CERIN
Canadian Emissions Reduction Innovation Network

CANADA EMISSIONS REDUCTION INNOVATION NETWORK (CERIN) PUBLIC REPORT

1. PROJECT INFORMATION:

Project Title:	Accurate Methane Emissions Measurement and Quantification from Petroleum Storage Tanks – Computational Model
Emissions Reduction Scope/Description:	Create a computational model of temperature fields in a petroleum storage tank. This model will be used to obtain a computational model of the methane emissions from a petroleum storage tank (not part of this project scope)
Applicant (Organization):	Vitas Consulting Services Inc.
Project Completion Date:	Mar 31, 2023

2. EXECUTIVE SUMMARY:

Currently, there is a need in the Canadian Oil and Gas industry for a broader and more accurate software package to provide an accurate modelling and estimation of methane emissions that could be used by all the industry players to estimate and report methane that is emitted by storage tanks and other Oil and Gas infrastructure. The need for a new modelling software to predict and report methane emissions was outlined by Dr Matthew Johnson from Carleton University and Clearstone Engineering in their study called **"Convective Evaporation Losses From Underground Storage Tanks" (2012).** Here is the recommendation from their study: ***"Based on an improved understanding of the mechanisms contributing to evaporation losses from storage tanks, efforts should be undertaken to develop improved emissions management model for these sources".***

In response to this need, Vitas is proposing to use Computational Fluid Dynamics (CFD) modelling to quantify the emissions and estimate the distribution INSIDE a storage tank. CFD is a computational technology that enables you to study the dynamics of things that flow. CFD software provides the power to simulate flows of gases and liquids, heat and mass transfer, multiphase physics, chemical reaction and fluid structure interaction through computer modeling. Using CFD, Vitas can build a computational model that represents a system or device that we want to study (i.e. petroleum storage tank). Then, Vitas will apply the fluid flow physics and chemistry to this virtual prototype, and the software will output a prediction of the fluid dynamics and related physical phenomena. The main outcomes from the model will be the methane emissions concentration, distribution along the free surface of the fluid inside the tank, pressure and temperature gradients inside the tank.

This project will consist of 2 parts:

Part 1 (current part). Create a temperature model of the product inside an existing storage tank. This part is very important because it will help us to get proof of concept for our modelling – how accurate our temperature model is compared to the real-life data. SAIT is to take temperature measurements in the field for verification. This part to be completed by Mar 31, 2023.

Part 2 (to be completed in future). Create a mathematical model of methane emissions (concentration, vaporization rate, distribution) inside a real-life storage tank. SAIT will be taking methane measurements from outside the tank to verify the model. Temperature data obtained in part 1 will be used as a main input to the emissions model in this part of the project. This part was presented to the CanERIC Industry Committee on June 15, 2023.

3. KEY WORDS

Computer Modelling

Methane Emissions in Storage Tanks

Computational Fluid Dynamics

Fluid and Gas Behavior Simulation

Methane Emissions Modelling

2. APPLICANT INFORMATION:

Applicant (Organization):	Vitas Consulting Services Inc.
Address:	179 Elgin Rise SE, T2Z 4Z6, Calgary, AB
Applicant Representative Name:	Alex Pletnyov
Title:	CEO & President
Applicant Contact Information:	Ph. 403-614-8113, email: info@vitasconsult.com

3. LEAD CONTRIBUTING PARTNER INFORMATION:

Organization:	SAIT, Centre for Energy Research and Clean Unconventional Technology Solutions (CERCUTS)
Address:	CA416, 1301 16 Ave NW, Calgary, Alberta, Canada T2M 0L4
Representative Name:	Dr. Vita Martez
Title:	Former NSERC Industrial Research Chair and Scientific Lead

4. PROJECT PARTNERS

Vitas and SAIT would like to thank Bonavista Energy Corporation for allowing VCS and SAIT to work on their tank. Bonavista provided access to their active site with a produced water storage tank and allowed the project participants to take measurements in the tank. Also, Bonavista provided a lot of valuable information about the storage tank and its operation.

Additionally, project participants would like to acknowledge Brian Van Vliet with Spartan Controls for his support and expertise in completing this project.

A. INTRODUCTION

With the Environment and Climate Change Canada (ECCC) proposed target to reduce the methane emission by 75% by 2030 relative to 2012 levels, it is critical for the industry partners to accurately quantify any fugitive and venting emissions from tanks at sites. Within the Oil & Gas industry, tank emissions evaluations have traditionally been developed using empirical analysis, physical testing and experience-based learning in the field. While these approaches remain important, the rise of simulation-based design, and particularly Computational Fluid Dynamics simulation, offers engineers the opportunity to explore designs and system operation digitally through detailed, accurate prediction of a wide range of physical and chemical behavior. In the development process, computational tools and models play a crucial role. Using mathematical models to simulate fluid and gas behavior in petroleum storage tanks will provide much cheaper, non-invasive solution to measuring and quantifying methane emissions in storage tanks. Currently, the most common software for modelling and reporting methane emissions in storage tanks is EPA TANKS. It provides a very generic approach to methane emissions modelling, and as such, does not provide an accurate estimation of methane emissions. This fact is acknowledged by EPA and they have published the following statement: “Since TANKS uses annual average liquid bulk temperature in the monthly calculations, a change in the temperature for one month will affect every month, in that changing one month changes the annual average. As such, the TANKS program will NOT adequately account for the monthly variations.” For this reason, EPA has stopped supporting the TANKS software and is slowly phasing it out. It is clear that to get an accurate estimation and model of methane emissions in storage tanks, it is critical to account for all temperature effects inside the tank (i.e. thermal convection, tank insulation, product mixing, etc.). Given all the above, there is a need in the Canadian Oil and Gas industry for a broader and more accurate software package to provide an accurate modelling and estimation of methane emissions that could be used by all the industry players to estimate and report methane emitted by storage tanks and other Oil and Gas infrastructure.

Vitas' scientist Fedir Pletnyov has developed a software package for modeling fluid and gas behavior in vertical cylinders (storage tanks) as part of his Ph.D. work at University of Calgary. The current project was proposed by Vitas with the purpose of obtaining a proof of concept for their modelling software. Vitas' modelling software could help to fill the technology gap and respond to the need for an accurate and comprehensive modelling tool, which could be used for methane emissions modelling, storage tank design improvements and optimization, and reporting to the regulator.

B. METHODOLOGY

1. OBJECTIVE.

Ultimate goal is to reduce methane emissions from Canadian Oil and Gas Sector, specifically from storage tanks.

Model -> Quantify -> Reduce

2. APPROACH.

Vitas' approach to creating an accurate model is the following:

- Model and describe all the physical processes that happen inside the storage tanks

- Gain full understanding of what's happening inside the tanks during fill up (i.e. flashing), mixing, pumping, temperature changes, etc.

To create methane emissions estimate and model, Vitas is planning to use one of the existing proven gas oil correlations (i.e. Vasquez Beggs Correlation). Vasquez and Beggs correlation was developed from data obtained from over 600 laboratory pressure volume temperature (PVT) analyses gathered from fields all over the world.

Solution Gas Oil Ratio

$$R_{so} = C_1 \, G p^{C_2} \cdot e^{C_3 \left(\frac{\gamma_o}{T + 460} \right)}$$

Not constant

The most important parameter that is used in this correlation is temperature of the product. Typically, in these calculations, the product temperature is taken as a uniform constant value. Another assumption that is usually made when using this correlation is that fluid inside the storage tanks is stagnant (i.e. not moving), which is not true. In reality, during the cooling process the fluid is constantly moving due to the phenomenon called thermal convection. Therefore, temperature inside the tank is non-uniform. That's where the inaccuracy comes from in other modelling software packages. Vitas has developed a software package that allows to simulate (in 2D and 3D) thermal convection flow patterns, temperature fields (w.r.t. to time) and other temperature effects inside storage tanks. This information can be plugged into the Vasquez Beggs model to obtain the most accurate results for methane emissions.

3. SCOPE OF WORK.

The scope of the project consists of 2 parts:

1) Part 1 (current part). Create a thermal model of the fluid inside a real-life tank (this will serve as a proof of concept for modelling temperature effects inside a tank).

2) Part 2 (to be completed in future). Use temperature data from part 1 in Vasquez Beggs correlation to obtain quantification of vapours (incl. methane) emitted from storage tank.

Due to the limited timelines to complete the project (only 2 months – Feb-Mar 2023), Vitas was only able to finish the first part of the above scope by Mar 31, 2023. The remaining scope will be completed in the following months, subject to receiving appropriate funding.

The scope of part 1 of the project can be broken down into the following activities:

a) Select a suitable tank for modelling that is located in close proximity to Calgary.

Since we are only doing a proof of concept for the thermal model, even a tank with produced water would suffice as long as Vitas can get its geometry specs and other important characteristics.

b) Do a field visit to the selected site. Obtain as much information about the tank as possible (geometry, insulation type, product type, potentially take a product sample, initial temperature of the product, etc.).

c) Create a temperature model of the fluid inside the subject tank based on all the known information (initial fluid temperature, ambient temperature, tank insulation, heaters (yes/no), fill rate and height, etc.).

d) Verify the obtained model is accurate by taking temperature measurements inside and outside the subject tank. This part is to be completed by SAIT.

4. TANK DESCRIPTION AND SPECS.

Client offered to use one of four different sites to run the project. All of the tanks at these sites were produced water storage tanks, which was still sufficient to run the first part of the project (proof of concept for the temperature model).

After visiting 2 of the 4 sites, Vitas has decided to select the tank located at 14-14-XXX-XXW5. Main reasons for choosing this tank were its size (400BBL, largest of all proposed tanks) and proximity to Calgary.

Tank Parameters:

1. Nominal diameter – 12ft (3.66m).
2. Nominal height – 20ft (6.1m).
3. Capacity – 400BBL.
4. Refill frequency – every 12 days.
5. Fill rate 10cm/day.
6. Tied into the flare.
7. 2 heaters near the bottom (max output temperature 160degC)
8. Insulated with foam – 5cm thick.
9. Type of product: production water
10. Main product components: Na, Cl, HCO3, SO4.
11. Max allowable working pressure – 0.25 psi
12. Product temperature coming from separator: 20 degC

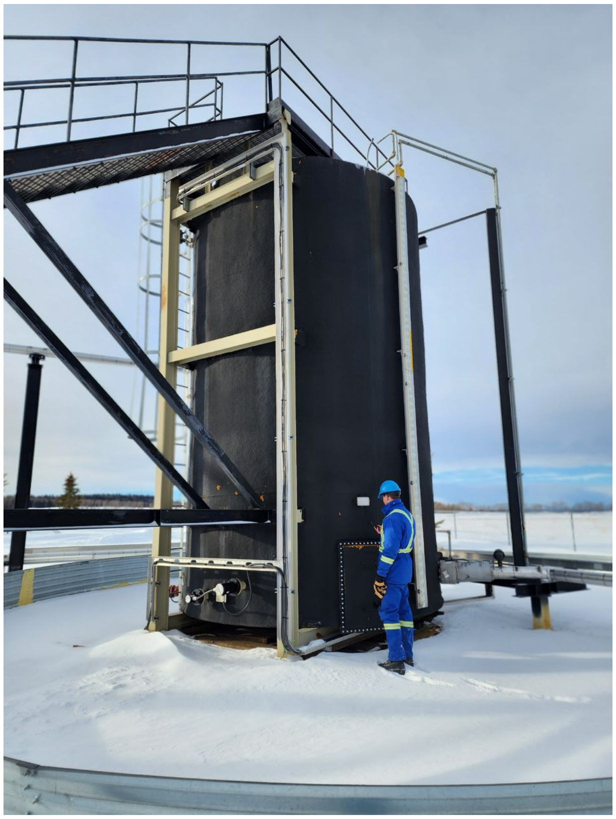


Figure 1: Photo of the subject tank

5. MODELLING.

The focus of the present model will be on tanks, which are typically fixed-roof vertical, cylindrical petroleum containers, holding incompressible Newtonian fluids to different levels with varying aspect ratios, a (= R/H, inside tank radius to height of liquid level above the bottom). Various liquids are of interest but a particular one is petroleum liquid and auxiliary liquids such as production sour water, condensate, and emulsion. Inside a buried tank, liquid within will be heated from the bottom and/or laterally and the heat flux is assumed uniform and steady. At the free surface, evaporation will be occurring but neither the temperature nor the heat flux will necessarily be uniform. The bottom of the tank could either be an insulated surface or it can be exposed to a uniform heat flux. A schematic diagram of the storage tank with various heat fluxes is shown in Figure 2. The tank wall is insulated but there is still some heat exchange with the ambient.

