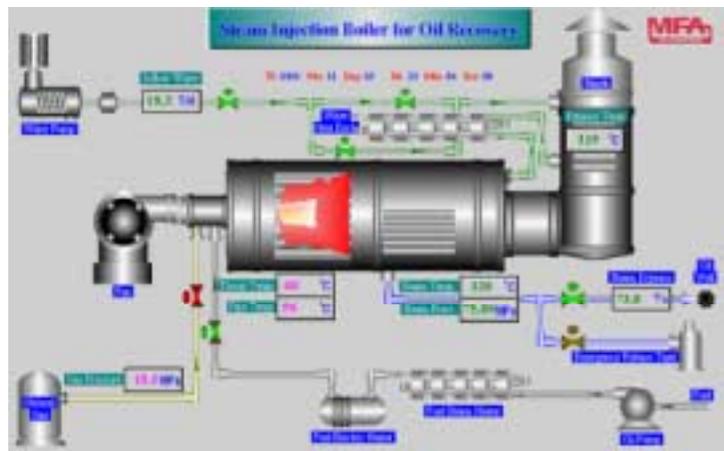
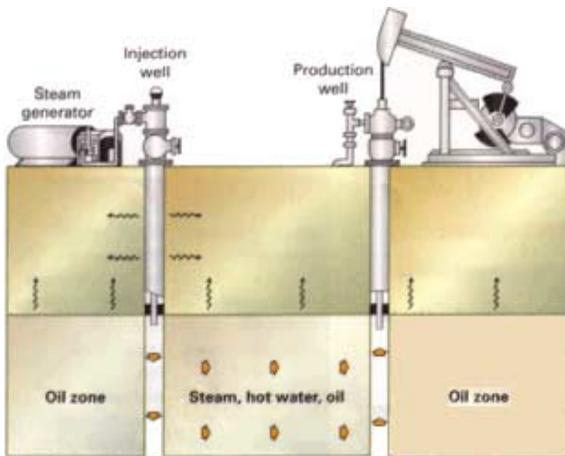


MFA Control and Optimization of Oil Recovery Boilers

| <i>Use of CyboSoft's Technology</i> | <i>Benefits</i> |
|---|--|
| Soft-sensor measurement of steam dryness in CyboMax to monitor the steam quality. | Monitors boiler steam dryness online to ensure consistent quality of steam for higher oil yield. |
| MFA control of steam dryness, temp, and pressure with optimal fuel-and-air ratio. | Improves boiler combustion efficiency while optimizing steam production and oil yield. |
| Easy integration and startup. | ROI in 1 year on energy savings (yield increase extra). |



CyboSoft's EOR Steam Boiler Control and Optimization Solution

Process: Light crude oil can be easily recovered by using the natural gas pressure within the reservoir and sub-surface pumping. However, heavy crude oil requires enhanced oil recovery (EOR) such as steam flood recovery. High pressure steam is injected into the reservoir. The steam and resultant hot water lower the viscosity of the heavy crude oil and enable it to flow into the reservoir and then be pumped to the surface.

Challenges: High pressure steam is generated by using special steam boilers. It is difficult to monitor and control the quality of the steam – steam dryness. The optimal steam dryness for oil recovery is at 72%. If it is too dry, too much energy is wasted. If it is not dry enough, the steam will not

have enough power to dissolve the oil.

Steam Dryness: Typically, steam dryness is manually determined by measuring the pH value of boiler inflow water and condensed water by using a test kit. Since it requires pH titration, it is a tedious job. The periodic test does not provide real-time data for automatic control of steam dryness.

Goals: To efficiently achieve maximum oil yield, it is desirable to monitor and control the steam dryness automatically.

Solution: CyboSoft offers a turnkey solution for steam dryness measurement and control. By using a special soft-sensor technology, steam dryness can be accurately calculated online. Model-Free Adaptive (MFA) controllers are used to automatically control steam pressure, temperature,

dryness, and water flow to ensure efficient and smooth boiler operation.

MFA Control: A 3-element MFA control system is implemented to control the dryness and critical process variables. Fuel-and-air ratio is auto-adjusted to improve combustion efficiency.

Application Story: PetroChina has deployed multiple MFA control and optimization systems for its EOR steam boilers in Liao-He Oilfield. PetroChina has certified the following success:

- A 3% to 4% increase in boiler combustion efficiency;
- A 17.6% electricity savings;
- Steam dryness measurement accuracy within +/- 1%;
- Steam dryness control within +/- 3% in all operating conditions; and
- Improved production safety and productivity