Arctic Challenger Re-purpose Report

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TABLE OF CONTENTS

1.0 INTRODUCTION

Superior Energy Services (Superior) has tasked Audubon Engineering Solutions (AES) to perform high-level review of the Arctic Challenger (ACS) to determine the potential production capacity of the vessel if used as a floating production vessel. The original purpose of the ACS was to serve as a containment vessel for arctic drilling. The process requirements for that service were to capture oil from the stack, overboard produced/cleaned water and flare all captured hydrocarbons. The new process requirements are to produce and adequately treat oil and water for sales and disposal, respectively.

As part of this effort AES has performed the following services:

- Generate compositions on a dry basis so lower water cut simulations can be run more easily.
- Provide a chart demonstrating the vessel's production capacity based on crude oil API gravity and gas-to-oil ratio (GOR).
- Provide a high-level list of equipment modifications needed to produce oil for sales, flare associated flash gas, and treat produced water for disposal.
- Develop a list potential limitations of the system.

2.0 PROCESS CAPABILITIES

2.1 Process Simulations

As a part of previous verification studies, process simulation models were developed for the facility using the Peng-Robinson correlation package in AspenTech HYSYS 8.4 software. The models utilize a combination of pure and hypothetical components.

Process models were evaluated using the 20° API Oil and 32° API Oil compositions utilized in the previous studies. The compositions are listed in Table 2.1-1 below. The compositions are on a dry basis (i.e. no water). Water cuts were assumed to be low based on a typical field in early life.

Table 2.1-1: Crude Oil Compositions for HYSYS Models

Component [mole fraction]	20° API Oil	32° API Oil
Methane	0.2079	0.2988
Ethane	0.0886	0.1328
Nitrogen	0.0017	0.0028
CO2	0.0014	0.0102
H2S	0.0000	0.0000
Propane	0.0307	0.0499
H2O	0.0000	0.0000
i-Butane	0.0170	0.0398
n-Butane	0.0170	0.0398
i-Pentane	0.0085	0.0264
n-Pentane	0.0085	0.0264
n-Hexane	0.0000	0.0004
n-Heptane	0.0000	0.0000
n-Octane	0.0000	0.0000
n-Nonane	0.0000	0.0000
n-Decane	0.0000	0.0000
Single Oil 1*	0.0494	0.1319
Single Oil 2*	0.1602	0.1705
Single Oil 3*	0.4090	0.0702

The Single Oil 1*, Single Oil 2*, and Single Oil 3* components are pseudo-components intended to model oil samples. A *Single Oil* can be defined with a couple of key parameters such as the volume average boiling point (VABP) and the API gravity. These were developed as a part of the original containment system design with direction from Shell. These three pseudo components were used to generate a light and heavy crude with the properties Shell wanted to model.

- Single Oil 1 is defined by a 450°F VABP and 32° API gravity as shown below. Single Oil 1 is the lightest pseudo-component for blending with the lowest molecular weight and viscosity. The Watson K factor indicates this oil is balanced crude between paraffinic and aromatic.
- Single Oil 2 is defined by a 740°F VABP and 28° API gravity as shown below. Single Oil 2 is a heavier pseudo-component for blending with the higher molecular weight and viscosity. The Watson K factor indicates this oil is paraffinic.
- Single Oil 3 is defined by a 680°F VABP and 12° API gravity as shown below. Single Oil 3 has the highest viscosity and lowest API gravity, but not the highest molecular weight. The Watson K factor indicates this oil is aromatic.

A lighter crude (higher API gravity) could be processed; however, it is likely that oil capacity will be dependent on the production GOR due to flare system limitations.

2.2 Name Plate Capacity

Per the original design and verification studies maximum design rates as a source control/recovery vessel for the Artic Challenger are listed in Table 2.2-1.

