SPE Heavy Oil Conference
10–12 June 2014
BMO CENTRE AT STAMPEDE PARK
Calgary, Alberta, Canada

SPE-170146-MS
Advances in Electrical Heating Technology for Heavy Oil Production

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Objective and Outline

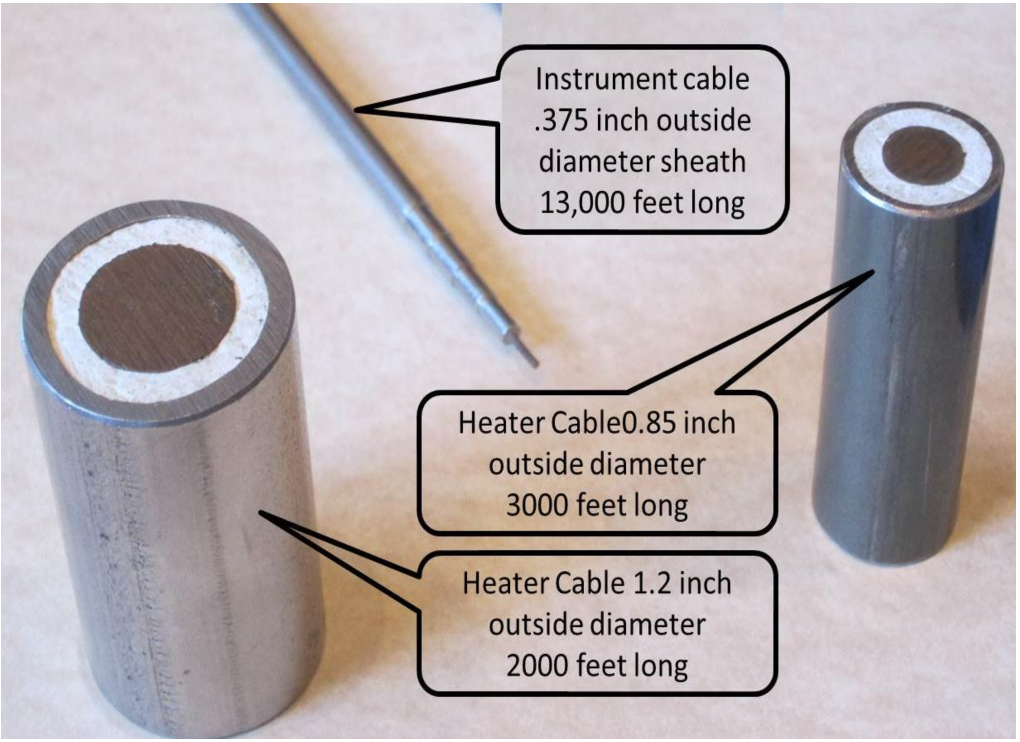
The objective of this paper is to introduce the capability of a higher voltage Mineral Insulated Heater Cable for downhole applications.

Questions to be answered:

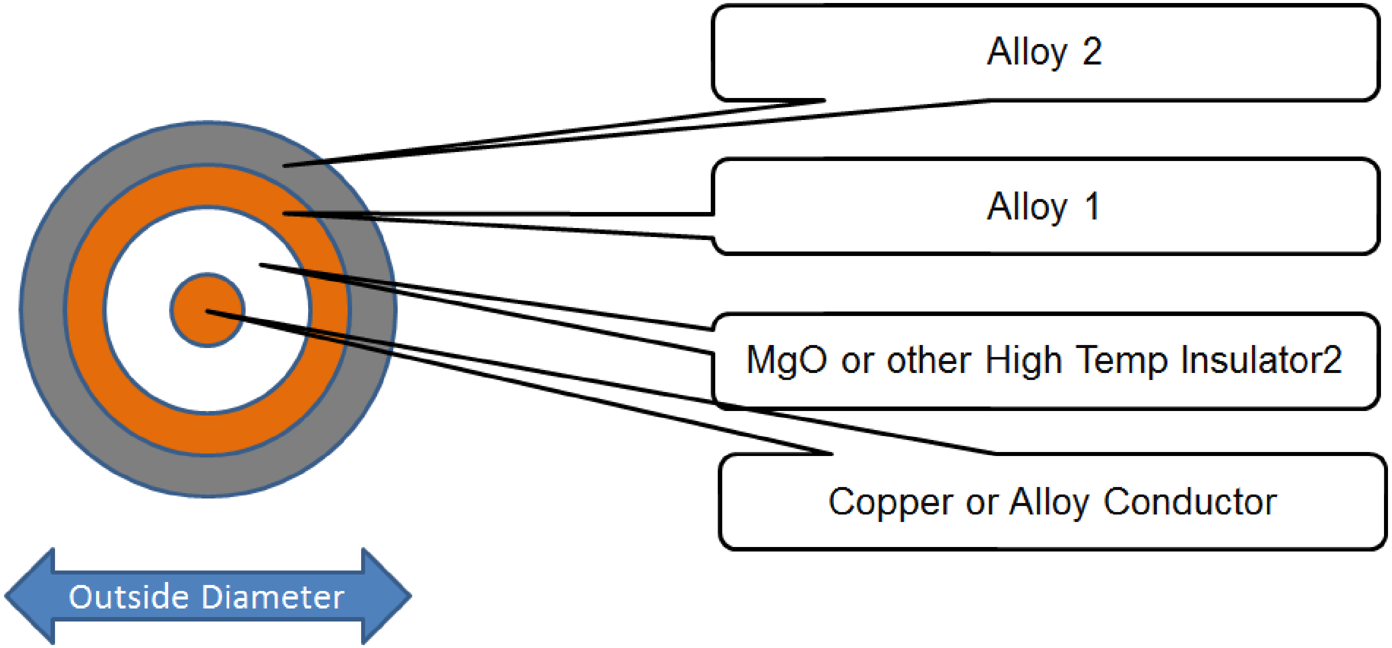
1. What is MI, Mineral Insulated Cable?
2. What are current and future applications of MI cable in downhole venues?
3. What are some current field results for low voltage MI cable?
4. What types of heater technologies are available?
5. Why is a higher voltage MI cable heater important and what is its economic value?
6. Conclusion

MI Cable Technology

1. MI Cable = Mineral Insulated Cable
2. Magnesium Oxide used as insulant. Same type of heater as used on electric stove top
3. Capable of High Temperature and High Watt Densities
4. This paper shows advances in higher voltage capability for MI Cable Heaters for downhole applications



MI Cable Construction Variations



	D1	D2	D3	D4	D5
Alloy 2	Stainless etc.	Stainless etc.	Iron Alloy etc.	Stainless	825
Alloy 1	Stainless etc.	Iron Alloy etc.	Nickel Iron	Nickel Iron	Iron Alloy etc.
Center	Copper	Copper	Nickel Iron	A180	A180
Diameter Inches	1.22	1.22	1.22	0.85	0.85

Electrical Heater Matrix

Temperature Source
Power Source

Parallel Circuit
Series circuit

Power Dissipated = I^2R

Therefore if we raise the voltage and reduce the current, the power dissipated in the conductor will be lower because of less I^2R heating in the conductor.

