

A Practical Application of GT-Suite to Solve a Performance Shortfall in a Scroll Compressor

Joe Ziolkowski

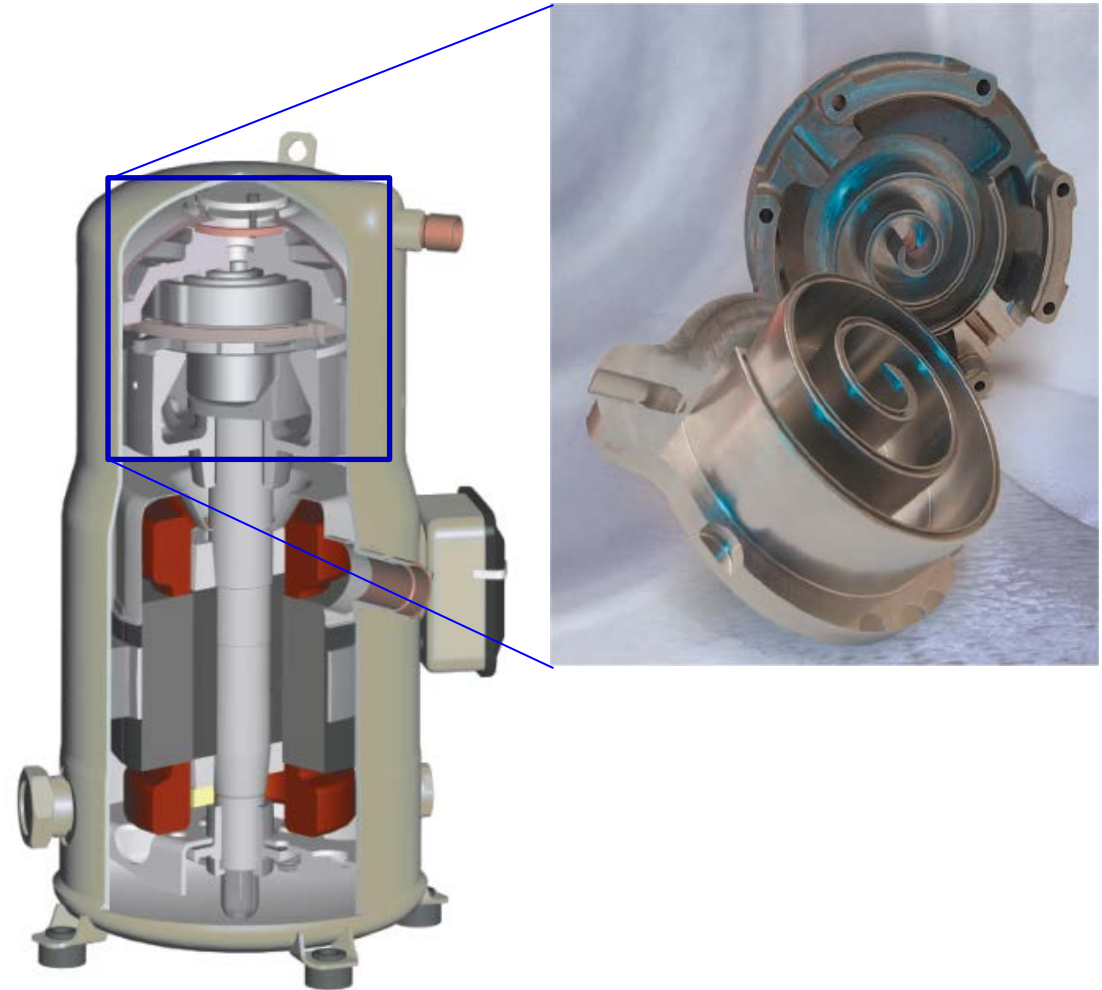
October 13-15, 2020

Agenda

- Scroll Compressor Background & Terminology
- Problem Statement
- GT-Suite Sensitivity Analysis
- Results
- Conclusions