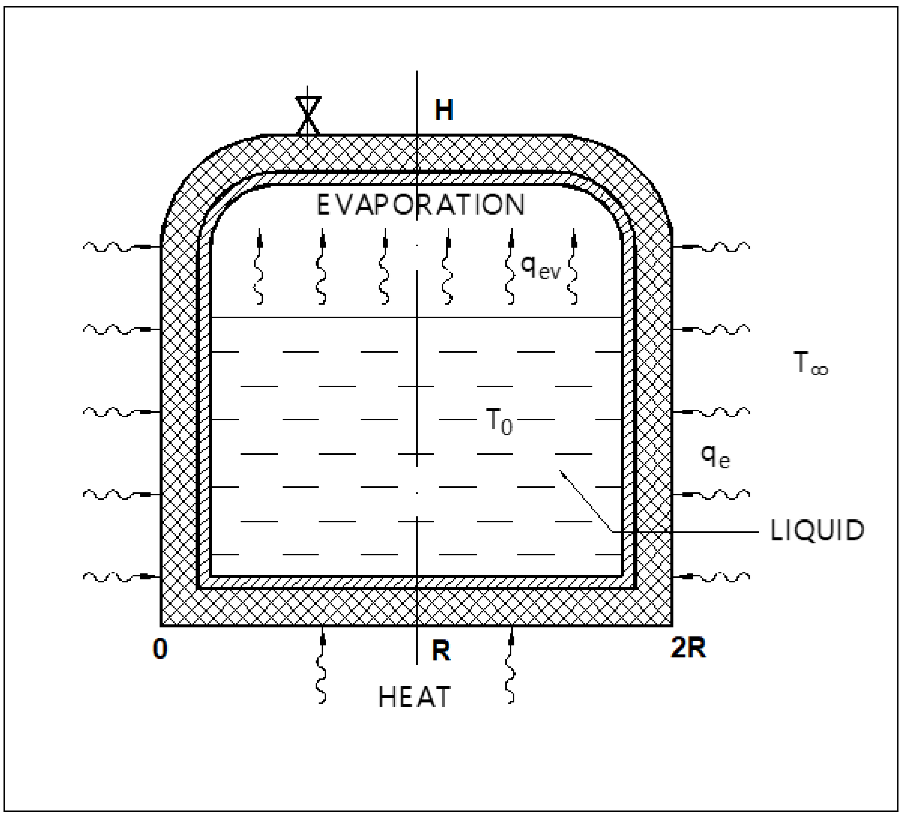


Figure 2: A schematic diagram of the storage tank with various heat fluxes

Freshly charged production sour water has temperature which is assumed uniform at (the temperature ~ +20ºC). The ambient temperature is varied but in the worst case scenario it is assumed to be equal to $T_{amb} = -20^o C$

The insulation thickness is from 0 to 5 cm. Initially, the liquid is assumed to be stationary. As heat exits out of the tank, the liquid would cool down and temperature gradients would develop within it. Heavier liquid will be at the top and lower density liquid at the bottom. The system is hydrodynamically unstable and convection currents will be spontaneously initiated when temperature gradients exceed some critical value. Any evaporation at the free surface contributes to local cooling and may enhance both thermal and concentration gradients before convective motion is initiated.

The scope of this study is to model the flow patterns of the liquid inside the storage tank, calculate the temperature field, and estimate the rates of heat accumulation in and transfer through the liquid to support continuous evaporation. The problem will be simulated using the 2-D and, later, 3-D formulations. 3-D solutions are computationally more expensive and 2-D simulation may be adequate for present conditions.

In this regard industry can calculate potential emissions off of their petroleum tanks.

The prevailing assumptions for the analysis are that:

- the fluid is incompressible and Newtonian.
- the flow is laminar.
- the physical properties of the liquid are constant, with the exception of density in buoyancy effects, as invoked in the Boussinesq approximation (it takes into account the vertical structure of the horizontal and vertical flow velocity).
- viscous dissipation of energy is negligible.
- contributions of radiation to heat transfer are small; and
- the level of the liquid is effectively constant (note, this is not a huge sensitivity item).

The last condition is a pseudo-steady assumption that may need to be relaxed if the liquid resides in the tank for long settling times without any new supply. In this report, the focus is on petroleum and other process fluids.

The governing vorticity and energy transport equations were solved by Alternating Direction Implicit method (using parallel technique) and Poisson Equation using Fast Fourier Transform (FFT) method.

This problem was programmed in C# using parallel computing techniques. Results were visualized in MATLAB. Results with visuals and their analysis are presented in Section C of this report.

C. PROJECT RESULTS AND KEY LEARNINGS

In order to obtain a better understanding of all the processes inside the storage tank, Vitas looked at a few different cases of thermal convection in the tank:

1) 2D case with natural convection.

2) 2D case with pure heat conduction (no natural convection, liquid is not moving).

3) Base case – so called lump-parameter modelling (simplified case).

4) 2D case with heater added to the model (real-life scenario)

To simplify the problem, it was assumed that ambient temperature was -20degC and no heaters were applied at the bottom of the tank. However, when temperature measurements were taken by SAIT, the ambient temperature was +1degC and 2 heaters were running at full power. This case was modelled separately (case #4).

1) 2D case with natural convection. Figures 3-10 below describe evolution of the cooling process of the fluid inside the tank for the duration of 5 days. Figure 9 summarizes how much the fluid temperature will drop after 5 days at different ambient temperatures (10 degC, 5 degC, 0 degC, -10 degC, -20 degC). Obviously, the lower the ambient temperature is, the cooler the fluid will get after 5 days. After the initial volatile period when fluid temperature is fluctuating, we are observing temperature stratification by layers with respect to height. Interesting observation is that the coolest zone shall be at the bottom of the tank: after 3 days (see Figure 6) we are noticing that the bottom of the tank starts to freeze up. In Figure 9, average bulk temperature is used, and we can see that it only starts to freeze up after 5 days.

An important conclusion here is that this fact confirms that bulk (average product) temperature cannot be used for estimating fluid freezing or evaporation processes. That's why EPA Tanks software wasn't providing accurate estimations.

In wintertime, to prevent fluid from freezing, two solutions are possible to be used: 1) increase insulation thickness at the bottom of the tank, 2) install heaters to warm up the fluid. In our case, heaters are used.

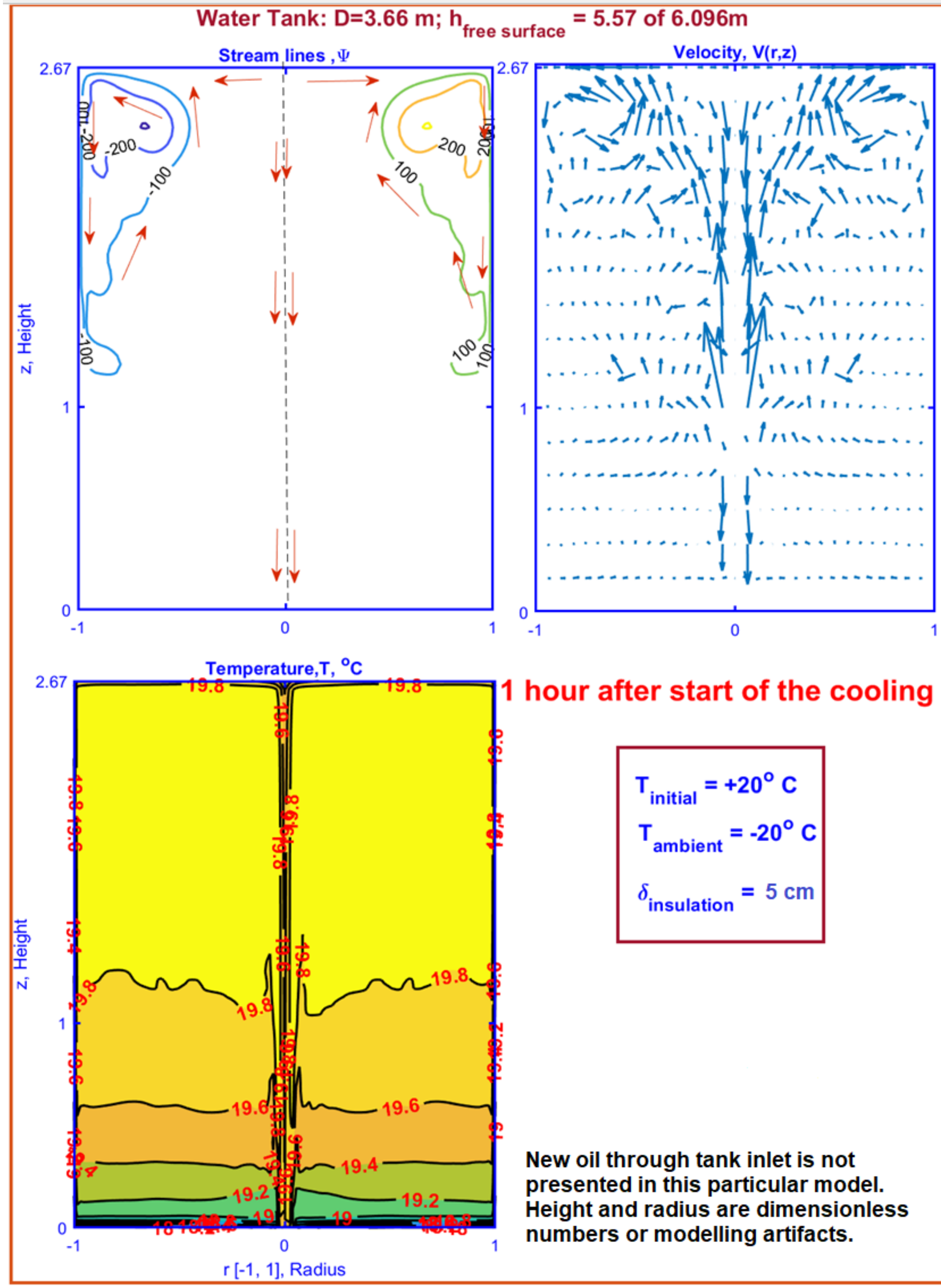


Figure 3: (1) 2D case of natural convection 1 hour after adding product into the tank.

