

*Reverse-Circulation Cementing
of Offshore Hydrocarbon Wells:
A Simulation Study*

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Well Completions

- Zonal Isolation
 - Cementing



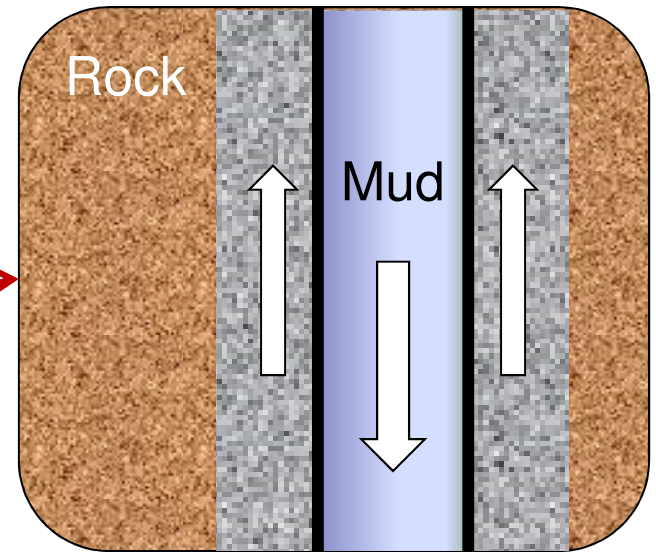
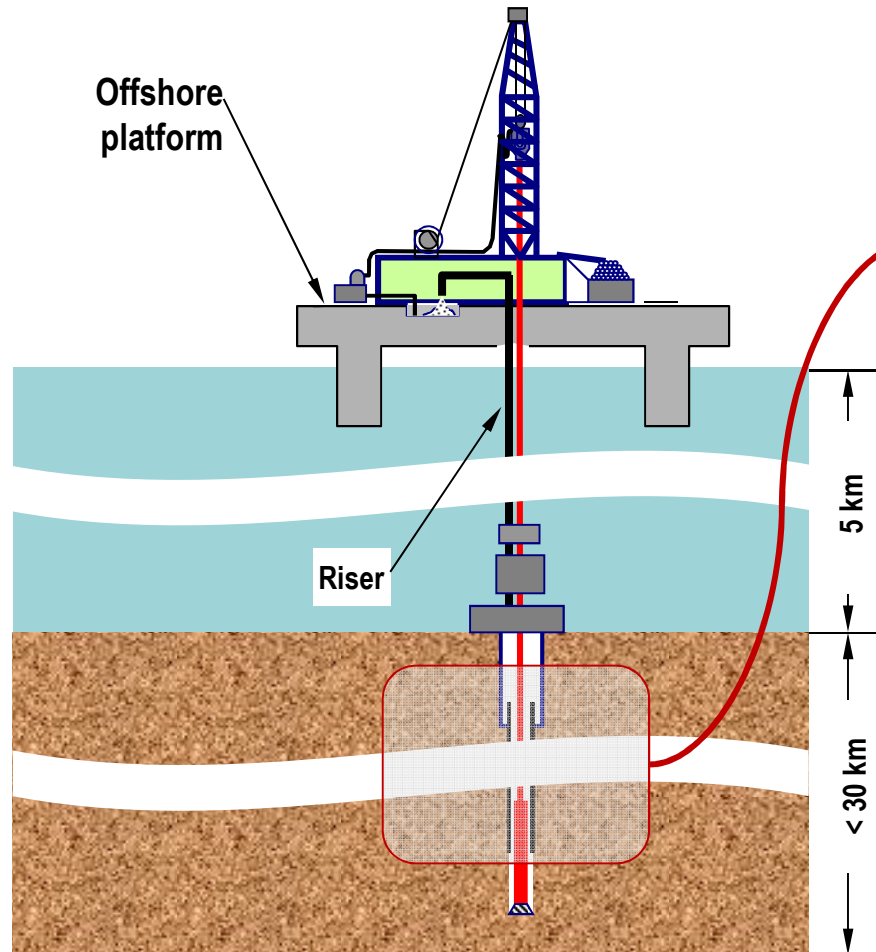
Offshore Well Drilling

Introduction

ECD Modeling

BHCT Modeling

Summary



Annulus
(Mud &
cuttings)

