Use of Electric Downhole Heaters to Prevent Wax Build-up, Offshore, West Africa

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AGENDA

- Issue - ensure a fluid temperature throughout the identified well-bore length that is above the expected wax appearance temperature
- Solutions – which Electric Downhole Product is best suited to application
- What has been achieved

Programme – First Steps

- **Pentair Thermal Management was contracted in June of 2006 to perform a Feasibility Study on the Down Hole Heating System for a proposed Development Field, located off the West African coastline. The intent of the feasibility study was to provide a technical and economically viable solution to the unique heating needs of these offshore wells.**

- **The first step in this study was to properly evaluate the well-stream and well-bore conditions, specifically to define the heat-input requirement for the length of the production tube.**

- **This process included the analysis of several well-bore geometries; gas-liquid ratios; fluid/gas temperatures, differing flow rates, and other well-stream specific criteria pertinent to the thermal-hydraulic modelling needs for these wells.**

Programme Requirement

- **The engineering study was needed to conclude the following:**
  - What is the target WHT under normal production?
  - What is the target temperature for well start-up?
  - Heat input required versus well conditions (P, T, GOR, water cut, gross liquid rate)
  - Which heater technology is appropriate? What is the reduction in WHT for each option?
  - Electrical sizing of topsides equipment (based on development concept). How does this differ between options?
  - Schedule and cost estimate for equipment and installation services

Field Conditions

- **Waxy Crude – WAT of +40°C, API of 33**
- **Fractured Reservoir with multiple wells**
- **Expected variable GOR over life of wells leading to variable flow rates**
- **Expected variable Water Cut over life of wells leading to variable flow rates**
- **Wax re-melt facility after shut-in**

Solution/ Modelling

- **Wellbore Model to Client Data Comparison**
    - Client Data Matching
        - Accuracy - to confirm the accuracy of the modelling software by using client Test data
    - Definition of Investigation Matrix ; to prepare lifetime scenarios – max flow for early well, intermediate flow for mature well, low flow for late well

- **Cases Without Down Hole Heating**

- **Cases With Down Hole Heating**

- **Cool-down & Heat-up**

Technology Discussion

Once the thermal-hydraulic modelling had been completed, the evaluation of the correct heating method could then be investigated.

- **Mechanical - Scraping/ Pigging –**
  - Lost production due to intervention
  - Frequency
  - Infrastructure costs & labour costs
- **Chemical**
  - Cost
  - Infrastructure costs
  - Recovery
  - Back-up

ELECTRIC DOWNHOLE HEATING

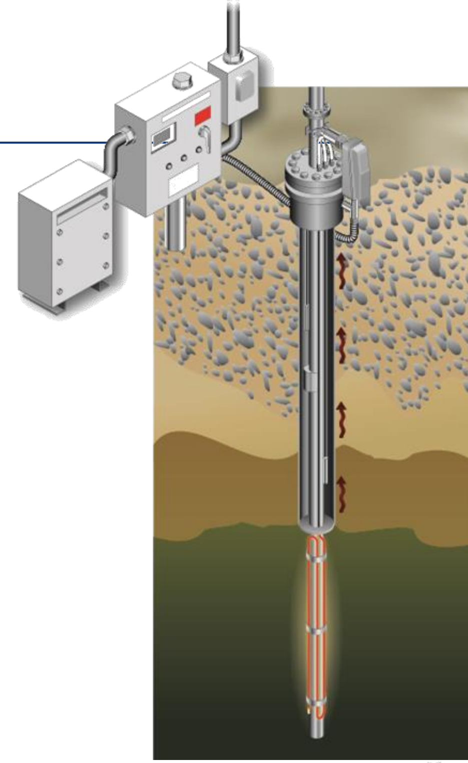
ENHANCED OIL RECOVERY (EOR)

Definition

Increase the amount of hydrocarbon entering the production tube by adding heat to the formation

Application

Heavy Oil production



Enhanced Oil Recovery (EOR)

