Peyto Exploration & Development Corp.

In-Pipe Turbine Generator-driven Chemical Injection Pumps

April, 2022

Contents

Executive Summary

Electrification of natural gas driven equipment is one of the most efficient methods of reducing emissions from the Oil and Gas Operations. In-Pipe Turbine Generator converts the kinetic energy of flowing natural gas and liquids into electricity. The technology is an alternative to solar panels used for wellsite power generation. The main advantage of the technology is 24-hour power generation which allows wellsite's to operate with less batteries.

The project scope has been adjusted numerous times since project approval in 2017. This was due to delays with CSA certification of the turbine. COVID-19 created an additional impediment to the project schedule due to disruption of corporate cashflows. The original project scope included installation of 100 IPTG devices. Final project scope has been limited to a technology demonstration with only two devices.

The objective of the limited technology demonstration was to determine if IPTG is suitable to operate in Western Canada. In order to achieve this objective, the turbine had to be tested in a variety of operating conditions. Test conditions had to include a variety of gas flow rates, weather conditions and gas compositions. Our intention is to cover as many of these conditions as possible through careful site selection and timing of the installations.

The first IPTG installation took place in October of 2021. The turbine was not able to generate sufficient power in the low flowrate case. Therefore, the solar panels were used to supplement the site power requirement.
The second installation took place in March of 2022. The turbine is generating sufficient power for site needs, which allowed for disconnection of solar panels.

In conclusion the pilot has proved that the IPTG technology is suitable to operate at wellsites with gas production in a variety of ambient temperatures. However, the technology is not suitable for sites where the gas flowrate rapidly declines after installation. Also, the cost of the turbine will have to be reduced to make the technology competitive with solar panels.

Project Description

Introduction

Eliminating methane venting from chemical injection pumps is critical to Alberta reaching its 45% reduction target outlined in the Alberta Climate Leadership Report to the Minister. Replacing gas-driven, methane-venting pumps with electric, non-venting alternatives can be accomplished with on-site electricity. The In-Pipe Turbine Generator (IPTG) could provide a reliable electricity source for remote sites and allow operators to convert to non-venting pump models.

The IPTG uses pressure within a production pipeline to generate electricity. Peyto anticipates that the technology will have to be adapted to Canadian Deep Basin operating conditions in order to achieve reliable power generation. Peyto Exploration and Development installed 2 In-Pipe Turbine Generators (IPTG's) to supply electrical power to approximately 4 chemical injection pumps and SCADA equipment on remotely located gas wells. These installations highlight the strengths and weaknesses of the IPTG technology that could potentially allow for adaptation of the technology to other Peyto facilities as well as other Oil and Gas operations nationally and internationally.

Once reliable turbine operation is achieved Peyto will allow other E&P companies to visit the installations sites. This will serve as a valuable marketing tool for the IPTG technology.

Background of the Project

The project was initiated in 2017 as a response to rapidly changing methane reduction regulations for the oil and gas industry. Peyto Exploration conducted an evaluation of sources of methane in its operations and determined that a large portion of the corporations' vented emissions are attributed to wellsites fuel venting. The vented gas is produced as an exhaust of pneumatic level controllers, pressure controllers and chemical pumps. The quantity of the vented fuel gas from the pneumatic equipment can be reduced by retrofitting high bleed devices with low bleed alternatives. Pneumatic chemical pumps must be electrified in order to eliminate vented gas. Electrifying chemical pumps required additional wellsite power generation.

Historically Peyto's wellsites have been equipped with solar panels to generate small quantity of electricity necessary for operation of measurement and communication equipment. Electric chemical pumps would add a significant new load to the system. Energy required to operate the pumps throughout the day would have to be generated during the daytime hours and stored on site using deep cycle lead batteries. Peyto decided to investigate alternative methods of power generation that would not depend on the angle of the incidence and amount of daylight hours. IPTG technology is capable of generation power through the day which significantly lowers the need for onsite energy storage.

The IPTG project was initiated as a collaboration between Lightning Master Corporation, ZKO Oilfield industries and Peyto. LMC was responsible for design and construction of the turbines. ZKO was responsible for field installation and support. Peyto's responsibility was to provide sites appropriate for the installations. The project was approved by the ERA in June of 2017.

Project Objectives

Including the objectives from original Contribution Agreement and any evolution/revisions made to the objectives over the course of the Project)

The primary objective of the project was to demonstrate that the IPTG technology can produce 100 W of power at 1MMcf/day gas flow in order to drive 4 chemical injection pumps, which in other cases would be powered by solar panels. The demonstrations was to:

- Prove that the technology is a suitable source of power for the Canadian Deep Basin. The Canadian Deep Basing gas plays provide several unique challenges for power generation using wells production stream. The production stream often contains frac flowback water, sand and condensate. The reliability of the turbines will also be tested in Canadian weather conditions.
- Break the "initial installation" barrier. The industry is often apprehensive of procurement of new technology due to inherent risk. ERA funding would allow Peyto to mitigate the project risk to a tolerable level.
- Serve as a demonstration project for the new IPTG product in the expectation that this technology will be applied on other gas wells in Alberta and British Columbia. Aside from chemical injection pumps, the IPTG's can generate electricity for other applications at remote gas wells, such as: communication equipment, logic controllers and lighting.

Performance/success metrics identified in the Contribution Agreement

Success Metric	**Commercialization target**	**Project target**	**Tazman Turbinz Achievement prior to project**
"Low-flow" power generation	100W at 500,000 cf/day gas flow	100W at 1 MMcf/day gas flow	140W at 2 MMcf/day gas flow
IPTG cost optimization	$18,000 per IPTG	$28,000 per IPTG	$28,000 per IPTG
IPTG cost ($/W)	$180 per watt	$280 per watt	$200 per watt
IPTG installation / service responsiveness	Alberta-based pipe /flange production, emergency stock, service personnel.	Alberta-based emergency stock, service personnel.	Florida-based produc-tion, stock, service personnel.

Project was approved in 2017. The original project scope consisted of 100 turbines. However, significant delays occurred in the expected project schedule because of the CSA Certification and budget cuts related to COVID-19 Pandemic. As a result, in 2021 the project scope was amended to include 2 turbines.

Project timeline leading up the turbine installation is summarized below.

1. Qtr 4, 2017 through Qtr 4, 2019: CSA Certification
   a. March 2018: obtained CSA certification for ordinary location using the single-stage IPTG design used for initial prototype testing.
   b. Qtr 4, 2017 through Qtr 4, 2018: design modifications for CSA compliance and Peyto requirements:
      i. All design drawings on SolidWorks in accordance with CSA documentation requirements (e.g., dimensions, tolerances, subassembly drawings).
      ii. Selection of CSA-approved vendors for critical parts (e.g., coils, cables, magnets, etc.).
      iii. Redesign of "CoolCube" to protect coils and other electrical components from ambient air.

      The IPTG initially passed CSA testing, but upon CSA review it was discovered that CSA had forgotten a required test. This required building new IPTG's (the old ones had been destroyed in testing by CSA) and testing within a chamber with controlled ambient temperatures. Again, the IPTG initially passed the test, but upon CSA review the certification was withheld due to the IPTG's erratic charging performance at elevated temperatures.
   c. Qtr 1, 2019 through Qtr 4, 2019: further design modifications for CSA compliance.
      i. Change to Samarium-Cobalt (SmCo) permanent magnets. SmCo magnets are highly resistant to corrosion and are stable over large temperature differences.
      ii. Optimization of coil design and CoolCube design to enhance heat dissipation.

      The CSA hazardous location certification was completed in December 2019 and issued to Tazman Turbinz in January 2020.
   d. Concurrently, Tazman Turbinz obtained CSA's manufacturing certification. This requires passing quarterly unannounced inspections where CSA verifies parts characteristics, tooling calibration, manufacturing procedures, etc.

2. Qtr 1, 2020 through Qtr 2, 2020: Vibration Reduction / Bearing and Lubrication Optimization
   a. Optimization of IPTG Monel shaft / SS stators & rotors designs / tolerances to ensure centering and smooth as flow over the blades. Concurrent optimization of suppliers CNC mills / lathes machining programs.
   b. Selection of double-row ceramic hybrid high-precision ball bearings encased in Titanium Nitrite coated stainless steel races.
   c. Selection of PTFE bearing seals for protection of bearings from chemical attack / particulates.