Fracture Gradient

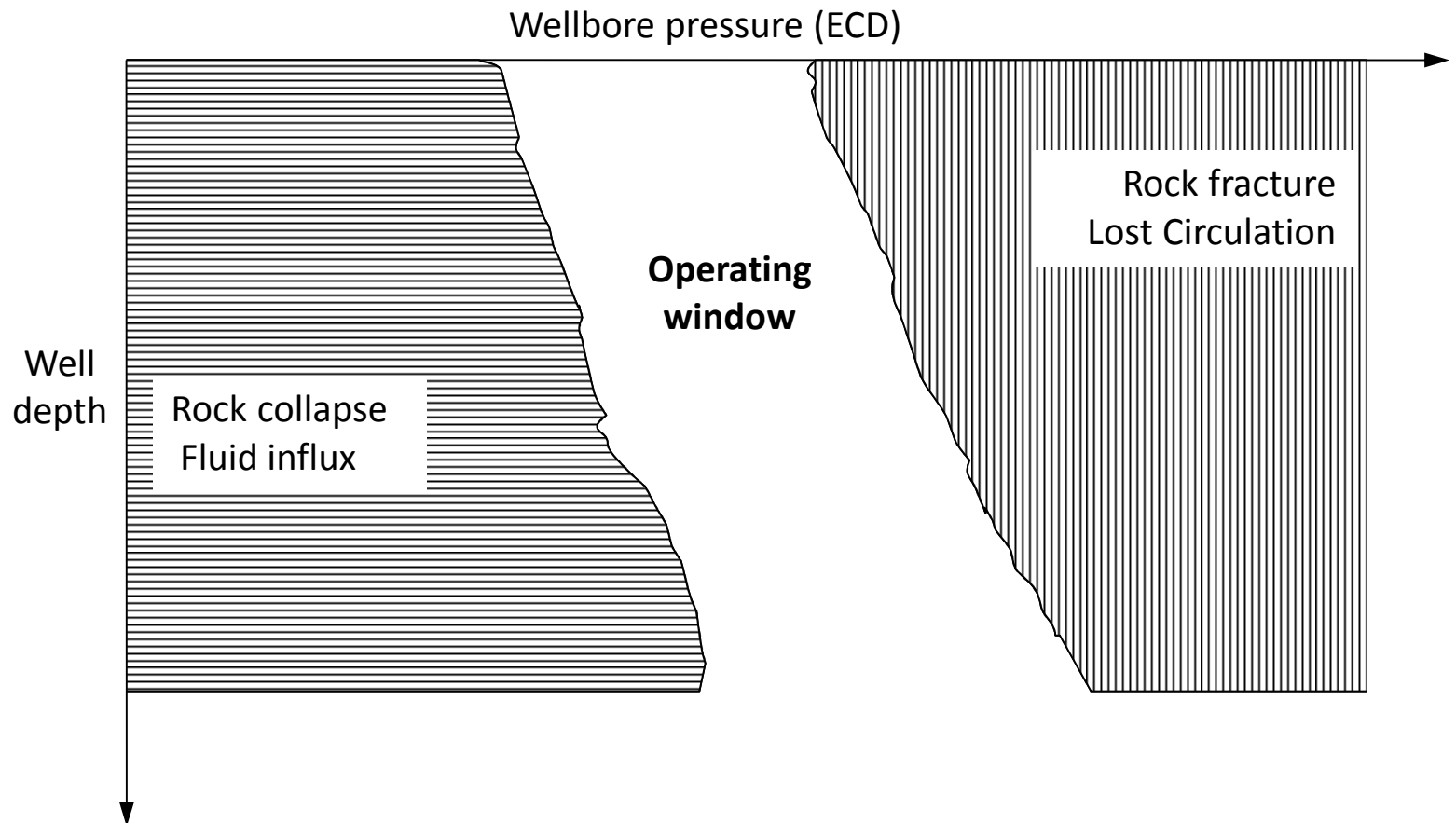
- Offshore: Narrow operating window

Introduction

ECD Modeling

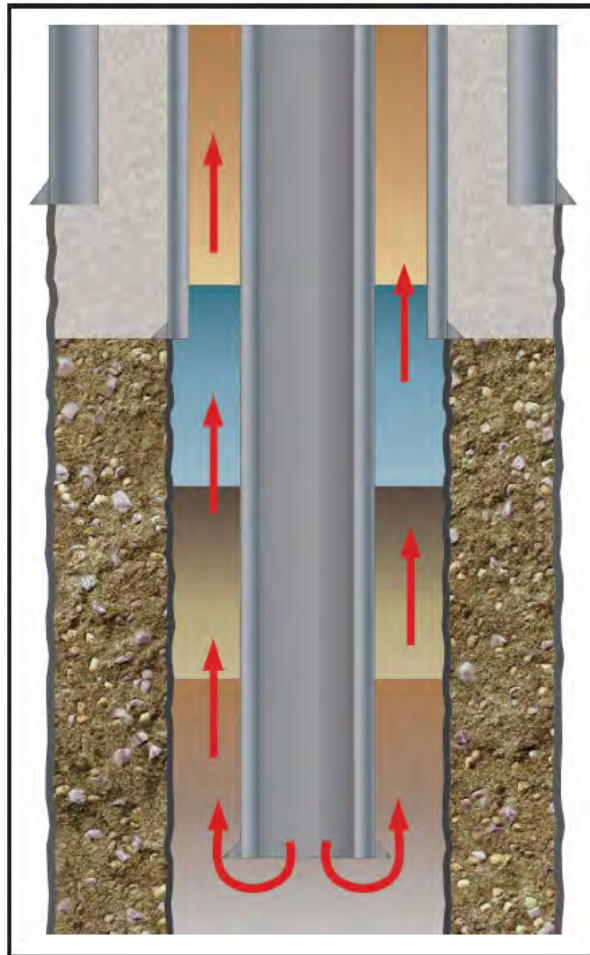
BHCT Modeling

Summary

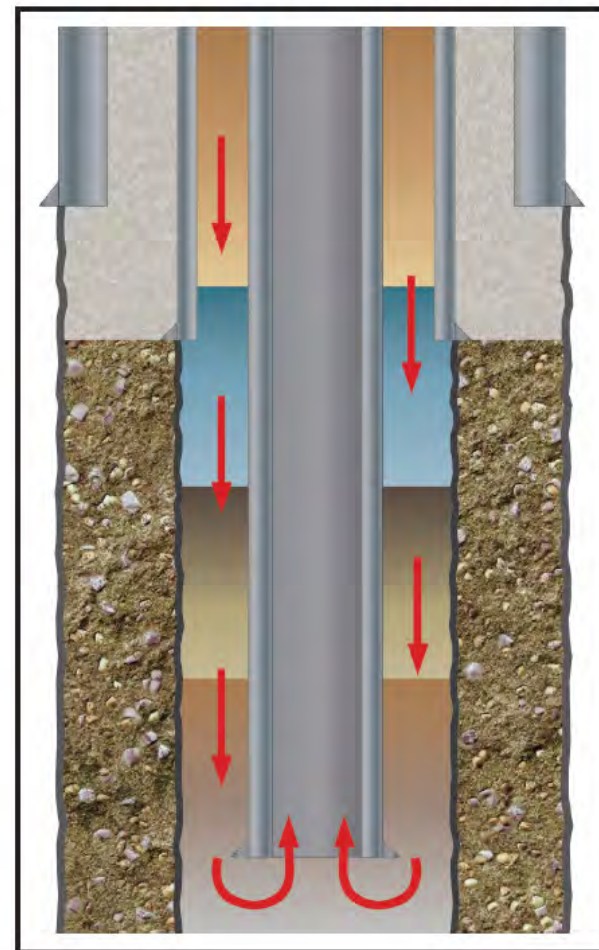


Conventional vs. Reverse Circulation

Flow Path of
Conventional Placement



Flow Path of
Reverse-Circulation Placement



Modeling Goals

- Equivalent Circulating Densities (ECDs)
- Bottom Hole Circulating Temperatures (BHCTs)
- Cement Temperatures