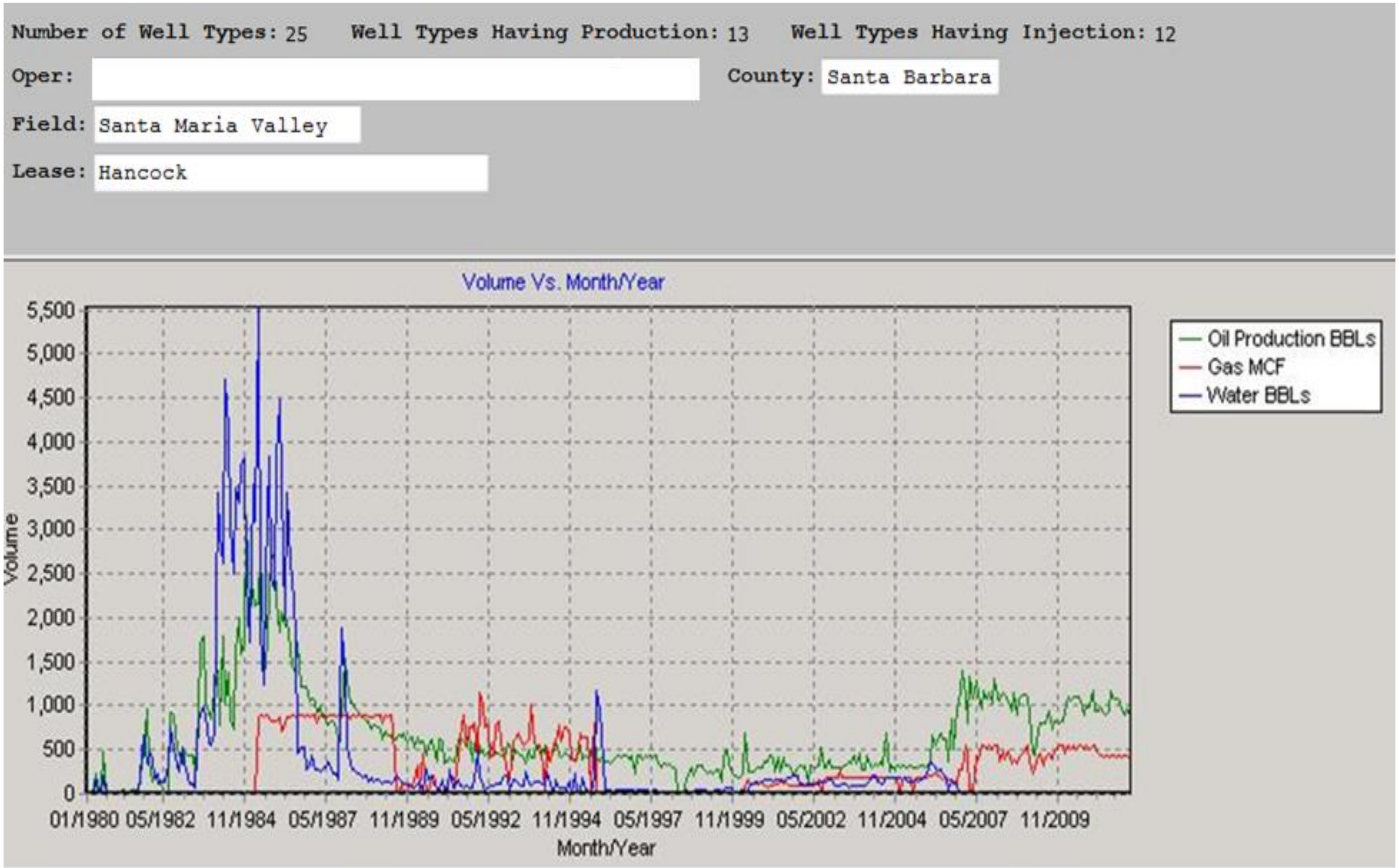
Electrical Heater Technology Matrix	Parallel Circuit $\frac{V^2}{R}$ Multiple Current Paths	Series Circuit I^2R Single Current Path
Temperature Source $Q = UA(T_H - T_L)$ Problem: Doesn't Heat	PTC Heating Cable Boiling Water Steam Oven Baking Human Body	NTC Heating Cable Downhole Heater Soldering Iron
Power Source $Q = UA(T_H - T_L)$ Problem: Burn Out	Zone Heating Cable Microwave Oven	Constant WattageSeries Cables MI Cable Stove Element Light Bulb

PTC = Positive Temperature Coefficient of Resistance
NTC = Negative Temperature Coefficient of Resistance

