» ADVANCED INSTRUMENTATION AND CONTROL TECHNIQUES

ADVANCEMENTS IN INSTRUMENTATION AND SURVEILLANCE SYSTEMS IN STEAM PROCESSES » CSS PROJECTS »

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ABSTRACT

One of the most common techniques in Enhanced Oil Recovery is steam injection, which adds thermal energy to a reservoir to stimulate production, increase the recovery factor, and extend the reservoir's lifespan. It is essential to measure all parameters during the steam injection process to analyze them in real-time.

The objective of this research is to present and detail the latest technological innovations in instrumentation and monitoring systems, as well as control of key operating variables during the steam generation and injection process in oil wells. These variables significantly impact the behavior of the viscosity of heavy oil present in the reservoir.

The methodology was based on the analysis of data obtained from the monitoring and control systems of the NK 30 TTS Steam Generator manufactured by Nakasawa and the operations in steam injection wells. The focus was on innovative instrumentation in the most critical variables to be considered during steam generation and injection.

This study provides valuable insights into how

technological innovations can enhance the steam injection process and optimize oil production in reservoirs. The findings will help the industry adopt new strategies for more efficient and sustainable recovery of energy resources.

1. TECHNOLOGICAL INNOVATIONS IN STEAM INJECTION PROCESSES (INSTRUMENTATION & SURVEILLANCE SYSTEMS)

At present there are great Technological Innovations in the field of Instrumentation, Monitoring and Control Systems for different industrial processes; which have been perfected over time, in order to optimize and facilitate the management of processes, improve the quality of the final product, and also minimize the intervention of the hand of man in the monitoring and control of the different process parameters.

Important innovations have been incorporated into steam generation systems, in order to improve data acquisition processes and guarantee steam quality; as well as to ensure the physical integrity of the equipment, of the personnel that performs the operations and maintenance, as well as to reduce the environmental impact.

Some of these innovations incorporated into the different sub-systems that make up the high-efficiency steam system are described below.

Raw Water and Treated Water Storage Tanks :

In the tanks, Float-type Magnetic Level Viewers have been incorporated, equipped with Transmitters and Level Switches, which report their signal to the control system:

- The Level Transmitter incorporated in the tanks allows continuous monitoring of the water levels, thus providing the advantage of generating alarms in the system to alert the operator in a timely manner and thus take the corresponding corrective actions (prevent overflow or emptying of the tank); this would prevent the suction pumps from working empty.

- The built-in Level Switches will issue stoppages of the WTP or the Steam Generator, and in this way prevent these equipments from working empty.

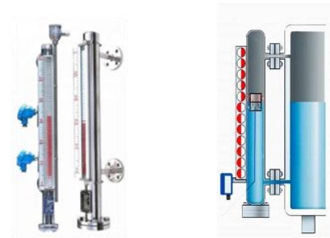

Fig. 1. Level Monitoring Devices.

Water Treatment Plant (WTP):

The following innovations have been incorporated into the water treatment plant:

- **Variable speed drive (VFD)** in the raw water pumps that feed the plant to adjust and maintain a constant and precise flow of water according to operational requirements.

Fig. 2. Speed Monitoring Devices.

- **Vortex - Type Electromagnetic Flow Transmitter** installed in the discharge line of the raw water pumps (Entrance to the WTP Filters), for constant and real-time monitoring of the feed water flow. This transmitter allows the automatic modification of the flow, varying the output signal in the VFD of the pump, according to the requirements of the process.

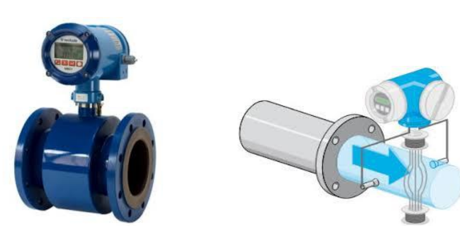

Fig. 3. Electromagnetic Flow Transmitter.

- **Electronic transmitters** for constant monitoring of the inlet and outlet pressure in the WTP filters. These transmitters allow monitoring to be carried out through the control system and alert the operator early on any drop or abrupt increase in pressure; In addition, the control system can be adjusted to a certain value to change the treatment train in the event that the pressure drop in the filter is very severe. This condition would determine if the filter is clogged; therefore, the control system can send a signal to perform an automatic change of the train to regeneration.