Trane Scroll Compressors

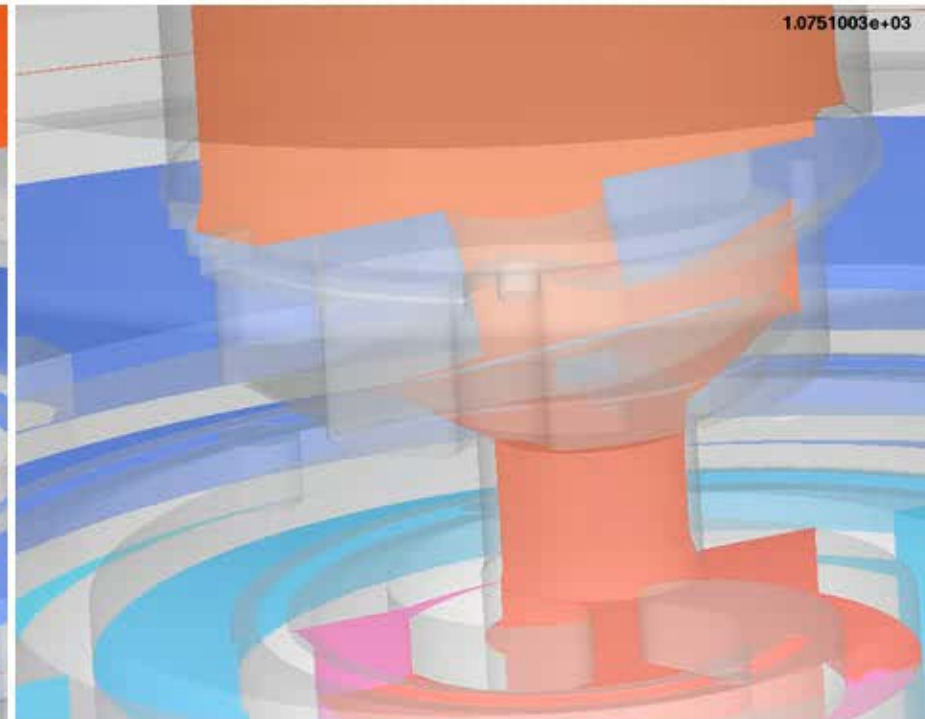
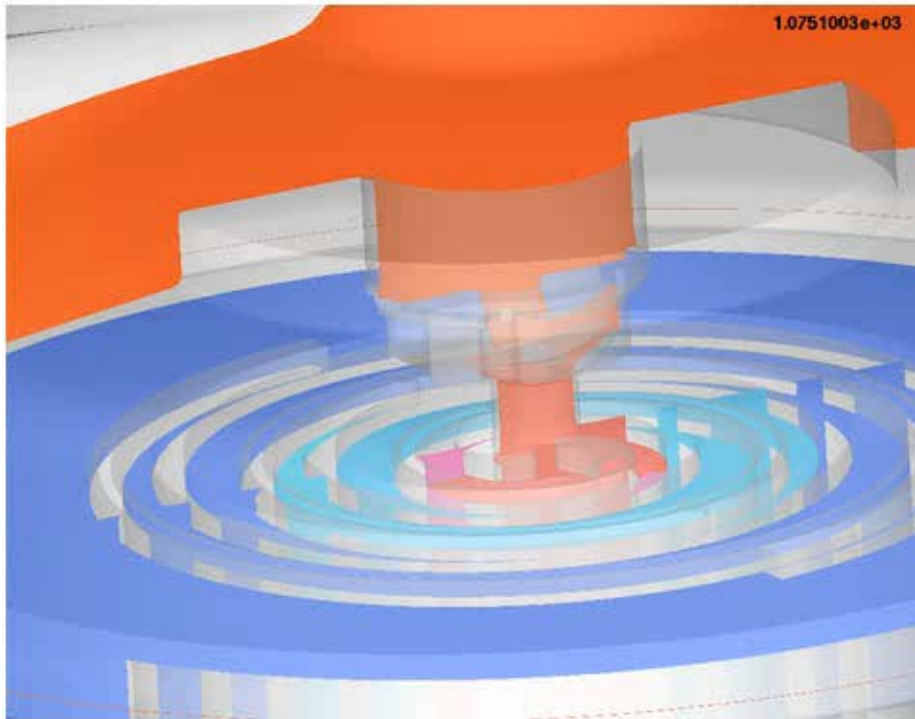
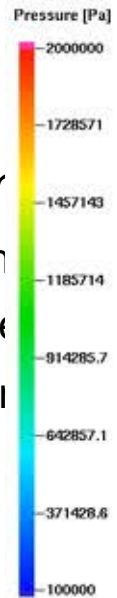
- A **scroll compressor** utilizes two opposing parts, with prismatic, spiral-shaped walls to form and compress a gas, usually air or refrigerant.
- Trane scroll compressors utilize a stationary “fixed” and moving “orbiting” scroll to create the compression mechanism.