Thermal Applications in Downhole Environments

Heavy Oil Use of Heating Technology	Type of Energy	Electrical Heater Status	Energy Cost	Recovery	Diluent Needed	Product Value
Cold Production	None		None	Low	None	Low
Cyclic Steam Stimulation	Steam	General Usage Worldwide	Low	Medium	High	Low
Steam Assisted Gravity Drainage SAGD	Steam	General Usage Worldwide	Low	Medium	High	Low
Cyclic Electrical Heater Stimulation	Electric	In Use in Central California	Medium	Medium	High	Low
Viscosity Reduction	Electric	World Wide	Medium	Medium	High	Low
Insitu Visbreaking	Steam or Electric	Alberta Modeling	Medium	Medium	Low/none	Medium
Insitu Upgrading Process	Electric	Shell Oil Shale & Heavy Oil	High	High	None	High
Flow Assurance	Diluent	Hot Oil	Low	Important	Yes	Varies
Flow Assurance	Electric	Polymer and MI Cable and SECT	Low	Important	No	Varies

Advantage of Electrical Heaters in Formation Stimulation



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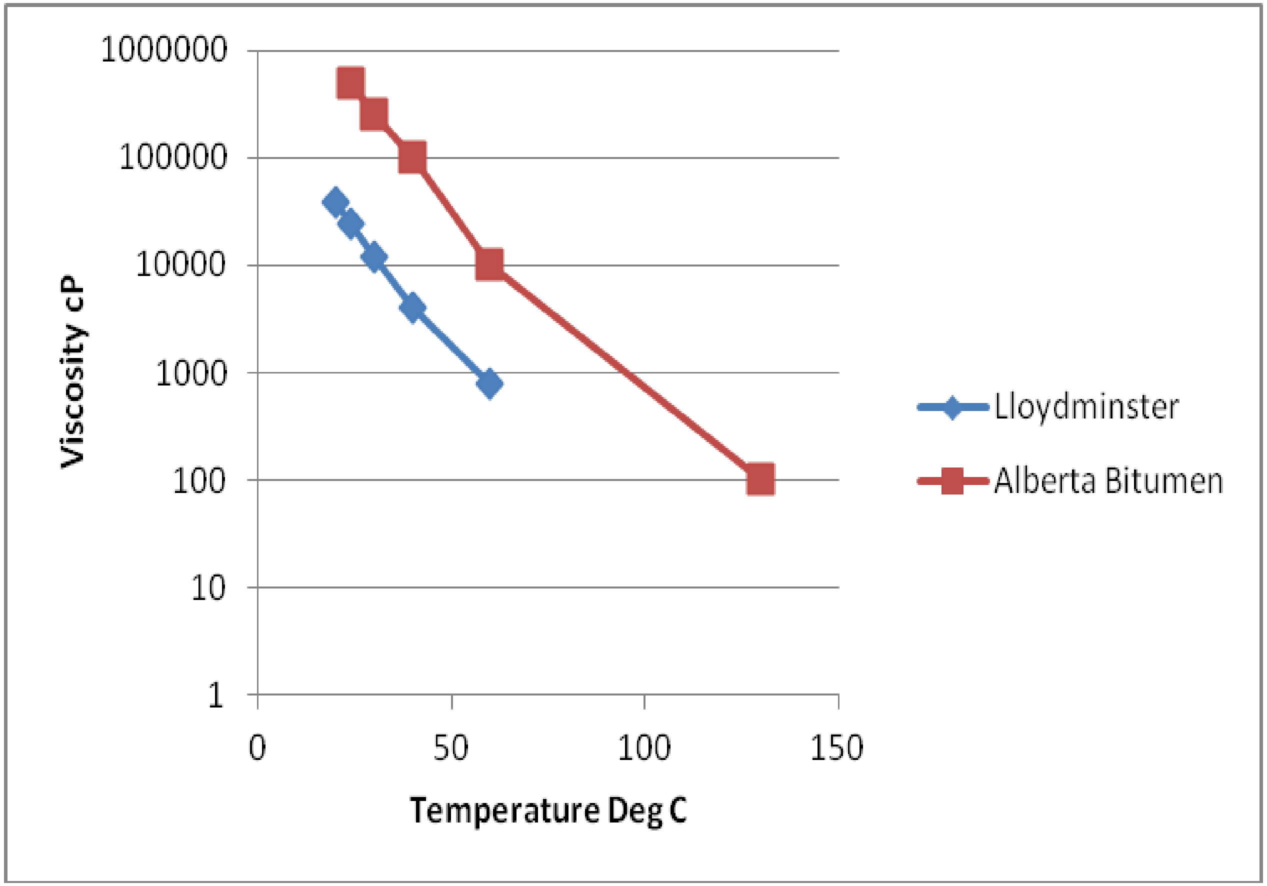
Electrical Heater Results in Santa Maria Valley CA Stimulation
12 Well Averages

