FINAL

ALASKA PIPELINE PROJECT

Gas Off-take Study

B&V PROJECT NO. 174126

PREPARED FOR

Alaska Gas Pipeline Project Office

4 NOVEMBER 2011

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Executive Summary

BACKGROUND AND SCOPE

The Alaska Pipeline Project (APP) is a natural gas pipeline project in development to supply natural gas from Alaska's North Slope to new markets in Alaska and other parts of the US, and also Canada. The pipeline is being developed cooperatively by TransCanada and ExxonMobil.

The APP may provide a minimum of five (5) gas off-takes (i.e. delivery points) from the pipeline to provide future gas supply to Fairbanks, Anchorage and small communities and industries along the proposed pipeline route. Black & Veatch has been retained to perform an assessment of two identified potential options to facilitate the delivery of natural gas to small communities and industry. The options under consideration are:

1. Compressor Station Side-Stream – Utilizing the natural gas regulated for the compressor turbine operations and station utilities at an assumed pressure of 600 psi to supply gas to local communities and industries.

2. Stub Gas Delivery – Install a small stub on the side of the APP pipeline at strategic locations along the route where potential gas delivery points may be required in the future. These stubs would be activated (hot tapped) when a commercial agreement has been reached for the gas supply at a later date.

BLACK & VEATCH FINDINGS AND RECOMMENDATIONS

Black & Veatch has reviewed the data available for both options and recommends that Option #2 (Stub Gas Delivery), involving the installation of a small pipe stub welded onto the side of the APP pipeline at strategic locations during construction of the pipeline. The small diameter stubs will initially not have live gas, but rather will be installed at intervals along the mainline offering flexibility with respect to potential delivery point additions in the future. Such delivery points would be achieved by a hot tap process utilizing the various pipe stub locations. This method of delivery point establishment represents the simplest, most flexible and economical way to provide the availability of natural gas to Alaska communities until a commercial agreement is in place.

Budgetary estimates of the costs involved with the Stub Gas Delivery option are summarized in the table below:

COST	COSTS PER LOCATION ($US)
Capital Costs	$150,000 - 200,000
O&M Costs	$50,000 - 75,000/year

The capital costs are for the M/R stations which will be built for gas delivery to the communities along the APP. Similarly, the O/M costs are for the weekly O/M activities by gas personnel for the M/R station and associated equipment.

While the Compressor Station Side-Stream option (Option #1), is, on the surface, an attractive option , considering the gas supply and pressure available at each compressor station; a deeper review of business and regulatory concerns results in a finding that issues associated with gas takes from the mainline compressor stations make the establishment of such delivery point likely unfeasible. Also, from the Alaska Pipeline Project Resource Report No. 1 Preliminary Draft, the proposed sites for the 8 compressor stations limits the possible gas delivery options for communities to those within a feasible distance to a particular compressor station.

Introduction

Black & Veatch has been retained by the Alaska Gas Pipeline Project Office (GPPO) to provide consulting services relative to the study and analysis of options for the provision of natural gas utility services to small communities and industries along the Alaska Pipeline Project (APP).

Black & Veatch has carried out a study to evaluate two options and methodologies to provide gas off-takes from the APP pipeline in Alaska. This study assesses the engineering considerations of the two options and evaluates their implementation in terms of strategic and economic benefits.

BACKGROUND

The APP is a natural gas pipeline project in development to supply natural gas from Alaska's North Slope to new markets in Alaska and other parts of the US, and also Canada. The pipeline is being developed cooperatively by TransCanada and ExxonMobil.

The APP may provide a minimum of five (5) gas off-takes (i.e. delivery points) from the pipeline to communities in Alaska. Two of the planned delivery points are assumed to be Fairbanks and Anchorage. The study has assumed that subsequent delivery points will be used to provide future gas supply to small communities and industries along the proposed pipeline route.

Providing these gas delivery points with relatively small gas loads may raise some issues:

- The main pipeline will operate between 2,000-2,500 psi_g. Reducing the gas pressure to below 100 psi_g safely and reliably may require multiple pressure regulation steps and gas heating stages.
- The gas in the pipeline will likely have a heating value higher than what is typically delivered to residential customers.

Scope

The GPPO retained Black & Veatch to evaluate two potential options to supply gas to small communities and industries along the APP pipeline, as specified by the GPPO. Black & Veatch assessed the two gas delivery point options and identified the optimum solution to assist small communities and industry gain access to the pipeline gas.

GAS DELIVERY POINT OPTIONS

The GPPO identified two potential options to facilitate the delivery of natural gas to small communities and industry. These options are:

1. Compressor Station Side-Stream - At all compressor stations, a gas pressure of 600 psi has been assumed for the compressor turbine operations and station utilities. This option would take advantage of the reduced gas pressure to supply gas to local communities and industries.
2. Stub Gas Delivery - Install a small stub on the side of the APP pipeline at strategic locations along the route where potential gas delivery points may be required in the future. This stubs would be activated (hot tapped) when a commercial agreement has been reached for the gas supply at a later date. Pressure reduction from 2,000-2,500 psi_g will be required at each gas delivery point location as activated.

Assessment of Available Data

PROCESS FLOW DATA

Black & Veatch reviewed the available preliminary project description provided in the APP Preliminary Draft Resource Report No. 1. The 48-inch-diameter Alaska Mainline will be designed for an annual average receipt capacity of approximately 4.0 to 4.5 bcfd with a Maximum Allowable Operating Pressure (MAOP) of 2,500 psig. A custody transfer meter station will be located at the GTP, eight compressor stations will be located along the pipeline at intervals of about 75 to 100 miles, and provision will be made for a minimum of five potential intermediate gas delivery points in Alaska.

The pipeline will be constructed of grade API X80 steel pipe with a minimum nominal wall thickness of 0.932 inch. North of the Brooks Range, the natural gas in the pipeline will be cooled to below freezing to minimize impact on the continuous permafrost. For stations located south of the Brooks Range, seasonal variation in station discharge gas temperature will range from about 25°F in the winter to about 45°F in the summer, resulting in an annual average temperature between 30°F to 35°F. See Figure 1 below for a map of the proposed APP pipeline.

