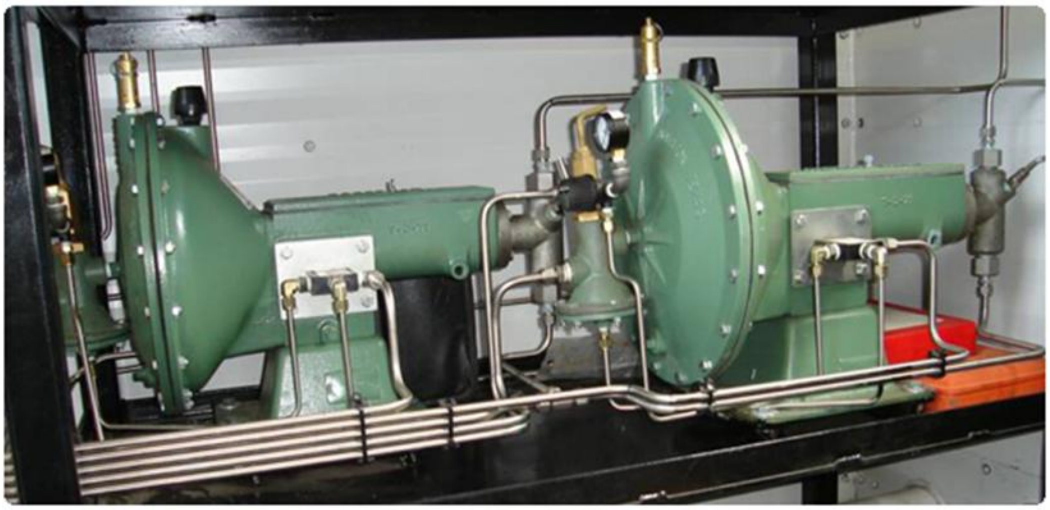
FUEL GAS BEST MANAGEMENT PRACTICES



Efficient Use Of Fuel Gas in Chemical Injection Pumps

MODULE 5 of 17

SUBMITTED BY: CETAC WEST

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sepac

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CETAC-WEST is a private sector, not-for-profit corporation with a mandate to encourage advancements in environmental and economic performance in Western Canada. The corporation has formed linkages between technology producers, industry experts, and industry associates to facilitate this process. Since 2000, CETAC-WEST has sponsored a highly successful eco-efficiency program aimed at reducing energy consumption in the Upstream Oil and Gas Industry.

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Background

The issue of fuel gas consumption is increasingly important to the oil and gas industry. The development of this Best Management Practice (BMP) Module is sponsored by the Canadian Association of Petroleum Producers (CAPP), the Gas Processing Association Canada (GPAC), the Alberta Department of Energy, Small Explorers and Producers Association of Canada (SEPAC) Natural Resources Canada (NRC) and the Energy Resources and Conservation Board (ERCB) to promote the efficient use of fuel gas in chemical injection pumps used in the upstream oil and gas sector. It is part of a series of 17 modules addressing fuel gas efficiency in a range of devices.

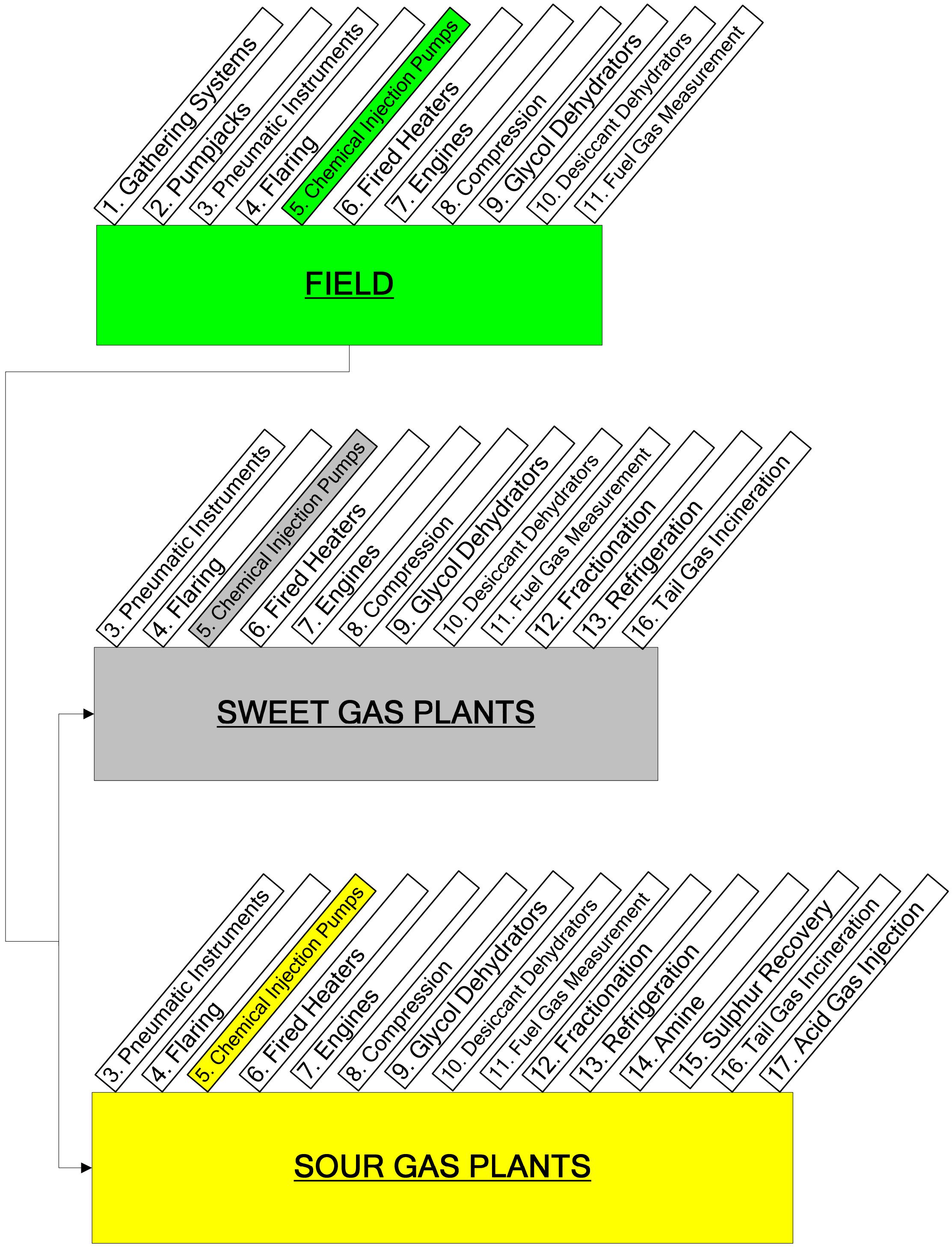
This BMP Module:

- identifies the typical impediments to achieving high levels of operating efficiency with respect to fuel gas consumption;
- presents strategies for achieving cost effective improvements through inspection, maintenance, operating practices and the replacement of underperforming components; and
- identifies technical considerations and limitations.