3. Qtr 3, 2020 through Qtr 4, 2020: Flange Selection / Testing / Welding in Accordance with Canadian CRN Requirements.
   a. 316 stainless steel ASME class 600 and class 900 raised-face slip-on flanges purchased in Canada.
   b. ASTM A350-LF2-CL1 flanges with impact testing certification for Canadian cold weather specs (minus 40° C).

c. Flanges / welding procedures were tested and certified in accordance with CRN (Canadian Registry Number).
d. Flange welding and subsequent hydraulic testing performed by Canadian partner company Westpower, located in Alberta. Westpower will also perform last-stage assembly in the future, reducing logistics time and costs and increasing Canadian (Alberta) content.

4. <u>Qtr 3, 2020 through Qtr 1, 2021: Control Cabinet Optimization to meet Peyto and CSA Requirements.</u>
   a. Switch from Midnite Solar to Morningstar's TriStar MPPT 600V ™ controller
   b. Select enclosure, transducers, rectifiers, computers, circuit breakers and other components that are CSA certified and rated for use at extreme temperatures.
   c. Develop software for remote monitoring of battery charge, rpms, and other parameters.
   d. Control panel / cabinet built by CSA / UL – certified panel builder.

5. <u>Qtr 1, 2021: build six IPTG's and three control cabinets in accordance with the designs / CSA criteria detailed above.</u>

6. <u>Qtr 3, 2021: Shipping IPTG's to Canada</u>

Technology risks

A. <u>Risk 1: Electrical Safety</u>

The In-Pipe Turbine Actuator (IPTG) was designed in compliance with the CSA and UL safety standards for motors and generators used in hazardous locations. These requirements include:

CSA C22.2 No. 0:15	General requirements: Canadian Electrical Code Part II
CSA C22.2 No. 60079-0:15	Explosive atmospheres - Part 0: Equipment
CSA C22.2 No. 60079-18:16	Explosive atmospheres - Part 18: Equipment protection by encapsulation
CSA C22.2 No. 145-11	Electric motors and generators for use in hazardous classified locations
UL No. 60079-0, 6th Ed.	Explosive atmospheres - Part 0: Equipment
UL No. 60079-18, 4th Ed.	Explosive Atmospheres - Part 18: Equipment Protection by Encapsulation
UL No. 674, 5th Ed.	Electric motors and generators for use in hazardous locations
CSA C22.2 No 100-14	Motors and Generators
CSA C22.2 No 94.2-15	Enclosures for Electrical Equipment
UL 50E, 2ND Ed.	Enclosures for Electrical Equipment
UL 1004-1, 2ND Ed.	Rotating Electrical Machinery

The coils of the generator are mounted outside of the pipe. To ensure electrical safety and for protection of the coils, they are enclosed within a cube mounted on the pipe on top of the coils.

The cube is filled with a potting compound for their physical protection and to prevent trapping any flammable gases around the coils.

The IPTG was subjected to rigorous analysis and testing by CSA Edmonton resulting in the issuing of a Certificate of Compliance (No. 70164245) CLASS - C422801 – Motors and Generators for Hazardous Locations (Class I Division 1).

Please see the attached CSA Certificate of Compliance dated April 26, 2021.

Conclusion: the IPTG performed in accordance with electrical safety requirements.

B. Risk 2: Coil Damage

The IPTG's eight coils, mounted within the "CoolCube" on the outside of the pipe, are rated for temperatures up to 200°C. Should coil temperatures exceed this level for an extended period, the coil wires may degrade and result in the coils shorting out. While this does not lead to risks in electrical safety, it will result in severe degradation of the electrical power output of the IPTG (depending on how many coils were affected).

Coil temperature is directly related to the turbine speed of rotation. To prevent damage to the coils, CSA as well as the manufacturer (Tazman Turbinz) have set a limit of 2200 rpm (210 Watt output).

Conclusion: no coil damage was encountered in the course of the project.

Note: the IPTG limitation of 2200 rpm / 210W is based on tests conducted by CSA Edmonton within a laboratory environment using a test stand of restricted capability. Renewed tests using a more sophisticated test stand are planned for Fall 2022. It is expected that this will result in the limitation being significantly raised.

C. Risk 3: Environmental Damage to the IPTG (especially due to extreme temperatures)

Based on sustained laboratory testing, the IPTG can operate at environmental temperatures between -40°C and +49°C. These values were set as the environmental temperature limits by CSA.

For this project, the IPTG's were installed in northern Alberta and were operated through the winter of 2021/2022. Over the course of the project, temperatures approached -40°C several times.

Conclusion: no damage was encountered during the project, attributable to low environmental temperature conditions.

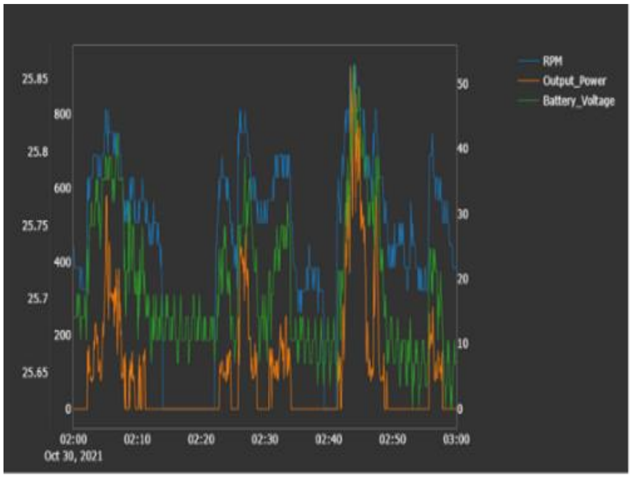
D. Risk 4: Mechanical Damage (particularly to the IPTG bearings)

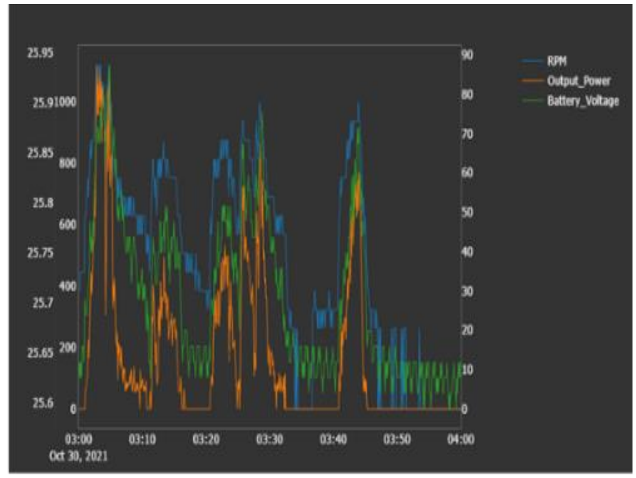
The most mechanically sensitive parts of the IPTG are its bearings. Bearing failure will result in the rotating assembly being degraded (lowering the rpm and the power output) or in the IPTG locking up entirely. To preclude such damage, the manufacturer has selected custom-built double-row ceramic ball bearings encased in Titanium Nitrite coated stainless steel races. The bearings are further protected by PTFE seals and a Perfluoropolyether/PTFE lubricant.

Damage to the bearings can arise due to several conditions:

1. Mechanical stress arising from frequent and severe acceleration / deceleration of the rotating assembly due to variations in the gas flow. This situation was, in fact,

encountered in the project as evidenced by the tracking of IPTG rpm at one of the project sites (see below):





2. Excessive vibration due to misalignment of the IPTG shaft or of other components in the rotating assembly. Vibration was tested at the beginning of the project with satisfactory results.
3. Water, ice, oil, sand, sediments in the gas flowing through the IPTG causing damage to the bearings or other rotating assembly components. In this project, there was a significant presence of such substance mixed into the gas flow.
4. Corrosive chemicals attacking the bearings, seals, or other parts in the IPTG rotating assembly.

Conclusion: no mechanical damage or degradation was encountered during the project.

E. Risk 5: Insufficient Power Generation

In the absence of the risk factors mentioned above (mechanical damage, coil damage, or other IPTG performance degradation), the failure of the IPTG to produce sufficient power is attributable to insufficient gas flow leading to a lower IPTG rpm's resulting in a lower power output.

In order to produce ~200 Watt, the IPTG needs to operate at around 2000 rpm. (Note: some of the wattage is consumed by the electrical system as the IPTG's AC power is converted to the DC power used in charging the well site's batteries.) The IPTG converts the energy from the gas flow into rotational force as the gas passes through two stages of stators and rotors. The stator and rotor blade angles and dimensions are designed to match the gas flow quantity / pressure / velocity.

