Borden Compressed Air Decentralization

Milestone 5

Project Evaluation, Monitoring, and Knowledge Sharing

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Newmont
PORCUPINE

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1.0 Project Background

Borden Mine is an underground mine at Chapleau township and produce around 300,000 tonnes of ore per month. There is no processing plant or tailings storage facility at the site and ore is transferred to the Dome site in Timmins. The operation is planned to operate 365 days per year on a 24-hour basis. The mine operation is not a steady state operation such as typical of a manufacturing plant, but changes continually as the mine expands deeper (up to 800 m expected) and laterally over the projected 15 year life of the mine.

Compressed air for underground mining operations is typically supplied by a large surface compressed air plant, distributed through a pipe network and used for air-powered mining equipment in the workplace. It is also regarded as a secondary source of oxygen in case of an emergency. It is not uncommon for existing underground mines to have tens of kilometers of distribution piping as it continuously expands as the mine grows.

Borden mine installed a high-efficiency compressed air (CA) system to reduce energy (electricity) consumption. There are two basic mechanisms for achieving electrical energy savings:

1. Elimination of CA leakage and pipe frictional losses associated with the centralized system, which can be onboard compressor or a distributed system typically with around 50 meters of connecting piping between distributed compressors and end-uses. Compared to the baseline system design of over 10,000 meters of piping, the new system is considered to effectively zero leakage and distribution frictional losses.
2. Shifting some end-uses from CA-powered to electric-powered. The most significant end-use switch are “face pumps” which perform dewatering in the mine. Each pump is sized with a 30 hp electric motor

Further details on the baseline and efficient systems are provided in the sections below

2.0 Project Milestones

2.1 Baseline and Measurement and Verification Plan Development

The M&V plan includes followings:

- Establish Measurement and verification plan following the IPMVP

  The M&V method to be applied to this project is best described as a hybrid of Option B, retrofit isolation, and Option D, calibrated simulation. The reason for this hybrid approach is that the baseline system is hypothetical in that it is the less efficient CA system that will never be built. As such, the baseline energy can only be determined through engineering calculations. Engineering calculations or simulation is the defining quality of an Option D method. The as-built efficient CA system is to be metered with individual meters on all significant equipment, which is defined as an Option B approach. Therefore, the overall method is best described as a hybrid of IPMVP Options B and D. The basic M&V equation will apply:

  Energy savings [kWh/yr] = Baseline Energy [kWh/yr] – Reporting Period Energy [kWh/yr] +/- Adjustments [kWh/yr]

- Establish baseline model: Developing a baseline and a measurement and verification plan will provide the base to determine after project completion what the project energy savings are. It will enable performing the post-mortem evaluation by ensuring all the right input parameters are measured and stored. A consultant will be retained to complete this work and will be reviewed and approved by IESO.

- Procure, install, and configure energy data acquisition equipment on the compressors: All vehicles (bolter, jumbo, drills) have an onboard compressor and either actual kw or working hour of onboard compressor is recorded on MySandvik/Optimine software.

  Decentralized compressor (as booster) for long hole drill has been equipped with a meter (totalizer).

  Night (9) data loggers is purchased and installed on the 8 dewatering electric pump boxes and Booster compressor.

  Selected data logger: AEMC PEL103

  with 3 x MA193-10-BK Sensors

2.2 Procure and install fixed infrastructure equipment for emergency response in a mine without a central compressed air plant

This milestone is to procure the “fixed” infrastructure for emergency response measures. The equipment includes all the pieces of the strategy that are not carried by personnel. This equipment needs to be brought in as the operation expands towards commercial production.

7 Drager refuge shelter (station) were purchased. All commissioned in underground and working well. Supplier is Drager.

We purchase 1 unit fitting 8 people and
we purchase 6 more units, fitting 16 people good for 72 hours.

The Dräger refuge shelter is constructed using structural 4x4 square tube and is completely seal welded. All penetrations for electrical connections are managed with transition plates made with ¾” couplings where commercial cord grips are used to maintain the sealed environment.
The sturdy design meets the requirements of the harsh environments in tunnelling and mining. The floor is also seal welded and equipped with 3/16” raised coin floor matting throughout the shelter.