FLOW ASSURANCE

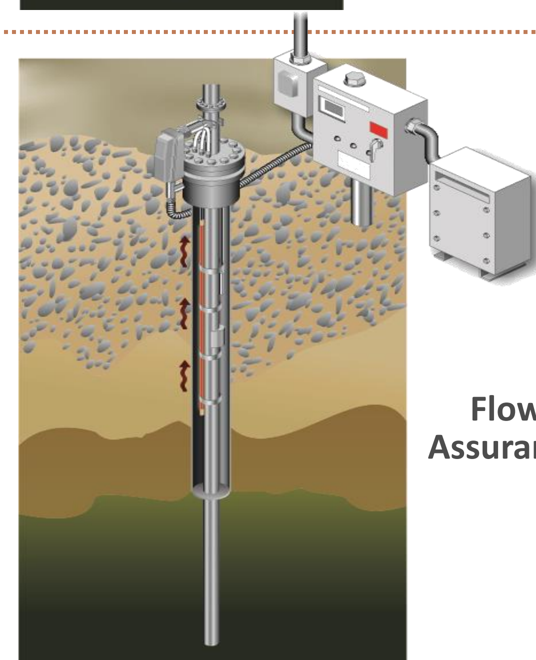
Definition

Getting the hydrocarbons from the reservoir to the wellhead

Application

Prevent Wax/Paraffin & Hydrate

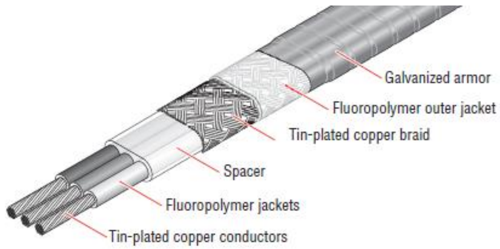
Reduce Viscosity from reservoir to well head (Heavy Oil)



Flow Assurance

PetroTrace Down Hole Heater Cables

PetroTrace

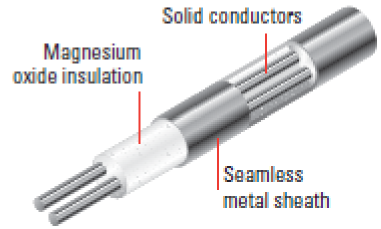


PetroTrace **DHSX**

Series resistance cables

Our DHSX downhole heater provides **Flow Assurance** heating to <u>3300ft (1km) </u>TD, in applications where lower power levels are sufficient.

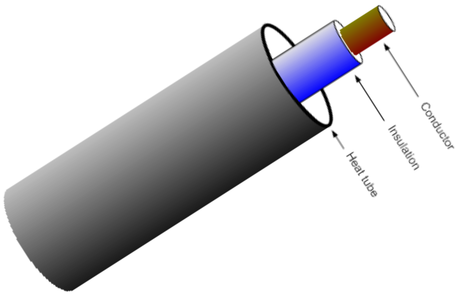
50 degC max
30kW to 45kW typical



PetroTrace MI cables

The downhole version of our MI cables are made to withstand the wellbore environment for **EOR and Flow Assurance** applications. Standard designs can provide very high power output over lengths up to <u>4000ft (1.2km), </u>reaching to <u>8000ft (2.4km) </u>TD or more.

482 degC max
20kW to 300kW typical



Coiled Tube Skin effect Systems (STSi)

For downhole use, we provide our STS heater in coiled tube form. This heater is well suited for **Flow Assurance** applications requiring moderately high power, for depths up to <u>6900ft (2.1km) TD.</u>

150 degC max
100kW to 400kW typical

Conclusion

Of the three Pentair technologies currently available for this type of application – DHSX, MI and STS – modelling shows that the MI Cable is the best overall solution for this service. The MI Cable can provide the required watt-density and can be manufactured to the lengths required.

Most importantly, the MI Cable can meet the requirements of the most extreme the well conditions in the Field. The DHSX or STS technologies may still be used on select wells where conditions are applicable; but if only one technology were to be deployed throughout the Field to meet the most extreme cases, then the MI technology would be the right answer.

Downhole Heating System

Offshore West Africa
600V 3-Phase with Wye Splice
P/N#: PTM-3P-3278-10
Revision: 2 - Change to 3278 feet, 600 Volts

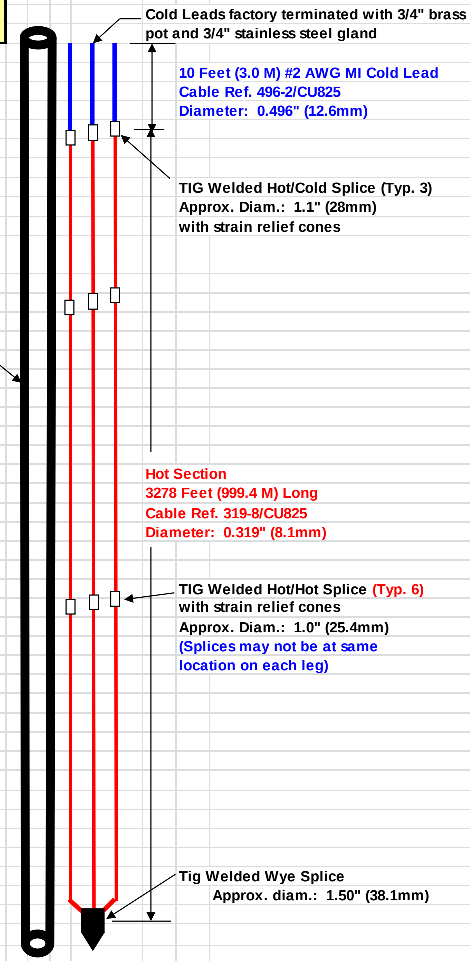
Each heater supplied on a wooden
Reel Part No. RL 78 x 36

