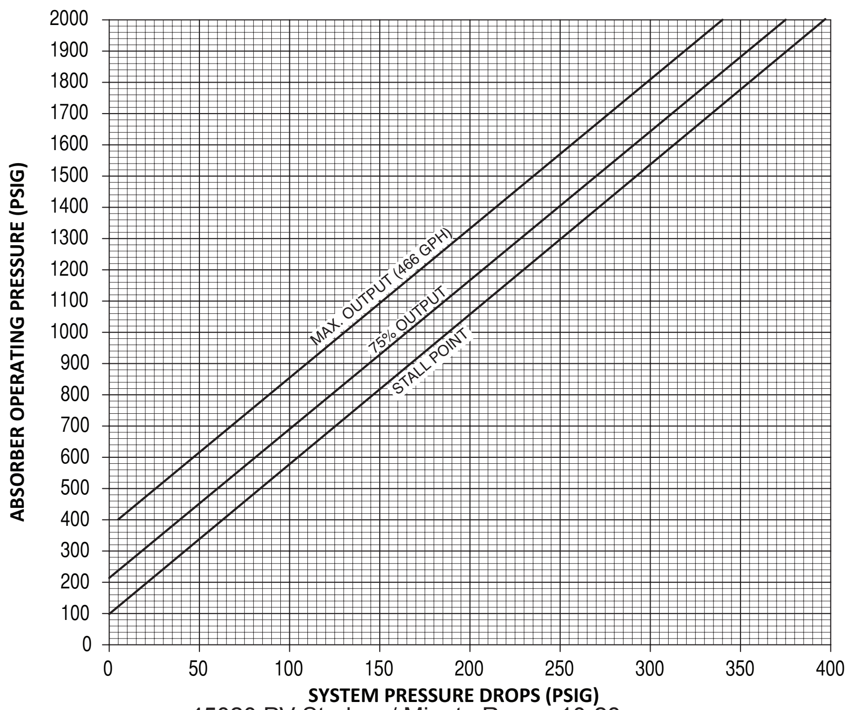
4020 PV Strokes / Minute Range 12 - 40
Figure 11



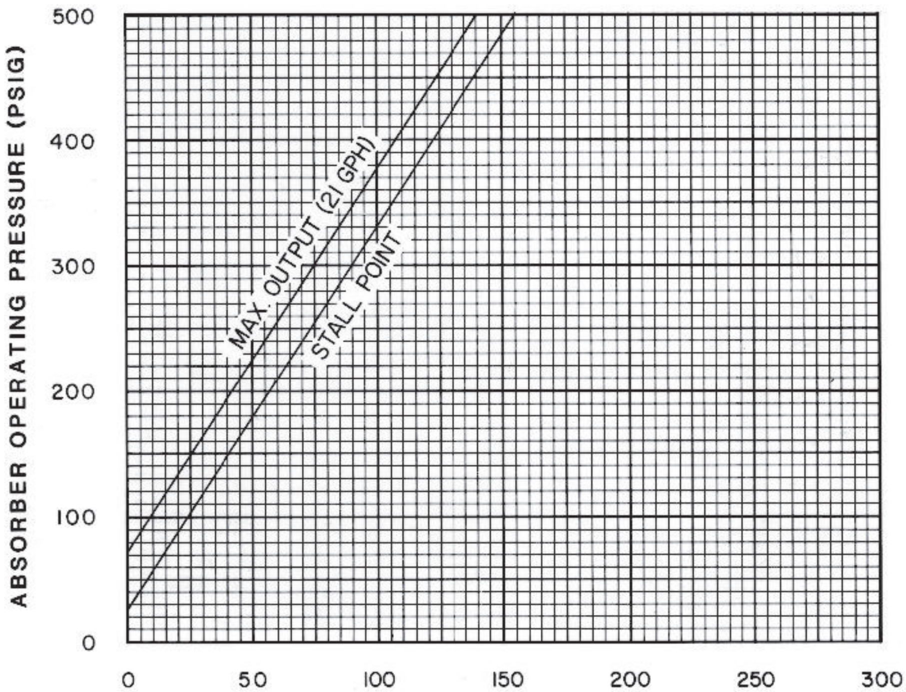
9020 PV Strokes / Minute Range 12 - 40
Figure 12



