Online Water Analysis in Thermally Enhanced Heavy Oil Recovery and Refinery Wastewater

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Final Project Report

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Project Information:

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Applicant Information:

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Project Partners

Agar Canada Corporation would like to thank our trusted partners and funders for their hard work, support and dedication to this project. Agar Corporation in Houston for their engineering support, Luxmux and NDT for the technology support, Devon Energy for the access to site information and samples and AI/SDTC for continued funding support. Without all the project partners support this project the ultimately Agar's new product for PPM oil in water measurements would not have been possible. We are excited to launch this new product in the industry and looking forward with working with our global distribution and representative network to access the market.

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A. EXECUTIVE SUMMARY

The finalized project by Agar Canada Corporation (Agar) allowed the development of a technology that is capable to measuring the parts per million (PPM) level of oil in water for Steam Assisted Gravity Drainage (SAGD) applications. The importance for this technology is represented in the ability for optimizing the quality of the produced water that is required for steam generation. This optimization is translated in more efficiency in the Once Through Steam Generator (OTGS) boiler used in SAGD which translated into energy savings and water consumption in SAGD operations.

With this project, Agar will become a leader in online water analysis in Canada. This is an enabling technology which will allow the heavy oil industry to optimize production while reducing GHG emissions and water usage. Online water analysis is important for the producers to identify upsets as soon as possible rather than waiting for sampling and lab results which may be performed only once per day or a few times per day. If, for example, the boiler operates for 12 hours with upset conditions before the lab analysis is ready, this will result in tube deposition for that period of time and eventual boiler damage, loss of production and can lead to more extreme cases of catastrophic failures in which the operator needs to dump all the water in the plant. Directive 81 of the Alberta Energy Regulator (AER) limits the amount of water producers are allowed make up with clean or brackish water. It can be seen how critical an upset in the water specifications are to operators and unfortunately, they do not have reliable and accurate PPM oil in water analyzer that can help them prevent and mitigate these risks.

The projects objective was the development of an online water analyzer for oil ensuring producers can operate at boiler designed steam quality, i.e. 80% instead of typical systems today ~76%.A boiler operating at 80% steam quality will need 78.31 MW while a system operating at 76% will need 79.82 MW to produce the same amount of steam, i.e. for a given amount of oil. 8,211 kg/hr of more water is needed in the 76% operations comparing to the 80%, typically 15% make up water is required in operations which will allow for a saving of 57,102 cubic meter / year per facility when using the online analyser to operate at 80% steam quality.

Although a full site demonstration was initially planned on this project with Devon energy, different circumstances, mainly Devon Energy being acquired by CNRL, affected the initial objective while limiting the scope by only completing the certification for the analyzer to make it ready for the field demonstration. These certificates are CSA for electrical standards and the Alberta CRN for the pressurized mechanical parts. Agar Canada is pursuing additional opportunities to field trial the new product in Canada in a SAGD operation.

A key component and result of the work performed on this project was the learning curve in terms of the designing for the right technology able to provide the necessary accuracy and sensitivity for the type of water being used in SAGD and meeting the required range of oil in water measurements, as well as the understanding of the different challenges faced by the industry to date. More specifically, the high Total Organic Carbon (TOC) found in produced water in SAGD operations makes it difficult for most fluorescence analyzers in the market today to measure the free oil accurately as both the free oil and the TOC fluoresce which gives incorrect readings as the producers want to the free oil only. Alternatively, infrared scattering types of analyzers measure the free oil and not the TOC but solids in the water will also give false readings. Therefore, the project learnings and outcomes is an analyzer that combines both fluorescence and infrared scattering so that TOC and solids can be subtracted from the final output. In addition, any optically based analyzer will be affected if the windows get coated, therefore the ultrasonic cleaning technology was integrated into the final solution. This knowledges was successfully achieved by working one on one with the producer in terms of specification and product samples that supported the R&D project until the final stage.

B. INTRODUCTION

Canada has 174 billion barrels of oil, 169 billion of which are located in the oil sands. This makes "Canada the third largest oil reserves in the world" with 97% of these reserves located in Alberta. For In-situ operations commonly referred to as thermally enhanced heavy oil recovery, steam is produced and injected into the ground to reduce the viscosity of oil so that it can be extracted. In-situ oil production in Canada is currently producing 1.2 million barrels of oil per day (BPD) with large amounts of water needed for the steam generation and approximating 4.8 million m^3 per day (4.8 Billion Litres/day). It is expected that in-situ production in Canada will double in the next ten years.

The Alberta Energy Regulator (AER), specifically Directive 81 regulates the amount of fresh, typically brackish water in which producers are allowed to dispose, requiring producers to typically re-use over 85% of the water which is injected and returned with the oil being produced. Water quality is therefore an important factor in heavy oil recovery and necessitates water treatment of which there are two common methods; warm lime softening which is typically used with OTSG boilers and; thermal evaporators which is typically used for drum boilers and provide higher water quality.

Knowledge or Technology Gaps

There are different procedures to bring the water within the required specifications prior to be processed by the OTSG. The "Warm lime softening" (WLS) is used for partial removal of Silica and hardness, followed by filtration to reduce suspended solids and ion exchange using weak acid cation exchange (WAC) resins for additional hardness removal, see Figure 1. In some cases, hot lime softening is used instead of WLS. For producers using conventional drum boilers, the water quality achieved with WLS-WAC will not meet boiler specifications for minimum water quality specifications. When using evaporators and drum boilers the water quality only suffices for boiler operation up to 1000psig with 98% steam quality. Attempted field trials above 1000 psig using evaporators with drum boilers at 98% steam quality have failed. Most of the heavy oil operations in Canada consist of using OTSG boilers with WLS-WAC water treatment and producing 80% steam quality up to 2000psig, see Figure 2. In order to ensure water quality and properly treat water, producers need to identify and measure contaminants. The parameters of interest in which they require an online analyser and do not have an available/reliable online solution consist of oil, Silica, Hardness and Iron. This project focused on a reliable analyser to measure the oil content in the water without errors due to TOC and suspended solids in the water.

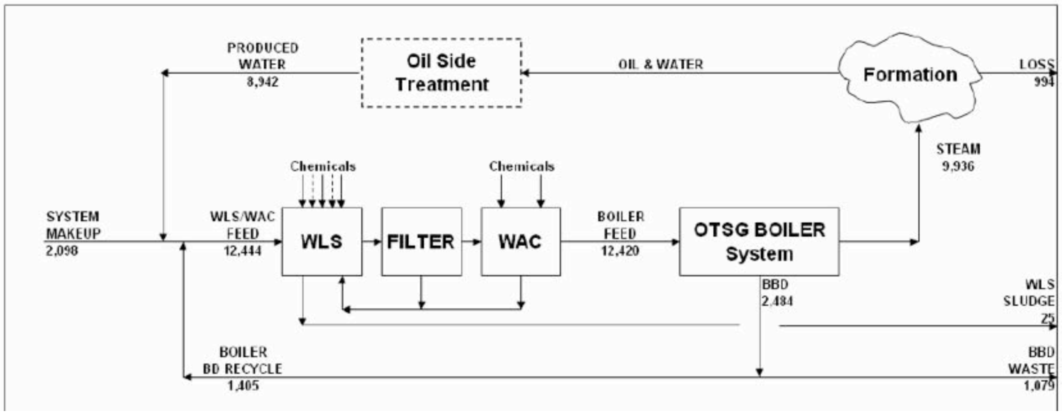

Figure 1: Schematic of Warm Lime Softener, Weak Acid Cation (WLS-WAC) Ion Exchange water treatment

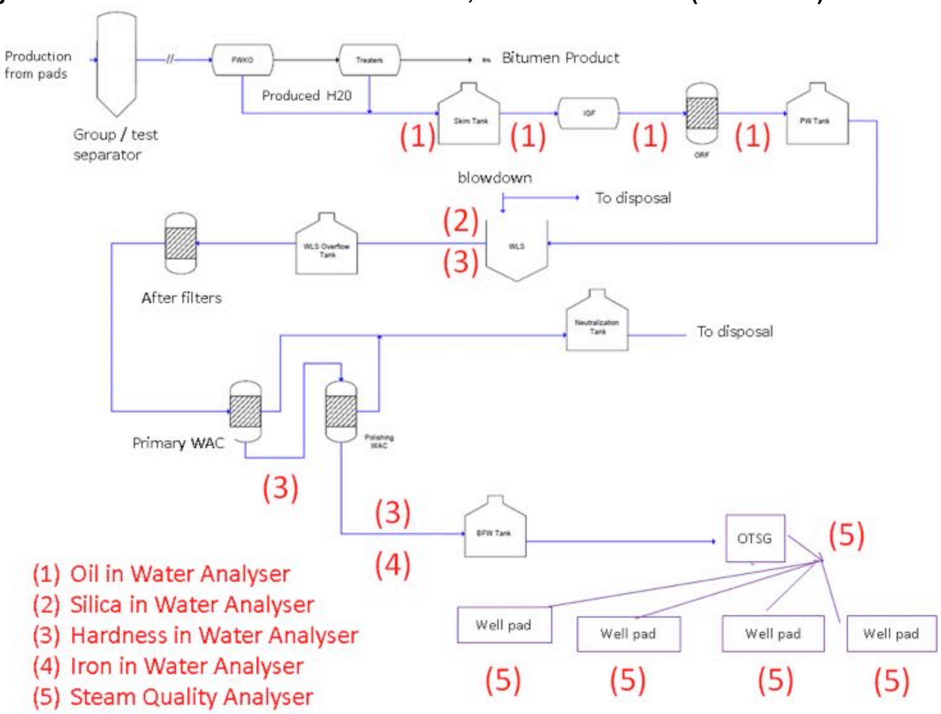

Figure 2: Typical SAGD WLS-WAC Process Flow sheet and online analyser requirements

Heavy oil recovery processes have traditionally used OTSG boilers to produce high-pressure steam for injection into geological formations containing heavy oil. The heat given up by the condensing steam lowers the viscosity of the heavy oil and allows the oil/water mixture to be brought to the surface. The oil is recovered as product to be sold and the water, referred to as produced water, is de-oiled and treated for boiler feedwater (BFW) to use for the OTSG, see Figure 3.

Water quality is an important factor in the efficiency of oil extraction in thermally enhanced heavy oil recovery. With increased regulatory constraints producers are required to recycle more of the produced water, i.e. clean and treat the water that returns from oil extraction process and are limited on the amount of makeup water allowed. Higher quality water ensures higher quality steam which equates to increased oil production. When water quality is poor deposits form on the tubes, hot spots are generated and the tubes rupture leading to expensive down time creating a need for better management of water quality measurement systems.

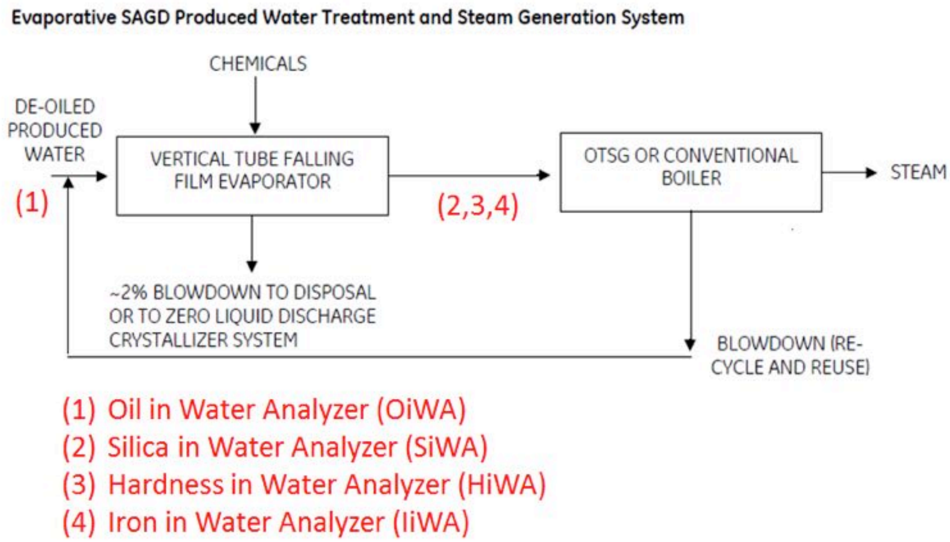

Figure 3: Heavy Oil Water Treatment and Analyser Requirements

C. PROJECT DESCRIPTION

The project consisted of developing an online water measurement analyser that allows for upsets in water treatment to be identified in real-time. The analysers consists of measuring oil in water allowing producers to operate more efficiently and at boiler designed specifications. With the combination of multiple technologies offered by Agar and Luxmux, the online analyser product offerings will deliver significant value added to producers. The solution provides online water measurement, a key area of concern in maintaining optimal boiler efficiency, reducing boiler tube deposition and boiler failure which leads to production down time and environmental hazards.