Table 2.2-1: Artic Challenger Original Maximum Design Rates(1)

Product	Rate
Oil [BPD](1)	25,000(2)
Water [BPD]	20,000(3)
Gas [MMSCFD]	15.0

Notes:

1 *The maximum design rates listed are for the Arctic Challenger acting as a Source Control/Recovery vessel.*

2 *Oil rate is based off 32°API oil. Design rate is reduced to ~17,000 BOPD for 20°API oil.*

3 *The specification for overboard water qualitywould be based on a decant permit received at initiation of recovery operation.*

2.3 Repurpose Capacity

AES developed a chart showing the oil production capacity based on crude oil API gravity and gas-to-oil ratio (GOR). The chart can be found in Section 6.1 – Attachment 1. Oil production capacity is shown on the Y-axis. Crude Oil API gravity is shown on the lower X-axis. Gas/Oil Ratio (GOR) is indicated on the upper X-axis. The oil production capacity vs API gravity curve is based on the available residence time in the Production Separator (V-120) and typical recommended residence times based on crude oil API gravity. There are two curves showing oil production capacity vs. GOR. One curve is based on the original maximum design gas rate of 15 MMscfd. The second curve is based on a new maximum design gas rate of 30 MMscfd. AES believes the 30 MMscfd design rate can be achieved with reasonable modifications to the vessel.

To determine the facility capacity using the chart requires API gravity and GOR be known. The chart is used to find the crude oil capacity based API gravity and also GOR. The smaller of the two capacities is the facility capacity. First, find the API gravity on the lower X-Axis and draw a line up to the "Residence Time Capacity Curve". Next draw a perpendicular line over to the Y-axis. The Y-axis value is the crude oil capacity based on residence time. Then find the GOR on the upper X-Axis and draw a line down to the "Capacity Limit – 30 MMscfd Curve". Next draw a perpendicular line over to the Y-axis. The Y-axis value is the crude oil capacity based on GOR. The smaller of the two crude oil capacity numbers is the facility capacity. Table 2.3-1 below shows the Arctic Challenger oil capacity based on residence time and maximum GOR for several API gravities.

Table 2.3-1: Arctic Challenger repurpose Capacity Table

API Gravity (˚)	Oil Capacity (BBL/D) (Residence Time Limited)	Max GOR (scf/BBL) (30 MMscfd Capacity Limit)(1)
40	49,000	612
35	29,000	1040
25	15,000	2000
15	7,000	>2600

Notes:

1. *Higher GOR may be achievable with additional modifications*

3.0 MODIFICATION OPTIONS

The following modification options are based on the assumption that the produced crude oil will be sold to a pipeline and the produced gas will be flared. It is worth noting that any modifications to the process conditions or modifications to the production equipment will require a re-validation and analysis of overpressure protection systems.

3.1 Process Equipment

3.1.1 Required Modifications

- Add LACT charge pumps
- Add a LACT skid.

3.1.2 Potential Modifications

- Add an oil treater depending on export criteria.
  - Increased generator load if using an electrostatic treater.
  - Need fuel gas conditioning system if fired treater.
  - Could potentially repurpose heat media system.
- Flowline and tie-back modifications for connecting to either wet or dry tree.
- Add crude oil cooler depending on export criteria.
  - Create cooling water system
- Add high pressure pipeline pumps and piping.
  - Could require larger generators.
- Recommend a redundant plate and frame exchangers to reduce downtime for maintenance cleaning.
- For a subsea tieback, add an onboarding launcher/receiver (depends on flowline configuration).
- To increase gas rates add mist eliminators to process vessels. Weir heights could also be lowered.
- Add a dry oil tank. Could possibly repurpose an existing vessel.
- Add a wet oil tank. Consider modifying a new or existing vessel for dual purpose.
- Add a pig launcher on the departing oil pipeline.

- Consider adding an inlet heater if cold start-up or operating conditions are expected. Cold production could generate wax and asphaltene issues.
- Depending on type of production additional chemicals could be required
  - Additional chemical injection locations could also be required.

3.2 Flare Relief System

3.2.1 Required Modifications

- Addition of a low pressure flare system to ensure crude oil Reid Vapor Pressure (RVP) can be met. Flare system will need to include the following:
  - LP flare knock out drum
  - LP flare stack/boom & tip (modification of existing boom)
  - LP flare system piping.
  - LP flare knock out drum pump

- Reverification of entire flare system based on proposed modifications and field production rates/characteristics.

3.2.2 Potential Modifications

- To increase the existing flare system capacity above 15 MMscfd the flare tip could be replaced or the system could be operated with a higher backpressure. It may be necessary to route the Production Separator (V-120) gas outlet to the new LP flare. Vessel nozzle size changes based on new PSV requirements.
- Add fuel gas system for flare tip pilots. Propane tank may not have adequate capacity for continuous flaring without frequent resupply.

