WATER/OIL MIXTURE HEATING SYSTEM FOR OIL FLOW AND BSW METERS ACCURATING BY ELECTRICAL RESISTANCES

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Abstract. *The Petroleum Measurement Laboratory (LAMP) at UFRN develops automatic and accurating oil flow and BSW meters tests. The plant design allows the real time simulation under differents operation conditions. The current tests still has been made on the room temperature. It was detected the need to implement a heating system in order to keep invariable the operation fluid temperature about 60 ^oC. The objective of the present work is to show a water/oil mixture heating system using electric resistances along the mixture tank recirculating and the test line piping. The proposed system have several advantages, such as: compact system, easy power control and low cost implementation. This work considers the piping thermal insulation as well as on the arched and mixture tanks. In modelling was used Solidworks software, and for flow simulation with heat transfer, the CFX and Cosmoflow softwares were used. The results obtained through the simulations show that the measurement system requirements can be obtained by this alternative proposal.*

Keywords: *petroleum, flow measurement, BSW, heating system, simulation.*

1. INTRODUCTION

The Petroleum Measurements Laboratory (LAMP), located in the Federal University of Rio Grande do Norte-UFRN develops automatic accurate tests in oil flow and BSW (Basic Sediments and Water) meters (Lima, 2000).

The ANP / INMETRO n. 1 resolution of 06/19/2000 about the supervised flow meters has caused disagreements on the calibrating procedures when compared to the measurement results between the laboratory conditions and real conditions of the parameters: flow, pressure, temperature, viscosity and density.

The accurate tests are still being made in the laboratory with fluids at room temperature, differently to what happens in field, where the instruments work with flow temperatures about 60ºC. The temperature parameter is the most influent in flow measurement accuracy. It directly affects the viscosity and density properties of the fluid.

According to the demanded requirements, a control system is being developed for the temperature variable in order to simulate the real thermal conditions in petroleum production installation. Considering the maximum tests values of flow and temperature, the system requests a considerable heat transfer which should be done through the surfaces of the mixture tank recirculation piping and complemented with the tests pipe. Therefore, the heating system simulation studies require the plant details, the operation fluids thermodynamic properties and the equipments' technical specifications as well as the measurement plant norms.

The presented solution consists of a thermal heating system using collar-type electric resistances disposed along the piping. The analysis proceeded in the investigation took in consideration in the selection of the available technologies in the market a specification that assisted to the requirements: electric installations in potentially explosive areas, available area for thermal transfer, available area for physical installation, availability of electric power system and adaptation of the temperature control with the instrumentation already existent.

For the validation of the proposed system several simulations were developed using the software ANSYS-CFX and SolidWorks.

2. APLICATION DESCRIPTION

The heating system will be implemented on the LAMP plant, whose structure is composite by six tanks: oil, water, mixer, auditor, residues and a treater tank used for water/oil separation. The system allows the water and oil reutilization on successive tests without discards.

To evaluate flow and BSW meters, was developed in laboratory a method of flow meters accuracy check, (Salazar et al, 2006). It is a new method proposed for obtaining the BSW conventional true value, by the liquid column total height in the auditor tank, hydrostatic pressure, local gravity, water specific mass and oil specific mass. The calibration executed counts with an automatic system for monitoring and data acquisition of some necessary variables to determinate the BSW, providing higher reliability on the measurements performed.

The proposed system allows perform several simulations under different operations conditions, as in field. It simulates different water and oil ratios. The Figure 1 shows the aspect of the laboratory.

Figure 1. A view showing the (LAMP) Laboratory Plant

The process consists on taking the chosen water and oil ratio and obtaining a mix through mixer tank recirculation during a previously set time. Then, this emulsified fluid is transferred through a piping with 22*m*, which is the instruments tests line. The emulsion is transmitted to the auditor tank which allows oil flow and BSW accurate measures. When the process finishes the fluid is transferred to treater tank, where by decantation the separation occurs, being the oil and water fluids transferred for their respective tanks afterwards.

3. HEATING SYSTEM USING ELETRIC RESISTANCES

The heating system design considered collar electric resistances as energy source, distributed all along the external piping surface. In the analysis were considered: the electric facilities requirements in explosive potentially areas, the area for thermal transfer, the necessary electric power and the temperature control system compatibility with the already existent instrumentation.

3.1. Eletric installations in explosive potentially areas

The main requirement for elaboration of an industrial project is the area classification. The areas where there are explosion risks are classified considering the fuel and oxygen mixture occurrence probability. The classification defines which kind of protection should be installed in the area.

