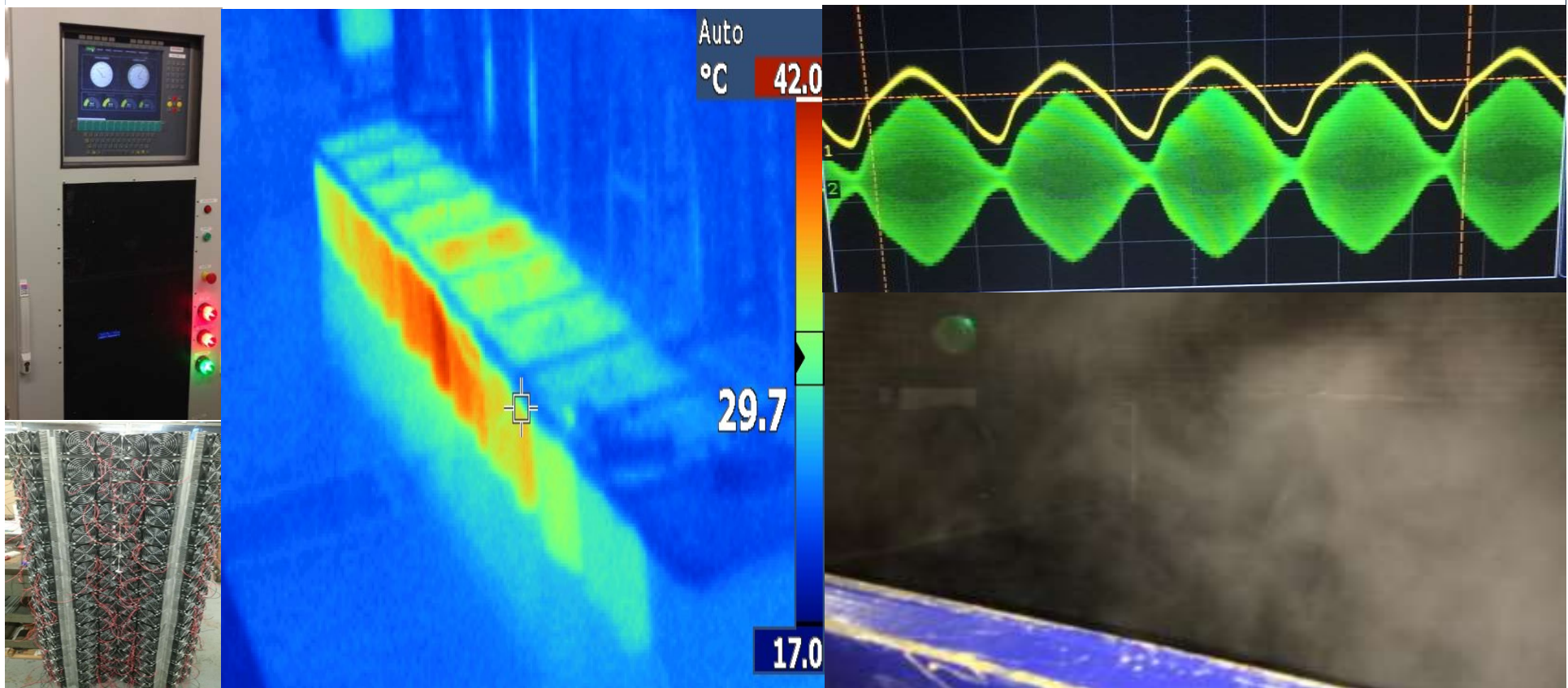


Tullow Oil - Innovative Heating Update



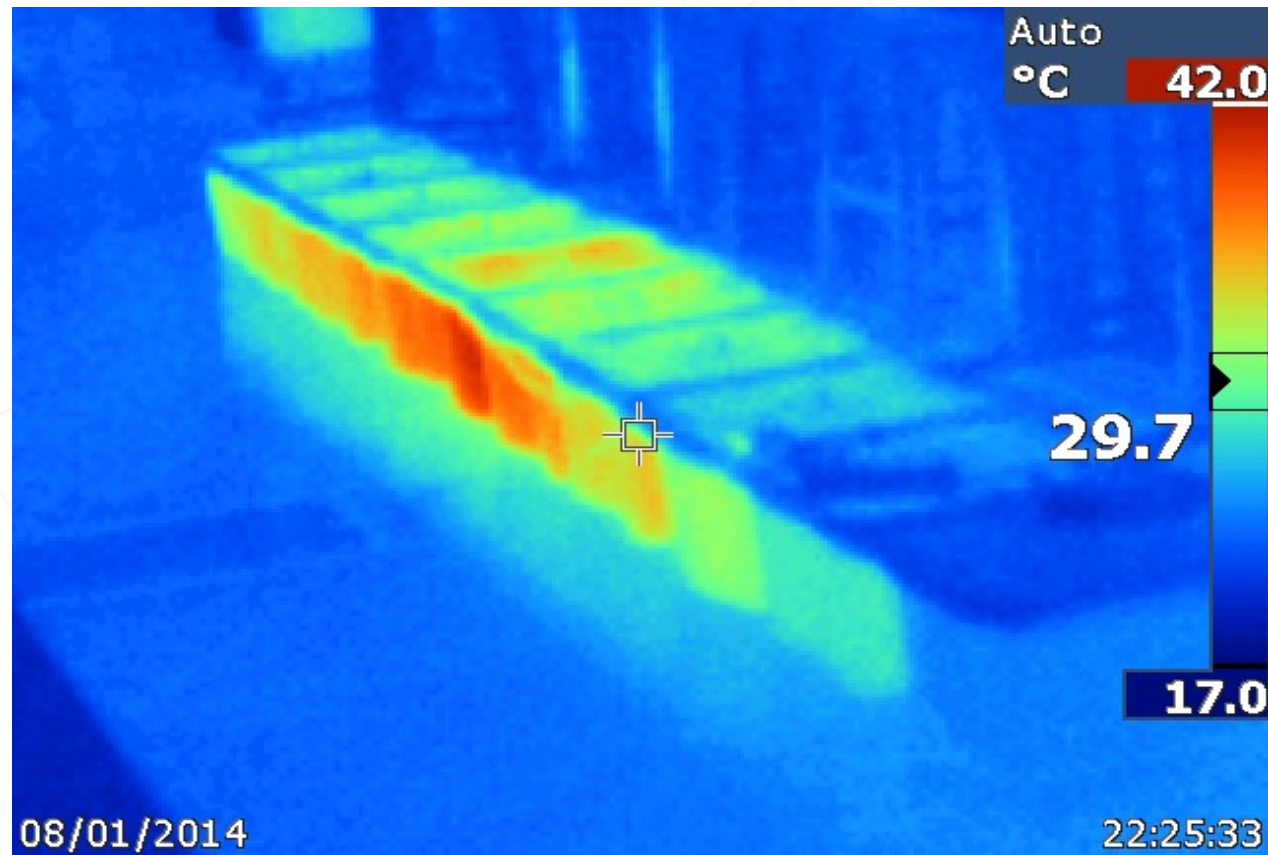
Shahrokh Mohammadi - January 2019



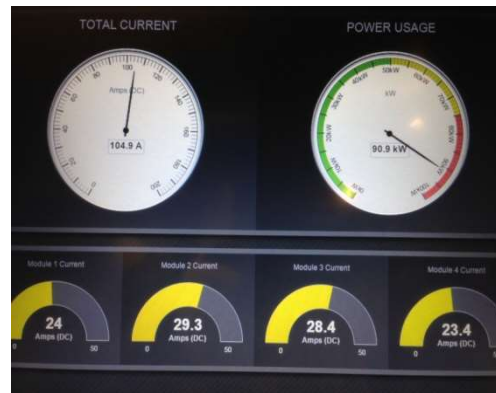
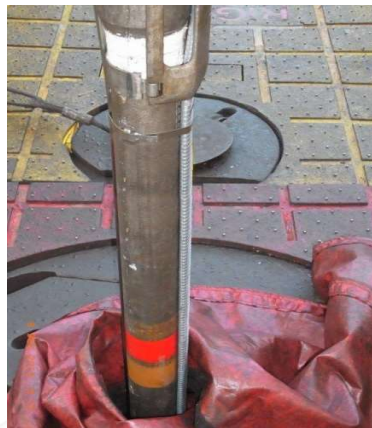
