» OPERATING PHILOSOPHY

Operational Guidelines for Steam Injection in Heavy Oil Fields

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SUMMARY

Maximizing hydrocarbon production in oil industry is of great importance in order to extract the highest percentage of crude oil from the reservoir. The factors affecting oil recovery depend not only on rock properties and fluid conditions but also on the technology available to extract the oil. One of the most common techniques is Enhanced Oil Recovery (EOR) using steam injection, which adds energy to the reservoir to stimulate production, increase the recovery factor, and extend the field's lifespan.

The main objective of this paper is to outline the principles and sequences governed by an Operational and Control Philosophy in Steam Generation and Injection operations for enhanced hydrocarbon recovery. By developing an operational philosophy, the effectiveness and efficiency of steam injection in oil wells can be successfully described. The methodology is based on analyzing data obtained from the Steam Generator SMT control systems and the operations of steam injection wells. The most important variables to consider during steam injection will be integrated.

To achieve this, the following improvements can be made to the summary:

Introduction: Emphasize the significance of maximizing hydrocarbon production and explain the role of technology in achieving this goal.

Objectives: Clearly state the purpose of the paper, which is to detail the principles and sequences governed by an Operational and Control Philosophy in Steam Generation and Injection operations for enhanced hydrocarbon recovery.

Methodology: Expand on the methodology used, including the analysis of data from Steam Generator SMT control systems and steam injection well operations.

By incorporating these improvements, the summary will provide a clearer overview of the paper's objectives, methodology, and key findings related to the Operational and Control Philosophy in Steam Generation and Injection operations for enhanced hydrocarbon recovery.

INTRODUCTION

The Steam Generator is a high-pressure boiler specifically designed for steam injection in oil fields. Its primary function is to convert water into steam at temperatures and pressures that deviate from atmospheric conditions, all in a single step. This specialized equipment is tailored for the efficient recovery of heavy and extra-heavy crudes with a gravity below 15 °API. Its design and capabilities make it a vital component in the steam injection process, enabling enhanced oil recovery in these challenging reservoirs.

Fig 1. SMT Steam Generator 25 MMBTU/hr

High-pressure and high-temperature steam generated by the Steam Generator produces saturated or superheated steam, delivering thermal energy (BTUs) to inject into the reservoir, stimulating the hydrocarbon and improving its viscosity and fluidity. This process facilitates the mobility of the crude oil, making it easier to extract. The Steam Generator, specifically the forced-circulation water-tube type, utilizes a coil for heat transfer and incorporates a combustion and exhaust system. The main function of the Steam Generator (SMT) is to produce high-pressure steam to compensate for the bottomhole pressure drop in the injection well.

The Operational Philosophy in Steam Generation and Injection is of utmost importance as it controls the operation of the Steam Generator and the Steam Injection process. This philosophy ensures the control of operational variables according to pre-established work schemes, aiming to minimize or eliminate failures and unproductive time in the process. It plays a critical role in optimizing the steam injection operations and enhancing the overall efficiency of the hydrocarbon recovery process.

GENERAL DESCRIPTION STEAM GENERATOR

The Steam Generator is a horizontal unit with a single pitch serpentine coil. This type of horizontal design is used for ease of installation and field repair.

The components and accessories of the steam generator are mounted on a robust steel structure integrated into a trailer divided into three zones.

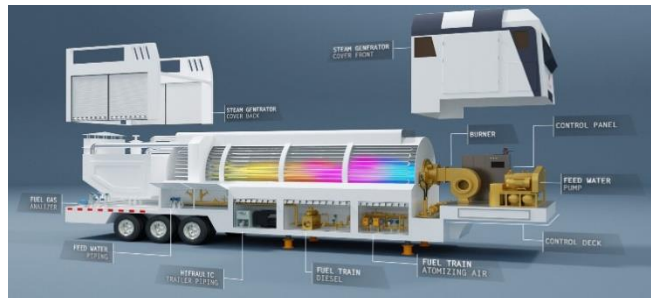

Fig 2. Parts of the SMT Steam Generator

Power and control section:

- CCM type panel, power supply and automation and control.
- Control system based on a programmable logic controller (PLC).
- Flame control system.
- Quintuplex bomb.
- Air compressor.
- Dual fuel gas burner.
- Pulsation dampers on the suction and discharge of the quintuplex pump.