In addition to the proposed pipelines, the APP pipeline is expected to include the installation and operation of eight compressor stations, two meter stations, fifty-two Main Line Block Valves (MLBV), five launchers, four receivers, and a minimum of five potential intermediate gas delivery points in Alaska. Of these, one meter station, four MLBVs, one launcher, and one receiver will be associated with the PTGP; the remainder will be located along the Alaska Mainline. The preliminary locations of aboveground facilities associated with APP pipeline are provided in the map found in Figure 2.

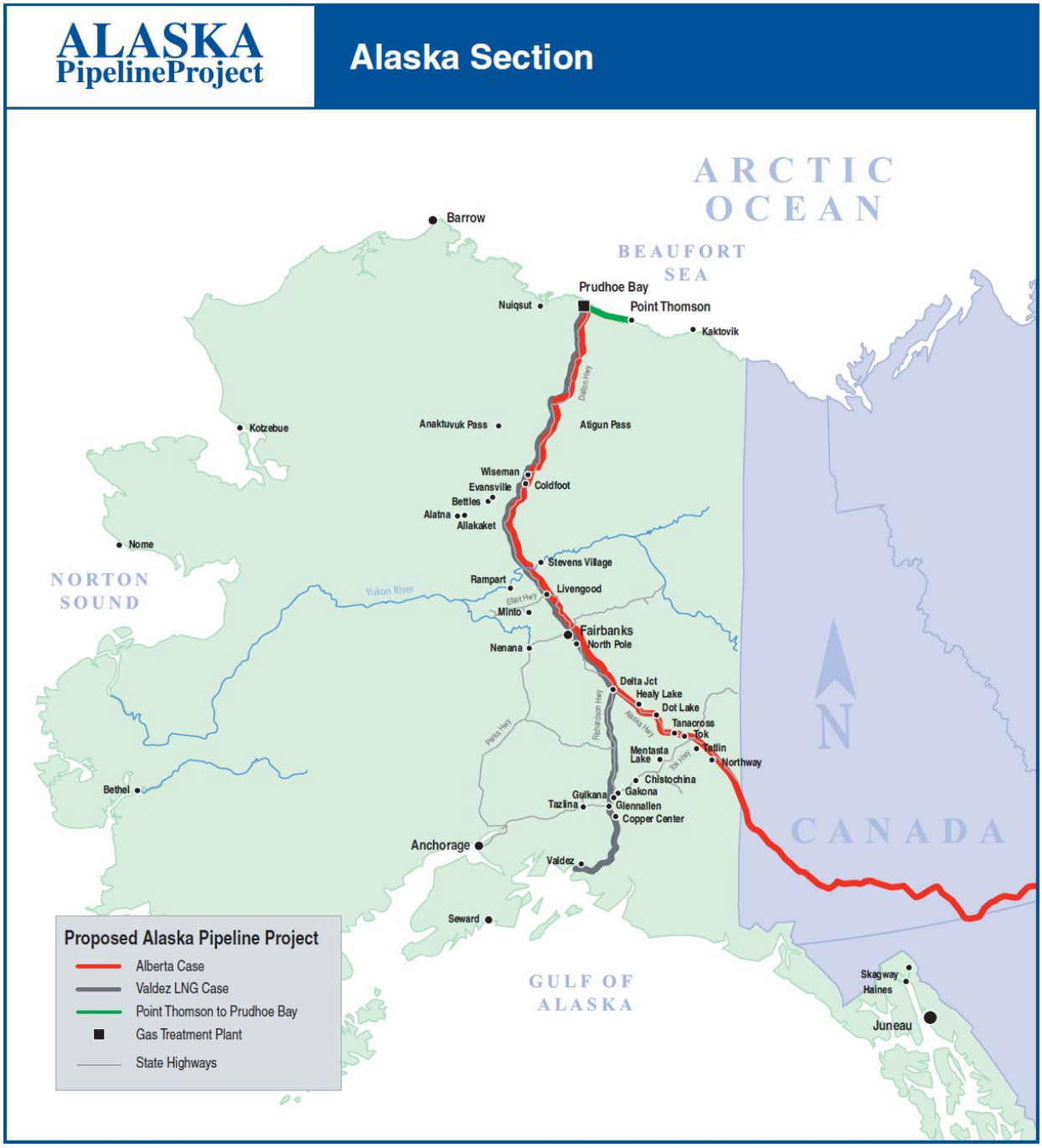


Figure 1. Map of proposed APP pipeline (Source: Alaska Pipeline Project – http://thealaskapipelineproject.com/docs/alaska_pipeline_project_map.pdf)