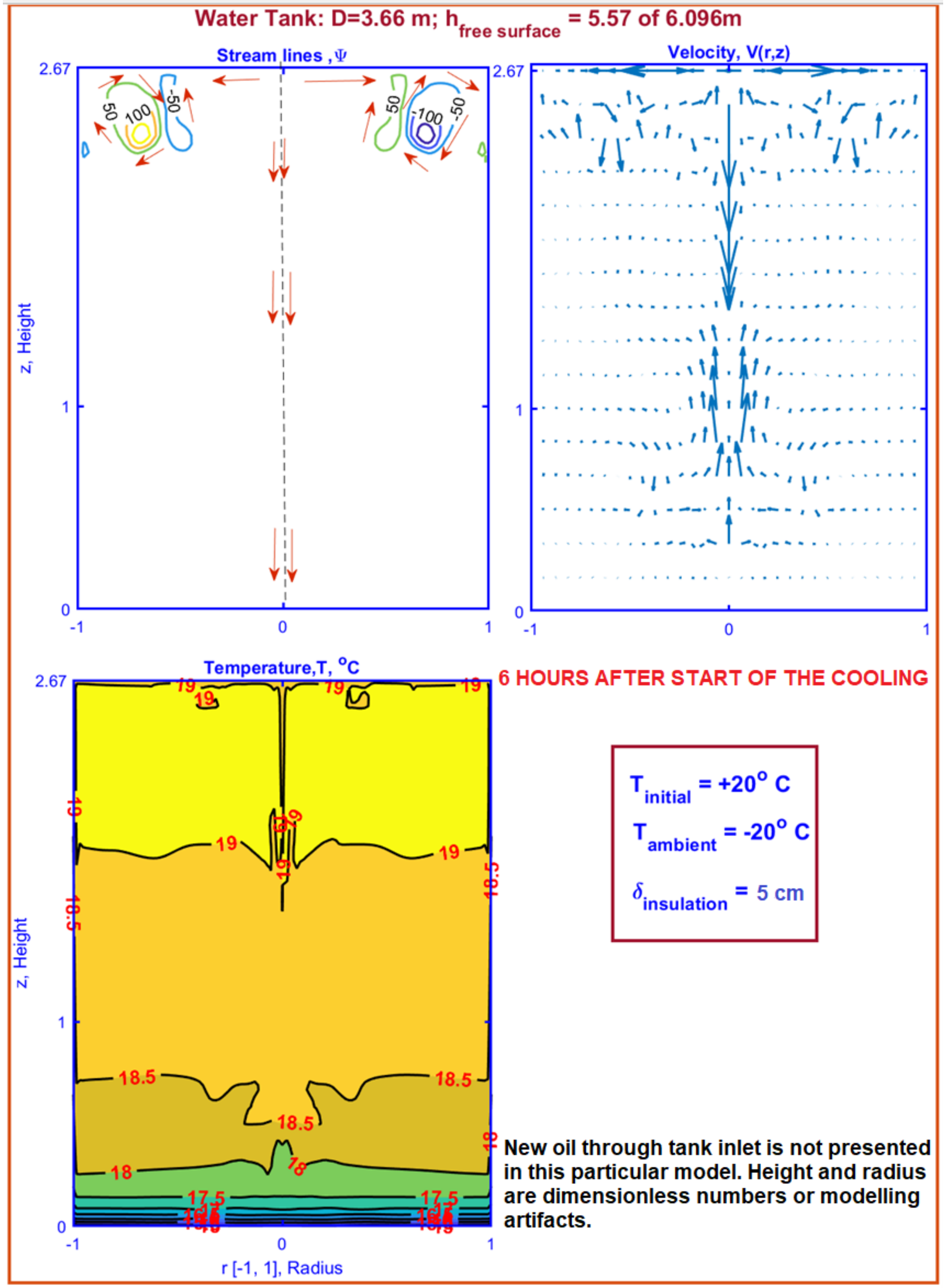


Figure 4: (1) 2D case of natural convection 6 hours after adding product into the tank.

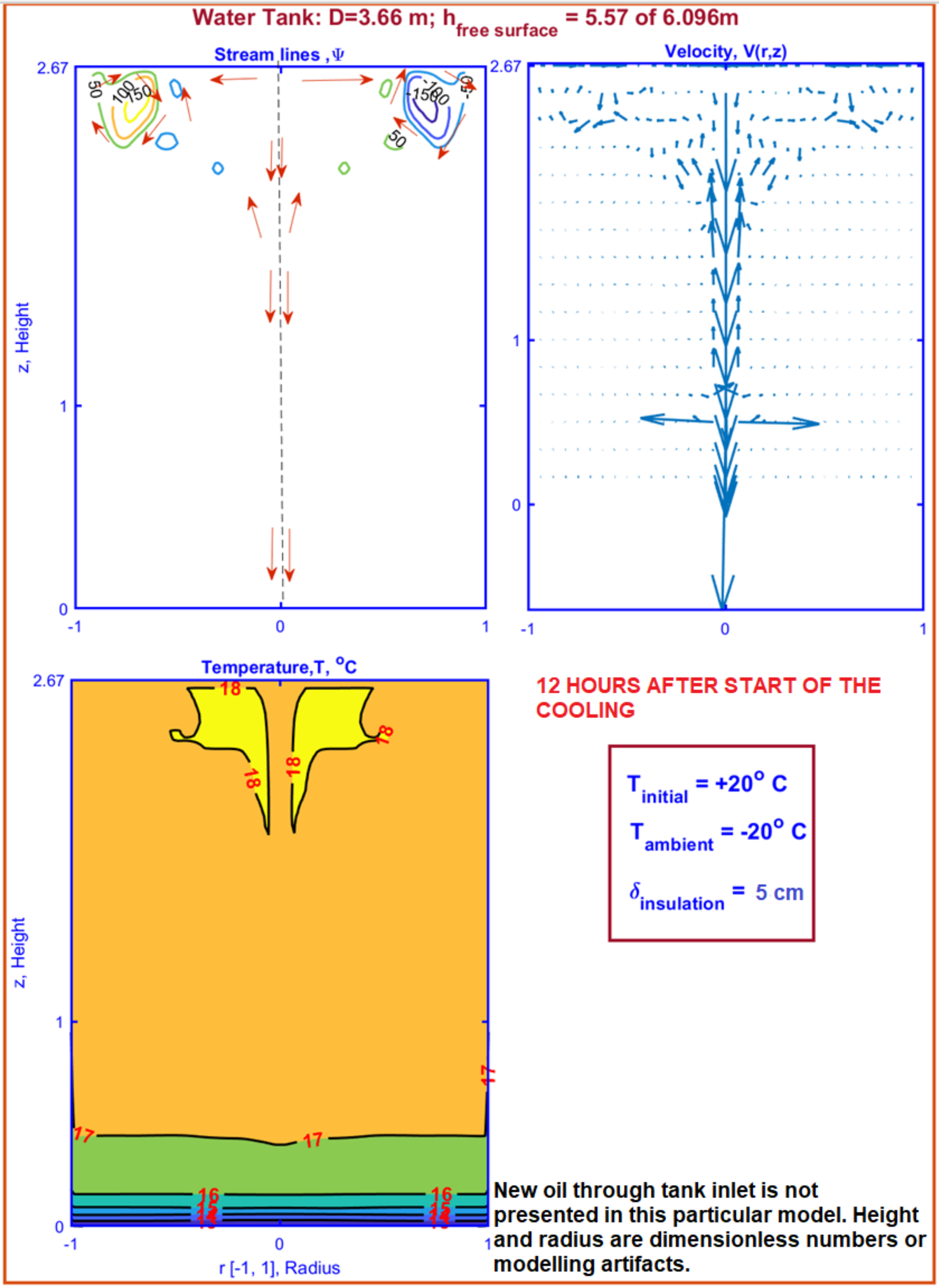


Figure 5: (1) 2D case of natural convection 12 hours after adding product into the tank.

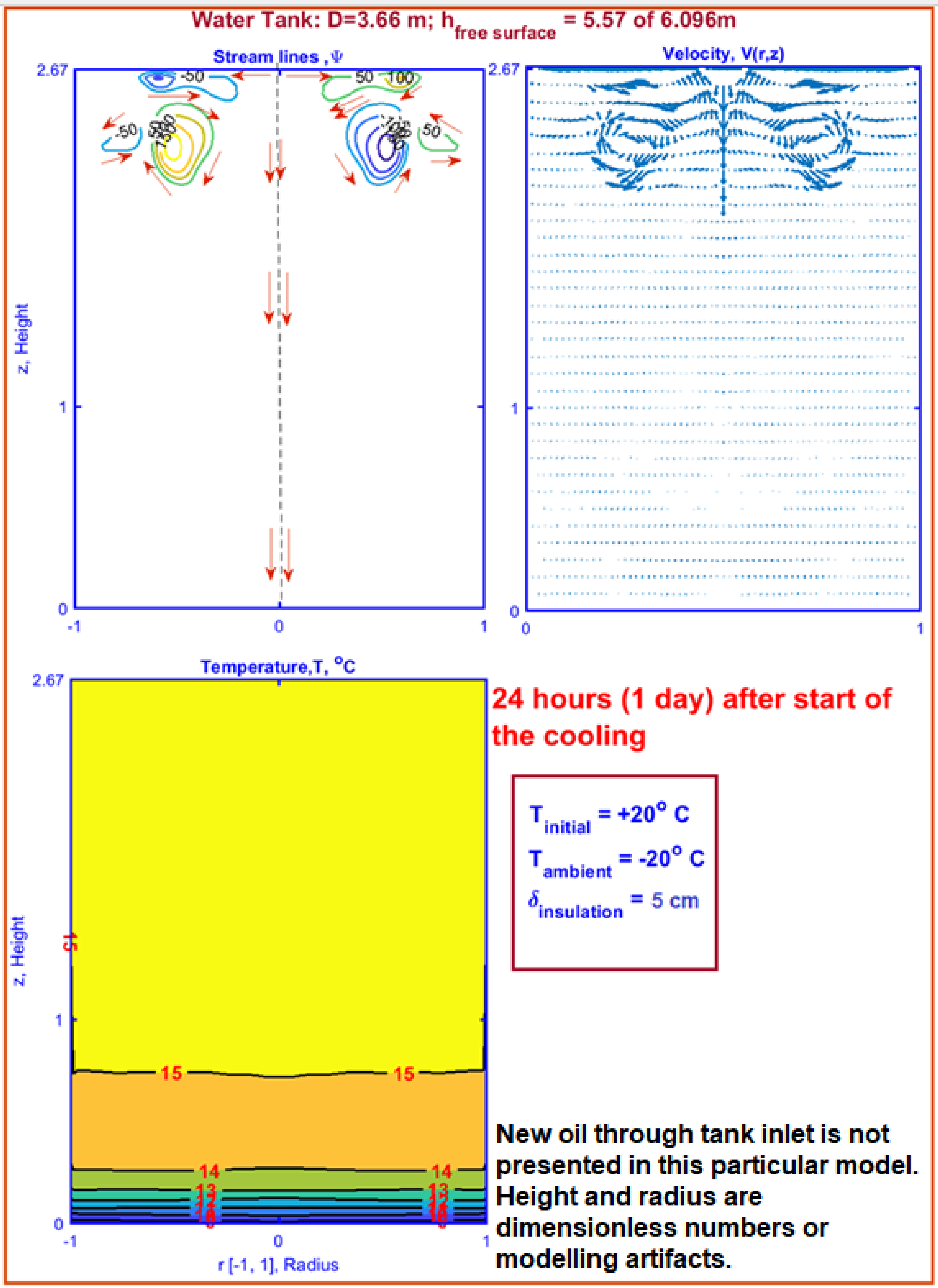


Figure 6: (1) 2D case of natural convection 24 hours after adding product into the tank.