Radiant Section:

Internally

- coil type pipes

Externally

- Feed water pre-heater.
- Fuel gas train.
- Diesel fuel train.
- Trailer hydraulic system.
- Water/steam interconnection
- controls and instrumentation

Convection Section

- Safety valves.
- Steam release valve.
- Steam vent valve.
- Combustion gas and steam quality analyzers.
- Temperature and pressure indicators.
- Flow, temperature and pressure transmitters.
- Steam pressure control valve.

1. STEAM GENERATOR STARTING PHILOSOPHY

The Steam Generator has an automatic control philosophy through a PLC, with a Gas / Diesel dual fuel burner, venting both in the pilot and in the burner, flame detection, electric ignition and continuous pilot which executes the sequence of starting, security and control.

The steam characteristic at the Steam Generator outlet is controlled by the pressure control loops in conjunction with the fuel control, the flow control loop and the steam quality analyzer.

To initiate the boot sequence on the Steam Generator, the following must be true:

Verificación of Permits.

- Generator emergency stop button, must not be active.
- Emergency stop button in control room must not be active ***. (IF APPLY).***
- Pilot gas vent valve open.
- Gas burner vent valve open.
- Pilot gas block valve closed.
- Gas burner shut-off valve closed.
- There should not be High steam temperature.
- There should be no High temperature radiant zone.
- There should be no Low water flow.
- There should be no low fuel gas pressure.
- There must not be high pressure of fuel gas.
- There should not be low air pressure in the burner fan duct.
- There should be no Low air pressure from the instrument.
- The flame controller must not be faulted.
- Permit lights on.
- Move the ignition selector of the flame programmer to “ON”, this verifies the low fire position of the control valve.

Once the ignition permits have been verified, the flame programmer executes the following action.

Pre-purge of gases in the steam generator home.

Place high fire in the “ON” position, on the control panel, to activate the burner air blower, to purge the flammable gases in the steam generator furnace.

Once the pre-purge time has elapsed, the flame controller positions the burner damper to low fire and the Pilot Gas “ON” indicator lights up on the Local Control Panel.

Pilot ignition.

Once the purge is finished, the flame controller starts the spark generation process, the pilot vent valve closes, the pilot block valve opens, the presence of flames is verified through the flame detector. turn on the pilot, the indicator light on the pilot on will come on on the dashboard and the sequence continues.

If the presence of a flame is not detected within a certain time, the ignition process is aborted, the vent valve opens automatically and the blocking valves close. The cause of the failure is investigated and corrected, then waits one minute before trying to light the pilot again.

Burner ignition.

Once the flame sensor detects a stable flame, the "GAS Pilot ON" indicator illuminates steadily, the Flame Controller proceeds to automatically close the vent valve of the line to the burner and energize the two Maxon block valves of the line to burner.

The gas will pass to the burner through the self-regulating pressure valve and the generator will ignite in minimum flame conditions (30-40%). Once the generator is lit, the operator must visually verify the quality of the flame and adjust it if necessary (intonation).

The adjustment of the operating conditions at the outlet of the Steam Generator is carried out from the Allen control system, to dispatch a defined quantity of steam with the required pressure and quality.

If a stoppage occurs in the steam generator, it must be verified that the condition causing the Stoppage returns to normal, the generator can be reactivated by the operator, resuming the burner ignition step on the Control Panel.

2. STEAM INJECTION PHILOSOPHY

When starting a Steam Generation and Injection cycle in an oil well, a sequence of activities must be followed to avoid back pressures or system failures when aligning the steam with the reservoir.

To achieve equilibrium in the system, it is essential to take into account the following premises:

- Open the master valve and the wellhead valve, to avoid back pressures in the steam injection stabilization process.
- As soon as the operating parameters are stabilized ± 300 psi / 300 °F at the outlet of the Steam Generator, the alignment of the steam to the reservoir begins.
- Gradually open the valve on the injection line to the well and slowly close the generator vent or relief valve to stabilize the process.
- Open the lateral valve of the "production casing" well and the relief or vent valve must be closed to avoid the gradual increase in temperature - pressure and the leakage of the thermal insulation (IF APPLICABLE).
- Observe in the local temperature and pressure devices or indicators the increase or behavior of the operating parameters in the Steam Generator, Wellhead and casing.
- Wait until achieving thermal equilibrium in the system and thermal expansion.
- , the operating values must be established according to the established injection program.
- Achieve minimum steam quality of 80% and adjust parameters
- Start of Injection Pi = Pb + 100 psi
- Max. Rat Water Flow (Qm) ≥ 52 gpm

3. EVALUATION OF OPERATION PARAMETERS.

During the steam generation and injection process, it is extremely important to constantly monitor the operational variables that may limit or cause damage to the proper functioning of the steam generator and the injection of steam into the well.