Weight/Heater:	1930	Lb.	875	Kg
Reel Weight:	456	Lb.	207	Kg
Estimated Shipping Weight/Htr:	2386	Lb.	1082	Kg

Section No.	Watts/FT (Watts/M) of Pipe	Watts per Section
Cold Lead	10.5 (34)	105
Hot Section	43.4 (142)	142,200

Running Current (Amps) in oil at avg. 127˚F (52.8°C)	136.7
Startup Current (Amps) at 68˚F (20°C)	160.3

- All heating and cold lead cables are 1/c Alloy 825 sheath.
- There will be at least as many Hot/Hot splices as shown.
- All splices TIG welded with Alloy 825 components.
- Location of joints to be staggered at least 1 foot (300mm) apart.



Power and Control

- **Four separate platforms**

- **Each with:**
  - Distribution board
  - Master control panel
  - Thyristor Controlled Power Cabinets

- **Thyristor Control used as electronic contactor (on/off control) with coarse power control via manual autotransformer taps.**

- **Local control via independent PLC with integration into remote DCS on FPSO for remote operation**

Fully automated multi-well control system

- **31 thyristor cabinets distributed across four platforms (3x 8, 1x 7).**
- **Each platform has its own DCS/PLC system for independent and local platform control.**
- **Remote information for all platforms available on field FPSO using subsea fibre optic communications network.**