3.3 Instrumentation

3.3.1 Potential Modifications

- Replace strap on meter with inline meters as needed for allocation metering requirements.
- Add sample points and sampling equipment as needed for allocation metering requirements.
- Add additional shut down valves as required for new equipment additions or changes to regulatory criteria.
- To facilitate testing requirements and minimize downtime perform modifications to allow level safety transmitters and settings to be tested without having to raise and lower the level in the vessels.
  The transmitters are guided wave radar type installed directly into the vessel vs. in an external bridle.

4.0 LIMITATIONS

The following describe various limitations that may impact the amount of crude oil produced by the ACS vessel.

The oil handling rate will likely be limited by the Production Separator (V-120), the Transfer Pump (P-110 A/B), or the flare system capacity. Modifications will be required to the Transfer Pump and potentially other equipment to achieve oil production rates over ~29,000 BPD. Modifications to the flare system will likely be needed if the gas rate exceeds 15 MMscfd before the residence time oil capacity limit is reached. The gas rate is limited by the flare tip (B-110) and the flare system.

Meeting crude oil pipeline specifications may also be a limitation. The current process design does not include an oil treater. AES estimates the current process can achieve a BS&W quality of 2-5% BS&W. Most crude oil pipelines require 1% or lower BS&W. Most crude oil pipeline also have a RVP specification of between 8.6 psia and 12 psia. The current process design would likely have some difficulty achieving this depending on the crude composition. AES recommends adding an atmospheric dry oil tank vessel if the current process cannot meet the pipeline RVP specification.

The water rate is limited by the Produced Water CPI Separator (T-100). It may be necessary to install additional water treating equipment if the required overboard quality exceeds what can be delivered by the CPI Separator. AES recommends adding a flotation cell downstream of the CPI separator to meet the 29 ppm oil in water daily average required in the Gulf of Mexico U.S. Federal Waters.

The Surge Drum and the Production Separator are three phase separators with weirs. The weir sets the overall level in the vessels. Since the process was originally designed for low GOR production, the weir is fairly tall and requires the vessels to operate at 80% full. This level reduces the amount of gas capacity of the vessels. Installing mist eliminators in the vessels should increase the gas handling capacity and reduce the oil droplet size carried over into the flare system.

The following is a list of other potential limitations that may exist depending on the type of well and production the facility is trying to produce:

- Vessels are rated only for low pressure (~150 psig). This may create flow assurance challenges downstream of the 10,000 psig choke manifold if high pressure wells are being produced
- Construction materials need to be reviewed to determine if the facility is to process sour production. Facility was designed for sour service to the extent practical. Field options could be further limited and/or additional equipment (amine plant, acid gas flare) could be required.
- Foaming in the separators will reduce effectiveness of current level instruments (guided wave radar).
- Emulsions in the separators will reduce effectiveness of current level instruments (guided wave radar).
- Fouling will reduce effectiveness of current level instruments (guided wave radar).
- Emulsions are difficult to separate and may reduce nameplate capacities.

- Emulsions could have high heat requirements.
- Heavy crudes could be challenging due to high viscosities and densities.
  - Pumps may not have enough horsepower.
  - Very heavy crudes may reduce effectiveness of heat exchangers.