The aim is to provide practical guidance to operators for achieving fuel gas efficient operation while recognizing the specific requirements of individual chemical injection pumps and their service requirements.

EFFICIENT USE OF FUEL GAS IN THE UPSTREAM OIL AND GAS INDUSTRY

MODULE 5 of 17: Chemical Injection Pumps



1. Applicability and Objectives

Chemical injection pumps (CIPs) are used throughout the oil and gas industry. Their primary purpose is to inject relatively small amounts of chemicals into process streams to enable the production and processing of petroleum products. CIPs are used to inject de-emulsifiers, solvents, de-salting agents, corrosion inhibitors, biocides, clarifiers, scale inhibitors, hydrate inhibitors, paraffin dewaxers, surfactants, oxygen scavengers, and H2S scavengers into the oil or gas pipeline. In Canada the injection of methanol into the natural gas process to reduce or eliminate hydrates (freezing), which can cause blockage in the pipeline, is also a major application of CIPs.

Today the majority of chemical injection pumps in our industry are driven by fuel gas. Alternatives to using fuel gas as the power source are compressed air, AC electricity, or solar (DC) electricity.

The availability of pressurized fuel gas has made it a convenient source of energy making it the energy of choice for chemical injection. In spite of the cost of natural gas and air emissions, its use as an energy source for CIPs dominates for the following reasons:

- Pneumatic CIPs are readily available, and are easy to size and order.
- Pneumatic chemical injection pumps are simple in design, making it easy for field operators to adjust and repair.
- Most operators have considerable experience with pneumatic chemical injection pumps.
- The initial capital outlay for a pneumatic CIP is low relative to the electric alternatives. However the operating costs including fuel gas are much higher.
- Reliable electricity is not available or economical at many locations.
- Solar powered chemical injection pumps are newer to the market place and have not had enough time to make a significant impact.
- Conversion to air at larger facilities still requires a large output of capital and infrastructure change which usually deters any immediate action.

It is estimated that there are well over 1 million pneumatic powered chemical injection pumps operating in the oil and gas industry. The volume of products injected by these pumps ranges from one liter per day to several hundred liters per day. Depending on the injection rate and pressures an individual pump can consume several hundred dollars to well over $10,000 annually in methane. This gas has both an economical impact as well as an environmental impact.

Approximately 30% of pneumatic CIPs applications are sour gas wells which use bottled propane as the energy source to drive the pumps. Propane, like natural gas, adds to both the cost and environmental impact of these pumps. In many cases propane is much more costly than natural gas due to trucking and logistics.

Technology exists today to dramatically reduce or eliminate use of fuel gas from CIPs and at the same time have a positive economic impact on the oil and gas companies. In addition to the large economic benefits to addressing fuel gas use in pneumatic chemical pumps there are many side benefits including:

- reducing green house gas emissions,
- reducing odors,
- increasing worker safety,
- reducing fire hazards.

This document discusses the different types of chemical injection pumps, the resulting gas consumption from these devices, and field optimization to improve both the economics and environmental aspects of operating these pumps. The best management practices presented here are practical steps to minimize the amount of fuel gas use that occurs with pneumatic CIPs.

2. Basic Improvement Strategy

The critical factors to ensuring a successful long term strategy to optimize fuel gas consumption from field wide operations are 1) educate personnel to recognize opportunity, and 2) perform field optimization using logical steps. Efficient operation of chemical injection pumps require:

- database or list of chemical injection pumps in inventory,
- knowledge of chemical injection pumps typical bleed rates and alternatives,
- routine maintenance and repair of any problems, and
- implementing the most appropriate technology.

2.1 Technology and Equipment

When looking at the basic improvements to reduce fuel gas consumption it is imperative that there is an understanding of the CIP, its application, limitations and operational conditions that may affect its performance. This information provides the basis to perform an assessment on an individual chemical injection pump.

2.2 Efficiency Assessment and Improvements

In order to optimize the performance of CIPs, it is recommended that a program including the followings steps be implemented: field survey, field measurements, data review, economic/environmental evaluation and implementation process.

2.3 Personnel Training and Expertise

Chemical injection pumps are not complicated however they do perform a very important task which must be well understood. The basic assessment of the pump should be performed by someone with some background in instrumentation or by an experienced operator who understands chemical injection pumps.

3. Inspection, Monitoring and Record Keeping

Operators should have a record program to support the company's CIP improvement system. Proper record keeping should assist in ensuring that optimal options are identified and that appropriate follow-up actions are implemented.

Although each company will define its record keeping system, consideration should be given to recording and retaining the following information:

- number of chemical pumps used,
- data sheets for each type of CIP in the field,
- expected fuel gas consumption by each chemical pump,
- records of changes/upgrades that have been performed,
- any test results,
- any economic analysis performed on CIPs in the field, and
- MSDS and other data sheets for each type chemical being injected.

4. Rapid Assessment of Fuel Gas Consumption from Chemical Injection Pumps

4.1 Types of Chemical Injection Pumps

Chemical Injection Pumps can be divided into two principle categories: pneumatic (gas driven), or electric driven. These categories are critical when looking at the potential opportunity for reducing fuel gas use. Both types of pumps have their advantages and disadvantages. When making assessments for a new CIP it is important to understand the benefits and limitations to both technologies.

Pneumatic (Gas Driven) Chemical Injection Pumps

Pneumatic chemical injection pumps can be categorized as either piston type or diaphragm type. Both pneumatic pumps operate in the same manner, but use different reciprocating mechanisms to drive the chemical. By design the pumps take pressurized gas and use the energy of the gas to drive the pump. This results in gas at near atmospheric pressure which is subsequently vented. The two styles of pneumatic CIPs are simple in design and both can be converted to use compressed air as the drive mechanism instead of natural gas.