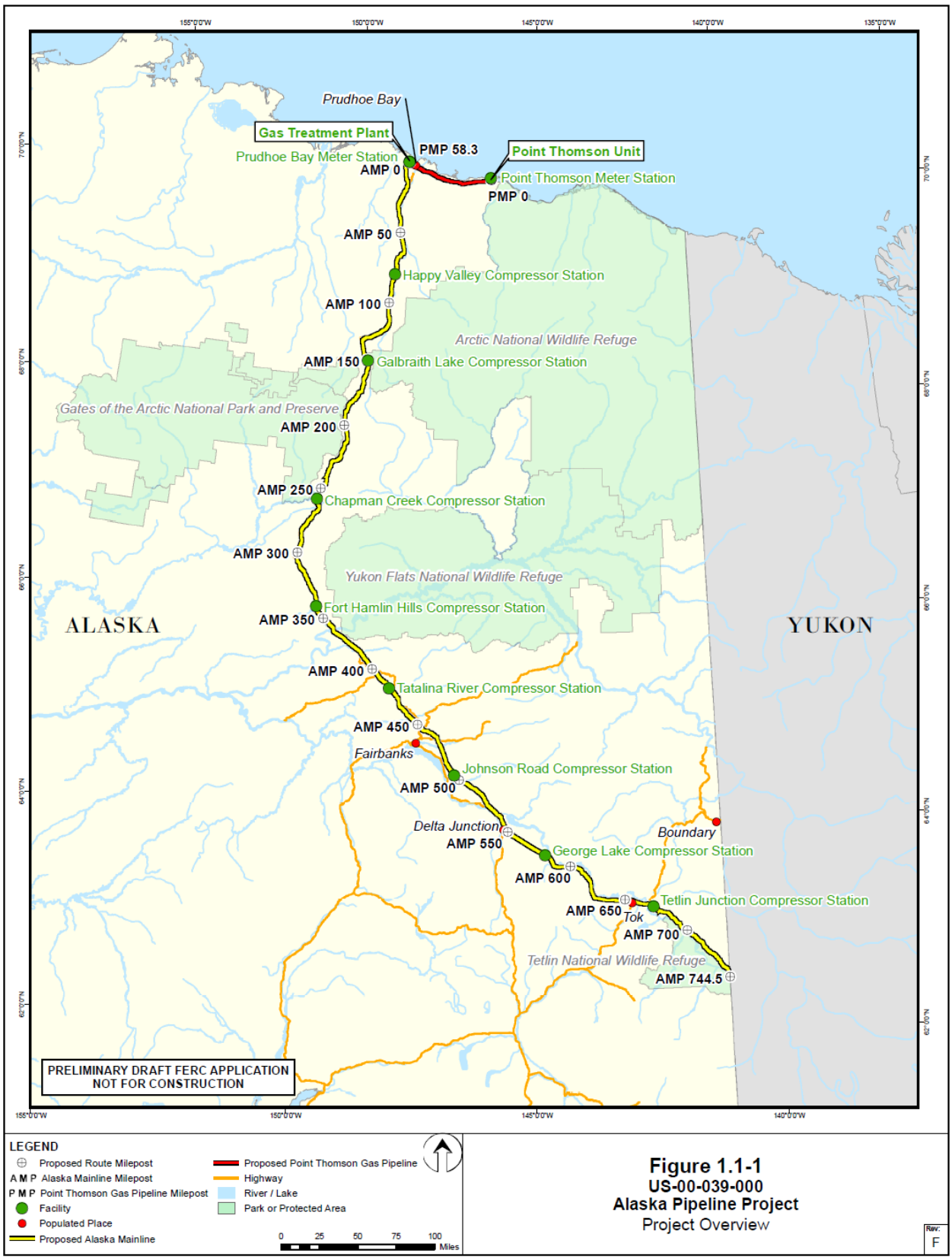


Figure 2. APP proposed pipeline route (Source: APP Resource Report No. 1 Preliminary Draft)

PROPOSED OPERATING CONDITIONS

Black & Veatch has reviewed the preliminary pipeline route and determined the climatic operating conditions to be expected. The pipeline extends from Prudhoe Bay in the North of Alaska, through Fairbanks in the centre of Alaska and to the Anchorage region in the South. Black & Veatch has obtained monthly air temperature averages for the regions of Fairbanks and Anchorage, with summer lows reaching approximately 50°F and winter temperatures as low as -20°F in the Fairbanks area. Figure 3 shows monthly mean low air temperatures for Fairbanks and Anchorage.

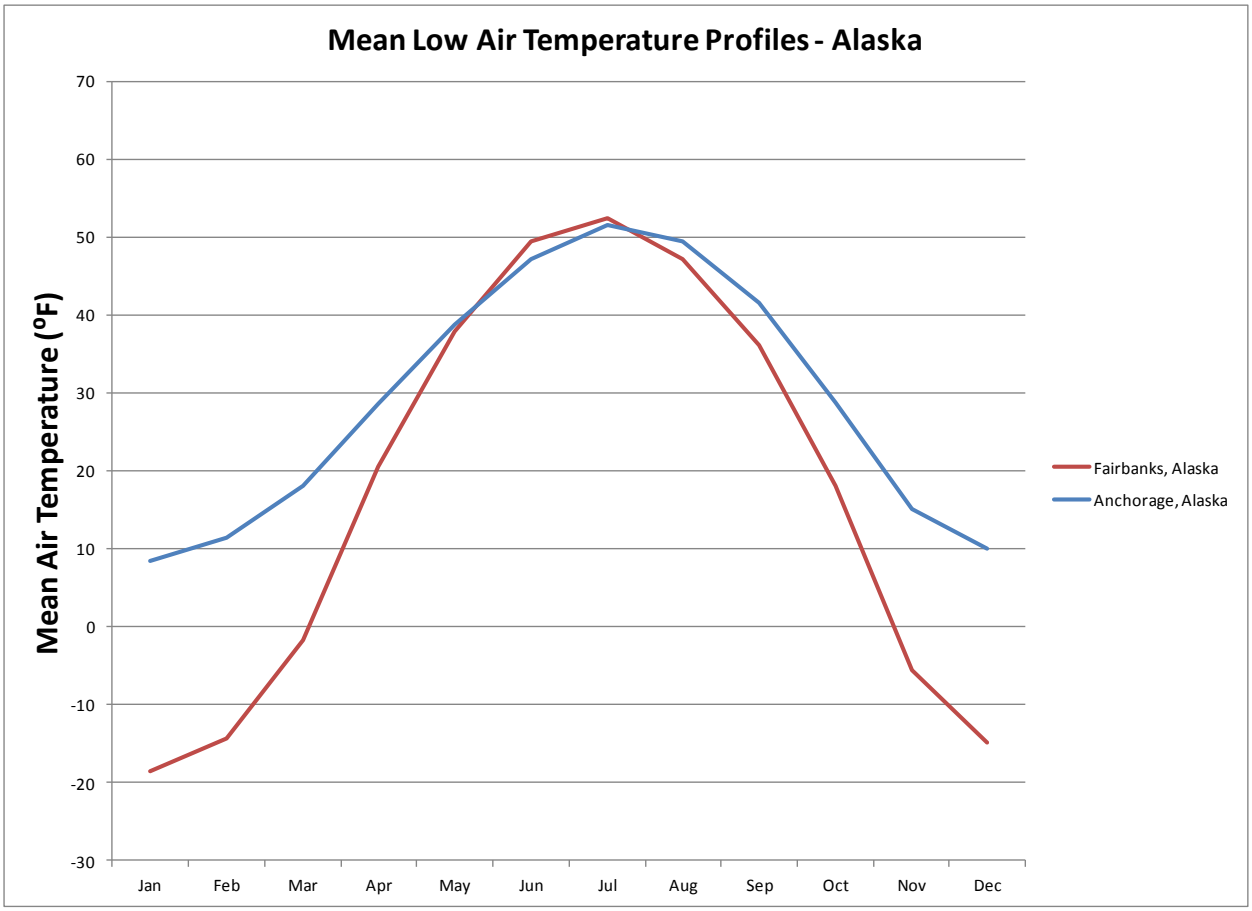


Figure 3. Monthly air temperature profiles for Fairbanks and Anchorage

As the APP pipeline will be underground for the majority of the pipeline route, Black & Veatch researched ground temperatures within the vicinity of the pipeline using publicly available sources. Figure 4 shows mean monthly ground temperatures for Toolik Lake and Coldfoot (from 1998 to 2001), which lie in northern Alaska near the pipeline route. Ground temperatures at approximately 65 cm depth range from 8-32°F at Toolik Lake; and from 19-34°F at Coldfoot. These temperatures will most likely be the coldest expected along the pipeline as they are in permafrost and are considered a conservative estimate.