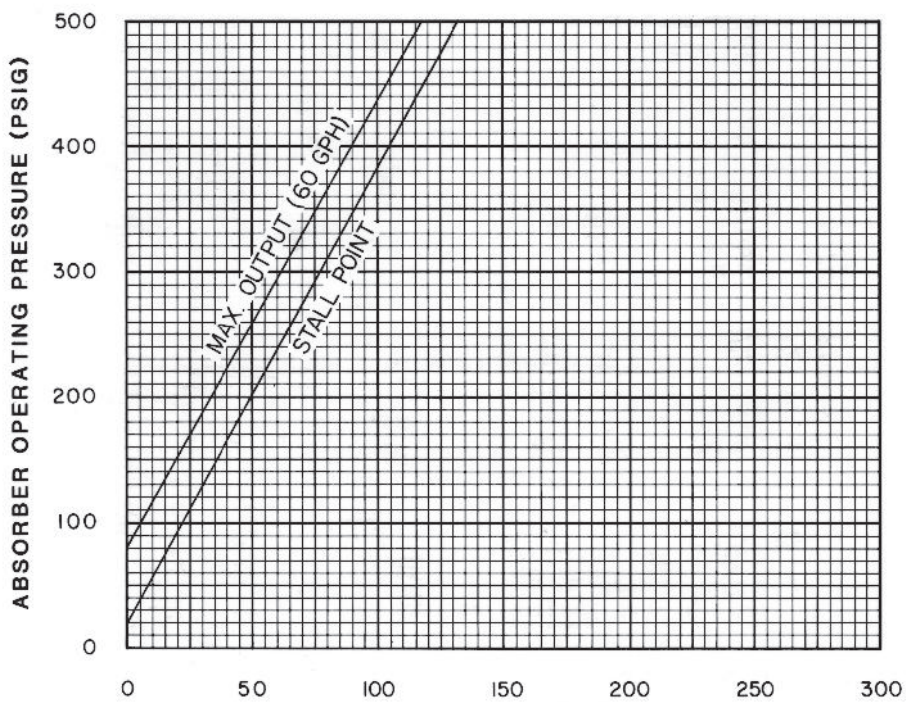
21020 PV Strokes / Minute Range 10-32
Figure 13



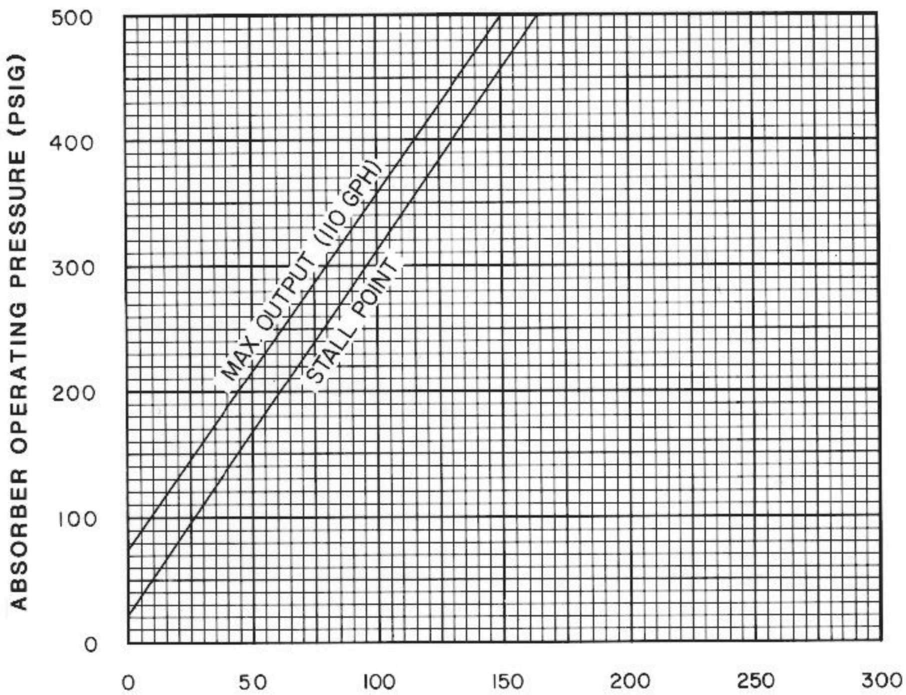
45020 PV Strokes / Minute Range 10-28
Figure 14