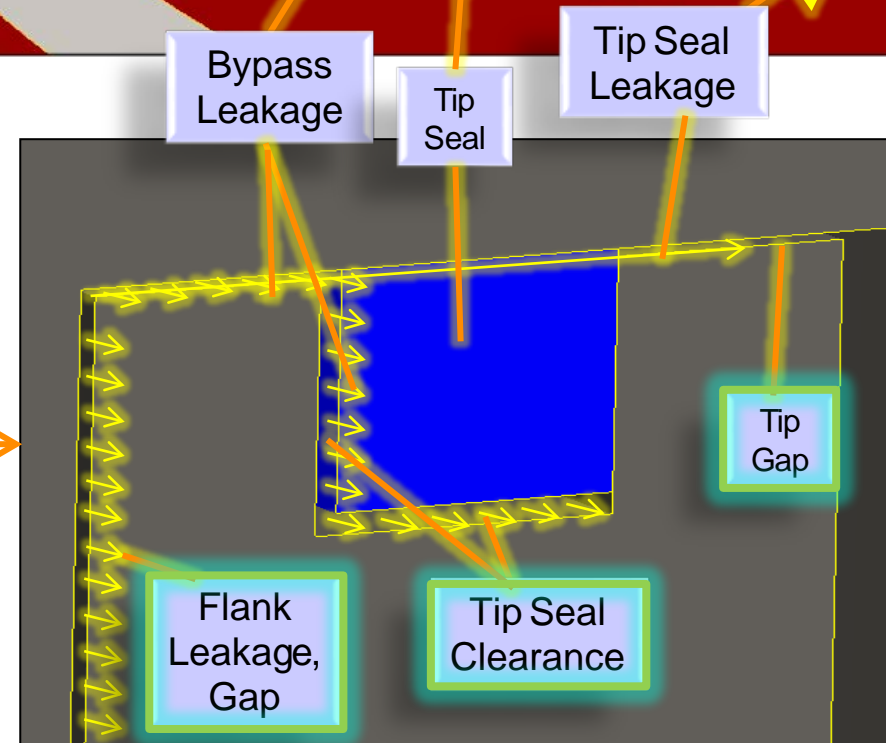
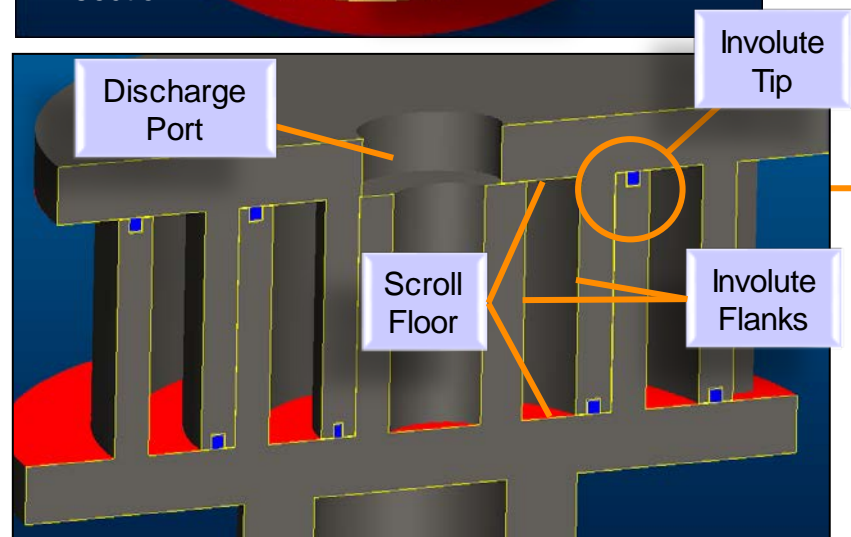
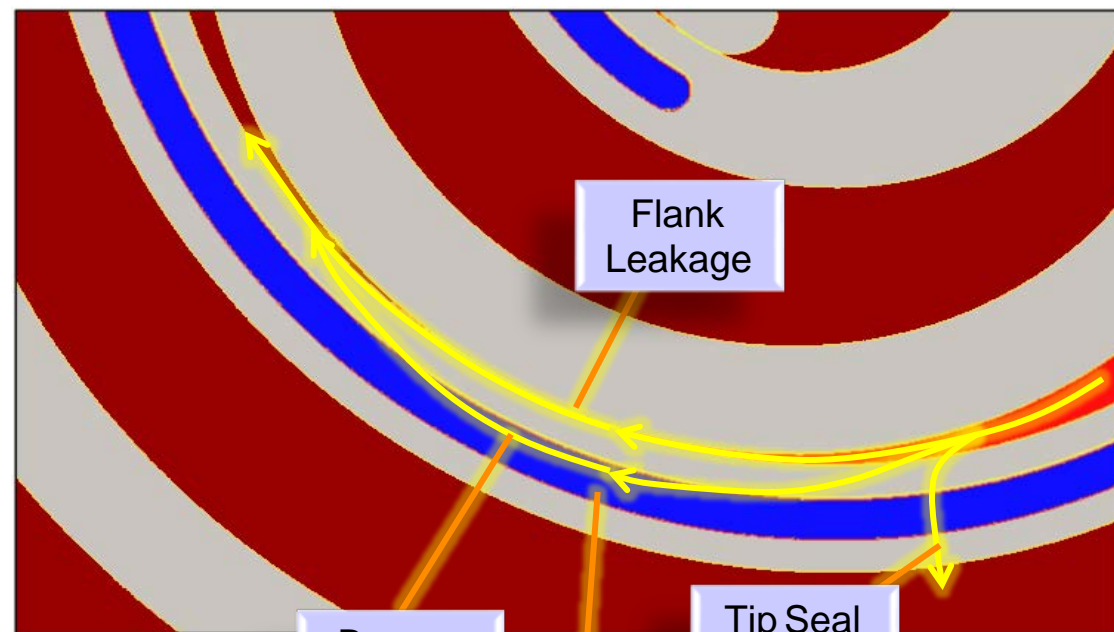
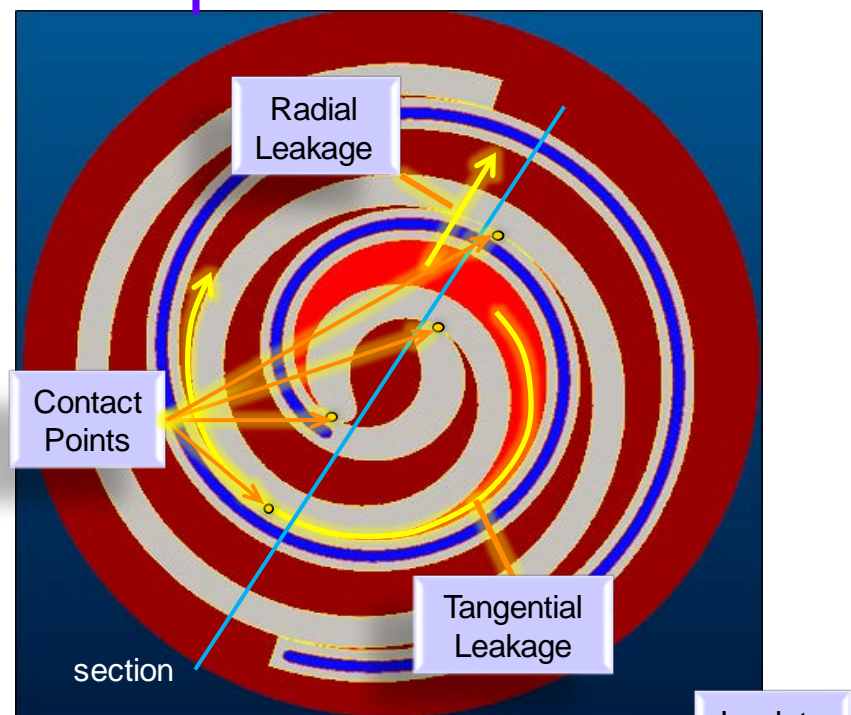
Scroll Co