Piston Type Chemical Pumps

The piston style of chemical injection pump shown in Figure 1 is considered a positive displacement plunger type. It has a single acting head and is piston powered with a spring return. Gas supply pressure from 35-150 psi, depending on the injection pressure, is introduced to the pump in order to move the plunger the desired stroke length. This stroke length has a direct relationship to the amount of product being injected. At the end of the stroke vent port is opened allowing the supply gas to vent to atmosphere. The piston returns back to its starting position via a spring return mechanism. The process then repeats itself until the desired volume is reached.

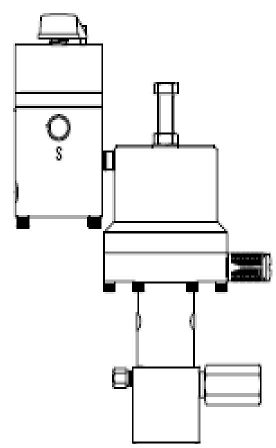


Figure 1 WellMark PIP Piston Pump

These pumps are constantly pumping; control of speed or rate of strokes per minute is accomplished by means of an external controller. Appendix A outlines the consumption of gas for a typical piston pump. This table will give an estimate for piston style pumps with the same plunger and piston sizes. The columns on the far right of the table show cost of gas to operate the pump on an annual basis. For more accurate values, similar tables can be developed for each specific brand of pump. The tables can be generated from data collected from the manufacturer similar to that shown in Appendix B and G. Actual field measurements are recommended and can be different than theoretical measurements.

Diaphragm Type Chemical Pumps

The diaphram CIP, shown in Figure 2 is also a positive displacement pump. It has a single acting head and is diaphragm powered. Gas pressure from 35-50psi, depending on the model of pump, is introduced to the diaphragm pump in order to move the plunger the desired stroke length. This stroke length has a direct relationship to the amount of product being injected. At the end of the stroke a trip mechanism is triggered on the diaphragm pump allowing full exhaust to atmosphere of the supply gas while returning the plunger back to its starting position via a spring return mechanism. The process then repeats itself until the desired volume is reached.

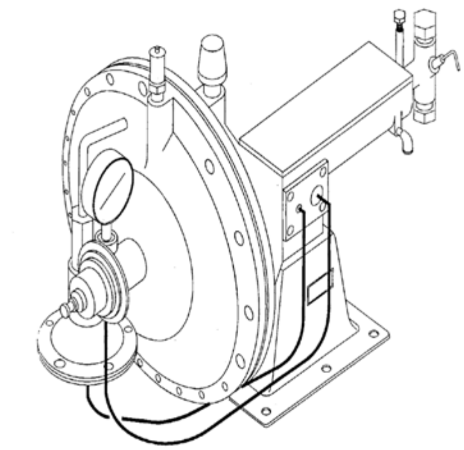


Figure 2 Texsteam Diaphragm Pump

Diaphragm pumps continuously pump: volume control is accomplished by regulating the exhaust gas discharge of the pump. A needle valve, located on the exhaust port of the pump is used to perform this function by controlling the number of strokes of the pump.

Appendix C shows two major manufacturers of diaphragm pumps and the natural gas consumption for models of various plunger diameters and stroke lengths. The column on the far right shows the gas consumption per liter of chemical for 100psi and 1,000psi injection pressures. Detailed data for cost of gas consumption for two common pump types can be found in Appendix D and E. These appendices are included as examples only. Accurate tables will need to be generated using data similar to that found in Appendix F and G which should be available from the pump manufacturer.

Electric Chemical Injection Pumps

Electric chemical injection pumps can be classified as either AC electricity or DC electricity. They are similar in pump design, both using a piston type drive mechanism, but the motors and power source are different. The advantage of electric pumps is that they do not vent gas.

AC (Alternating Current) Electric Chemical Injection Pumps

There are two types of AC electric pumps available for CIP applications: continuous injection pumps and time controlled intermittent injection pumps.

Continuous injection pumps have been in the market place a very long time and are well proven. An AC motor is connected to a gear box which in turn is connected to a fluid end assembly. Many gear turn down ratios are available allowing a wide variety of volume requirements to be realized.

On a time controlled intermittent injection pump, see Figure 3, the fluid end or the pump body is connected directly to the motor. The piston on the pump is moved back and forth by means of an eccentric cam assembly located on the motor shaft. The amount of product needed to flow over a 24 hour period is calculated and the timer is set to inject the fluid based on the pump running intermittently as required.

Figure 3 AC Pump (Sirius Instrumentation and Controls Inc.)

The time controlled intermittent injection pump and the gear driven continuous injection pump perform the same function. The time controlled pump uses less electricity and requires lower maintenance than the continuous drive pump, making it a more economical solution. The gear driven continuous injection pump however is able to pump larger volumes at higher pressures than the intermittent pumps.

DC (Direct Current) Electric Chemical Injection Pumps

In recent years technologies have been developed to address applications of electric pumps where AC power does not exist. Improvements to solar power technologies and the introduction of low power consumption motor/pump assemblies have led to the development of DC electric chemical injection pumps (Figure 4). These new pumps have allowed electric powered CIPs to operate in remote areas providing an environmental and sound economical alternative to the pneumatic chemical injection pumps in many applications.

Figure 4 DC Pump (Sirius Instrumentation and Controls Inc.)

4.2 Performance of Pneumatic Chemical Injection Pumps(CIPs)

The amount of fuel gas a pneumatic chemical injection pump uses is dependent on several factors, some we have control over after the pump is purchased and some we do not. The factors effecting fuel gas use rates in individual pumps are listed in the following sections. The discussion herein is centered on pneumatic chemical injection pumps as electric pumps do not vent gas.

It is important to be aware that not all manufacturers use the same standards to measure bleed rates in the laboratory and typically results in field applications will be higher.

Pump Design

Optimum performance of any CIP can be enhanced by sizing the pump according to the process conditions and the amount of chemical required. Figure 5 shows the effect of piston sizes (1/2" and 3/16"), and stroke length on gas consumption.

For example assume the volume and pressure requirements for a particular application could be met with either a 3/16" long stroke or a 3/16" short stroke pump. In using the long stroke pump the gas consumption would be reduced by 60% over the shorter stroke. Similarly if the injection pressure and volume requirements could be met using a ½" diameter plunger rather than a 3/16" plunger the gas consumed could be reduced by 80%.