Below are two links explain about product detail and operation:
https://www.youtube.com/watch?v=Og5FbJiXhbk&ab_channel=Dr%C3%A4gerGlobal

https://www.youtube.com/watch?v=atPmP-egE7w&ab_channel=JavelinTechnologiesInc.%7CATriMechCompany

Total of 8 Cache (storage) units were purchased, 4 SCBA Cache and 4 Pas Colt Cache to store SCBAs and Pas Colt apparatuses. Each Cache stores 10 apparatuses. With having 4 SCBA Cache units, we stored 40 SCBA units.

Cache units are installed between refuge stations.

Miners had to carry Pas Colt units with themselves before going to underground. However, there were extra Pas Colts in caches in case of emergency.

From 2020 all SCBAs and Pas Colt were replaced by OXY 3000 and OXY 6000. The Cache units are currently used for storing OXY 6000.

One Charge station were purchased, located in underground for charging SCBAs. One decentralized charger (compressor) were purchased at the surface for charging Pas Colt (later Saver). The need of air charger units was eliminated after replacement of all SCBAs/Pas Colt with OXY 6000 (see milestone 3 for details).

Dräger Charge Air D5 SCBA Refill Station:

The Dräger Charge Air is a pneumatic SCBA refilling system that is stored at approved locations underground. Each Charge Air filling station contains banks of cylinders that are used to store compressed breathing air at a pressure of 6000psi. These stations refill an SCBA from 0 to 4,500psi in as little as 50 seconds.
The refill stations are designed to remain pressurized while underground, which makes it ready to use at any moment. A miner can refill a SCBA by opening the main pressure valve on the control panel. This instantaneously charges all the refill lines with 4500 psi of breathing air. As soon as the valve is open, the miner can attach the refill line to the SCBA's quick connect refill port. As soon as the lines are connected, the Charge Air will instantly begin recharging the SCBA cylinder. The filling station will automatically stop once the cylinder pressure reaches 4500 psi.

Click here for more information about Charge air system.

2.3 Purchase and develop a policy to procure personal self-rescue devices and train and onboard newemployees

This milestone is to procure sufficient personal self-rescue devices to outfit everyone at Borden, including all training activities as well as developing a standard procedure related to training and retraining on existing employees are well as onboarding of new employees at Borden.

We started purchasing self-rescue equipment from 2017 as we opened Borden mine. There had been trials, experiments and transitions from initial idea of using air charging self-rescue equipment (Pas-Colt for few minutes / SCBA bigger units good for 1 hr) to oxygen generating Self-Contained Self-Rescue (SCSR) apparatuses which is explained below:

1) 2017-2019: Pas Colt – SCBA :
   The original plan was to equip miners with Pas-Colt self-rescue units (short term breathing apparatus, good for 10 minutes) in case of emergency and smoke. Miners had carry Pas Colt (which was in a special bag) as they start their shift:

Figure 1- Pas Colt in the bag.

In case of smoke/emergency, they could open up the bag and wear the Pas Colt, which had air for 10 minutes / walk for around 300 meters to reach SCBA Cache (storage unit).

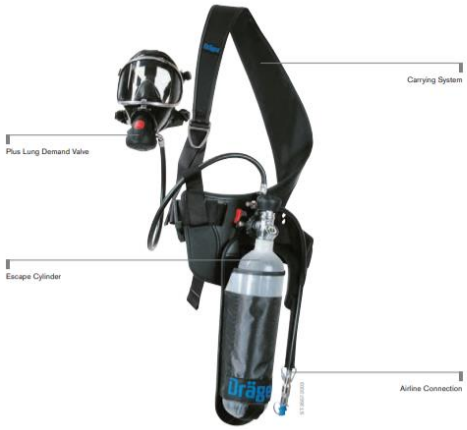


Figure 2- Pas Colt unit.

SCBA Cache unit are located between refuge shelters. At SCBA Cache miners had to exchange Pas Colt lung demand valve to SCBA unit. With SCBA units they could have air for 1 hour, long enough to access refuge shelter.

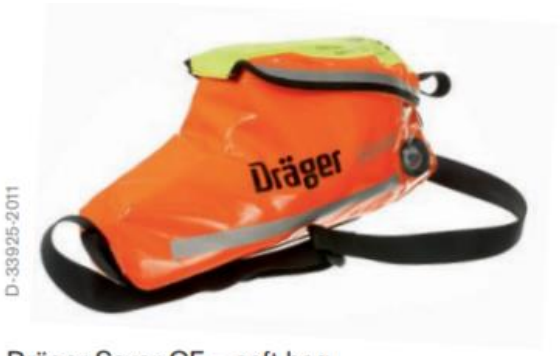
SCBA model are PSS-3000: Click here for more information and product detail.

