# Transient System Model to Virtually Predict Energy Consumption & Pull Down for a Refrigerator


**Whirlpool GTEC Team**

**Atul Jadhav**

Senior CAE Specialist

Roshan Kumar

Ankur Kumar

Pratik Kokate

Amit Mandal

**GT-SUITE Team**

Venkatesh Dasari


Whirlpool CORPORATION

# Whirlpool Corporation

- Committed to being the **best Global Kitchen and Laundry company**, in constant pursuit of improving life at home
- Founded over **114 years** ago in 1911
- **$19 billion revenue** in 2023
- Product sold in over **130 countries**
- **59,000 employees** worldwide
- 55 Manufacturing and Technology Centers

## Our Brands

Whirlpool, KitchenAid, JENNAIR, MAYTAG, AMANA, BRASTEMP, Consul, insinkerator, GLADIATOR, acros, SWASH, everydrop, affresh APPLIANCE CARE

Whirlpool Corporation (NYSE: WHR) is a leading kitchen and laundry appliance company, in constant pursuit of improving life at home and inspiring generations with our brands. The company is driving meaningful innovation to meet the evolving needs of consumers through its iconic brand portfolio, including Whirlpool, KitchenAid, JennAir, Maytag, Amana, Brastemp, Consul, and InSinkErator. In 2023, the company reported approximately $19 billion in annual sales, 59,000 employees, and 55 manufacturing and technology research centers. Additional information about the company can be found on Facebook, LinkedIn, Instagram and YouTube.

Whirlpool Corporation Confidential

# Whirlpool of India Ltd - Global Technology & Engineering Center (GTEC)

- Whirlpool Corporation's only **Integrated Global Technology & Engineering Center** outside US operating under Whirlpool of India Ltd (WOI)

- **22 years of Value Creation for Whirlpool**

- Comprising of product & technology teams of **900+ engineers**

Whirlpool Corporation Confidential

# Problem Statement

## Objective

- To develop **Transient System Models** for **Energy Consumption** & **Pull Down test** for a **Refrigerator** using GT-SUITE software

## Technical Background

- With increased demand for using household appliances, manufacturers are looking for **innovative & sustainable solutions** with their **Product Development Process**
- Virtual Product Development (**VPD**) is the key driving force to achieve these targets and gaining a lot of popularity with its ability **to reduce time to market**

Whirlpool Corporation Confidential

# Problem Statement

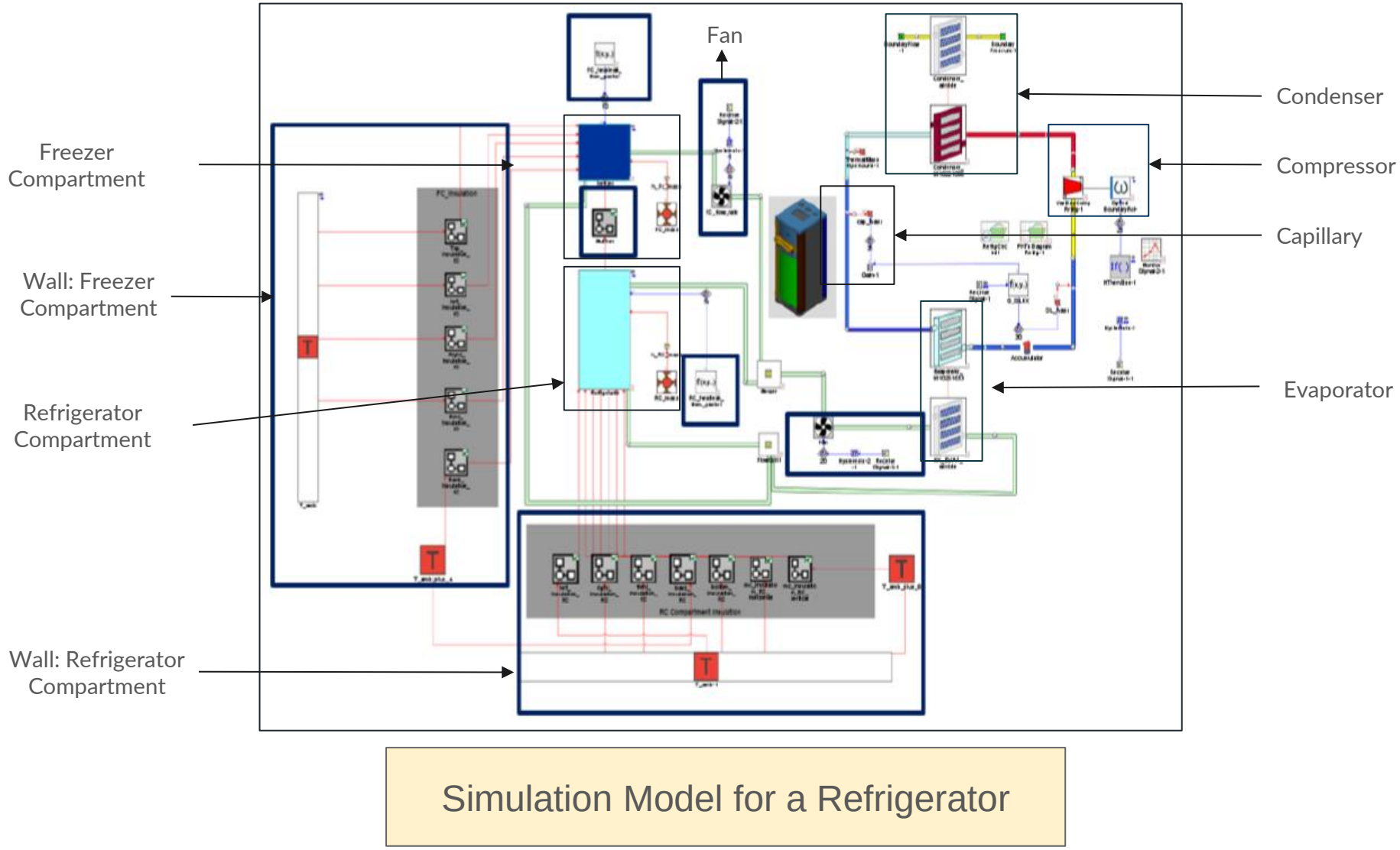
- We use **System Models** in our Refrigerator product development to determine the **performance of a system** under **different operating conditions** to quickly **evaluate different concepts** & **make preliminary decisions** in a **virtual environment**