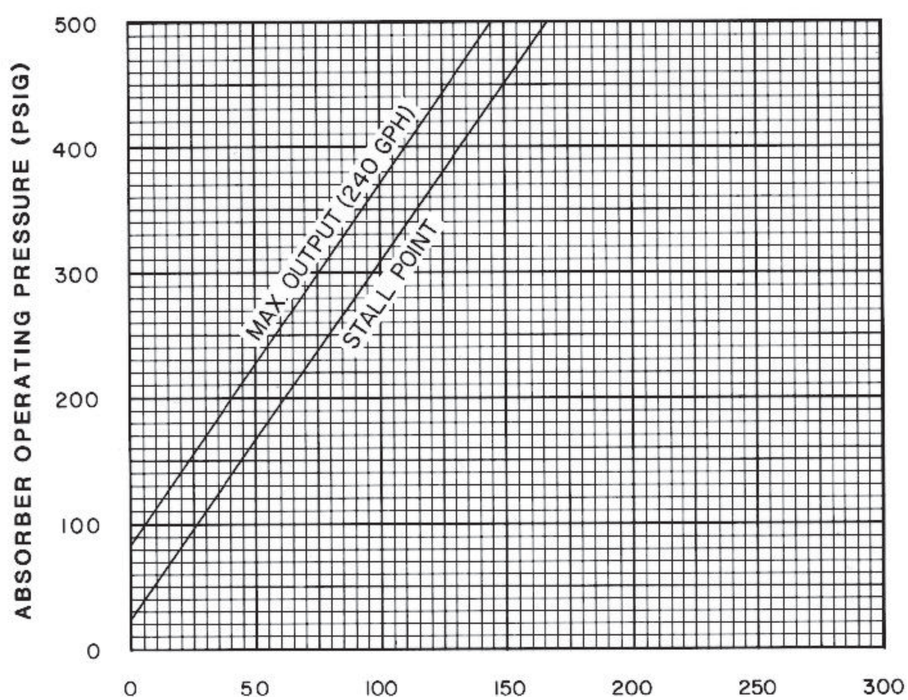
2015 SC Strokes / Minute Range 5-55
Figure 15



