FINAL

# TECHNICAL MEMORANDUM – POWER GENERATION STATION RELIABILITY IMPROVEMENTS LPGH EVALUATION

## SD-413 PGS Reliability Improvements Phase 3

**EBMUD Project SD-413**

**B&V PROJECT NO. 405542**

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**PREPARED FOR**

East Bay Municipal Utility District

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BLACK & VEATCH

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# 1.0 Purpose

The East Bay Municipal Utility District (EBMUD) Main Wastewater Treatment Plant (MWWTP) is located in Oakland, California. In May 2020, EBMUD entered into an agreement with Black & Veatch (B&V) to prepare a Power Generation Station (PGS) Reliability Improvements Evaluation Technical Memorandum (SD-413). This project was undertaken to evaluate the power generation station's reliability and provide recommendations for the design of facility improvement.

This Technical Memorandum (TM) will consider short term and long term operation of the Low Pressure Gas Holder (LPGH).

A separate technical memorandum provides recommendations for other PGS reliability improvements projects based on risks and budgetary costs.

# 2.0 Background

The Power Generation Station (PGS) at the MWWTP is comprised of PGS1, engine generator system and PGS2, turbine generator system. In 2018 a reliability and assessment study, identified the PGS as critical facilities required for emergency preparedness and in need of various improvements.

The existing PGS1 was installed in 1986, and consists of three, 2.1 megawatt (MW) reciprocating internal combustion engine generators; a low pressure gas holder; three 2-stage reciprocating compressors; two waste heat exchangers; a plant effluent (3W) water cooling system; a diesel fuel system; a lube oil system; and a compressed air system. PGS1 was modified in 1993 and 2005. The diesel fuel storage capacity was increased, radiators were added to cool at least one engine generator in the event plant effluent water was interrupted, cooling loop heat exchangers and pumps and a boiler were added.

In 2012, PGS2 was installed and consists of one 4.6 MW turbine generator, a gas conditioning system, a gas compressor skid, 3W water cooling loop heat exchangers and pumps, and an effluent water cooling system for the turbine oil and compressor.

The LPGH was originally installed in the low pressure (LPDG) to provide gas storage for the engine generators. Following the turbine generator installation, the LPGH remained in operation, but in a different configuration. Instead of connecting directly to the digesters and the LPDG system, a bypass valve was added in the main gas header. The gas blower on the new gas conditioning system is used to boost the gas pressure through the gas conditioning equipment and maintain the storage volume in the LPGH. The level of the piston in the LPGH is currently controlled through the operation of the gas conditioning blower.

A virtual workshop with EBMUD staff was held on July 14, 2020, to discuss concerns and operation of the LPGH. This TM will address staff concerns with the existing LPGH and provide recommendations for short term and long term improvements.

# 3.0 Digester Gas System

The digester gas system is broken into three systems, the low pressure digester gas (LPDG) system, the medium pressure digester gas (MPDG) system, and the high pressure digester gas (HPDG) system. Figure 3-1 shows a schematic diagram of the digester gas system.

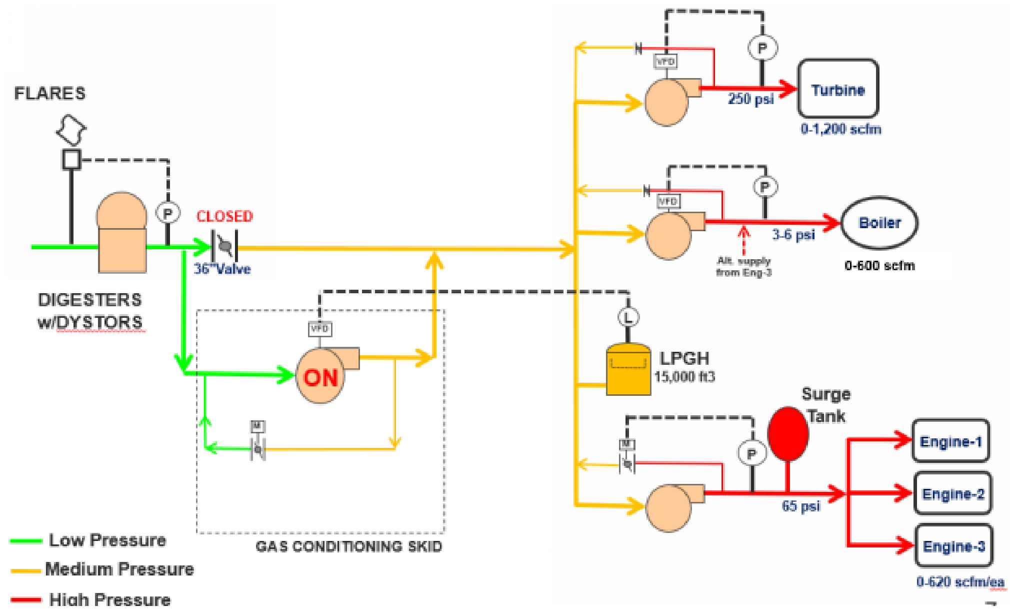


**Figure 3-1 Existing Digester Gas System**

## 3.1 LOW PRESSURE DIGESTER GAS SYSTEM

The LPDG piping system collects the digester gas produced in the digesters and conveys it to the gas conditioning system. The LPDG piping was replaced in 2005 with a 36-inch header routed from the digesters to the LPGH to minimize pressure loss.

Digester 2 has a Dystor dual membrane gas storage cover. The cover provides low pressure storage for the gas and also controls the gas pressure within the LPDG system. Additional dual membrane gas storage covers are scheduled to be installed on Digesters 3 and 4 by 2022. These gas membranes are to be provided by Westech and each will have a storage volume of 242,000 cubic feet ($ft^3$). The new membranes will have an operating pressure setpoint between 6 and 10 inches water column (wc) and a maximum design pressure of 12 inches wc.

Two high capacity flares, to burn excess digester gas, have been recently installed. These flares have a total capacity of 3,000 standard cubic feet per minute (scfm). Four existing low capacity flares also have the capability to burn excess digester gas and have a total capacity of 3,600 scfm. The flare operation is controlled based on LPDG header pressure.

### 3.1.1 LPDG Issues

The existing dual membrane gas storage cover at Digester 2 does not have a means of indicating the position of the inner membrane. There is no way to tell how much gas is being stored within the membrane. Indication is only provided when the gas membrane system is full or empty. Because of this limitation, the gas membrane is currently operated in the full condition, and the flare controls are set to operate the flare once the cover is full and the gas pressure exceeds the LPDG system pressure setpoint.