The graph shows the importance of design in assuring that gas consumption is minimized. If a pneumatic pump is to be selected, choosing the smallest pump with the largest plunger diameter will achieve the least amount of emissions. Consulting the manufacturers specification sheet will help in establishing these criteria.

Frequency of operation is directly related to the amount of product being injected and the size of the plunger performing the operation. In many cases an increase in plunger size can decrease the frequency of operation without affecting the process. A decrease in frequency of operation will result in a direct decrease in fuel gas usage.

Tuning the injection flow to a process requires an understanding of the relationship between the chemical to be injected and the process requirements. Evaluation of the injection process and tuning should be conducted by an experienced operator, or chemical supplier.

Costs due to pumping may be reduced in some cases by ensuring that the rate of chemical injection is as required. Additional chemicals and lost fuel gas can be costly so it is advisable to consult your resident expert in chemical pumping to optimize the chemical quantity and frequency of chemical injection pumps.

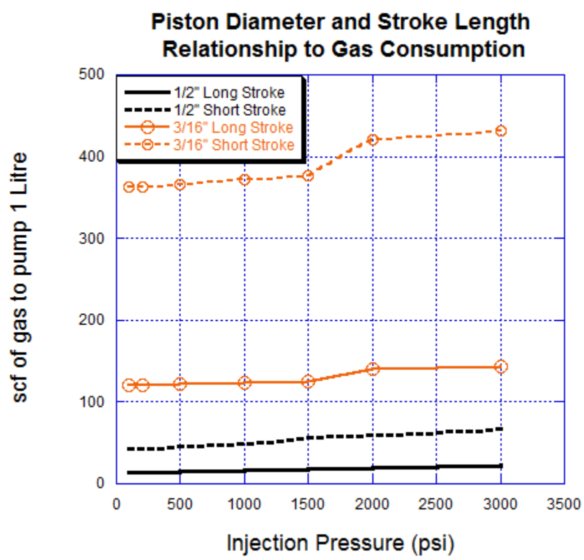


Figure 5
Frequency of Operation

Injection Pressure

In diaphragm and piston pumps, the higher the injection pressure the higher the gas consumption. Figure 6 shows the relationship between injection pressure and gas consumption for a Texsteam 5100 with a ½" diameter piston operating between 100 and 3,000 psi injection pressure. The gas consumption increases by 65% over this pressure range for both long and short stroke pistons.

It should be noted that DC powered electric pumps are limited in high pressure applications, due to both design and power limitations.

Pump Condition

Pump condition is an important factor in maintaining operations within design parameters. If a pump is not maintained properly, particles may enter the moving parts and impact the pumps operation, mostly in the form of general wear on the packing, pistons and switching valves. Pump inefficiencies may result from leaks or blockages and may develop into significant fuel losses. Typically inefficient pumps are sped up to maintain desired chemical flow which results in more fuel gas loss and subsequent costs.

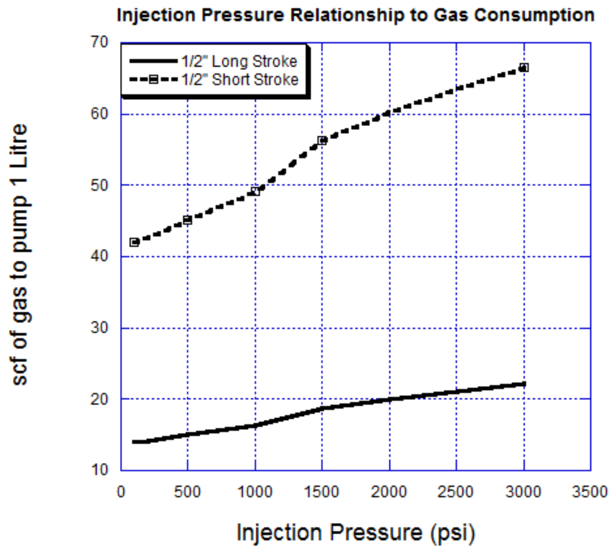


Figure 6
Injection Pressure Relationship to Gas Consumption

Pumps should be maintained periodically and replaced as necessary. Switching valves also cause significant fuel gas usage and should be replaced as soon as a leak is identified.

Gas Supply Pressure

Gas supply pressure depends on the style of pump being used. Smaller diaphragm pumps typically require 35psi for proper operation, while larger diaphragm pumps require approximately 50psi. Pumps operating at excess inlet pressure will bleed off gas and therefore should have the inlet gas tuned to the required operating pressure.

Piston pumps require fuel gas between 35 to 150psi depending on the injection pressure required. The inlet pressure acts on the small surface area of the piston to achieve a larger outlet pressure. The higher the injection pressure the higher the supply pressure. Like diaphragm pumps an excess in inlet pressure over that required will result in unnecessary fuel gas use.

Overview

If the use of fuel gas in CIPs cannot be eliminated, saving can be accomplished by recognizing the resources available and optimizing the instruments accordingly. Proper design, operation and maintenance will help to match the needs of your process and minimize the use of fuel gas. The following points are a synopsis of the topics above:

- Size CIPs according to the injection pressure and volume.

- Optimize CIP design by increasing the stroke and diameter of the pump to minimize frequency.
- Ensure pump injection pressures are as required.
- Perform frequent maintenance and inspection programs to prevent leaks.
- Ensure pumps have specified fuel gas supply pressure.

5. Operational Checks Testing and Adjustments

In order to optimize the performance of pneumatic chemical pumps, it is recommended that a program including the followings steps be implemented:

- Conduct a comprehensive field survey.
- Undertake field measurements to establish vent rates.
- Data review to identify opportunities for improvement.
- Perform economic/environmental evaluation of options.
- Implementation of preferred options.

Field Survey

In order to determine what the opportunity in any field or operation may be, the first step is to understand what CIPs are currently in place. The most efficient method to perform this task is to assign a person familiar with the field and CIPs to complete a table similar to that outlined below. The table should allow additional room for notes as shown in Appendix H. Keeping the table short and concise allows the operator to be efficient during the field survey process. The task should be focused on getting all the correct information as efficiently as possible.

LSD	Facility Desc.	Electricity Available	Manufacturer	Pump Model	Pump Type	Diameter	Supply Pressure	Condition	Gas Type	Injection Pressure	Injection Rate

LSD - This is the location number, LSD (Land Survey Description).

Facility Description - Facility Description, type of facility, wellsite, metering station, plant, separator, etc.