Targeted/Selective Heating via High Frequency Heating HFH Wells – Classic



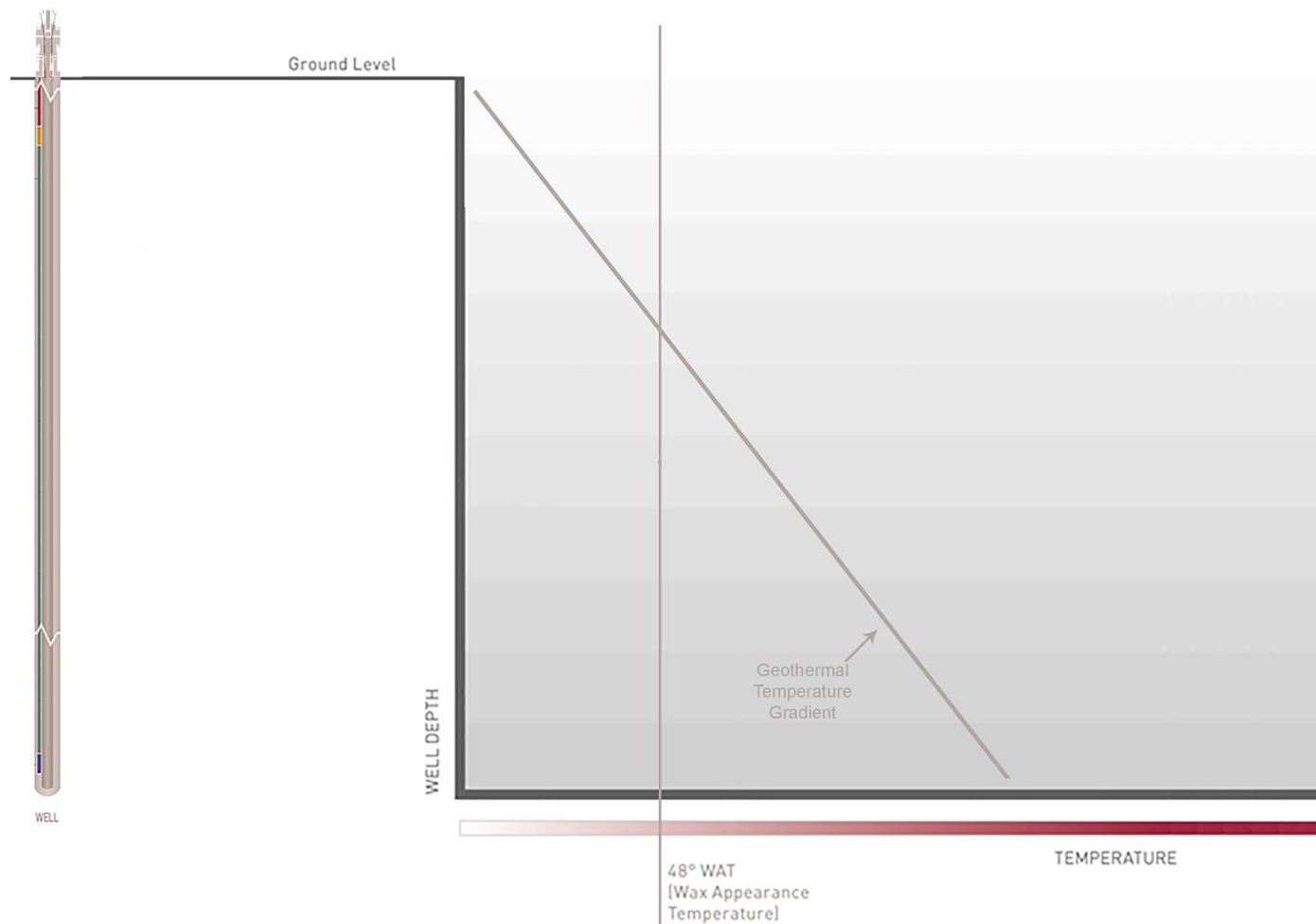
- Simulated heating of well 1000m deep
- Ten boxes each with 100m cable (in water)
- Any box can be targeted/selected for heating via HFH