- Happens in

- Suction
- Compression
- Discharge

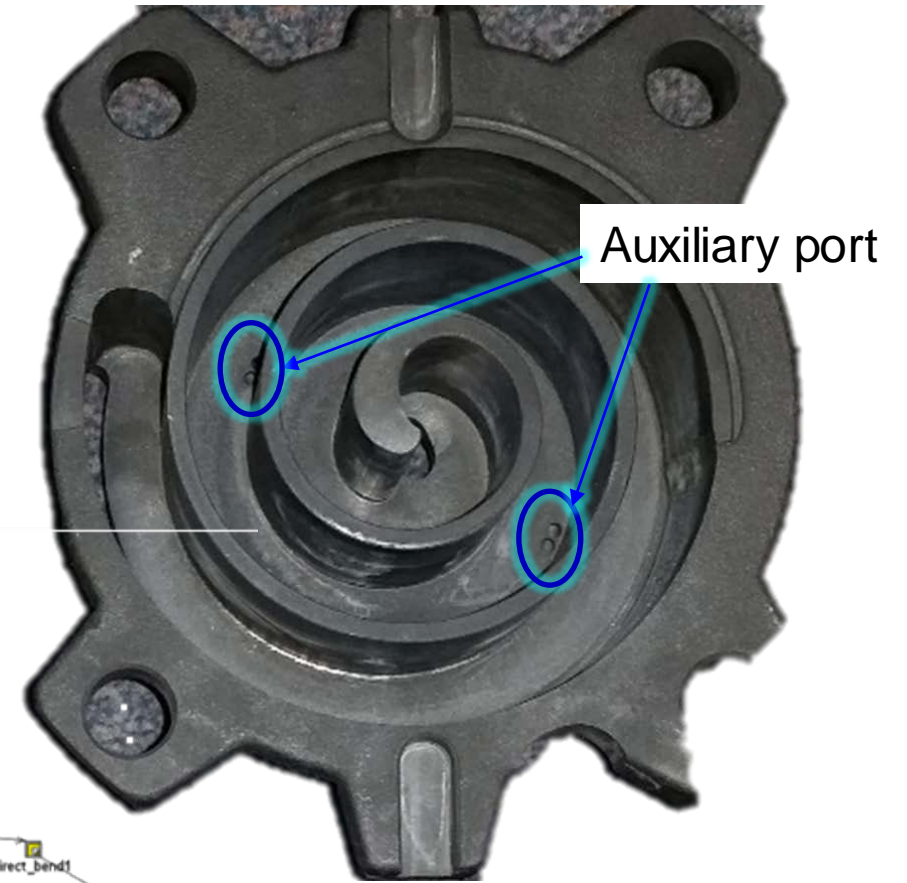


Scroll Compression Losses

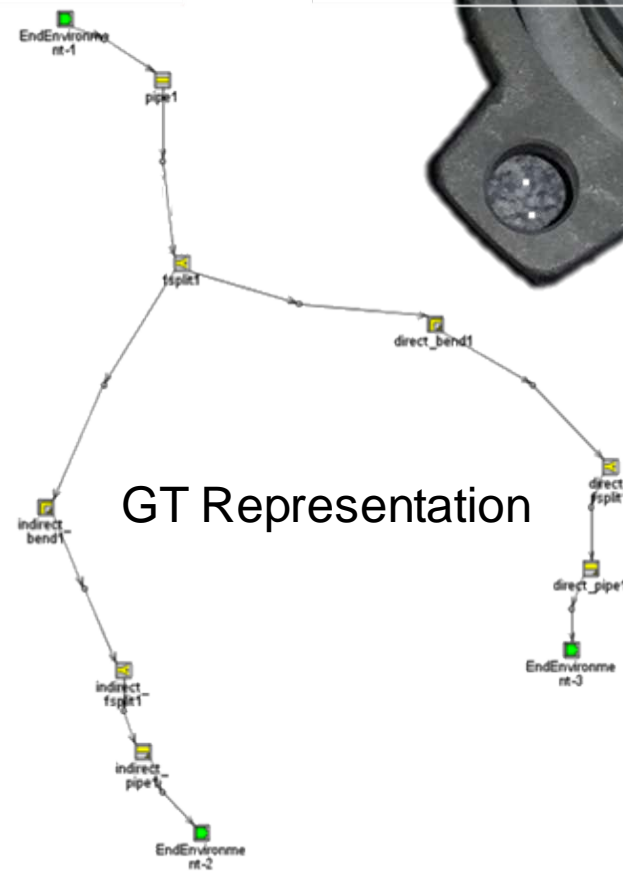
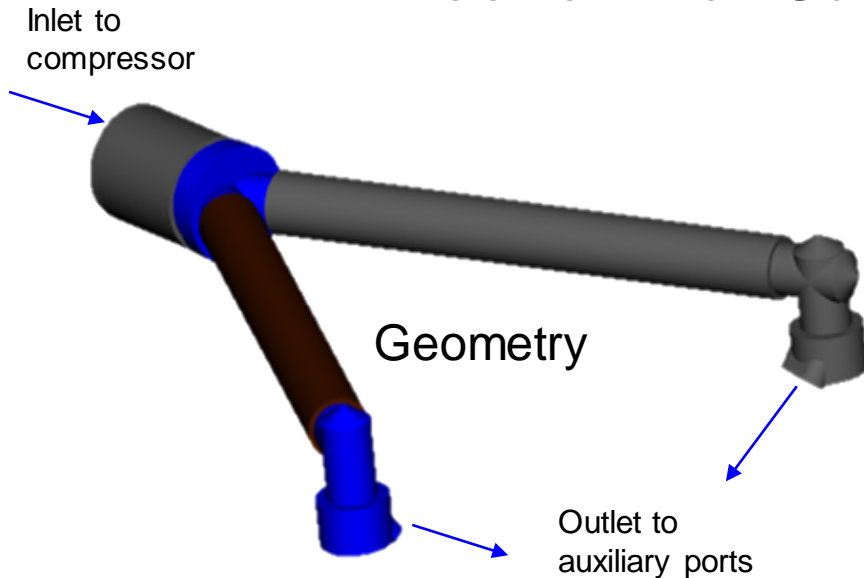