Electricity Available - This is an important factor to understand if there is any potential for converting pneumatic pumps to electricity.

Manufacturer - Is the manufacturer of the chemical pump, should be located on the identification plate.

Pump Model - This is also located on the identification plate.

Pump Type - Type of chemical injector.

Diameter - For a diaphragm pump enter the plunger diameter, for piston pumps enter both piston and plunger diameters.

Supply Pressure - If there is a gauge downstream of the regulator read the supply pressure here, chemical injectors can have supply pressures anywhere from 35 PSI to 90 PSI depending on the type and application.

Condition - This is the condition of the chemical pump and should be indicated by either: good or poor.

- Good - clean, no visible signs of wear and tear, operating properly, no irregular sound or feel due to excessive venting of gas.
- Poor - any signs of wear and tear, dirty. Constant venting of the switching valve. Fluid leaks in the diaphragm housing.

Gas Type - This will be typically either be fuel gas, propane, or air,

Injection Pressure - The process pressure which the chemical is being injected, ensure the units are recorded.

Injection rate - A field measurement may be required. Ensure the units are recorded.

Field Measurements

The most accurate information for quantifying gas consumption rates from CIPs are field measurements, however, this data is not always available. Appendices A, D, and E give basic gas consumption per liter of chemical pumped for various types of pumps. The basic gas consumption rates identified are only a guideline for specific pumps at specific injection pressures. It is recommended that field tests be taken where ever possible to confirm the fuel gas usage of CIPs. Pump suppliers may also be able to generate tables similar to those in the appendix that cover the injection pressures, pump sizes and stroke lengths applicable.

If there is no field data for your particular chemical pump and you have a significant number of these devices, then you should perform field measurements to obtain accurate data. Statistical methods can be applied to ensure that a representative sample is taken. Vent gas from chemical pumps does not necessarily leave the pump through the exhaust line. In some cases the chemical pump will be leaking gas through diaphragm housing or through fittings attached to the switching valve. To ensure that all of the gas vented is measured, the chemical pump will need to be bagged. A plastic bag encloses the pump and is taped tightly around a piece of plastic tubing. The tubing is attached to an accurate meter designed to measures flow rates in the range of the pump. The meter should be attached to the tubing line from the bag and the fittings “snooped” to ensure no leaks are present. The total flow should be measured over as long a time as practical (at least one hour) to ensure accuracy of the data. A longer measurement time will give a more representative measure of any flow rate fluctuations. The data should then be converted to standard conditions of pressure and temperature and presented in terms of scf/hr.

Data Review

After the survey is complete the data needs to be reviewed to asses the opportunity for reducing fuel gas use. For each pump the vent rates will need to be understood from either field measurements or from manufacturer data. If using manufacturer data it will be beneficial to generate tables similar to those in Appendix A, D, and E**.** If there is no manufacturer’s data available field measurements should be performed. Note, physically measuring all pump consumption rates is impractical and should be avoided.

To begin the assessment of the field data refer to the logic diagram in Appendix I. The first step in the logic diagram is to determine if AC power is available. If it is and compressed air is also available then the pneumatic pumps should be converted to compressed air. If AC power is available but compressed air is not then the next step would be to determine the feasibility of converting all chemical pumps to compressed air. Traditionally economics drive this decision in larger facilities where additional air is required and safety is a concern. Electric pumps are also an option when considering the conversion. DC power may also be an alternative for powering pumps; however, DC power has some restrictions on pumping volume and pressure that must be taken into consideration.

Understanding the gas consumption of the chemical pumps, and the applicability of electric alternatives is critical in assessing the opportunity for savings. By referring to the logic diagram in Appendix I, the collected field data, and operations personnel, complete assessment of each device can be achieved.

Economic/Environmental Evaluation

In completing a thorough review of the field survey data, an understanding of where the opportunities are and any additional field measurements is required. Assessment of field data should allow the development of a list to track what pumps need to be replaced, resized or repaired.

The primary driver is almost always economics. Economic benefits are calculated based on the reduction in gas consumption from the replacement with either: compressed air, AC electric or a DC solar powered option.

The reduction in fuel gas can be defined as:

$$S = (scfh)_{old} \times 8{,}760 hr/yr \times P/1000$$

S = Savings in Canadian dollars for each year after installing the new device. Savings do not include the cost of replacement equipment or the additional savings from potential carbon credits.

$(scfh)_{old}$ = Fuel gas use rate of existing device in standard cubic feet per hour.

P = Price of gas in Canadian dollars per thousand standard cubic feet.

$$Payout = (C_{new})/S$$

Payout = Time in years to pay for the project

C_{new} = Cost of the new project

Field experience has demonstrated that there are other benefits related to fuel gas savings including:

- reducing environmental impacts due to reduced greenhouse gas release,
- improving worker safety and reducing the risk of fire hazards.

Repair or Replacement

During the field study and data review there will be many pumps which require maintenance and repair. Prior to proceeding with maintenance or repair it is recommended that the assessment of the CIPs is complete. Having an understanding of the requirements for the larger group of CIPs will aid in determining the most appropriate method to replace and or repair deficient pumps.

Implementation

After identifying the pneumatic devices that can be profitably replaced, retrofitted or maintained, devise a systematic plan for implementing the required changes. This can include modifying the current inspection and maintenance schedule and prioritizing replacement or retrofits. At this stage everything should be outlined and ready to move forward to obtain the savings. It may be most cost-effective to replace all those devices that meet the technical and economic criteria of your analysis at one time to minimize labor costs and disruption of operation.