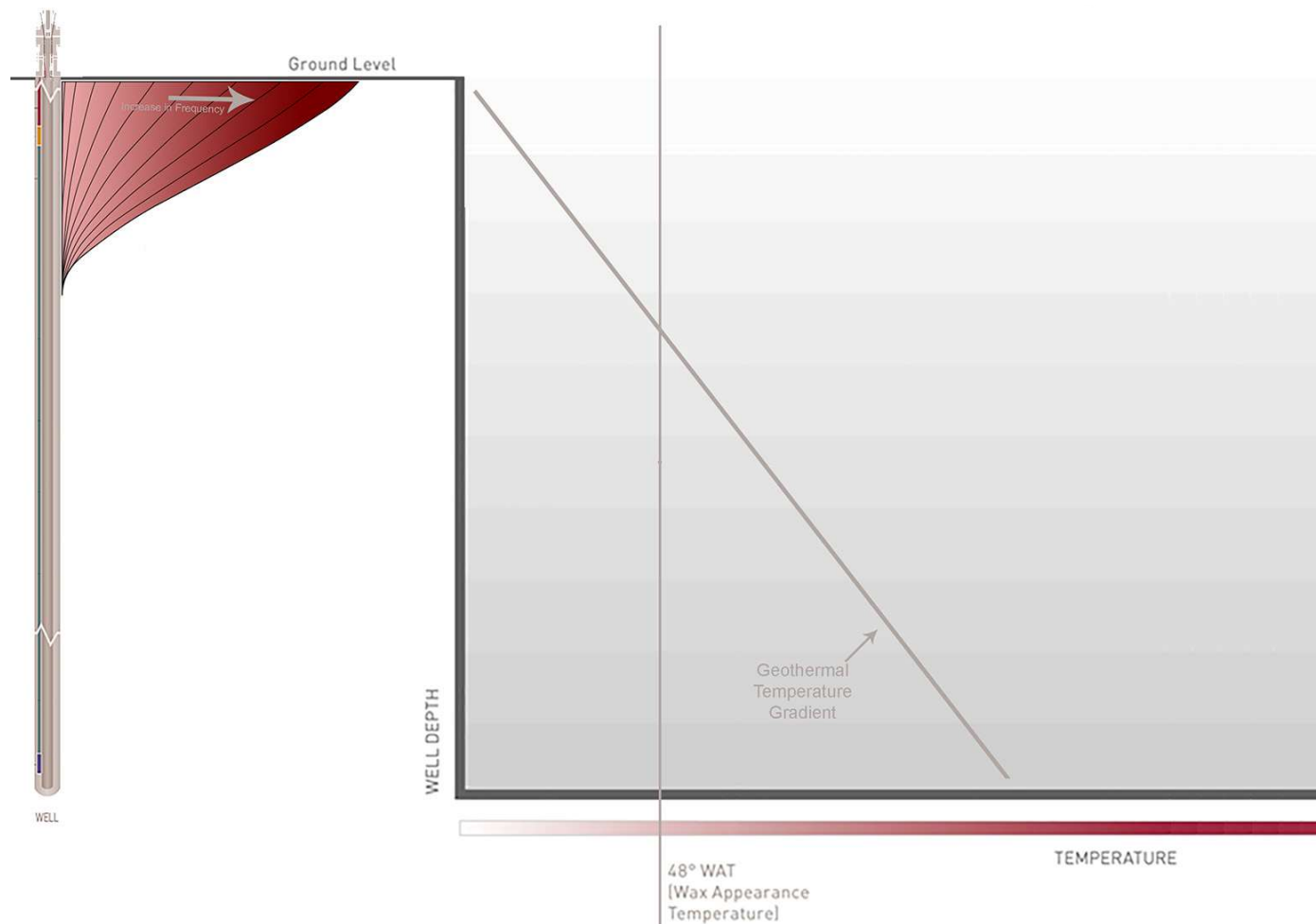
HFH Classic – SIT on a Test Well



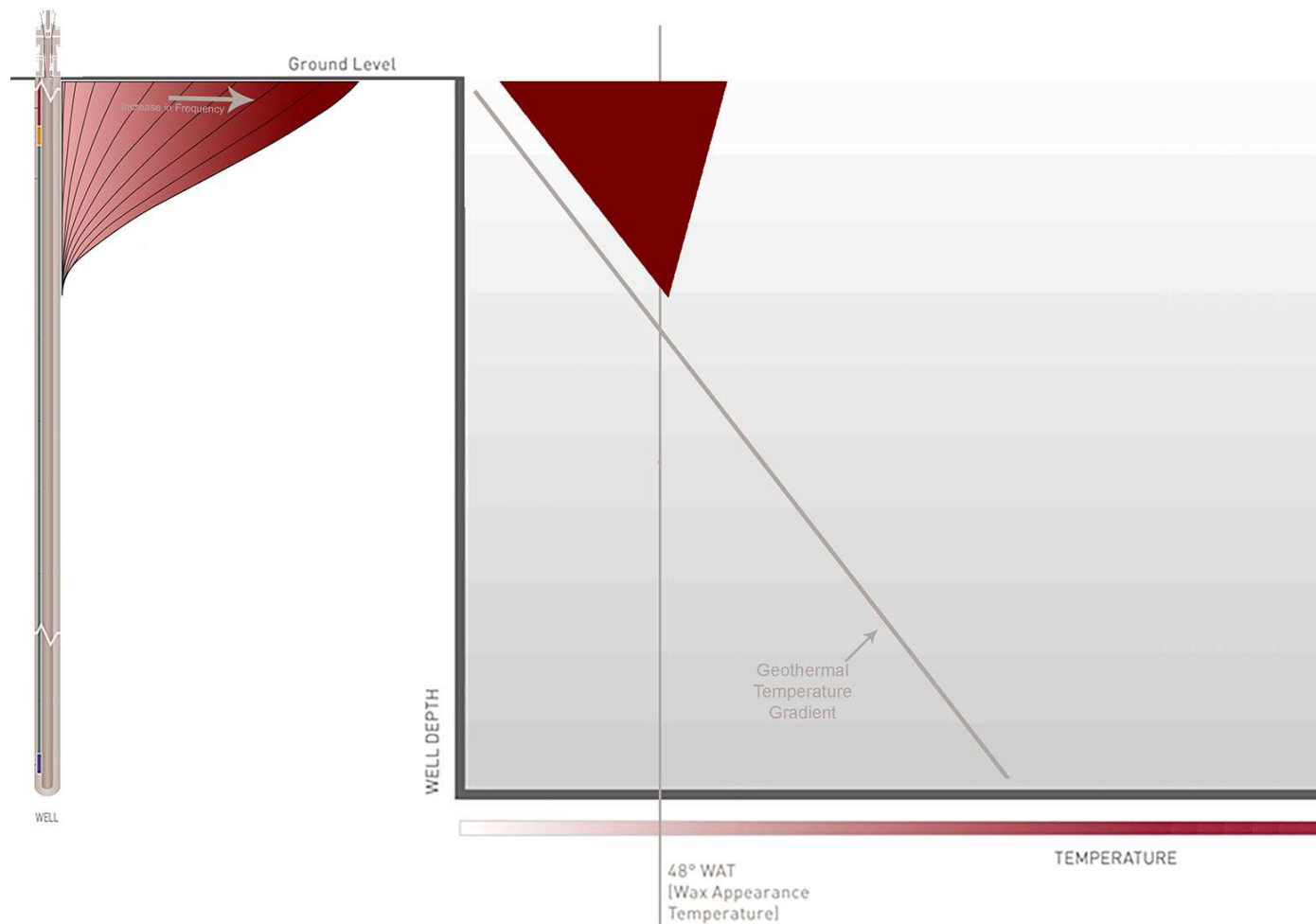
Heat Profile Comparisons



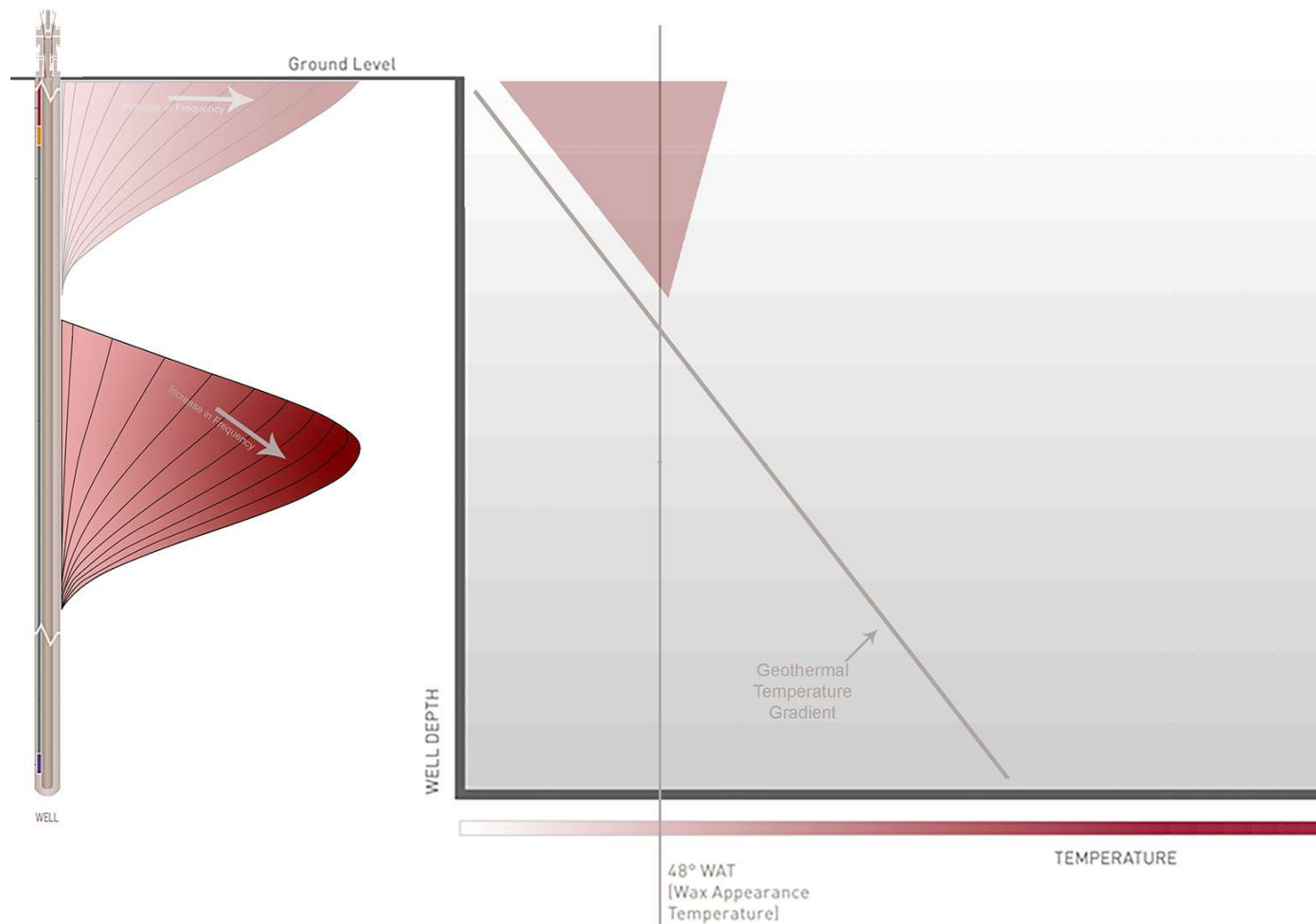