The overall objective was to develop an online and real-time identification, measurement and analysis of water in the WLS-WAC water treatment, specifically free oil in water, so that producers can operate boilers at designed 80% steam quality with confidence.

At the end of the project and in order to achieve a commercial ready online water Analyser, Agar's objective was to develop a number of product versions based on different ranges for oil.

The system for oil in water trade names OW-450 will have the following specifications shown in Table 1.

Metric	Ideal target	Minimum requirement
Detection limits (ppm)	0-10,000 ppm	0-10,000 ppm
Objective resolution	0.2%	2%
Accuracy	2% Full Scale	2% Full Scale
Repeatability	2% Full Scale	2% Full Scale

Response cycle Time	1 Minute Per Cycle	5 Minutes Per Cycle
Lower Detection Limit	1% Full Scale	1% Full Scale
Unit Sale Price	\$500k	\$500k

Table 1. OW-450 System Specifications

Obtaining CSA and CRN certification for the OW-450 represents a key objective since its required for any technology to be installed for either commercial or field trial testing purposes.

D. METHODOLOGY

The project had a number of stages and facilities used.

a) Devon Energy provided process information such as water temperatures, flow rates, desired oil ranges. This allowed Agar to assess initial product requirements.

b) Devon provided site access at Jackfish and water samples were taken, see Section F. in which the profile of the pipes and different oil concentrations at various points in the measurement stream provided Agar important data for designing the system to meet the end user requirements. The water samples where sent to Agat Laboratories to provide an oil in water concentration measurement using similar lab methodologies as Devon uses on site for lab analysis, methodology shown in Figure 4. Below.

Test Name	Principle	Reference	Procedure	Instrument	General Purposes
Alkalinity	An acid is used to titrate the sample until a certain pH is reached	APHA Standard Methods 2320B	A known amount of sample is titrated with standard sulphuric acid until a pH of 4.5 is reached	Mettler TL-70 Autotitrator	Alkalinity of water is its acid-neutralizing capacity and is the sum of all the titratable bases.
Electical Conductivity (EC)	Dissolved ions allow water to conduct electricity; a probe measures the electicity being passed.	APHA Standard Methods 2510B	A sample of water is placed in a beaker and a probe is immersed in the water.	HACH Conductivity meter	Determination how saline a water is. The higher the value, the more ions are present.
Oil in Water (OIW)	Aromatic hydrocarbons flouresce under a certain wavelength of light	US EPA Method 1664	A known volume of water is agitated with a known volume of solvent. The solvent goes into a cell in an instument that measures the amount of flouresence	TD 500D Flourimeter	Analysis of produced water samples suspected to contain heavy oil.
Total Dissolved Solids	Gravimetric analysis done by evaporating a water sample	APHA Standard Methods 2540C.	A well-mixed sample is evaporated to dryness at 180 ± 5°C in a pre-weighed dish. The increase in the weight of the dish represents the total dissolved solids (TDS).	Oven	The actual physical determination of the amount of solids dissolved, often used in junction with EC.
Total Suspended solids	Filtration of a watrer sample to retain particulate matter on a glass fiber filter	APHA Standard Methods 2540D.	A well-mixed sample is filtered through a weighed filter of standard pore size, dried in an oven and rewieghed. The residue	Oven, filtration asembly	Amount of undissolved solids that can cause issues with a process stream
Density	A liquid is introduced into an oscillating sample tube and the change in oscillating frequency determines the density of the sample.	ASTM D5002	A liquid is introduced into an oscillating sample tube and the change in oscillating frequency determines the density of the	Anton Paar DMA4500 densitometer	Typically for determination of purity of sample, sales value, or transportation calculations.
pH	Electochemical probe	APHA Standard Methods 4500-H	A sample of water is placed in a beaker and a probe is immersed in the water.	HACH HQ pH Meter	A measure of the acidity/basicity of a sample often for corrosion purposes
Metals by Inductively Couple Plasma - Opyical Emission Spectrophotometry (ICP)	The power of the radiation emitted by an analyte after excitation is directly proportional to the analyte concentration.	APHA Standard Methods 3120.	A sample is aspirated into a plasma torch and the light intensity correlates to a concentration. The instrument is calibrated for each element of interest	Thermofisher iCAP 6000	The main elements of interest for a productioin facility are related to hardness (eg. Ca, Mg,), deposition (eg. Si), and corrosion (e.g Fe, Mn)
Chloride (Cl)	The chloride content is determined by precipitation potentiometric titration with silver nitrate.	APHA Standard Methods 4500-Cl- (D)	A known volume of water is titrated with silver nitrate until a specific electometric end point is obtained.	Mettler TL-70 Autotitrator	Measurement of freshness of samples, contamination from another source (saline or fresh)
Chemical Oxygen Demand (COD)	Oxidizable organic compounds react, reducing the dichromate ion (Cr2O72-) to green chromic ion (Cr3+). The remaining amount of yellow Cr6+ is determined.	APHA Standard Methods 5220D.	A known volume of sample is combined with a strong oxidizing agent, heated for two hours, cooled, then measured on a calibrated spectrophotometer.	Hach DR3900 Spectrophotometer	COD is typically an environmental factor with criteria to minimize oxygen depletion of natural waters
Total Organic Carbon (TOC)	A series of chemical reactions converts the organic carbon into a state where a colorometric measurement is made	APHA Standard Methods 2540C.	The sample undergoes a variety of chemical reactions to eliminate the inorganic carbon and convert the organic carbon to carbonic acid. The carbonic acid causes a color change. The intensity of the colour change is measured on a spectrophotometer.	Hach DR3900 Spectrophotometer	TOC can be used for evaluation of hydrocarbon or other chemical contamination

Figure 4. Methodologies for water lab analysis

c) Next steps was to do detailed engineering work done in Agar Houston, Luxmux and NDT. Solidworks was used for 3D CAD modelling and simulation tools, Altium Designer was used for Electronics design, ray tracing software for optical model. BOM and design drawings were created and send for manufacturing and purchasing.

d) System performance was verified at Agar's Houston oil in water flow loops shown in figure 5. Step c) was repeated with modifications and step d) was repeated.

e) Lastly CRN and CSA certifications where submitted and received so that product could be tested in the field. For CRN the 3D CAD and mechanical BOM provided the basis of the engineering calculations for pressure maintaining components and submitted to ABSA. Pressure maintaining components where validated using hydro testing in Agar Houston per the standard at 2.5x pressure of process to ensure no leaks. For CSA electronic design files, schematic and BOM of all electronic and optical components was submitted for CSA approval.

E. PROJECT RESULTS

Task 1: Develop and Test Water Quality Analyzer System

The initial task was related to the development and initial test for the analyzer. During that stage Agar worked on analyzer development to meet the accuracy and repeatability requirements for the measurement ranges required by Devon Energy.

The OW-450 was developed and tested and showed good results for the desired ppm ranges. Initial tests though showed that the optical sensor could meet the range required with the accuracy needed and therefore majority of the work was focused around the optical sensor and the ultrasonic sensor integration. A number of pilot repeatability tests and long terms tests were performed in Agar Houston flow loops for weeks at a time. Additional capabilities where added to the optical unit, specifically around the combination of infrared and fluorescence in the same unit. The addition of both infrared and fluorescence optical capabilities increases the analyzers accuracy capability because TOC and suspended solids can be removed from free oil readings. Various types of oil where used in the testing, ranging from lighter to heavier crudes and similar results were achieved. Figure 5. Below show tests completed on May 2017, the graph shows ppm levels of oil injected on the X axis and Y axis shows the sensor RAW output (RAW meaning the sensor is not calibrated and outputting its RAW data). On the right the Agar Houston test flow loop is shown and the main components for this version of the analyzer testing. The flow loop is filled with 40L of water and controlled amounts of oil are injected into the circulating loop. The oil is circulated for ~5 minutes while the sensor is continuously reading and then another oil injection occurs and this is repeated for all points on the graph. At the end of the test the loop is flushed out with water many times in order to remove all the oil that may be stuck on piping walls, this step takes over an hour to fully remove all the oil from the loop. From the graph we can see a clear correlation from the RAW data against the ppm concentration from the flow loop, a liner response was achieved. In this initial version the fluorescence probe and infrared probe where inserted at separate points in the loop, later designs incorporated them into one insertion point as shown later in this report.

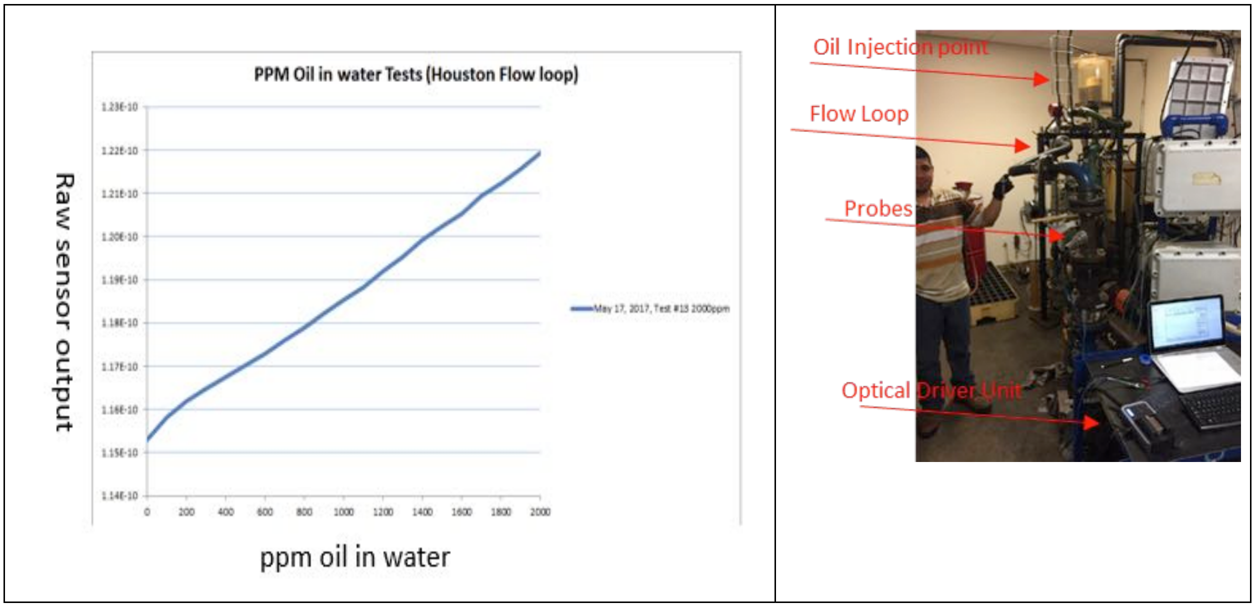

Figure 5. Testing May 2017 in Agar Houston flow loop for optical sensor from 0-2000ppm range.

Figure 5. shows a closer view of the initial probes used for testing. The fluorescence probe and infrared probe shown below on the image on the left and on the right the fluorescence probe is shown when turned on.