Fig. 4. Electronic Transmitter.

- **Variable speed drive (VFD)** is used in the motors of the chemical and brine injection pumps, to adjust and maintain their injection flow rates through the control system, according to operational requirements.

Fig. 5. Variable speed drive (VFD).

- **Vortex type Electromagnetic Flow Transmitter** is installed in the treated water outlet line for constant flow monitoring in real time; as well as for the registration and totalization of the flow of treated water produced. Through this transmitter, the flow rate of the chemicals to be injected can be automatically modified, varying the output signal on the VFD of the chemical product pumps to carry out the proper dosing of the same, according to the requirements of the process.

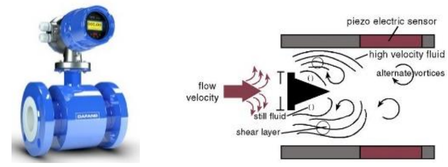

Fig. 6. Electromagnetic Flow Transmitter.

- **Vortex type Electromagnetic Flow Transmitter** is installed in the discharge line of the Brine pump to control the injection flow in real time. With the signal of this device, through the monitoring and control system, the injection can be automatically adjusted, varying the output signal in the VFD of the pump and in this way perform the proper dosing of brine, according to the requirements. of process.

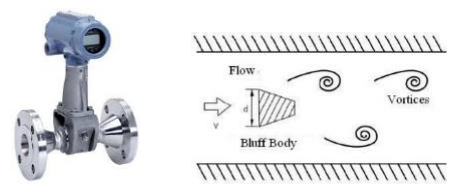

Fig. 7. Electromagnetic Flow Transmitter.

- **Chemicals and brine tanks,** Agitators were incorporated to keep the mixture homogeneous; as well as **Float Type Level Switches are incorporated** to monitor the low level in the tanks. These switches allow pump and agitator stoppages to avoid empty work.

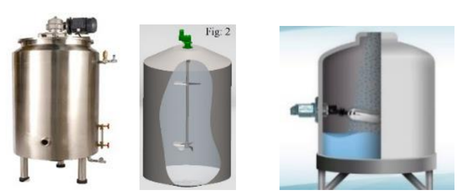

Fig. 8. Chemical tanks.

- **Electronic Hardness Analyzer-Meter,** installed in the treated water outlet line of the WTP, to determine the quality of the treated water in real time. With the signal from this device and through the monitoring and control system, the operating treatment train can be automatically sent to regeneration if required, and activate the standby train.

Fig. 9. Electronic Hardness Analyzer-Meter.

Water Treatment Plant Diagram with Innovations

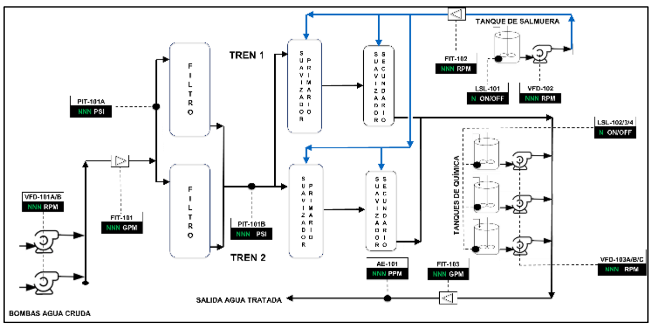

Fig. 10. Construction Phase WTP.

Steam Generator:

The following technological innovations have been incorporated into the latest generation Steam Generator:

Instrumentation in the Quintuplex Pump

- **A Variable Speed Drive** on the water pump motor (Quintuplex), to adjust and control the flow of water to the steam generator, according to the operational requirements of the process.

Fig. 11. Speed Variator.

- **Vibration Switches,** have been installed in the Water Pump to generate alarms and warn the operator when there is a high vibration, due to abnormal operation of the pump. These devices, through the Control System, generate a stoppage of the pump to avoid possible damage to the equipment. In the event that the vibration is excessive or severe, these devices, through the Control System, generate a stoppage of the pump to avoid possible damage to the equipment.

Fig. 12. Vibration Switches.

- **An Oil Lubrication System** in the pump box, to lubricate the gears efficiently when the pump speed is very low. (This, in the event that the Generator is Operating at its Minimum Capacity).

Fig. 13. Oil Lubrication System.