Heat Profile Comparisons - Targeting Near Wellhead Region



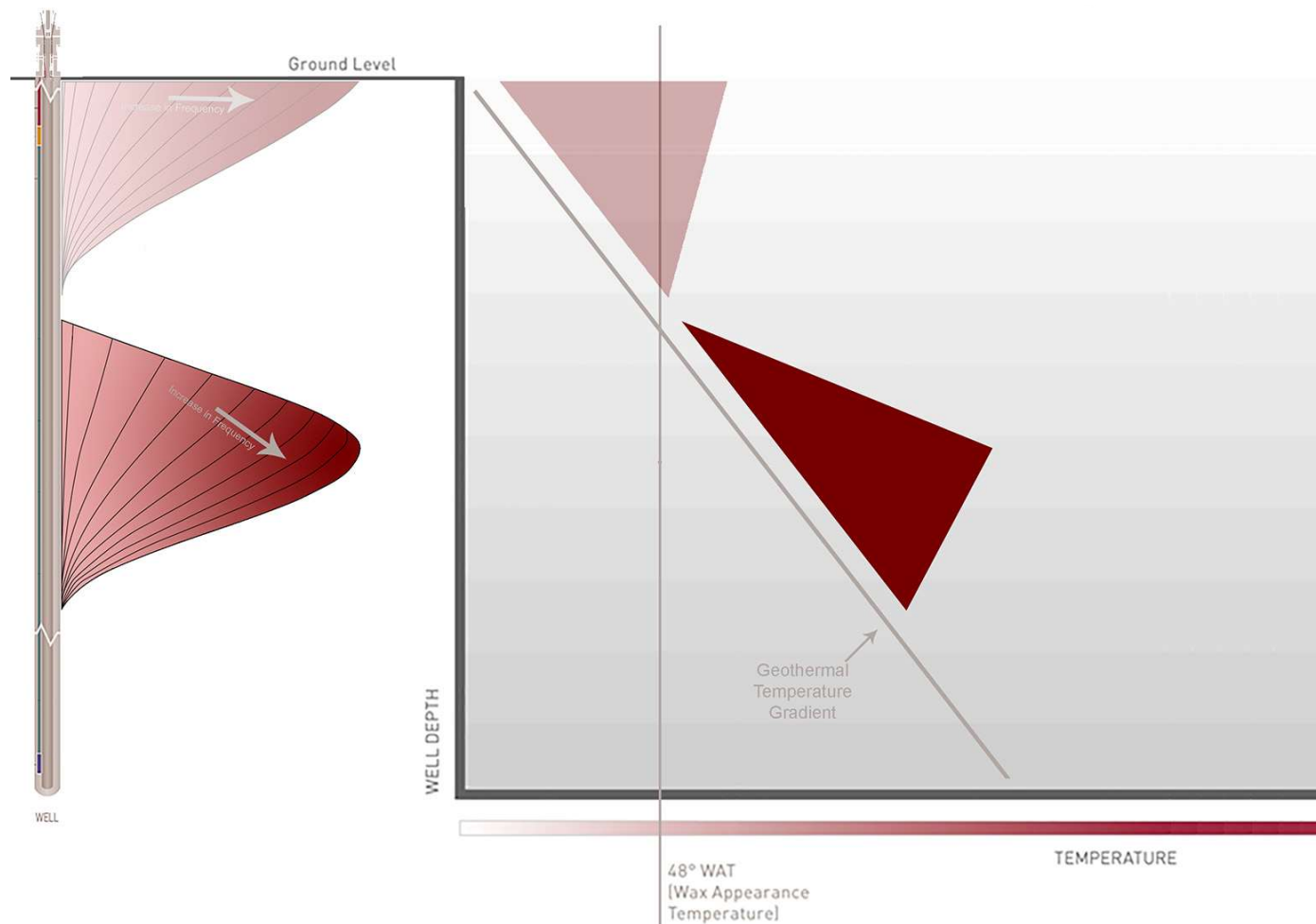
Targeting Near Wellhead Region – Heat Profile Imposed



