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CORE Liner® ESG Advantages

I. Context

As part of its environmental, social and governance (ESG) responsibilities, and to comply with regulatory requirements and initiatives, the energy and the utilities industries ramped up their efforts to further reduce their environmental impact. As a result, the industry currently aims to build infrastructure that is safe, long-lasting and minimizes the GHG emissions. Controlling the GHG emissions is a large task as it needs to be done over the entire chain of the operational activities, starting from the well head up to consumption.

II. Pipelines

Pipelines play a major role in the energy supply chain and are the safest way of transporting oil and gas products from the well head to the consumer. When building new pipelines, end users aim to build pipelines that are safe, reliable, cost effective and having the smallest possible impact on the environment. Historically, most pipelines were built from carbon steel, which made them susceptible to corrosion.

III. Carbon Steel Pipelines

The industry adopted several measures to fight the corrosion of carbon steel pipelines, including pipe coating, cathodic protection, and chemical treatment. These measures proved reasonably successful; however, did not fully eliminate corrosion. In some instances, the industry used plastic liners that are field pulled into carbon steel pipelines. Field pulled liners were successful in combatting corrosion but introduced other challenges such as requiring buried flanges and buried jumper vents. In recent years, the industry increasingly adopted the use of non-metallic pipelines which were mostly immune to corrosion.

IV. Non-metallic Pipelines

Although non-metallic pipelines promised to resolve the corrosion concerns, they introduced several new concerns, such as reduced pipelines robustness. Several non-metallic pipelines were quite susceptible to installation damages and required a specialized trench construction. Some non-metallic systems had a very low fatigue endurance limit and ruptured frequently in liquid services involving pressure cycling and pulsations. In addition, non-metallic pipelines significantly increased the GHG emissions in pipelines operating in gas service as a result of gas permeation.

V. CORE Liner®

As the most damaging potential effects pipelines may have on the environment are the consequences of a release, the industry previously had to contend with either using carbon steel pipelines and struggling with corrosion control, or using non-metallic pipelines and being constrained by their limitations. CORE Liner®, which is a pipe-in-pipe system that utilizes an outer carbon steel pipe for structural strength and an inner plastic liner for corrosion resistance combines the strength and versatility of carbon steel, and the corrosion resistance of plastics.

A. The Containment Solution

As a result of its unique construction, CORE Liner® offers a dual containment solution, where the primary containment of the bore fluids is provided by the inner plastic liner, and the secondary containment is provided by the steel pipe. In the unlikely event of a breach in the plastic liner, any bore fluids that would leave the pipe bore would get contained in the annular space located between the outside of the plastic liner and the inside of the steel pipe. In that case, the liner breach can be effectively and quickly located using CORE Linepipe® Liner Breach Location Procedure, so that the breach location is identified, and the breach is expeditiously cut out and replaced with a new pipe section.

B. Primary Containment Exception Monitoring

The annular space of CORE Liner® is continuous along the pipeline length, and CORE Liner® is provided with a factory-built thread-o-let port at every flange. The unique characteristics of CORE Liner® of dual containment, continuous annular space and flange ports not only allow for the containment of any fluid loss before having a release into the outside environment, but also enable the possibility of monitoring the primary containment for breaches. The flange port can act as an annular space detection point by being equipped with sensors capable of measuring the pressure, temperature and/or moisture, and relaying the data remotely by cellular network.

C. Midline Fittings

In addition to the port available at every CORE Liner® flange, CORE Linepipe® also offers a midline fitting which is a pup mounted with a factory-built thread-o-let port. The midline fitting can be installed at strategic locations along the pipeline length to enable remote sensing of the annular space at critical pipeline locations, and also provides a sensing point in case the breach location procedure needs to be used. The need for, the number, and location of the midline ports is dependent on the profile and layout of the pipeline in question. Typically, it may be advantageous to have ports at intervals of around 1 km, at low points of the pipeline, and before and after environmentally sensitive areas.