It is essential that during the steam generation and injection process take into account the following premises:

- Record in the book and the daily report sheet, the operational parameters during the steam injection cycle.
- They will record all the novelties that occur during the injection cycle.
- Keep close watch on the behavior of the annular valve, to avoid back pressure, repression or leaks.
- The pressure in the annular space should not exceed 1200 psi during the injection period.
- During the injection period, the annular temperature should not exceed 300°F.
- If an elongation value greater than 7” is reached, it must be notified immediately.
- Continue steam injection until reaching the programmed tons.
- Maintain flow and injection pressure.
- Comply with the scheduled injection days.
- Finish injection cycle.
- Analyze the behavior of Pressure and Temperature in the steam generator, wellhead and production casing.

Limits or operational parameters

DESCRIPTION	LIMIT VALUE
Water flow (GPM)	*<52 GPM*
Suction Steam generator	*30PSI*
PSI steam discharge	*<1800PSI*
Temp. steam discharge	*<630 °F*
Temp. radiant zone	*<750°F*
Temp. chimney	*<700°F*
Air compressor	*80-100PSI*
steam quality	±95 *%.*
inlet pH	*7.0*
output pH	*12.0*
Or $_2$ entrance to the Generator	*0.10mg/kg.*
Hardness of water	*⩽0.1mg /l*
DESCRIPTION	**LIMIT VALUE**
Fuel gas	*0.7MMSCFD*
Net Thermal Efficiency	*90%*
maximum heat released	*25 MMBTU/Hr.*
Wellhead Pressure	*<2100PSI*
Temp. wellhead	*<600*
Production Rev. Pressure	*≤1,200 psi*
Temp. Rev. Production	*< 300°F*
Elongation	<14"
O $_2$ concentration	*18 – 21%*
$_{H2S}$ concentration _	*<5ppm*

4. IMPORTANCE OF MONITORING THE VARIABLES DURING THE STEAM INJECTION PROCESS

In order to obtain reliable results in the Steam Generation and Injection process in oil wells, it is extremely important to have reliable data on the process that allows for the issuance of reliable reports.

In the Steam Generation and Injection process, the continuous monitoring of the parameters is carried out through an Operations Report where they are read in the local indicators, transmitters and panel view located in the Steam Generator, treatment plant. and well head, in addition to performing chemical physical analysis of the water to check water hardness, dissolved O $_2$ and steam quality.

An out-of-limit operational parameter can shorten the useful life of the generator, treatment plant, or injection well. Therefore, it would lead to a low production rate in the reservoir, a structural failure in the well, or damage to the steam generator pipes.

Operational parameters that must be constantly monitored or analyzed to avoid misoperation or system failures are described:

Water Hardness or CaCO3

High concentrations of calcium and magnesium salts in the feed water to the steam generator favor the formation of deposits and scale on the pipe surface, which causes losses in heat transfer efficiency. Due to this cause, the hardness in the feed water to the steam generator must be zero (0 ppm).

O_2 entrance to the Generator

High concentrations of oxygen in the feed water to the steam generator cause pitting in the pipes, attacking copper and copper alloys. Corrosion reduces the heat transfer rate, efficiency and reliability of the Steam Generator.

The oxygen present in the water favors the corrosion of the metallic components of a Steam Generator. Pressure and temperature increase the rate at which corrosion occurs.

That is why an oxygen sequestering product must be adequately injected and its concentration must be less than 0.10mg/kg *.*

pH determination

In order to avoid corrosion of the metal parts of the steam generator due to the presence of oxygen, the degree of alkalinity or acidity (pH) is measured. The pH represents the acid or alkaline characteristic in the water, so its control is essential to prevent corrosion problems (low pH) and deposits (high pH).

pH value scale (hydrogen ion concentration):

- pH between 0 and 6 indicates acidic water.
- pH equal to 7 indicates neutral water.
- pH equal 8 and 12 indicates alkaline water.