In Zone 0, an explosive mixture is found permanently or for a long time. In Zone 1, there is an explosive mixture presence probable during the normal operation, but when it occurs, the permanency time is limited. In Zone 2, an explosive mixture presence is found only in equipment fail case, where it happens for a short time (Jordão, 2002).

The security circuit installation should obey the NBR 5410 resolution, considering that the equipments must be approved for that classified area. Moreover, the wires and cables must be grounded and insulated.

Regarding to the plant area classification, the resistances were specified considering its location on the installation. The heating system electric installation was chosen to the explosion proof. The Figure 2 shows the electric circuit components to resistances connection (passage box, stamped unit and nipples)

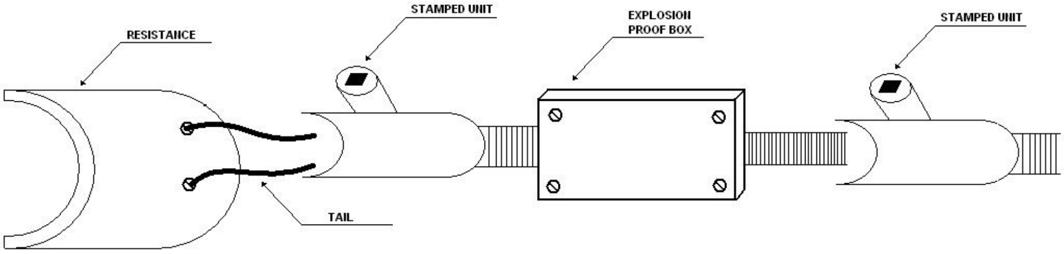

Figure 2. Electric resistance individual circuit

It was chosen the electric resistance with ceramic covering insulation. The resistances power wire are flexible cables linked to a stamped unit, been this linked to explosion proof box, from where will be done the electric power and avoiding the ignition propagation through the environment.

3.2. The thermal transfer requested area

It was lifted up the thermal transfer area in the plant, which it is possible for collar electric resistances installation. There is a track of 12m in the test line and other of 8m in the of the mixture tank recirculation line, corresponding to the 3.35 m² area.

The energy balance indicates that the heating area using the electric resistances system proposed would be possible only when the mixer tank recirculation piping heating area is combined with the test piping line heating area. The temperature should be controlled and stabilized about 60º*C*. This method allows reducing the source's power. In order to minimizing the losses, becomes necessary the piping and mixture tank appropriate thermal insulation.

3.3. The system installation available area

The available physical space for the work fluid heating system installation is limited by the architectural and piping plant project. The use of a heating system with electric resistances has as advantages low cost and the space economy, requesting just the space for the electric command installation and the piping covering with appropriate resistances.

The Figure 3 shows the resistances installation design simulation on the piping using the Solid Works Software

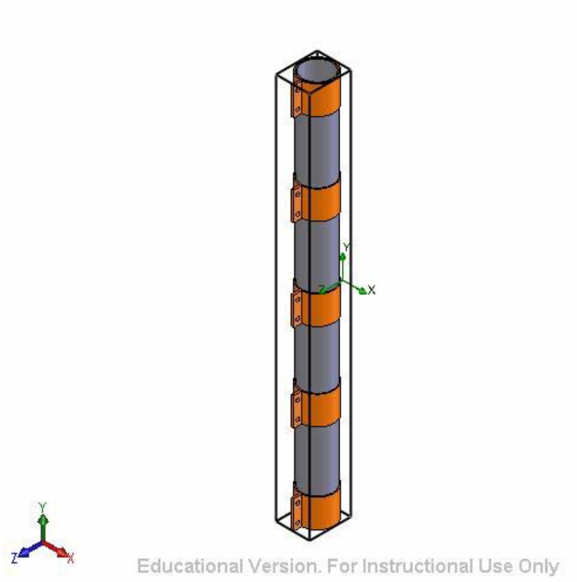

Figure 3. Electric Resistances Installation

3.4. Necessary eletric power Specification

The necessary electric power for the heating system was based on some project requirements, considering the installation technical viability and the available power by the laboratory for this application being about 125 kVA.

In the project conception were adopted some considerations. The work fluid was considered for the worst condition of BSW = 100%, considered as water. This situation was adopted based on local productive wells information (Costa, 2004).

The temperature variation adopted was 30°C, being considered the operation temperature at 60°C and room temperature about 30°C. The Figure 4 shows the Petroleum Measurements Laboratory Plant, indicating the mixture tank recirculation line and the test line.