There are several reasons why the IPTG may produce less power than expected:

- A mismatch between the IPTG's stator / rotor design and the well site's flow characteristics.
- Gas flow at the well site being sporadic with significant down times and/or reduced gas flow.

- Diminishing gas flow over time.

Conclusion: all three of these conditions were encountered within the scope of the project. That being said, the IPTG has supplied sufficient power at the second well site in this project from first installation to the present.

To reduce the occurrence of insufficient power generation in future installations, the following measures should be adhered to:

1. Ensuring a correct match between the IPTG's stator/rotor design version and the expected flow characteristics of the well site.
2. The initial flow of the gas well should exceed the IPTG's requirements. As the well's flow diminishes over time, the flow through the IPTG can then be modified by gradually opening a valve installed in series with the IPTG.
3. Gas wells with frequent fluctuations of gas flow are not suitable for the efficient operation of the IPTG.

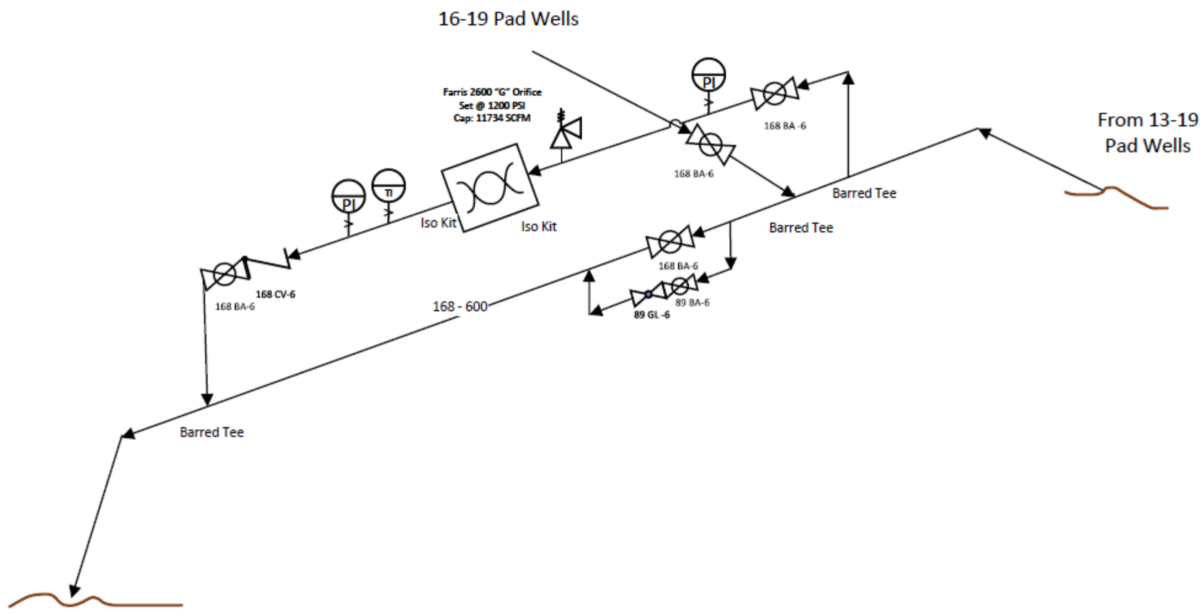
F. Risk 6: Charge Control System Failure

The IPTG operates in conjunction with a conductor cable carrying the IPTG's AC current to a control cabinet where it is converted to DC current through rectifiers. This current is regulated by a charge controller which charges and monitors the well site's batteries. The control cabinet itself is housed within an environmentally resistant enclosure which is mounted outside of the Class I Division 1 area. Failure of any of the cables, controllers and electrical components can result in the IPTG not being able to charge the well site's batteries or equipment. During the project, there was an issue with the charge controller defaulting to factory settings after losing power. A technician rectified the issue by reloading the controller configuration on site.

Conclusion: Minor electrical issues were encountered in the course of the project.

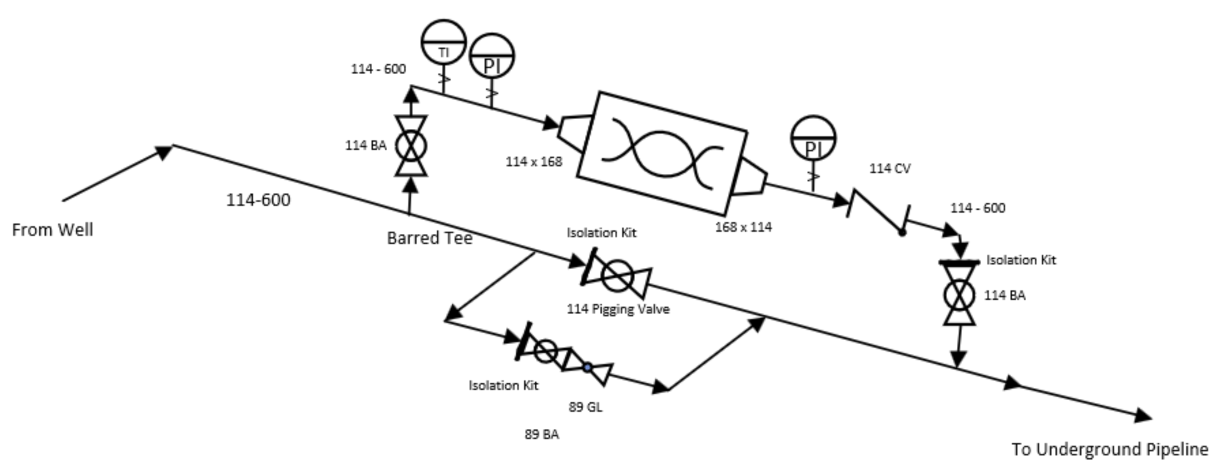
Project Work Scope

Installation of each turbine required pipe modifications to the pipeline headers. At installation site 1, gas from seven wells was directed through the turbine. A bypass was installed to throttle gas around the turbine if necessary, and full-bore bypass was kept in place to ensure maintenance pigging of the downstream pipeline was still possible. A management of change process had to be followed to review all piping changes and ensure any additional risks were addressed. Since the pressure rating of the turbine is lower than the pipeline, a PSV was installed upstream of the turbine to protect the device from overpressure. The electrical panel for the turbine was installed next to the existing wellsite RTU at both sites. The existing masts were used to mount the cellular booster antennas for remote communications.



Site 1 Diagram – Gas from 13-19 and 16-19 pads flowed into the header and through the turbine. The 6” bypass valve is normally closed. The 3” Throttling valve was also normally closed to maximize flow through the turbine.

The second installation was very similar to the first. The pipeline at site 2 was 4” instead of 6”, so reducers had to be used on either side of the turbine. Only a single well flow produces through site 2, so overpressure protection of the turbine was provided by the PSV on the wellsite separator.



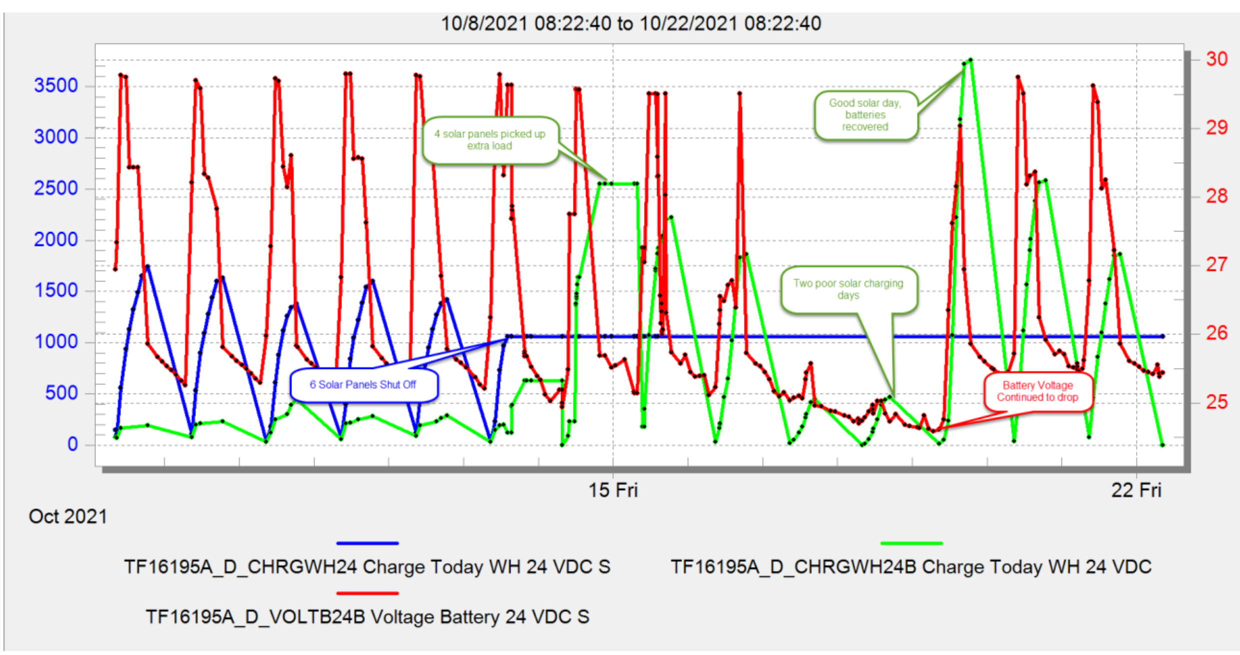
Site 2 Diagram – Gas from well flowed into header and through turbine. The 4" Inline pigging valve was normally closed unless operations needed to launch pig. The 3" throttling valve was pinched to allow enough gas to bypass the turbine, so it does not overspeed.