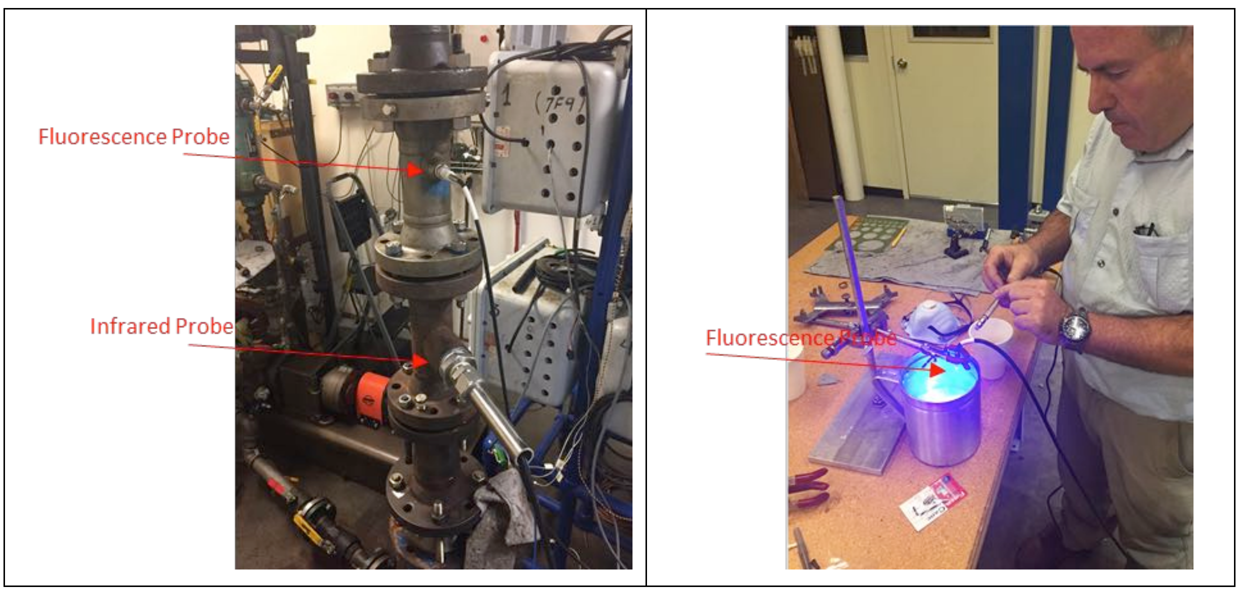

Figure 6. Agar Houston flow loop

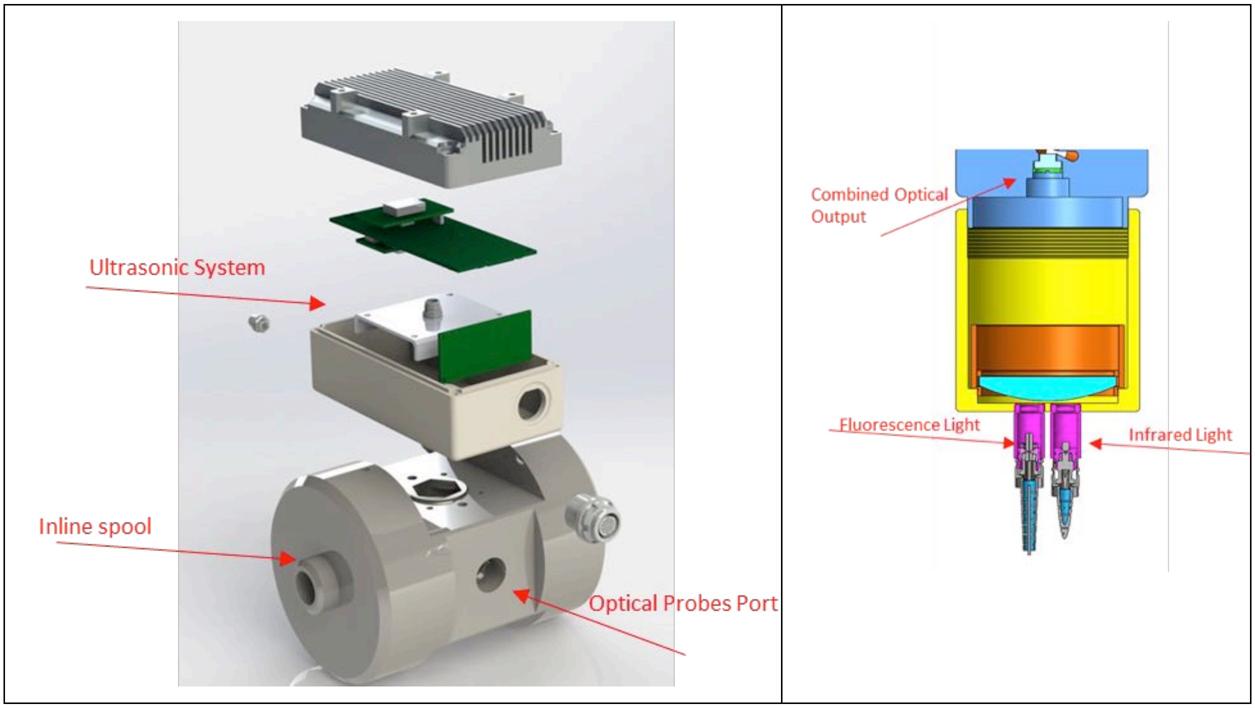

Figure 7. Electronic integration Luxmux and NDT

After initial tests where completed the next prototype built combined the fluorescence, infrared and NDT into a single spool piece as shown in Figure 7. The spool included the two optical probes connected via fiber optic to the optical driver system which sits in the explosion proof enclosure. The spool is connected inline with the water flowing and only fiber optic and electrical cable go from the spool to the explosion proof housing. Figure 7. On the right shows the two optical inputs combined into one beam for the Optical Probes Port. The system shown in Figure 7. was used for additional testing in the Agar Houston flow loops shown below.

Figure 8. shows testing with the system from Figure 7. On October of 2017. Figure 8a. shows tests without the ultrasonic turned on, the system was seeing good sensitivity of the OW-450 in the low ppm range. We can see that oil coating the sapphire windows between runs led to repeatability issues.

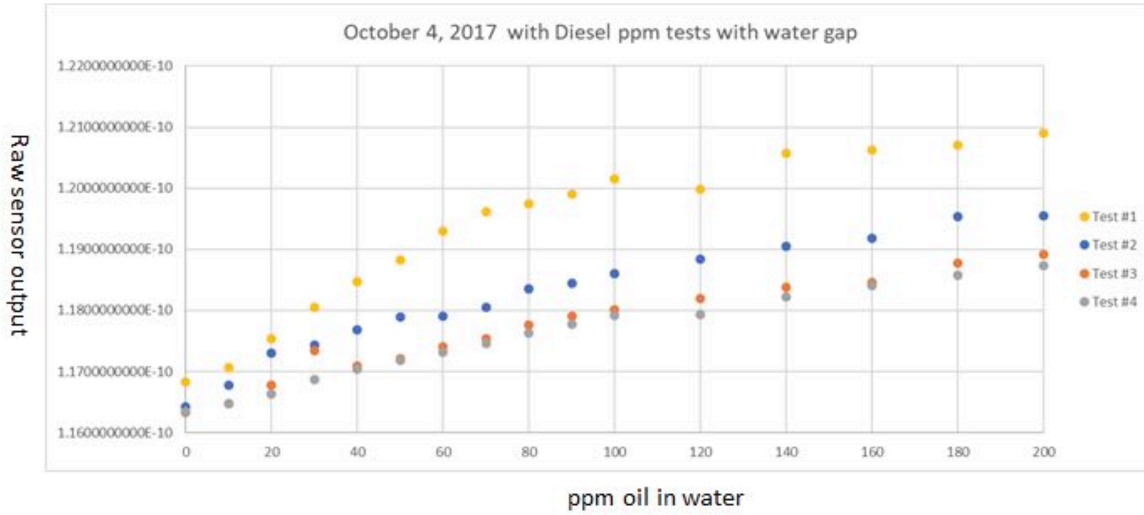

Figure 8a. Testing results for the OW-450 in Houston flow loop from October 4-October 5 2017.

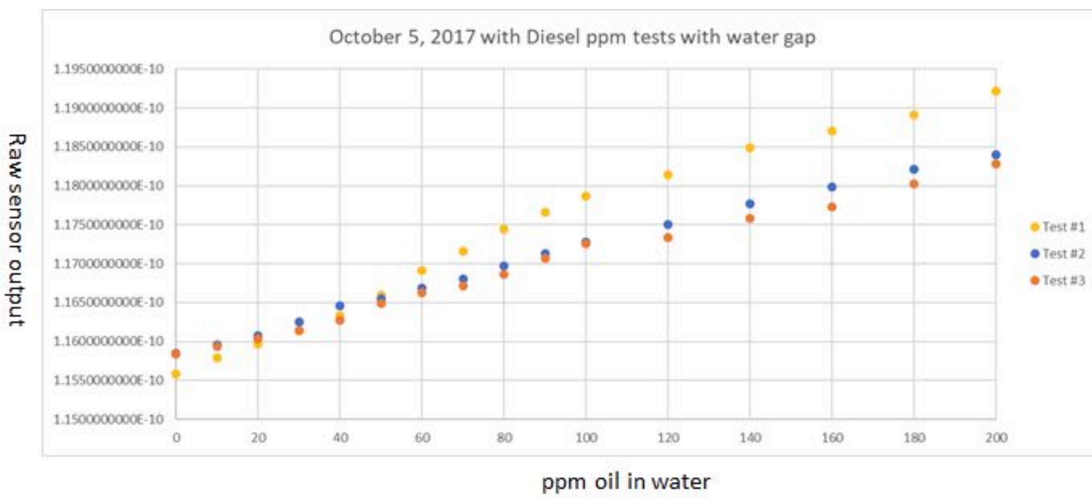

Figure 8b. Testing results for the OW-450 in Houston flow loop from October 4-October 5 2017.

figures 8b. shows the OW-450 response of the RAW data vs the ppm oil in water inserted into the flow loop for the low ppm range application with the ultrasonic turned on. The curves in Figure 8b. are now linear and did not become “flat” like in Figure 8. Without the ultrasonic but the lines in figure 8b. had different slopes which is not desired. Engineering work was done mainly on the probe interface section where it was determined the issues of repeatability can be resolved. A number of tests were performed during the period spanning of two months, additional capabilities to the sensor where added to address the issues such as additional infrared wavelengths which can detect the thin layers of coatings on sensor interface and removed.

The two ranges are shown in figure 9. below for loop tests performed. Similar mixing conditions of 5 minutes per oil injection into the loop was performed for all the runs.

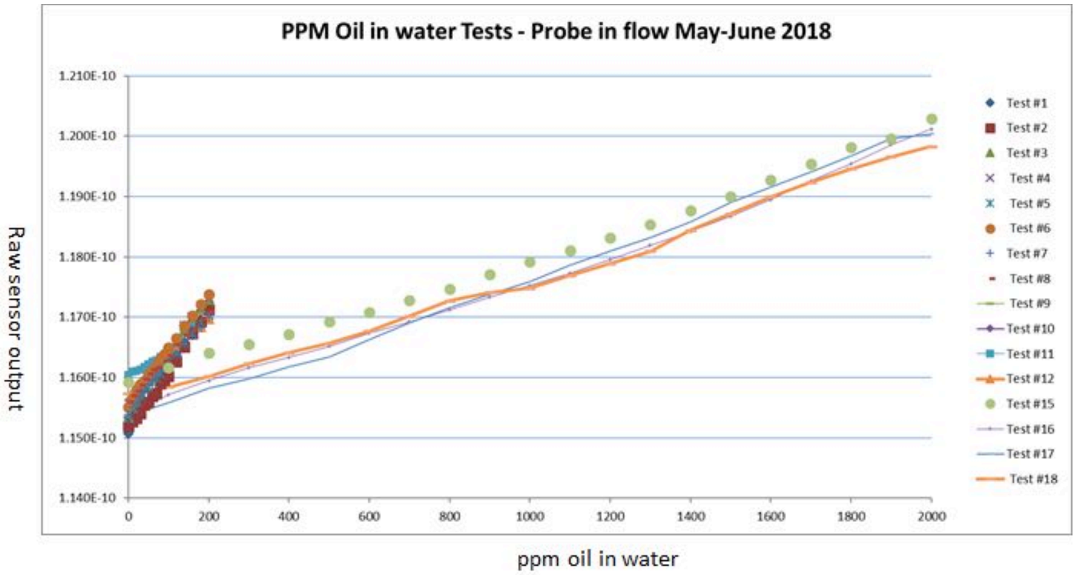

Figure 9. Testing results for the OW-450 in Houston flow loop May-June 2018

Figure 9. shows the addressed repeatability issues from previous tests where solved with adding ultrasonic cleaning and infrared capabilities to the OW-450. In the figure a large number of tests where run and different injections where done. 5-minute increments where done between injection points for both ranges, it can be seen the 0-200ppm set vs the 0-2000ppm set have different slopes which is expected due to the mixing ratio differences between injections (same amount of time between points but for lower ppm less oil was injected per time interval so it had more time to mix at a given ppm range hence the RAW value is higher). Based on these tests the OW-450 met the desired criteria the final sensor configuration was chosen and integration work into the housing commenced. The final design is shown in Appendix I and II which was used to obtain CSA and CRN certifications.

The additional capabilities added to address the measurement errors included ultrasonic cleaning which removes debris and coatings on the sensor head. In addition, Near Infrared (NIR) source was added which provides information on the amount of oil coating on sensor head. The NIR allows for the OW-450 to real-time adjust the signal level to account for any oil that has coated the sensor head.