## Commercial Impact

- During the **early product development stage**, it is important to know **system performance** under different test conditions such as **Energy and Pull-Down**
- These tests constitute **major percentage of lab workload** inside project
- Transient System Models can **minimize the need for physical testing** by **enhancing decision-making** in the **initial phases of our project**

Whirlpool Corporation Confidential

# Simulation Model - GT-SUITE




Simulation Model for a Refrigerator

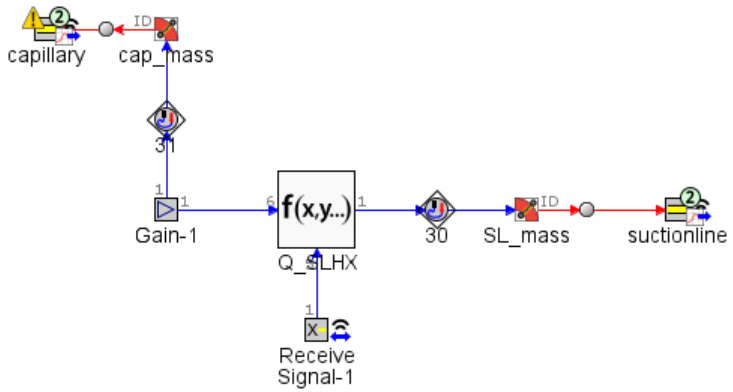
Whirlpool Corporation Confidential

# Modeling at Component Level - GT-SUITE Templates

## Compressor

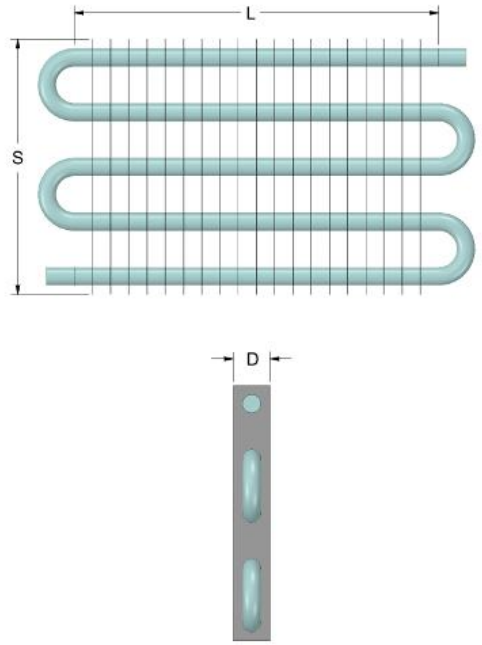
Map based with data from supplier

## Suction line heat exchanger




Made from primitives and math function

## Condenser

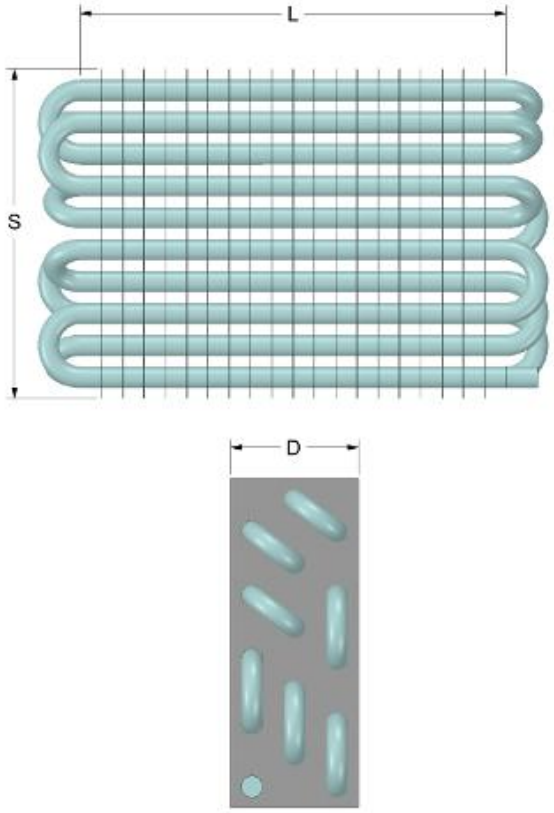



Tube fin HX with Round tube serpentine template

Whirlpool Corporation Confidential

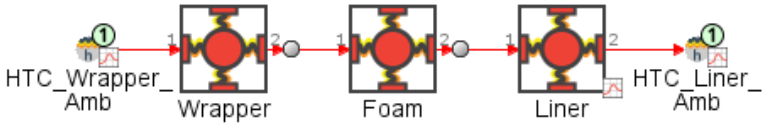
# Modeling at Component Level - GT-SUITE Templates