Pas-Colt QTY: 40
PSS-3000 SCBA QTY: 44

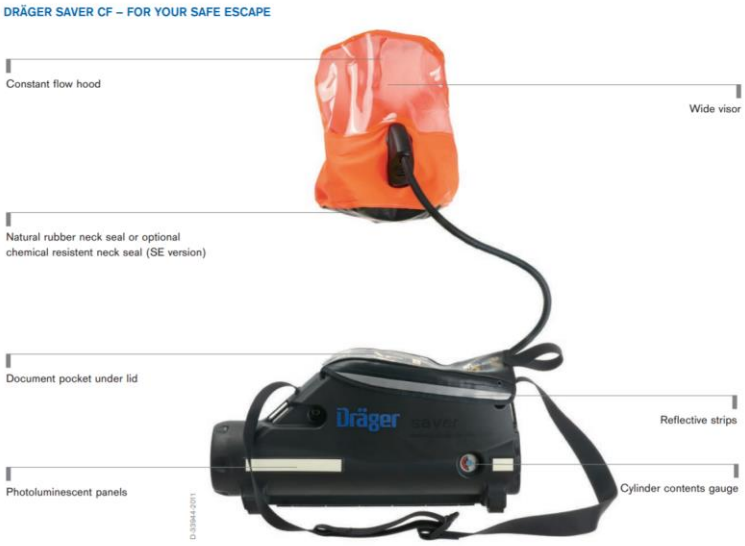
2) 2019-2020: Saver – SCBA:
Pas Colt usage became challenging for the below reasons and replaced with Saver:

i. Duration: it was found that 10 minutes of air was not sufficient to make to the SCBA Cache. During emergency trials some people were out of air before reaching the cache units.
ii. Clean shave: to wear Pas Colt units, people had to be clean shaved to make sure that it is sealed properly. It was challenging to keep every one at site cleaned shaved.
iii. Complexity: there had been a lot of effort for proper training. However, the procedure of switching Pas Colt to SCBA was founded to be complex for miners and confidence level of using Pas Colt were low since it was a new practice at gold mines.

Pas Colt was replaced with Saver unit which was A) sufficient for 15 minutes (comparing Pas Colt good for 10 minutes). Walk out trial increased from 300 meter with Pas Colt to 600 meter with Saver. B) Saver was a neck seal vs Pas Colt which was a mouth seal. Consequently, people did not need to be a clean shaved.



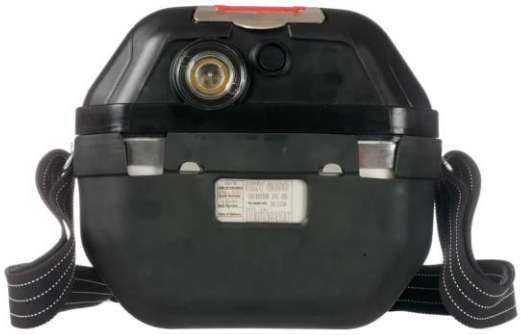
Dräger Saver CF – soft bag



Saver QTY: 120 (we traded 40 Savers with 40 Pas-Colt and ordered 80 more Saver, resulting in 120 Savers).
SCBA QTY: 44

3) 2020 – Present: OXY products:
Although there were a good progress from Pas Colt to Saver in term of duration and sealing requirements, people had to switch from Saver to SCBA and then find their way to refuge shelter. Also, Saver maintenance was very high. There were issues and incidents regarding its durability and visibility. There was durability issue with them in a hard rock mine and site reported many damages for Saver units. In addition, Saver and SCBA needed a compressed air system to refill their air cylinder.

From late 2019 / early 2020 Newmont (previously Goldcorp) decided to change its emergency response approach from compressed air needed apparatuses (SCBA, Saver,…) to OXY 3000 which are self-contained self-rescue oxygen generating products.