• Overall Project achievements relative to stated objective and performance metrics

Success Metric	Project target	Site 1	Site 2
"Low-flow" power generation	100W at 1 MMcf/day gas flow	3.2W at 2 MMcf/d	180W at 8.5 MMcf/d
IPTG cost optimization	$28,000 per IPTG	$30,000	$30,000
IPTG cost ($/W)	$280/watt	$9375/W	$167/watt
Total Install Cost	$192,660	$105,450	$72,484
Installed IPTG cost ($/W)	$978/watt (estimated total project cost/200W)	$32,953/watt	$403/watt
IPTG installation / service responsiveness	Alberta-based emergency stock, service personnel.	Waiting on fabrication of redesigned turbine blades from manufacturer.	

Site 1:

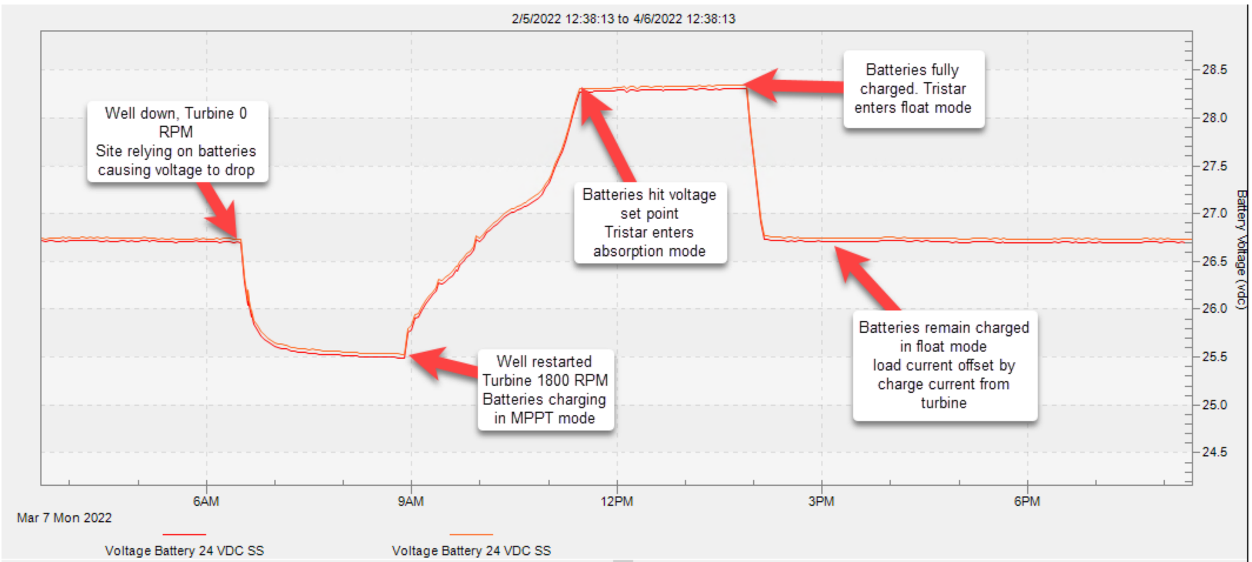
The initial installation underperformed relative to the stated objectives. The turbine did not achieve sufficient RPM to effectively generate electricity. Below is a chart that includes battery voltage vs daily cumulative watt-hours provided by our solar chargers. It is noted where 6 panels were shut off, and how the 4 others picked up the extra load. On the 17th and 18th, there was poor charging days. The battery voltage continued to drop, not stay flat or charge. This result verifies that that the IPTG alone cannot satisfy the load requirements of the site, and the solar panels must remain in service.



The site required the existing solar array to maintain battery voltage. Peyto and LMC have agreed on a redesign of the turbine blades to achieve higher RPM with the lower flowrate available.

Site 2:

The second turbine installation has provided sufficient power generation to meet the demands of the site. At 8.5 MMcf/d, the turbine operates at 1800 RPM. The solar arrays on the site have been shut down. The turbine is exclusively providing power. The Tristar controller is in float mode for much of the day. This indicates that the turbine generator is producing more power than required. See chart below of charge cycle when well was shut down for 2.5 hours.



At these flowrates, the turbine is dependable for 24hr power generation. Longer term, this site will experience the same challenges as site 1 as the gas well declines and available flowrate is reduced. Gas wells naturally decline during their life cycle. Power generation on site must be suitable to ensure adequate generation when gas rates decline. The turbine will need to be redesigned for a lower flow rate to be effective.

• Analysis of results

There was significant cost difference to install the turbine at each site. This is partly due to efficiencies identified after the first install. Most of the savings were identified as site-specific such as pressure relief valves requirements, pipe and valve size, ability to re-use existing valves etc. Depending on the site selected, it is possible for future installation costs to exceed those noted below. As the device is commercialized, the time to install will decrease, leading to lower labour costs.

	Site 1	Site 2
Turbine and Control Panel	$ 31,500	$ 31,500
Westpower	$ 13,102	$ 11,903
Travel	$ 4,072	$ 4,543
Pipe, Valves, Fittings	$ 40,283	$ 16,712
Labour and Installation	$ 17,959	$ 11,231
Communication	$ 2,006	$ -
Total	**$ 108,921**	**$ 75,889**
Grand Total	**$**	**184,810**

Commercialization

The Contribution Agreement was signed on October 25, 2017. The target completion date of the project was March 2020. The project objectives were:

1. The introduction of a technology for power generation which reduces methane emissions (the IPTG neither combusts nor emits methane gas).
2. Serve as a demonstration project for the IPTG product in the expectation that this technology will be applied on other gas wells in Alberta and British Columbia.

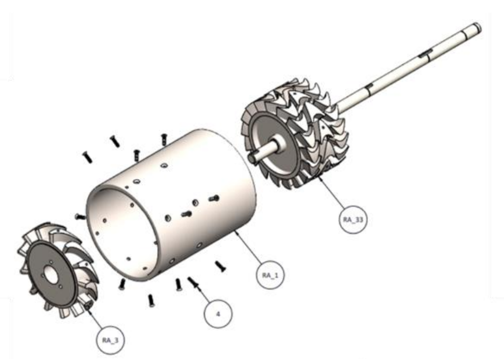
Several achievement targets were identified at the start of the project to be completed during the project itself and subsequently moving to full commercialization. Additional technology advancements were made to meet CSA regulatory compliance and to enhance the operation / reliability of the IPTG. Targets / technology advancements included the categories discussed below:

A. <u>IPTG operation at lower gas flow rates</u>

The IPTG was originally designed for and tested on gas wells in West Virginia which had flow rates significantly higher than that encountered at many well sites in Alberta. One of the Project objectives was therefore to redesign the IPTG for operation at lower flow rates, with the project target set at 1.0 MMcf / day (28,000 m^3/ day).