	PRODUCTION W/O HEATER			PRODUCTION W/HEATER			
Well #	DH Temp (F)	Oil (bpd)	H2O* (bpd)	DH Temp (F)	Oil (bpd)	H2O* (bpd)	Increase
1	109	1	1	234	3	0	300%
2	111	1.6	0.6	243	4.4	0	275%
3	115	1.7	0.7	245	4.4	0	259%
4	102	2.3	1	255	6.1	0	265%
5	105	2	1	225	5.3	0	265%
6	98	1.5	1	242	5	0	333%
7	88	2	1	285	13	0	650%
8	109	4	0	295	14	0	350%
9	110	1	0	285	14	0	1400%
10	107	3	0	265	17	0	567%
11	110	3	0	265	13	0	433%
12	121	4	1	216	12	0	300%
	TOTAL	27.1	7.3		111.2	0	**410%**

Viscosity is Extremely Temperature Dependent

Viscosity comparison: Alberta Bitumen with Lloydminster Crude Oil



Comparison of 600 Volt Heater System with 4160 Heater System

Cable Voltage	600 Volt	4160 Volt
Power per foot	144 watts per foot	140 watts per foot
Operating Temperature	400° C	400° C
Length of heated section	250 feet	2000 feet
Outside design diameter of MI cable	1.00 inch	0.75 inch
Diameter of heater wire in MI	0.25 inch	0.155 inch
Diameter of Overburden wire in MI	0.25 inch	0.155 inch
Overburden Loss as % of Total	51.9%	11.8%
Estimated weight of 3 cables/foot	5.3 lbs/ft.	3.0 lbs/ft.
Overburden length	2000 Feet	2000 feet

Economic Analysis of Downhole Electrical Heater Voltage

Economic Cost Comparison	600 volt	4160 volt
Total system power kW	225	953
Heated length	250	2000
System power per foot kW	0.90	0.48
kW % lost in Overburden	51.9%	11.9%
Cost per kWh for electricity $	$0.10	$0.10
hours of operation per year	8000	8000
Power Cost Per Year $	$180,000	$762,400
Cost per foot of heated formation	$720	$381

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Conclusions

1. Electrical Heaters are available for downhole applications
2. Electrical heaters have been used and been successful in numerous applications
3. MI Cable Heaters have more optimum capabilities in numerous applications in the downhole environment than polymer insulated heaters, i.e. higher temperature capability and higher power capabilities
4. A MI Cable heater with 4160 volt capability can provide longer heated sections for both vertical and horizontal wells
5. A MI Cable heater with 4160 volt capability will have less overburden losses leading to a more economic life cycle cost for the system
6. **Expected uses for this technology are: viscosity reduction in heavy oil, pre heat for SAGD wells to lower water use as well as primary heating for SAGD, reservoir stimulation analogous to cyclic steam stimulation, and flow assurance applications**

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Thank You for your attention

Are there any Questions?