Document Preview



Publisher	American Petroleum Institute	Language	English
Document ID	72-B001		
Content Type	Conference Paper		
Title	Accurate Bottom-Hole Temperatures Are Needed		
Authors	Frank Shell,Phillips Petroleum Company, Bartlesville, Oklahoma, Art Tragessert,The Western Company, Houston, Texas		
Source	Annual Meeting Papers, Divison of Production, March 6 - 8, 1972 , Houston, TX		
Copyright	1972. American Petroleum Institute		
Preview	INTRODUCTION		

How hot is a 16,000-foot well? For years this has been a much debated question. All men are agreed that the answer depends on many variables. Among these are well location, drilling rate, type of drilling fluid, type of

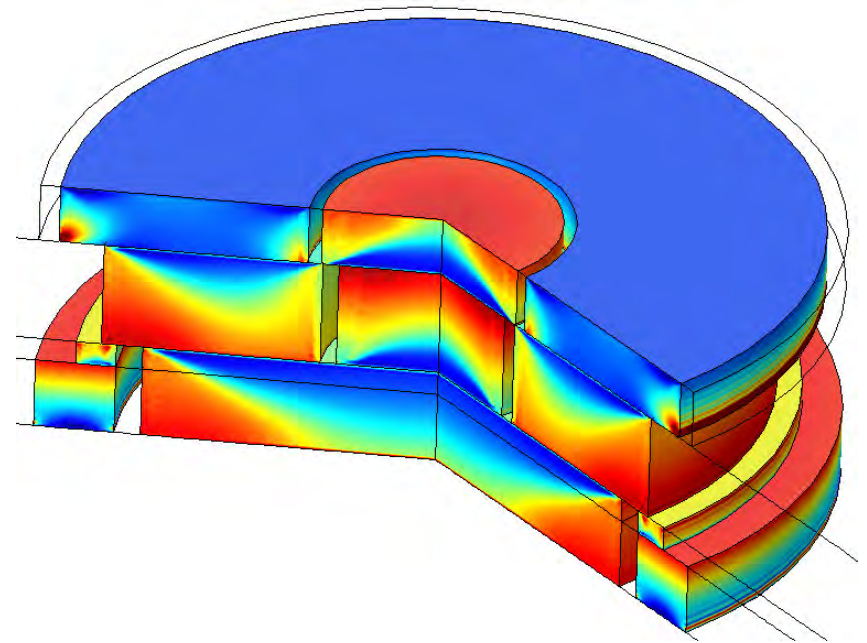
Equivalent Circulating Densities

- Correlations

- Limited Applicability
 - Simple
 - Fast
- $$f = \frac{16}{Re_B} \left[1 + \frac{Bi}{6} - \frac{1}{3} \frac{Bi^4}{(f Re_B)^3} \right]$$

- CFD

- Flexible
- Time-Consuming
- Requires expertise



Equivalent Circulating Densities

- Significant decrease in ECDs

	ECDs from Correlations (ppg)		
	Conventional	Reverse	Change
Region 1	14.170	12.545	-11%
Region 2	14.238	13.039	-8%
Region 3	13.435	12.794	-5%

$$ECD = \rho_{equiv} = \frac{\Delta P}{gh}$$

Bottom Hole Circulating Temperatures

Introduction

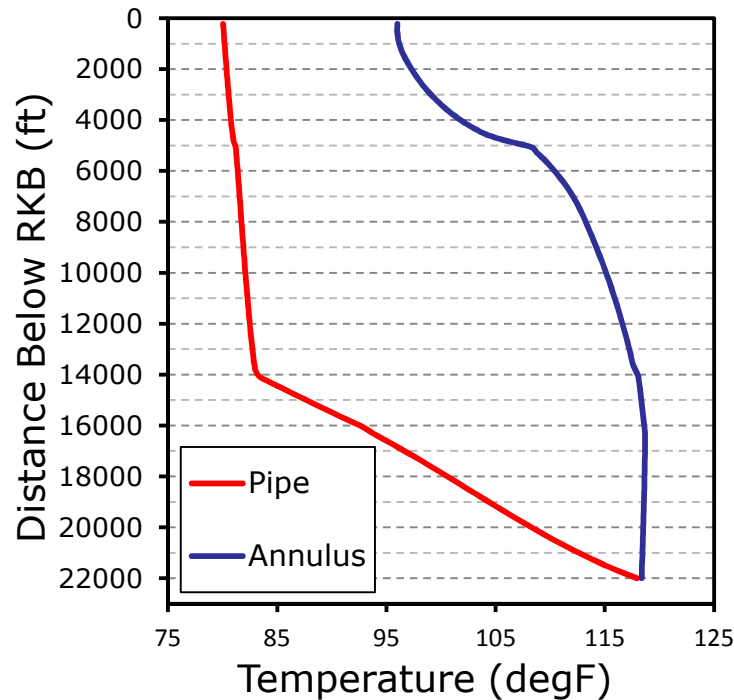
ECD Modeling

BHCT Modeling

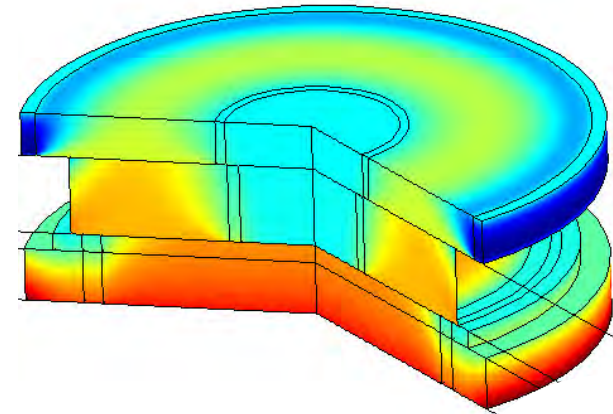
Summary

- Assumptions in Modeling Techniques
 - Geothermal Temperature
 - 1-D or 2-D

1-D Data

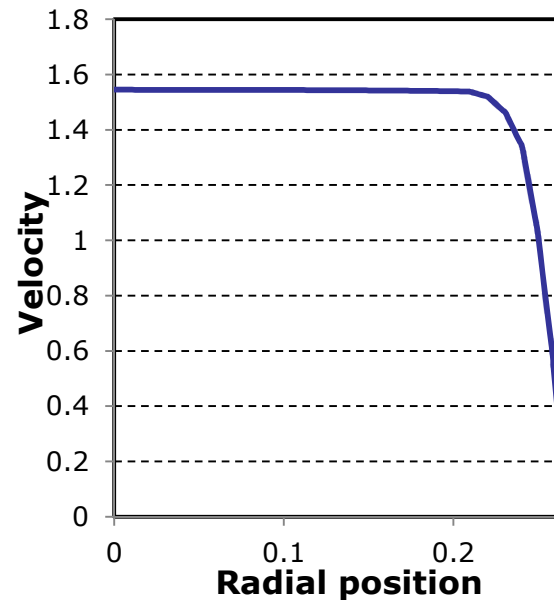


2-D Data



Solution Techniques

- Finite Element Analysis
 - Comsol
- Equations
 - Unidirectional Navier-Stokes Equations
 - Heat Equation with Convection