Vapor Injection

- Auxiliary (economizer) port located in compression to inject refrigerant vapor
- Piping network pressure drop and heat transfer, can significantly affect mass flow rate
 - Pressure drops characterized through submodeling



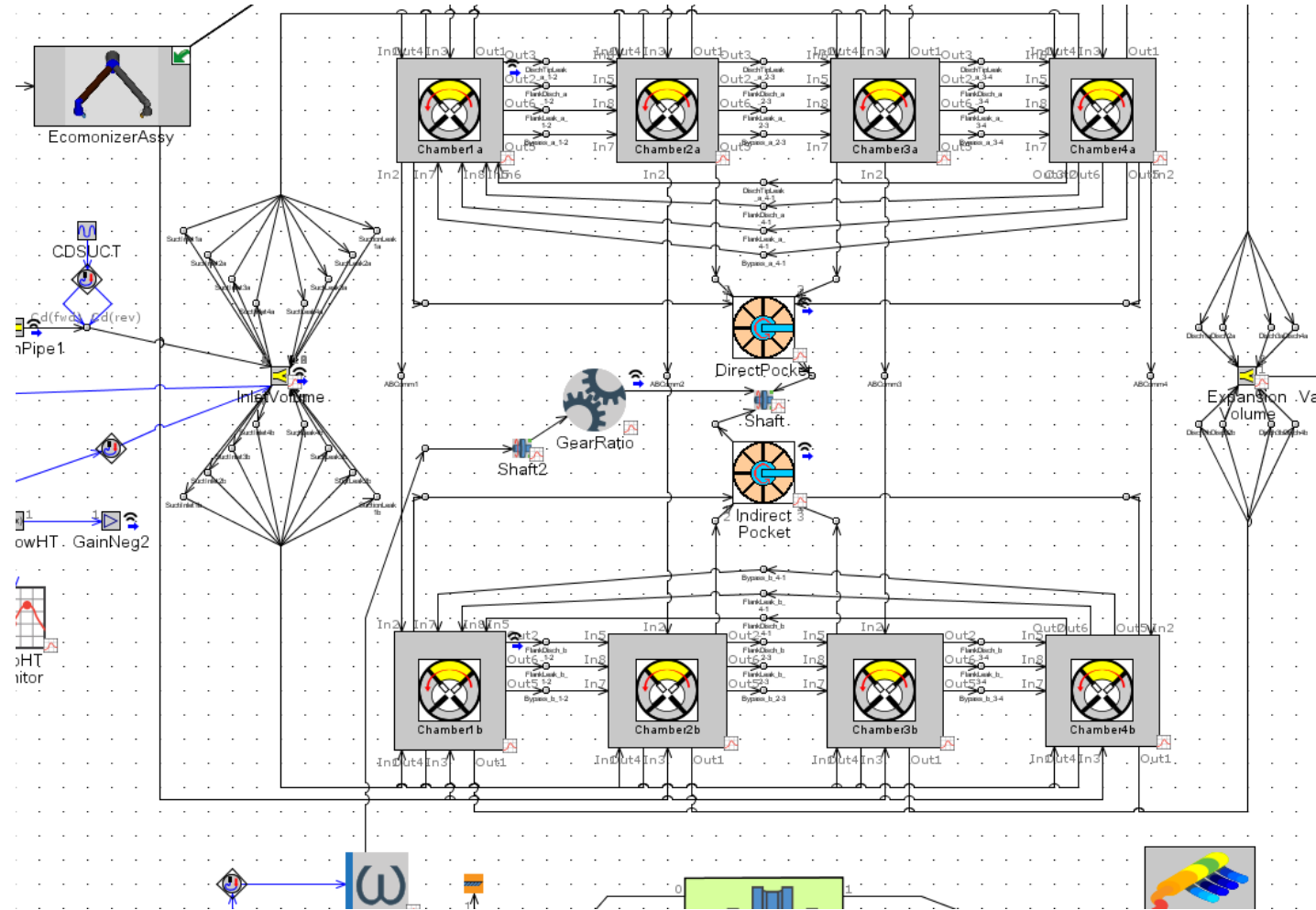
Economizer Gallery



GT Representation

Prototype Performance Shortfall

- Based on observed performance during prototype lab testing
- Economizer Mass Flow Rate 19% below target (Shortfall #1)
- Compressor Efficiency 8% below target (Shortfall #2)
- Root cause investigation
 - Heavy reliance upon analytical tools
 - GT-Suite Sensitivity Analysis
 - Using detailed chamber-compressor model
 - Basic level calibration



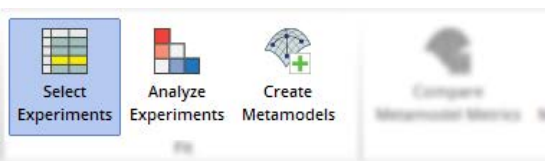
GT-Suite Sensitivity Analysis

- Full-Factorial DOE
 - 5 Factors
 - 3 Levels
 - 243 Experiments
- Performed at 2 performance rating conditions
- Quantitative sensitivity results desirable
 - Choice of min/max values must be realistic and reflective of actual differences

The screenshot shows the GT-Suite software interface for Design of Experiments (DOE). The 'Advanced' tab is selected, showing 'DOE Type: Full Factorial' and '# of Experiments: 243'. Below this, a table lists parameters and their levels.