## Evaporator




Tube fin HX with Round tube serpentine tube custom layout template

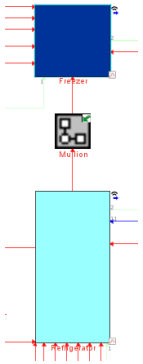
## Multi layer Insulation




Made from primitives using Thermal mass and convection connections

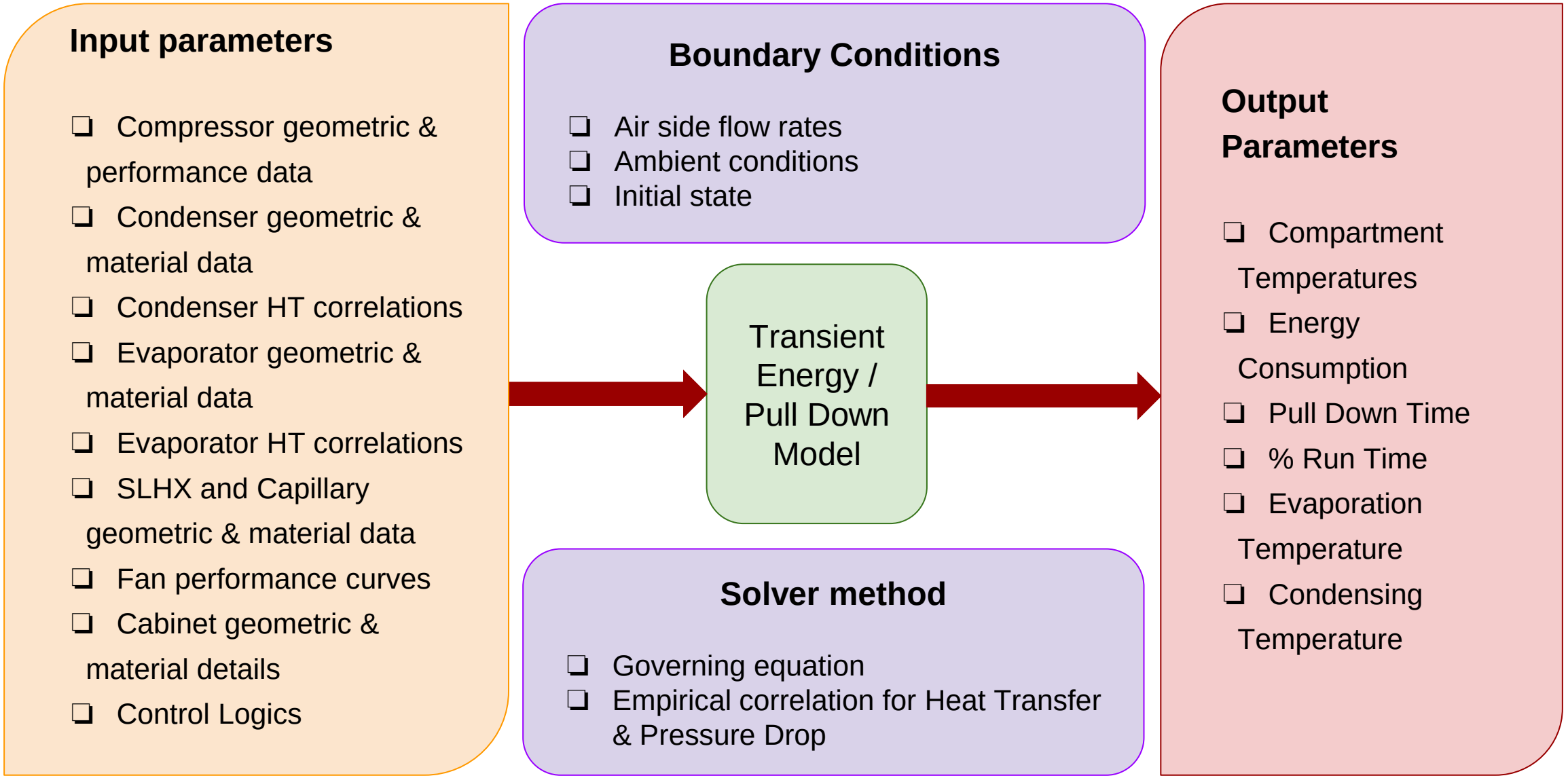
## FC and RC Compartments

Made from Flow split general template



Whirlpool Corporation Confidential

# Simulation Model Map




Whirlpool Corporation Confidential

# Test Details

## Energy Test

Power consumed by an appliance to maintain certain temperatures inside compartment over a defined time span

| Compartment | Target Average Air Temperature (degC) |
|---|---|
| Refrigerator | 4 |
| Freezer | -18 |

## Pull Down Test

Pull down test is performed to measure the reserve capacity of a refrigerating appliance particularly at high ambient temperatures.