Modeling Difficulties

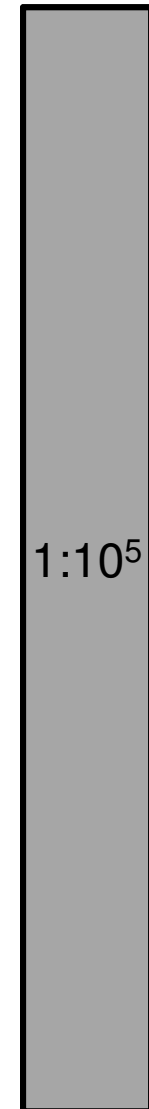
- Large Aspect Ratio
 - Meshing
 - Numerical Errors

- Solution: Rescale Equations
 - Radial: Conduction
 - Vertical: Convection

$$\frac{\partial \theta}{\partial t^*} + v_z^*(r) \frac{\partial \theta}{\partial z^*} = \frac{1}{\psi Pe} \nabla_r^2 \theta$$



← Rescale



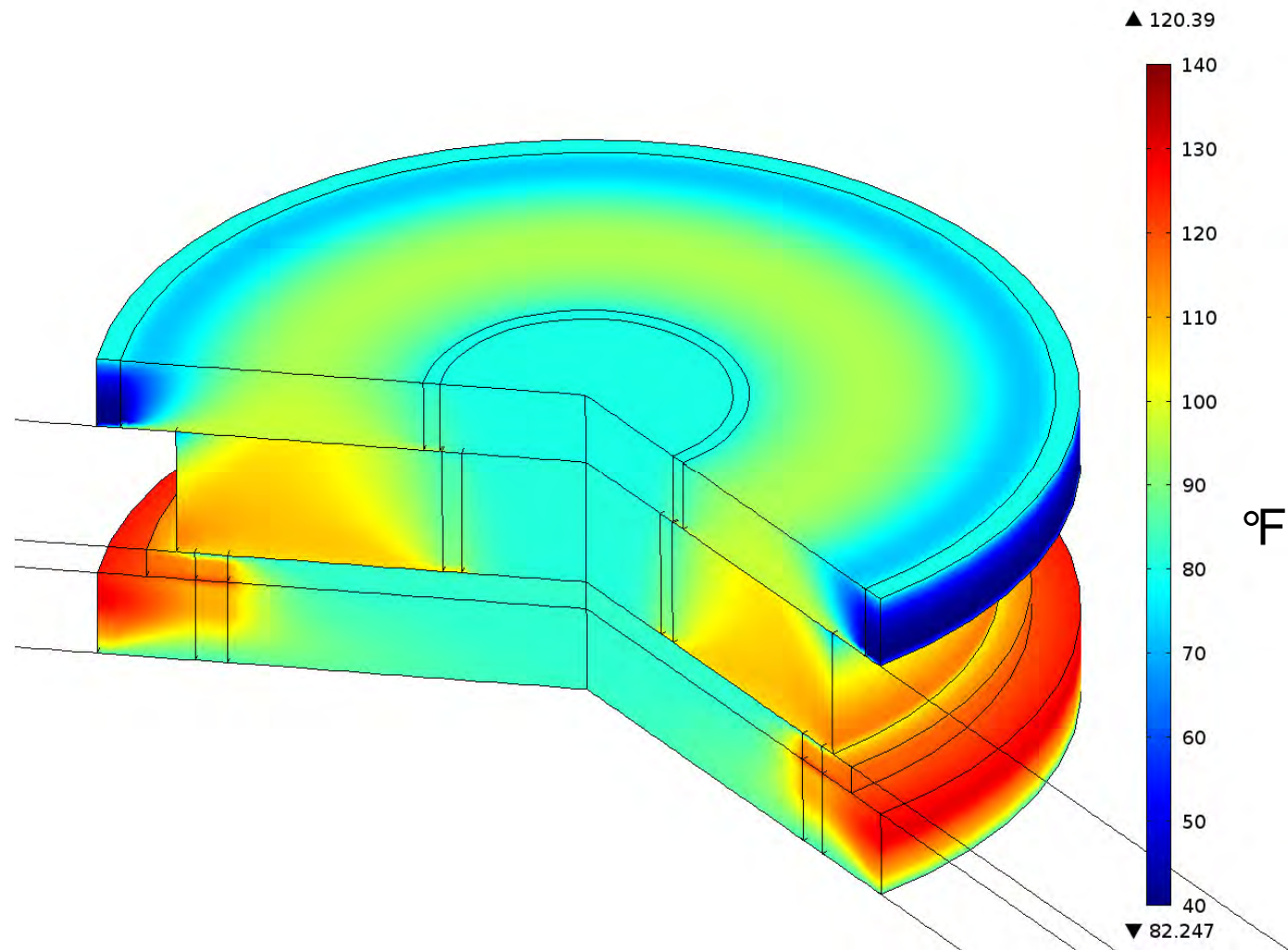
Temperature Results-Conventional

Introduction

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Temperature (°F) in Conventional Circulation at the end of circulation