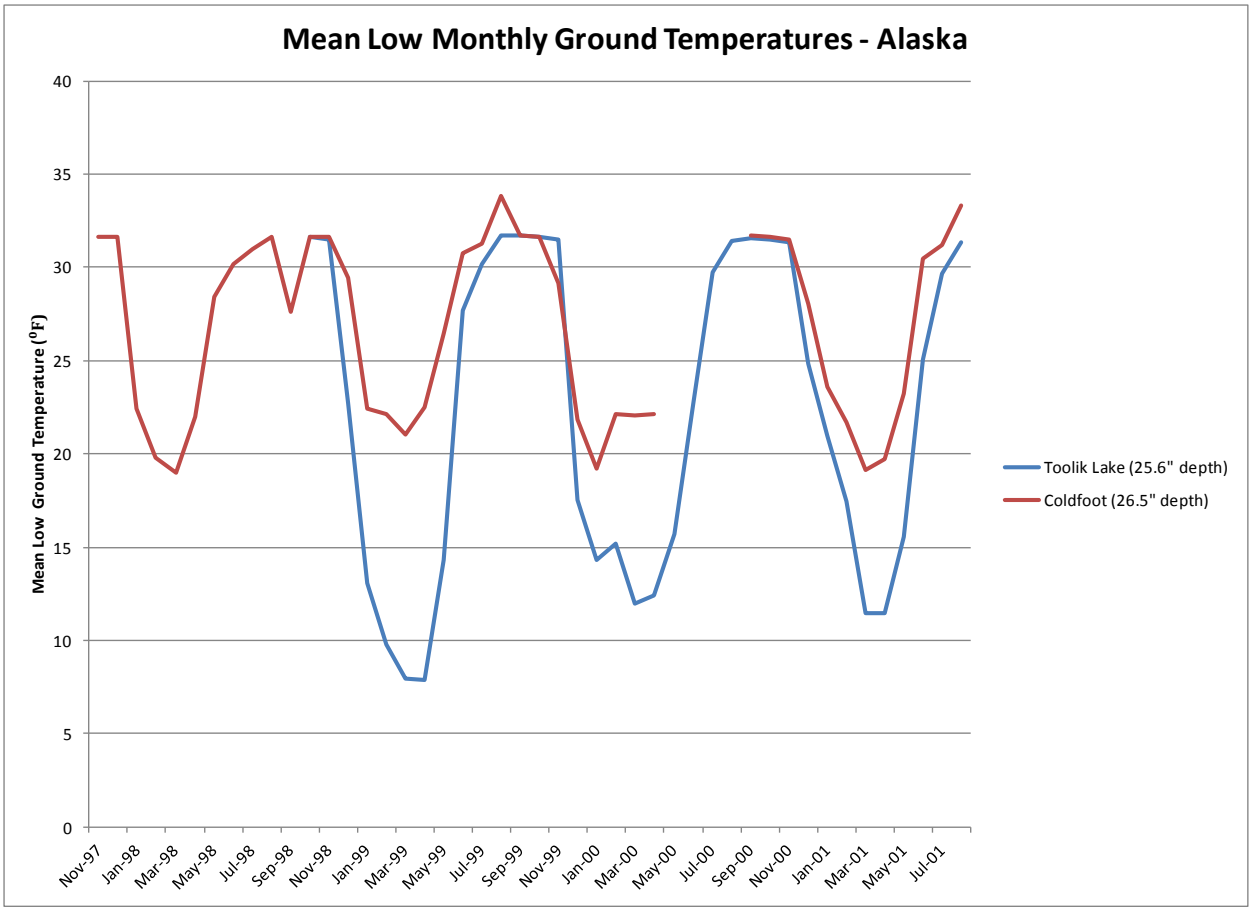


Figure 4. Mean monthly ground temperatures for the northern regions of Alaska along the APP pipeline route

PROPOSED COMPRESSOR DATA

Limited data was available for the proposed compressor station layouts and design for the APP. From the Alaska Pipeline Project Preliminary Draft Resource Report 1, along the Alaska Pipeline Project Mainline, eight compressor stations will be required at intervals where gas pressure will need to be increased to offset pressure losses caused by friction. Each compressor station will include gas compression equipment to increase the pressure of the gas entering the station to a pressure as high as 2,500 psig. Cooling equipment will cool the compressor discharge gas leaving the station to a temperature of about 30°F year-round at stations located north of the Brooks Range due to continuous permafrost conditions in this region. For stations located south of the Brooks Range where permafrost is discontinuous, seasonal variation in station discharge gas temperature will range from about 25°F in the winter to about 45°F in the summer, resulting in an annual average temperature between 30°F to 35°F. The gas compressors will be driven by gas turbines, fueled by natural gas sourced from the pipeline.

PIPELINE GAS ANALYSIS

Black & Veatch reviewed the available gas analysis data provided by AGIA. The gas specification proposed for transmission in the pipeline is relatively uncommon in a number of its characteristics, namely the high calorific value of the gas and its low water content. The AGIA gas specification nominates a "rich" and a "lean" gas case; the former containing heavier hydrocarbons (C_2 and above) than the later, as characterized in Table 1.

Table 1. Post treatment gas composition (Source: AGIA Request for Applications, July 2, 2007)

GAS COMPONENT	LEAN GAS (MOLE %)	RICH GAS (MOLE %)
N_2	0.7	0.6
CO_2	1.5	1.5
C_1	89.9	86.4
C_2	5.8	7.1
C_3	1.7	3.6
iC_4	0.1	0.3
nC_4	0.2	0.4
C_5+	0.1	0.1
	100	100
Heating Value (BTU/ft^3)	1,067	1,118

Black & Veatch used the gas composition as provided in Table 1 to verify the thermal content of each gas case and develop the thermodynamic characteristic of the gas. The results of this verification are provided in Table 2.