Thyristor cabinet suite for multi well fully automated control system

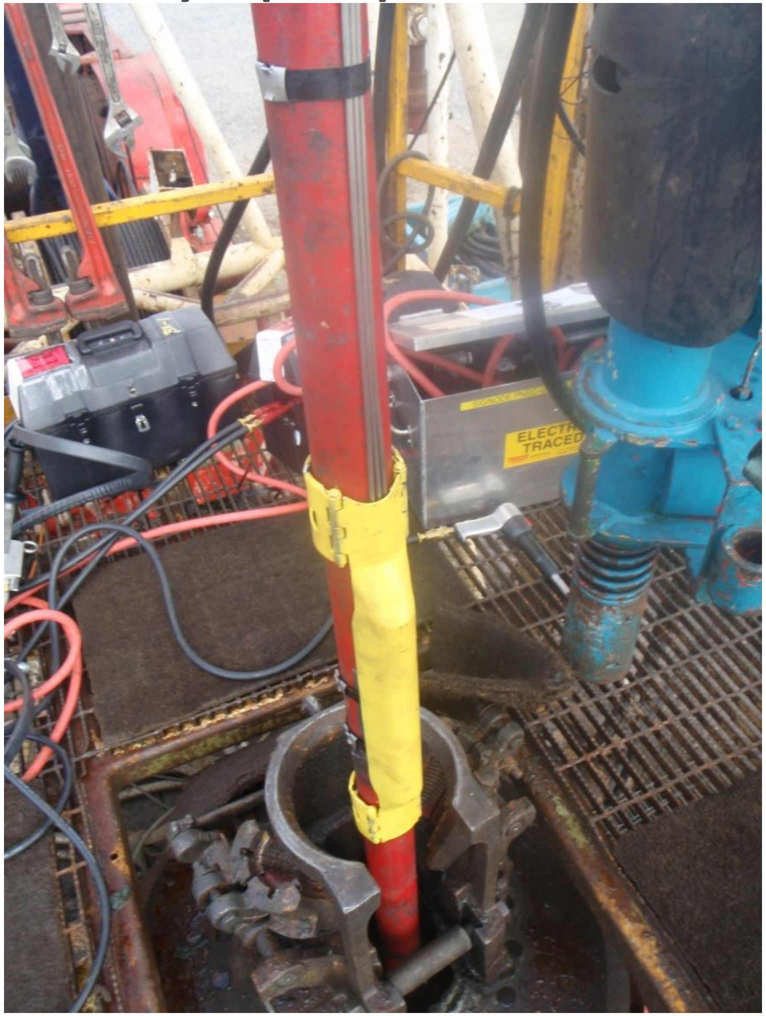
MI Heater Installation

Wye Splice Protector

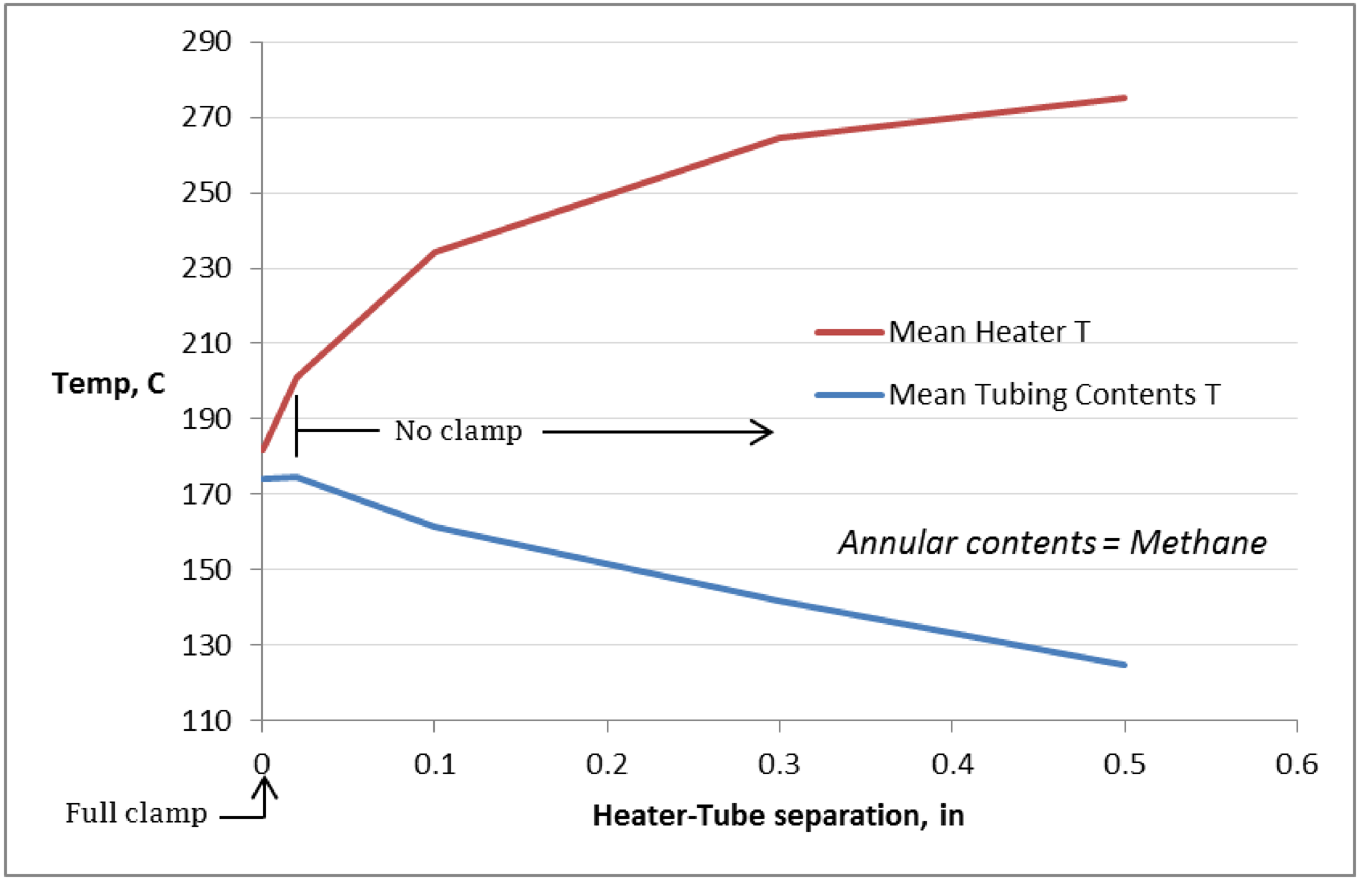
Cable Clamps & Protectors

Centralizing Clamp

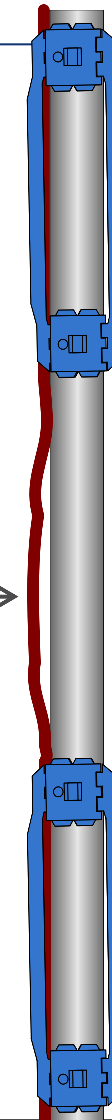
Wye splice protector



Heater-Tubing Separation (cable "sag") effect



Cable sags away from tubing



Clamping heater to tubing improves heat into tubing

MI Heater Installation

Mandrel Based Penetrator

Individual Penetrator System

What has been achieved

- A number of heaters have been deployed and operational since 2010
- “ …. Oil production rates have greatly increased on wells with DHH deployed compared to those that haven’t”
- “….wells which did not have DHH, wireline intervention could not pass beyond the mud line whereas those which did have DHH installed were as clean as a whistle”
- “…Full evaluation is on-going as field performance has been affected by other operational issues but the wellbore heating is doing exactly what it was designed to do”
- Some heaters were inactive for 10 months but were restarted without problem allowing production to re-commence.

Thank You!