5015 SC Strokes / Minute Range 10-50
Figure 16



10015 SC Strokes / Minute Range 10-48
Figure 17



20015 SC Strokes / Minute Range 10-40
Figure 18

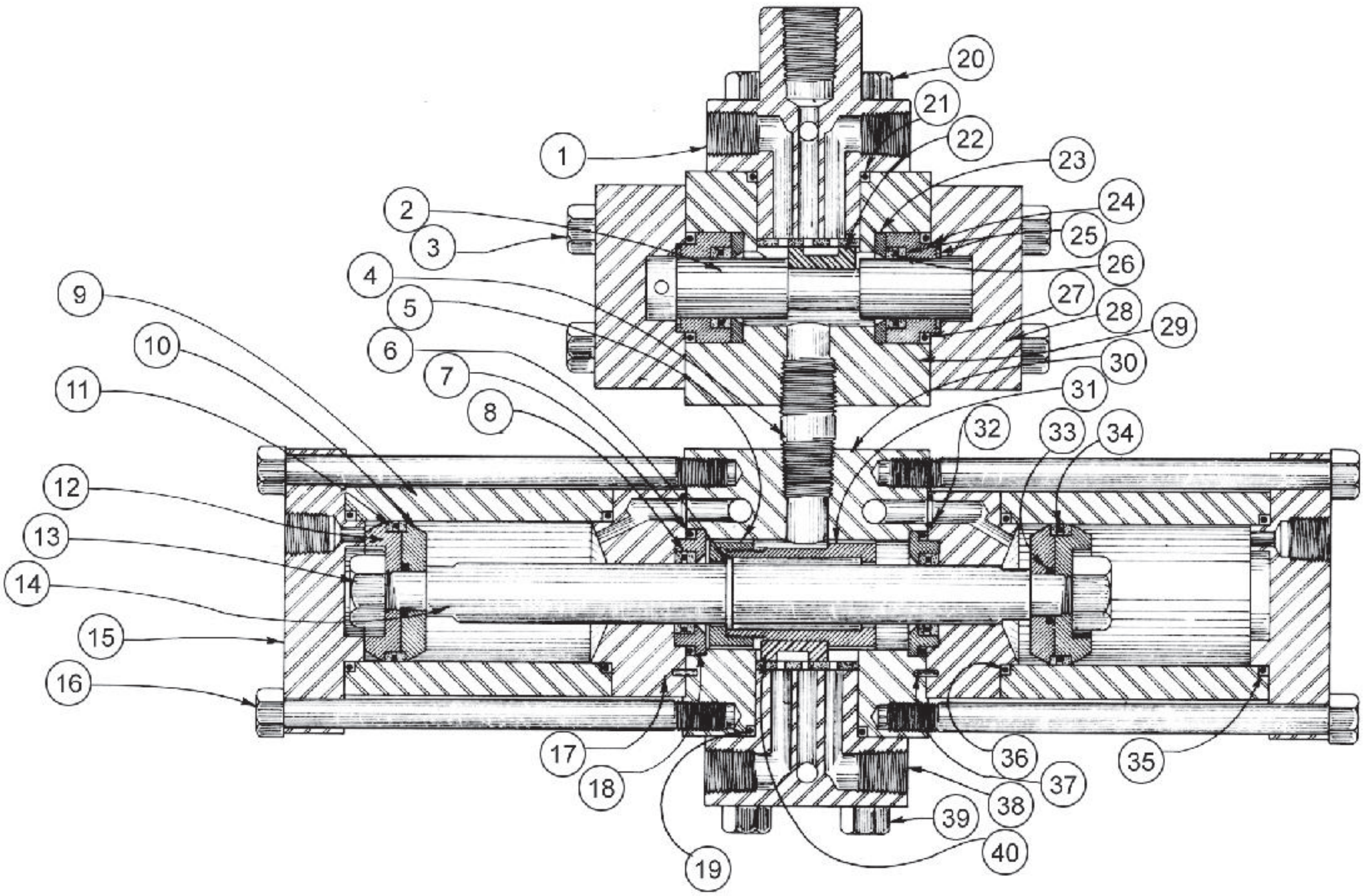


Figure 19

Key Description

1 Pilot Piston Valve Housing, Steel
2 Pilot Piston, Stainless Steel
3 Screw, Plated Steel
4 Nipple, Plated Steel
5 Actuator Cap, Steel
6 Snap Ring, Stainless Steel
7 O-Ring, Nitrile
8 O-Ring & Back Up, Nitrile & Teflon
9 Cylinder, PV - Stainless Steel
SC - Stainless Steel
10 Piston Seal Retainer, Steel
11 Back Up, Teflon
12 Piston, Steel
13 Nut, Plated Steel
14 Piston Rod, Stainless Steel
15 Cylinder Head, Ductile Iron
16 Screw, plated Steel