High strength waste is brought into the facility and fed into the digesters. High strength waste can cause significant fluctuation of gas production. The waste is fed into the digesters on a weekly cycle. The haulers that supply the waste do not usually operate on the weekends. Gas production increases during the week and peaks on Fridays. Gas production is typically lower on Saturdays and Sundays. The newer gas membranes (scheduled to be installed on Digesters 3 and 4) will have the ability to indicate partial storage volumes, increasing the ability to control gas utilization operation and flares automatically.

Using volume instead of header pressure produces a greater buffer for control. Current operation on pressure gives little time to react to issues. The addition of volume indication with the new gas membrane storage, will give more time to react to issues in the gas system. As a result, waste gas going to the flare can be reduced. The cogeneration units can then be controlled off the gas storage volume in the membranes either automatically or manually to provide a more consistent power output.

## 3.2 MEDIUM PRESSURE DIGESTER GAS (MPDG) SYSTEM

The MPDG system consists of a gas conditioning system and a low pressure gas holder (LPGH), and provide MPDG to the boiler, engine and turbine gas compressors.

The digester gas conditioning system was installed as part of the PGS2 turbine generator installation to meet the gas quality requirements for turbine operation. LPDG is routed from the 36-inch main header to the conditioning skid. The conditioning system boosts the gas pressure with a single multi-stage centrifugal blower, reduces moisture in the gas by lowering the dew point of the gas to 40 F, and reheats the gas to around 75 F to meet the relative humidity requirement of the gas turbine. Siloxane removal vessels were included to reduce siloxane levels of the gas. Following siloxane removal, the gas is piped back to the 36-inch main header. Since, the higher gas quality of the cleaned gas would reduce engine maintenance, besides the turbine, the cleaned gas is used for the engine generators and boiler.

The LPGH balances fluctuations in flows between the gas conditioning blower and the gas compressors. The LPGH is a modified Wiggins type dry gas storage system. An inverted piston with a gas tight membrane which is attached to the piston sides and to the outer tank side is used to contain the gas. The piston rides up and down on the gas volume in the tank. A series of cables, pulley, and weights are used to maintain gas pressure and stabilize the piston. The LPGH operates at 6 inches wc and provides 15,000 $ft^3$ of storage.

A boiler provides supplement heat to the heating water system. The boiler is fueled from the MPDG system. A boiler gas booster increases the MPDG pressure to the boiler from 6 inches wc to 5.5 psig.

### 3.2.1 Gas Conditioning Issues

The gas conditioning system was designed for a maximum flow of 3,000 scfm, which matches the total gas flow requirement of all 3 engine generators and the turbine generator. Because of the moisture removal from the gas, the actual maximum flow out of the conditioning system is lower, 2,838 scfm. This does not meet the gas flow requirement for operating all the three engine generators and turbine generator.

The discharge pressure out of the gas conditioning system, as indicated in the manufacturers process and instrumentation diagram (P&ID), indicates a pressure range of 2.08 to 2.43 pounds per square inch gauge (psig). Based on a site visit on August 14, the human-machine interface (HMI) screen indicated a discharge pressure of 1.8 psig (at 2500 scfm) out of the moisture removal system. Per the manufacturers P&ID, this should be 3.5 psig. There is about 1.7 psi additional pressure loss through the heat exchangers than what was considered in the design. Based on site visit photos, it appears a third heat exchanger was installed, after the original design. This additional pressure loss, limits supply pressure to the header to values estimated to be between 0.4 to 0.8 psig, or 11 to 22 inches wc. A review of the blower curve indicates that any additional pressure, without reducing capacity, would require a new blower.

A 36-inch bypass valve was installed in the main gas header, between the inlet and discharge connection going to the gas conditioning system. When there is a failure in the gas conditioning system, such as the gas blower going down, then the 36-inch valve is manually opened. Once the valve is opened, raw digester gas goes directly from digesters to the PGS units. At this point, control is based on digester gas pressure in the header. Recently, this valve was automated by adding an electric actuator. As part of the PGS Reliability Improvements TM, costs for redundancy for the gas conditioning system is provided. If there is a failure in the gas conditioning system, automatic switch over is provided and will keep from manually switching the bypass valve.

### 3.2.2 LPGH Issues

The LPGH has been in operation for almost 35 years and has developed issues over the years. As presented in the PGS Reliability Improvement TM, the LPGH has the highest Business Risk Exposure of any of the assets evaluated. This is because it has a high potential for failure and high consequence of failure. The potential for failure is due to the age of LPGH and the significant repair requirements. The LPGH needs the gas membrane, stabilizing sheaves and pulleys replaced. The high consequence of failure represents the potential of these failing items causing digester gas to leak.

In the virtual workshop with EBMUD staff the following list of concerns was developed related to the existing LPGH.

- The flexible membrane that connects the piston and the tank wall has not been changed since the original installation in 1986. Typically, the membrane should be replaced every 10 to 15 years, with some membranes needing to be being replaced every 5 years. EBMUD staff suspects the diaphragm is leaking based on evidence of a pressure drop in the tank when the LPGH isolation valve is closed.
- The piston is supported and stabilized with four cables with sheaves, attached to counterweights. One of four cables has broken and the unit has relied on only 3 cables for the last few years.
- The tank drain underneath the piston is plugged and it is believed water has accumulated below the piston. Staff indicated they have never inspected below the piston.
- Staff think there is possible accumulation of pyrophoric iron sulfate under the piston.
- Originally the LPGH had two inlet/outlet pipes. In 2018, one of the common inlet/outlet pipes was eliminated. With the single inlet/outlet pipe, there is no way to release pressure, causing operational issues.
- Changes in structural seismic codes may mean the foundation may have to be modified.

- To make modifications to the tank, the existing LPGH would have to be offline for a minimum of 2 to 6 months. Modifications would include cleaning out and inspecting the inside of the tank, replacing cable and sheaves, repairing the drain, replacing the membrane, and recoating the interior.
- If the LPGH is replaced, the gas holder may be down for longer than 6 months. This could be shortened by relocating the LPGH.
- Typically, the gas conditioning blower is controlled by the variable frequency drive (VFD) to maintain the LPGH at 70 percent full. When the piston reaches high level, set at 85 percent full, the tank inlet valve closes to keep the relief valve from opening on high level and releasing digester gas to the atmosphere.
- Structural design of the LPGH is limited to 8 inches wc. and the current operating pressure is 6 inches wc. It is not possible to increase the operating pressure of the LPGH.
- An additional concern of operating the MPDG system without the LPGH is that the LPGH provides a buffer for system upsets. For instance, when the turbine drops off suddenly, high pressure gas flows back into the header. The blower needs to slow down and the 36-inch valve needs to open to allow gas to flow back into the main LPDG header to limit significant pressure increases.
- When starting up without the buffer provided with the LPGH, compressors start pulling the gas out of the header too quickly. The blower controls may need an active PID to ramp up the blower in a controlled fashion. EBMUD staff did a test by adding a PID loop, that worked well during stable operations, but control was lost when high fluctuations in gas flows occurred. Tests did show the blower could provide gas without the LPGH. Additional tests to be performed with the blower discharge pressure increased to see if higher pressures will better handle the pressure fluctuations.