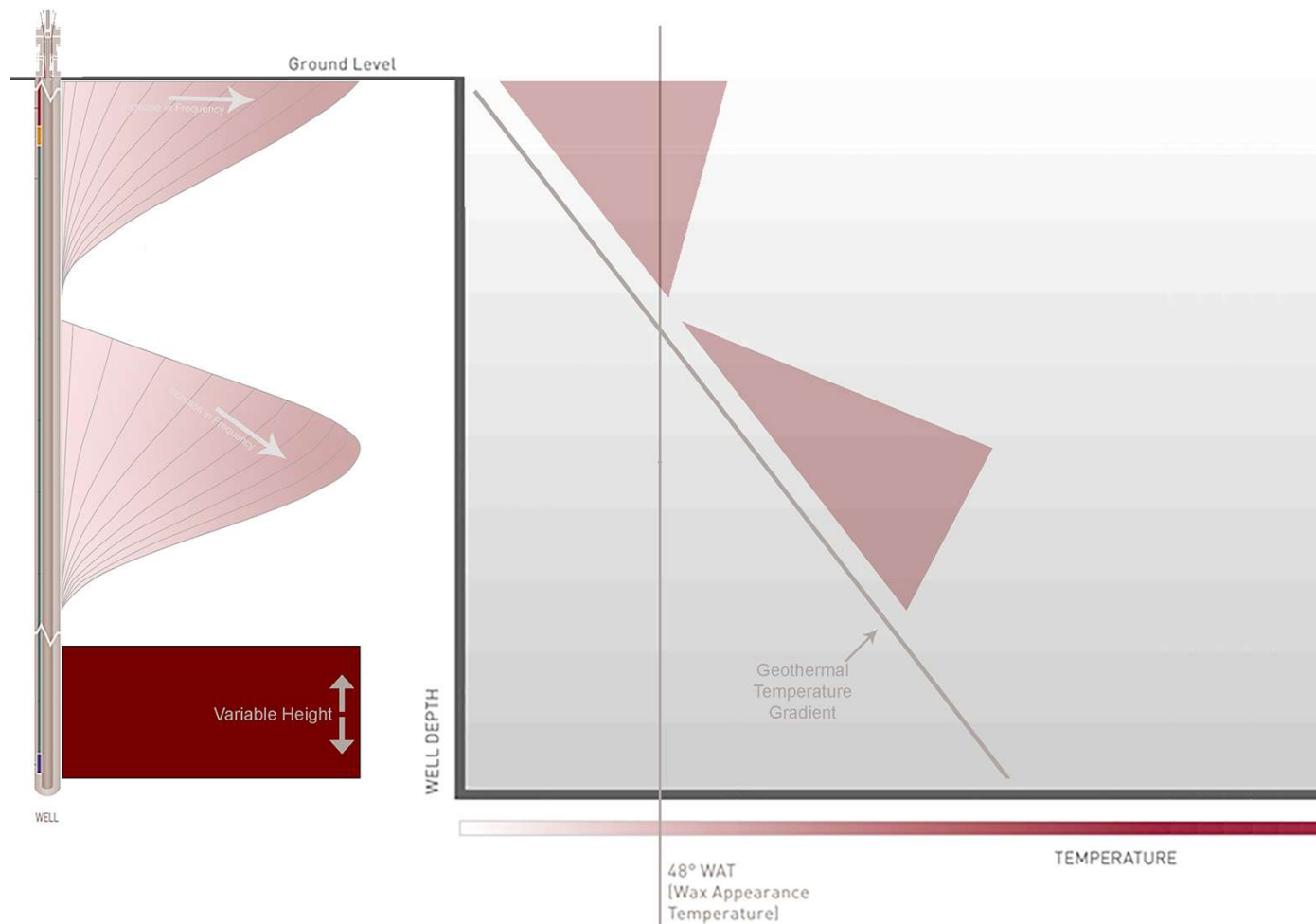
Heat Profile Comparisons – Targeting Lower Region



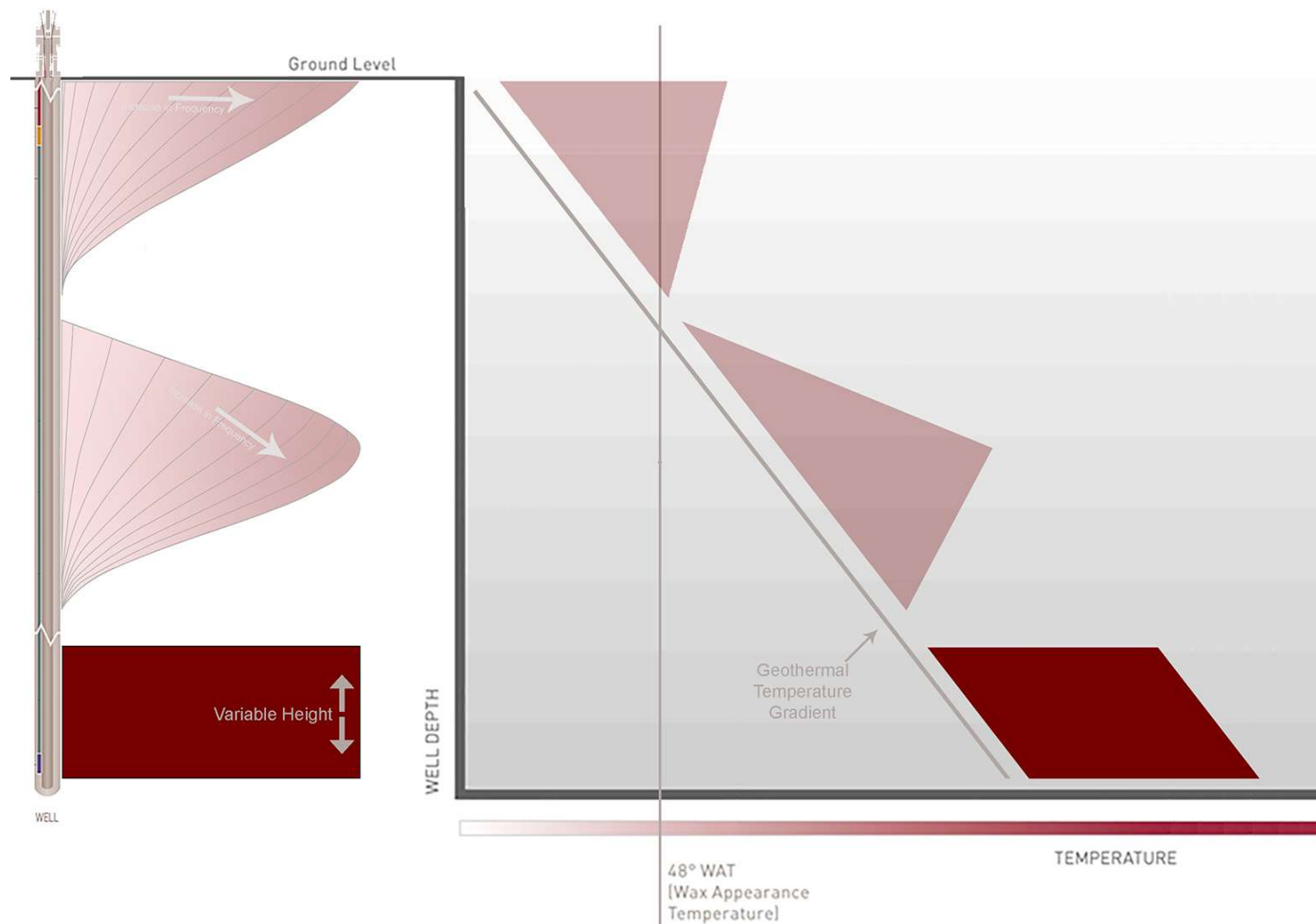
Targeting Lower Region - Heat Profile Imposed