Watch this video for donning of Oxy 3000/6000

OXY product is used as a mandatory Self Rescue Self Contained to be carried by all employees at Newmont sites, including Borden Since:

i. It is self-oxygen generating and eliminates need of compressed air completely. OXY units have KO2 (Potassium superoxide) cartridge which generates oxygen with exhaling CO2, filling breathing bag with O2 and this cycle can continue for 30 minutes in Oxy 3000 and 60 minutes in oxy 6000. Implementing Oxys eliminate need of SCBA, Saver or Pas Colt. We traded OXY 6000 with SCBA units.
ii. It is user friendly and simple to use.
iii. Robust with low maintenance cost: The metal/plastic exterior shell with an interior integrated shock absorber protects the KO2 cartridge against damage in harsh environments such as mining, sewage work and within the petrochemical industry. The exterior shell will be left behind when the device is activated. This feature allow employees safe, effective and uncomplicated escape from hazardous environment. They can be used maintenance-free up to 10 years.
iv. Compact, light and ergonomic.

It is mandatory to carry OXY 3000 to enter Borden Underground, which is enough to get in to the refuge station. There are 105 of OXY 3000 units. Also, there are 40 of OXY 6000 in Caches at the Borden Underground as a backup which provide clean air for 1hour.

OXY 3000 QTY: 105 unit- good for 30 minutes
OXY 6000 QTY: 40 (traded with 42 SCBA) – good for 60 minutes, located at Cache units.

training Materials are attached in the report for Milestone 3.

2.4 Procure dewatering face pumps

Purchase and implementation of eight electric dewatering pumps , pumps starter and pump boxes. The electric dewatering pumps completely removes pneumatic face pumps which is used in other mines for dewatering process.

Per attached P&ID, A 3 hp (220V) are low head to pick up water from ground and discharge it in the pump box. The 30hp pump (1000V), discharge water from the pump box to the closest sump.

2.5 Project Evaluations, Monitoring, and Knowledge Sharing

This milestone addresses project monitoring, cost, benefit and saving as well as lessons learned helping others to improve efficiency of compressed air usage. Section 3 will address milestone 5 outcomes in details.

3.0 Project Evaluation, cost and savings.

3.1 Baseline

The baseline CA system is the hypothetical system which is not being constructed by Goldcorp. This system is a centralized CA system powered by three (3) compressors, each with 350 hp motors. Appendix 1 contains a specification sheet for the baseline compressors. Appendix 2 contains the current estimate of the annual baseline energy of 4,967 MWh. The baseline compressor size and baseline energy estimate were derived by identifying major equipment and expected CA flow rates. The estimated baseline CA flowrate is approximately 4,700 SCFM, including an estimate of 720 SCFM of leakage. Based on the average and peak SCFM requirements of the baseline system, Atlas Copco 350 hp units (rated at 1,811 SCFM each, and 333 kW input power) were identified as suitable equipment. The baseline energy estimate is equivalent to 57% of rated total input of the three baseline compressors. It is critical to note that the baseline energy is not fixed in this M&V plan, and that the calculations need to be updated as part of the M&V analysis and reporting. The basis for the calculations will be to account for *adjustments* described below.

- **Baseline adjustment:**

IPMVP divides adjustments into two categories: routine adjustments, and non-routine adjustments.

The above baseline is calculated with the average rate of 2,500 tonnes of ore and waste moved per day. Per approved M& V plan the baseline energy of 4,967 MWh/yr will be adjusted if the actual mine ore production rate, averaged over the reporting

period, deviates from 2,500 tonnes of ore and waste tonnes per day by more than +/- 15%. This adjustment is likely to be a direct scaling of the baseline energy.

- Equipment adjustment:

Primary baseline anticipated to have shotcrete machine, jackleg, stoper, cement offload for underground and surface. However, these equipment were not purchased based on the nature of the Mine rock and stope filling methodology. Consequently, total consumption is adjusted from 9,810 to 6,160 SCFM and grant total (SCFM) is adjusted to 2,956.8 SCFM, which is 37.2% reduction in demand.

Since power has linear correlation with flow, adjusted baseline power consumption is: 4967 x 62.8 = 3119.3 Mwhr /year

- Ore adjustment:

Based on 2020, 2021 and 2022 production data the average rate of ore and waste movement at Borden is 5,000 tonnes per day. The adjusted baseline energy will be (3,119.3x2) = 6,238.5 Mwhr/ day

3.2 Project plan monitoring and energy usage

Bolters, Jumbos (development drill) and Long hole drill have an onboard compressor. The compressor working hour of onboard compressor is recorded on the machine and can be drive remotely.

Decentralized compressor (as booster) for long hole drill has been equipped with a meter (totalizer).

Data loggers were purchased and installed on dewatering electric pump boxes.