Task 2: System Mechanical and Electrical

The task 1 completion allowed Agar to focus on the electrical and mechanical design in order to have a commercial equipment that includes the CSA and CRN certification as main requirement for field installation.

CSA Certification

Generally, CSA standards contain requirements to ensure protection against fire hazard, mechanical hazard, and shock or energy hazard. Certification means that products conform to accepted standards on a continuing basis. Products so certified can display the CSA Certification Mark, which is a registered trademark. Though CSA Certification applies mainly to CSA standards, the organization also certifies to U.S. standards such as ANSI/UL, and to international standards such as IEC (International Electrotechnical Commission and ISO (International Organization for Standardization). In addition, CSA Verification may be based on standards of other agencies.

A license to use the CSA mark is only given after a thorough testing and evaluation process. For this specific product, the field certification is the one that applies since it's not released for manufacturing.

During the work to certify the analyzer with CSA standards, electrical drawings as well as full specifications are required for the inspector prior to the physical evaluation. The main electrical components for the analyzer are the AGAR Data Acquisition System (DAS), optical system and ultrasonic.

The exact drawings of the system sent for CSA certification are shown in Appendix I. The system sits inside the exposition proof housing shown in Figure 11 below. The electronics include all the power supplies, the DAS system, the control of the ultrasonic and the optical electronics with optical sources integrated. The explosion proof housing gets mounted beside the spool ~2m for the fiber optic, electrical cables and conduit not to be too long. CSA certified conduit and connections go from the explosion proof housing to the spool element which interfaces with the water. The CSA certificate obtained for the OW-450 system is shown in figure 10.


CSA GROUP™

Field Certification
Certificate of Compliance

Certificate: 80024283 **Master Contract:** N/A

Project: 80024283 **Date Issued:** December 2, 2019

Issued to: Agar Corporation, Inc.
5150 Tacoma Drive
Houston, Texas 77041
USA
Sales Order: Q-111183

Attention: Brent Beers

The products listed below are eligible to bear CSA Field Certification Labels, bearing the CSA Mark shown.

Issued by: Allen Anderson

PRODUCTS

CLASS – 2258 02 - PROCESS CONTROL EQUIPMENT - For Hazardous Locations

CSA Field Certification Label(s) issued: from serial numbers FB349820

Class 1, Division 2, Group D, T3

Model Number: TQM102AS
Serial Number: 80000613
120VAC 3.6A Supply,
Ambient Temperature: -20°C to 50°C

DQD 507.10 Rev 2019-10-24 © 2018 CSA Group. All rights reserved. Page 1

Figure 10. CSA certificate encompassing Luxmux/Agar equipment

Figure 11. Equipment with markings

CRN Certification

The Canadian Registration Number (CRN) is a number issued by each province or territory in Canada by an authorized safety authority for any boiler, pressure vessel or fitting that operates at a pressure greater than 15psig (1 barg). The pressure related parts requiring the CRN certifications is the spool piece which goes inline with the water. The Application process required the calculation for the maximum pressure in the field which included a 2.5x safety factor. The drawings submitted for CRN certification is in Appendix II.

The CRN identifies that the design has been accepted and registered for use in that province or territory. The certificate obtained is shown in Figure 12. The Alberta Boilers Safety Association (ABSA) is the authority in the province of Alberta that certifies any pressurized equipment that includes from fittings up to vessels. The oil in water analyzer sensor does fall within the fitting category and it must have a unique CRN certificate In Alberta that certify the safety and operational conditions.

ABSA
the pressure equipment safety authority

9410 - 20 Ave N.W.
Edmonton, Alberta, Canada T6N 0A4
Tel: (780) 437-9100 / Fax: (780) 437-7787

January 28, 2020

Attention: Hernan Beltran
AGAR CANADA CORP
250007 MOUNTAIN VIEW TRAIL
SPRINGBANK, AB T3Z 3S3

The design submission, tracking number 2020-00220, originally received on January 15, 2020 was surveyed and accepted for registration as follows:

CRN : 0F20414.2 **Accepted on:** January 28, 2020
Reg Type: NEW DESIGN **Expiry Date:** January 28, 2030
Drawing No. : 01972-A17473 (2 PAGES) Rev E As Noted
Fitting type: PPM OIL IN WATER PROBE
Design registered in the name of : AGAR CORPORATION INC

Description	MAWP	Design Temperature	MDMT
Internal Pressure	5000kPa	150 °C	-29 °C

The registration is conditional on your compliance with the following notes:
See drawing list in the Scope of Fitting Designs.

As indicated on AB-41 Statutory Declaration form and submitted documentation, the code of construction is ASME B31.3.

- This registration is valid only for fittings fabricated at the location(s) covered by the QC certificate attached to the accepted AB-41 Statutory Declaration form.
- This registration is valid only until the indicated expiry date and only if the Manufacturer maintains a valid quality management system approved by an acceptable third-party agency until that date.
- Should the approval of the quality management system lapse before the expiry date indicated above, this registration shall become void.

An invoice covering survey and registration fees will be forwarded from our Revenue Accounts.

If you have any question don't hesitate to contact me by phone at (780) 433-0281 ext 3306 or fax (780) 437-7787 or e-mail Wangi@absa.ca.

Sincerely,

WANG, IAN, P. Eng.
DOP Cert. No. D00009643

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Figure 12. CRN certification

F. KEY LEARNINGS

The development of this analyzer allowed Agar to understand with details the challenges faced by the producers when processing the process water prior to steam generation.

One of the key learnings during this project was the verification of multiple PPM levels across the cross section of the pipe that reflected the need to provide not only the right solution but the proper product specification to reduce the uncertainty caused by the nature of the process.

During a visit to Devon's Jackfish facility various sampling points where selected for the PPM samples. The results from the sampling is shown below in figures 13-15.

Picture 3. Sampling point option#2 Inlet of Skim Tank

Figure 13. Devon sampling ports

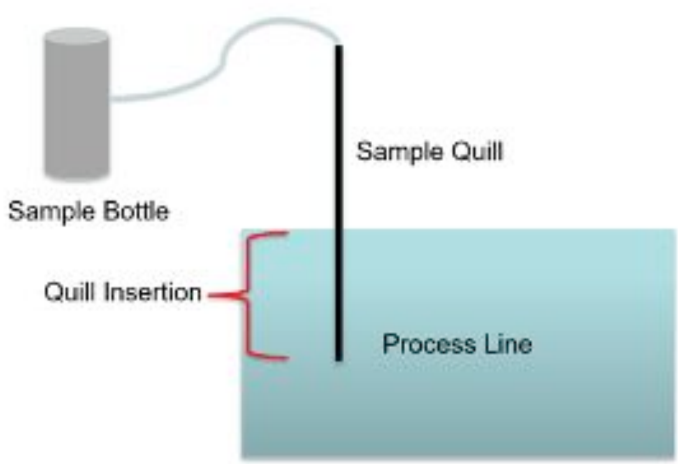


Figure 14. Sampling methodology

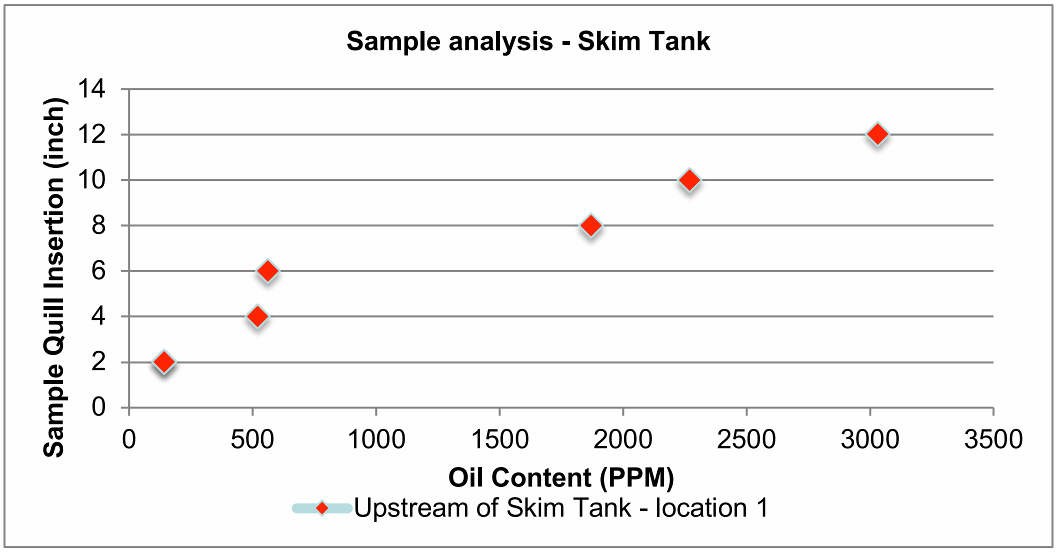


Figure 15a. Upstream of Skim Tank Analysis Location 1

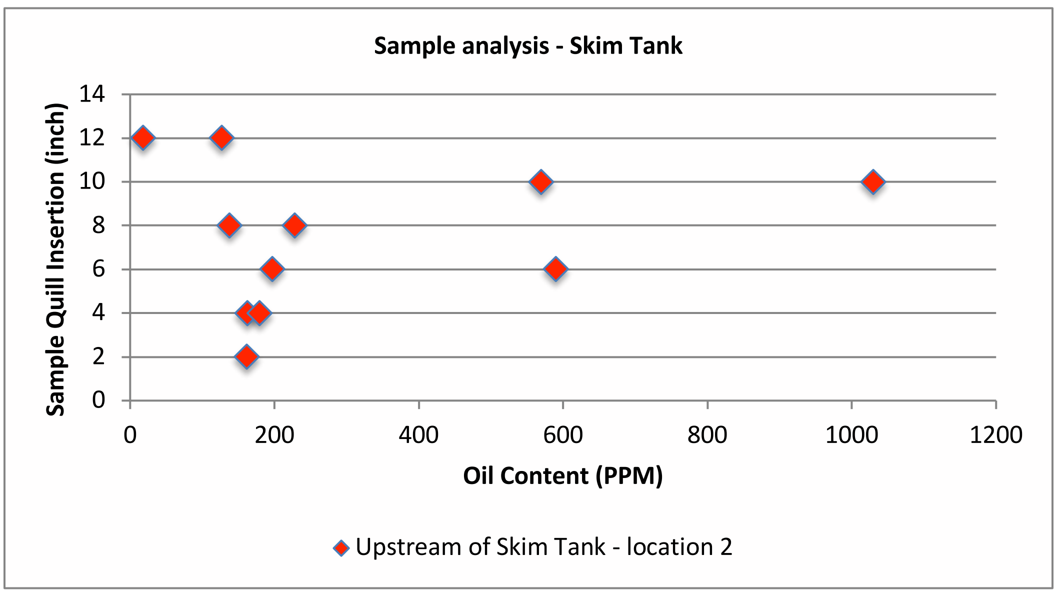


Figure 15b. Upstream of Skim Tank Analysis Location 2

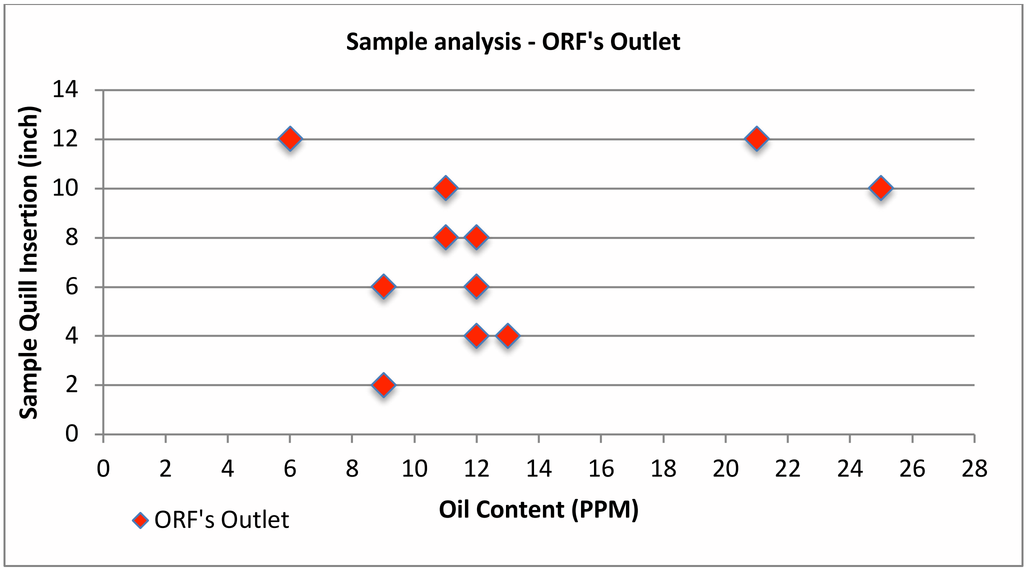


Figure 15c. Upstream of Oil Removal Filter (ORF)

In the figures above, samples were taken at various elevations across the pipe at different points in the process at Devon's Jackfish facility. The samples were then taken to lab analysis of the oil concentration. It can be seen that for the skim tank the concentration varies from as low 150ppm to as high as 3000ppm, however, at the ORF (oil removal filter) the concentration ranged from 4ppm to 30ppm. These results confirmed the initial approach of two different applications as well as the right location for each of them.