### 3.2.3 MPDG System Controls

When PGS2 was installed, the control scheme changed so that the gas blower, as part of the new gas conditioning system, is controlled off the volume of gas in the LPGH. The blower speed is controlled by a VFD to provide a flow to maintain a gas volume level in the LPGH of around 70 percent. If the storage volume experiences a full condition, the relief valve on the LPGH opens and releases digester gas. To prevent this occurrence, a signal is sent to close the LPGH isolation valve when the LPGH is at 85 percent of volume. No additional gas is sent to the LPGH and no digester gas is released.

The LPGH has hardwired signals with the volume LPGH signal coming into a splitter, with one going to the GE PLC and the other one going to the gas conditioner. The District uses the LPGH signal to the gas conditioning system as the gas blower is part of the conditioning system. The digester gas conditioning system is provided with its own local control panel and PLC that is used to control the operation of the gas blower.

Signals from the gas conditioning local control panel are used for PGS control and are very noisy and slow to react, making it difficult to test and control the blowers. With the noise of the analog signals, a PID loop has a hard time reacting to the signal causing a swing in blower speed. It is suspected that having high voltage and low voltage in a single control panel may be causing the noisy signals. It is recommended to separate the control panel into two panels, with one for high voltage and one for low voltage. Capital costs for this modification is included in the PGS Reliability Improvements TM.

There are several PLCs in the digester gas system that are from different manufacturers, some are by Allen Bradley and one by GE. The facility main DCS does not do any control through the PLCs, it only receives limited information. PLCs talk to each other on read/write blocks only. A data concentrator PLC collects data from one PLC and sends it to another PLC. As part of the PGS Reliability Improvements TM, capital costs were included to migrate controls and tie in alarms to the DCS.

## 3.3 HIGH PRESSURE DIGESTER GAS (HPDG) SYSTEM

The HPDG system consists of the gas compressors and piping up to the cogeneration equipment. For PGS1, three, 2-stage piston type gas compressors compress the MPDG up to 60 psig for utilization in the engine generators. A surge tank is connected to the HPDG header to provide a buffer between the compressor and engines. For PGS2, an oil flooded rotary screw compressor, by Vilter, compresses the MPDG up to 250 psig for utilization in the turbine generator. Gas piping between the compressors and engine generators is being replaced by plant staff. Buried gas piping between the compressor and the turbine generator is to be replaced in a future project. As part of the PGS Reliability Improvements TM, capital costs were included for replacing this piping.

The main issue seen in the HPDG system is the starting and stopping of the compressors causing fluctuations in the gas pressure in the MPDG system. When the LPGH is taken out of service, these fluctuations in gas pressures would be problematic.

# 4.0 Low Pressure Gas Holder

Due to the issues with the LPGH as discussed earlier, the gas holder will need to be taken out of service for several months for repair or replacement. Alternatively, it could be completely removed from the system. This section examines short term and long term options for operating the MPDG system without the LPGH.

The main issue with taking the LPGH out of service is how the gas conditioning gas blower handles the fluctuations in gas flows and pressures during starting and stopping of the engines and turbine. In previous tests conducted by staff when isolating the LPGH and adding a PID loop, the system operates with minimal issues operating at steady state conditions. The system loses control if pressure fluctuates significantly.

## 4.1 EXISTING GAS UTILIZATION FACILITIES

A survey was done of wastewater treatment facilities that have digester gas utilization systems to understand whether there are facilities that have a similar setup; systems where the MPDG operates at a low pressure and does not have gas storage.

All facilities surveyed did not have gas storage as part of the MPDG system, but all facilities operate either at a pressure of 5 psig or greater or have gas compressors pull directly from the LPDG system. No facilities were identified that operated at similar MPDG pressures (6 inches wc) as the EBMUD facility. Table 4-1 provides information on the other systems investigated for comparison.

**Table 4-1 Gas Utilization Facilities**

| FACILITY | LPDG STORAGE | GAS BLOWER | MPDG STORAGE | GAS COMPRESSOR | HPDG STORAGE | GAS UTILIZATION |
|---|---|---|---|---|---|---|
| EBMUD | Yes, membranes | Yes | Yes Dry Seal at 6" wc | Yes 65 psi to EG and 250 psi to TG | Surge tank for EG None for TG | 3 EG and 1 TG |
| DC Water | None | Yes to 10 psig | None | Yes to 220 psig | None | 3 TG |
| Gwinnet Co, GA | None | None | None | Yes to 65 psig | Yes, 4 propane tanks | 1 EG |
| IRWD, CA | Yes, Dry Seal | Yes to 5 psig | None | Yes to 80 psig | None | 3 MT |
| Oceanside, CA | None | Yes to 5 psig | None | No | None | 1 EG |
| Milwaukee Jones Island | None | None | None | Yes to 250 psig | None | 3 TG |
| Milwaukee South Shore | None | None | None | Yes to 55 psig w/gas treat | Sphere at 55 psig | 4 EG |
| Kansas City Blue River | Yes, gas holder cover | Yes to 5 psig | None | None | None | 3 EG |
| OCSD Plant 1 | Yes, Dry Seal | None | None | Yes to 75 psig | None | 3 EG |
| OCSD Plant 2 | Yes, Dry Seal | None | None | Yes to 75 psig | None | 5 EG |
| San Jose | Yes, Dry Seal | None | None | Yes to 55 psig | None | 4 EG |
| Dublin San Ramon, CA | None | None | None | Yes to 40 psig | None | 3 EG |
| Sunnyvale, CA | None | Yes | None | None | None | 2 EG |
| Winston Salem Muddy Creek | None | Yes to 5 psig | None | Yes to 60 psig | Sphere at 60 psig | 1 EG |
| Rochester, MN | None | Yes to 5 psig | None | Yes to 60 psig | Sphere at 60 psig | 2 EG |
| Vancouver, BC | Yes, Dry Seal | Yes to 5 psig | None | None | None | 4 EG |

| FACILITY | LPDG STORAGE | GAS BLOWER | MPDG STORAGE | GAS COMPRESSOR | HPDG STORAGE | GAS UTILIZATION |
|---|---|---|---|---|---|---|
| Monterey, CA | Yes, Dry Seal replaced with Membrane | None | None | Yes to 75 psig | Sphere at 75 psig | 3 EG |
| Paso Robles, CA | None | Yes to 5 psig | None | None | None | 1 EG |
| Omaha, NB | Yes, dry seal/ membrane | None | None | Yes | Sphere | 3 EG |
| Las Vegas | None | Yes to 5 psig | None | Yes | Sphere | 3 boilers |
| **EG = engine generator**<br>**TG = turbine generator**<br>**MT = micro turbine** | | | | | | |