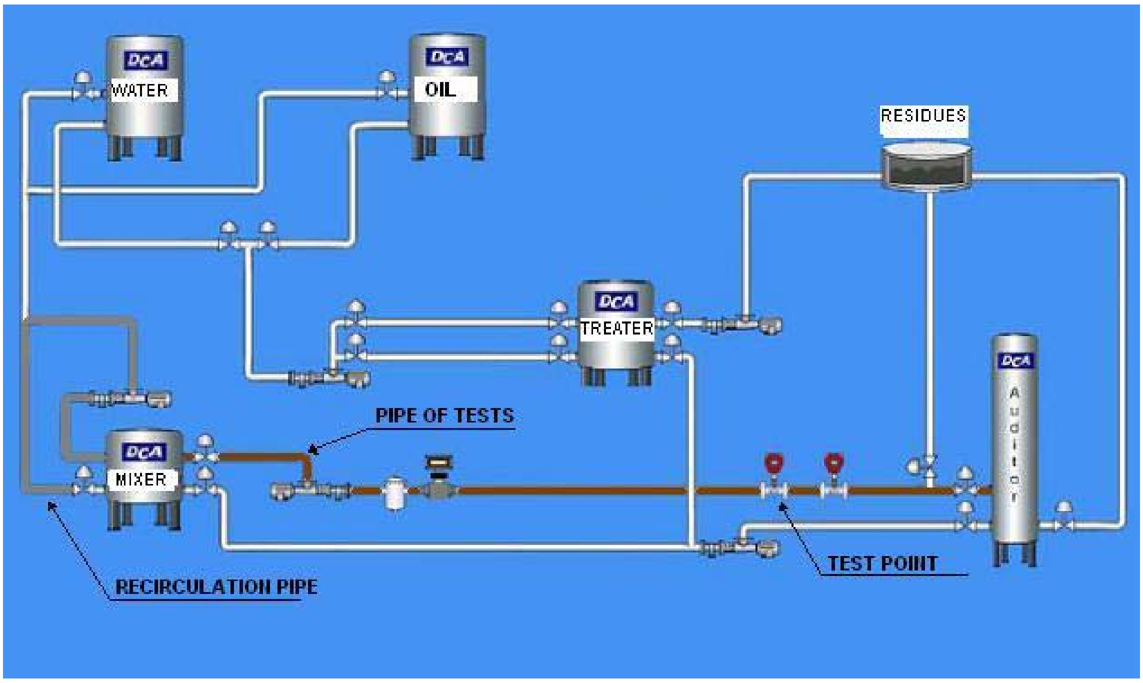

Figura 4. Diagram of measurements tests line.

The maximum test flow t was chosen from the maximum capacity of the meters used in the area, about 12m³/h.

The mass flow is obtained by Eq. (1).

$$\dot{m} = \rho \cdot Q = 1000 \frac{kg}{m^3} \cdot \frac{1h}{3600s} \cdot \frac{12m^3}{h} = 3{,}33 kg/s \tag{1}$$

Where:

ρ : Fluid specifies mass;

Q : Fluid volumetric flow;

The necessary heat quantity to vary the fluid’s temperature is calculated by Eq. (2).

$$q_1 = \dot{m} c_P \Delta T \tag{2}$$

Where:

q_1 : Convection heat transferred to the fluid;

$\dot{m}$: Mass flow of the fluid;

c_p : Specific heat of the fluid (4,18 *kJ/kg.K*)

ΔT : Fluid temperature gradient (30*K*)

The necessary electric power to obtain the temperature gradient wanted is 417.58 kW, in agreement with Eq.(2).

The energy losses caused by the resistances happen through direct and piping dissipation. It could be minimized by appropriate thermal insulation.

The energy balance through the heat transference system caused by electric resistances to the working fluid is obtained by Eq.(3).

$$\dot{E}_{af} + \dot{E}_{g} - \dot{E}_{ef} = \frac{dE_{ac}}{dt} = \dot{E}_{ac} \quad (3)$$

Where:

$\dot{E}_{af}$: Inlet heat transfer rate;

$\dot{E}_{ef}$: Outlet heat transfer rate;

$\dot{E}_{ac}$: Remained heat transfer rate;

$\dot{E}_{g}$: Generated heat transfer rate;

Boundary condition in steady state: The heat transfer inlet rate and remained rate are both null, therefore the heat transfer outlet rate is same that heat transfer generated rate.

The pipe´s external surface temperature can be estimate by the heat transfer generated rate conservation.