Throughout the project there were many learnings about how to measure PPM oil in water accurately, reliably and the downfalls of competing technologies and methods. Any optical method suffers from coating on windows and that was the main purpose of the NDT technology using ultrasonic cleaning. Aside from the coating the two techniques of combining of near infrared scattering together with UV fluorescence for PPM oil in water measurements showed advantageous for end user. Fluorescence is a good method, but its downfall is that it measures both free oil and TOC dissolved in the water. End users are interested in the fee oil only and not the organics in the water which is usually high in SAGD heavy oil operations in Canada. The near infrared scattering measures all solid particles in the stream, so its measures the free oil but any solids which might be flowing will provide false readings. Therefore, the combination of NIR and Fluorescence provide the total solution for just measuring free oil which is what the end customers require. With the ultrasonic cleaning combined to that it ensures accurate and repeatable readings over time. Lastly coupled with Agar's flow measurements, and process parameters both skid type solutions and inline spool insertions can be provided to end customers. Lastly Agar experimented with tapered venturi style piping, this showed that it increases the accuracy of the system if small pressure drops are acceptable to end customers because the tapered approach brings all the water into the measurement volume of the sensor. The tapered approach is applicable to installations up to 3" pipe diameters, for 3" and up inline mixers or multiple measurement points increase the accuracy of the system to provide a full ppm oil in water measurement across the profile of the stream.

G. OUTCOMES AND IMPACTS

Online water analysis is important for the producers to identify upsets as soon as possible rather than waiting for sampling and lab results which may be performed only once per day or a few times per day. If, for example, the boiler operates for 12 hours with upset conditions before the lab analysis is ready, this will result in tube deposition for that period of time and eventual boiler damage, loss of production and can lead to more extreme cases of catastrophic failures in which the operator needs to dump all the water in the plant. Directive 81 of the Alberta Energy Regulator (AER) (**Error! Reference source not found.**) limits the amount of water producers are allowed to flow into disposable wells. It can be seen how critical an upset in the water specifications are to operators and unfortunately, they do not have reliable and accurate ppm oil in water analyzer that can help them prevent and mitigate these risks.

As soon as one of these parameters reaches upset conditions not only is there loss of production due to reducing steam quality to 60% and shutting down boilers but now the amount of water being disposed may exceed Directive 81 of the Alberta Energy Regulator (AER) and lead to fines. In typical operations the plant is designed to handle 22% blow down water (78% steam quality), in an upset condition the produced water still comes on so now the plant needs to dispose of almost all the water. For operations of 35,000 bpd plant each boiler takes around 156,000 kg/hr of water so 936,000 kg/hr for the plant, if two boilers are reduced to 60% and four boilers are shutdown the plant will be disposing ~686,400 kg/hr of produced water to the environment during an upset until the issue is fixed which may lead to fines for the producers for not meeting Directive 81.

An online analyser for these parameters will allow the producers to take preventive actions immediately, rather than waiting for lab results, allowing producers to take preventative actions before the parameter reaches upset conditions, for example oil in water the operator has the time from when it exceeds 0.5ppm until it reaches 2ppm to rectify the problem. Without such a tool producer will not exceed 74%-78% as the risk of damage to their boilers increase. Assuming that the outcome of implementing the proposed new water, analyzer measurement system is successful, the operators will have the ability to run closer to the boiler specifications of 80% steam quality. An increase in 4% steam quality could lead to an increase of 1.3% in production, assuming 3:1 Steam to Oil Ratio (SOR).

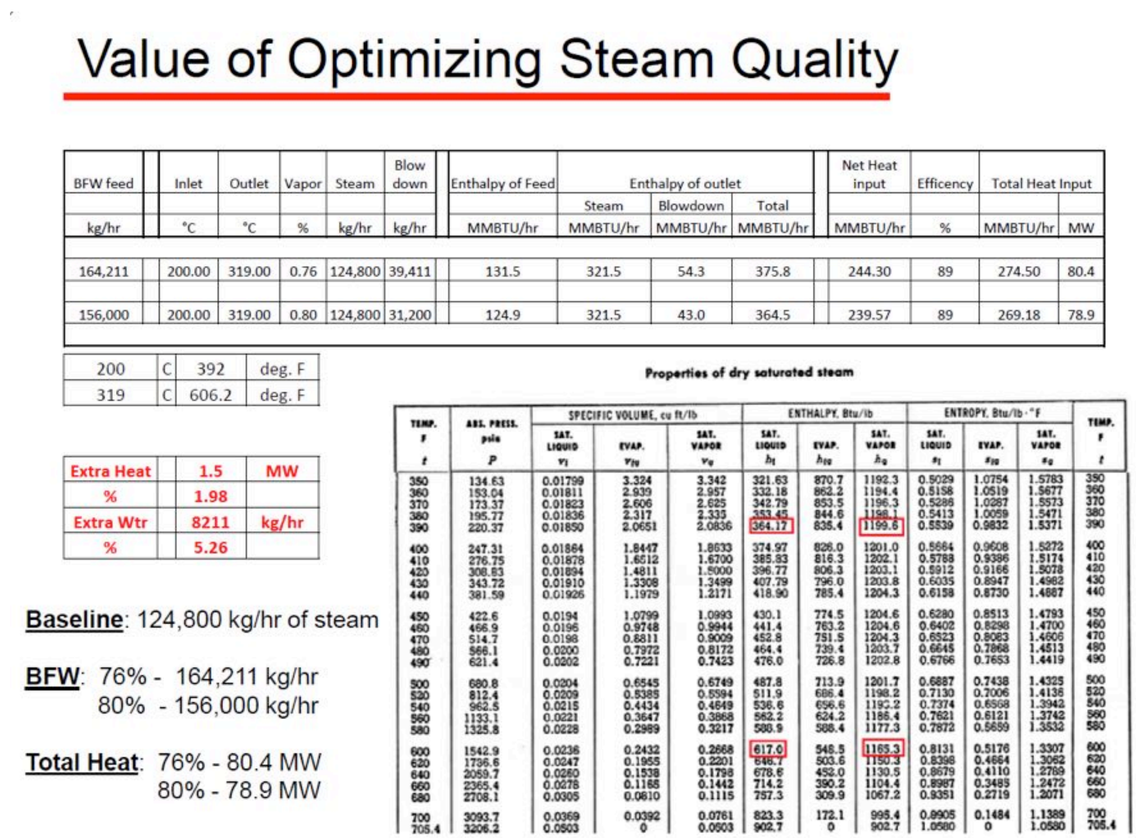
There are two scenarios shown in figure 16a and Figure 16b, the first one is when comparing the boiler operation at 76% steam quality and at 80% steam quality in order to get the same amount of steam, i.e., 124,800 kg/hr and the second scenario is keeping the BFW constant at 156,000 kg/hr and seeing how much more steam is available at 80% steam quality in comparison to 76% steam quality.

To perform the straightforward calculations enthalpy is used which is well know from the steam tables. The water coming into the boiler is at 200 Degrees C and 319 Degrees C coming out. The enthalpy of the feed water is calculated for both qualities and the enthalpy of the water plus the vapor is calculated for the output of the boiler (the numbers are taken from one phase, i.e. saturated water and saturated vapor from the defined steam tables as a function of temperature). By subtracting the enthalpy of the output from the input the total energy added to the system is computed. Finally taking boiler efficiency at 89% the total heat input is derived for both scenarios. In the case of getting a constant amount of steam for 76% and 80% it can be seen that one requires 1.51MW less energy to get the same amount of steam, furthermore more water is required. At 124,800 kg/hr of steam and 3:1 SOR this scenario produces 262 barrels per hour (bph) of oil. So, a per barrel foot print will provide: 0.30687 MW/bph @ 76% and 0.301145 @ 80%.

In the second scenario the producer keeps the BFW the same at 156,000 and gets more steam at 80% comparing to 76%. With an SOR of 3:1 the producer will only get 249 bph of oil at 76% quality and the same 262 bph in the case of 80%. Although in this scenario 2.5MW more heat is required the carbon footprint per barrel of oil is lower, i.e. 0.3068273 MW/bph @ 76% and 0.301145 MW/bph @ 80%. It can be seen at both scenarios increasing steam quality is more economical and the carbon footprint associated with a barrel of oil is lower.

From the second scenario it was shown that increasing to 80% steam quality you get 13 bph more oil. At $40 for a barrel of oil this leads to increase of revenue for the producer of $4.38 Million a year per boiler for 351 day operation per year. Per WLS-WAC facility having 6 boilers this equates to $26,282,880 increase in revenue per year at $40 a barrel.

Thermally enhanced heavy oil production is at ~1.2 million bpd in Canada and expected to double in the next ten years. If assuming a typical OTSG is used in production in all the Canadian heavy oil market, there are ~191 OTSG or similar in operation. By 2022 it is expected that there will be 350 OTSG boilers. With the addressable market being relatively small Agar Canada will need to ensure the pricing of the product is appropriate. Fortunately, the value proposition that the solution offers is huge. Steam quality can be directly related to yield rates in SAGD production. For a 4% increase in steam quality there is approximately a 1.3% increase in production.



Value of Optimizing Steam Quality

BFW feed	Inlet	Outlet	Vapor	Steam	Blow down	Enthalpy of Feed	Enthalpy of outlet			Net Heat input	Efficency	Total Heat Input	
							Steam	Blowdown	Total				
kg/hr	°C	°C	%	kg/hr	kg/hr	MMBTU/hr	MMBTU/hr	MMBTU/hr	MMBTU/hr	MMBTU/hr	%	MMBTU/hr	MW
164,211	200.00	319.00	0.76	124,800	39,411	131.5	321.5	54.3	375.8	244.30	89	274.50	80.4
156,000	200.00	319.00	0.80	124,800	31,200	124.9	321.5	43.0	364.5	239.57	89	269.18	78.9