It is recommended that the pH of the water in the steam generator be in the range of 7.0 - 12.0

The treatment of the feed water for a Steam Generator is essential to ensure its useful life, and to avoid corrosion and incrustation problems.

The quality assurance of the steam generator feed water is achieved by complying with the requirements of the standards, which define the recommended limits for the parameters involved in water treatment.

Steam Quality

It is given by the mass percentage of dry (80%) and wet (20%) steam in a liquid-steam mixture. 80% dry steam, 20% wet steam that entrains dissolved solids, thus reducing the possibility of vaporization, preventing or avoiding precipitation, deposition, or scaling and subsequent failure in steam generator piping. There are technologies such as Nakasawa's Super Matroid Technology that can handle 95 to 98% quality without affecting the operation of the steam generator because it has a cyclone separator in the steam generation system.

Fig 3. Steam Quality Monitoring

H2S concentration

The concentration of H2S in fuels can accelerate the corrosion processes of the system and in concentrations greater than 5 PPM, it is harmful to health; This is a colorless, toxic, flammable, corrosive, and polluting gas that is heavier than air. If it is not monitored correctly, it can cause mild irritation of the eyes and respiratory tract, unconsciousness, possible pulmonary edema, death and irreversible damage to the equipment, for this reason its maximum allowable working value is 5 ppm, it is recommended to work under a 0 ppm.

Production Casing

Section of a well through which the production fluids and injected fluids move. In the design for steam injection, the injection tubing goes inside its section, for which it is essential to isolate the tubing from the casing. You can use the VIT pipe or, failing that, an insulator with N2. When high temperatures occur, the casing and cementation can suffer irreparable damage if not properly insulated, they can suffer high elongation or browning and the thermal gasket can fail.

Elongation

Elongation is an important parameter to monitor, since during the cyclical steam injection process, the mechanical structure of the well expands due to the expansion effect received by the heat transmitted from the saturated steam. Elongation is represented as an increase in length where high strain means that the material is ductile and is caused by wellbore thermal stress related to material fatigue. To avoid deformations and possible structural damage to the tubing, a ≤15” elongation is recommended.

In systems with insulated piping, the Casing elongation is in the range of "0 to 1.5" due to its excellent insulation.

Fig 4. Wellhead – Elongation.

5. GRAPHICS FOR MONITORING OPERATIONAL PARAMETERS IN THE BEHAVIOR OF STEAM GENERATION AND INJECTION.

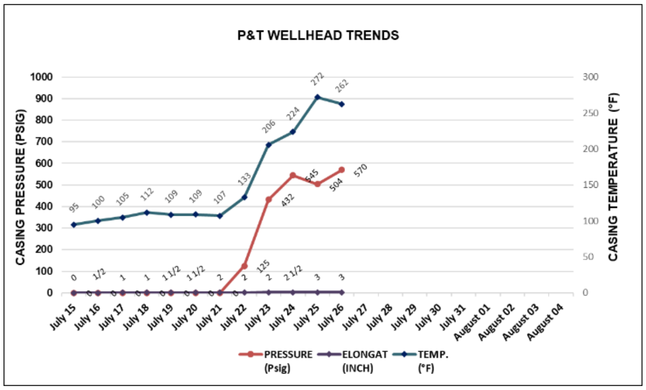

Fig 5. Pressure and Temperature Behavior in the Wellhead – Production Casing and Elongation of the Well

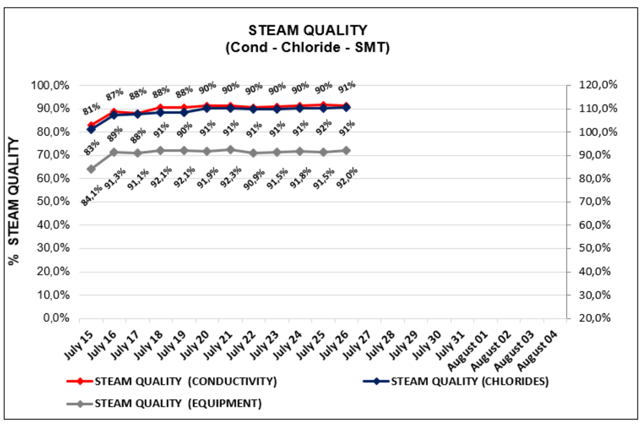

Fig 6. Behavior of Steam Quality in the Steam Generator.