In order to capture a higher percentage of the energy from the gas flow, the rotating assembly was redesigned to include two stator / rotor stages rather than only one stage:

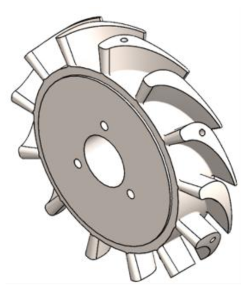
ITEM NO.	DESCRIPTION
RA_1	IPTG _ V2.0 - DUAL STAGE TURBINE - TURBINE CASING
RA_3	IPTG _ V2.0 - TURBINE STATOR - STAGE 1
RA_33	IPTG _ V2.0 - DUAL STAGE - ROTATING ASSEMBLY - ASSEMBLY _ 02
4	FLAT HEAD _ TORX DRIVE _ MACHINE SCREW _ No. 8-32 x 0.625 _ 18-8 STAINLESS STEEL



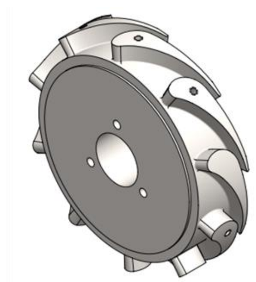
The flow specifications for the two sites selected for the Project were 3.9 MMcf / day (110,000 m^3/ day) at a pressure of 2500 kPa (365 psi) and a temperature of 10° C (i.e., 50° F). Actual flow rates fluctuated over the short term and diminished over the longer term. Our estimate from the project sites is that at a flow rate of 110,000 m^3/day, the IPTG (as designed for these sites) will spin at around 1750 rpm and generate ~170 W power with some of this power (~40W) lost in voltage conversion and charge controller operation.

This result does not represent the maximum capability of the IPTG. The project IPTG's were deliberately designed to deliver less than maximum power since the sites' power requirements were moderate (around 100W). Operating under a CSA-imposed maximum rpm of 2200, it was prudent to size the generator so as to generate the required power at rpm below the CSA limit.

For full commercialization in Alberta and British Columbia, the IPTG needs to operate at flow rates in accordance with the project target of 1.0 MMcf / day (28,000 m^3/ day). (Note: the even lower commercialization target initially set in the ERA contribution agreement appears to be out-of-reach for the IPTG.) In order to generate the required rpm at lower flow rates, the flow needs to be concentrated on a smaller area within the IPTG so as to increase the velocity. This is accomplished through a modification of the stator/rotor design, especially that of the front stator (flattening the blade angle and reducing the height of the blades) as shown below.



Front stator
(current design)



Front stator
("low-flow" design)

The "low-flow" IPTG is in the process of being built as of May 2022. After testing in the lab, it will be installed at one of the project sites for field trial later in 2022. This revised turbine is not part of the ERA project.

B. Maximum power generation

The project and commercialization target for maximum power generation of the IPTG was set at 250 Watt.

The CSA-imposed limit as of May 2022 is 210 Watt at 2200 rpm. These restrictions represent the limitations of the CSA test facility rather than that of the IPTG. Laboratory trials suggest that a sustained maximum power generation of 400 Watt (possibly higher) is achievable. Re-certification tests using an upgraded test facility are scheduled for later in 2022.

Contributing to the improvement in maximum power generation were several design modifications made over the course of the project. This included the third-party coil production and the design of the e-core (which concentrates the magnetic flux onto the coils). The most critical change was the switch to permanent magnets made of Samarium-Cobalt (SmCo). This compound has a more stable performance at elevated temperatures, permitting higher rpm / higher wattage.

C. Cost optimization

Significant cost reductions have been achieved in the production of machined components. Rotors, stators, the shaft, and other critical parts are now machined on state-of-the-art 3-axis and 4-axis mills.

With the CNC programs written and tooling built, through-put times and the associated costs have been reduced.

However, cost reduction efforts suffered a significant setback in early 2022. Pricing for the high-grade metals used for the IPTG (AISI Grade 303 stainless steel, Monel shaft) have recently jumped by an average of 40%. As of May 2022, it is not certain whether these costs will stabilize, continue to rise or will possibly descend again. A re-evaluation of costs and pricing for the IPTG will need to be performed.

D. Reliability

The project target metric calls for an IPTG overhaul (preventive maintenance) to be performed in 12-month intervals.

As of May 2022, the project IPTG's have been running since October 2021 / February 2022 without need for intervention.

Laboratory testing suggests that the IPTG will run indefinitely in a controlled laboratory environment. Thanks to tight tolerances and high-quality materials, wear-and-tear is very minimal. However, this cannot necessarily be extrapolated to field installations where the IPTG may be subjected to extreme conditions and fluctuations in temperature, pressure and flow rate as well as to various liquids, sediments and corrosive chemicals mixed with the natural gas medium. The two IPTG's installed under this project have been running satisfactorily under such challenging conditions.

At least one of the two project IPTG's will be removed from the well site and internally inspected later in 2022. Based on the results of the inspection, recommendations will be made on whether scheduled maintenance is required for the IPTG and – if so – what this maintenance entails.

E. Alberta-based production / installation / field service

So as to serve IPTG customers located in Western Canada in a timely and efficient manner, a project target stated in the ERA contribution agreement requires local (Alberta) services. This requirement has been satisfied:

- Welding of flanges and some other parts is performed by a highly qualified and experienced company located in Alberta, Canada. The IPTG is furnished with 316 stainless steel flanges (ASME class 600 raised-face slip-on). For Canadian customers, ASTM A350-LF2-CL1flanges with impact testing certification for cold weather specs can be provided. Flanges and welding procedures were tested and certified in accordance with CRN (Canadian Registry Number). 100% pressure testing is performed at the Alberta factory after the flanges are mounted.
- IPTG installations and field services are also performed by an Alberta-based company.

F. Control cabinet

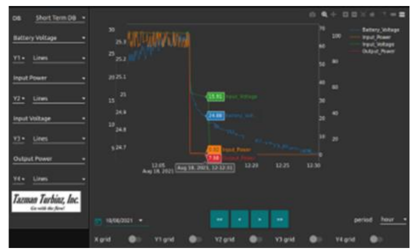
Going beyond the original scope of the project, Tazman Turbinz has designed a control cabinet which fulfills two critical functions:

- Conversion of the AC electric current generated by the IPTG into DC current for use in charging batteries or for powering DC equipment directly.
- Remote monitoring of the batteries' charge state and the IPTG's performance.

Components inside the control cabinet include a battery charge controller, rectifiers, transducers, and an industrial computer. A Teck-90 conductor cable connects the cabinet to the IPTG. All components were selected for CSA compliance and for usage in severe Canadian weather conditions.

The industrial computer will be capable of regulating a control valve in the future. Based on input data (IPTG rpm and battery charge status), the industrial computer will open or close the valve so as to induce the required gas flow so as to generate the desired power.

The control cabinet will also permit remote monitoring of the IPTG performance and of the battery charge state, showing both status in real time and historical data.



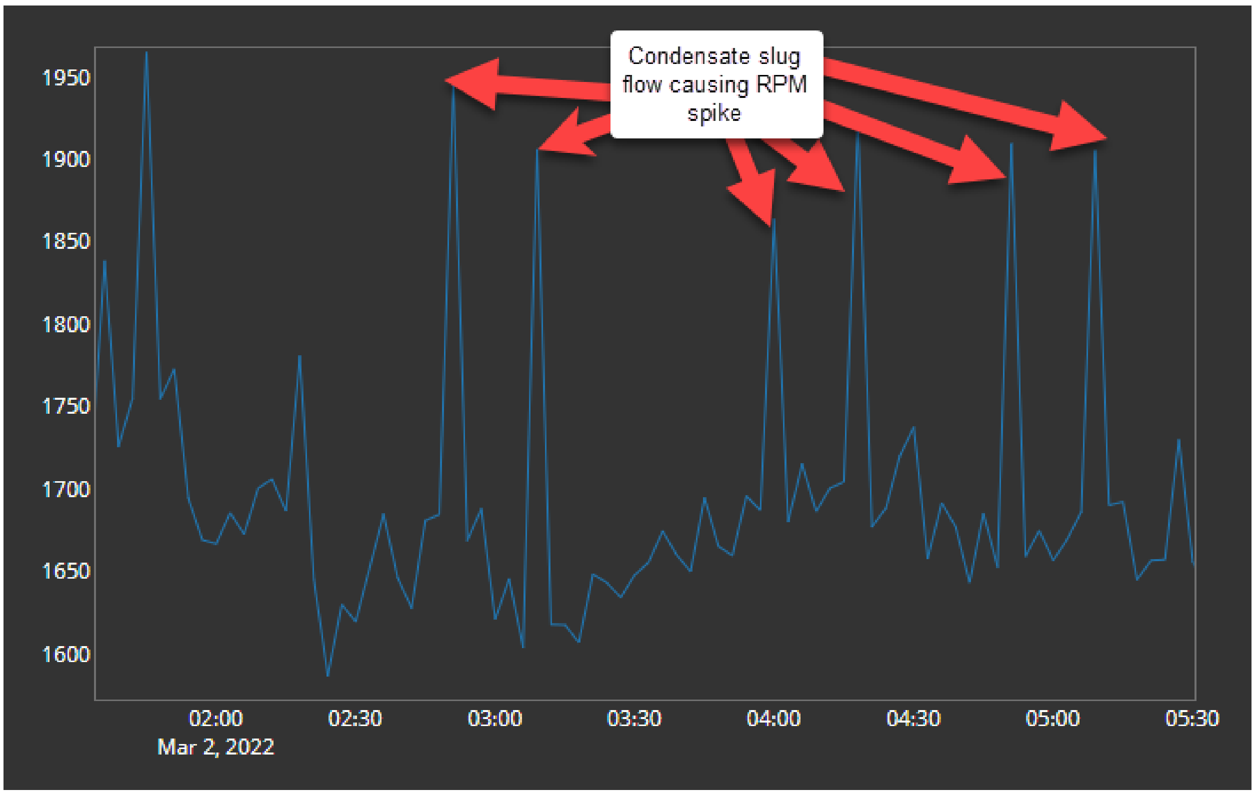
Tazman Turbinz can provide its customers with a fully assembled control cabinet as well as with the software for remote monitoring. This will be particularly useful for the customer when installing the first IPTG units. Subsequently, customers may decide to build their own control systems. In that case, Tazman Turbinz will be happy to share its hardware and control software knowledge with the customer.