Appendix A
Piston Chemical Pump Gas Consumption Cost Analysis

Linc 84T-10,11,12,14 Series Pneumatic Piston Pumps

Cost of operation assumes natural gas CDN $6per 1000 scf

Model	Plunger Diameter	Piston Diameter	Strokes Per Minute	Liters per Day	scf required per liter @ 50 psi supply	scf required per liter @ 100 psi supply	scf required per liter @ 150 psi supply	scf per day @ 50 psi supply	scf per day @ 100 psi supply	scf per day @ 150 psi supply	cost of gas per year @ 50 psi supply	cost of gas per year @ 100 psi supply	cost of gas per year @ 150 psi supply
84T-10	3/16"	2 1/4"	4	0.5	30	53	75	15	26	37	$ 32	$ 57	$ 81
			10	1.2	30	53	75	36	65	92	$ 80	$ 142	$ 202
			20	2.4	30	53	75	73	130	184	$ 159	$ 284	$ 404
			30	3.7	30	53	75	109	194	276	$ 239	$ 426	$ 605
			40	4.9	30	53	75	145	259	369	$ 318	$ 568	$ 807
			50	6.1	30	53	75	182	324	461	$ 398	$ 710	$ 1,009
			60	7.3	30	53	75	218	389	553	$ 478	$ 851	$ 1,211
84T-11	1/4"	2 1/4"	4	1.2	30	53	75	34	61	87	$ 75	$ 134	$ 190
			10	2.9	30	53	75	86	152	217	$ 187	$ 334	$ 475
			20	5.8	30	53	75	171	305	434	$ 375	$ 668	$ 950
			30	8.6	30	53	75	257	457	651	$ 562	$ 1,002	$ 1,425
			40	11.5	30	53	75	342	610	867	$ 749	$ 1,336	$ 1,899
			50	14.4	30	53	75	428	762	1,084	$ 937	$ 1,670	$ 2,374
			60	17.3	30	53	75	513	915	1,301	$ 1,124	$ 2,003	$ 2,849
		3"	4	1.2	53	94	134	61	108	155	$ 134	$ 237	$ 338
			10	2.9	53	94	134	152	270	386	$ 334	$ 592	$ 846
			20	5.8	53	94	134	305	540	773	$ 668	$ 1,183	$ 1,692
			30	8.6	53	94	134	457	811	1,159	$ 1,002	$ 1,775	$ 2,538
			40	11.5	53	94	134	610	1,081	1,545	$ 1,336	$ 2,367	$ 3,384
			50	14.4	53	94	134	762	1,351	1,931	$ 1,670	$ 2,959	$ 4,230
84T-12	1/2"	3"	4	4.6	53	94	134	244	432	617	$ 533	$ 945	$ 1,351
			10	11.5	53	94	134	610	1,081	1,545	$ 1,336	$ 2,367	$ 3,384
			20	23.0	53	94	134	1,220	2,162	3,090	$ 2,671	$ 4,734	$ 6,767
			30	34.6	53	94	134	1,830	3,242	4,635	$ 4,007	$ 7,101	$ 10,151
			40	46.1	53	94	134	2,439	4,323	6,180	$ 5,342	$ 9,468	$ 13,535
			50	57.6	53	94	134	3,049	5,404	7,725	$ 6,678	$ 11,835	$ 16,918
		4"	4	4.6	94	167	240	433	767	1,103	$ 948	$ 1,680	$ 2,415
			10	11.5	94	167	240	1,084	1,921	2,761	$ 2,374	$ 4,207	$ 6,047
			20	23.0	94	167	240	2,168	3,842	5,523	$ 4,749	$ 8,414	$ 12,095
			30	34.6	94	167	240	3,252	5,763	8,284	$ 7,123	$ 12,621	$ 18,142
84T-14	1"	4"	4	18.4	94	167	240	1,735	3,074	4,418	$ 3,799	$ 6,731	$ 9,676
			10	46.1	94	167	240	4,337	7,684	11,045	$ 9,497	$ 16,829	$ 24,189
			20	92.2	94	167	240	8,673	15,369	22,091	$ 18,994	$ 33,657	$ 48,379
			25	115.2	94	167	240	10,841	19,211	27,613	$ 23,743	$ 42,072	$ 60,473

Appendix B
Piston Chemical Pump Selection Chart

The LINC 84T-10, 11, 12 & 14 Series: Pneumatic, Plunger-Type Metering Pump Selection Chart

Model Number	Plunger Diameter	Piston Diameter	Maximum Rate Gal/Hr	Maximum Rate Liter/Hr	Minimum Rate Gal/Hr	Minimum Rate Liter/Hr	Maximum Pressure psi *	Maximum Pressure bar	Amp. Ratio	Strokes Per minute	Volume Per Stroke cc	Stroke Lengt h
3/16” Plunger with Timer												
84T-10x1	3/16”	2¼”	0.32	1.21	0.002	0.015	10,000	689	125:1	4 – 60	0.34	1”
¼” Plunger with Timer												
84T-11x1	¼”	2¼”	0.76	2.88	0.01	0.038	6,370	439	75:1	4 – 60	0.80	1”
84T-11x2	¼”	3”	0.64	2.42	0.01	0.038	10,000	689	120:1	4 – 50	0.80	1”
½” Plunger with Timer												
84T-12x2	½”	3”	2.5	9.5	0.03	0.10	2,550	176	30:1	4 – 50	3.2	1”
84T-12x4	½”	4”	1.5	5.7	0.03	1.10	5,100	352	60:1	4 – 30	3.2	1”
1” Plunger with Timer												
84T-14x4	1”	4”	5.1	19.3	0.20	0.77	1,190	82	14:1	4 – 25	12.8	1”

* Maximum pressure based on 100 psi supply pressure

Appendix C
Pump Manufacturers' Data for Diaphragm Pumps

Manufacturer Model	Plunger Diameter, in	Stroke Length, in.	* Natural Gas Consumption scf/l
Western Chemical Pump Inc	⅜ ⅝	⅞ ⅞	28-32 11-15
Texsteam Series 5000	¼ ⅜ ½ ¾ 1 1 ¼	½,1 ¼ ½,1 ¼ ½,1 ¼ ½,1 ¼ ½,1 ¼ ½,1 ¼	74-200 37-97 21-56 10-31 6-16 4-12
Texsteam Series 5100	⅛ ¼ ⅜ ½	⅓,1 ⅓,1 ⅓,1 ⅓,1	121-372 65-214 32-130 14-49

* Range of consumption is for injection pressures between 100 and 1,000 psi.