## 4.2 MPDG SYSTEM OPERATION WITHOUT LPGH

At some point of time the LPGH will need to be taken out of service to be repaired, replaced completely, or taken out of service permanently. Tests performed by plant staff with a PID loop for blower control have indicated that the gas treatment blower operates well during steady state conditions, but when there is a disruption, the MPDG system loses control and shuts down. Any large fluctuations in gas flows, either high or low, effect the control system of the gas blower when the LPGH is not in operation. Additional testing is to be performed by the District staff to see if additional pressure out of the existing blower will handle the large fluctuations in gas flows.

This section will look at different options to limit or reduce these fluctuations to keep the MPGS in operation, when the LPGH is not in operation. Figure 4-1 shows the current control setup for the MPDG system when the LPGH is out of service. The blower speed, thus flow, is controlled from the MPDG header pressure.

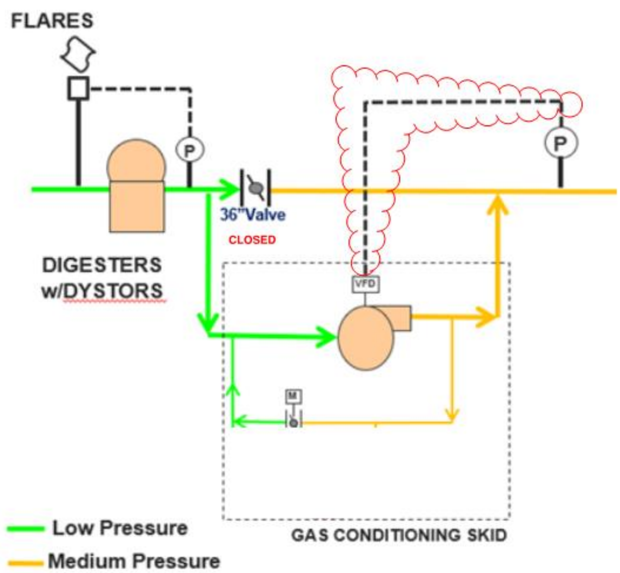


**Figure 4-1 MPDG System without LPGH**

### 4.2.1 Low Pressure Fluctuations

Low pressure or flow fluctuations can be caused by bringing on line gas utilization systems which can cause low pressure shutdown of compressors or loss of control of the gas blower. The following are a list of possible solutions to help equalize pressure.

- Tune PID loop to ramp up blower quicker. This has been tried previously, with some success. This could be investigated further to determine whether there are other methods to implement this approach or improvements to this approach which could be made to the control system. Additional testing is to be performed by the District staff to see if additional pressure out of the existing blower will handle the large fluctuations in gas flows. This option does not require any additional equipment costs.
- A pressure reducing valve (PRV) could be installed around the 36-inch bypass valve to bleed raw gas into the MPDG header during low pressure fluctuations. This option allows raw digester gas to be used to equalize pressure in the MPDG system when the gas blower

cannot react fast enough to meet low pressure conditions. A pressure reducing valve would be set to open at a pressure similar or just less than the operating pressure of the LPGH. An issue with this option is that raw digester gas would be introduced into the gas that was just treated. District staff has indicated no raw gas is to go to the turbine as it would avoid the service agreement with Solar, the manufacturer of the turbine generator. Another issue is the size of the valve. Due to low pressure operation and minimum pressure difference between LPDG and MPDG system, the size of the valve could be quite large. Figure 4-2 provides a schematic of this option.

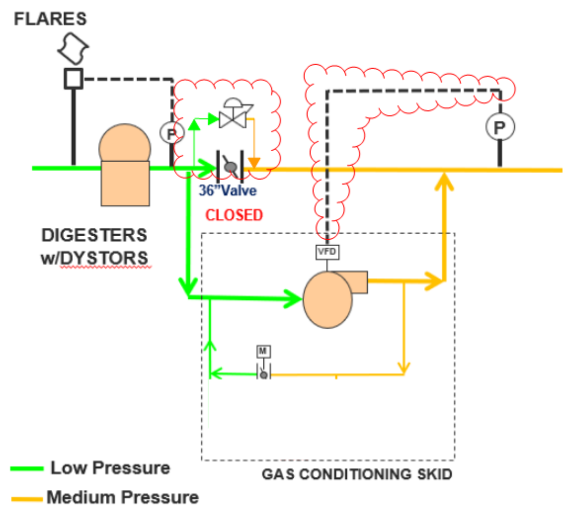


**Figure 4-2 MPDG System without LPGH – LPGH Bypass Valve**

- A PRV and actuated valve could be installed to bleed HPDG from surge tank into MPDG header. This option would use the high pressure gas to the engines to be bled back into the MPDG system on low pressures. The surge tank operates at 65 psig. On low pressure conditions in the MPDG header, the actuated valve would open and the PRV will regulate the higher pressure in the HPDG surge tank into the MPGS to maintain a constant minimum pressure. An issue with this option would be the pressure in the tank could be bled down significantly and cause operational issue with the engines. Figure 4-3 shows a diagram of the valve additions for this option.

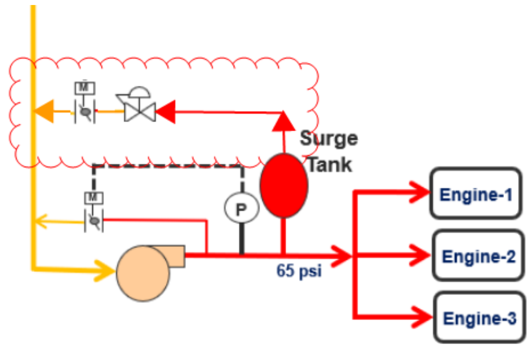


**Figure 4-3 MPDG System without LPGH – Surge Tank**

- A gas storage tank and blower could be installed to bleed gas back into the MPDG header during low pressure fluctuations. This option would include a small rotary lobe type gas blower and a gas storage tank to store MPDG at a higher pressure, say 10 psig. On low pressure fluctuations, a PRV in the tank discharge piping would open and bleed the compressed MPDG back into the system to equalize pressure. Figure 4-4 provides a diagram of the additional equipment for this option.