17 Piston Rod Gland, Ductile Iron
18 Piston Rod Seal Retainer, Steel
19 O-Ring, Nitrile
20 Screw, Plated Steel
21 O-Ring, Nitrile
22 “D” Slide, Nylon
23 Pilot Piston Seal Retainer, Steel
24 Pilot Piston Bearing, Steel
25 Back Up, Teflon
26 O-Ring, Nitrile
27 O-Ring, Nitrile
28 Pilot Piston Cap, Ductile Iron
29 Body (Pilot Piston), Ductile Iron
30 Body (Main Piston), Ductile Iron
31 “D” Slide Actuator, Steel
32 O-Ring, Nitrile
33 O-Ring, Nitrile
34 O-Ring, Nitrile
35 O-Ring, Nitrile
36 O-Ring, Nitrile
37 Index Pin, Stainless Steel
38 Main Piston Valve Housing, Steel
39 Screw, Plated Steel
40 “D” Slide, Nylon

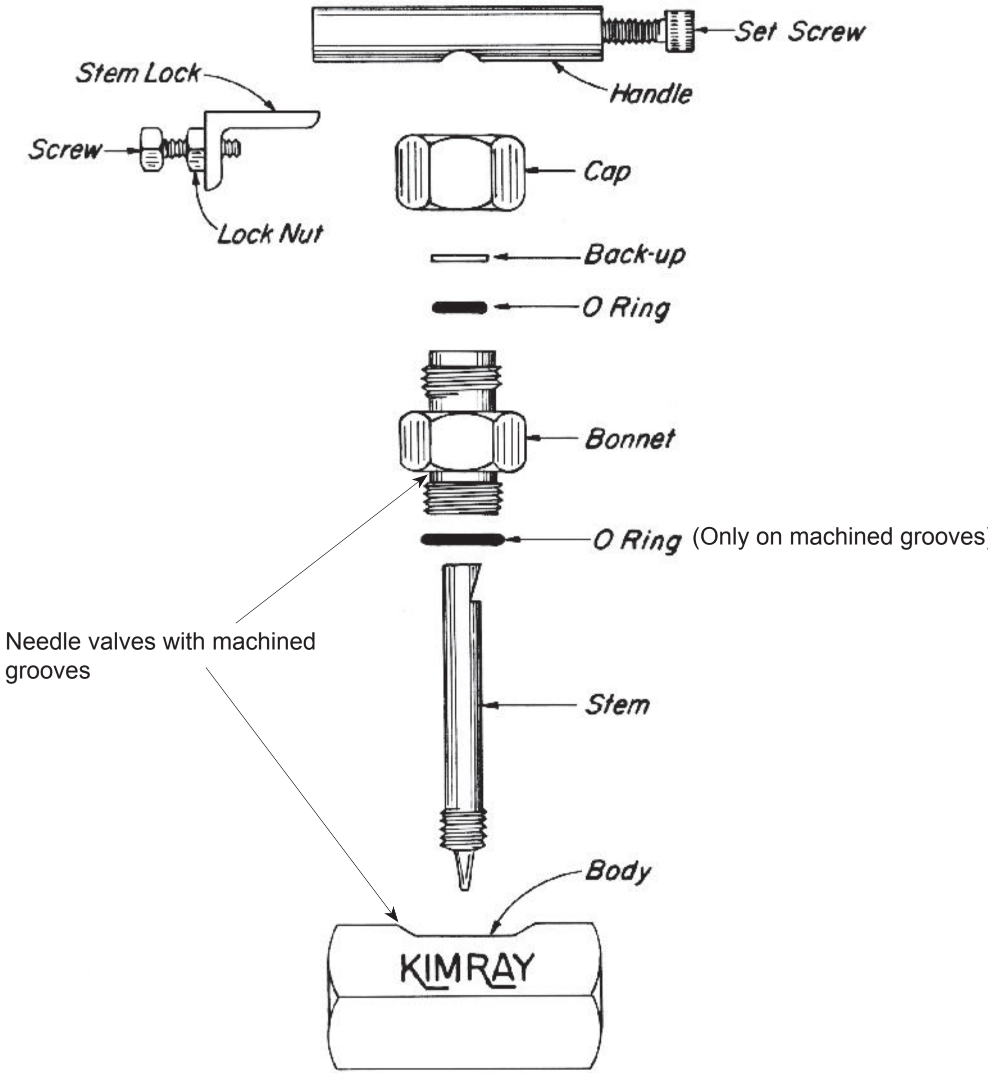
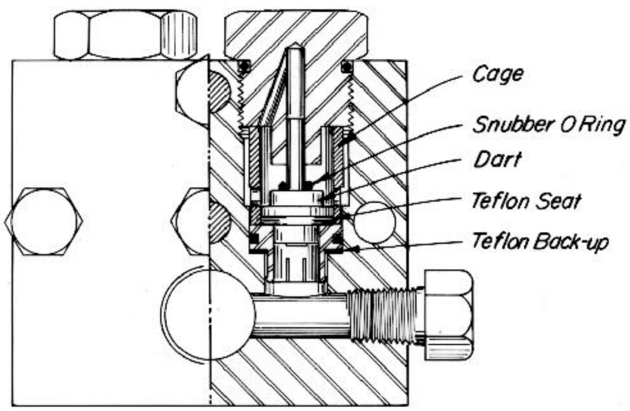