Appendix D
Texsteam 5100 Series Gas Consumption Cost Analysis

Piston size	Strokes per minute	Liters of methanol per day	Scf required per liter	Scf per day	Cost of Gas Per Day	Cost of Gas Per Year
3/16"	6	8	122	924	$ 6	$ 2,024
	12	9	122	1155	$ 7	$ 2,529
	18	11	122	1386	$ 8	$ 3,035
	24	13	122	1617	$ 10	$ 3,541
	30	17	122	2079	$ 12	$ 4,553
1/4"	6	8	66	546	$ 3	$ 1,195
	12	11	66	744	$ 4	$ 1,629
	18	17	66	1116	$ 7	$ 2,444
	24	23	66	1488	$ 9	$ 3,259
	30	26	66	1736	$ 10	$ 3,802
3/8"	6	11	39	444	$ 3	$ 972
	12	23	39	888	$ 5	$ 1,945
	18	38	39	1480	$ 9	$ 3,241
	24	53	39	2072	$ 12	$ 4,538
	30	62	39	2442	$ 15	$ 5,348
1/2"	6	23	15	342	$ 2	$ 749
	12	47	15	713	$ 4	$ 1,560
	18	68	15	1026	$ 6	$ 2,247
	24	91	15	1368	$ 8	$ 2,996
	30	114	15	1710	$ 10	$ 3,745

Cost of Operation assumes natural gas price of CDN $6 per 1000 scf
Calculations done for 500 psi injection pressure

Appendix E
Texsteam 5000 Series Gas Consumption Cost Analysis

Piston size	Strokes per minute	Liters of methanol per day	scf per Liter	scf per day	cost of gas per day	cost of gas per year
1/4"	10	19	74	1400	$ 8	$ 3,066
	20	26	74	1960	$ 12	$ 4,292
	30	38	74	2800	$ 17	$ 6,132
	40	45	74	3360	$ 20	$ 7,358
	50	57	74	4200	$ 25	$ 9,198
	60	68	74	5040	$ 30	$ 11,038
3/8"	10	30	37	1120	$ 7	$ 2,453
	20	68	37	2520	$ 15	$ 5,519
	30	83	37	3080	$ 18	$ 6,745
	40	114	37	4200	$ 25	$ 9,198
	50	148	37	5460	$ 33	$ 11,957
	60	170	37	6300	$ 38	$ 13,797
1/2"	10	64	21	1370	$ 8	$ 3,001
	20	114	21	2418	$ 15	$ 5,295
	30	163	21	3466	$ 21	$ 7,590
	40	220	21	4675	$ 28	$ 10,238
	50	269	21	5723	$ 34	$ 12,532
	60	326	21	6932	$ 42	$ 15,180
3/4"	10	114	10	1080	$ 6	$ 2,365
	20	193	10	1836	$ 11	$ 4,021
	30	288	10	2736	$ 16	$ 5,992
	40	348	10	3312	$ 20	$ 7,253
	50	454	10	4320	$ 26	$ 9,461
	60	492	10	4680	$ 28	$ 10,249

Cost of Operation assumes natural gas price of CDN $6 per 1000 scf
Calculations done for 50 psi injection pressure

Appendix F
Gas Consumption Charts

Texsteam 5100 Pump

Gas Consumption Chart (Standard Cubic Feet of Gas Required to Pump One Gallon)

For inlet regulator sizing double the requirement indicated

INJECTION PRESS. IN PSI		100	200	500	1000	1500	2000	3000	3500	4000	5000	6000
½" Plunger 1" Stroke	5105	53	54	57	62	71	76	84	95			
½" Plunger ⅓" Stroke		159	162	171	186	213	228	252	285			
⅜" Plunger 1" Stroke	5103	120	126	148	164	177	185	243	278	314	355	374
⅜" Plunger ⅓" Stroke		360	378	444	492	531	555	729	834	942	1055	1122
¼" Plunger 1" Stroke	5101	244	245	248	270	288	308	340	355	369	405	497
¼" Plunger ⅓" Stroke		732	735	744	810	864	924	1020	1065	1107	1215	1491
3/16" Plunger 1" Stroke	5104	457	458	462	469	476	530	545	555	560	575	589
3/16" Plunger ⅓" Stroke		1371	1374	1386	1407	1428	1590	1635	1665	1680	1725	1776

Texsteam 5000 Pump

Gas Consumption Chart (Standard Cubic Feet of Gas Required to Pump One Gallon)

For inlet regulator sizing double the requirement indicated

INJECTION PRESS. IN PSI		50	100	150	200	250	300	400	500	600	700	800	900	1000	1500	2000	3000	3500	4000	5000	600	7000	8000	9000	10000
¼" Piston Long Stoke	5002	280	281.2	282.4	283.6	284.8	286	289	292	294.6	297.2	300	303	306	318	330	356	368	380	404	428	452	476	500	522
¼" Piston Short Stroke		700	703	706	707	709	712	720	724	731	737	741	748	756	779	802	854	872	897	937	984	1017	1057	1090	1122
?" Piston Long Stoke	5003	140	140.6	141.2	141.8	142.4	143.0	144.5	146	147.3	148.8	150	151.5	153	159	165	178	184	190	202	214	226	238	250	262
?" Piston Short Stroke		355	355.6	356.2	356.8	357.4	358.0	359.5	361	362.3	363.6	365	366.5	368	374	380	393	399	405	417	429	441	453	465	477
½" Piston Long Stoke	5005	80.6	81.2	81.8	82.4	83	83.6	84.8	86	87.2	88.4	89.6	90.8	92	98	104	116	122	128	140	152	164	176	188	200
½" Piston Short Stroke		200.6	201.1	201.8	202.4	203	203.6	204.8	206	207	208.4	209.6	210.8	212	218	224	236	242	248	260	272	284	296	308	320
¾" Piston Long Stoke	5004	36	37	38	39	40	41	43	45	47.3	49.4	51.3	52.8	55.6	66	76.2	97	107	114	121					
¾" Piston Short Stroke		89	91	92	94	95	96	99	101	105	109	111	113	117	132	145	172	183	190	191					
1" Piston Long Stoke	5006	20.6	21.2	21.8	22.4	23	23.6	24.8	26	27.2	28.4	29.6	30.8	32	38	44	56	62							
1" Piston Short Stroke		50.6	51.2	51.8	52.4	53	53.6	54.8	56	57.2	58.4	59.6	60.8	62	68	74	86								
1¼" Piston Long Stoke	5007	13.6	14.2	14.8	15.4	16	16.6	17.8	19	20.2	21.4	22.6	23.8	25	31	37	49								
1¼" Piston Short Stroke		32.6	33.2	33.8	34.4	35	35.6	36.8	38	39.2	40.4	41.6	42.8	44	50	56									