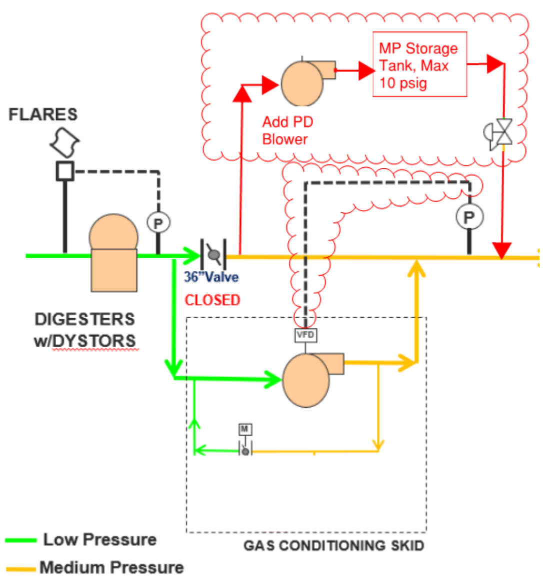


**Figure 4-4 MPDG System without LPGH – Gas Booster Storage**

- Natural gas or blended natural gas and air could be added into the MPDG header during periods of low pressure fluctuations. A pressure reducing valve regulates pressure into the MPDG header by bleeding natural gas into the system. Bleeding raw natural gas into the system affects the heating value of the blended gas, which may cause fuel issues in the engines or turbines. A blended air and natural gas system would provide gas near the heating value of the MPDG and would have little effect on the engine or turbine operation. Figure 4-5 provides a schematic of this option.

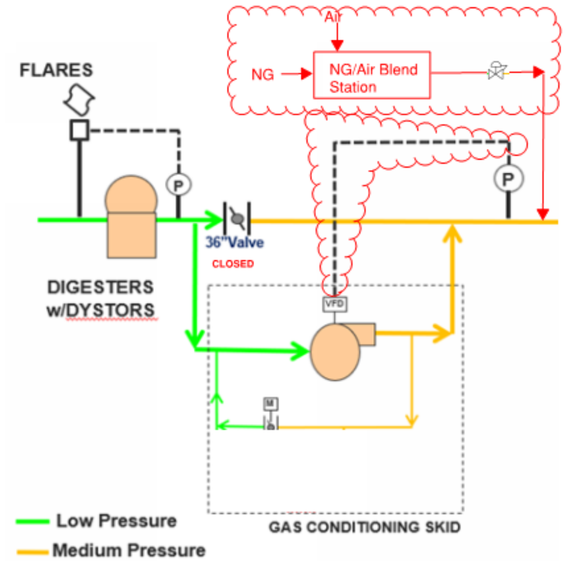


**Figure 4-5 MPDG System without LPGH – NG Addition**

### 4.2.2 High Pressure Fluctuations

High pressure fluctuations caused by gas utilization system shut downs may cause loss of control of the gas blower without the LPGH in operation. The following are a list of possible solutions.

- Tune PID loop to ramp blower down quicker.
- Add a pressure reducing valve around blower and bleed MPDG back into LPGH header. This option bleeds off MPDG on high pressure to equalize the pressure in the MPGH system during times of high pressure fluctuations. The valve would be a back pressure control type valve that opens on high pressure. Figure 4-6 provides a schematic of this option.

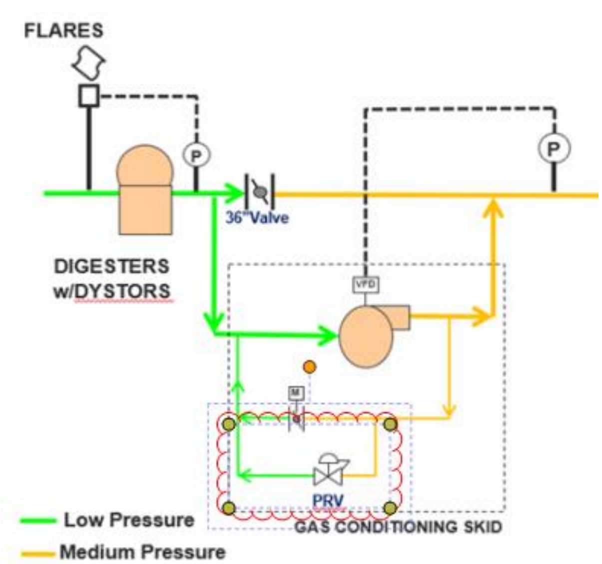


**Figure 4-6 MPDG System without LPGH – Add Bypass Valve**

- Allow the gas blower to run at full speed and control MPDG pressure with an automatic recirculation valve. Instead of controlling the blower VFD off MPDG header pressure, allow the blower to operate at full speed and use the recirculation valve to maintain the pressure in the MPDG header. This option is not very efficient in that the gas blower would operate at full power at all times and does not take advantage of the VFD speed reduction and reduced electricity usage. Figure 4-7 provides a schematic of this option.

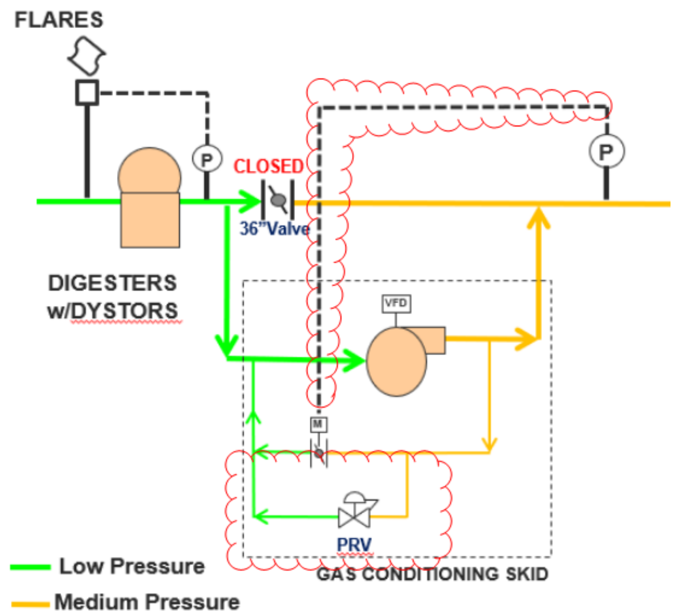


**Figure 4-7 MPDG System without LPGH – Control Recirc Valve**

- One issue that was brought up by EBMUD staff was that when the turbine generator shuts down, the pressure between the compressor and the turbine flows back into the MPDG header causing high pressures. A solution for this is to add a check valve in the PGS2 compressor suction piping and add a small bypass with an actuated valve that would open and allow HPDG to bleed slowly back into MPDG header. Figure 4-8 provides a schematic of this option.