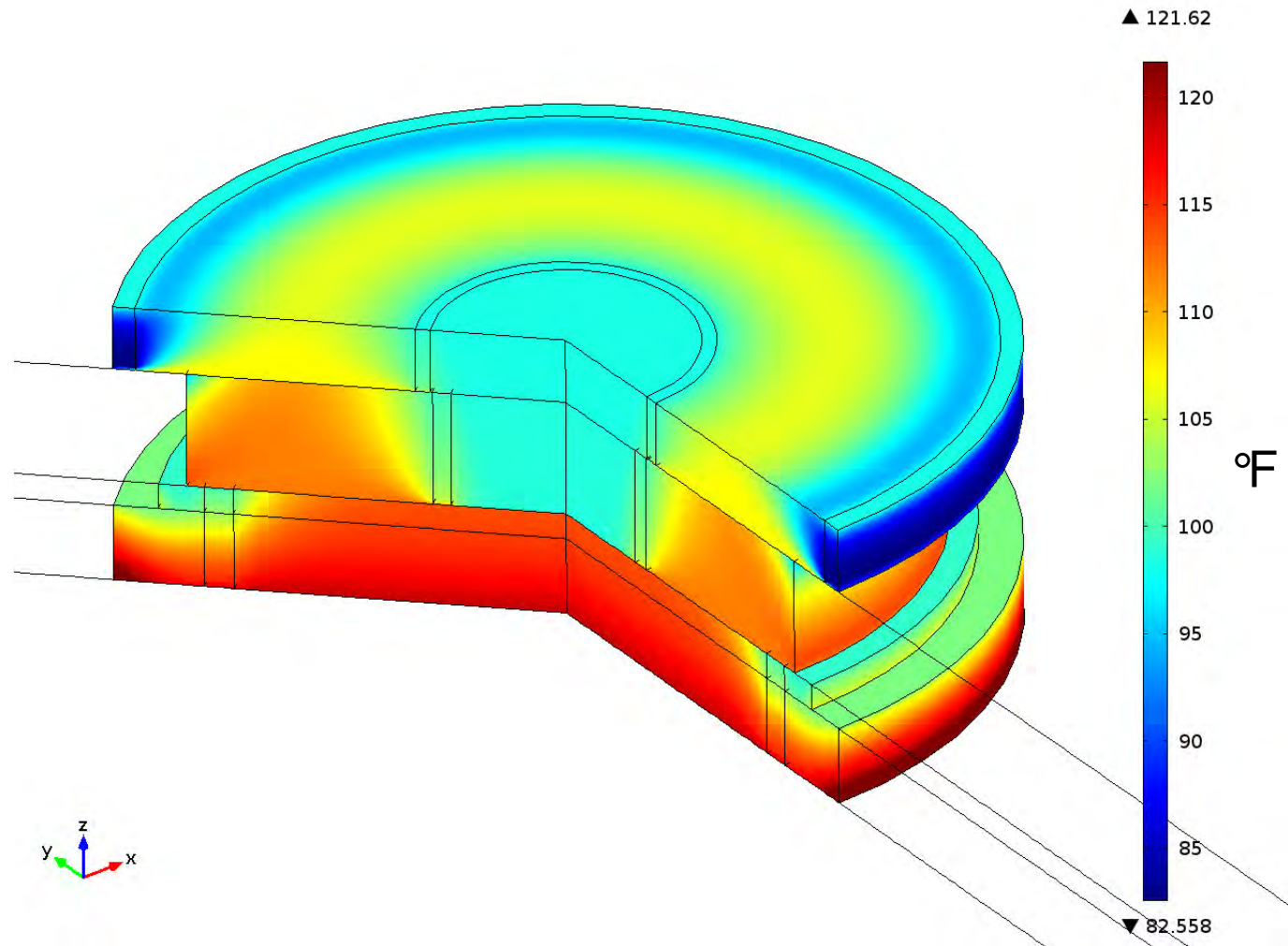
Temperature Results-Reverse

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Temperature (°F) in Reverse Circulation at the end of circulation