## Test Method [Energy Test]

Test Setup as per Standard

↓

Set Chamber Temperature : 32 degC

↓

Run the test and let the product stabilize as per standard

↓

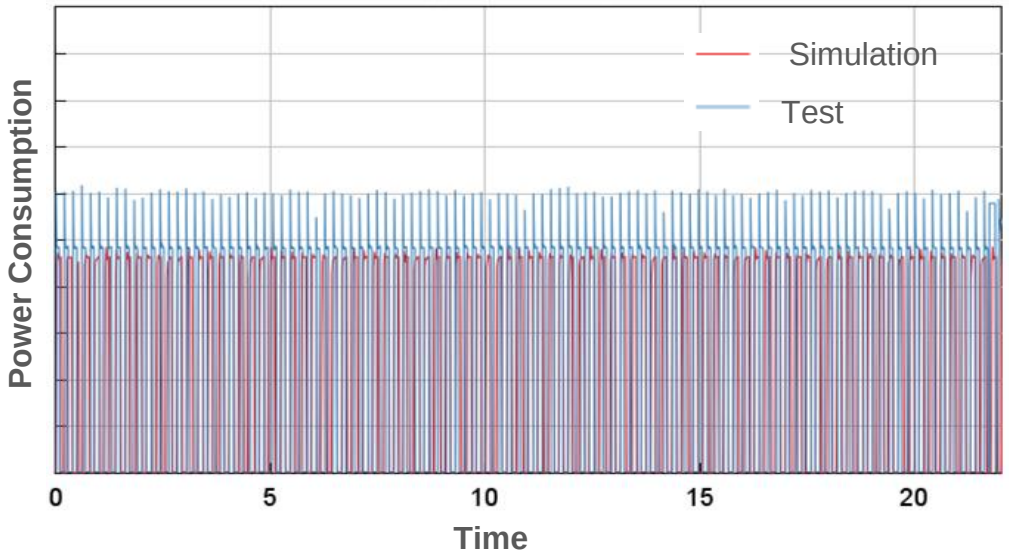
Collect the data as per requirements