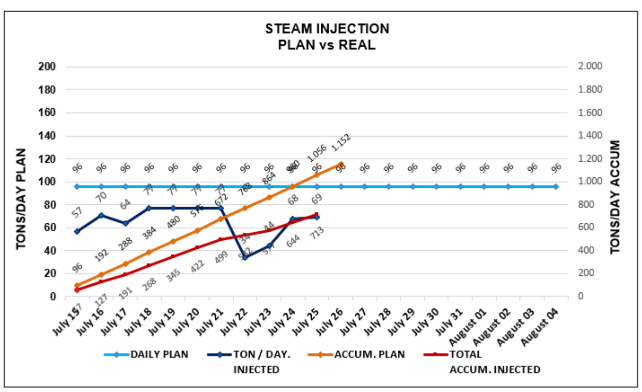

Fig 7. Behavior of Injection of Tons of Steam in the Well.

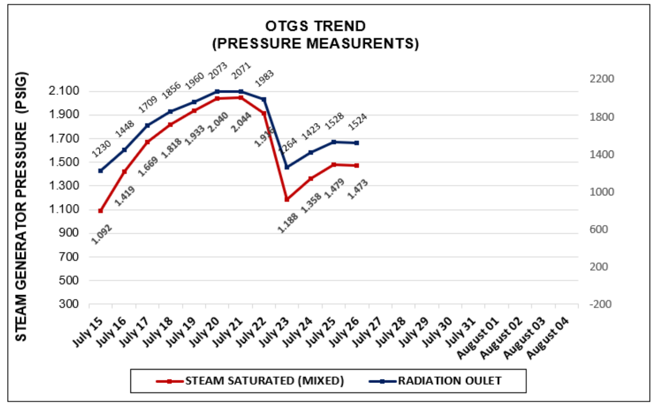

Fig 8. Pressure behavior of the Steam Generator.

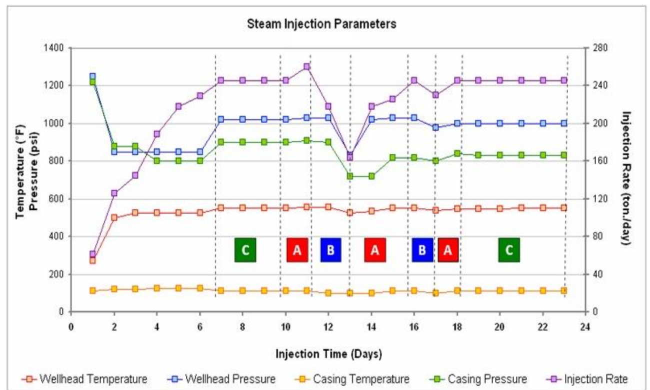

Fig 9.- Graph model in the behavior of parameters taken in the Generation and Injection of steam.

CONCLUSIONS

- The generated operational philosophy ensures the success, effectiveness, and efficiency of steam injection. By following a well-defined operational philosophy, operators can optimize the steam injection process and achieve the desired results in enhanced hydrocarbon recovery.
- Obtaining reliable results in the Steam Generation and Injection process in oil wells is of utmost importance. Keeping accurate and reliable data throughout the process enables the generation of

trustworthy reports and facilitates informed decision-making.

- When initiating a cycle of Steam Generation and Injection in an oil well, it is crucial to follow a sequence of activities to avoid counter pressures or system failures when aligning the steam with the reservoir. Proper planning and adherence to a well-structured sequence minimize operational risks and ensure smooth operation.

- Operating beyond the defined limits of operational parameters can significantly reduce the lifespan of the steam generator, treatment plant, or injection well. It is essential to monitor and control these parameters within acceptable ranges to prevent equipment failures and optimize their longevity.

- By improving these conclusions, we emphasize the importance of a well-defined operational philosophy, reliable data management, adherence to proper sequences of activities, and the significance of operating within defined limits to ensure successful steam injection operations and enhance the longevity of associated equipment.

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