Lessons Learned

Communication – In order to actively monitor the turbine, sufficient cellular service is required. Although site 1 had service, a booster was still required to ensure communication was maintained. On occasion, the cellular provider does maintenance. This has caused the modem to lose connection and not re-establish until the device is power cycled on site. It was also determined at one point that the cellular data plan was insufficient for the volume of data being transferred. The device would lose connection until the allowable data is reset in the following month. This issue was resolved by adding more data to the cellular plan.

Programming – During a cold period last winter, the batteries at site 1 had completely depleted. After they had been swapped for charged batteries, the tristar charge controller for the turbine had blacked out and defaulted to factory setting. This prevented the device from providing power to the site. This was repaired by re-configuring the tristar to operate in parallel with the solar chargers on site. The resolution for this issue is to ensure there is adequate power generation on site to keep the charge controller from shutting off completely for an extended period.

Liquids – The turbine was designed to handle liquids. At site 1, liquids in the pipeline were in an annular flow regime. This may have contributed to the reduced RPM of the turbine, leading to low power generation. At site 2, the turbine was installed immediately downstream of a 3-phase separator. The pipe flowing into the turbine was a combination of gas and condensate. The flow regime here was noted to be annular mist, although given the high production rate, the pipe was essentially only gas. When the separator condensate dump valve opened into the line, the regime would immediately change to slug flow, almost exclusively liquid condensate. This caused the turbine RPM to spike for brief periods of time, which can cause the device to exceed the CSA rated 2200 RPM. The bypass around the turbine had to be left open to ensure the RPM did not exceed 2200 RPM, leading to a lower RPM rate whenever the separator is not dumping condensate to the pipeline. This can be addressed by having an automated control valve on the bypass of the turbine. As the turbine RPMs increase, the bypass around the turbine will open, causing a reduction in turbine RPM. This would ensure the turbine remains at an optimal RPM, provided there is sufficient flow.



The project proved more challenging for the IPTG manufacturer (Tazman Turbinz Corp, based in Florida, USA) than had been originally anticipated. This contributed to the delays encountered in this project (original date of completion was to be March 2020). The most important challenges / learning opportunities are described below.

A. <u>Modifications for Canadian regulatory compliance / environmental conditions</u>
   1. CSA certification for hazardous locations. The IPTG underwent rigorous analysis and testing by CSA Edmonton. The current IPTG design iteration received certification on

April 26, 2021. In the process of obtaining the CSA certification, a number of design modifications were necessary.

2. Welding and testing of flanges in accordance with Canadian Registration Number (CRN) regulations. This required approval of the welding design and an impact test performed at low temperature. A hydrotest is performed at the completion of each spool production. CRN registration was granted on December 4, 2020. The welding operation is performed by an experienced provider located in Alberta, Canada.
3. The control cabinet was redesigned so that all components are CSA-approved (as is the panel builder) and rated for use at extreme temperatures.

B. <u>Well sites with strong flow rate fluctuations.</u> In the development of the IPTG, Tazman Turbinz Corp. assumed that gas flow at well sites would follow a long-term trend (generally declining) with moderate fluctuations around this trend line. Such changes in the flow rate can be accommodated by using a control valve in line with the IPTG, with or without feedback loop. One of the project's well sites displayed more severe short-term fluctuations, with the IPTG rpm at times exceeding 2000 and then descending dramatically all the way to zero. Such flow characteristics cannot be sufficiently smoothed out with a control valve. Power generation by the IPTG will be sub-optimal as the IPTG rpm are frequently outside of the efficient operating range. Based on this experience, it is not advised to use the IPTG when gas flow rates are highly variable.

C. <u>Modifications for lower-flow applications.</u> In order to operate at lower flow rates (as are apparently common on Alberta gas well sites relative to some other areas), the IPTG rotating assembly required redesign so as to capture the kinetic energy of the gas in a more efficient manner. Market research by Tazman Turbinz was not able to find technology already in operation that could meet this challenge. Using in-house calculations to determine optimal stator / rotor dimensions as well as empirical testing, Tazman Turbinz has developed an IPTG configuration for lower-flow well sites. As mentioned in the "Commercialization" section (see above), this IPTG version will be tested on site later in 2022. A limitation of this "low-flow" IPTG version is that it is sensitive to over-speeding. Tazman Turbinz therefore intends to develop a control loop using an industrial computer (already included in the current control panel) and a control valve so as to optimize the flow rate through the bypass-mounted IPTG. ERA will be updated with the results from the low flow turbine design.

Environmental Benefits

Emission Reduction Impact

For Projects that result in direct GHG emissions reductions, please quantify the GHG reductions in a manner consistent with the Measurement Monitoring and Verification (MMV) plan specified in the conditions of the funding agreement (if applicable). A description of the baseline scenario for all GHG reduction calculations including justification for why that is the most appropriate choice of baseline should be included. The basis, scope or size of the Project must be provided to enable an emissions reduction intensity calculation. • For Projects that result in associated or enabled emissions reductions, i.e., emission reductions that are facilitated but are not directly attributed to the technology (carbon separation technologies, measurement and monitoring, behavior tracking programs, etc.), please provide a forecast of expected GHG reductions in Alberta from commercial roll out of the technology in Alberta by the years 2030 and 2050, and thereafter. • For Projects that result in future and indirect GHG emissions reductions, i.e., after subsequent market adoption or further commercialization, please provide a forecast of the estimated annual GHG reductions in Alberta from commercial roll out of the technology in Alberta by the years 2030 and 2050, and thereafter. The expected start date of commercialization and level of market saturation and speed of market adoption should be described. This can be presented as a year over year commercial rollout, or it can be in reference to a published reference market size and anticipated % adoption • Discussion regarding how the completed Project may help facilitate a low-carbon economy and secure Alberta's success in a GHG-constrained future should be included.

Provincial methane reduction regulation places strict limits on the emissions of the pneumatic chemical pumps. This regulation differs for existing and "new" wellsites. Pneumatic pumps installed prior to January 1st of 2022 are allowed to continue to operate but their exhaust volume must be less than limit specified by the regulation. New wellsite's, built after Jan 1st of 2022, must be equipped with electric chemical pumps.

Therefore, the baseline case for the IPTG is an older website equipped with pneumatic chemical pumps. Natural gas wells have steep decline profiles where the production during the first year of operation can decline by as much as 70%. Unfortunately, the turbine installed at Site 1 (lower flow case) was not able to continuously generate electricity due to low gas flow rate. Therefore the turbine is not suitable for installation at older sites. Peyto installed the second turbine at a new well that was completed in March of 2022. This well produced 8.5 MMscfd, which was sufficient to power the chemical pumps at the wellsite. This site as per regulation had to be equipped with electric pumps therefore the installation of the turbine did not result in reduction of emissions. In order to highlight the potential of technology in this application Peyto calculated emissions that would have been vented by pneumatic chemical pumps if they were installed during site construction.