Selected data logger: AEMC PEL103 with 3 x MA193-10-BK Sensors

Table-1 shows total annual power consumption used by onboard compressors, Mobile compressor for long hole drill and electric dewatering pump. The total energy consumption is 336.12 MWhr/ hr

Equipment	Compressor capacity (KW)	Utilization	annual working hour	MWhr/year
Bolter	4.125	60.00%	2987	7.39
Jumbo 1	18.5	60.00%	4797.8	53.26
Jumbo 3	18.5	60.00%	5884	65.31
Long hole drill	18.5	60.00%	3054	33.90
Mobile compressor	90	60.00%	3054	164.92
Electric dewatering pump				11.34
Total Energy consumption				336.12

Table 1

Total energy saving of compressed air project will be:

Total energy saving : 6,238.5 - 336.12 =5,902.38 Mwhr / year

Borden electricity cost is $70 / Mwhr

Consequently, the total energy saving will be:

Total energy cost saving: 5,902.38 x 70 = $413,166.6 / Year

3.3 Project Cost

Below table identified project details and related cost for each milestone.

Total project cost is: $1,971,805.6

Milestone	Activity	cost
Demonstration Preparation	Develop a baseline and Measurement and verification Plan.	$10,000

	Procure, install and configure energy data acquisition for the compressors	
Procure and install fixed infrastructure equipment for emergency response in a mine without a central compressed air plant	Seven Drager refuge shelters Eight Cache (Storage) units (4 SCBA Cache and 4 Pas Colts)Charge One D5 Charge Station and Training unit One Decentralized breathing air compressor	$1,406,829.48
Purchase and develop a policy to procure personal self-rescue devices and train and onboard newemployees	Purchase of 40 Pas Colt Purchase of 44 PSS-3000 SCBA Purchase of 120 Savers (40 traded with Pas Colt and 80 purchased) Purchase of 105 OXY 3000 (Purchased by Corporate) Purchase of 40 OXY 6000 – traded with 40 SCBA units	$222,742.8
Procure dewatering face pumps	Purchase of eight electric pumps (3hp and 30 hp) with Pump starter and Pump Box	$332,233.32
Total Project cost		$1,971,805.6

IESO funded Borden compressed air project and allocated fund is $500,000.

With considering project cost, IESO fund and annual energy saving, simple payback is :

SP= ($1,971,805.6-$500,000) / $413,166.6 = 3.56 years

4.0 CONCLUSION AND LEASON LEARNED

The project is being built out without central compressed air, which is a departure from industry norm. Followings are lesson learned and advantages to eliminate centralized compressed air system:

Since there is no air pipeline, different types of SR (self-rescuer) equipment dependent from centralized compressed air system method is used, including SCBAs, Pas Colt and Savers to Oxygen generating SCSR (self-Contained self-rescuer) Oxy3000 and Oxy6000 . The self-rescuer equipment need air cylinder, which requires an air changer and compressor. Although transmission from centralized compressor to de-centralized unit reduced air leak and energy waste, SR equipment such as Pas Colt and SCBAs could not eliminate a need for air charger. As Newmont replaced all SR equipment (such as SCBAs, Pas Colt, Saver) with Oxy products the need for compressed air is totally eliminated.

As lesson learned for SR equipment:

- Borden mine proved that centralized compressed air pipe line network can be eliminated for refuge station and SRSC equipment (such as SCBA, etc) with de-centralized compressed air or using oxygen generating units (such as OXY3000/6000) which do not need compressed air refill.
- From Borden mine experience, Pas Colt, Saver and SCBA may not be a good solution for emergency response for a hard rock mine due to complexity, high maintenance and low durability
- OXY 3000 / 6000, as a self-generating oxygen SCSRs, were a successful experience since they are user friendly, robust, safe, with low maintenance cost, and they do not need compressed air at all.

In a typical mine, because there is an extensive compressed air network underground compressed air is available and used in other end-users such as dewatering pumps that do not necessarily require compressed air. One key aspect is the use of compressed air powered dewatering ‘face pumps’ in the deepest underground working area, which can be fully powered by electricity at a higher efficiency than using compressed air. This project completely removes this option as smaller compressors are occupied by critical end-users such as drilling, and the purchase of electrical dewatering pumps.

Since Centralized compressed air system is eliminated at Borden mine, following advantages are observed:

- Elimination of capital cost and maintenance time / cost to install and maintain centralized compressor system
- Elimination of capital cost and life time maintenance cost of compressed air pipeline

- Significant reduction of energy consumption and energy waste since:
  - need of supplying air to SR equipment is fully eliminated
  - Air pipe line leakage in eliminated
  - Electrical pumps are used instead of pneumatic face pumps with much higher efficiency.