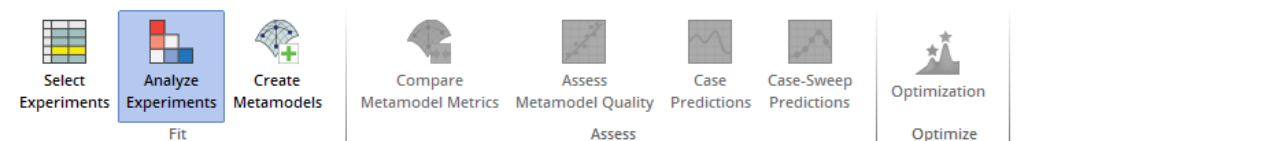
Parameter	Unit	Variable	Min/Max Value Source	# of Levels
FGAP (DOE)		Flank Gap	design differences + Part Inspections	3
HCLdirect (DOE)		Tip Gap	Assembly log	3
WSLdirect (DOE)		Tip Seal Width	Assembly differences	3
EconPressure (DOE)		Economizer Gallery Pressure Drop	GT/CFD Submodeling	3
EconSuperheat (DOE)		Economizer Gallery Superheat	Previous test data	3

Variable	Min/Max Value Source
Flank Gap	design differences + Part Inspections
Tip Gap	Assembly log
Tip Seal Width	Assembly differences
Economizer Gallery Pressure Drop	GT/CFD Submodeling
Economizer Gallery Superheat	Previous test data



Sensitivity Analysis Results

- Results post-processed to the same reference frame as the problem statement



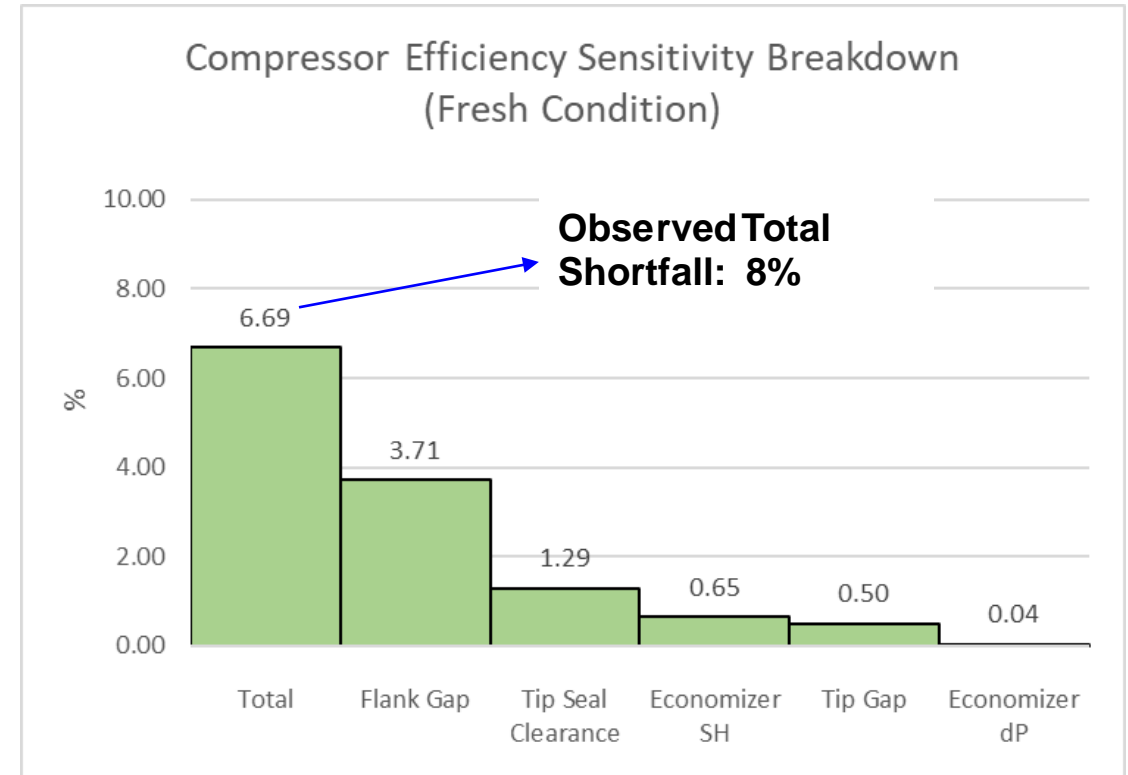
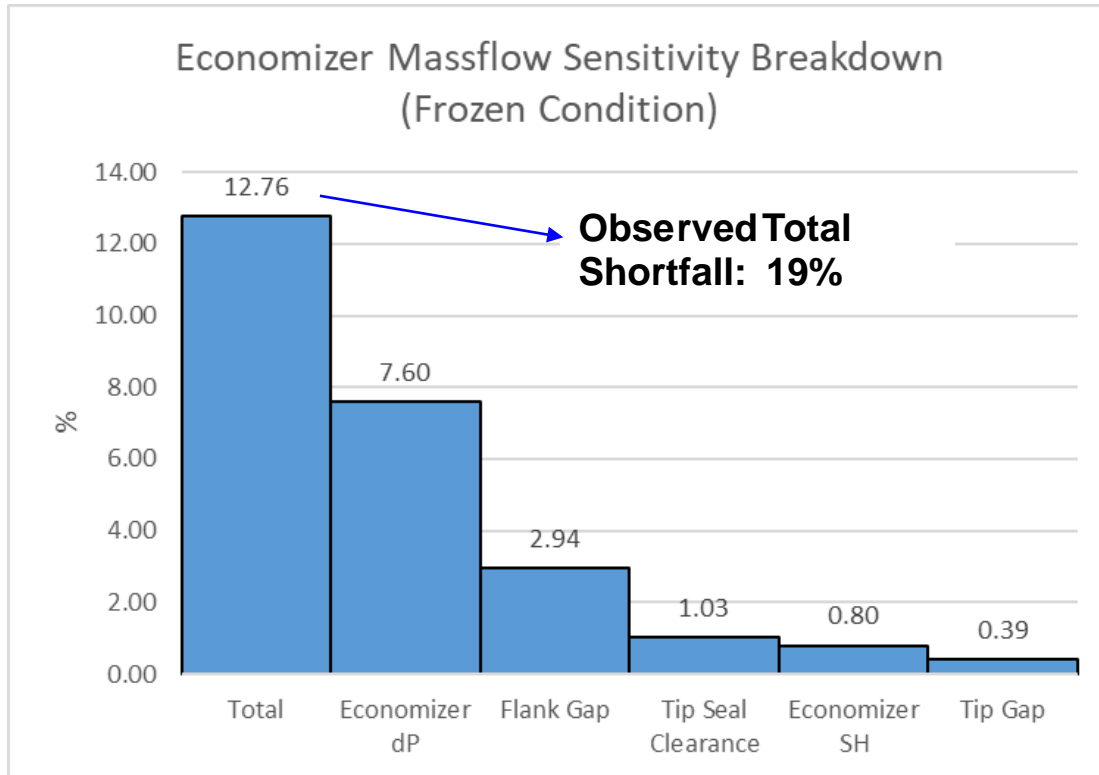
Relative Sensitivities and Correlation Coefficients Analysis									
#	Experiment Set	Case	Response	HCLdirect	FGAP	WSLdirect	EconPressure	EconSuperheat	Linear R-Squared
Type				Factors					
1	Default	1 - Case - 1	Economizer_Mass_Flow_Rate	0.03964	0.2956	0.2400	0.2805	0.3838	0.9997
2	Default	1 - Case - 1	Suction_Mass_Flow_Rate	0.08362	0.4773	0.3864	0.08046	0.01246	0.9997
3	Default	1 - Case - 1	Compressor_Efficiency	0.04382	0.4696	0.3868	0.004952	0.08238	1.0000
4	Default	1 - Case - 1	Economizer_Volume_Flow_Rate	0.09032	0.3754	0.3047	0.2188	0.05885	0.9999