200	C	392	deg. F
319	C	606.2	deg. F

Extra Heat	1.5	MW
%	1.98	
Extra Wtr	8211	kg/hr
%	5.26	

Baseline: 124,800 kg/hr of steam

BFW: 76% - 164,211 kg/hr
80% - 156,000 kg/hr

Total Heat: 76% - 80.4 MW
80% - 78.9 MW

Properties of dry saturated steam

TEMP. F t	ABS. PRESS. psia P	SPECIFIC VOLUME, cu ft/lb SAT. LIQUID v_f	EVAP. v_{fg}	SAT. VAPOR v_g	ENTHALPY, Btu/lb SAT. LIQUID h_f	EVAP. h_{fg}	SAT. VAPOR h_g	ENTROPY, Btu/lb·°F SAT. LIQUID s_f	EVAP. s_{fg}	SAT. VAPOR s_g	TEMP. F t
350	134.63	0.01799	3.324	3.342	321.63	870.7	1192.3	0.5029	1.0754	1.5783	350
360	153.04	0.01811	2.939	2.957	332.18	862.2	1194.4	0.5158	1.0519	1.5677	360
370	173.37	0.01823	2.606	2.625	342.79	853.5	1196.3	0.5286	1.0287	1.5573	370
380	195.77	0.01836	2.317	2.335	353.45	844.6	1198.1	0.5413	1.0059	1.5471	380
390	220.37	0.01850	2.0651	2.0836	364.17	835.4	1199.6	0.5539	0.9832	1.5371	390
400	247.31	0.01864	1.8447	1.8633	374.97	826.0	1201.0	0.5664	0.9608	1.5272	400
410	276.75	0.01878	1.6512	1.6700	385.83	816.3	1202.1	0.5788	0.9386	1.5174	410
420	308.83	0.01894	1.4811	1.5000	396.77	806.3	1203.1	0.5912	0.9166	1.5078	420
430	343.72	0.01910	1.3308	1.3499	407.79	796.0	1203.8	0.6035	0.8947	1.4982	430
440	381.59	0.01926	1.1979	1.2171	418.90	785.4	1204.3	0.6158	0.8730	1.4887	440
450	422.6	0.0194	1.0799	1.0993	430.1	774.5	1204.6	0.6280	0.8513	1.4793	450
460	466.9	0.0196	0.9748	0.9944	441.4	763.2	1204.6	0.6402	0.8298	1.4700	460
470	514.7	0.0198	0.8811	0.9009	452.8	751.5	1204.3	0.6523	0.8083	1.4606	470
480	566.1	0.0200	0.7972	0.8172	464.4	739.4	1203.7	0.6645	0.7868	1.4513	480
490	621.4	0.0202	0.7221	0.7423	476.0	726.8	1202.8	0.6766	0.7653	1.4419	490
500	680.8	0.0204	0.6545	0.6749	487.8	713.9	1201.7	0.6887	0.7438	1.4325	500
520	812.4	0.0209	0.5385	0.5594	511.9	686.4	1198.2	0.7130	0.7006	1.4136	520
540	962.5	0.0215	0.4434	0.4649	536.6	656.6	1193.2	0.7374	0.6568	1.3942	540
560	1133.1	0.0221	0.3647	0.3868	562.2	624.2	1186.4	0.7621	0.6121	1.3742	560
580	1325.8	0.0228	0.2989	0.3217	588.9	588.4	1177.3	0.7872	0.5659	1.3532	580
600	1542.9	0.0236	0.2432	0.2668	617.0	548.5	1165.3	0.8131	0.5176	1.3307	600
620	1736.6	0.0247	0.1955	0.2201	646.7	503.6	1150.3	0.8398	0.4664	1.3062	620
640	2059.7	0.0260	0.1538	0.1798	678.6	452.0	1130.5	0.8679	0.4110	1.2789	640
660	2365.4	0.0278	0.1165	0.1442	714.2	390.2	1104.4	0.8987	0.3485	1.2472	660
680	2708.1	0.0305	0.0810	0.1115	757.3	309.9	1067.2	0.9351	0.2719	1.2071	680
700	3093.7	0.0369	0.0392	0.0761	823.3	172.1	995.4	0.9905	0.1484	1.1389	700
705.4	3206.2	0.0503	0	0.0503	902.7	0	902.7	1.0580	0	1.0580	705.4

(a)

Value of Optimizing Steam Quality, increase in production approach (Constant BFW)

BFW feed	Inlet	Outlet	Vapor	Steam	Blow down	Enthalpy of Feed	Enthalpy of outlet			Net Heat input	Efficency	Total Heat Input	
							Steam	Blowdown	Total				
kg/hr	°C	°C	%	kg/hr	kg/hr	MMBTU/hr	MMBTU/hr	MMBTU/hr	MMBTU/hr	MMBTU/hr	%	MMBTU/hr	MW
156,000	200.00	319.00	0.76	118,560	37,440	124.9	305.4	51.6	357.0	232.09	89	260.77	76.4
156,000	200.00	319.00	0.80	124,800	31,200	124.9	321.5	43.0	364.5	239.57	89	269.18	78.9

(b)

Figure 16. Enthalpy calculations for optimizing steam quality based on two approaches (a) constant steam (b) constant BFW

The project outcome of the OW-450 is shown in Table 2 below in comparison to the project objectives. The main outcomes the detection limits are higher then initially targeted, based on the loop results up to 5% (50,000ppm) of oil can be measured with the OW-450. The resolution, accuracy and repeatability were all achieved. The targeted sales price is much lower than initially anticipated based on the final engineering drawings and BOM.

Metric	Ideal target	Project Outcome
Detection limits (ppm)	0-10,000 ppm	0-50,000 ppm
Objective resolution	0.2%	0.1%
Accuracy	2% Full Scale	2% Full Scale
Repeatability	2% Full Scale	2% Full Scale
Response cycle Time	1 Minute Per Cycle	1 Minutes Per Cycle
Lower Detection Limit	1% Full Scale	0.25% Full Scale
Unit Sale Price	$500k	$100k

Table 2. OW-450 Analyzer Specification

H. BENEFITS

With this project, Agar can become a leader in online water analysis in Canada. This is an enabling technology which will allow the heavy oil industry to optimize production while reducing GHG emissions and water usage. Online water analysis is important for the producers to identify upsets as soon as possible rather than waiting for sampling and lab results which may be performed only once per day or a few times per day. If, for example, the boiler operates for 12 hours with upset conditions before the lab analysis is ready, this will result in tube deposition for that period of time and eventual boiler damage, loss of production and can lead to more extreme cases of catastrophic failures in which the operator needs to dump all the water in the plant. Directive 81 of the Alberta Energy Regulator limits the amount of water producers are allowed to flow into disposable wells. It can be seen how critical an upset in the water specifications are to operators and unfortunately, they do not have reliable and accurate ppm oil in water analyzer that can help them prevent and mitigate these risks. In typical operations the plant is designed to handle 22% blow down water, in an upset condition the produced water still comes on so now the plant needs to dispose of all the water. For operations of 35,000 bpd plant each boiler takes around 156,000 kg/hr of water so 936,000 kg/hr for the plant, if two boilers are reduced to 60% and four boilers are shutdown the plant will be disposing ~686,400 kg/hr of produced water to the environment during an upset until the issue is fixed which may lead to fines for the producers for not meeting Directive 81.

The projects objective of demonstrating online water analysis for oil ensuring producers can operate at boiler designed steam quality, i.e. 80% instead of typical systems today ~76%.

To first quantify the environmental benefits of analysing water quality online and ensuring the producers can operate at 80% steam quality, the first law of thermodynamics is used and the enthalpy is calculated for an OTSG **Error! Reference source not found.**. By calculating the enthalpy of the feed water and the enthalpy of the steam output the amount of heat applied to the system can be derived. In a similar fashion in **Error! Reference source not found.** the same calculation is performed for a system producing 76% steam quality and comparing the amount of heat required to get the same steam flow rate of 124,800 kg/hr. It can be seen that a boiler operating at 80% steam quality will need 78.31 MW while a system operating at 76% will need 79.82 MW to produce the same amount of steam, i.e. for a given amount of oil. 8,211 kg/hr of more water is needed in the 76% operations comparing to the 80%, typically 15% make up water is required in operations which will allow for a saving of 9,517 cubic meter / year when using the online analyser to operate at 80% steam quality.

Based on the calculations **Error! Reference source not found.** the GHG emissions can be calculated for a 1.51MW reduction in heat requirements for a system operating at 80% due to the analyser solution providing online water measurements and ensuring operators are meeting Boiler feed Water (BFW) quality to OTSG specification for 80% steam quality. Based on the emission factors for burning natural gas to generate steam shown in **Error! Reference source not found.**the reduction in GHG per OTSG boiler as shown Table 3 below. On average one WLS-WAC water treatment facility services 6 boilers and assuming 351 days a year operation.

CO2	16.53	Ktonnes/year
NOx	17.46	tonnes/year
PM	0.88	tonnes/year
Sox	0.07	tonnes/year

Table 3. GHG emission reduction per WLS-WAC Facility (6 boilers at 1.51MW per boiler) utilizing the online water monitoring analyzer

In terms of potential for this technology, out of the Water recovery and energy saving for SAGD, assuming a 118,013 bpd refinery, and assume that this is a *good* refinery. It "only" dumps 0.5% of the crude, it has a great recovery system, and it "only" costs the refinery $60/bbl. of the dumped crude between the reduced slop value and the throughput reduction. This costs the refinery $35,403 a day, nearly $13M (million) a year. An average refinery could easily be looking at two or three times the lost potential revenue. A larger, less optimal refinery, with 500,000bpd could be looking at losses in excess of $100,000,000 a year.

The potential market rollout in SAGD for the OW-450 is shown Table 4 below.

Year	Canada			Rest of World		
	Forecast (Units)	Unit Price	Revenues ($)	Forecast (Units)	Unit Price	Revenues ($)
2019	0	100,000	0	0	100,000	0
2020	0	100,000	0	0	100,000	0
2021	0	100,000	0	0	100,000	0
2022	1	100,000	100,000	1	100,000	100,000
2023	5	500,000	300,000	3	100,000	300,000
2024	10	1,000,000	300,000	10	100,000	1,000,000
2025	10	1,000,000	500,000	10	100,000	1,000,000
2026	25	2,500,000	500,000	15	100,000	1,500,000
2027	25	2,500,000	500,000	15	100,000	1,500,000

Table 4. Market Roll-out Table SAGD

I. RECOMMENDATIONS AND NEXT STEPS

The goal of field implementation, initially planned, was modified due the circumstances with Devon Energy. Nevertheless, the milestones achieved with this project allows to have a product ready for field testing in a SAGD facility as next steps. As part of the future actions for the testing, AGAR is actively looking for a partner, with access to an SAGD facility, that allows the evaluation of the technology developed in order to identify any possible changes/upgrades that will ultimately enable this technology for the purpose presented originally on this project.

A potential partnership identified is the Water Development Technology Centre (WDTC), which is located in Alberta with the ability to not only test technologies under the same process conditions but vary the operation so they can be exposed to a wider range than in a facility in use where variations are usually controlled to be eliminated. AGAR is currently working with WDTC with respect to its steam quality Analyzer (the development of the steam analyzer was a project also funded via SDTC in the past). The steam quality analyzer is scheduled for a year field trial at Suncor Firebag facility and was delivered to their facility on March 16, 2020. Its is currently being commissioned for the start of the field trial. Agar will work on getting the OW-450 into field trials as well with WDTC.

In addition, Agar will pursue other commercial application for the OW-450. Some areas it will commercialize the OW-450 is for heat exchangers and wastewater applications. In the USA in 2008 the 146 refineries operating had a total capacity of 17.23 million of barrels per day. 710,500,000,000 cubic feet of natural gas was consumed by 146 refineries in the US in 2008. According to these numbers an average refinery can be defined as 118,013 barrels per day capacity. Therefore, an average refinery consumes ~168MW of natural gas to heat the various processes in the refinery.

Recovering oil from wastewater is often legally necessary, and, at least compared to the total loss of that oil, profitable. Considering that a typical refinery will accidentally dump between 0.5% and 2.0% of its total throughput to the Waste Water Treatment Facility (WWTF), it's easy to understand why a potential recycling of hundreds of thousands of barrels of oil per year would be attractive. Assuming a 118,013bpd refinery and assume that this is a *good* refinery. It "only" dumps 0.5% of the crude, it has a great recovery system, and it "only" costs the refinery $60/bbl. of the dumped crude between the reduced slop value and the throughput reduction. This costs the refinery $35,403 a day, nearly $13M (million) a year. An average refinery could easily be looking at two or three times the lost potential revenue.

J. KNOWLEDGE DISSEMINATION

Currently the industry does not have a reliable online water quality analyzer for oil, in the ppm range. Devon Canada Corporation has indicated to Agar that they rely on lab analysis to derive the required measurements from the water as the fluorescence-based type oil in water devices. There are other technologies in the industry which have attempted to provide online analysis. There are some other commercialized products that may be considered as "close" competitors are seen in Table 5. belowTable 5. Alternative Technologies. The solutions that are offered however are not real time. In some cases, they are relatively complex and expensive to set up and maintain and are therefore not ideal for heavy oil extraction.

Analysis of produced water for the oil sector has been addressed through the use of several different technologies. The technology chosen is largely dependent on the parameter that is being tested. Online fluorescence-based oil in water measurements have difficulties with background interferences mainly the TOC in SAGD applications and scaling problems limiting the operation of these devices. Infrared scattering-based systems alone will have issues with suspended solids. The combination approach taken by Agar in the OW-450 is the ultimate solutions for ppm oil in water monitoring ins SAGD applications.