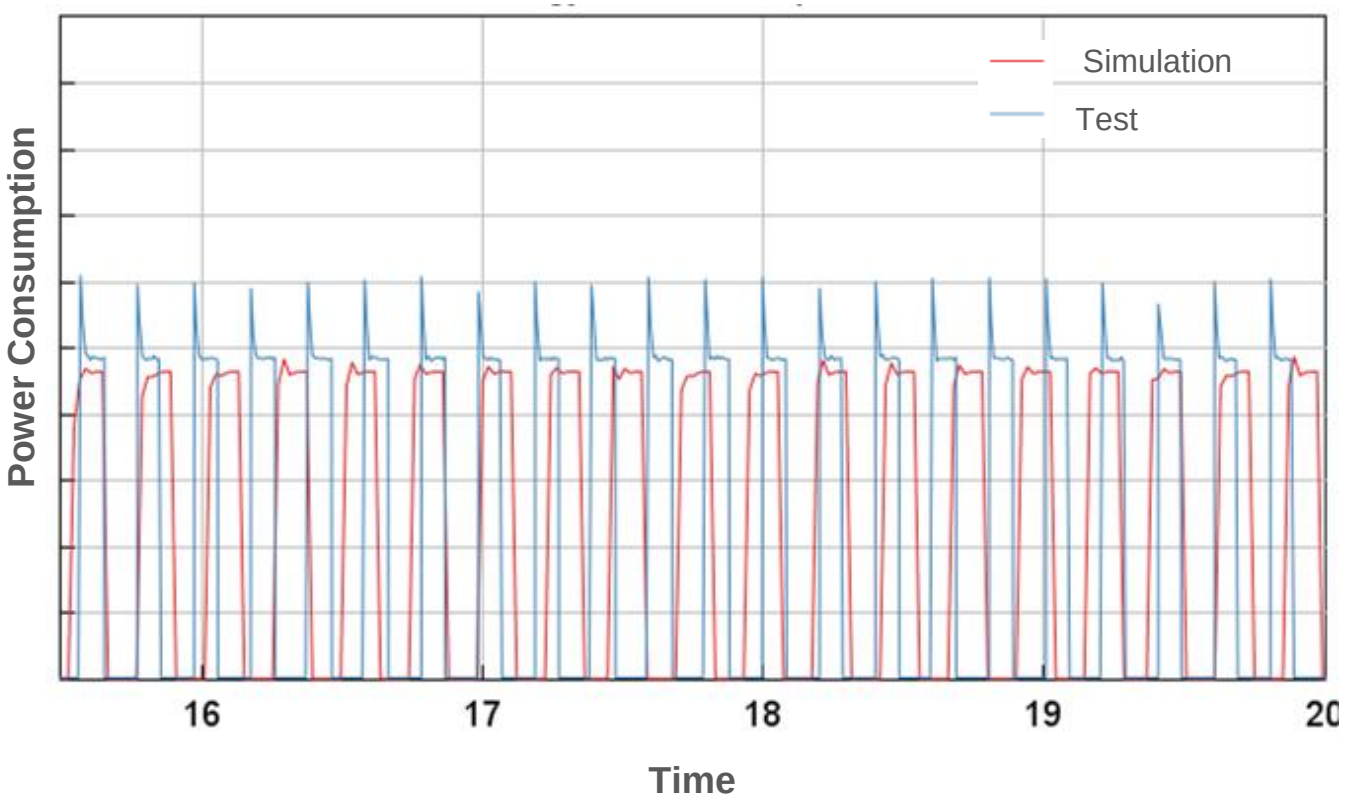
↓

Calculate the energy consumption

Whirlpool Corporation Confidential

# Energy Test Results | Power Consumption

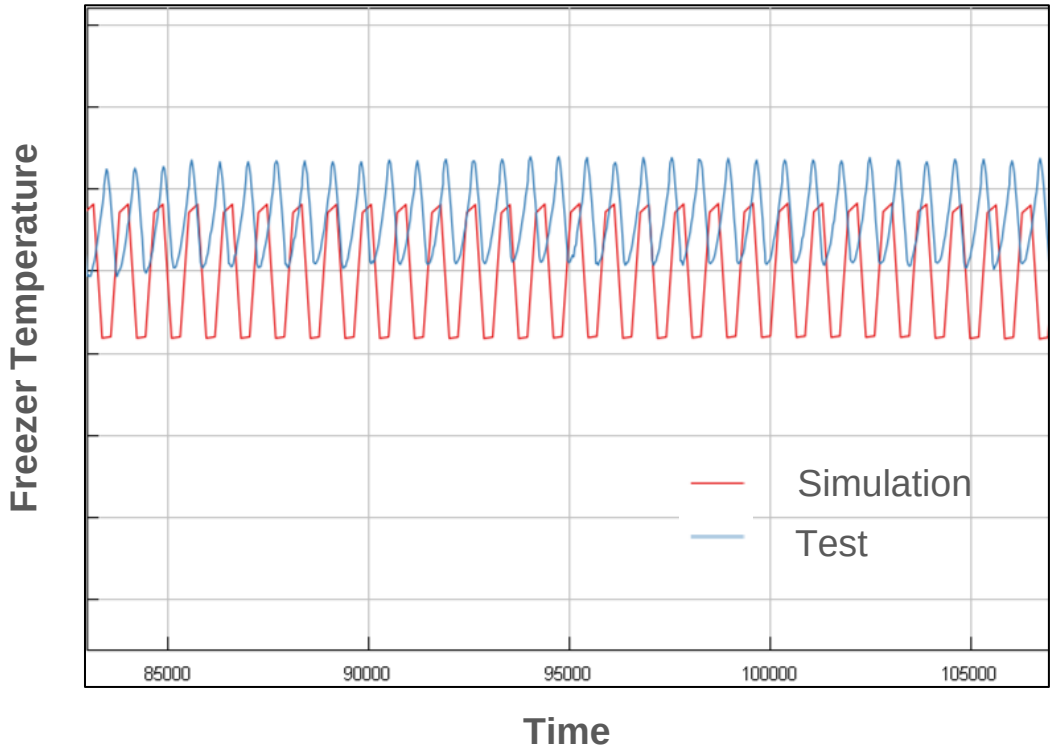


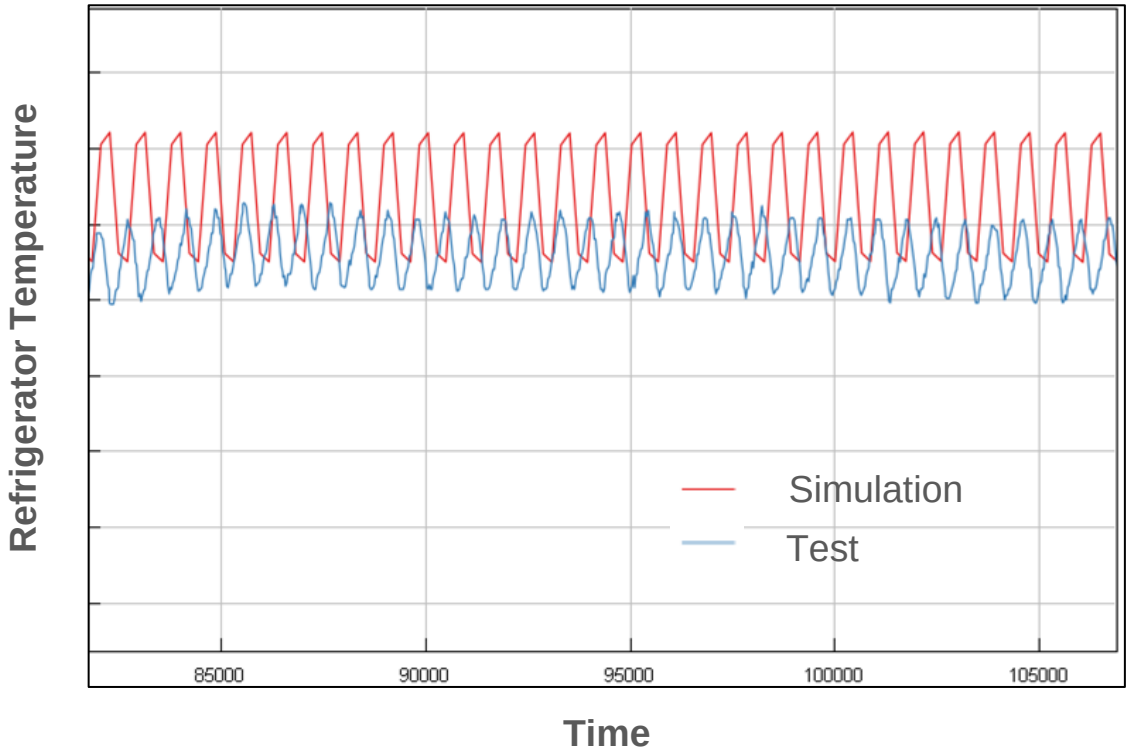




- **Stability:** GT-SUITE is able to run the simulation for 24 hours with stable performance
- **Power Consumption:** GT-SUITE is able to predict the power consumption for 24 hours with around 10 % error margin