Figure 20

Table 12 - 6000 PSIG W.P. NEEDLE VALVES																
N.P.T SIZE	VALVE NO.	ORFICE SIZE	PUMP SIZE	BODY	BONNET	CAP	STEM	HANDLE	SET SCREW	BACK UP	O-RING	O-RING	STEM LOCK	STEM LOCK ASSY	SCREW	LOCK NUT
TYPE 303 STAINLESS STEEL STANDARD ON ALL PUMPS EXCEPT 45015 PV PUMP																
1/4 in.	1911	1/16 in.	1720	1911A	1603D	1603F	1957A	1603B	1964	1978	638	265	6746	2271A	2274	2275
1/4 in.	1957	1/8 in.	4020	1957C	1603D	1603F	1957A	1603B	1964	1978	638	265	6746	2271A	2274	2275
3/8 in.	1956	3/16 in.	9020	1956C	1955D	1955F	1956A	1955B	1963	1979	153	2631	6747	2270A	2274	2275
1/2 in.	1955	9/32 in.	21020	1955C	1955D	1955F	1956A	1955B	1963	1979	153	2631	6747	2270A	2274	2275
CARBON STEEL STANDARD ON 45015 PV PUMP ONLY																
3/4 in.	1954	13/32 in.	45020	1954C	1954D	1954F	1954A	1954B	1962	1980	154	2131	6748	2269A	2274	2275
TYPE 316 STAINLESS STEEL - AVAILABLE ON SPECIAL ORDER AND EXTRA COST																
1/4 in.	1911S6	1/16 in.	1720	1911A6	1603D6	1603F6	1957A	1603B	1964	1978	638	265	6746		2274	2275
1/4 in.	1957S6	1/8 in.	4020	1957C6	1603D6	1603F6	1957A	1603B	1964	1978	638	265	6746		2274	2275
3/8 in.	1956S6	3/16 in.	9020	1956C6	1955D6	1955F6	1956A	1955B	1963	1979	153	2631	6747		2274	2275
1/2 in.	1955S6	9/32 in.	21020	1955C6	1955D6	1955F6	1955A	1955B	1963	1979	153	2631	6747		2274	2275
3/4 in.	1954S6	13/32 in.	45020	1954C6	1954D6	1954F6	1954A	1954B	1962	1980	154	2131	6748		2274	2275