Appendix G
Theoretical Gas Consumption for Piston Pumps

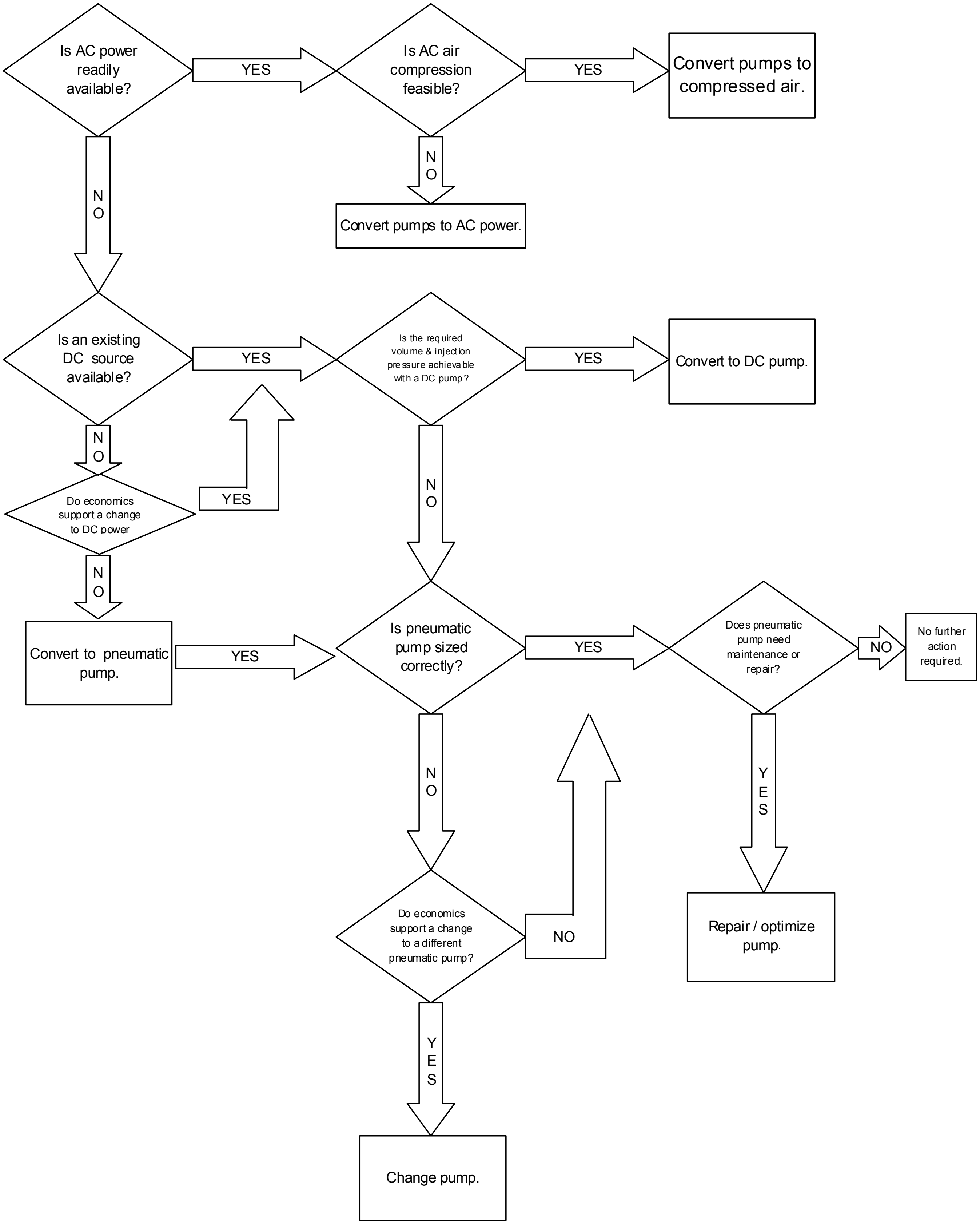
ACTUATION PISTON DIA. (IN)>>	1.50	2.25	3	4	4	4	6	8	10
>> CONFIGURATION >>	SPRING RETURN NO RELAY	SPRING RETURN NO RELAY	SPRING RETURN NO RELAY	SPRING RETURN NO RELAY	SPRING RETURN INCLUDING RELAY	GAS RETURN INCLUDING RELAY	GAS RETURN INCLUDING RELAY	GAS RETURN INCLUDING RELAY	GAS RETURN INCLUDING RELAY
SUPPLY PRESS. (PSI)	VOLUME DISPLACED BY PISTON FOR 1" STROKE(CUBIC FEET)								
	0.00102265	0.00230097	0.00409062	0.00727221	0.00727221	0.01454441	0.03272492	0.05817764	0.09090257
	THEORETICAL GAS CONSUMPTION FOR EACH 1" STROKE (SCF)								
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0017	0.0039	0.0069	0.0122	0.0122	0.0244	0.0550	0.0978	0.1527
20	0.0024	0.0054	0.0097	0.0172	0.0172	0.0343	0.0772	0.1373	0.2146
30	0.0031	0.0070	0.0124	0.0221	0.0221	0.0442	0.0995	0.1769	0.2764
40	0.0038	0.0086	0.0152	0.0271	0.0271	0.0541	0.1218	0.2165	0.3383
50	0.0045	0.0101	0.0180	0.0320	0.0320	0.0640	0.1440	0.2561	0.4001
60	0.0052	0.0117	0.0208	0.0370	0.0370	0.0739	0.1663	0.2956	0.4619
70	0.0059	0.0133	0.0236	0.0419	0.0419	0.0838	0.1886	0.3352	0.5238
80	0.0066	0.0148	0.0264	0.0468	0.0468	0.0937	0.2108	0.3748	0.5856
90	0.0073	0.0164	0.0291	0.0518	0.0518	0.1036	0.2331	0.4144	0.6474
100	0.0080	0.0180	0.0319	0.0567	0.0567	0.1135	0.2553	0.4539	0.7093
110	0.0087	0.0195	0.0347	0.0617	0.0617	0.1234	0.2776	0.4935	0.7711
120	0.0094	0.0211	0.0375	0.0666	0.0666	0.1333	0.2999	0.5331	0.8330
130	0.0101	0.0226	0.0403	0.0716	0.0716	0.1432	0.3221	0.5727	0.8948
140	0.0108	0.0242	0.0430	0.0765	0.0765	0.1531	0.3444	0.6123	0.9566
150	0.0115	0.0258	0.0458	0.0815	0.0815	0.1630	0.3667	0.6518	1.0185

Appendix H

Field Survey

LSD	Facility Desc.	Electricity Available?	Manufacturer	Pump Model	Pump Type	Diameter	Supply Pressure	Condition	Gas Type	Injection Pressure	Injection Rate	Notes

Appendix I
Logic Diagram



Appendix J
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