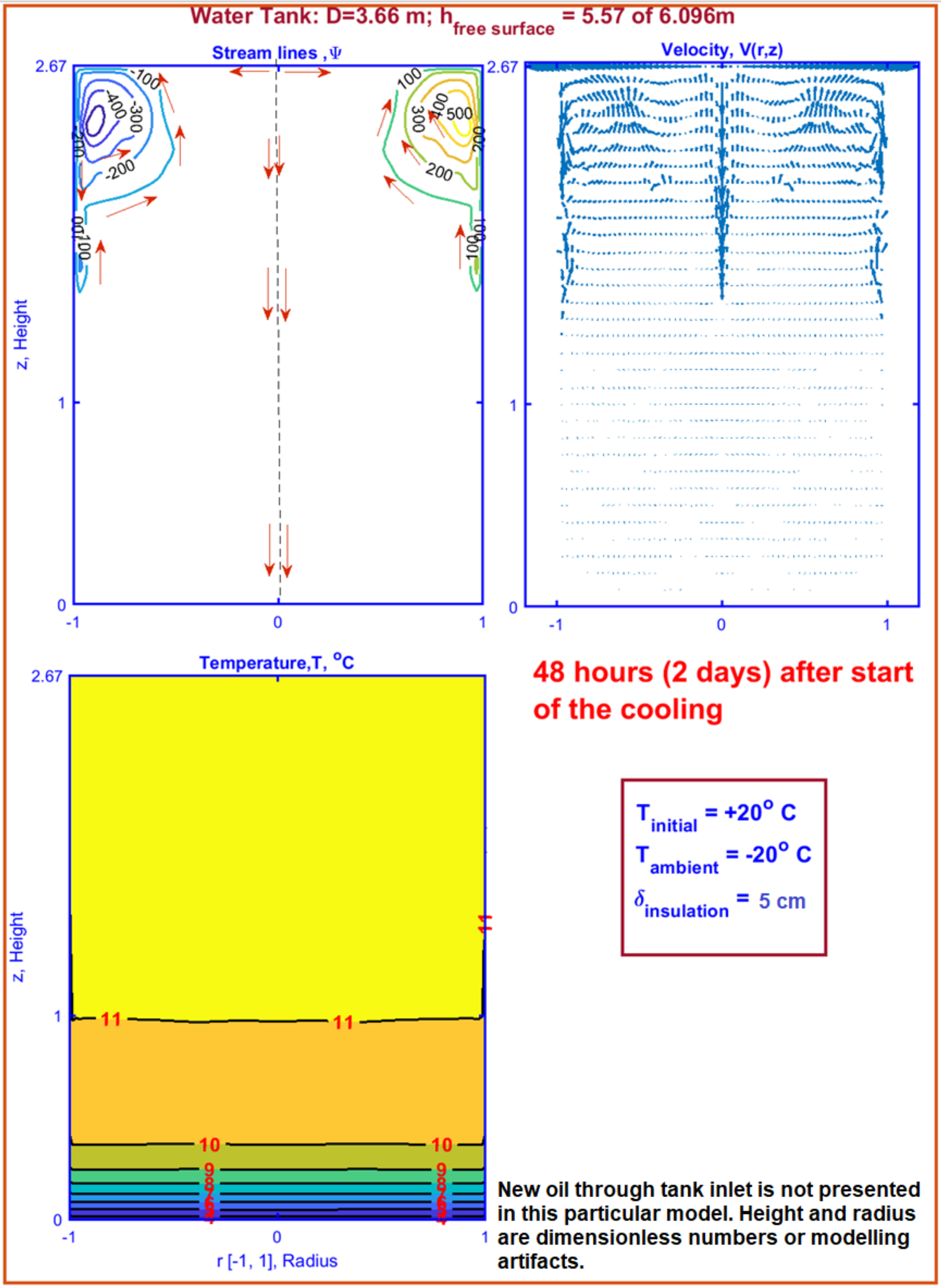


Figure 7: (1) 2D case of natural convection 48 hours after adding product into the tank.

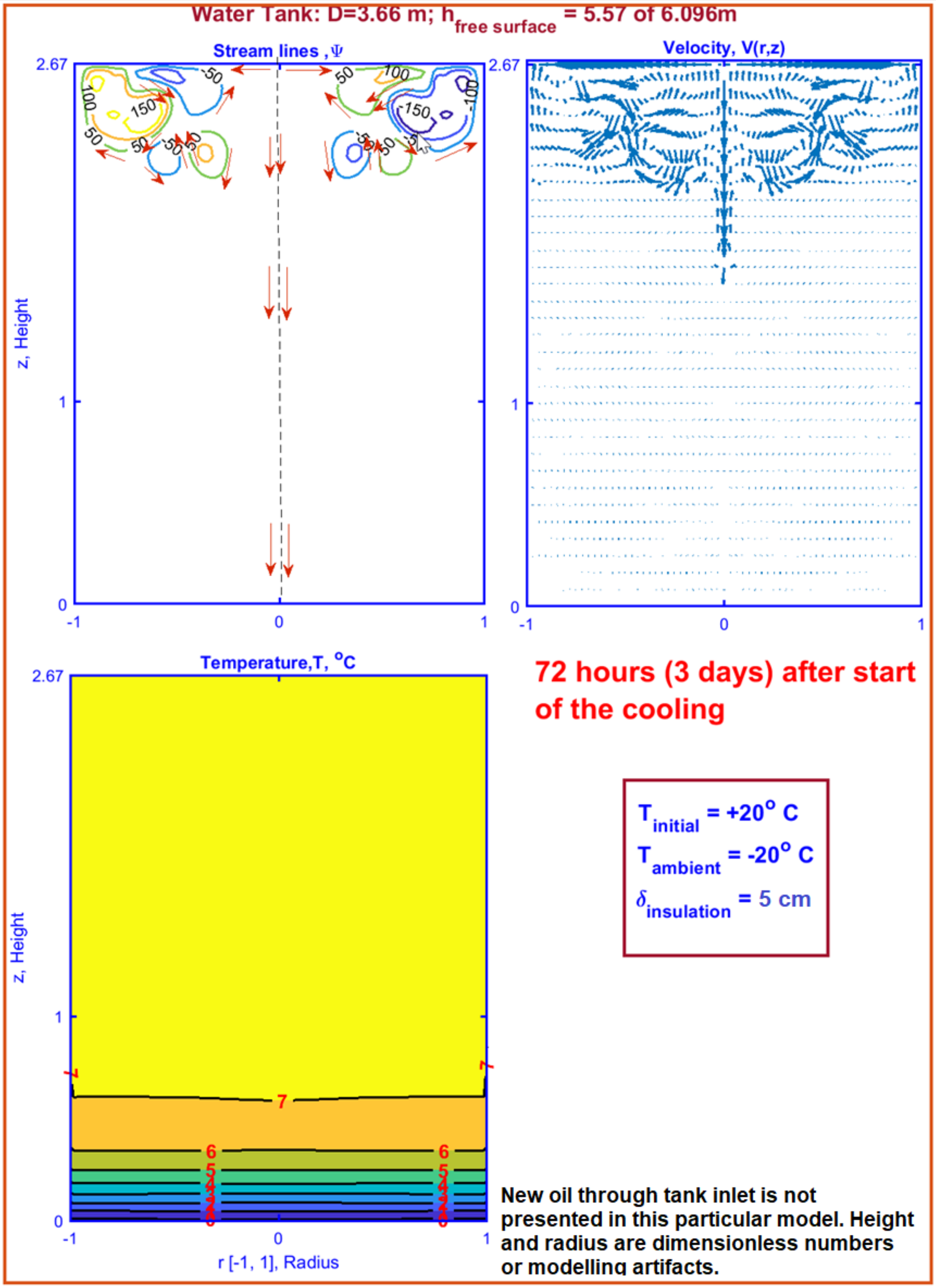


Figure 8: (1) 2D case of natural convection 72 hours after adding product into the tank.

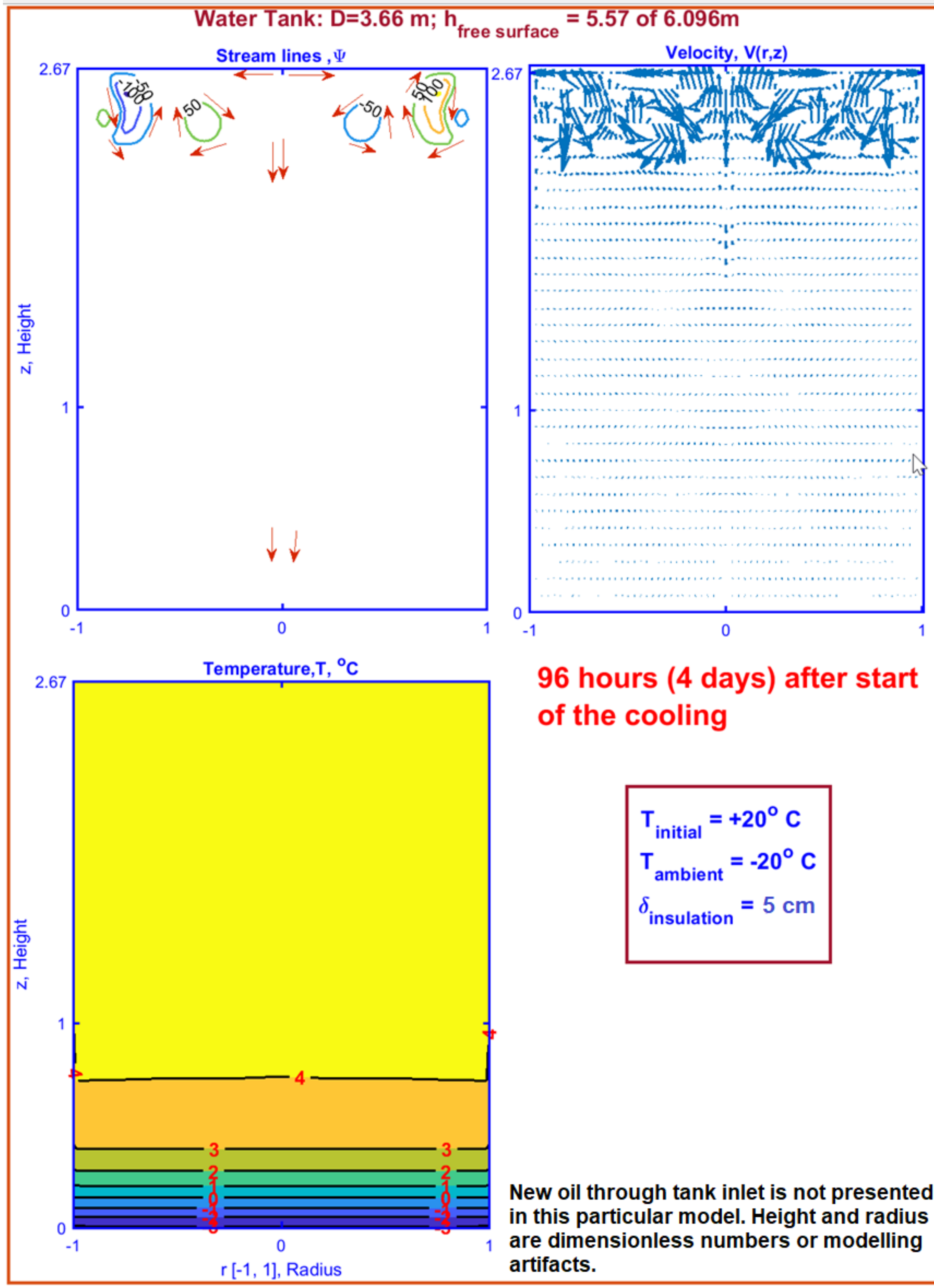


Figure 9: (1) 2D case of natural convection 96 hours after adding product into the tank.

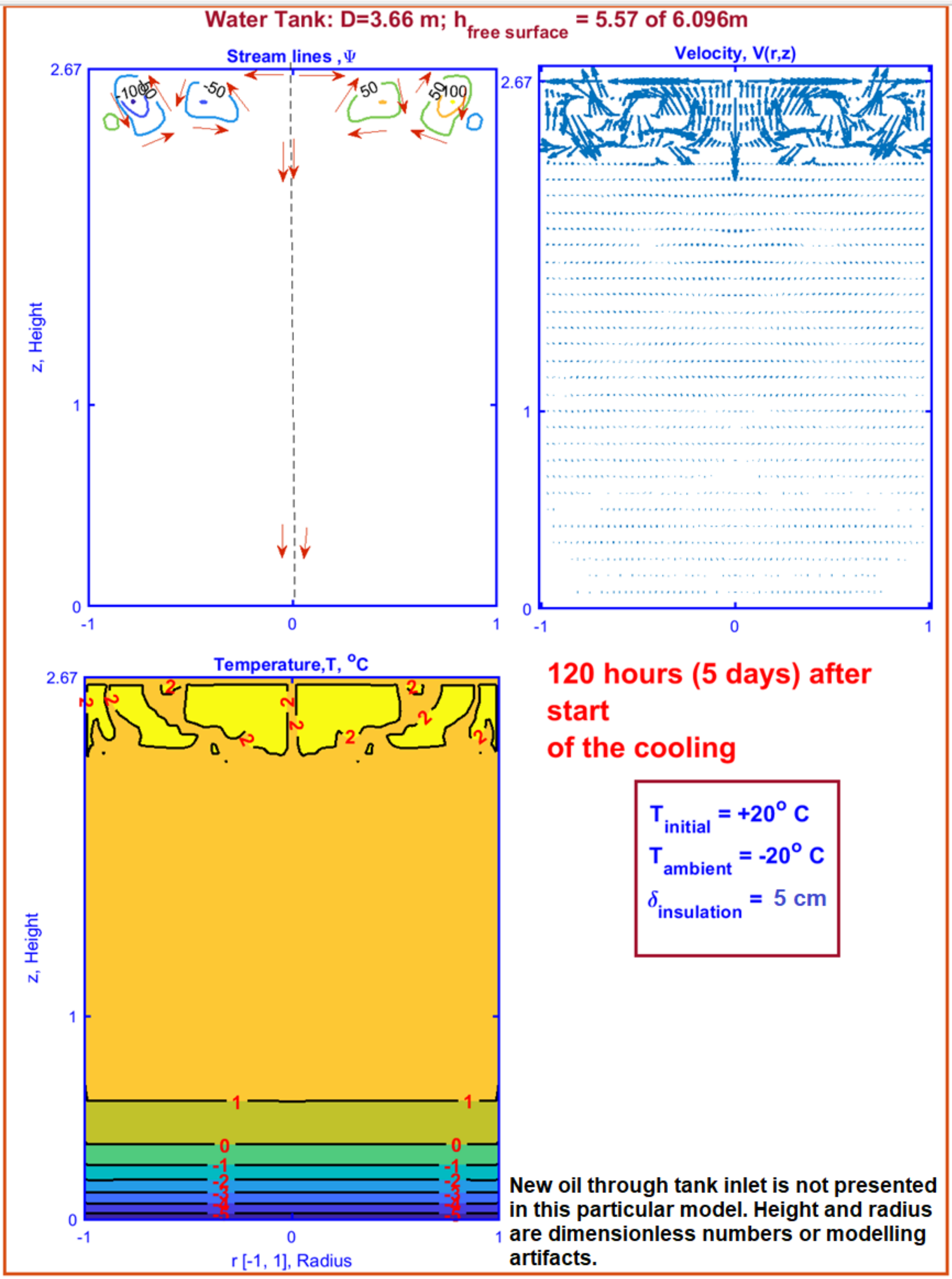


Figure 10: (1) 2D case of natural convection 120 hours after adding product into the tank.