...

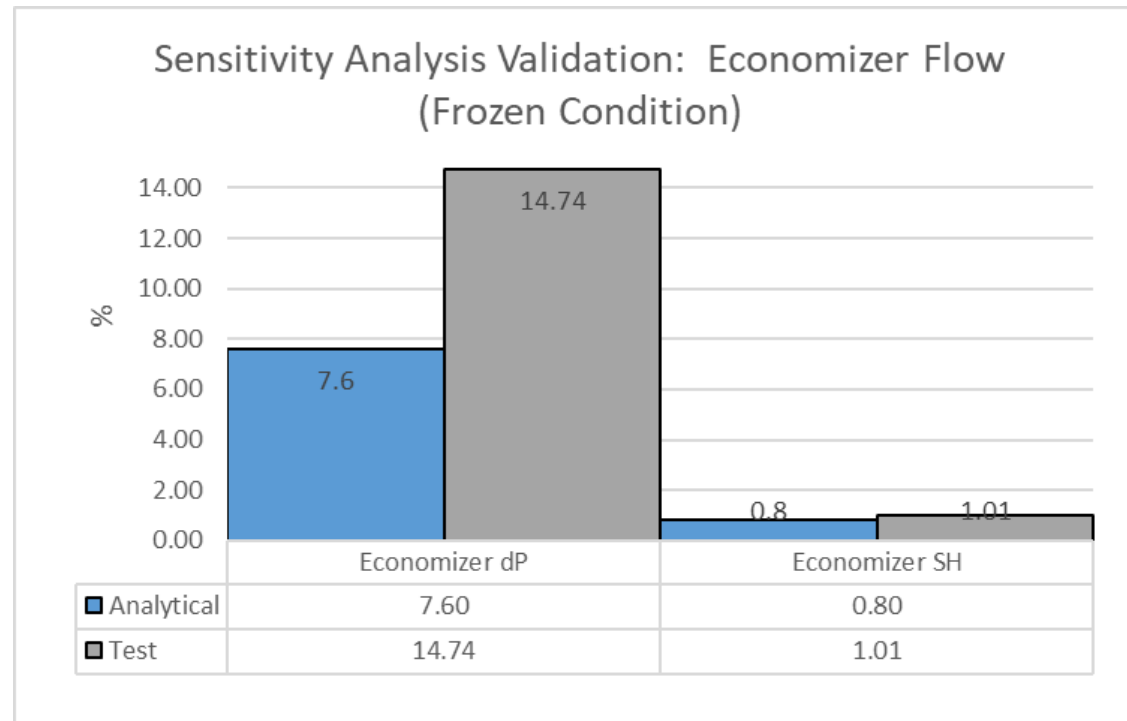
Sensitivity Analysis Results

- Gives the relative contribution of each factor to the total performance shortfall
- Results show a model under-prediction
 - Closer on Compressor Efficiency



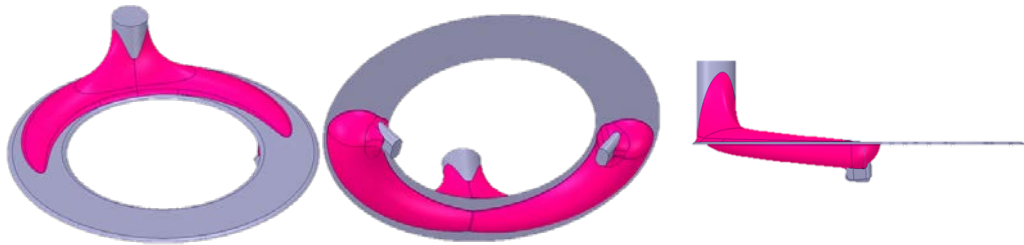
Sensitivity Analysis Validation

- A qualitative and quantitative assessment was made through testing
- Results confirm an overall under-prediction of the economizer dP factor by almost 2x
- Relative strength of the two factors produces the same conclusion