Table 2. Thermal content and thermodynamic characteristics of lean and rich gas cases

GAS PROPERTY	LEAN GAS		RICH GAS	
	AGIA Provided	B&V Calculations	AGIA Provided	B&V Calculations
Heating Value (BTU/ft^3)	1,067	1,069	1,118	1,118
$T_{critical}$ (^{0}R)	-	364.8	-	375.4
$P_{critical}$ (psi$_a$)	-	673.5	-	672.7

Communities using Natural Gas with similar characteristics

Black & Veatch researched information on the existing use of high end thermal-value content natural gas, similar to that specified by AGIA, for residential, commercial and industrial purposes. Most notably, parts of gas systems in Alberta, Canada, and eastern United States, have high BTU content ranging from 1000 to 1110 BTU/scf and have not experienced any significant issues with high BTU content with gas usage in their area.

Table 3 below provides information on the existing use of high energy content natural gas, similar to that specified by AGIA for residential, commercial and industrial purposes:

Table 3. List of exisitng facilities using high energy natural gas

COMPANY	LOCATION	BTU CONTENT (BTU/SCF)	REPORTED PROBLEMS
AtcoGas	Drayton Valley, Alberta, Canada	1,110	Ideally, gas BTU content would not vary by more than 100 BTUs to allow correct appliance orifice selection.
AtcoGas	Edson, Alberta, Canada	1,097	Ideally, gas BTU content would not vary by more than 100 BTUs to allow correct appliance orifice selection.
Florida Gas	Gulf Coast/Florida	>1,000	N/A
Dominion Transmission Inc	Appalachian Region, USA	>1,100	N/A
Dominion Transmission Inc	Pennsylvania, USA	1,090	N/A

NATURAL GAS PHASE DIAGRAM

Black & Veatch used the Aspen Hysys chemical process simulation software to calculate and produce phase envelope and hydrate formation curve predictions. Using the chemical composition data provided above, the Aspen software was used to produce phase envelopes for both the lean and the rich gas cases. For the purpose of generating these curves, Black & Veatch assumed a conservative, maximum level gas–stream water content of 0.8 lb_w/MCF.

The gas phase envelope and hydrate formation curves for the lean and the rich gas cases are provided in Figure 5 and Figure 6 respectively.