Table 13 - Glycol Pump

Pump Size	Cage No.	Dart No.	Suction Back-Up	Dis Back-Up	Scrubber O-Ring	Teflon Dart Without Cage
1720 PV 2015 SC	1941	1940	1907	1666	647	1735
5015 SC 9020 PV	1938	1937	1908	1667	647	1736
10015 SC 21020 PV	1933	1932	1909	1668	153	1737
20015 SC 45020 PV	1935	1934	2445	1669	265	1738



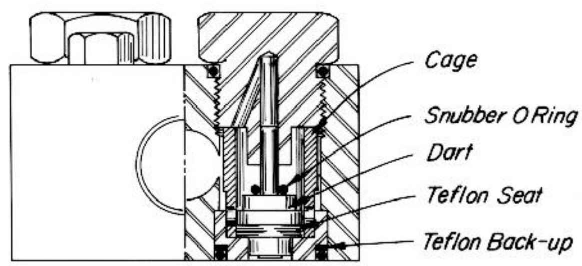
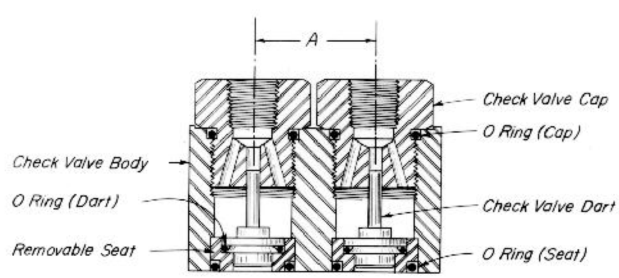
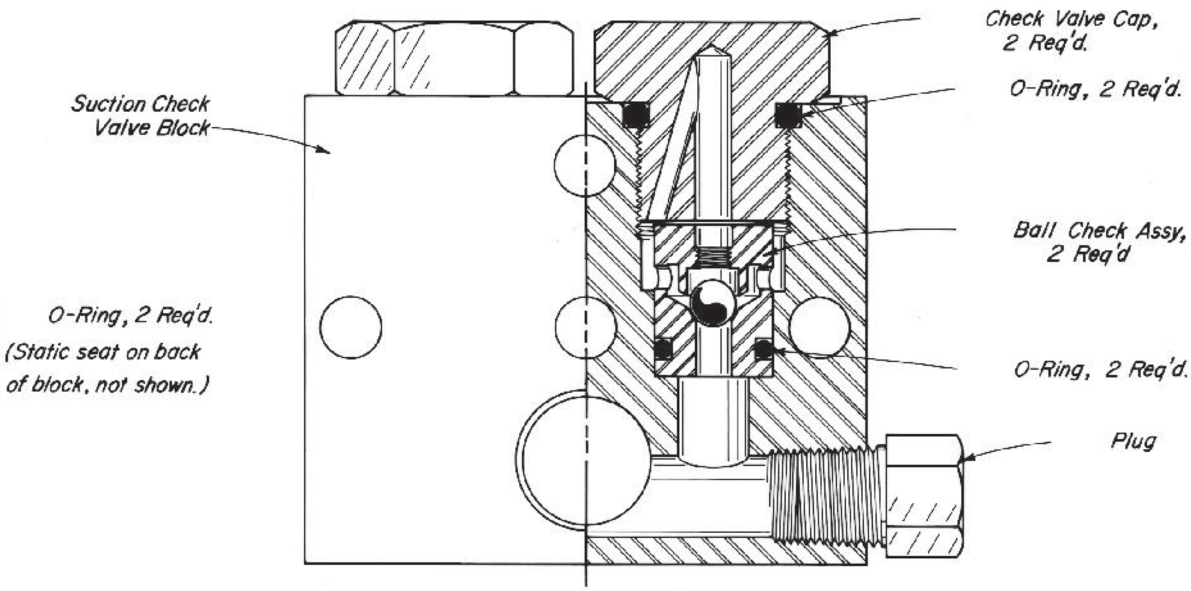