Temperature Results

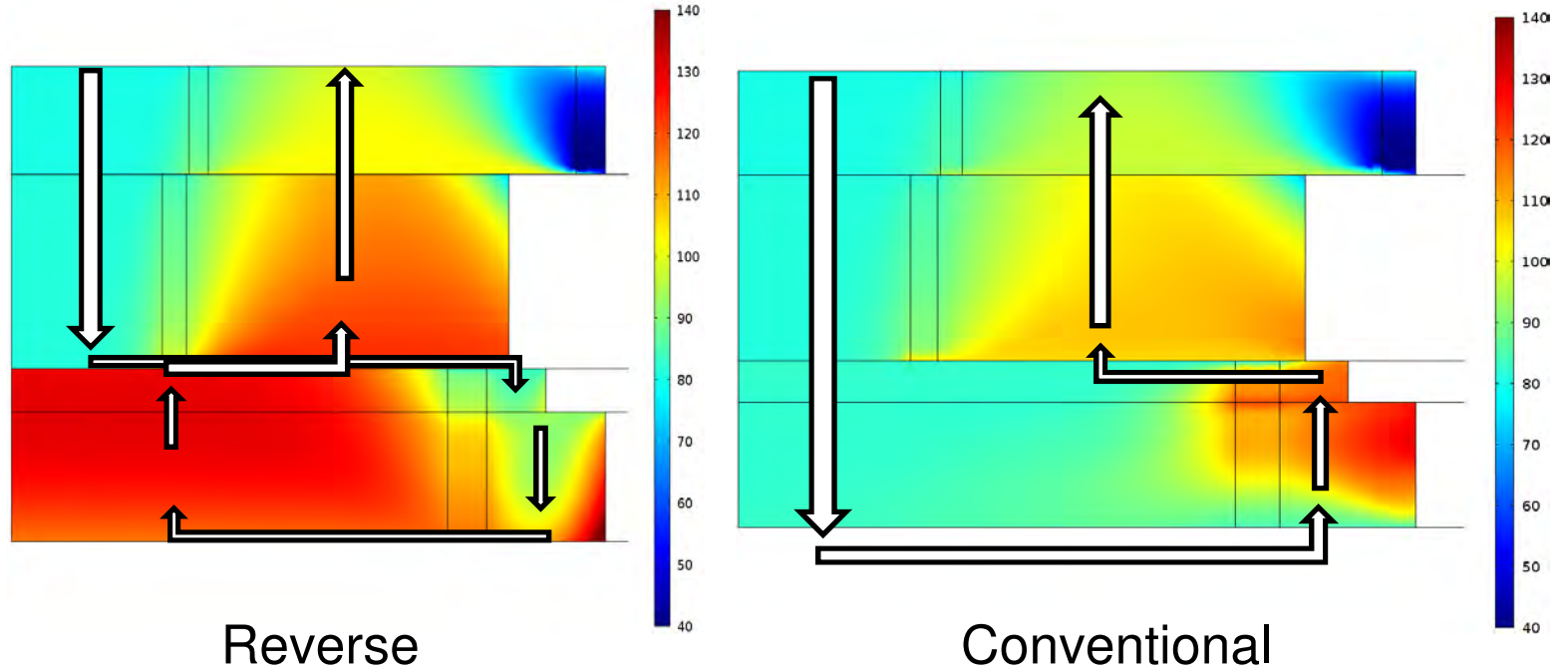
- Arrows indicate flow direction

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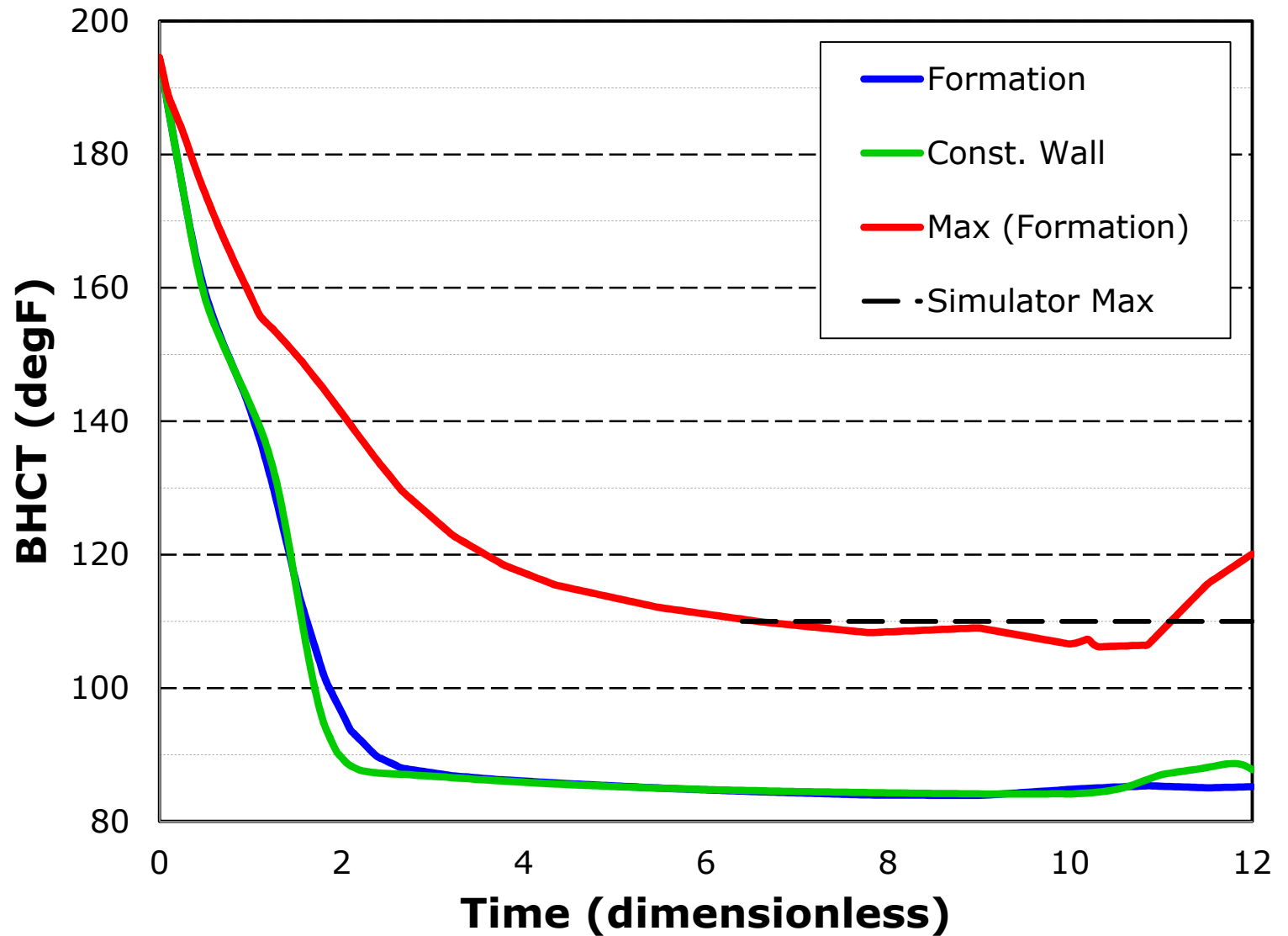
BHCT in Conventional Circulation