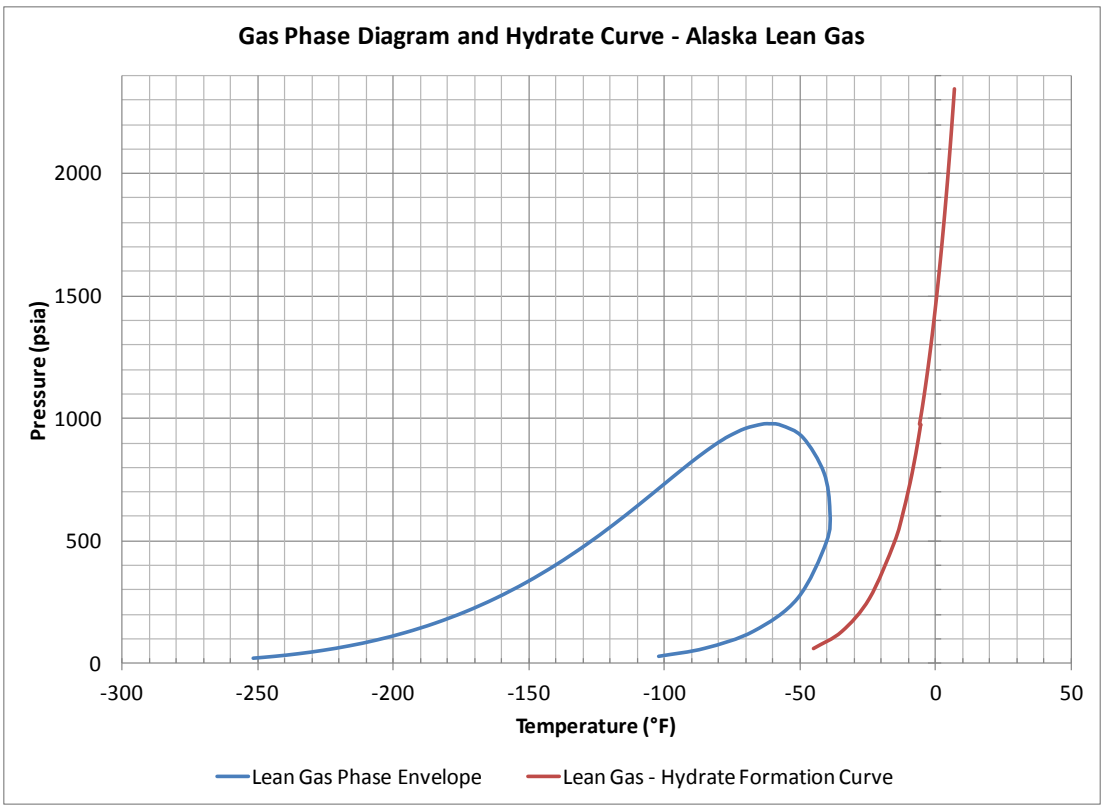


Figure 5. Gas phase envelope and hydrate formation curve for the lean gas case

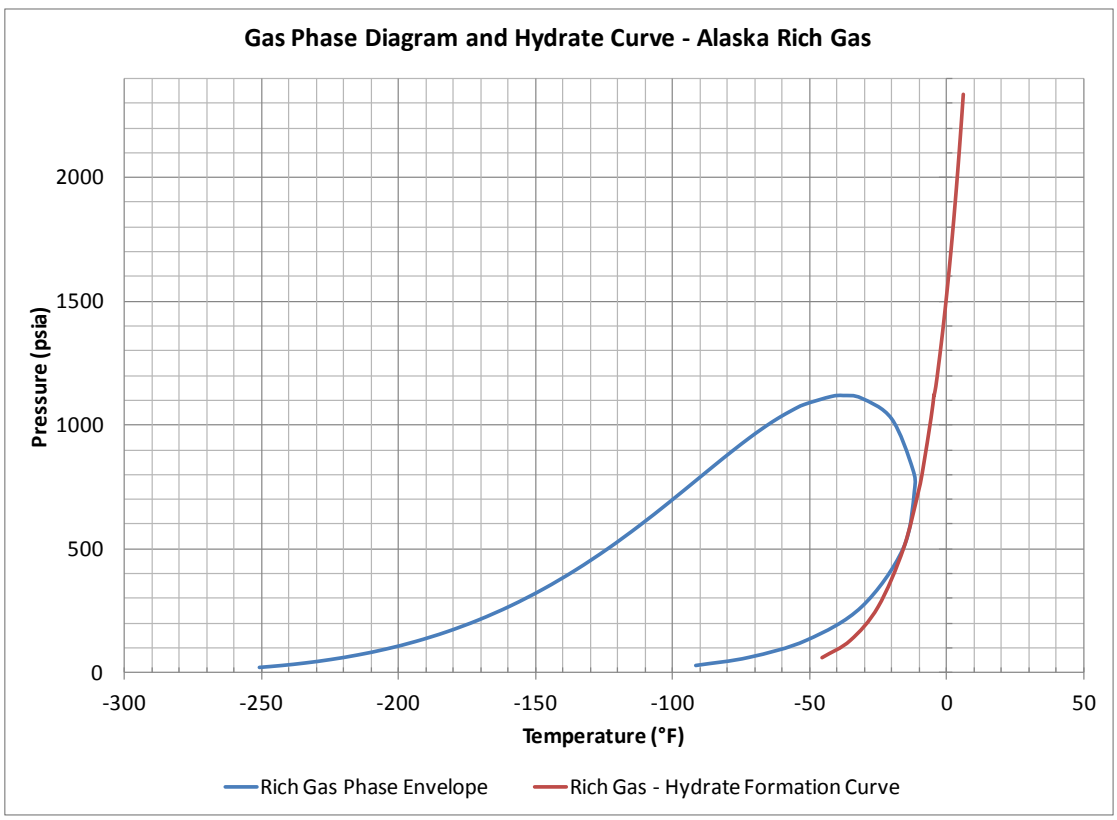


Figure 6. Gas phase envelope and hydrate formation curve for the rich gas case

Black & Veatch has carried out an initial design assessment of the pressure drop ratchet regime necessary to regulate the gas from 2,500 psig to 125 psig. Due to the high initial pressure, low water content of the gas stream, and low delivery point operating temperature (assumed to be 32^0F), a three-stage regulation, and four stage heating process is required with intervals at 1,700 psig and 800 psig in order to achieve delivery of utility-level pressure gas supplies above 32^0F and without concern for the development of hydrates (based on the rich gas case). Raising the temperature of the gas by 28^0F at each pressure interval allows the final gas temperature at 125 psi_g to be above 32^0F, with some heating redundancy. The results of this analysis are depicted in Figure 7.

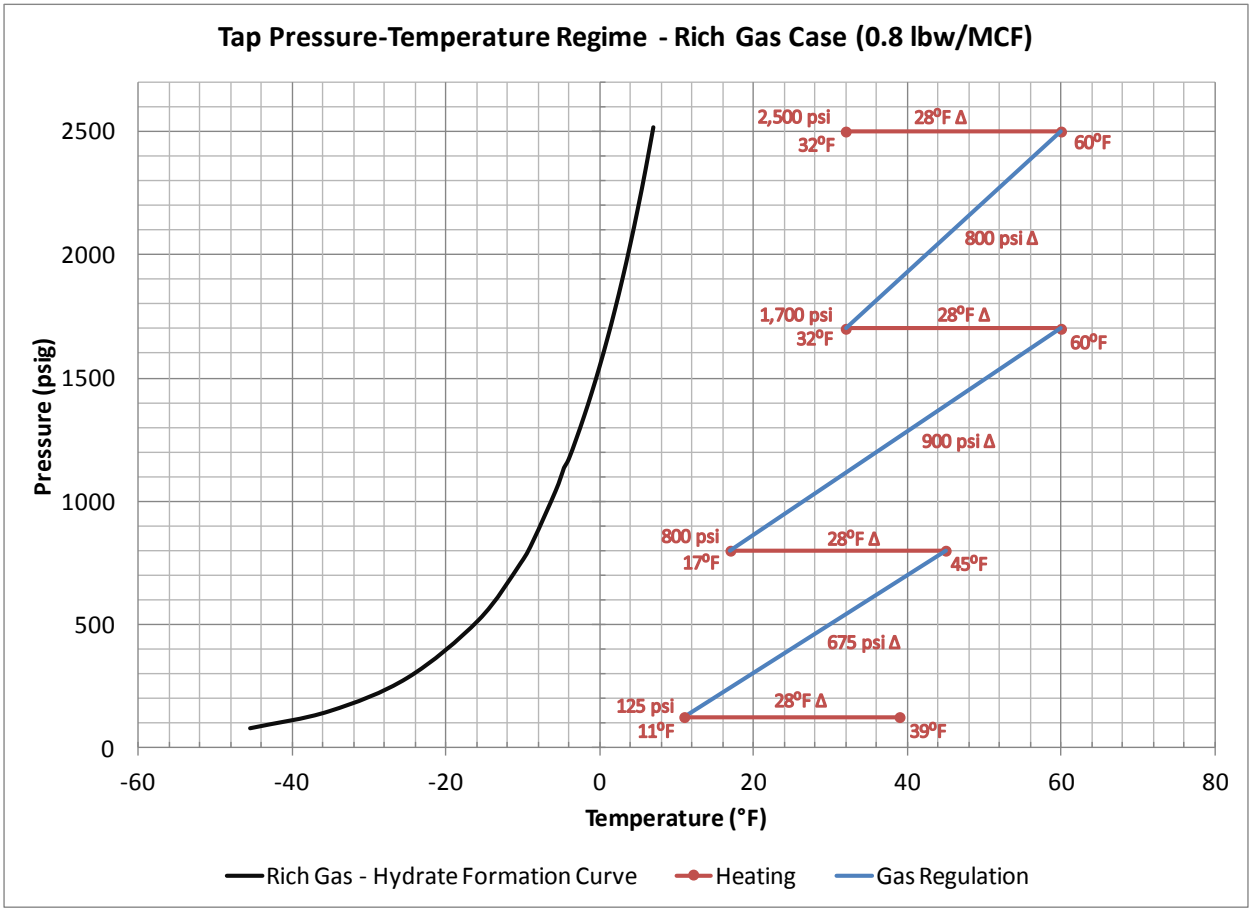


Figure 7. Gas delivery tap pressure-temperature regime

GAS USER INFORMATION AND DATA

Black & Veatch utilized a number of documents provided by the State of Alaska during the course of this project and documents in the public domain as a result of numerous studies and reports associated with the Alaska Pipeline Project (APP). These include:

- State of Alaska's AGIA Request for Applications
- Alaska Pipeline Project's Preliminary Draft Resource #1
- Northern Economics In-State Gas Demand Study
- Alaska Pipeline Project Map

Evaluation of Options

Black & Veatch reviewed two options per the Scope of Work to compare which would provide the most economical and flexible solution to supply gas to small communities and industries along the APP pipeline.

COMPRESSOR SIDE-STREAM OPTION

Evaluation of Compressor Operations

The eight (8) compressor stations designed to be constructed along the APP pipeline have the purpose of maintaining pipeline gas pressure. However, to do this, the compressor station requires natural gas at reduced pressures to fuel the compressor turbines and other station utilities. Typically, the compressor stations include the equipment required to reduce the pipeline pressure gas to lower pressures (i.e. 600 psig) or similar levels than the 2500psig mainline pressure.

While there are benefits to the compressor side-stream option in taking advantage of the reduced pressure gas stream to feed the gas for the gas delivery facilities, Black & Veatch recommends not pursing this option for gas delivery to serve communities. A deeper review of business and regulatory concerns results in a finding that issues associated with gas delivery from the mainline compressor stations make the establishment of such delivery points likely to be unfeasible due to regulatory and business drivers. From the Alaska Pipeline Project Resource Report No. 1 Preliminary Draft, the proposed sites for the 8 compressor stations limits the possible gas delivery options for communities to those within a feasible distance to a particular compressor station.

STUB GAS DELIVERY SITE OPTION

User Characteristics

Black & Veatch reviewed the In State Gas Demand Study, prepared by Northern Economics in January, 2010 for TransCanada Alaska Company LLC, which describes the potential gas usage of communities along the APP pipeline. The analysis for natural gas included the following major consumer sectors:

1. Residential and commercial sector (demand for space heating, water heating, and cooking);
2. Electric power sector (demand for generation of electricity); and
3. Industrial sector (both demand for heating and power generation, and for feedstock gas).

While the Northern Economics study is not a market survey that predicts customer commitments, it does provide a snapshot of the user characteristics for small communities along the APP pipeline that are potential targets for gas delivery tap locations in addition to the taps proposed for the provision of gas supplies to Fairbanks and Anchorage delivery points. For purposes of estimating and sizing the equipment needed for gas delivery locations for this study, Black and Veatch used these load estimates with adjustments for the seasonality of gas usage taken into consideration. Overall, these potential gas loads are relatively small for typical local gas distribution systems and the loads may vary depending on actual conditions at the time the local communities decide to develop a local natural gas distribution system. The load estimates and the described equipment and estimates are to be used for planning purposes only and cannot be construed as final load estimates, actual equipment design or final cost estimates for building the natural gas local

distribution systems. Black and Veatch recommends that a full market study be performed to identify gas loads and customer commitment potential before final design and cost estimates can be produced for gas delivery tap equipment and the ensuing local gas distribution system.

Total potential gas usage ranges from less than 1 MMCFD to 9 MMCFD as shown in Table 4 below.

Table 4. Potential small community demand ranges (Source: Northern Economics In-State Gas Demand Study Volume 1: Report, Figure ES-5)

LOCATION	GAS USE PREDICTION (MMcfd)
Livengood	9
Valdez	7
Big Delta	1
Delta Junction	1
Deltana	1
Fort Greely	1
Wiseman	<1
Coldfoot	<1
Stevens Village	<1
Harding-Birch Lakes	<1
Dot Lake	<1
Tok/Tanacross/Tetlin	<1
Northway Junction/Northway Village	<1
Paxson	<1
Gakona	<1
Gulkana	<1
Glennallen	<1
Copper Center	<1
Willow Creek	<1
Tonsina	<1

Gas Delivery Stub Locations

Black & Veatch has reviewed the Alaska Pipeline Map, other GIS data and recommends that the taps be installed on the APP to potentially serve the communities along the route. Due to the relatively inexpensive budgetary estimate costs of the recommended small diameter stubs associated with installation, operations, and maintenance costs, Black & Veatch recommends installation of stub taps during pipeline construction to facilitate maximum flexibility for access to the communities along the APP. Black & Veatch did not evaluate the gas delivery locations from the most effective way to serve these communities as this was not a part of the scope of this project and will largely depend on the commercial aspects of the distribution infrastructure needed to ultimately serve these communities. However, it is anticipated that the small diameter stub size will allow for sufficient gas supply volumes for all potential delivery point site except for Fairbanks or Anchorage.

Black & Veatch recommends that a full system planning study be performed to determine the best way to utilize the gas delivery locations to serve the communities from a cost and reliability perspective. To that end, although the provision of emergency gas supply facilities may need to be considered in the future, Black and Veatch has not included any research of the need for and cost of emergency gas supply facilities at gas delivery locations as this is not a part of the scope of this project. An assessment of the need for emergency gas supply facilities for the communities being served by the gas delivery taps, from a reliability and redundancy standpoint, should be included in any future studies.

Operation and Equipment

Black & Veatch recommends installing a small diameter stub piece of pipe in the locations marked for tapping. The stub piece would be welded on and tested during construction of the pipeline. The stub would not have live gas in it and it's end location would be marked with a standard pipeline marker for future reference once a commercial agreement has been reached for the community the stub would serve.

Once a commercial agreement is reached, the pipeline would need to be tapped at the stub location. The hot tapping procedure would involve removing the stub cap and securing an isolation valve to the end of stub. Hot tapping equipment would then be connected to the isolation valve, the valve would be opened, and the pipeline would be tapped whilst in operation. With the isolation of the valve and removal of the hot tapping equipment, the gas delivery location would be ready for service. This work will be carried out by qualified personnel preferably APP personnel familiar with tapping high pressure pipelines. The stub would be extended and a metering/regulating (M/R) station installed as depicted in Attachment 1.