Ambient Temperature Influence on Unheated 400BBL Tank

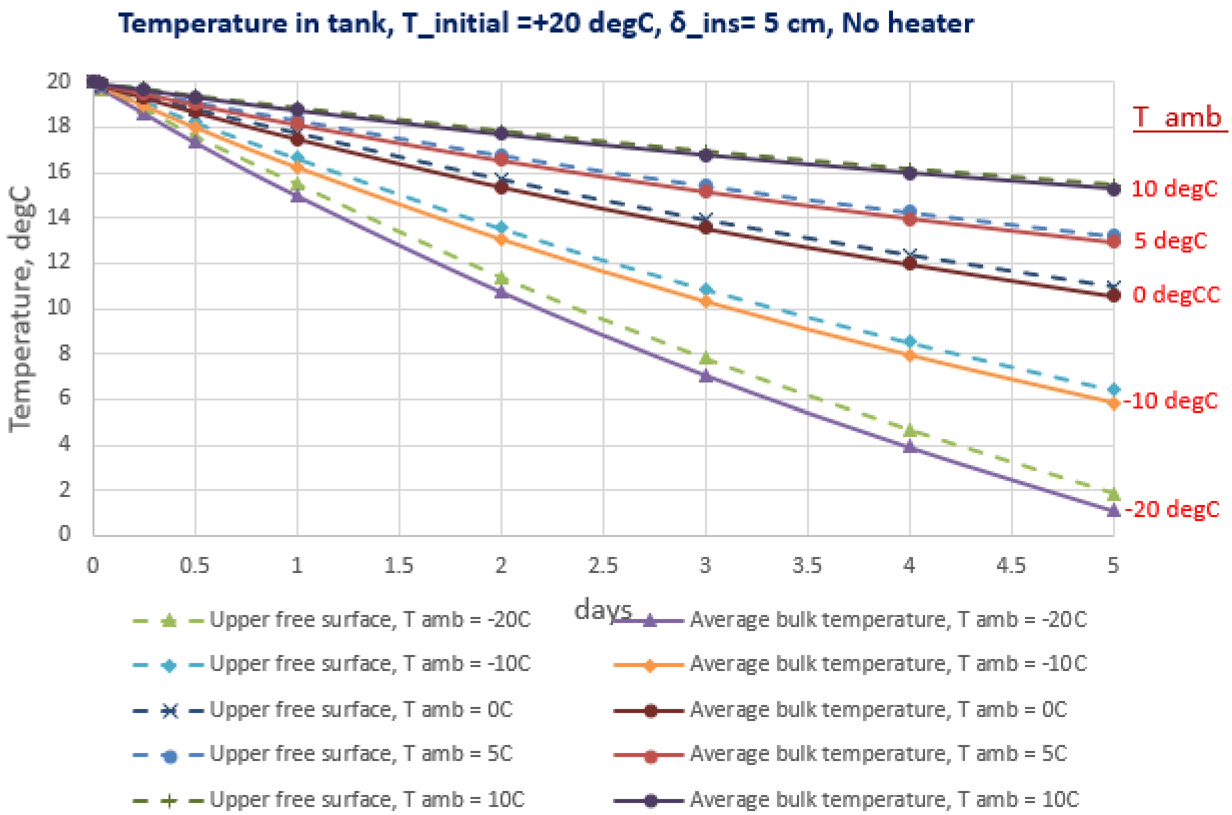


Figure 11: Summary of the cooling process of the fluid for the duration of 5 days at 5 ambient temperatures (10 degC, 5 degC, 0 degC, -10 degC, -20 degC (2D case of natural convection)).

2) 2D case with pure heat conduction (no natural convection, liquid is not moving). Now, it is interesting to compare the effect of natural convection vs pure conduction of the fluid (no natural convection, fluid is not moving). It can be seen that fluid starts to freeze up uniformly around the walls (side, top and bottom) of the tank after 2 days of cooling, which proves that this model does not fully represent all of the thermal processes inside the tank. This model would be used by EPA Tanks software and once again shows that it is inaccurate.

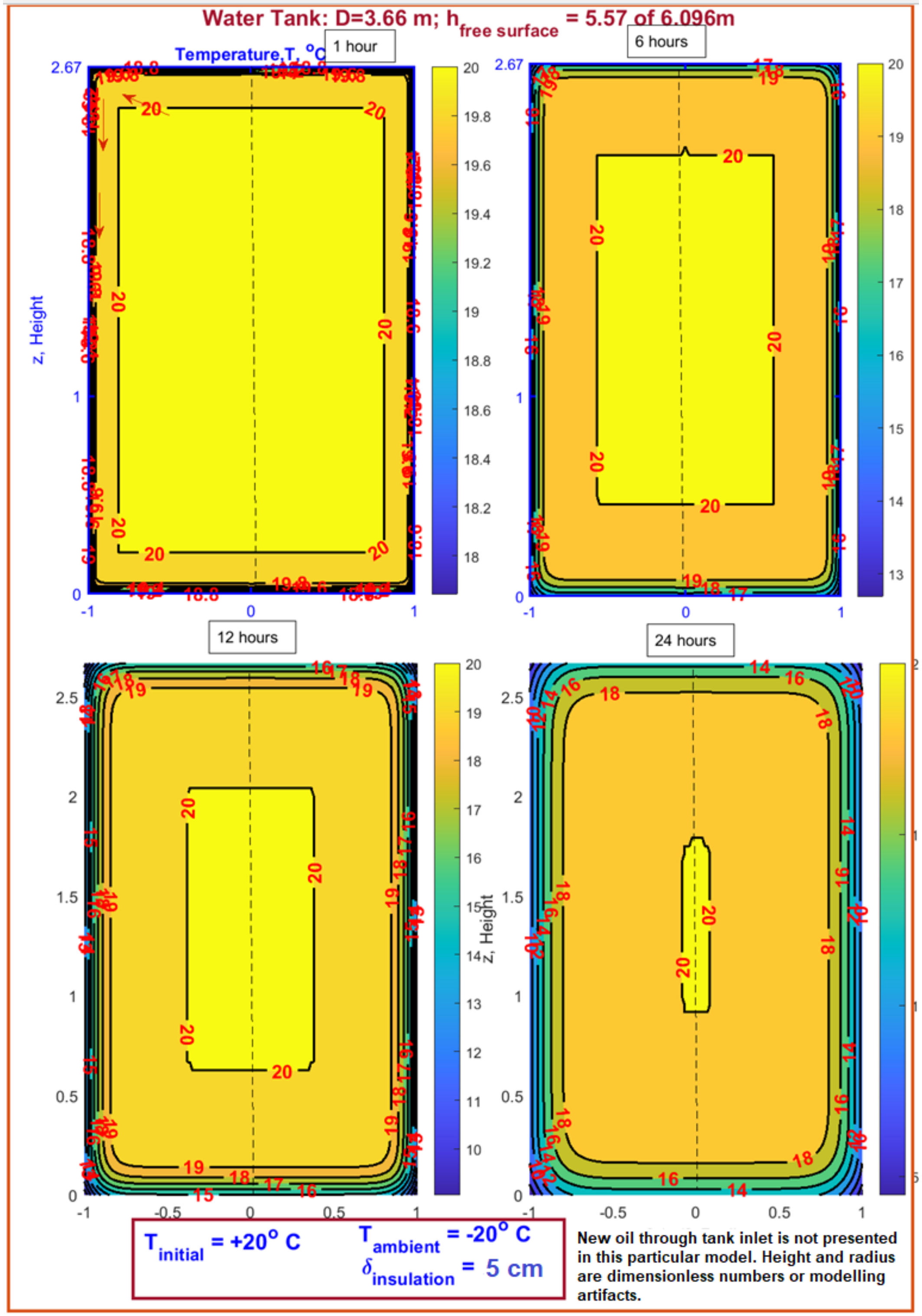


Figure 12: (2) 2D case of pure conduction 1h, 6h, 12h and 24h after adding product into the tank.

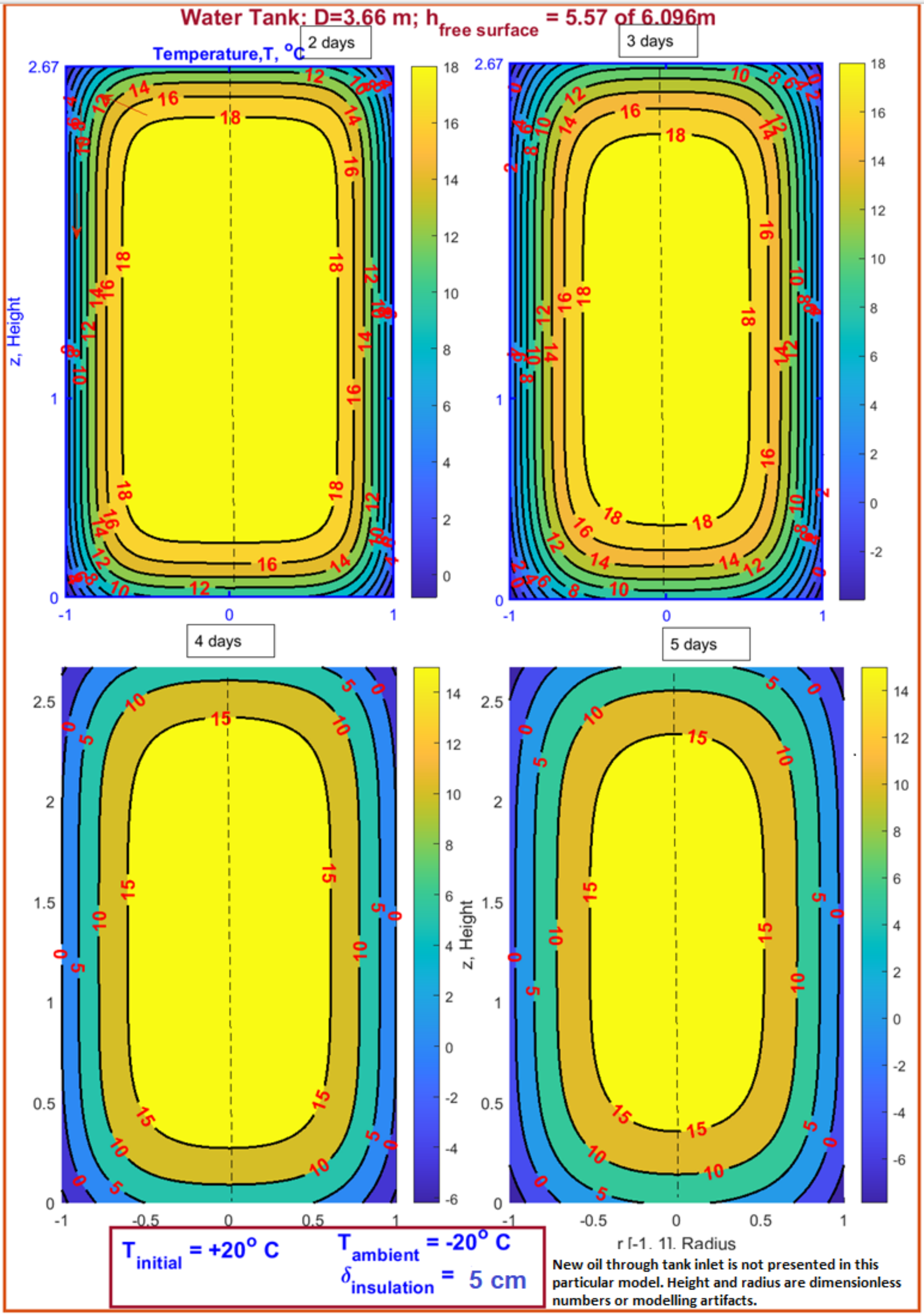


Figure 13: (2) 2D case of pure conduction 2, 3, 4 and 5 days after adding product into the tank.