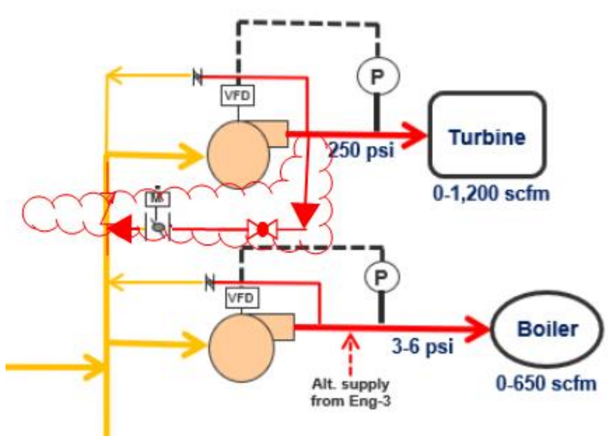


**Figure 4-8 MPDG System without LPGH – Turbine Compressor Check Valve**

### 4.2.3 Long Term Option

As indicated previously, other facilities with gas utilization systems, operate the MPDG system at pressures of at least 5 psig following gas treatment or they use high pressure compressors to draw directly from the LPDG system from the digesters and operate gas treatment at high pressures. In the PGS Reliability Improvements TM, one recommendation to provide greater reliability of the gas conditioning system is to provide a redundant gas blower. The blower would be sized such that the system capacity increases to 3,000 scfm.

The additional consideration in this TM is to replace the existing gas blower and add the redundant gas blower to meet capacity requirements and provide 5 psig of pressure from the gas conditioning skid. Operating at this higher pressure allows better absorption of fluctuations in gas flows and pressures, without losing control of gas blower operation.

If future testing of the existing gas blower indicates a lower discharge pressure can produce stable operation, then the new blower with a lower discharge pressure could be provided.

### 4.2.4 Summary

In the future, the LPGH is going to have to be taken out of service for repair or replacement. Controlling high and/or low pressure fluctuations is critical in keeping the MPDG system operating during this time. District staff will be performing testing to see if higher pressure out of the gas blower will better handle fluctuations in gas flows. If this is successful, then short term modifications won't be necessary. If not, the following is recommended:

For high pressure fluctuations, it is recommended that a PRV be installed around the blower such that on high pressure the valve opens allowing high pressure gas to be sent back to the LPDG system. In addition, it is recommended that for the turbine gas compressor, a check valve be installed in the compressor suction piping and a smaller bypass valve be piped around the check valve to allow pressure to be bled slowly to the MPDG header to keep high pressure from building up in the MPDG header.

For low pressure fluctuations, a means of quickly adding gas quickly to the MPDG system is needed to equalize the pressure. Options for these include

- Bypass raw gas from LPDG to the MPDG header.
- Send blended natural gas/air into the MPDG header on low pressure.
- Send HPDG from the engine compressor discharge surge tank to the MPDG.
- Add a blower and tank in the MPDG system to compress MPDG into the tank to be used at a later time when the gas pressure drops.

Since District staff has concerns about sending raw gas to the MPDG header and adding a blower and tank would be expensive, these options won't be considered. Sending blended natural gas/air to the MPDG header or using HPDG from the engine compressor surge tank sent to the MPDG header would be considered as options. There appears to be existing equipment/valving to do either option. District staff could look at either option if testing on higher gas blower pressure isn't successful.

For longer term operation without the LPGH, it is recommended the gas blower be replaced and a redundant blower be added. The new blowers would be sized to provide at least 5 psig pressure out of the gas conditioning skid and additional capacity provided to allow all engine generators and the turbine generator to operate simultaneously.

## 4.3 MPDG SYSTEM OPERATION WITH LPGH

Consideration should be given to operating the MPDG system with the LPGH in service or by providing other means of storage gas. Options include, rehabilitating the existing LPGH to get it back to near original condition, replacing the unit with a new LPGH, or replacing the unit with a different type of gas storage system.

### 4.3.1 Rehabilitating LPGH

The existing LPGH is in poor condition and items identified to be replaced include the gas membrane, cables and pulleys. For another B&V project for the City of New York, North River Plant, their 1980's vintage LPGH located in the LPDG system was rehabilitated. The original scope included items similar to EBMUD LPGH modifications, such as replacing membrane and cable/pulley system. It also included replacing the bottom of the piston and tank and completely replacing the tank drainage system. The LPGH isolation valve had to replaced be due to leaking. During construction when the tank was inspected, additional corrosion issues with the tank wall were identified, and the tank had to be relined with stainless steel cladding by change order. The concern with rehabilitating the tank is being able to sufficiently define the scope ahead of time to avoid the potential for increasing scope and costs once the tank is assessed. Because of the risk due to unknown costs associated with rehabilitating the LPGH, this option will be eliminated from consideration.

### 4.3.2 Replace LPGH

The LPGH could be replaced with a new unit of similar size or a taller unit which would give additional gas storage. A new unit would take several months or longer to demolish the existing tank and construct a new tank. If a new space could be found for the replacement LPGH, then the the existing LPGH could be kept on line, while the new LPGH was being constructed, reducing the time the LPGH would be off line. Replacing the LPGH represents the highest cost option.

Another option would be to replace the LPGH with another type of gas storage system. In previous B&V projects with LPGH installed in LPDG systems, it was more expensive to replace an existing LPGH with a similar unit, than to install another means of low pressure gas storage.

A gas membrane storage system, similar to those installed on the digesters, is a much less expensive means of gas storage. The membrane storage system would be ground mounted and could be mounted on the existing concrete slab. A gas membrane storage system, having a similar storage volume as the LPGH, could be installed in the same foot print as the LPGH. Additional space would need to be found for the air blowers used to keep the membrane inflated. At the Monterey One Water facility, B&V replaced the existing LPGH, which was of a similar size as the EBMUD unit and was located in the same footprint as the LPGH. The new gas membrane storage system cost significantly less than to replace the LPGH in kind. The concern with the membrane gas holder is having sufficient space around the unit for additional accessories.