In collusion, Borden mine shows elimination of centralized compressed air is possible for underground mines, leading to significant saving of energy and maintenance cost during life of mine.

APPENDIX A - Baseline air compressor specification sheet

COMPRESSOR DATA SHEET

Rotary Compressor: Fixed Speed

MODEL DATA - FOR COMPRESSED AIR			
1	Manufacturer: **Atlas Copco**		
2	Model Number: **GA 315-125**	Date:	**03-09-2016**
	[X] Air-cooled [ ] Water-cooled	Type:	**Screw**
	[X] Oil-injected [ ] Oil-free	# of Stages:	**1**
3*	Rated Capacity at Full Load Operating Pressure [a, e]	**1811**	acfm [a,e]
4	Full Load Operating Pressure [b]	**125**	psig [b]
5	Maximum Full Flow Operating Pressure [c]	**132**	psig [c]
6	Drive MotorNominal Rating	**350**	hp
7	Drive Motor Nominal Efficiency	**96.2**	percent
8	Fan Motor Nominal Rating (if applicable)	**4.0**	hp
9	Fan Motor Nominal Efficiency	**83.0**	percent
10*	Total Package Input Power at Zero Flow [e]	**85**	kW [e]
11	Total Package Input Power at Rated Capacity and Full Load Operating Pressure [d]	**333**	kW [d]
12*	Specific Package Input Power at Rated Capacity and Full Load Operating Pressure [e]	**18.4**	kW/100 cfm [e]

*For models that are tested in the CAGI Performance Verification Program, these items are verified by the third party administrator.
Consult CAGI websitefor a list of participants in the third party verification program: www.cagi.org

NOTES:
a. Measured at the discharge terminal point of the compressor package in accordance with ISO 1217, Annex C; ACFM is actual cubic feet per minute at inlet conditions.
b. The operating pressure at which the Capacity (Item 3) and Electrical Consumption (Item 11) were measured for this data sheet.
c. Maximum pressure attainable at full flow, usually the unload pressure setting for load/no load control or the maximum pressure attainable before capacity control begins. May require additional power.
d. Total package input power at other than reported operating points will vary with control strategy.
e. Tolerance is specified in ISO 1217, Annex C, as shown in table below:

Member CAGI Compressed Air & Gas Institute

Volume Flow Rate at specified conditions		Volume Flow Rate	Specific Energy Consumption	No Load / Zero Flow Power
m^3 / min	ft3 / min	%	%	
Below 0.5	Below 15	+/- 7	+/- 8	
0.5 to 1.5	15 to 50	+/- 6	+/- 7	+/- 10%
1.5 to 15	50 to 500	+/- 5	+/- 6	
Above 15	Above 500	+/- 4	+/- 5	

ROT 030

10/11 R8 This form was developed by the Compressed Air and Gas Institute for the use of its members. CAGI has not independently verified the reported data.

APPENDIX B - Baseline CA Energy Calculation Summary

Equipmrent Required	Required Compressed Air Consumption (SCFM)	Number	Total Consumption (SCFM)
Jumbo	500	3	1,500
Production drill	500	1	500
blowpipe	1,000	1	1,000
Shotcrete machine	750	1	750
jackleg	200	1	200
stoper	200	1	200
face pumps	40	4	160
Bolter	500	6	3,000
Cement offload UG	500	4	2,000
Cement offload surface	500	1	500
	4,690	23	9,810
Total peak demand (SCFM)			9810
Total average demand (SCFM)		40%	3924
Leakage		20%	784.8
Grand total (SCFM)			4708.8

Required pressure:	100	psig			
Pressure gain due to gravity	1.4	psig/100m			
Ramp length to centroid	4000	m			
Ramp length to centroid	13,123	ft			
depth to centroid	400	m			
Pressure gain from gravity	5.6	psig			
Design ramp pipe diameter	6	"			
Number of pipes required	2		to minimize pressure drop		
Design flow	5000	SCFM			
Estimated pressure drop	20	psig			
Required pressure at compressor	114.4				
The information above is used for the vendor to provide a quote for the compressors with the following inform					
Total installed power (use 315 hp = 90% of 350 hp)	945	kW	1267.266	HP	567
Annual power consumption @ 60% utilziation	4967	MWh			