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BHCT in Reverse Circulation

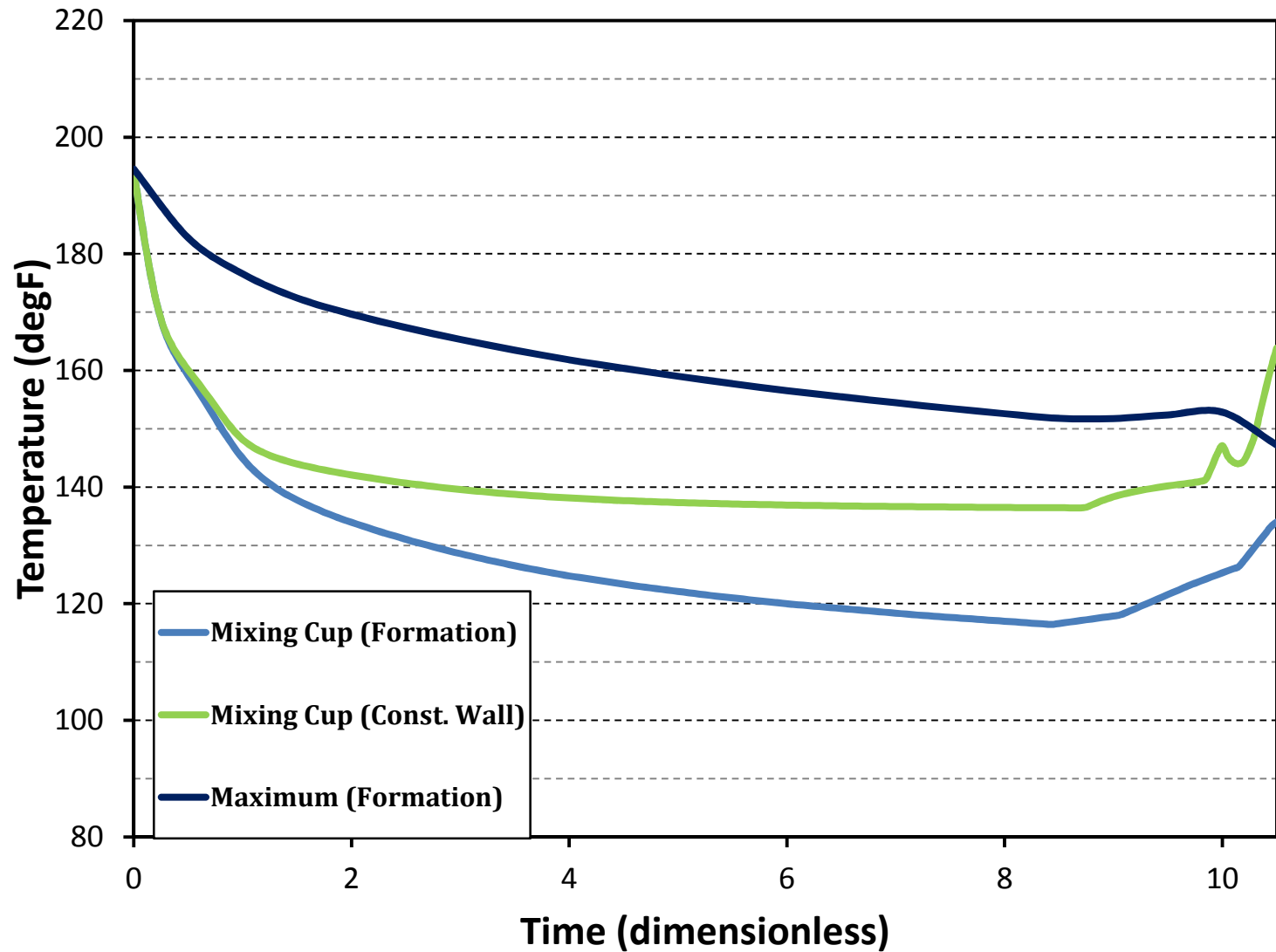
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Temperature Results

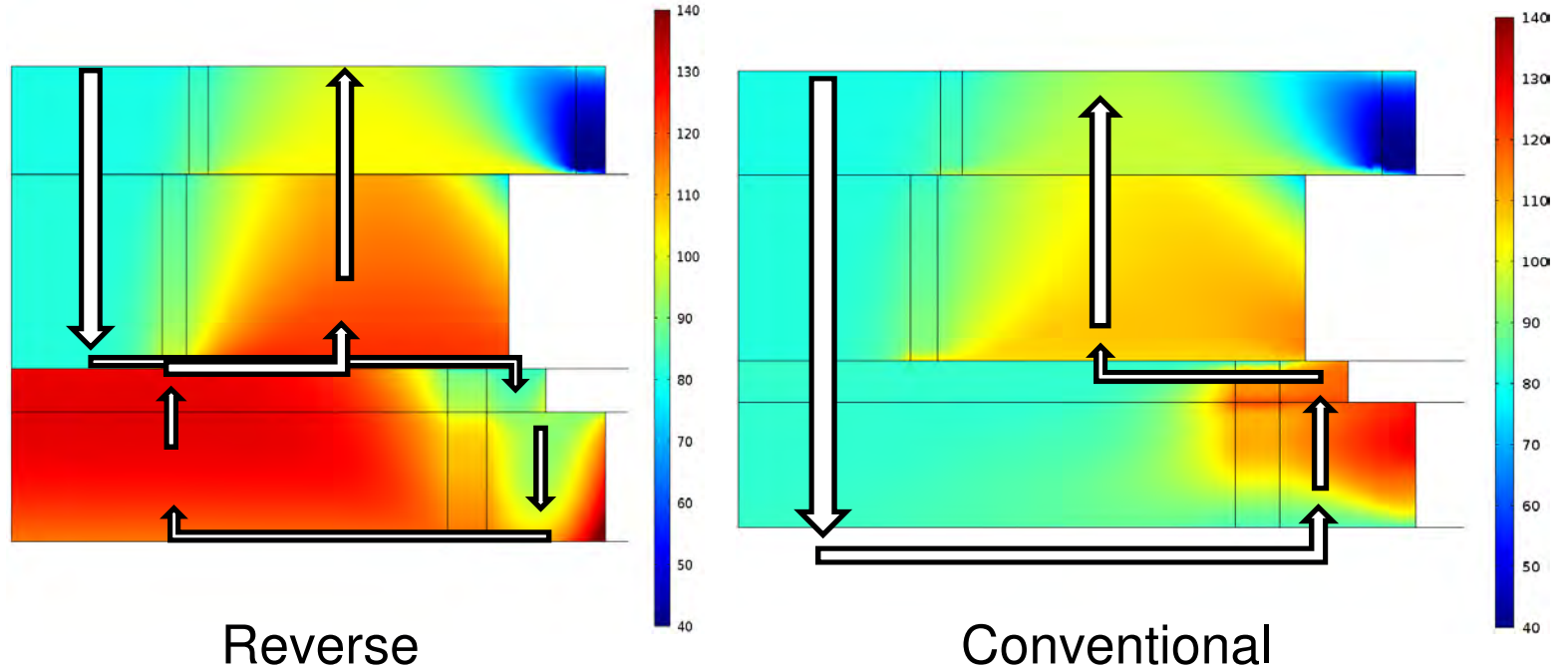
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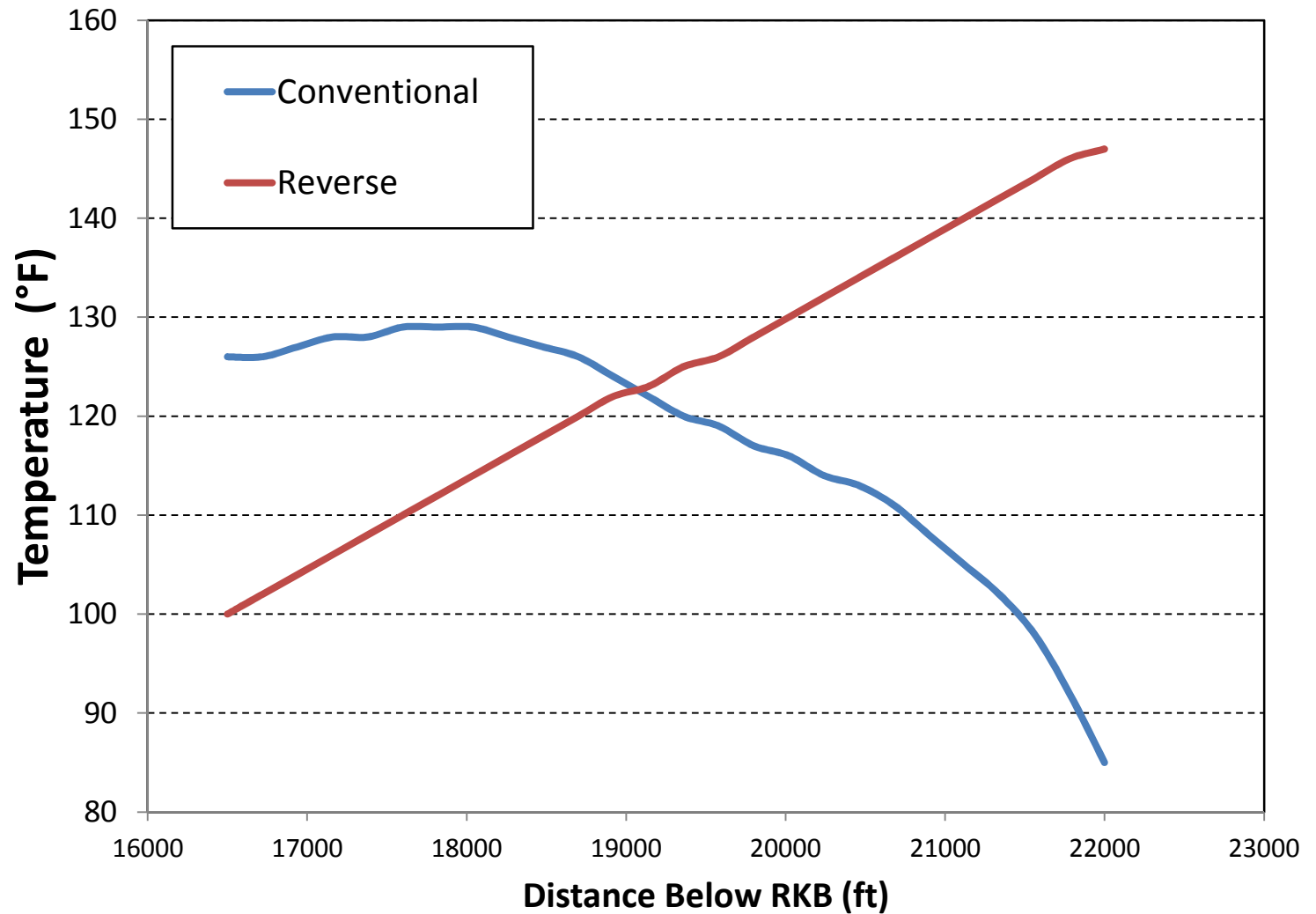
Cement Temperature—With $T_{\text{formation}}$