3) Base case – so called lump-parameter modelling (simplified case).

This approach was investigated because this is the typical technique that is used by engineers in the Oil and Gas Industry. It is the simplest model, and it can be seen from Figures 14-16 that the cooling process with this approach is much slower than that with natural convection.

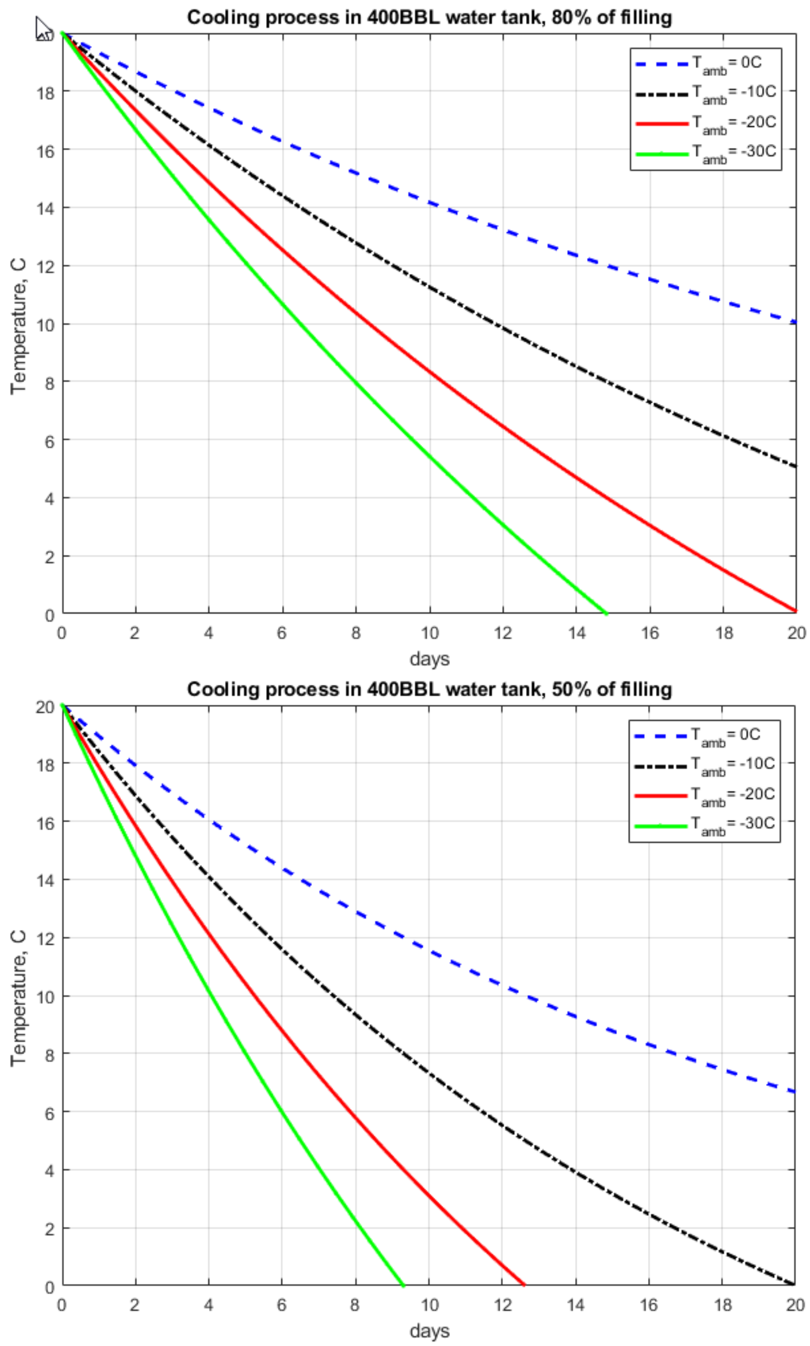


Figure 14: (3) Base case for insulation thickness of 5cm – 80% vs 50% fill ratio.

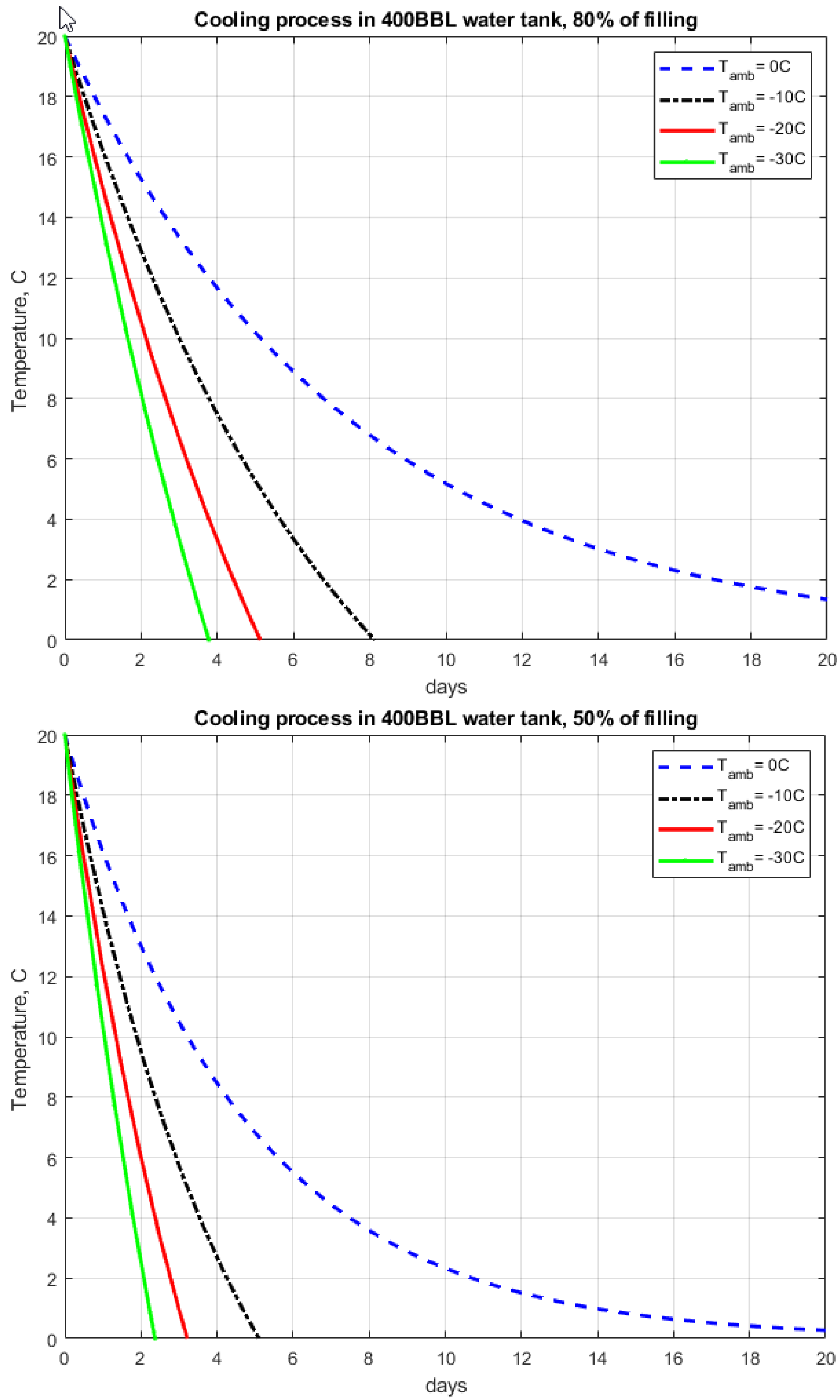


Figure 15: (3) Base case for insulation thickness of 1cm – 80% vs 50% fill ratio.

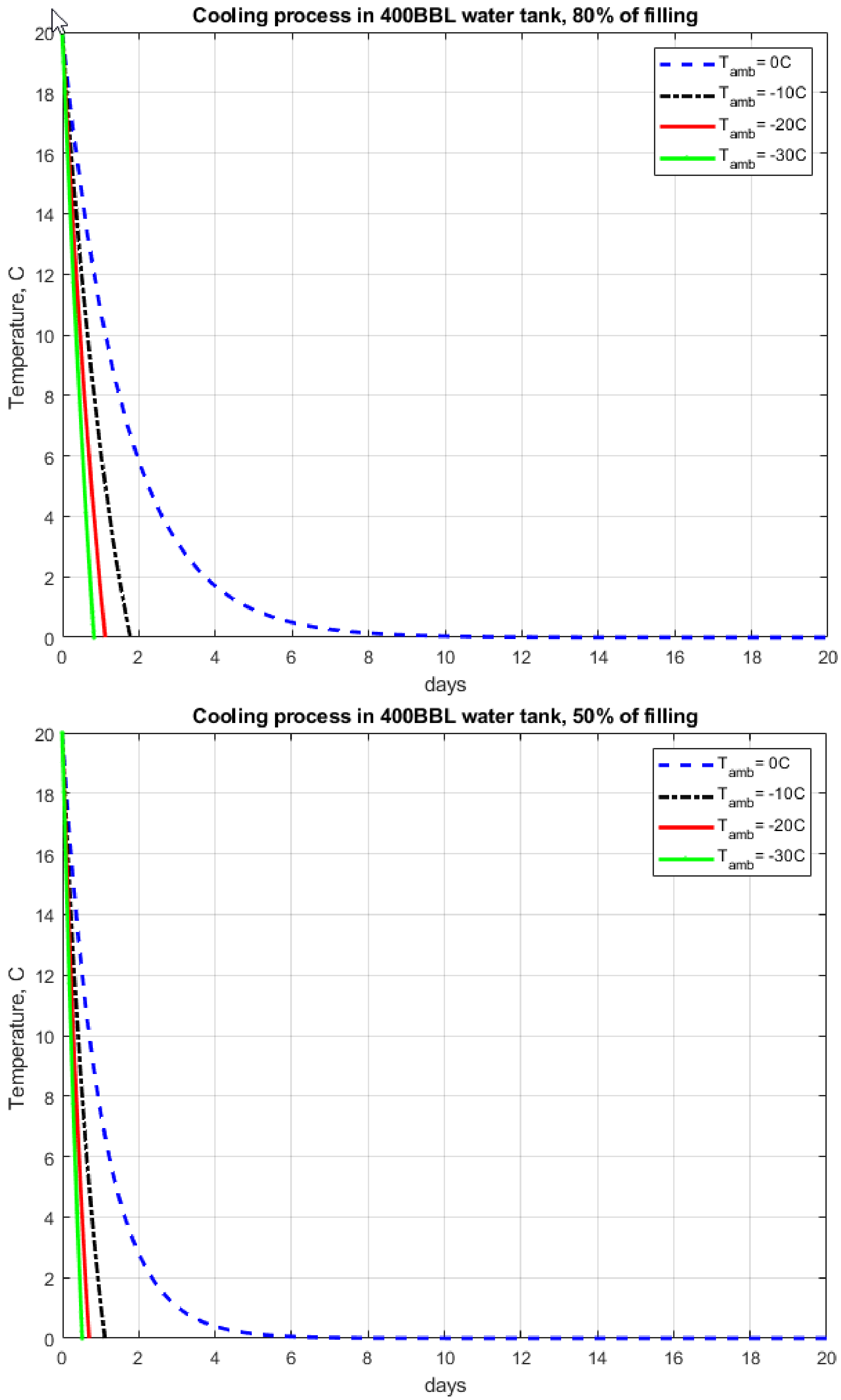


Figure 16: (3) Base case for insulation thickness of 0cm – 80% vs 50% fill ratio.