VI. Gas Emissions

A. Gas Permeation

Gas molecules have a natural ability to very slowly move through materials. This is referred to as gas permeation. The rate of gas permeation depends on the type of material, the type of gas, the temperature and the pressure differential across the material. Gas permeation through carbon steel material is so small that it is practically considered non-existent. As gas permeation occurs through plastic materials at a several orders of magnitude higher rate than through metallic materials, the use of non-metallic pipelines brought forward the discussion of permeation levels and its impact on GHG emissions from non-metallic pipelines. Gas permeation in non-metallic pipelines causes fugitive emissions along the length of non-metallic pipelines as permeated gases escape directly into the atmosphere, in addition to the continuous uncontrolled release of permeated gas from the annulus of multi-layered non-metallic pipelines into the atmosphere.

B. Emissions Terminology

The permeated gases may be released or handled in various ways. The industry uses the following terminology to refer to the various possibilities:

1. Fugitive Emissions:

Uncontrolled gas emissions that are continuously released to the atmosphere. These emissions can occur by permeation through the pipe wall directly to the atmosphere, by continuous venting of the annular space of multi-layered pipes, or as emissions from a leaking joint.

2. Controlled Venting:

The planned and controlled venting of gases from the annular space to the atmosphere. This is typical of plastic lined carbon steel pipelines.

3. Captured Venting:

The planned and controlled venting of the annular space where the vented gases are captured and managed such that to have Zero-emissions to the environment.

C. Gas Permeation Rates

The volume of the permeated gas can be calculated as follows:

$$V = \frac{K.A.(Pp1 - Pp2)}{t}$$

Where,

Symbol	Description	Metric Units	Imperial Units
V	The volume of the permeated gas	$cm^3/(m.sec)$	$in^3/(ft.sec)$
K	The permeation coefficient	$cm^3/(cm.sec.MPa)$	$in^3/(in.sec.psi)$
A	The area over which permeation is happening	cm^2/m	in^2/ft
P_{p1}	The partial pressure of the gas in the 1st space	MPa	Psi
P_{p2}	The partial pressure of the gas in the 2nd space	MPa	Psi
t	The thickness of the material	cm	In

The permeation coefficients for high density polyethylene materials at 40^0C (104^0F) are as follows:

Gas	Permeation Coefficient, K	
	$cm^3/(cm.sec.MPa)$	$in^3/(in.sec.psi)$
Methane	1×10^{-7}	1.07×10^{-10}
Carbon Dioxide	5.5×10^{-7}	5.88×10^{-10}
Hydrogen Sulfide	1×10^{-7}	1.07×10^{-10}

A survey of the published literature indicates that the permeation data for Fiberglass pipes is scarce. However, it seems that reasonable estimates of the permeation coefficients of fiberglass pipes at 40^0C (104^0F) can be approximated as below.

Gas	Permeation Coefficient, K	
	$cm^3/(cm.sec.MPa)$	$in^3/(in.sec.psi)$
Methane	3×10^{-9}	3.2×10^{-12}
Carbon Dioxide	2×10^{-8}	2.1×10^{-11}
Hydrogen Sulfide	3×10^{-9}	3.2×10^{-12}

VII. Fugitive Emissions of RTP products

Typically, RTP products emit the entire volume of gas that permeates the inner liner to the atmosphere. This happens either by permeation through the plastic outer jacket over the length of the pipeline, or by continuous venting at the vent holes at the end of every reel of pipe. An estimate of the volume of the fugitive emissions of an RTP pipeline is shown in the below table.

	Fugitive Emissions, m^3/km/month			Fugitive Emissions, ft^3/mile/month		
	Service Pressure, MPa			Service Pressure, psi		
Gas mixture	**1**	**5.1**	**10.2**	**145**	**740**	**1480**
84% Methane	1.06	5.87	11.85	59.7	331.5	669.6
15% CO2	1.04	5.76	11.64	58.6	325.6	657.7
1% H2S	0.01	0.07	0.14	0.7	3.9	8.0
Total	**2.11**	**11.70**	**23.63**	**119.0**	**661.0**	**1,335.2**

Note: The above calculations are based on a service temperature of 40^0C (104^0F) and an SDR of the inner liner of 17.