Introduction

ECD Modeling

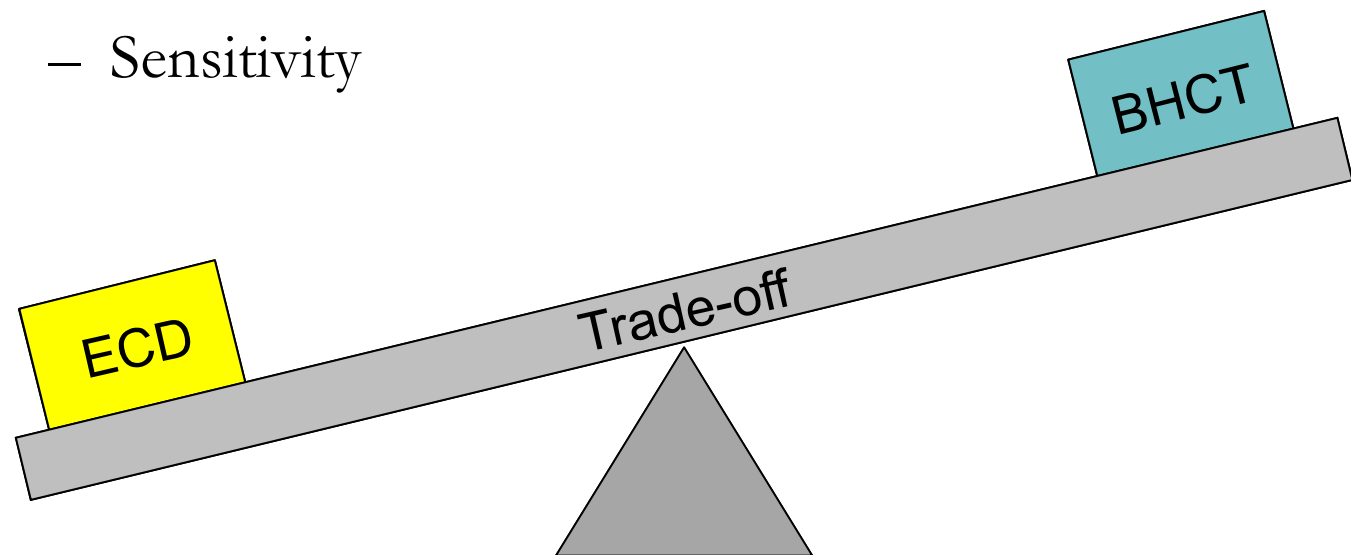
BHCT Modeling

Summary



Summary

- Reverse Circulation
 - ECDs reduced
 - BHCTs increased (≈ 40 °F)
 - Cement Temperatures increased (≈ 20 °F)
- Annulus
 - Sensitivity



Acknowledgements

- Funding
 - RPSEA
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 - Jeff Watters (CSI)