4. HEATER ADDED TO THE MODEL.

Now, let’s look at the cases when heater(s) is added to the model. Figure 17 shows the case when the heater is set to 5 degC and ambient temperature is -20degC for an infinite period of time. It can be seen that after a certain amount of time (exact time was not calculated as it is a very time-consuming process), the fluid will start to freeze up on top of the tank (in the center).

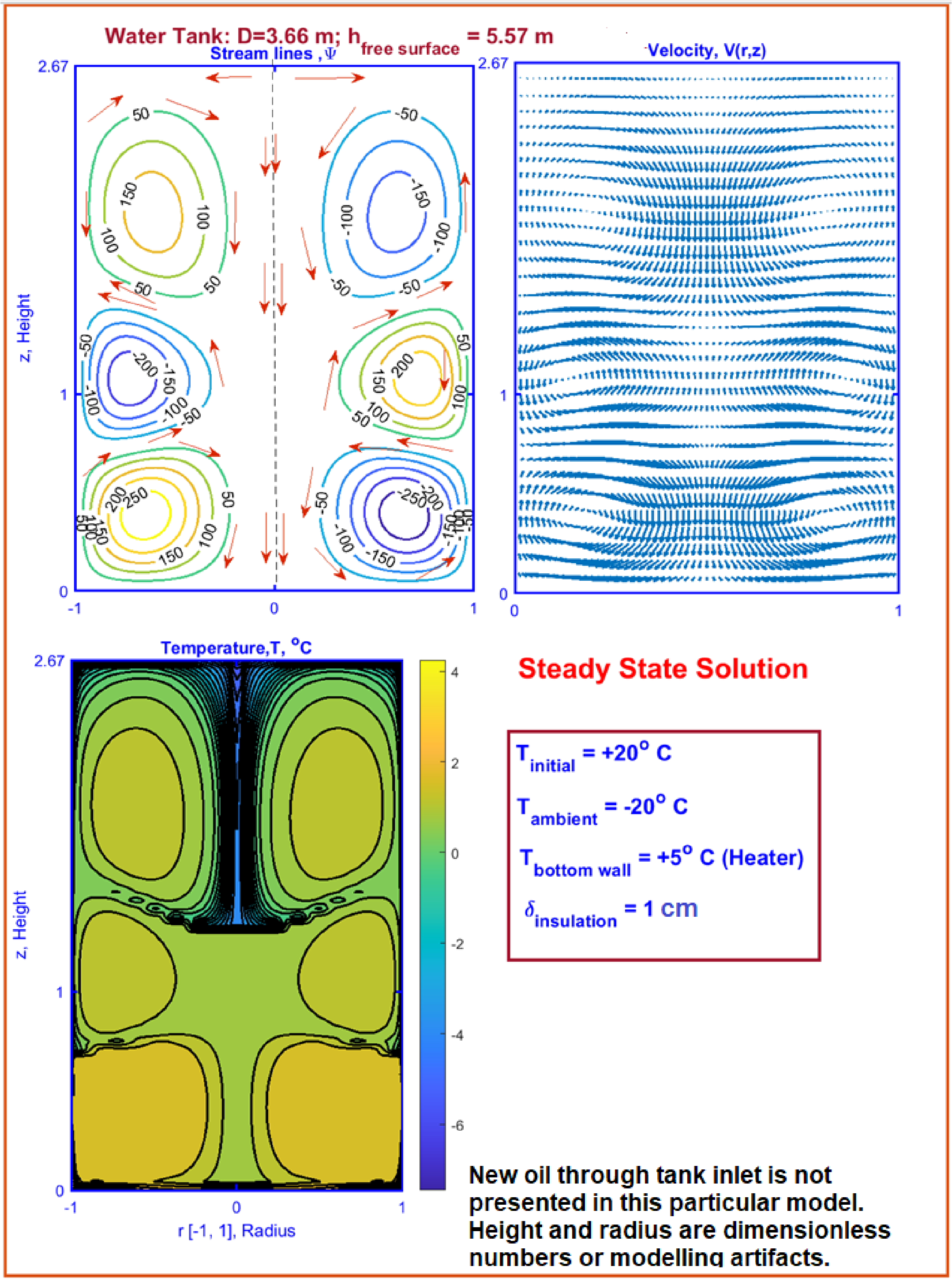


Figure 17: (4) Heater added at +5degC, ambient temperature = - 20degC

To simulate such a strong convection Vitas had to use very fine grid size (512 x 512 cells) and very sophisticated finite difference schemes (monotonic conservative).

4) RESULTS VERIFICATION FOR MODEL 4 (REAL-LIFE SCENARIO WITH ADDED HEATERS)

Finally, to verify the results, Vitas and SAIT travelled to site and took some temperature measurements inside and outside the tank. Inside the tank, measurements were taken by lowering a temperature probe into one of the pipes on top of the tank (Figure 18).

Figure 18: Temperature measurements taken inside the tank.

The temperature probe was 3.5m long. Based on the info provided by the client, the fluid level on that day was approximately 2.5m. Tank height is 6.06m. Given all this info, we can conclude that measurements were taken slightly above the fluid level (appr. 20cm), but the probe was not submerged into the water. On the outside of the tank, measurements were taken using infrared thermometer (temperature gun) at 3 different heights on 4 sides of the tank.

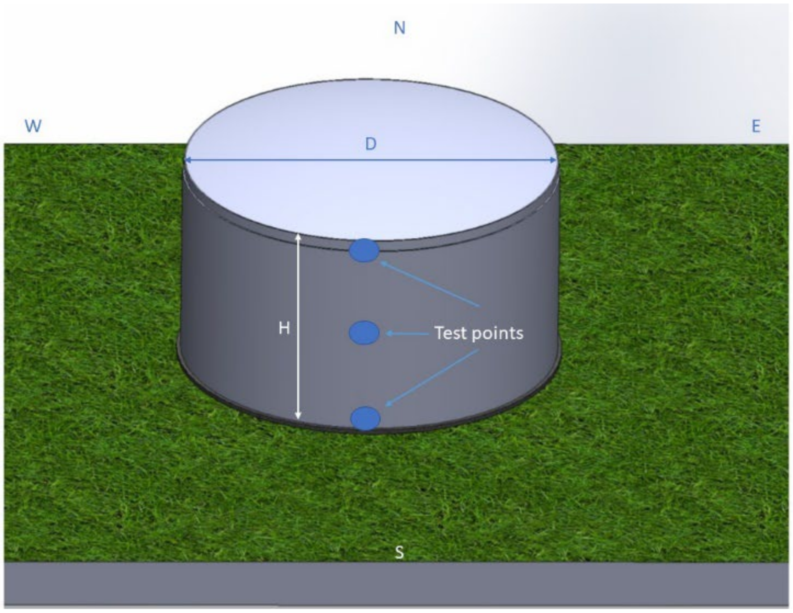


Figure 19: on the outside of the tank, temperature measurements were taken at 3 test points on 4 sides (North, East, West, South) of the tank.

Below are the temperature measurements taken in the field in Celsius:

	External Tank Measurements												
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	
Time	North			West			South			East			Ambient Temp
9AM	4.0	4.0	4.5	4.5	4.0	5.5	2.3	2.5	4.8	5.8	6.9	7.0	0.0
10AM	3.5	4.0	4.8	4.0	4.8	5.9	2.1	2.7	4.5	6.9	6.9	7.0	0.0
11AM	1.2	1.2	2.8	3.9	4.2	4.7	1.8	2.0	2.6	3.8	4.1	4.6	0.0
12PM	3.2	4.1	4.8	5.1	4.8	5.9	4.5	3.7	5.1	5.8	5.8	7.0	0.0
1PM	3.5	3.7	5.5	3.6	3.3	5.2	3.0	3.1	5.9	5.0	5.9	6.1	0.0
2PM	4.7	8.6	5.5	7.0	7.4	8.1	6.0	7.6	7.4	8.9	11.0	9.9	0.0
3PM	8.3	14.8	11.1	14.0	13.5	12.8	11.3	11.6	9.3	26.8	26.0	20.0	0.0
4PM	2.8	3.0	6.1	3.9	3.7	3.2	4.5	5.2	7.8	11.6	13.6	10.6	1.0

Table 1: Temperature Measurements Taken Outside the Tank

Tank height = 6.06m, fluid level = 2.5m, probe length = 3.5m.

Internal Tank Measurements in Celsius	
Time	Depth = 3.5m
9AM	60.0
10AM	60.4
11AM	59.0
12PM	60.1
1PM	62.0
2PM	60.6
3PM	62.3
4PM	61.5

Table 2: Temperature Measurements Taken Inside the Tank

Weather conditions on the test date: cloudy, ambient temperature 0…+1 degC.

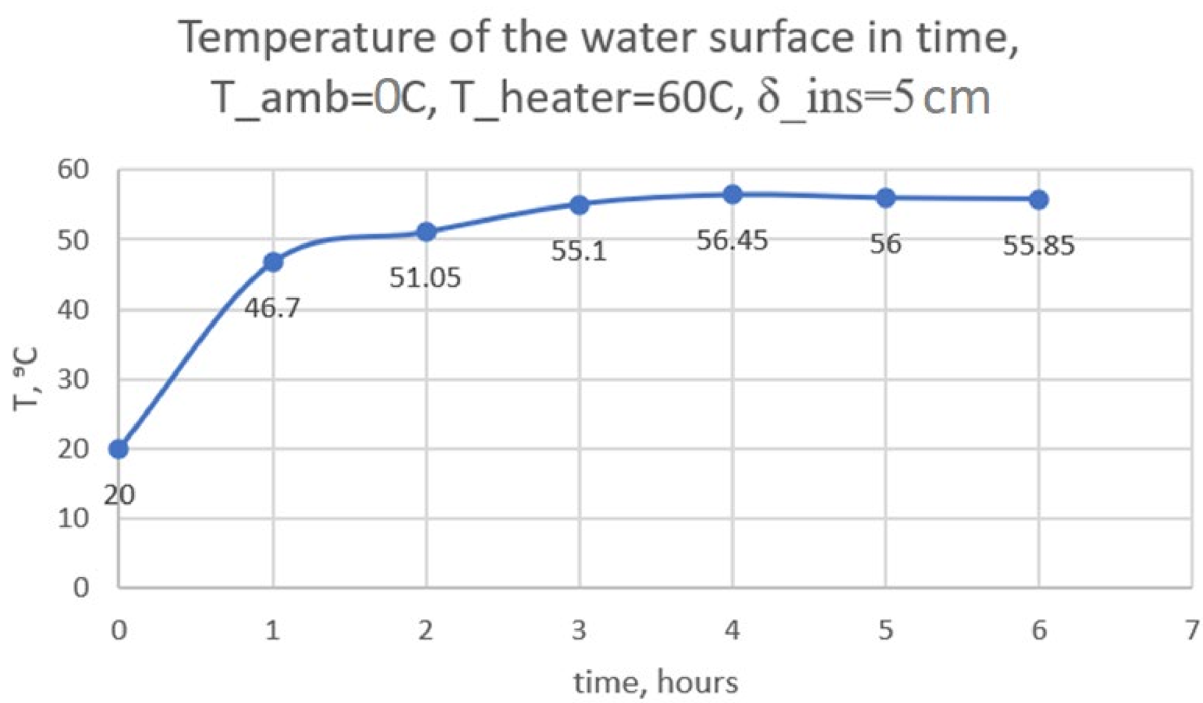


Figure 20: Temperature Change of Water Surface During the First 6 Hours after Pumping into the Tank

As can be seen from Figure 20, modelled temperature plateaus at around 56 degC with heaters set to around 60 degC and ambient temperature at 0 degC. The actual measured values are shown in Table 2. They fluctuate between 59 and 62 degC, which is slightly higher than that in the model – 3-5 degC difference. This can be explained by the fact that heat coming from the sun (even though it was a cloudy day, there will always be some heat coming from the sun) was not accounted for in the model. For future models, temperature adjustments will have to be made to account for the sun.