Boundary condition: neglecting the losses of heat to environment, the energy conservation can be obtained based on Eq.(4); and considering internal temperature of the tube (T_i) the same of the operation temperature (*To*), *Ti = To = 60ºC.*

$$\dot{E}_{af} = q_1 = q_2 = 417{,}58\text{kW} \quad (4)$$

Using the boundary conditions in the heat transfer by conduction equation, considering the external diameter d_e = 0,0889*m* and the internal diameter d_i = 0,0779*m*, the total length of the resistances *L=12m*, steel-carbon thermal conductivity (*k*) of 60,5*W /m.K* (Incropera and Witt, 1992), and substituting the Eq.(4) in Eq.(5), it is obtained the estimate value of T_e.

$$q_2 = \frac{T_e - T_i}{\frac{\ln \frac{r_2}{r_1}}{2\pi k L}} \quad (5)$$

Therefore, the pipe outside temperature is about T_e*=72ºC.*

The results obtained in the simulations using the CFX software, for the same conditions in the analytical calculation as: kind of fluid, temperatures, flow and work pressure, heat transfer rate by the electric resistances and the pipe material specification were concordant with analytical calculations presenting an error of 10%. The results showed that the variation of the wanted temperature can be reached in the point of measurement test with the implementation of the proposed system.

The Figure 5 shows the simulation using the CFX software, where the arrows indicate the flow direction of the fluid through the pipe, and the marked area indicates the heating place.

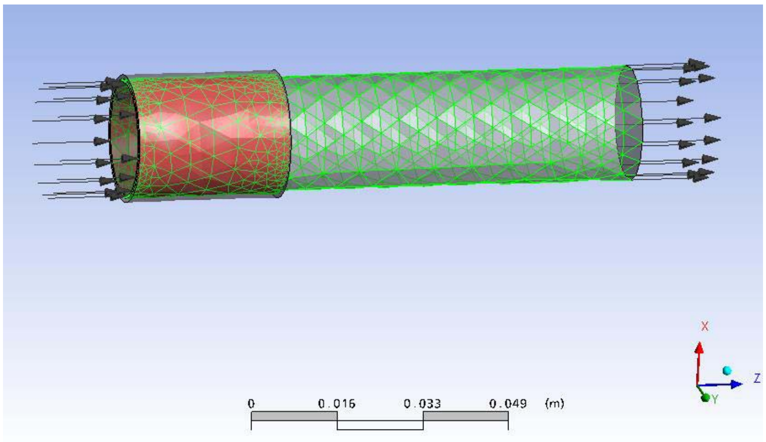

Figure 5. Heat transfer simulation on CFX software.

4. CONCLUSION

The calculations and simulations performed show that the proposed system can be adapted to the required application. The study was limited on the metrological condition of measurement and evaluation of high BSW rate (about 90%) oil flux meters.

The proposed system has advantages such as easy implementation, easy control and low cost if compared with a heat-exchange, and has also a smaller size.

The necessary heat transfer to obtain the thermal gradient required in the work fluid requests the use of the recirculation and tests piping to provide the necessary heating area.

The installed power can be reduced using the recirculation system for a larger time, accumulating thermal load in the fluid contained in the mixer tank, and reducing the necessary thermal gradient in the test piping.

The simulations using the CFX software are in agreement with analytical results.

This study will be validated based on the system implementation and it will serve as case study for training in simulation and use in other LAMP applications.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Lima, C. E. G., 2000, “Automação de testes de produção e determinação do BS&W de poços produtores de petróleo”, Dissertação (Mestrado em Engenharia Elétrica) – Universidade Federal do Rio Grande do Norte, Natal, Maio 2000.

Portaria conjunta ANP/INMETRO n. 1 de 19/06/2000. http://www.anp.gov.br/leg/inmetro.asp

Incropera, F.P. and Witt, D. P. de, 1992, “Fundamentos de Transferência de Calor e Massa”, Ed. LTC, Rio de Janeiro, Brazil.

Salazar, A.O., Maitelli, A. L., Quintaes, F. de O., Júnior, E. G. A., Dantas, I. A. C., Assis, L. A. A. de, Silva, D. S. da and Amado, J. A. D., 2006, “Automação, Controle e Supervisão de uma Planta Industrial Utilizando Tecnologias em Redes Industriais”, Proceedings of the XVI Brazilian Congress of Automatics.

NBR 5418 - Instalações elétricas em atmosferas explosivas, Associação Brasileira de Normas Técnicas - ABNT.

NBR 5410 - 2005 - Instalações Elétricas de Baixa Tensão, Associação Brasileira de Normas Técnicas - ABNT.

Jordão, D. de M., 2002, “Manual de Instalações Elétricas na Indústria do Petróleo”, Ed. Qualitymark, Rio de Janeiro, Brazil.

Costa, R.O., “Curso de Bombeio Mecânico”, Petrobras UN-RNCE/ST/ELV, 2004.

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