VIII. Fugitive Emissions of HDPE Pipes

HDPE pipes are solid wall and all the gas that permeates the pipe wall is emitted directly to the atmosphere as fugitive emissions. An estimate of the volume of fugitive emissions generated by an HDPE pipeline is shown in the below table.

	Fugitive Emissions, m^3/km/month			Fugitive Emissions, ft^3/mile/month		
	Service Pressure, MPa			Service Pressure, psi		
Gas mixture	**0.25**	**0.5**	**1**	**36**	**73**	**145**
84% Methane	0.19	0.38	0.76	10.7	21.4	42.9
15% CO2	0.19	0.37	0.75	10.5	21.1	42.1
1% H2S	0.00	0.00	0.01	0.1	0.3	0.5
Total	**0.38**	**0.76**	**1.51**	**21.4**	**42.7**	**85.5**

Note: The above calculations are based on a service temperature of 40^0C (104^0F) and an SDR of 11.

IX. Fugitive Emissions of Fiberglass Pipes

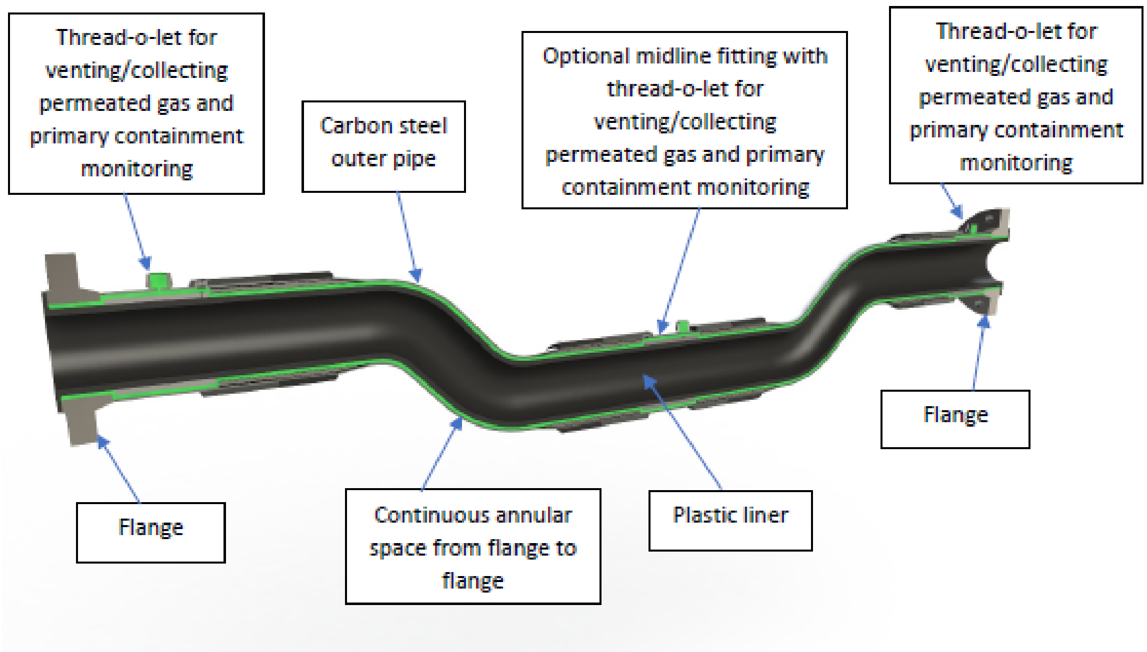
Fiberglass pipes are solid wall and gases that permeate the pipe wall are directly emitted to the atmosphere as fugitive emissions. An estimate of the volume of fugitive emissions generated by a fiberglass pipeline is shown in the below table.