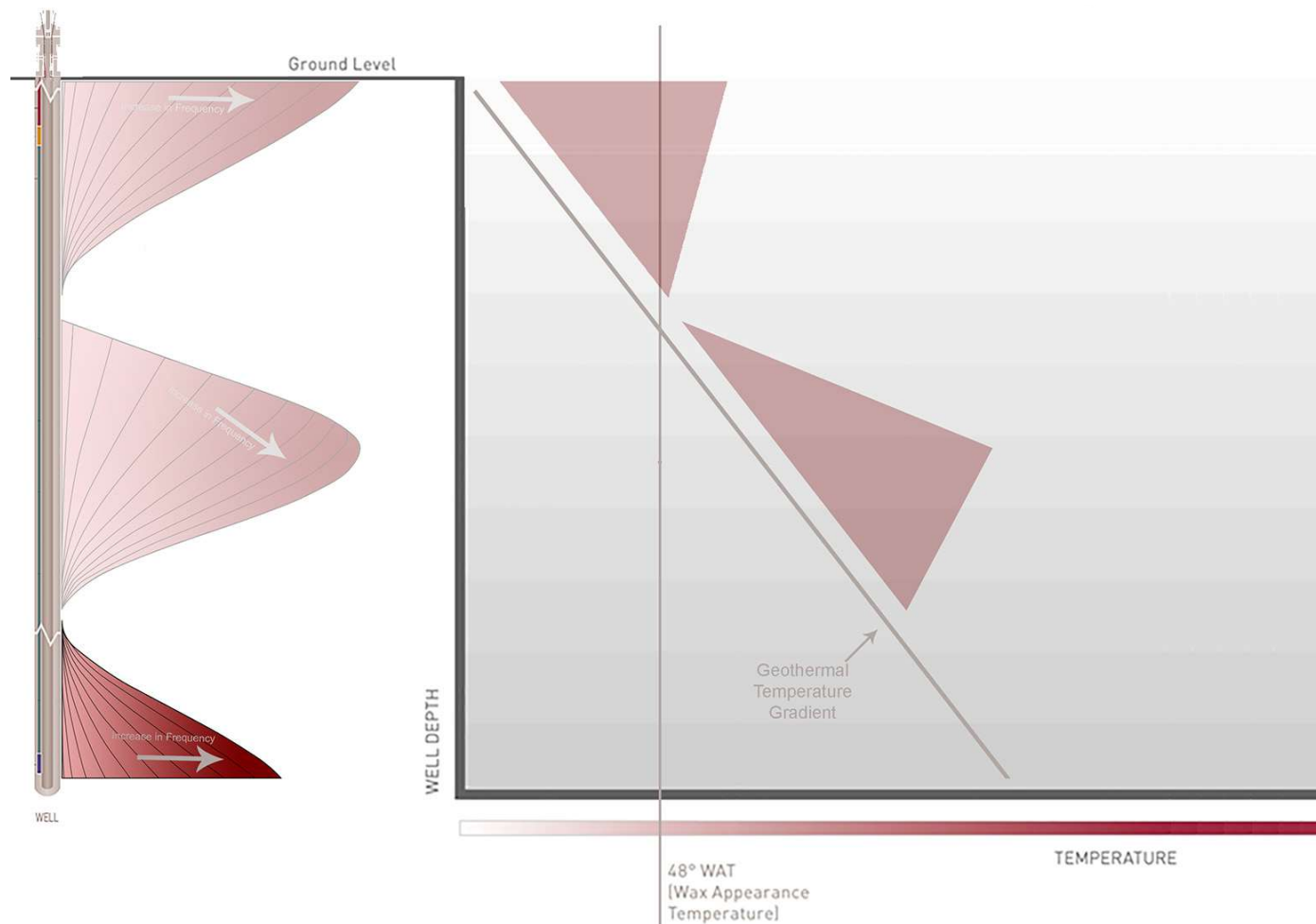
Heat Profile Comparisons – Intense Heating Lower Region with LFH