	Hach System FP360 sc OIW Sensor	**Applied Analytics OiW-100**	**ARJAY HydroSense 2410**	**Turner Designs NeTD**	**Horiba OCMA-310**
Measuring Principle	UV Fluorescence	Dispersive UV-Vis absorbance Sptectrophotometry	UV Fluorescence	Fluorescence	Solvent Extraction NDIR Analysis
Range	0.1 - 15 ppm mg/L Oil		0 - 500 ppm	1 ppb - 1000 ppm	0 - 200 mg/L
Accuracy		2% full scale	+/- 0.1 ppm		0 - 99.9mg/L = 0.1 mg/L
Repeatability	2.5% of reading		+/- 1 ppm	10%	0 -9.9 mg/L +/- 0.2 mg/L
Lower Limit of Detection (LOD)	1.2 ppb (PAH)				
Response Time	10 s (T90)	10s	10 s	< 10 s	
Reagent Consumption	NA				20 ml ratio of sample to solvent 2:1

Table 5. Alternative Technologies ppm oil in water

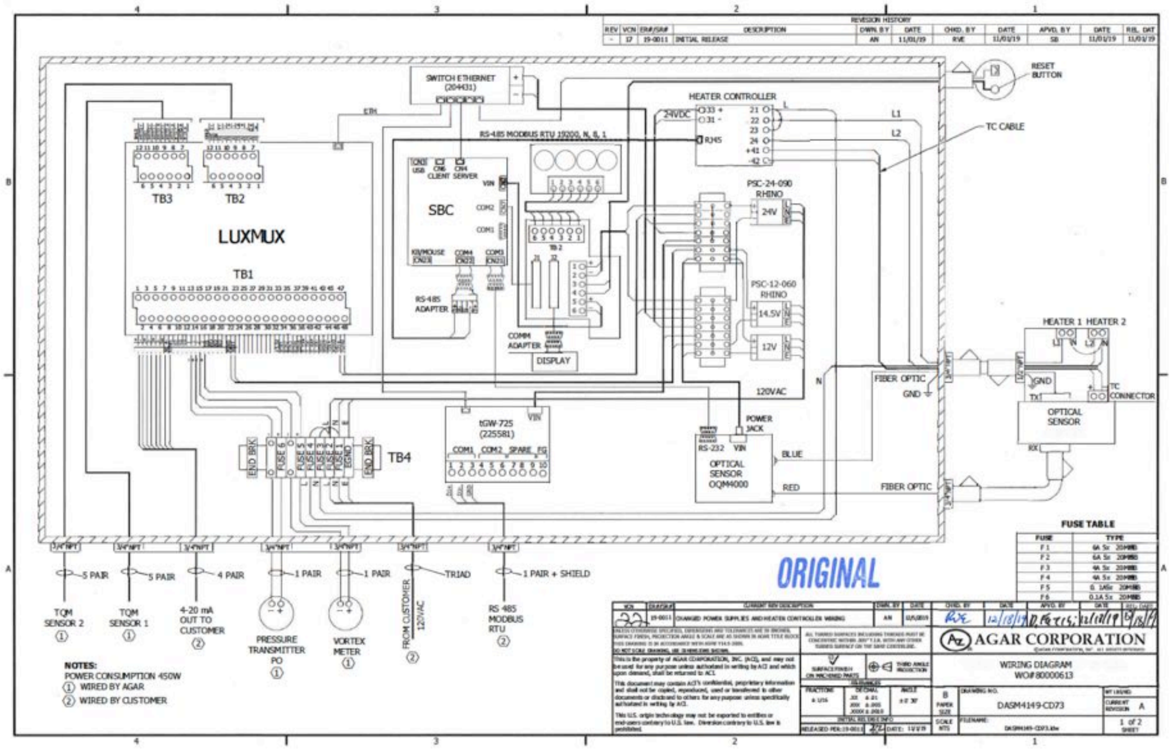
K. CONCLUSION

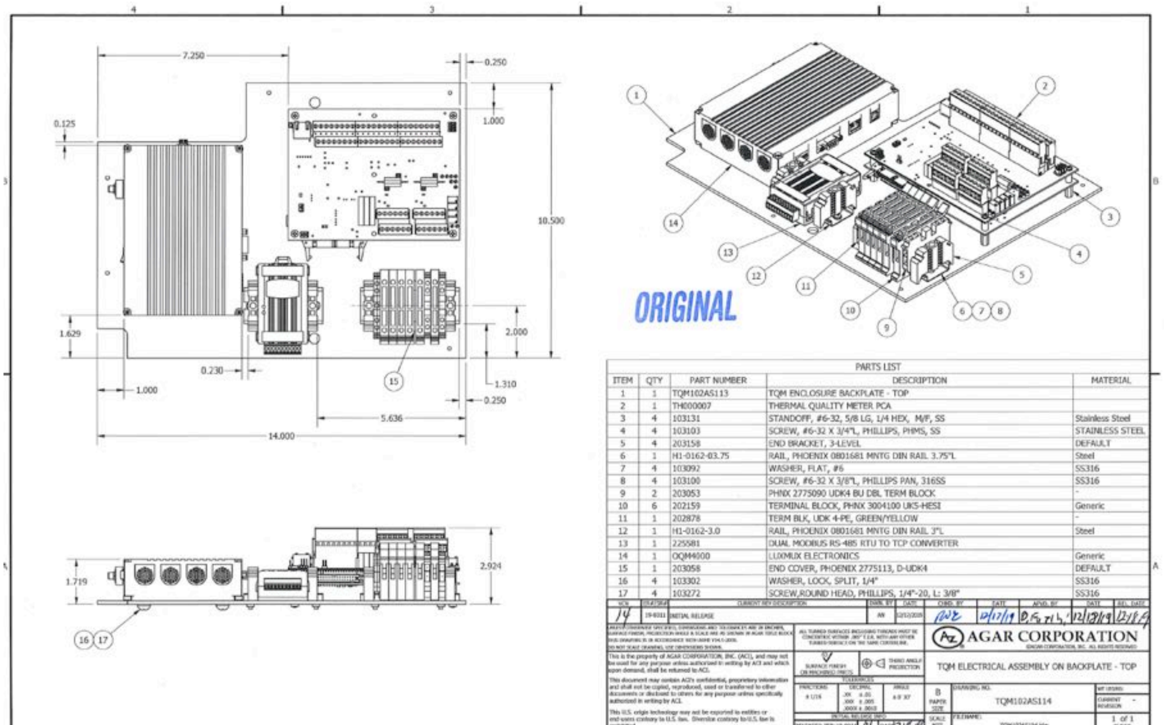
The proposed joint project with Agar Canada Corporation, Luxmux Technology Corporation, and Devon Canada Corporation consist of developing online water measurement analysers that allows upsets in water treatment to be identified in real-time. The analysers consist of measuring oil in water allowing producers to operate more efficiently and at boiler designed specifications. With the combination and variations of multiple technologies offered by Agar, Luxmux and NDT Ultrasonics the online analyser product offerings will deliver significant value added to producers by providing online water measurement, key areas of concern in maintaining optimal boiler efficiency, reducing boiler tube deposition and boiler failure leading to production down time and environmental hazards.

The development process leads us to the better understanding of the oil concentration distribution across the pipeline at different locations at Devon's facility. This activity allowed us to not only to confirm the range but to identify the application based on the oil concentration. During this project a PPM oil in water analyser combining three technologies, fluorescence, NIR and ultrasonic for a complete solution was developed, tested in Agar Houston pilot loops and certified with CSA and CRN. The next step will require to identify a facility where the oil in water analyzer can be used to verify its functionality and potentially improvements on its operation.

Appendix I. CSA Certification

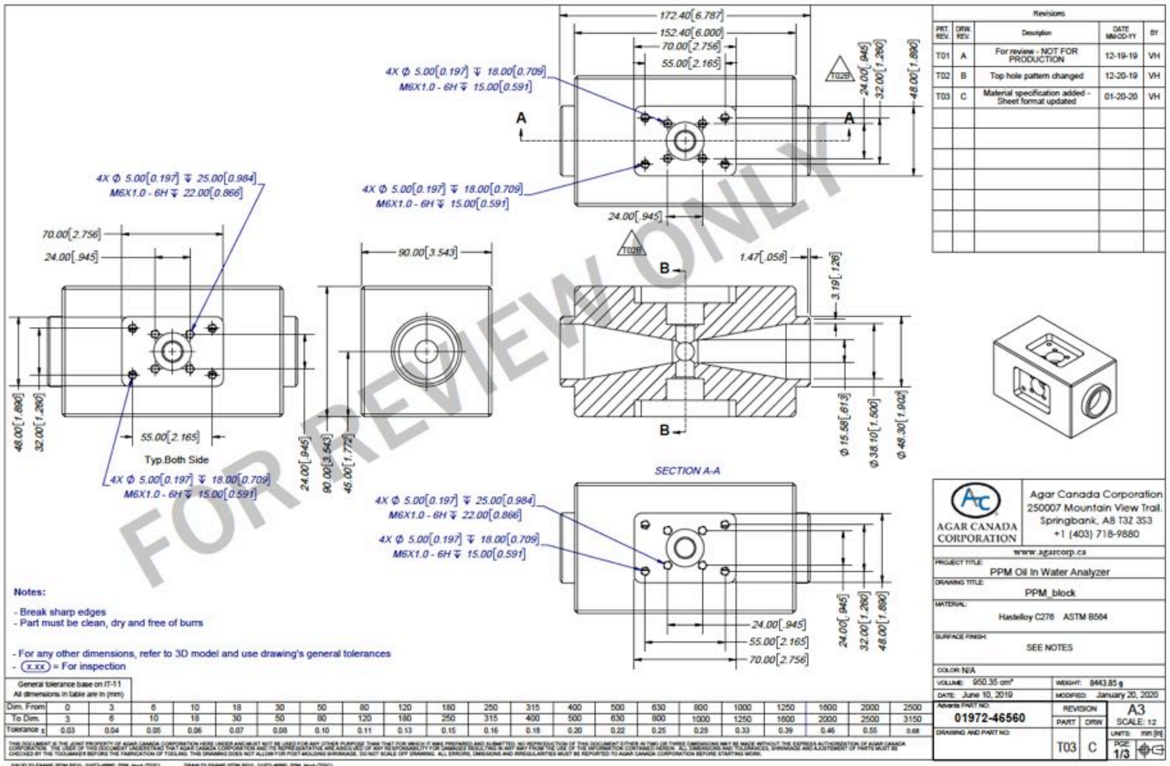
The following drawing shows the ones used for the online oil in water analyzer that was integrated as single equipment with multiple instruments.