	Fugitive Emissions, m^3/km/month			**Fugitive Emissions, ft^3/mile/month**		
	Service Pressure, MPa			**Service Pressure, psi**		
Gas mixture	**1**	**5.1**	**10.2**	**145**	**740**	**1480**
84% Methane	0.06	0.28	0.57	3.1	16.0	31.9
15% CO2	0.07	0.34	0.67	3.7	19.0	38.0
1% H2S	0.00	0.00	0.01	0.0	0.2	0.4
Total	**0.12**	**0.62**	**1.24**	**6.9**	**35.2**	**70.3**

Note: The above calculations are based on a 100 mm (4”) pipe with a 4 mm (0.157”) wall thickness and a service temperature of 40^0C (104^0F).

X. CORE Liner® in Gas Service

The below schematic shows a simplified CORE Liner® system and highlights the main features that are important for the gas permeation discussion.



The gases that permeate the inner plastic liner of the CORE Liner® pipeline are totally contained in the annular space. The fact that the plastic liner of a CORE Liner® pipeline is fully encapsulated within the carbon steel pipe prevents fugitive emissions from developing over the length of the CORE Liner® pipeline. These permeated gases are only disposed of during intentional controlled venting events and can be managed and safely handled without being released to the atmosphere. Accordingly, a CORE Liner® pipeline may be operated in a manner not to release any permeated gas to the environment, i.e. CORE Liner® pipelines can be operated as Zero-emissions pipelines.

As the gas permeates the plastic liner of the CORE Liner® pipeline, the pressure in the annular space increases. The annular pressure acts as a backpressure and drastically reduces the amount of gas that permeates the plastic liner. As a result, the volume of gas that needs to be managed during a monthly venting event of a CORE Liner® pipeline operating in gas service is very small, is independent of the operating pressure of the pipeline and can be estimated as follows.

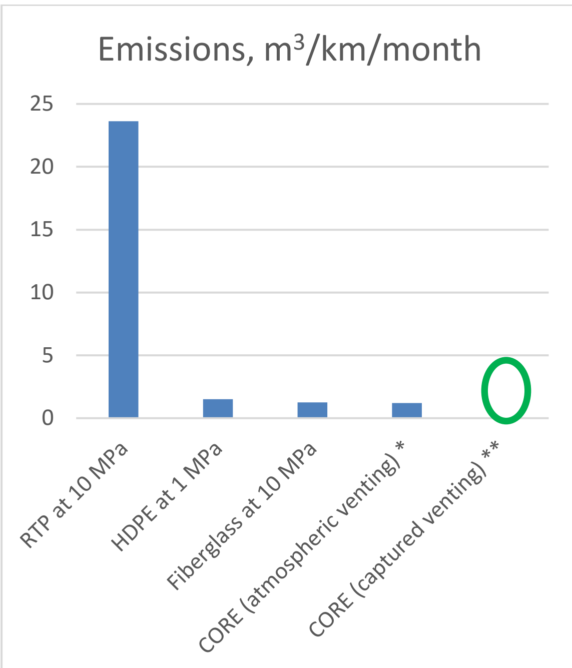
Gas mixture	Venting Volume, m^3/km/month	Venting Volume, ft^3/mile/month
84% Methane	0.60	33.9
15% CO2	0.59	33.3
1% H2S	0.01	0.4
Total	**1.20**	**67.6**