- **Electronic Flow Transmitter Type Differential Pressure,** this is installed in the discharge line of the Quintuplex Pump. This device sends a proportional flow signal to the monitoring and control system where the measurement and totalization of the flow of water to the generator is recorded. Through this transmitter, the monitoring and control system sends a proportional signal to the control valve of the fuel gas line to the burner (when operating with gas), or to the VFD of the Diesel fuel pump (when operating with gas). operating with diesel). Through these parameters, the control of the operation of the Generator is carried out.

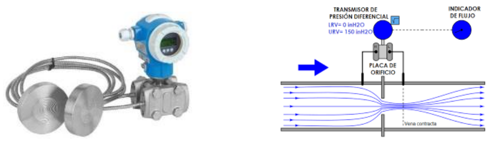

Fig. 14. Electronic Flow Transmitter.

Innovations in the Monitoring of Combustion Gases

- **Combustion Gas Analyzer** is installed at the base of the chimney to carry out constant and real-time monitoring of the gases resulting from Combustion, in order to control emissions into the Environment. The signal from this device is sent to the monitoring and control system where, in addition to registering these values, it automatically also makes adjustments to the fuel / air ratio with some algorithms to maintain an O2 level of 3% in exhaust gases. Exhaust, and in this way to be able to maintain a constant control of the emissions to the environment.

  In addition, the Control System Using these data, it issues an alarm signal for low or high % oxygen (O2), for high PPM of sulfur dioxide (SO2) and high PPM of nitrogen dioxide (NO2) to alert the operator so that he can take corrective actions when regard.

Fig. 15. Combustion Gas Analyzer

Instrumentation for the capture of Pressure and Temperature information

- **Multiple Temperature Measurement Points in the Radiant Section of the Steam Generator.** This to Maintain a Constant and Accurate Monitoring of the Temperature of the Tubes in the entire Radiant Section of the Steam Generator. With the signal from these devices, the control system generates pre-alarms to alert the operator, but also generates shutdowns of the generator due to high temperatures of the tubes in the radiant section to avoid damage.

Fig. 16. Temperature Sensors.

- **Steam Pressure Control Station at the System Outlet.** This is installed to maintain constant monitoring and to be able to control the pressure of the steam system, which goes to the well, keeping the generator running at a constant pressure within the established parameters. With these values, the system makes adjustments automatically, through the VFD of the Quintuplex Pump, the Gas control valve to the burner and the VFD of the Blower for the flow of Combustion Air from the burner (water, air and gas), to exercise control of the Generator. This device, through the Control system, also generates an alarm due to high steam pressure in the discharge, which alerts the operator to take corrective action in this regard.

Fig. 17. Pressure sensors.

- **Pressure Control Valve** is installed in the steam discharge line of the generator to regulate the steam injection pressure according to well conditions.

Fig. 18. Pressure Control Valve.

Fig. 20. Pressure Control Valve.

Steam Quality Measurement

- **Continuous Steam Quality Meter.** This device allows continuous and real-time monitoring of the quality of steam that is being produced and that is delivered to the generator outlet. With the data from this device, an alarm signal will also be generated in the system for low and high steam quality, which helps alert the operator to take corrective actions.

Fig. 19. Continuous Steam Quality Meter.

Gas Scrubber:

In the Fuel Gas purification system, innovations have been incorporated in the field of instrumentation; they are mentioned here below:

- **Pressure Control Valve (self-controlling - pneumatic).** For the permanent regulation of the gas pressure that enters the Purifier.

- **Pneumatic Level Controller and a Pneumatic Level Control Valve.** These are placed Integrated in a closed control loop, to carry out the level control of the condensed liquids that are extracted to the gas.

Fig. 21. Pneumatic Level Controller.

Combustion System:

Innovations have been incorporated into the generator combustion system to improve operation, performance and efficiency. Some of these innovations present in the equipment are detailed below:

- **Variable Frequency Drive (VFD) on the Burner Fan Motor.** It was installed to control the mixture and obtain a greater efficiency of the flame, and in this way obtain the ideal calorific power of combustion.

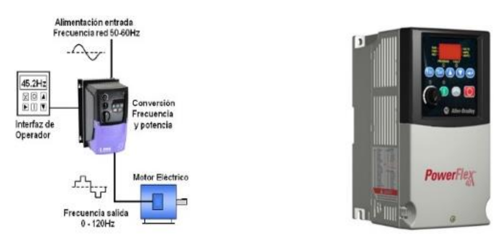

Fig. 22. Variable Frequency Drive (VFD).