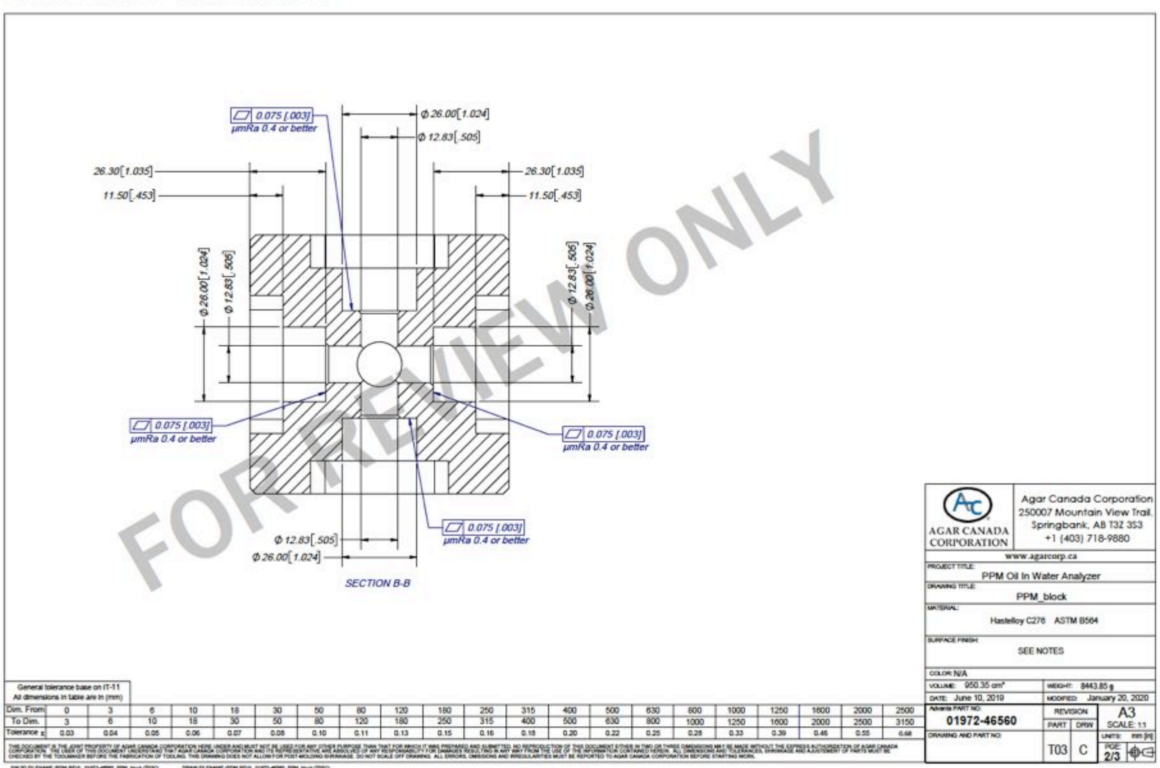


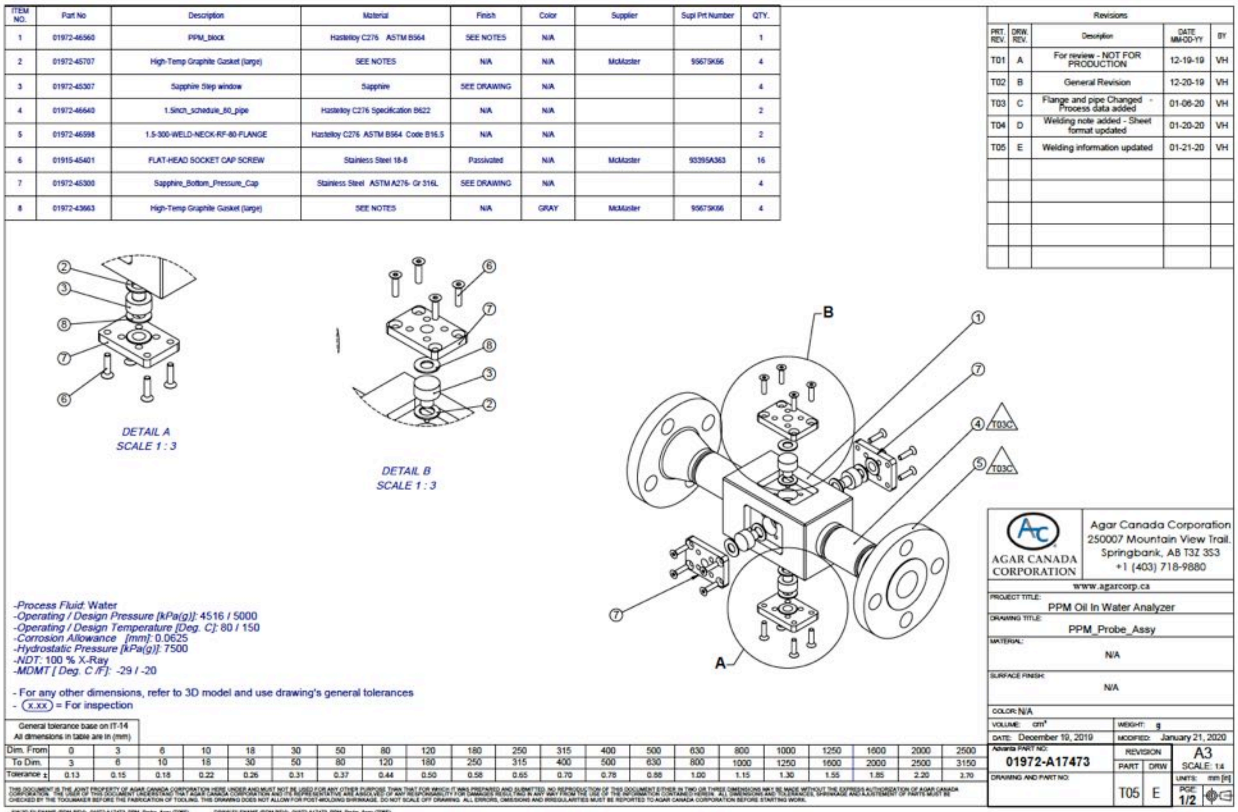


Appendix II. CRN Certification

The following drawing shows the ones used for the online oil in water analyzer related to the CRN certificate with ABSA.






ITEM NO. | Part No | Description | Material | Finish | Color | Supplier | Supl Prt Number | QTY.
1 | 01972-46560 | PPM_block | Hastelloy C276 ASTM B564 | SEE NOTES | N/A | | | 1
2 | 01972-45707 | High-Temp Graphite Gasket (large) | SEE NOTES | N/A | N/A | McMaster | 9567SK66 | 4
3 | 01972-45307 | Sapphire Step window | Sapphire | SEE DRAWING | N/A | | | 4
4 | 01972-46640 | 1.5inch_schedule_80_pipe | Hastelloy C276 Specification B622 | N/A | N/A | | | 2
5 | 01972-46598 | 1.5-300-WELD-NECK-RF-80-FLANGE | Hastelloy C276 ASTM B564 Code B16.5 | N/A | N/A | | | 2
6 | 01915-45401 | FLAT-HEAD SOCKET CAP SCREW | Stainless Steel 18-8 | Passivated | N/A | McMaster | 93395A363 | 16
7 | 01972-45300 | Sapphire_Bottom_Pressure_Cap | Stainless Steel ASTM A276- Gr 316L | SEE DRAWING | N/A | | | 4
8 | 01972-43663 | High-Temp Graphite Gasket (large) | SEE NOTES | N/A | GRAY | McMaster | 9567SK66 | 4
Revisions
T01 A For review - NOT FOR PRODUCTION 12-19-19 VH
T02 B General Revision 12-20-19 VH
T03 C Flange and pipe Changed - Process data added 01-06-20 VH
T04 D Welding note added - Sheet format updated 01-20-20 VH
T05 E Welding information updated 01-21-20 VH
DETAIL A
SCALE 1 : 3
DETAIL B
SCALE 1 : 3
-Process Fluid: Water
-Operating / Design Pressure [kPa(g)]: 4516 / 5000
-Operating / Design Temperature [Deg. C]: 80 / 150
-Corrosion Allowance [mm]: 0.0625
-Hydrostatic Pressure [kPa(g)]: 7500
-NDT: 100 % X-Ray
-MDMT [Deg. C /F]: -29 / -20
- For any other dimensions, refer to 3D model and use drawing's general tolerances
- (X.XX) = For inspection
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Springbank, AB T3Z 3S3
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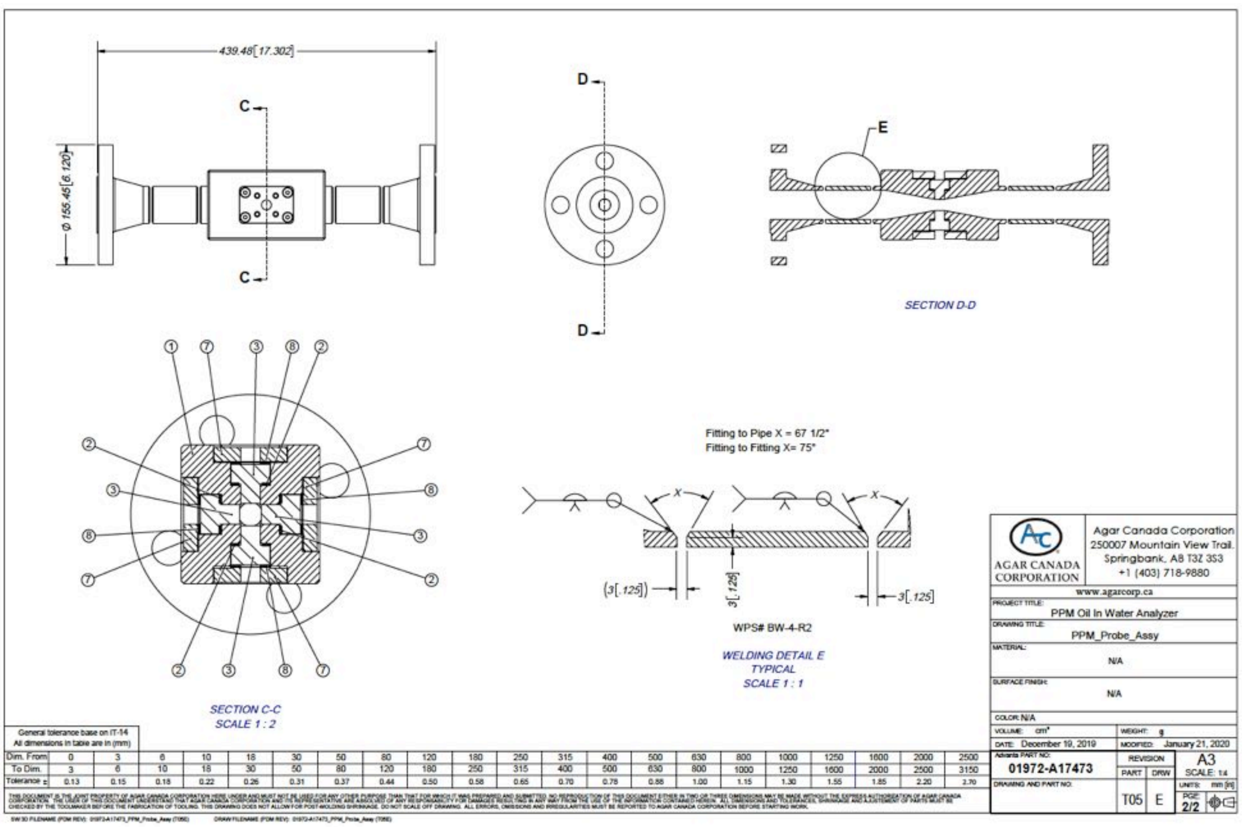
PROJECT TITLE: PPM Oil In Water Analyzer
DRAWING TITLE: PPM_Probe_Assy
MATERIAL: N/A
SURFACE FINISH: N/A
DATE: December 19, 2019
MODIFIED: January 21, 2020
01972-A17473
A3
SCALE: 1:4
T05 E
1/2


439.48[17.302]
Ø 155.45[6.120]
SECTION D-D
SECTION C-C
SCALE 1 : 2
Fitting to Pipe X = 67 1/2°
Fitting to Fitting X= 75°
WPS# BW-4-R2
WELDING DETAIL E
TYPICAL
SCALE 1 : 1
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PROJECT TITLE: PPM Oil In Water Analyzer
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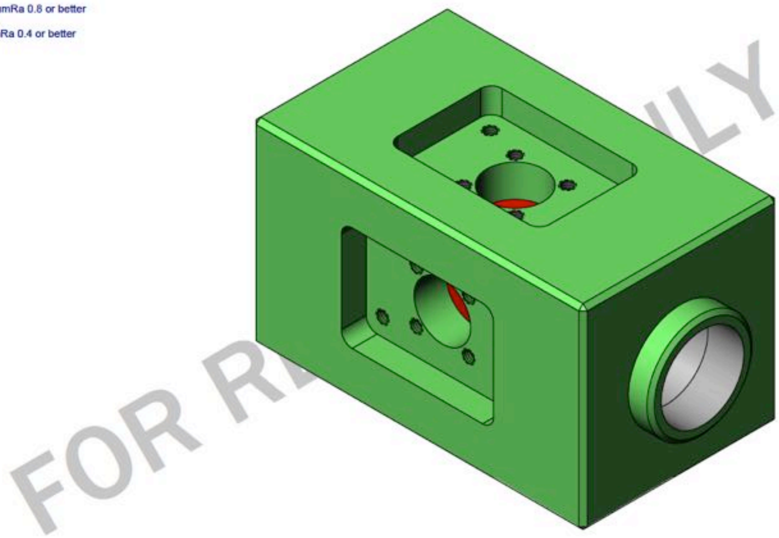
01972-A17473
A3
T05 E
2/2

!! Refer to color document !!

Surface finish:

- Gray faces: µmRa 1.6 or better
- Green faces: µmRa 0.8 or better
- Red faces: µmRa 0.4 or better



General tolerance base on IT-11
All dimensions in table are in (mm)

Dim. From	0	3	6	10	18	30	50	80	120	180	250	315	400	500	630	800	1000	1250	1600	2000	2500
To Dim.	3	6	10	18	30	50	80	120	180	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150
Tolerance ±	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.13	0.15	0.16	0.18	0.20	0.22	0.25	0.28	0.33	0.39	0.46	0.55	0.68

SW3D FILENAME (PDM REV): 01972-46560_PPM_block (T03C) DRAW FILENAME (PDM REV): 01972-46560_PPM_block (T03C)

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PROJECT TITLE:	PPM Oil In Water Analyzer
DRAWING TITLE:	PPM_block
MATERIAL:	Hastelloy C276 ASTM B564
SURFACE FINISH:	SEE NOTES
COLOR:	N/A
VOLUME:	950.35 cm³
WEIGHT:	8443.85 g
DATE:	June 10, 2019
MODIFIED:	January 20, 2020
Advanta PART NO:	01972-46560
REVISION PART:	T03
REVISION DRW:	C
DRAWING AND PART NO:	
A3	SCALE: 1:1
UNITS:	mm [in]
PGE:	3/3