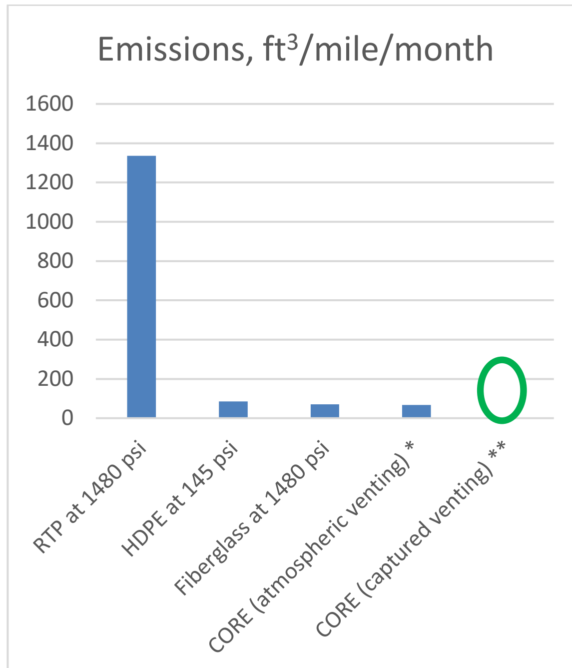
The volume of gas present in the annulus that needs to be managed in the uncommon event when the CORE Liner® pipeline bore needs to be de-pressured can be estimated as follows.

		Gas Volume, m^3/km/depressurization			Gas Volume, ft^3/mile/depressurization		
		Service Pressure, MPa			Service Pressure, psi		
Product	**Gas mixture**	**1**	**5.1**	**10.2**	**145**	**740**	**1480**
CL-440	**84% Methane**	0.14	0.71	1.42	7.9	40.0	80.1
	15% CO2	0.02	0.13	0.25	1.4	7.2	14.3
	1% H2S	0.00	0.01	0.02	0.1	0.5	1.0
	Total	**0.17**	**0.84**	**1.69**	**9.3**	**47.7**	**95.3**
CL-648	**84% Methane**	0.21	1.06	2.12	11.8	60.0	119.9
	15% CO2	0.04	0.19	0.38	2.1	10.7	21.4
	1% H2S	0.00	0.01	0.03	0.1	0.7	1.4
	Total	**0.25**	**1.26**	**2.53**	**14.0**	**71.4**	**142.8**
CL-856	**84% Methane**	0.27	1.39	2.78	15.4	78.7	157.4
	15% CO2	0.05	0.25	0.50	2.8	14.1	28.1
	1% H2S	0.00	0.02	0.03	0.2	0.9	1.9
	Total	**0.32**	**1.66**	**3.31**	**18.4**	**93.7**	**187.3**

XI. Emissions of the various Pipe Options

A comparison of the gas emissions of the various pipeline options are as follows:





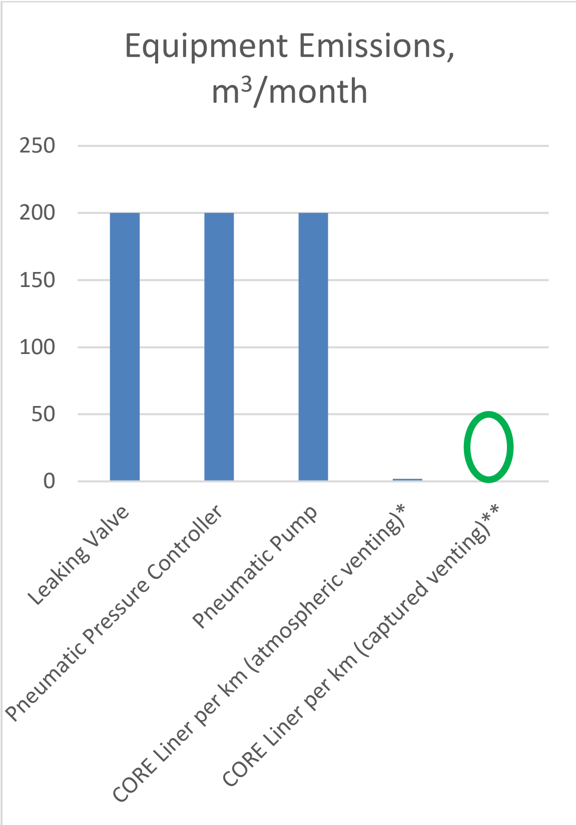
* Applicable when CORE Liner® is vented to the atmosphere, and valid for any operating pressure.