The M/R station would consist of 3 sections where the pressure would be reduced in 3 steps from the inlet pressure of 2500 psig to the desired outlet range of 125-300 psig. There will also be 4 stages of gas heating required. The equipment specified is approved natural gas industry equipment built to the federal pipeline safety regulations and industry standards. It is anticipated that the M/R section could be pre-fabricated in sections off-site and brought to the site for final installation once the site has been prepared.

While the gas analysis indicates that the composition of the natural gas in the pipeline will be dry and no issues with liquids are expected, Black & Veatch recommends the addition a gas filter

separator as a preference item in the design. This will be considered in budgetary preparation and will account for any instances of increased water content of the gas during operation.

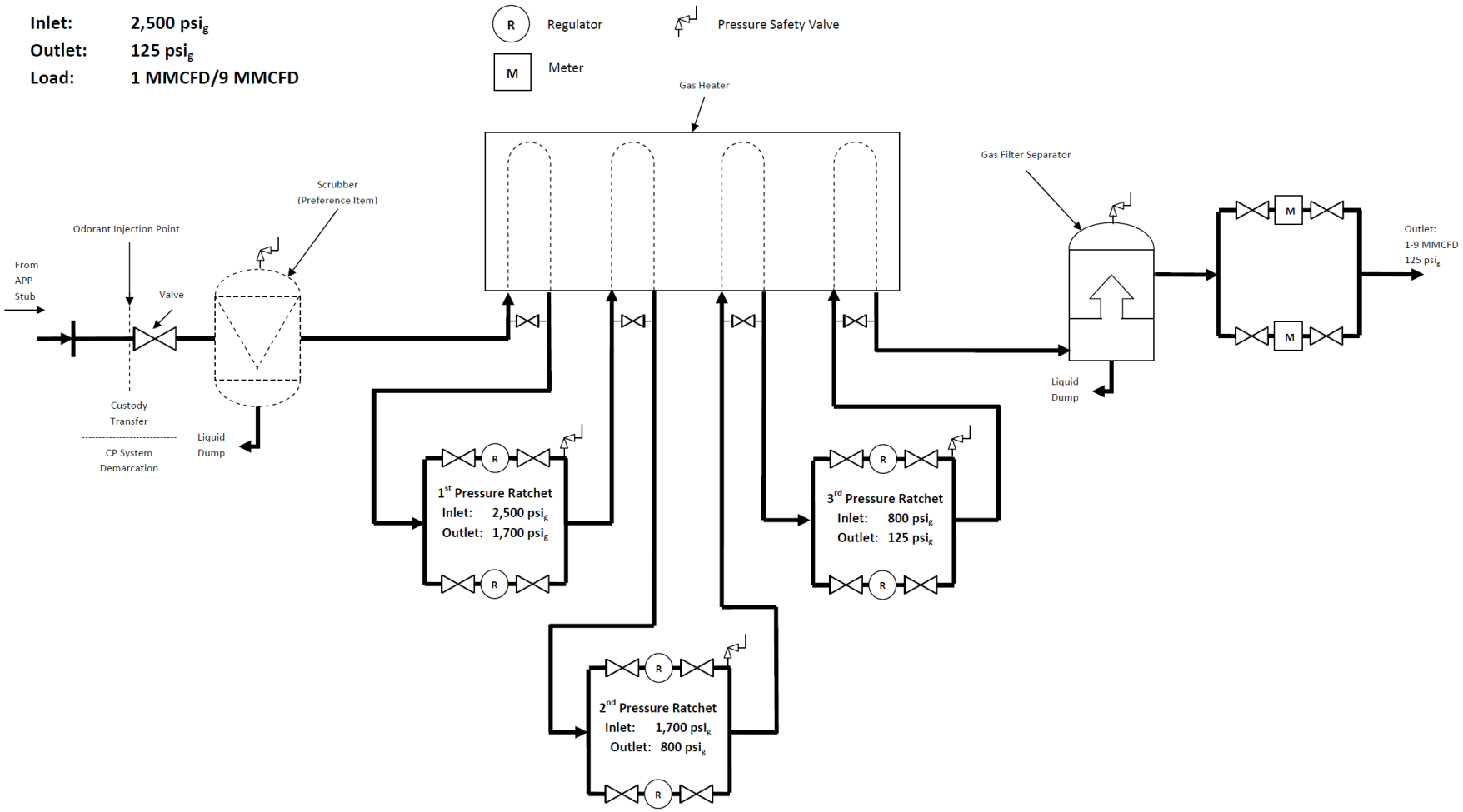
Operations and maintenance (O&M) procedures for the small diameter stub and later the gas delivery system including the Metering and Regulating (M/R) Station and facilities should be developed in accordance to the federal safety pipeline regulations (49CFR192) and industry standards and best practices. The recommended O&M practices for the small diameter stub would be minimal until the gas stub is hot tapped and gas is flowing through the stub, the M/R Station and gas delivery facilities. For the small diameter stub, a visual inspection is only needed to ensure no earth movement around the area of the stub and that the pipeline marker identifying the end of the stub is in place.

For the M/R station and gas delivery facilities, it is expected that personnel will conduct O/M activities on a weekly basis for each site for items such as valve maintenance, regulator maintenance, leak detection, other equipment maintenance (heater, odorizer, separators, etc.) Typical O/M costs are shown below.

Macro Budget

From discussions with equipment suppliers, prefabricators and contractors who build equipment, Black & Veatch estimates the cost of the equipment for the Stub Gas Delivery option to be as shown in Table 5. This cost estimate is based on the assumption that several M/R stations are constructed at the same time and does not include any line items for the stub, hot tapping operations or the distribution system downstream of the M/R station. The cost estimate below is solely for the system as shown in Attachment 1.

Table 5. Macro budget line items

COST TYPE	LINE ITEM	COSTS PER LOCATION ($US)
Capital Costs	M/R Station (Attachment 1)	$150,000 - 200,000
O&M Costs	M/R Station (Attachment 1)	$50,000 – 75,000/year

Attachment 1 – Stub Gas Delivery Point Metering/Regulation