Month	Vented Volume	Gas Composition		Density		Emissions		
	e3m3	CH4 Mol Fr	CO2 Mol Fr	CH4 (kg/m3)	CO2 (kg/m3)	CH4	CO2	CO2eq
Jan	1.938	0.8691	0.0095	0.68	1.86	1.14	0.03	28.6
Feb	4.781	0.8691	0.0095	0.68	1.86	2.82	0.08	70.6
March	6.717	0.8691	0.0095	0.68	1.86	3.96	0.12	99.1
April	5.930	0.8691	0.0095	0.68	1.86	3.50	0.10	87.5
May	2.805	0.8691	0.0095	0.68	1.86	1.65	0.05	41.4
Monthly Average	4.434	0.869	0.010	0.678	1.861	2.615	0.078	65.4
Annual Projection	53.210	10.429	0.114	8.142	22.335	31.376	0.941	785.3

Other Environmental impacts

IPTG's performance did not warrant adoption for this technology at majority of natural gas wellsites. No other environmental benefits were identified at this time.

Economic and Social Impacts

- Description of the projected economic impacts in Alberta, including revenues, cost savings, job creation, investment attraction, economic diversification, tax revenue, etc., based on the outcomes of the Project.
- Description of how the Project has resulted in increased innovation capacity in the province through training of highly-skilled personnel, knowledge development, postsecondary partnerships, research organizations, startup companies, etc.
- Discussion of how the Project impacted local communities, underserved communities, and/or indigenous groups.
- Discussion of any other equity, diversity and inclusion related Project work and outcomes.

The concept of turbine generators is not new. For example, they are used extensively in hydro-electric power plants. However, using a turbine generator for applications on natural gas wells has not been done before. This application poses significant challenges:

- Electrical safety and regulatory requirements.
- Aggressive medium, often mixed with sediments, water, ice, etc.
- Variable flow characteristics (pressure, flow rate) and environmental conditions.

To meet these challenges, the IPTG is based on a highly innovative design. This applies in particular to the rotating assembly (rotors / stators machined out of single blocks of stainless steel mounted on a Monel shaft together with a magnet carries all finely balanced and supported by bearings of the highest quality). It is also the case for the electrical system, with the coils mounted on the outside of the pipe so a to preserve the integrity of system. (Note: this design sacrifices efficiency for safety and reliability, which are essential in this application.)

Even though the IPTG was developed in Florida, USA, it was quickly determined that Western Canada was the most attractive target market. Canada has taken strong measures toward the reduction of methane emissions. An important alternative energy source, solar power, can prove problematic due to weather conditions. Given the IPTG's bulk (~200 kg / 450 lbs including cables, control panel and shipping crate), it is not economical to produce the IPTG outside of Alberta for Canadian applications. Shipping costs for the components make fabrication in Alberta favorable. The decision was made to maximize Alberta content as much as possible. In percentage of total value for the IPTG, the control panel and field services, the breakdown currently and in the future is as follows:

Cost Category	% of Total Value	Current Sources		Future Sources	
		USA	Canada	USA	Canada
Raw materials (metals / plastics)	15%	100%	0%	50%	50%
Specialty IPTG components (bearings, coils, …)	9%	100%	0%	100%	0%
Control components (rectifiers, controllers, …)	7%	100%	0%	0%	100%
Spool parts (pipe, flanges) and cables	11%	40%	60%	0%	100%
Consumables (potting compound, fasteners, …)	4%	100%	0%	0%	100%
Machining operations	17%	100%	0%	50%	50%
Welding / pressure testing	11%	0%	100%	0%	100%
IPTG assembly and testing	9%	100%	0%	0%	100%
Control cabinet assembly	4%	100%	0%	0%	100%
Field services (installation, etc.)	13%	0%	100%	0%	100%
% of Total	**100%**	**70%**	**30%**	**25%**	**75%**

If it is a given that the well site operator moves away from fuel/gas generators to “clean energy”, the operator could consider three alternatives:

1. In-Pipe Turbine Generator (IPTG). Up-front costs include the IPTG and its control cabinet, the construction of a bypass furnished with flanges and a control valve, and a moderate number of batteries.
    - Advantage: 24/7 power generation independent of weather conditions.
    - Disadvantage: dependent of sufficient gas flow for the operation of the IPTG.
2. Solar panels. Up-front costs include the panels and the control cabinet and a significant number of batteries (capable of maintaining a charge during solar panel downtime).
    - Advantage: lower up-front costs than the IPTG.
    - Disadvantages: dependent of weather conditions. Battery damage / costs due to weather or pilferage.
3. Hybrid IPTG / solar panels solution. Up front costs combine the above with some savings due to fewer required batteries.
    - Advantages: higher reliability ensuring well-site operations. Reduced risk of battery damage.
    - Disadvantage: up-front costs.

Scientific Achievements

Concept of the In-Pipe Turbine Generator

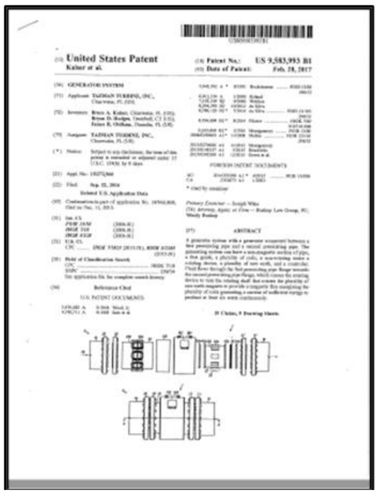
Tazman Turbinz’ sister company, Lightning Master Corp., provides lightning and surge protection and electrical bonding to customers primarily in the upstream oil & gas market. Customers expressed the need for reliable electric power production at the well site. They also expressed concerns regarding greenhouse gas emissions and increasing regulatory attention being paid to this issue.

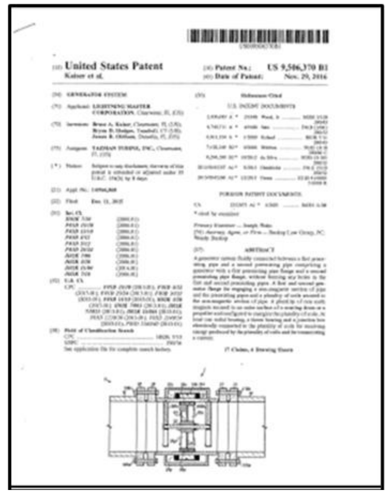
There was also an obvious source of power already on the gas well sites which did not require combustion and release of greenhouse gases: the kinetic energy of the gas itself.

Seeing an opportunity, Tazman Turbinz developed the concept of the IPTG (i.e., using the gas flow to rotate magnets on the inside of the pipe to create AC current with coils on the outside of the pipe).

Tazman Turbinz holds two IPTG patents:

- US 9,506,370 B1 filed 29 Nov. 2016. Generator system connected to pre-existing pipe. Magnets mounted on a rotating drum generate current in coils with drum rotation driven by gas flow through the pipe.
- US 9,583,993 B1 filed 28 Feb. 2017 covering recent modifications to the IPTG.


United States Patent
US 9,583,993 B1
Feb. 28, 2017


United States Patent
US 9,506,370 B1
Nov. 29, 2016

A. <u>Development of stator / rotor assembly</u>

Many of the technologies required in building the IPTG are in the public domain. Tazman Turbinz adopted best practices regarding pipe and flange selection, coil and e-cores, bearings and bearing seals, etc. However, Tazman was not able to find existing technologies for the construction of a velocity-compounding axial 2-stage turbine for use in a natural gas pipeline. Some applications were similar (e.g., turbine generators using steam), but there were some crucial differences to the IPTG.

- Working with gas that does not vent to atmosphere. The IPTG needs to minimize the impact on the natural gas in terms of pressure drop and temperature.
- The goal of the IPTG is to generate only enough power so as to meet the demands of the well site – not much more.
- The need to perform reliably in the presence of potentially corrosive chemicals (H_2S), water, sand or other foreign sediments at varying pressures and temperatures.

Tazman's innovative stator / rotor design minimizes the pressure drop. The temperature drop is also minimized by heat generated in eddy currents in the pipe being transferred back to the gas before it exits the IPTG. As mentioned in previous sections of this report, the stators / rotors are constructed using high-grade materials machined from single blocks so as to ensure the mechanical strength needed in the application.

To calculate optimal blade geometry, Tazman Turbinz developed its own extensive program to calculate all of the factors involved: energy transfer, pressure and temperature impacts, the resulting rotational velocity. This was combined with very tight tolerances to ensure minimal vibration which could result in wear and tear on the IPTG. The rotors and stators are produced on state-of-the-art four-axis mills. A screen shot of the blade geometry design program provides some insight into its complexity.