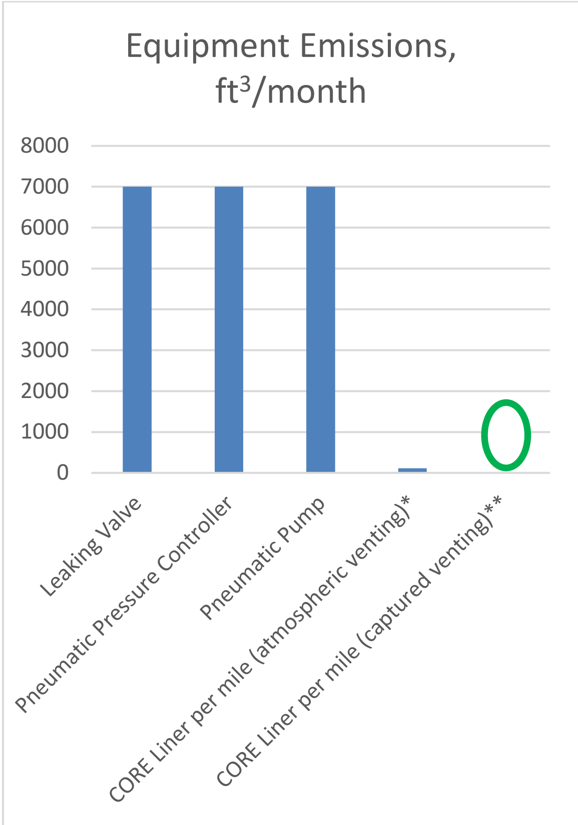
** Applicable when the vented gas of CORE Liner® is captured and managed, and valid for any operating pressure.

XII. Putting the Values in Perspective

A. Comparison to Equipment

To put the above values in perspective, a leaking valve, a pneumatic pressure controller, or a pneumatic pump are estimated to release around 200 m^3 (7,000 ft^3) of GHG/month each. The gas volume of 1.2 m^3/month/km (68 ft^3/month/mile) of a one-kilometer (one mile) CORE Liner® pipeline generated at the monthly venting event is 0.6% (1.0%) of a leaking valve. The vented gas at the CORE Liner® vent point can be easily collected and dealt with without any release to the environment. A properly managed CORE Liner® system can be a <u>Zero-emissions</u> system.





* Applicable when CORE Liner® is vented to the atmosphere, and valid for any operating pressure.