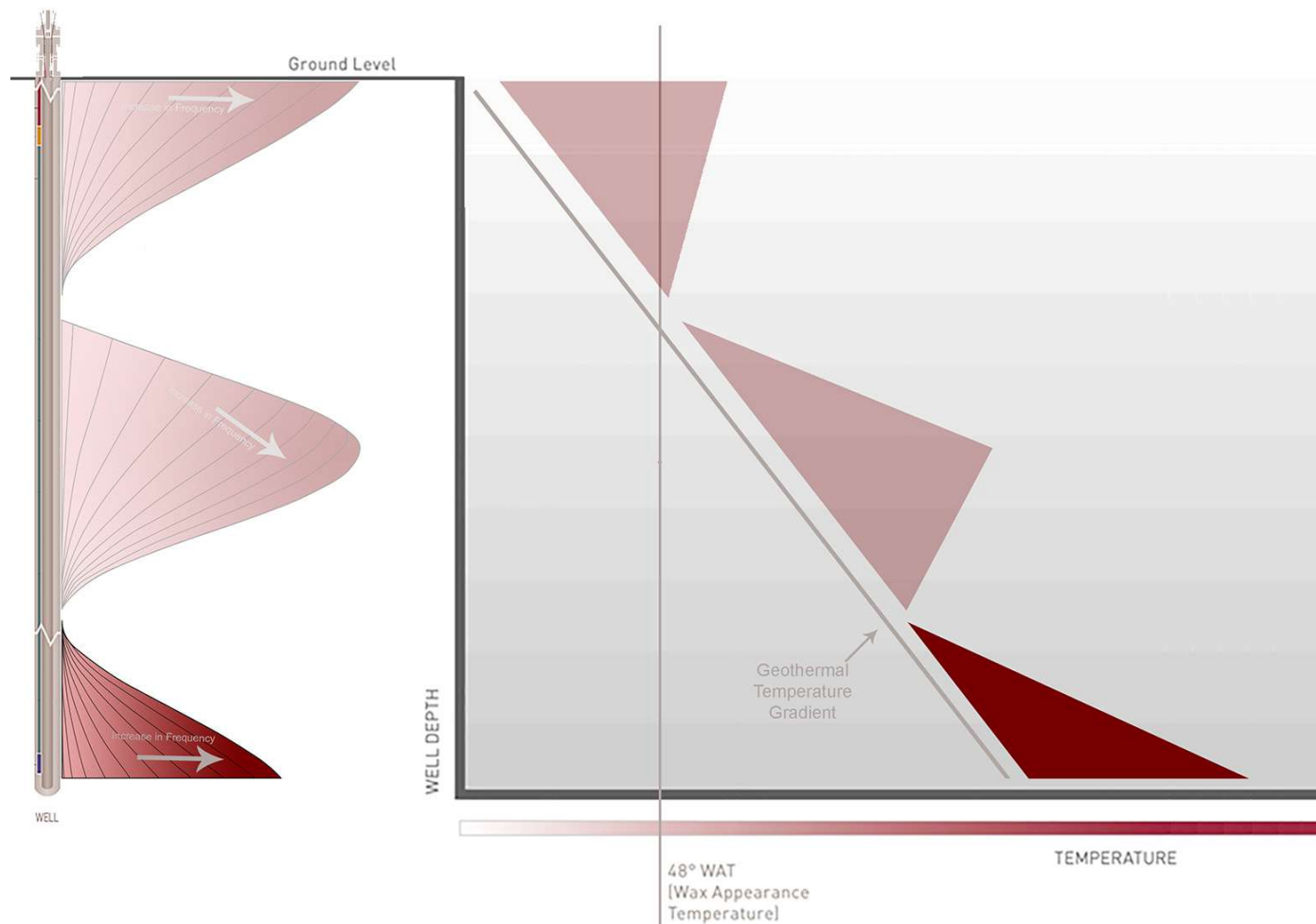
Intense Heating Lower Region with LFH – Heat Profile Imposed



Intense Heating Lower Region with HFH – Heat Profile Imposed



Intense Heating Lower Region with HFH – Heat Profile Imposed



Integrated Thermal Management System - ITMS Delivers a Variety of Solutions



Power Factor - Definition

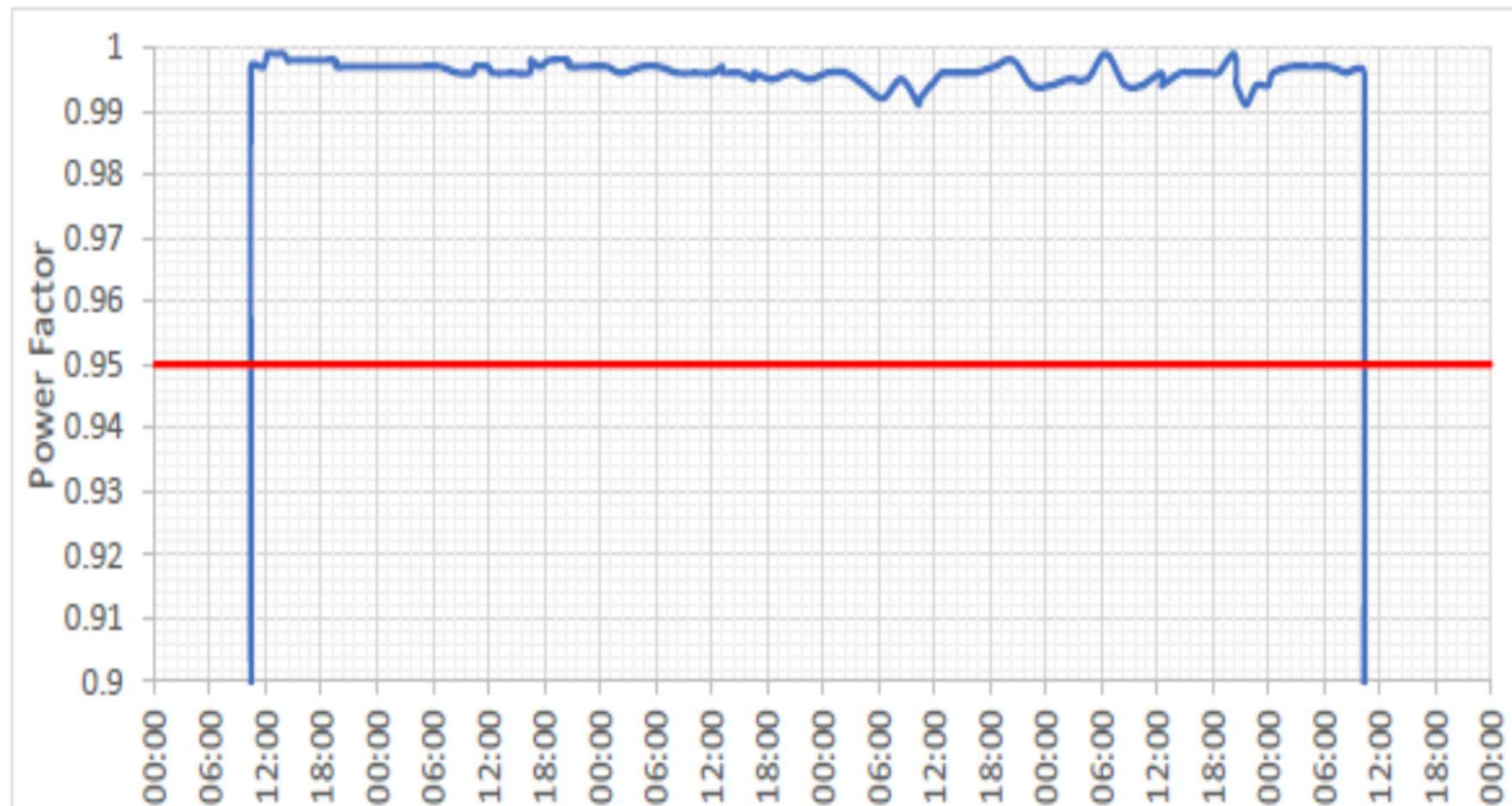


"Real Power" is the rate of doing useful work of a system. This is calculated by multiplying the instantaneous voltage and current over several cycles and finding the average value.