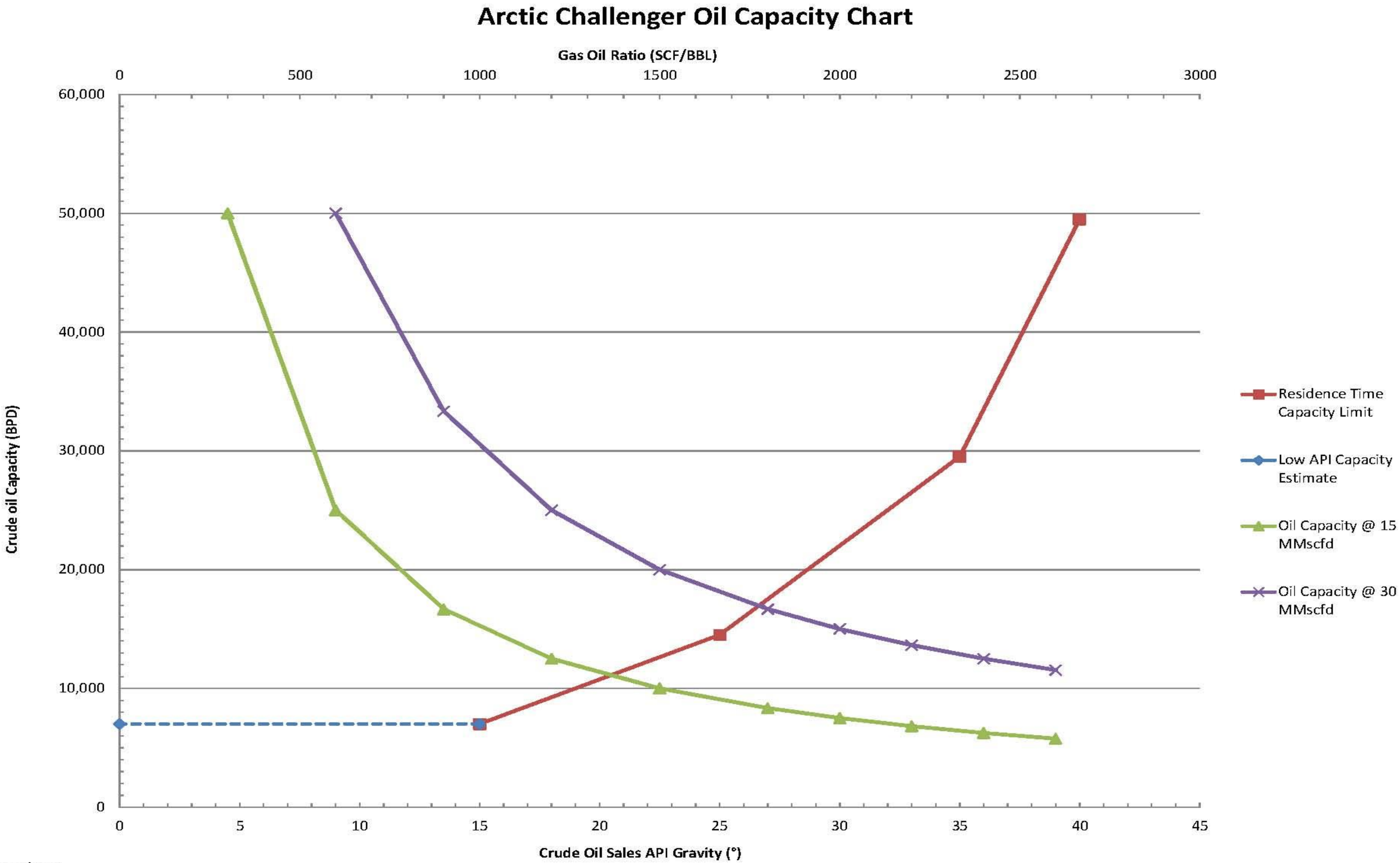
5.0 CONCLUSION

Audubon Engineering Services (AES) was asked to determine the potential production capacity of the Arctic Challenger (ACS) if the vessel was used as a floating production vessel. AES developed the Arctic Challenger Capacity chart shown in Attachment 2 as a means to show the potential capacity of the facility as a function of crude oil API gravity and gas-to-oil ratio (GOR). AES also developed a list of required and potential modifications to achieve the capacity for the production equipment, the flare system and instrumentation. A list of potential limitations for the facility was also developed. Overall the capacity chart indicates that the ACS system has potential to produce significant volume of crude oil. It may be necessary to add some pieces of equipment and modify the existing production system, but AES has not identified anything insurmountable at this time.

6.0 ATTACHMENTS

6.1 Attachment 1 – Arctic Challenger Oil Capacity Chart

6.1 Attachment 1 – Arctic Challenger Oil Capacity Chart



Instructions:

1. Find the API gravity on the lower X-Axis and draw a line up to the "Residence Time Capacity Curve".
2. Draw a perpendicular line over to the Y-axis. The Y-axis value is the crude oil capacity based on residence time .
3. Find the GOR on the upper X-Axis and draw a line down to the Capacity Limit – 30 MMscfd curve.
4. Draw a perpendicular line over to the Y-axis. The Y-axis value is the crude oil capacity based on GOR.

Notes:

1. Oil capacity over 30,000 BPD will require a review of the production equipment to determine if there what pump, heat exchanger, and instrument limitations may exist.
2. 30 MMscfd gas capacity will require modifications to flare system/tip to