Since theoretical calculations only go so far, Tazman Turbinz also designed an IPTG test stand for proof-of-concept testing. This test stand includes a Vortex flowmeter, several temperature and pressure transducers, a vibration sensor, a control valve, and thermocouples for measuring temperature at critical points in the IPTG and the pipe. The system is controlled using a Schneider Electric PLC.

Tazman Turbinz has had discussions with the University of Calgary. The intention on both sides is that the University of Calgary would assist in the IPTG testing and provide an independent analysis of the results.

Overall Conclusions

Two IPTGs were installed as part of the trial. Site 1 was unsuccessful at generating adequate power for the site. The underlying issue was that the turbine was designed for a much higher flowrate. The low flow characteristics of site did not cause sufficient RPM to generate power.

The IPTG at site 2 did adequately generate electricity for the site. The solar panels have been shut down and the site is running solely on power generated from the IPTG. As the flow on the well declines, this site will experience the same issues as site 1. The turbine required high flow to remain effective.

Overall, the installation cost and power generation outputs of the turbine do not compete with solar and battery technology that are currently available. As solar panel efficiencies go up, they remain favorable for remote power generation at remote wellsites. Reassessment of this conclusion should be made in the future as both solar and IPTG technologies progress.

Next Steps

- Discussion about the next steps for the technology/process/innovation, including potential follow-up Projects
- Long-term plan for commercialization of the Project technology/learnings
- Commercialization-related actions to be undertaken within two years of Project completion
- Potential partnerships under development with technology integrators, adopters, etc.

The IPTG is ready for immediate commercialization when used within the constraints mentioned earlier, which were:

- Maximum of 2200 rpm / 210 Watt as imposed by the CSA Class I Division 1 hazardous location certification.
- Gas flow characteristics (flow rate / pressure / temperature) able to sustain a steady rotation of at least 1300 rpm (more for higher power generation) in the IPTG.

Several Alberta-based gas well operators have expressed interest in conducting their own initial IPTG installations.

It is Tazman Turbinz' intention to significantly broaden the range of applications of the IPTG at remote natural gas well sites. In order to do so, the following next technological steps are planned and already being pursued.

1. Low-flow IPTG version. Changes in the stator / rotor geometry will enable this IPTG version to generate higher rpm / power in applications with lower gas flow rates. This IPTG version has already been designed, but still needs to be empirically tested.
2. Control valve regulated by the industrial computer already installed in the control panel. The current system is able to capture the IPTG rpm. This data can then be used to open or close the valve periodically to ensure that the flow characteristics through the IPTG are in the optimal range.
3. Recertification testing of the IPTG. The current rpm / power restrictions reflect the limitations of the CSA testing facility. Using the new Tazman Turbinz test stand, a more accurate and realistic test can be conducted. We expect that the limit will be raised to around 400 Watt. The process for re-certification has already been initiated.

Beyond technical changes to the IPTG, it will be important to decrease its costs. Some cost reductions are possible through higher volumes, thereby decreasing the proportion of costs for machine set-ups and other processes. Some tooling improvements can be made (e.g., for coil production). However, the quickest advancement with the highest return is to move production closer to the market. Currently, a very high proportion of costs are due to the shipment of heavy, bulky parts over long distances and an international border. While some sensitive or CSA-prescribed parts may not be changed in the near-term, several moves toward an Alberta-based supply chain will be implemented.

- The construction of the control cabinets and the sourcing of its components.
- Welding of the flanges and of some other parts onto the pipes is already being performed by a partner in Alberta.

- Field services (installation and maintenance) is also already being done by an Alberta company.
- Eventually the machining of some parts and the last-stage assembly / testing could be moved to Alberta. This step will require CSA approval.

Communications plan

This project was a collaboration Between Peyto, Emissions Reduction Alberta and Tazman Turbinz. There was input from all groups throughout the project. Results have been shared and discussed amongst all involved parties. Peyto intends to share the results of the low flow turbine design with ERA when results are available.

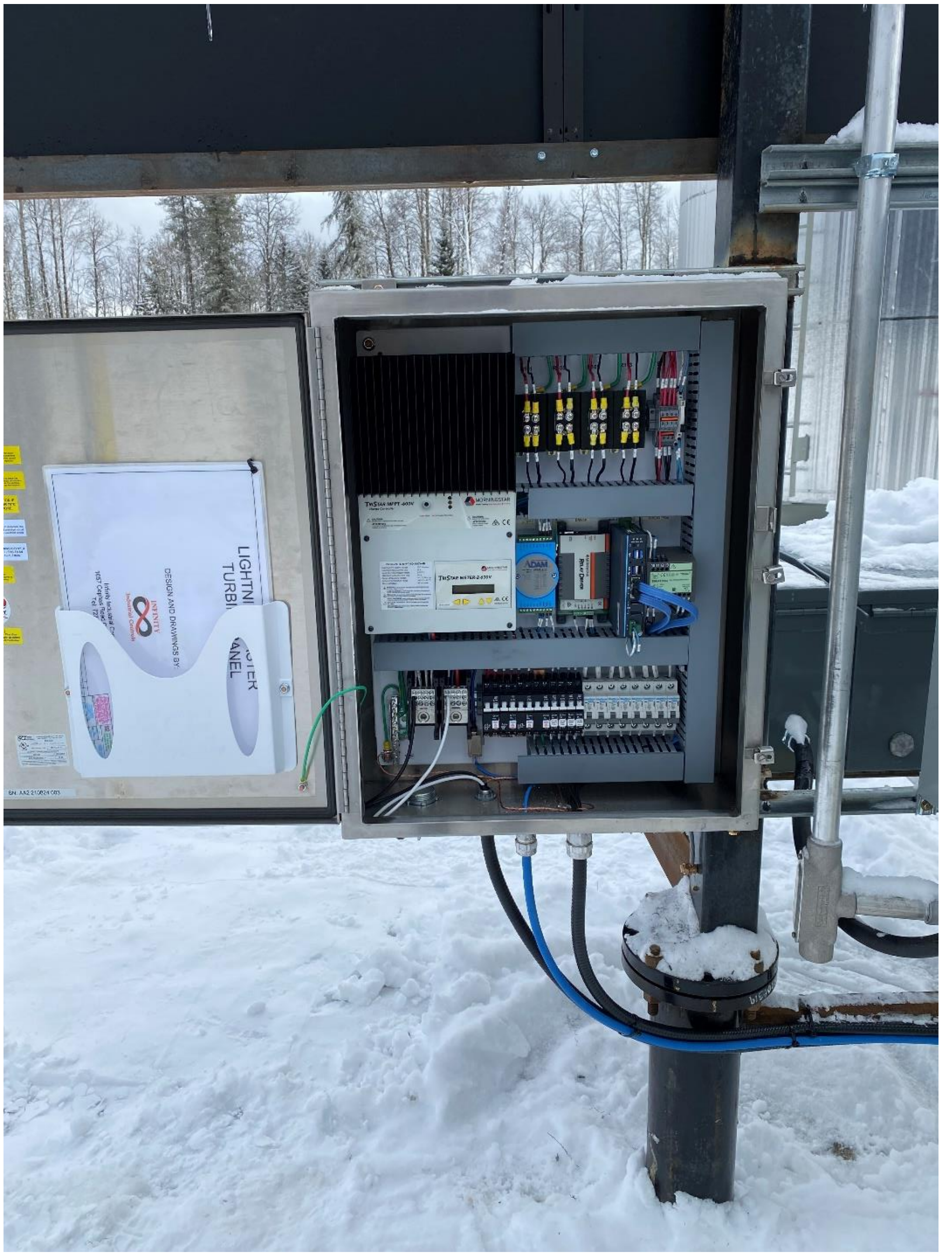
Installation Photos

Site 1 Install

Site 1 Control Panel next to Peyto RTU

Site 1 Control Panel

Site 2 Install



Site 2 Control Panel

Intake side of IPTG

Discharge side of IPTG.

EMISSIONS REDUCTION ALBERTA	Project Emissions Reductions	ID: F0160093

Recipient Organization	Peyto Exploration
Title	In-Pipe Turbine Generator Field Demonstration Project

GHG Emission Reductions (ERs): 2011–2050	
2011	0
2012	0
2013	0
2014	0
2015	0
2016	0
2017	0
2018	0
2019	0
2020	0
2021	0
2022	0
2023	0
2024	0
2025	0
2026	0
2027	0
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2044	0
2045	0
2046	0
2047	0
2048	0
2049	0
2050	0

Please Refer to ERA’s Website For the Quantification Methodologies
https://www.eralberta.ca/calculating-ghg-emissions-reduction/