- **UV Type Flame Detector:** This is equipped with a self-checking system to verify if there is any obstruction in the lens of the device. Through this instrument, a failure alert signal can be generated and, in this way, carry out the corresponding corrective measures.

Fig. 23. UV type Flame Detector.

Wellhead:

As far as instrumentation is concerned, innovations have also been incorporated at the wellhead level to improve Surveillance plans in the Enhanced Recovery Processes, in order to complement the efficiency of the system in steam injection:

- Wireless electronic pressure and temperature transmitters, installed in section C of the wellhead, for constant, real-time monitoring of these parameters in the Production Casing (to determine insulation integrity). The signal from these devices is sent to the monitoring and control system remotely.

Fig. 24. Wireless electronic pressure and temperature transmitters.

Steam Generator NK 30 TTS 25 MMBTU/hr

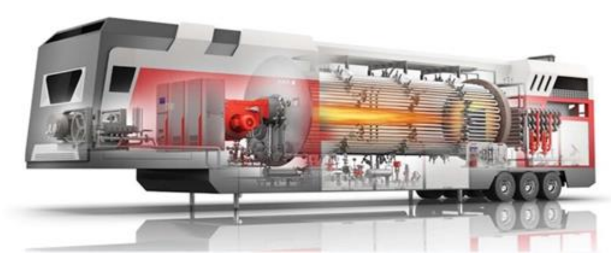

Fig. 25. NK 30 TTS Steam Generator.

2. TECHNOLOGICAL INNOVATIONS FOR HIGH EFFICIENCY IN THE STEAM PROCESS.

The latest technology studied to generate steam with high efficiency is inspired by mathematical principles and its generalized structure of the concept of linear independence with formulations, to achieve maximum efficiency in the process called by its designers **Super Matroid Technology (SMT)** , consisting of a high efficiency cyclonic separator, a superheater coil , mixers with control valve and a sampling system, to generate high quality steam (greater than 95%); which uses high TDS feed water without loss of condensed water and thermal energy. This process makes steam injection more effective and very cost effective.

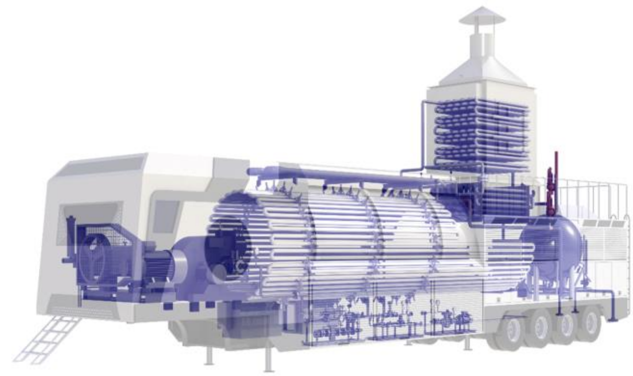

Fig. 26. High Efficiency Steam System.

The entire system is installed on a compact skid, with the exception of the superheater coil that is installed between the radiant and convection sections inside the steam generator.

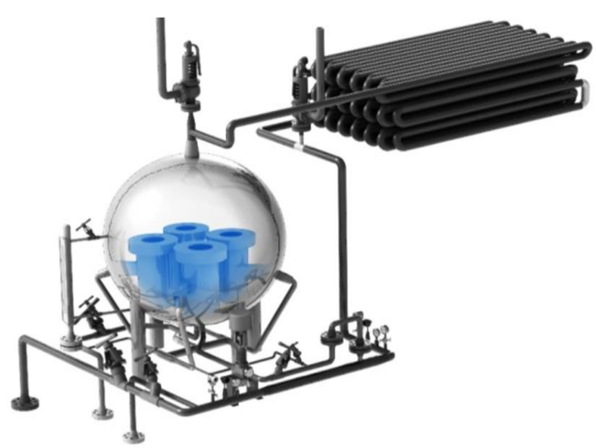

Fig. 27. High Efficiency 3D System in Vaporization.