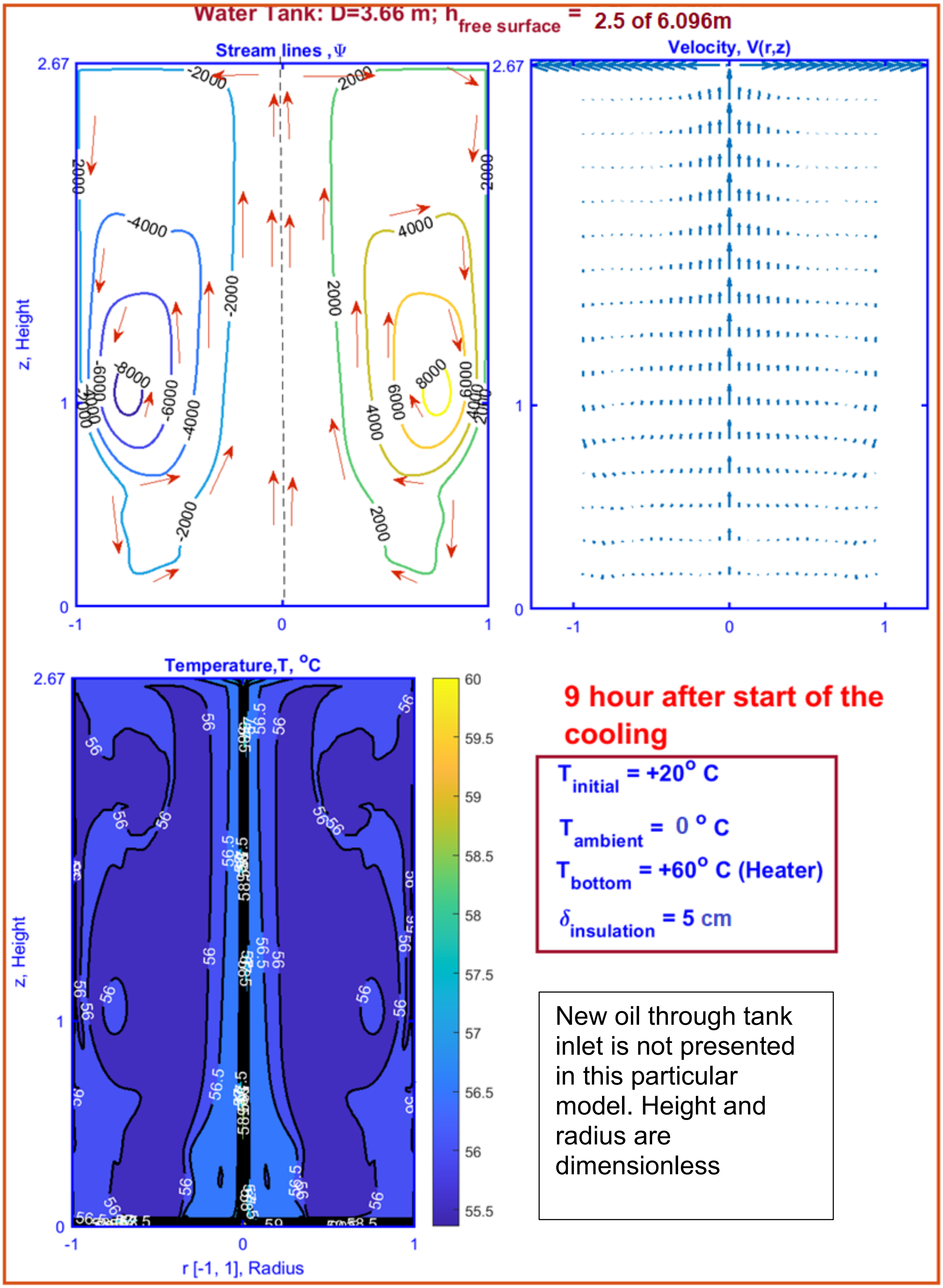


Figure 21: (4) Temperature Effects of Heaters at 60 degC on the Fluid

The chemical composition of the fluid in the tank showed that no methane was contained in the water. This can be explained by the fact that even if there was a small amount of methane present in the water when it was pumped into the tank from the separator, it most likely evaporated instantaneously. In future studies, Vitas is planning to estimate how much methane is contained in the product. For this purpose, it would be preferred to use actual oil tanks for the research, not produced water tanks.

Detailed chemical composition report for the product can be found in Appendix A at the end of this document.

PROJECT AND TECHNOLOGY KEY PERFORMANCE INDICATORS

Organization:	Current Study	Commercial Deployment Projection
Project cash and in-kind cost ($)	Vitas/SAIT Cash Contribution: $31,600 Vitas/SAIT In-kind Contribution: $18,000 CanERIC Cash Contribution: $48,000	Vitas/SAIT Cash Contribution: $50,000 Vitas/SAIT In-kind Contribution: $25,000 Additional Funding Required: $70,000
Technology Readiness Level (Start / End):	7	8
GHG Emissions Reduction (kt CH_4/yr):	0	0.057kt/yr (est.)
Estimated GHG abatement cost ($/kt CH_4)	$0	$13,000 (est.)
Jobs created or maintained:	1	2

NOTES: For the estimated amount of GHG emissions, it was assumed that at the end of the project Vitas will be able to propose a tank for vapor recovery unit (VRU) installation. Once a VRU is installed, 95% of methane will be caught from the tank and processed. It is estimated that an average of 0.057kt/yr of methane is emitted by one tank. The cost of an average VRU is $13,000/yr (EPA).

D. RECOMMENDATIONS AND NEXT STEPS

As mentioned in section B of the report, this was just the first smaller part of the project: temperature effects on liquid and gas inside the storage tank were modelled and a proof of concept was obtained for this part of the project.

In the second part of the project, Vitas will be using its existing software package, which is now optimized for petroleum storage tanks (previously it was designed for LNG storage tanks), to model temperature inside a petroleum storage tank and plug this data into the existing oil gas correlations (i.e. Vasquez Beggs, Beggs Robinson, etc.) to obtain accurate methane emissions model and estimation. The accuracy of the model will be verified by our academic partner SAIT using an FTIR (Fourier transform infrared spectrometer) instrument.

Vitas has the following recommendations for the next part of the project:

1) The storage tank for this study is ideally an oil tank, not a produced water tank. As the results showed in part C, the amount of methane in the produced water storage tank is negligible and it escapes from the tank the moment a new batch of product comes from the separator. As such, it is crucial to get the access and do the modelling on the larger oil storage tank that will be constantly emitting methane and other gases as presented in June 15 Industry Committee meeting.

2) Duration of the project should be between 10 to 12 months to study the effects of different seasonal temperatures and as a result varying ambient temperatures on fluid and vaporization inside the tank. One of the main issues with the existing software EPA Tanks is the fact that ambient temperature is taken as an average annual temperature and, as a result, the model was becoming very inaccurate (ambient temperature could be off by over 30degC). Studying the cyclical nature of ambient temperature and its effects on the processes happening inside the storage tank will help to avoid similar issues with our model. Also, longer project duration will allow Vitas to better account for specific design characteristics of the tank (i.e. heaters, insulation type, roof type, wall thickness, refill rate, etc.), which, in turn, will help make the model as accurate as possible.

3) To obtain more precise results, it is recommended to create a 3D model, not 2D. This will be a very time-consuming process and will require high computing power with sophisticated parallel computing algorithms. In return, this will allow Vitas to account for temperature effects that are not symmetric around the tank.

4) Long term (2-3 years) it would be very important to study multiple tanks, not just a single tank. This will help to get a better understanding of all the processes that happen inside the storage tank, look at different scenarios (various petroleum products, different tank geometry, fill rates, etc.). Once this is done, the software package for modelling fluid behavior will be continuously updated with new tank parameters and additional features to increase the accuracy of our estimates and models.

For the commercial deployment, Vitas' models and estimates will have to be validated by various industry players (academia, producers, regulator).

5) In order to better determine next steps for the technology, it will be important to get feedback from the regulators (AER, CER). This input will provide Vitas a better understanding of what the regulations and requirements are for the producers and tank farm operators. Potentially this could lead to adding new features to the software and help producers to report methane emissions with much higher accuracy.

6) Vitas' ultimate goal is to create a software application that will allow oil producers, regulators and scientists to estimate methane emission rates, concentration and distribution within the tank by entering tank and product parameters (i.e. tank geometry, type of product, ambient temperature, etc.) into the graphical user interface (GUI). At the end of phase II of the project, Vitas will start working on creating this cloud-based GUI that will be patented and licensed out to clients.

Appendix A

Natural Resources Canada / Ressources Naturelles Canada

Canada

ALBERTA INNOVATES

PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA

AGAT Laboratories

WATER ANALYSIS

PB2B					23W002872B
Container Identification	Sample Point Code	Meter Code	AGAT WDMS Number	Previous Number	Laboratory Number

AGAT CLIENT AB	TANK	14-14-033-04W5
Operator Name	Sampling Point	Unique Well Identifier

NOT AVAILABLE				
Well Name	Well License	Well Status	Well Fluid Status	LSD

GARRINGTON	NOT APPLICABLE	VITAS CONSULTING SERVICES	NOT AVAILABLE
Field or Area	Pool or Zone	Sampler's Company	Name of Sampler

Test Interval (mKB)				Elevation (m)		Pressure (kPa)		Temperature (°C)	
From :	To:	Test Type	Test No.	KB	GRD	Source	Received	Source	Received

Mar 03, 2023	Mar 03, 2023	Mar 09, 2023	Mar 09, 2023	Calgary - Tin Tin Ma - Reporter
Date/Time Sampled	Date Received	Date Analyzed	Date Reported	Location - Approved By - Title

Other Information : SMALL TANK

CATIONS

Ion	mg/L	mmol/L	meq/L
Na^+	15.8	0.7	0.7
K^+	TRACE	TRACE	TRACE
Ca^{2+}	7.1	0.2	0.4
Mg^{2+}	TRACE	TRACE	TRACE
Ba^{2+}	TRACE	TRACE	TRACE
Sr^{2+}	TRACE	TRACE	TRACE
Fe^{2+}	12.9	0.2	0.5
		Total	1.6

ANIONS

Ion	mg/L	mmol/L	meq/L
Cl^-	14.1	0.4	0.4
Br^-	TRACE	TRACE	TRACE
I^-	4.9	0.0	0.0
HCO_3^-	12.2	0.2	0.2
SO_4^{2-}	11.4	0.1	0.2
CO_3^{2-}	Nil	Nil	Nil
OH^-	Nil	Nil	Nil
		Total	0.8

2
Cation/Anion Ratio

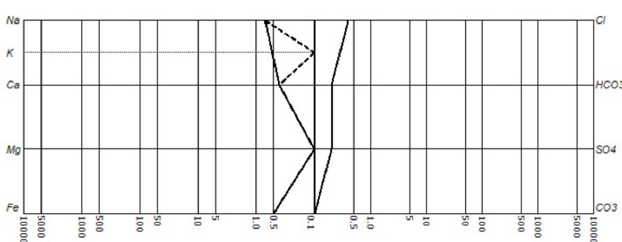
OTHER MEASUREMENTS

Total Dissolved Solids (mg/L)

54	
TDS (Calculated) mg/L	TDS (110) mg/L
120	
TDS (180) mg/L	TDS (at Ignition) mg/L

	4.99
	Observed pH
N/D	0.911
H_2S (25°C) mg/L	Relative Density (25°C)
433.456	0.00
Resistivity/OHM·m (25°C)	Salinity %
	10.00
	Total Alkalinity as $CaCO_3$ mg/L
1.3490	
Refractive Index (25°C)	

Stiff Diagram (meq/L)



Results relate only to the items tested. Cations were determined according to: ASTM D 4691, EPA 200.7, EPA SW-846 6010C, ASTM D1067, SM 2320B. Anions were determined according to: SM 4-66 to 4-71, SM 4110B, ASTM D1067, SM 2320B.

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