## 4.4 OPINION OF PROBABLE CAPITAL COSTS

### 4.4.1 Short Term Operation

As described previously, short term operation without any gas storage in the MPDG system would consist of addition of a PRV around the blower, along with a check valve and bypass upstream of the turbine gas compressor for high pressure operation. For low pressure operation a control valve would be installed around in the 36-inch LPDG header valve to bleed LPDG into the MPDG header. The opinion of probable capital costs (Class 5 order of magnitude) would be approximately $106,000.

### 4.4.2 Long Term Operation

Long term operation of the MPDG system would be dependent on whether gas storage is to be maintained or not. Costs were developed for 3 options to keep gas storage and one option for operating without storage. These options are:

- Option 1: Replace the LPGH in kind.
- Option 2: Replacing the LPGH with membrane gas storage.
- Option 3: Remove LPGH from the system and operate without storage by replacing the gas conditioning blower with two new units to provide redundancy and meet capacity requirements.

Equipment costs for the first 2 options were based on an evaluation done for the Monterey One Water facility. They had a similar size LPGH that was also in poor shape. We received costs from McDermott/CB&I, who provided the original LPGH to replace the unit with a new unit and for rehabilitating the LPGH with a new membrane, new cables and pulleys to stabilize the units and other miscellaneous items. These costs were used to develop the cost for these 3 options.

For Option 3, costs for new centrifugal blower packages and associated controls for the gas conditioning system was received from an equipment packager.

The equipment total capital costs include costs for the new equipment or modifications, equipment installation, demolition where required, and other facility modifications.

The construction and design cost factors listed in Table 4-2 were used to generate the total expected project costs. Contractor markups and general requirements are costs required by the contractor to do the work. Market conditions are an allowance for doing work in the Bay Area.

**Table 4-2 Construction and Design Cost Factors**

| ITEM | COST FACTORS |
|---|---|
| Equipment Installation | 40% |
| Electrical and Instrumentation | 15% |
| Site Work | 5% |
| Contractor's Markups | 20% |
| General Requirements | 25% |
| Market Conditions | 15% |

| | |
|---|---|
| Contingencies | 35% |

The opinion of probable capital costs (Class 5 Order of Magnitude) for the three options with the required system improvements are summarized in **Table 4-3**. Detailed capital costs for each option are presented in Appendix A.

**Table 4-3 Opinion of Probable Capital Costs**

| ITEM | PROBABLE CAPITAL COSTS | | |
|---|---|---|---|
| | OPTION 1 NEW LPGH | OPTION 2 GAS MEMBRANE | OPTION 3 NO STORAGE - NEW GAS BLOWERS |
| **Capital Costs** | | | |
| Equipment Total Costs | $3,205,000 | $1,214,000 | $1,221,000 |
| Contractor's Markups (20%) | $641,000 | $243,000 | $244,000 |
| General Requirements (25%) | $802,000 | $303,000 | $305,000 |
| Market Conditions (15%) | $480,000 | $182,000 | $183,000 |
| Contingencies (35%) | $1,626,000 | $616,000 | $620,000 |
| **Total Project Capital Cost** | **$6,754,000** | **$2,558,000** | **$2,573,000** |

For long term operation, the opinion of probable capital costs is lowest for installing the gas membrane type gas storage system at $2.56 million. In comparison, operating without gas storage with new gas conditioning blowers operating at 5 psig or greater costs $2.57 million. Based on operation of the MPGS at other facilities, it is recommended that in the future no gas storage be provided, but the gas blowers would need to be replaced with units that meet design capacity and provide a minimum of 5 psig over all flow conditions. Operating at higher pressure, has been utilized successfully at many other facilities with gas utilization equipment. The higher pressure reduces the sensitivity from pressure fluctuations as compared to the current operation at low pressures. If future testing of existing blowers at higher operating pressures is successful, then the new blowers with a lower operating pressure could be provided.

# 5.0 Summary of Findings and Recommendations

The following are a summary of findings for the digester gas:

- The digester gas system is divided into three main systems, based on operating pressure, Low pressure, medium pressure, and high pressure.
- The LPDG system operates at 6 inches wc and is controlled by the pressure in the gas membrane storage and waste gas flare operation. Future gas membrane storage will be installed at Digesters 3 and 4 by 2022 and system pressure will be increased to between 8 to 10 inches wc and will have means to indicate the amount of gas stored in each gas membrane. This will help better balance the gas production and gas utilization flows. Also, the power output of the generators could be controlled based on the amount of gas stored.
- The MPDG system was implemented when the turbine generator was installed. A gas conditioning system was installed to meet the gas quality requirements for the turbine. The engine generator also utilizes the conditioned gas. Pressure in the MPDG system, 6 inches wc, is controlled by a gas blower that maintains a set volume of gas storage in the LPGH.
- The HPDG system is downstream of the gas compressors for the engine generators and downstream of the gas compressor for the turbine.
- As presented in the Reliability Improvement TM, the LPGH has the highest Business Risk Exposure of any of the assets evaluated. This is because it has a high potential for failure and high consequence of failure. The LPGH is over 34 years old and is need of repair. Replacement of the gas membrane, sheaves and pulleys to stabilize the piston is necessary.
- To rehabilitate the LPGH will mean the LPGH will have to be taken out of the service and the MPDG system will need to operate with no storage/buffer for several months. Rehabilitation of the LPGH was eliminated from consideration, because of unknown costs.
- EBMUD staff has tested the operation of the MPDG system without the LPGH in service. A PID loop was incorporated for the blower to anticipate demand on engine or turbine startup. The test had limited success. It was felt high fluctuations in gas flows from starting and stopping the gas utilization equipment and noisy signals in the control panel were the reasons for the limited success. Further tests are planned to see if high blower discharge pressure will help control gas pressure fluctuations.
- A survey of wastewater treatment facilities that utilized digester gas in their gas utilization system was performed. The main outcome of this survey was that none of the facilities had gas storage in their MPDG system, but all operated the MPDG system at higher pressures than currently operated at the EBMUD facility, at least 5 psig.

The following are a summary of recommendations:

- Short Term Recommendations:
  - If future testing of the existing gas conditioning blower to see if higher operating pressure would handle pressure fluctuations, then additional short term modifications won’t be required.
  - To reduce the effect of low pressure fluctuations in the MPDG system, either blending natural gas/air could be sent to the MPDG header or HPDG from the engine compressor surge tank could be sent to the MPDG header could be considered. There appears to be some existing infrastructure to do either of these items.