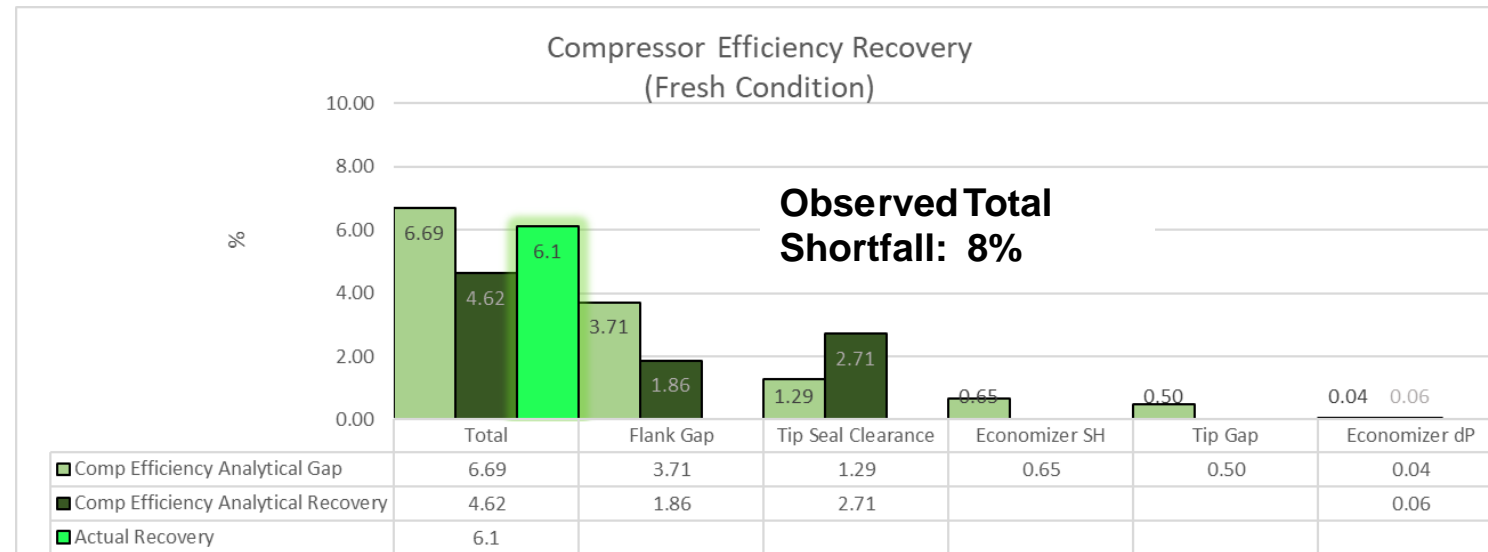
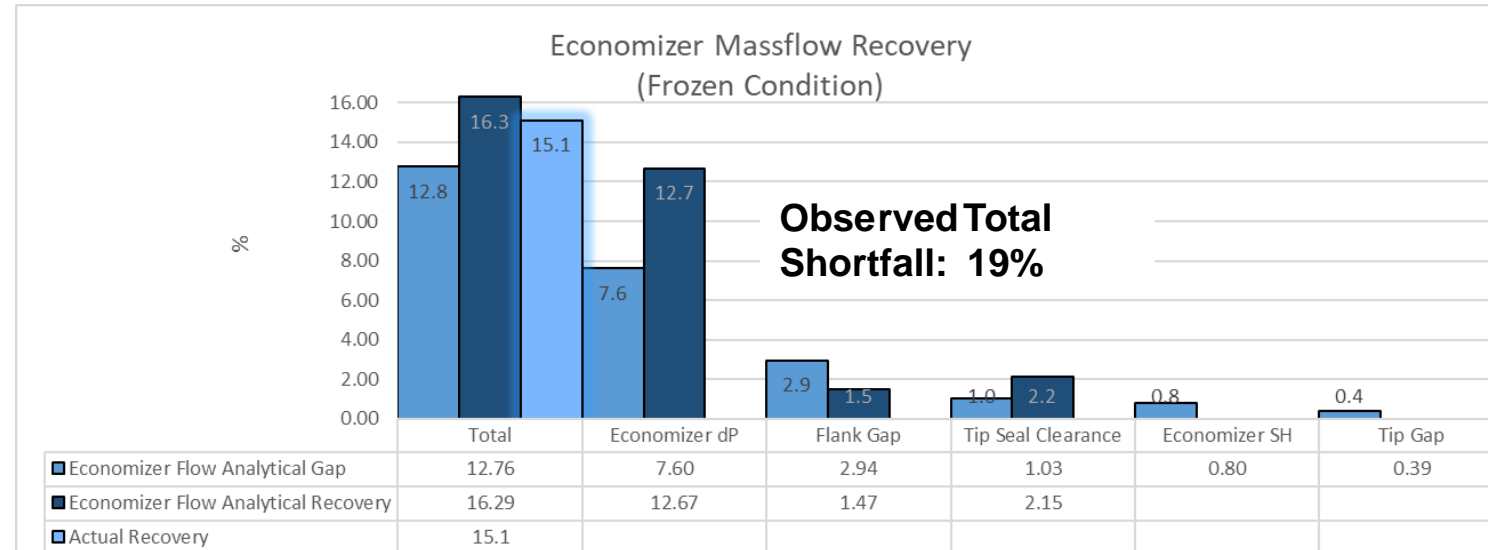


Performance Recovery

- Successful recovery of most of the performance shortfall
- Recovery achieved through:
 - Reduced economizer gallery flow resistance



- Reductions in nominal flank gap and tip seal clearance



Conclusions

- A simple sensitivity analysis was used to quickly solve a challenging performance shortfall problem
- Quantitative results were obtained by using realistic min/max factor values
- A simple validation test was conducted, which boosted confidence and helped to better quantify recovery expectations.
- Recovery factors were targeted based off GT-Suite analysis, and produced satisfactory problem resolution
- The value of a quickly solved problem, such as this, could be \$50k-\$40M!

Questions?