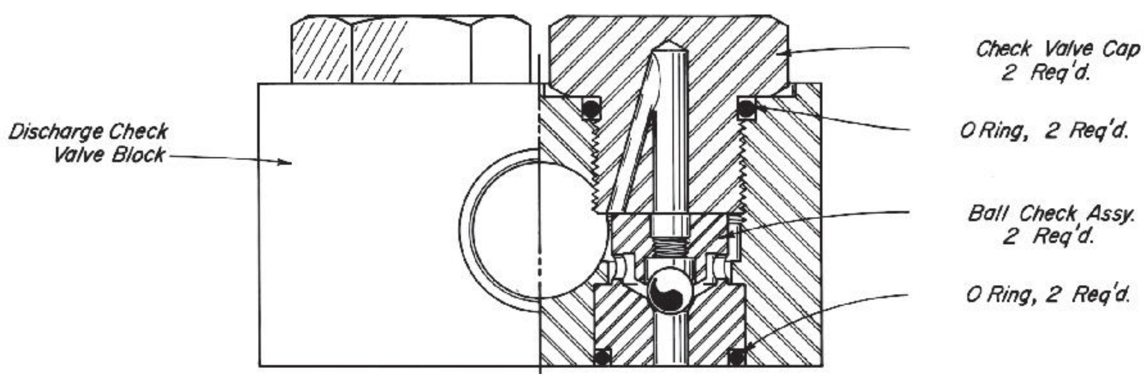
Table 14 - Split Discharge

Part Name	Qty Req'd	1720 PV	4020 PV and 2015 SC	9020 PV and 5015 SC	21020 PV and 10015 SC	45020 PV and 20015 SC
Check Valve Body	1	1940	1907	1195	1196	1197
"O"-Ring Seat	2	1937	1908	1151	156	801
Removable Seat	2	1932	1909	1131	1133	1173
Rev. Rem. Seat	2	1934	2445	1948	1949	1950
"O"-Ring Dart	2	855	855	154	924	156
Dart	2	1307	1307	853	854	1163
"O"-Ring Cap	2	155	155	156	157	801
Check Valve Cap	2	1327	1327	1114	1199	1198
Tapped Hole Size	NPT	1/4 in.	1/4 in.	3/8 in.	1.2 in.	3/4 in.
Dimension "A"	Inches	1 1/2 in.	1 1/2 in.	1 11/16	2 5/16	3



Split Discharge


Check Valve Cap, 2 Req'd.
O-Ring, 2 Req'd.
Suction Check Valve Block
Ball Check Assy, 2 Req'd
O-Ring, 2 Req'd. (Static seat on back of block, not shown.)
O-Ring, 2 Req'd.
Plug

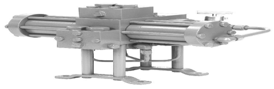

Check Valve Cap 2 Req'd.
O Ring, 2 Req'd.
Discharge Check Valve Block
Ball Check Assy. 2 Req'd.
O Ring, 2 Req'd.

Base Codes for Kimray Glycol Pumps

Once all spaces are filled, remove all dashes and condense without spaces.

Base Code		Trim Material		Elastomer		Certification	
Code		Code	Description	Code	Description	Code	Description
Three character base code from page ii		-	Standard	-	Standard (Buna-N)	-	No Certifications
				AF	Aflas	MTR	Material Test Reports (i.e. Steel Casting)
				HSN	High Saturated Nitrile	SPT	Static Pressure Tests
				V	Viton		

Code	Description
GAB	4020 PV Glycol Pump
GAC	2015 SC Glycol Pump
GAD	1720 PV Glycol Pump
GAF	9020 PV Glycol Pump
GAG	5015 SC Glycol Pump
GAH	21020 PV Glycol Pump
GAI	10015 SC Glycol Pump
GAJ	45020 PV Glycol Pump
GAK	20015 SC Glycol Pump



Kimray is an ISO 9001- certified manufacturer.
Kimray quality assurance process maintains strict controls
of materials and the certification of parts used in Kimray glycol pumps.