Whirlpool Corporation Confidential

# Energy Test Results | Compartment Temperatures

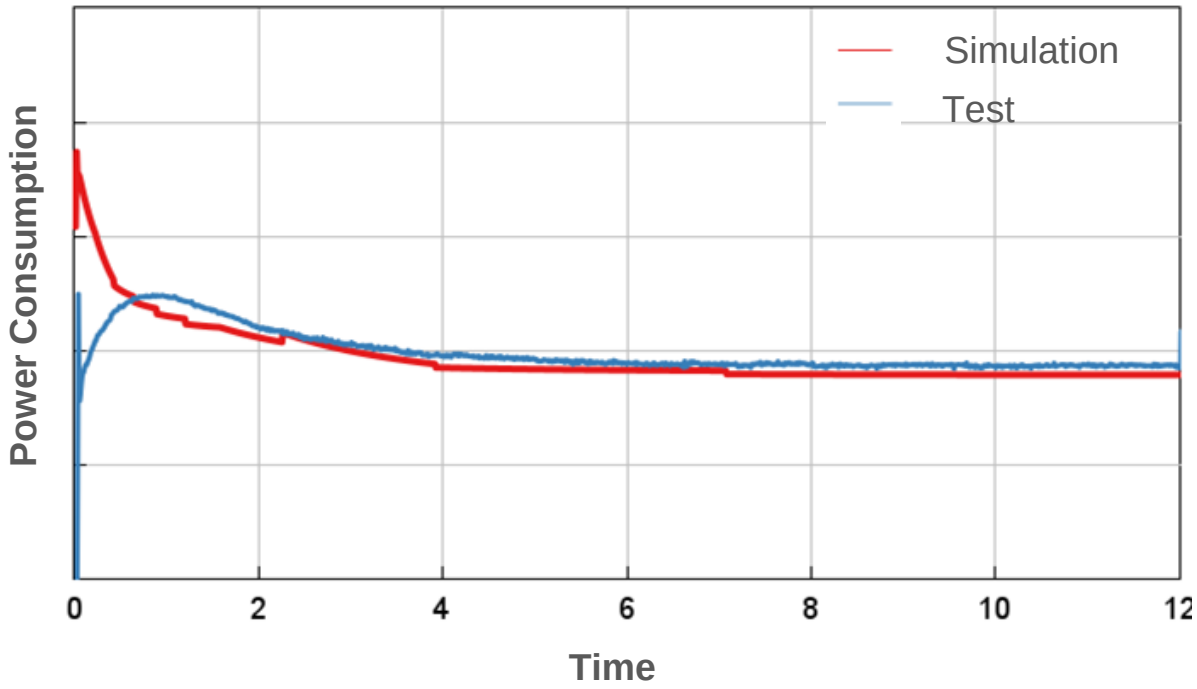


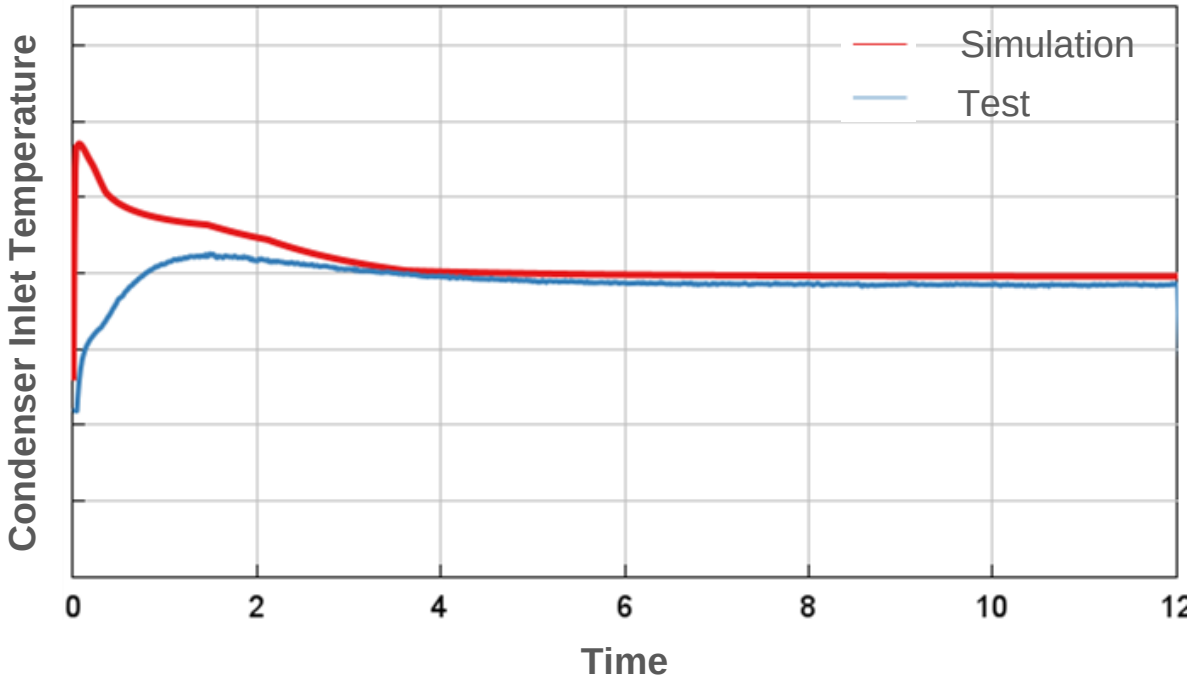




- ➔ ON/OFF events are well captured in simulation