** Applicable when the vented gas of CORE Liner® is captured and managed, and valid for any operating pressure.

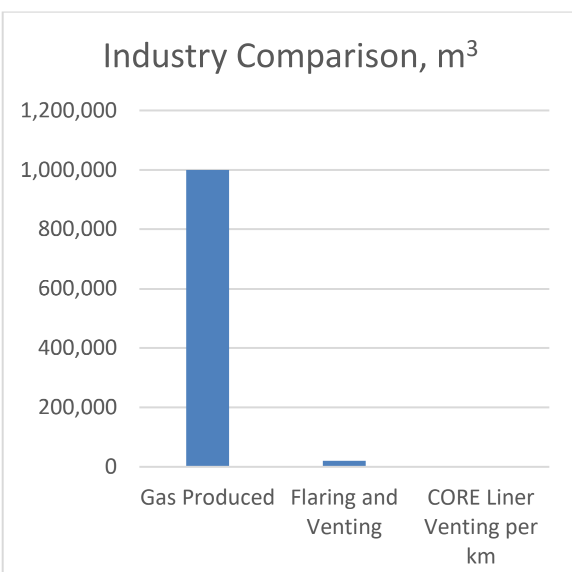
B. Comparison to the Industry

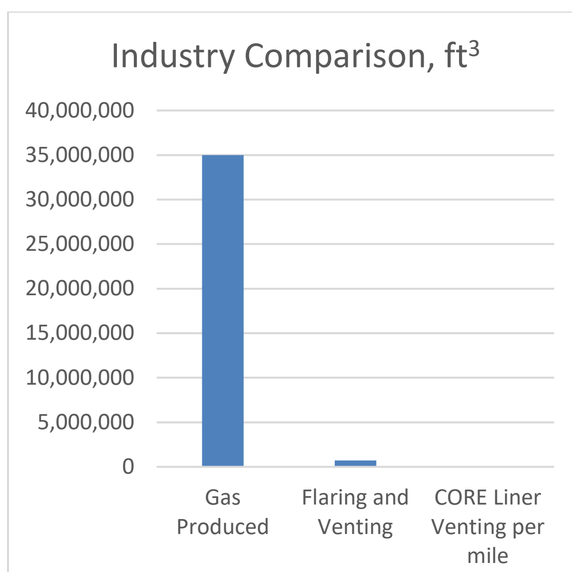
Considering a more general perspective, a CORE Liner® pipeline could transfer 1,200,000 m^3 (42 MMSCF) of gas/month and would emit 1.2 m^3/month/km (68 ft^3/month/mile) if vented to the atmosphere. Accordingly, a one-kilometer (0.6 mile) CORE Liner® pipeline would vent 1 m^3 (35 ft^3) for every 1,000,000 m^3 (35 MMSCF) of transported gas.

In comparison, the Alberta Energy Regulator (AER) report ST60B-2020 indicates that the industry wide solution gas conservation rate in 2019 was 97.7 %. This means that for every 100 m^3 (3,500 ft^3) of solution gas produced, 97.7 m^3 (3,420 ft^3) were delivered whereas 2.3 m^3 (80 ft^3) were lost to flaring or venting, i.e. the industry roughly flared or vented 1 m^3 (35 ft^3) of gas for every 50 m^3 (1,750 ft^3) of gas produced.

Accordingly, for every 1,000,000 m^3 (35 MMSCF) of gas produced, 20,000 m^3 (700 MSCF) were lost to flaring and venting along the upstream extraction and processing chain, and 1 m^3 (35 ft^3) would have been lost in a one-kilometer (0,6 mile) CORE Liner® pipeline.

	Gas Volume, m3	Gas Volume, ft3	Gas Conservation, %
Gas Produced	1,000,000	35,000,000	
Flaring and Venting	20,000	700,000	98%
CORE Liner Venting per km	1	35	99.9999%
CORE Liner Venting per mile	1.6	56	99.9998%





XIII. Operational Guidance

The vent ports of CORE Liner® consist of a thread-o-let with a ½” NPT opening. One vent port is available on each CORE Liner® flange. A vent port is also available on each midline fitting. Typically, the vent port is connected in the field to a vent tube that is ½”, 316 stainless steel, NPT thread, TW 0.035”. Any permeated gas can be collected from the vent tube and either pressurized and reinjected into the production stream or directed to the disposal unit. Sour gas can be scrubbed through a compact, bottle type hydrogen sulfide scrubber.

CORE Linepipe evaluates every project on a case-by-case basis via the application review process. The aim is to verify the suitability of CORE Liner® for the anticipated service conditions and to provide any applicable recommendations to ensure the pipeline will successfully operate over its design life. Please contact CORE Linepipe for any questions or to request an application review.

XIV. Summary

CORE Liner® pipelines are a very attractive option for fulfilling ESG goals, and offer the following advantages:

- Corrosion resistant pipelines with plastic lining on all wetted surfaces.
- Increased operational flexibility as it avoids the limitations of non-metallic pipelines.
- Use a robust metal-on-metal mechanical interference fit joining system.
- Offer dual containment thus virtually eliminating the possibility of a release to the environment.
- Enable the option of remotely monitoring the integrity of the primary containment.
- Use patented high performance sealing rings for flanged joints in high pressure or high temperature applications.
- Eliminate the need for buried flanges and the related potential leaks on field pulled liner systems.
- Eliminate the need for buried jumper vents as the built-in annular space of the CORE Liner® is continuous along the entire pipeline length.
- Inherently capture the permeated gases and enable their responsible management.
- Enable achieving <u>Zero-emissions</u> along the length of the pipeline.