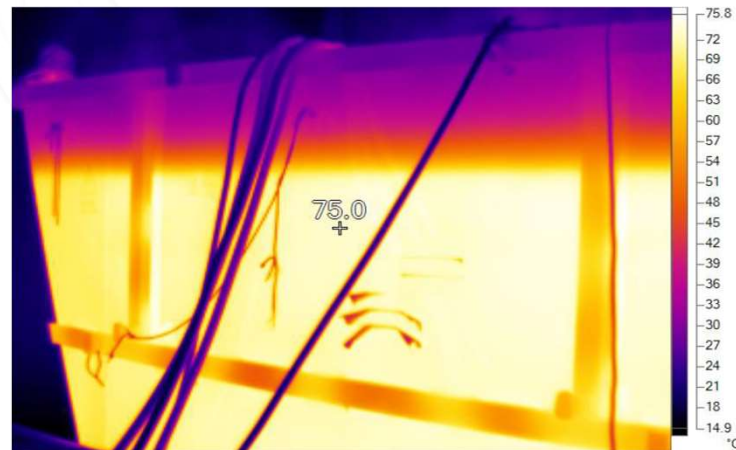
"Apparent Power" is the product of the root mean square (RMS) of the voltage and current and is used to rate equipment performance.

***Power factor** = Real Power/Apparent Power*

- s (~ 33%)



ITMS – Factory Acceptance Test



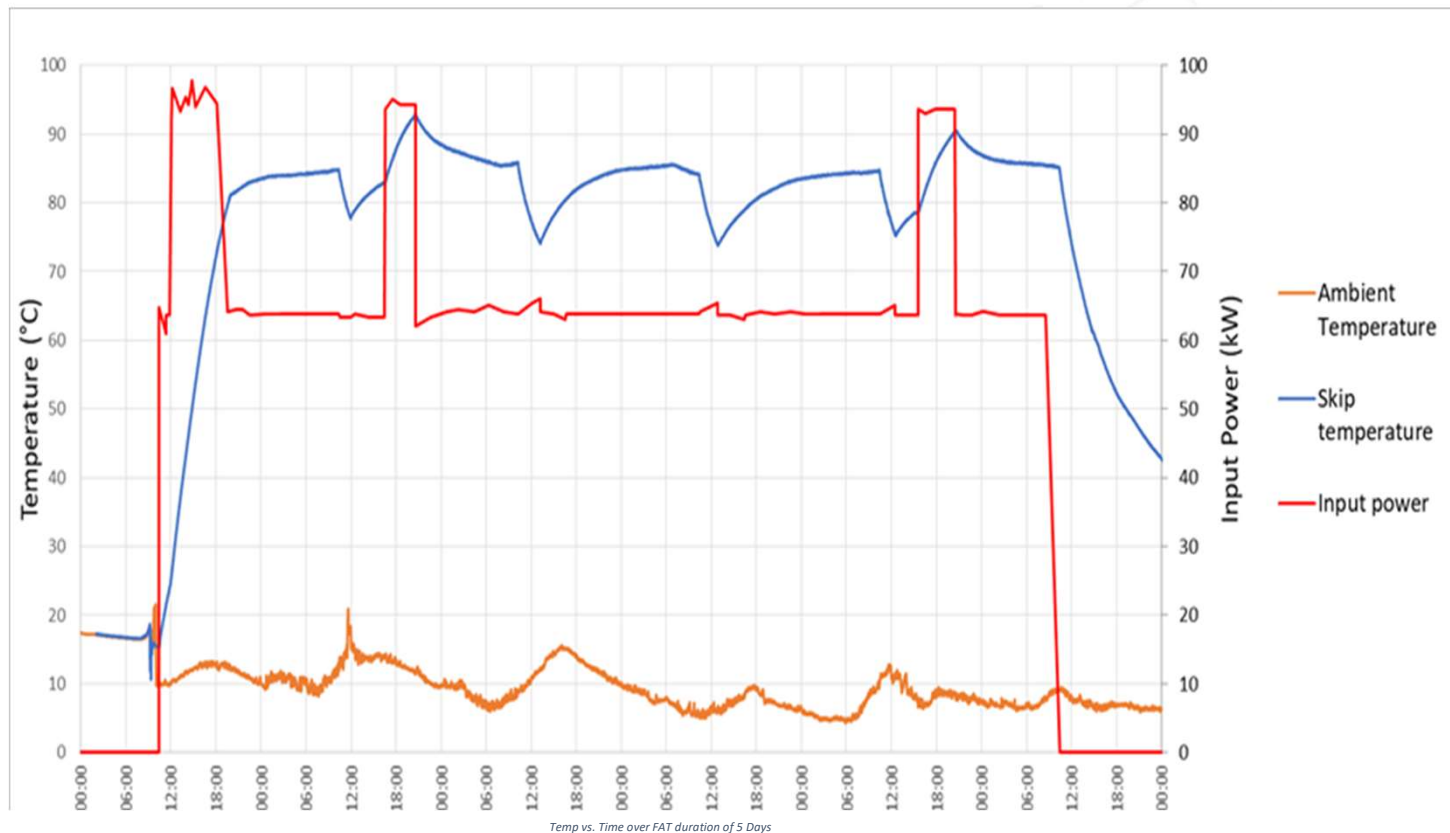
Average skip air
cooled skin
temperature of
75 C

Thermal image of the skip after 7.5 hours at 90 kW

ITMS – FAT 2018 Sample Data



- About 9m³ of water in a metallic skip in open air
- Ambient temperature over five days ~ 10 C
- Input power average of 67KW
- Fresh(cold) water added four times to replace evaporation



ITMS – Key Benefits



- With **ITMS** (based on Power Electronics) “**total-variability-as-a-function-of-time**” is a given.
- The Operator has total freedom to adjust heat requirements “**as-and-when**” necessary.
- **ITMS** uses standard **off-the-shelf ESP/MLE cables** at a fraction of the cost of specialist/bespoke heat trace cables.
- **ITMS** may be used to **heat any fluid flow path** (Injector or Producer Wells, Flowlines, Export Pipelines, etc.).
- **ITMS** permits **optimisation of power consumption** as a function of time.
- **ITMS** may be used to **generate heat in-situ** to control heat intensity, required in location as a function of time.
- **ITMS** lowers **NOX emissions** to atmosphere.
- **ITMS** can deliver **controllable levels of heat** to optimise oil recovery.

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