Some of the advantages offered by this innovation:

- Unlike a normal steam separator installed at the outlet of the steam discharge line, there is no loss of condensate or thermal energy, thus saving 9% feed water and 12% fuel gas.
- Steam is delivered to the well with a minimum quality of approximately 90% to 99%; so it will require less feed water to deliver the same amount of heat compared to 80% dry steam.
- The SMT steam generator is ideal for delivering steam to a distant well, considering heat losses in surface lines, delivering steam at 90% dryness or better at the wellhead.
- Eliminates the need for any additional steam separator, heat exchanger, effluent pre-treatment plant, re-injection into the subsoil or effluent transport to a safe area designated by the operator (after carrying out a study).
- The SMT system can handle high TDS values (up to 10,000 ppm) to generate high steam quality values, unlike a Conventional Generator, which is limited by its ability to work with TDS values up to 4,000 ppm to generate quality maximum steam of 80%.
- Increased productivity compared to conventional OTSG technology of 80% quality (> 21%)

Technological innovations incorporated in the High Efficiency System in the Vaporization Process.

- **A Differential Pressure Type Flow Transmitter** has been incorporated **together with a Pressure Transmitter and a Temperature Transmitter,** in the steam outlet line of the radiant zone of the Steam Generator. The values of the signals generated by these devices are sent to the monitoring and control system where the measurement and totalization of the volume of steam that leaves the radiant zone of the generator is recorded and delivered to the High-Quality Innovative System of Steam.

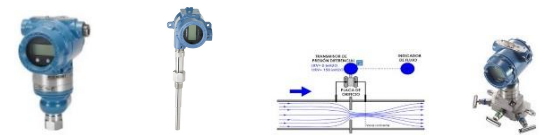

Fig. 28. Pressure and Temperature Transmitter

- **Magnetic Level Viewer with Level Transmitter:** The Cyclonic Separator has a built-in transmitter that reports its signal to the control system where the record is made and continuous monitoring of the liquid level in the separator is maintained. With the values of this Parameter, the monitoring and control system also sends a proportional signal to the Mixing Station Control Valve, where the Superheated Steam in the Super Heater and the Condensate that had already been steamed in are mixed again. the Separator.

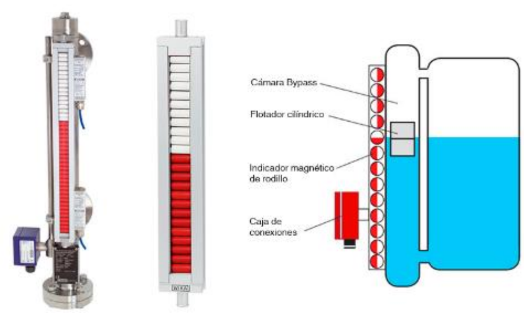

Fig. 29. Magnetic Level Viewer.

- **Pressure Transmitter and a Temperature Transmitter:** this system has this transmitter installed in the dry steam output line of the separator that goes to the coil over heater. This in order to be able to maintain through the control system a constant monitoring of the pressure and temperature of the dry steam that leaves the cyclone separator and that enters the coil on the Super Heater.

Fig. 30. Pressure and Temperature Transmitter

This system has also incorporated **a Pressure Transmitter and a Temperature Transmitter** In the steam outlet line of the coil on the heater that goes to the mixing station. The signal from these devices is sent to the monitoring and control system where these values are recorded and the difference (increase) in steam temperature as it passes through the Overheating Coil is verified through the system.

- In the Mixing Station, the system has a **Control Valve incorporated** that receives a signal through the system to do the proper dosing of condensate to superheated steam. The signal received by the valve is modified through the control system, depending on the signal sent by the level transmitter of the cyclone separator.

Fig. 31 Control Valve

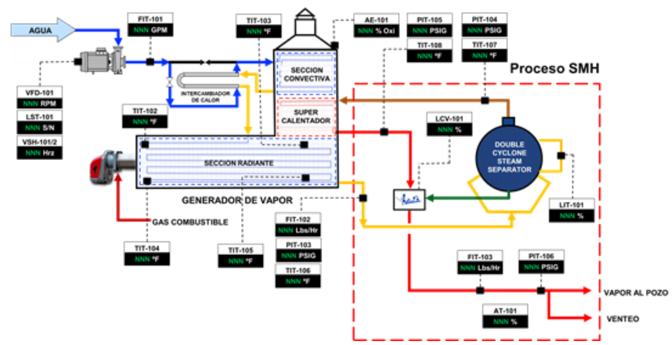

Fig. 32 High Efficiency Instrumented System in Vaporization.

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