  - To reduce the effect of high pressure fluctuations in the MPDG system, a pressure control valve should be installed in the gas piping to bleed MPDG into the LPDG system.
  - To keep HPDG from back feeding high pressure gas into the MPDG system and causing high pressure issues, a check valve, with a small actuated operated bypass valve around the check valve, would be installed in the compressor suction piping to slowly bleed off the HPDG pressure into the MPDG system. The bypass valve would be adjusted to keep the pressure down below a minimum pressure in the MPDG system.
  - The high voltage controls and low voltage controls in the digester gas conditioning system control panel be installed in separate control panels, to eliminate noise in the control signals.
  - The Class 5 opinion of probable capital costs for these improvements is $106,000.
- Long Term Recommendations:
  - Eliminate the use of the LPGH in the MPDG system. Instead or rehabilitating or replacing the LPGH, the gas blower in the digester gas conditioning system can be replaced with a new blower that would be sized to produce a minimum of 5 psig pressure at all operating conditions and increase the capacity of the unit so all the engines and turbine can be run together. With the higher pressure, one of the cooling heating exchangers was assumed to be replaced. If further testing of the existing gas blower at higher discharges produces stable conditions, the new gas blower discharge pressure could be decreased.
  - As part of the PGS Reliability Improvements TM, a second gas blower is recommended to provide for redundancy and improve MPDG system reliability.
  - The Class 5 opinion of probable capital costs for these options would be $2,570,000.

# Appendix A. Opinion of Probable Construction Costs

**EBMUD - PGS Reliability**

## Task 1: Option 1 - Replace LPGH With New LPGH

Description: Replace LPGH with new LPGH with the same capacity.

## Capital Costs

| | | New LPGH Option | | |
|---|---|---|---|---|
| Description | Cost Factors | Cost per unit | No. | Total Cost |
| **Equipment Costs** | | | | |
| New LPGH | | $ 2,500,000 | 1 | $ 2,500,000 |
| **Equipment Total** | | | | **$ 2,500,000** |
| Demolition | | $ 100,000 | 1 | $ 100,000 |
| Concrete Pad | | $ 750 | 150 | $ 112,500 |
| Concrete Pile | | $ 14,000 | 20 | $ 280,000 |
| Misc Piping and Valves | | $ 100,000 | 1 | $ 100,000 |
| **Total** | | | | $ 3,092,500 |
| **Total Equipment Costs** | | | | **$ 3,092,500** |
| Installation - % of Equip Costs | 0% | | | $ - |
| **Total with Installation** | | | | **$ 3,092,500** |
| Electrical & I&C | 2% | | | $ 62,469 |
| Site Work | | | | $ 50,000 |
| **Total Capital Cost w/o markups** | | | | **$ 3,204,969** |
| Contractor Markups | 20% | | | $ 641,314 |
| General Requirements | 25% | | | $ 801,563 |
| Market Conditions | 15% | | | $ 480,104 |
| Contingencies | 35% | | | $ 1,626,281 |
| **Total Capital Cost w/markups** | | | | **$ 6,754,231** |

## EBMUD - PGS Reliability
## Task 1: Option 2 - Replace LPGH with Gas Membrane Gas Storage

Description: Replace LPGH with Gas membrane gas storage system. The new gas membrane storage system will have the same capacity as the LPGH and will fit within the existing LPGH footprint.

## Capital Costs

| | | Gas Membrane Option | | |
|---|---|---|---|---|
| Description | Cost Factors | Cost per unit | No. | Total Cost |
| **Equipment Costs** | | | | |
| Gas Membrane System | | $ 300,000 | 1 | $ 300,000 |
| **Equipment Total** | | | | **$ 300,000** |
| Demolition | | $ 100,000 | 1 | $ 100,000 |
| Concrete Pad | | $ 750 | 150 | $ 112,500 |
| Concrete Pile | | $ 14,000 | 20 | $ 280,000 |
| Misc Piping and Valves | | $ 100,000 | 1 | $ 100,000 |
| **Total** | | | | $ 892,500 |
| **Total Equipment Costs** | | | | **$ 892,500** |
| Installation - % of Equip Costs | 40% | | | $ 120,000 |
| **Total with Installation** | | | | **$ 1,012,500** |
| Electrical & I&C | 15% | | | $ 151,875 |
| Site Work | | | | $ 50,000 |
| **Total Capital Cost w/o markups** | | | | **$ 1,214,375** |
| Contractor Markups | 20% | | | $ 242,632 |
| General Requirements | 25% | | | $ 303,715 |
| Market Conditions | 15% | | | $ 181,913 |
| Contingencies | 35% | | | $ 616,253 |
| **Total Capital Cost w/markups** | | | | **$ 2,558,888** |

**EBMUD - PGS Reliability**

**Task 1: Option 3 - Higher Pressure Blower and Redundancy**

Description: Add redundant blower, increase capacity and pressure to 5 psig out of skid.
Replace existing gas blower, with unit with increased capacity and pressure to 5 psig out of skid.
Increase HEX capacity.
Separate HV and LV in panel.

## Capital Costs

| | | Modify Existing Gas Treatment | | | |
|---|---|---|---|---|---|
| Description | Cost Factors | Cost per unit | No. | | Total Cost |
| **Equipment Costs** | | | | | |
| Gas Blowers | | $ 300,000 | 2 | $ | 600,000 |
| New HEX | | $ 150,000 | 1 | $ | 150,000 |
| **Equipment Total** | | | | **$** | **750,000** |
| Demolition | | $ 2,000 | 1 | $ | 2,000 |
| Misc Piping and Valves | | $ 10,000 | 1 | $ | 10,000 |
| **Total** | | | | $ | 762,000 |
| **Total Equipment Costs** | | | | **$** | **762,000** |
| Installation - % of Equip Costs | 40% | | | $ | 300,000 |
| **Total with Installation** | | | | **$** | **1,062,000** |
| Electrical & I&C | 15% | | | $ | 159,300 |
| Site Work | 0% | | | $ | - |
| **Total Capital Cost w/o markups** | | | | **$** | **1,221,300** |
| Contractor Markups | 20% | | | $ | 244,260 |
| General Requirements | 25% | | | $ | 305,325 |
| Market Conditions | 15% | | | $ | 183,195 |
| Contingencies | 35% | | | $ | 619,810 |
| **Total Capital Cost w/markups** | | | | **$** | **2,573,890** |