- ➔ Detailed Sensor modelling is planned to reduce discrepancy in simulation & test data

Whirlpool Corporation Confidential

# Pull Down Test Results | Power consumption & Condenser Inlet Temperature

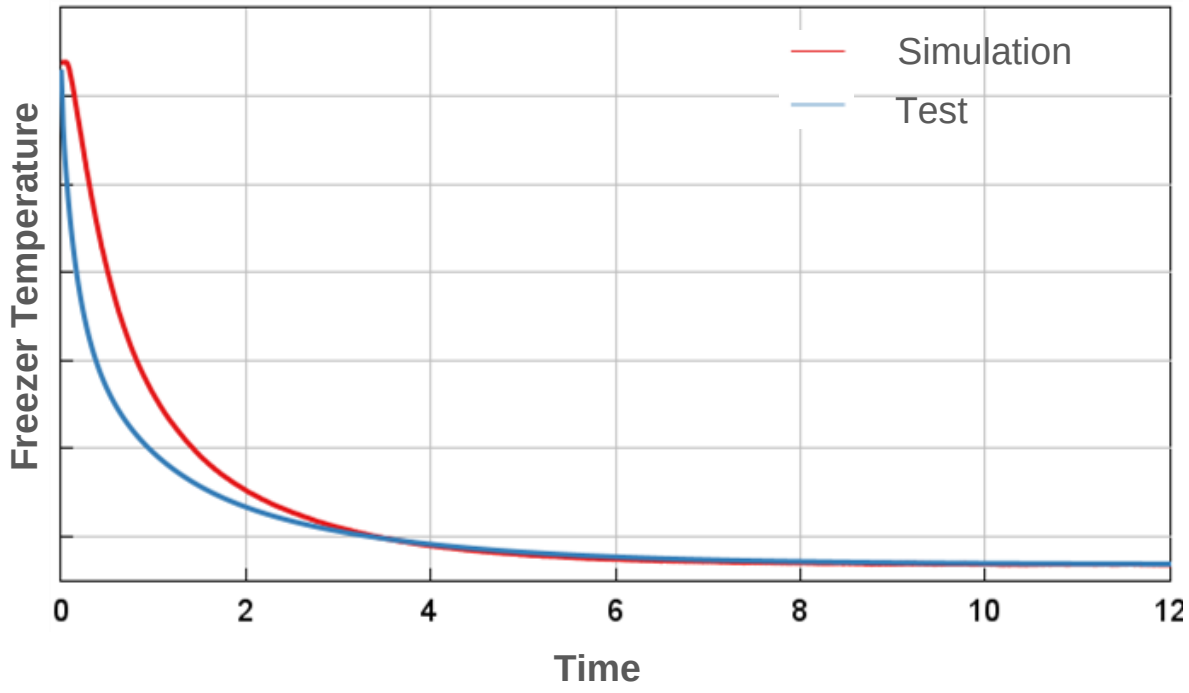


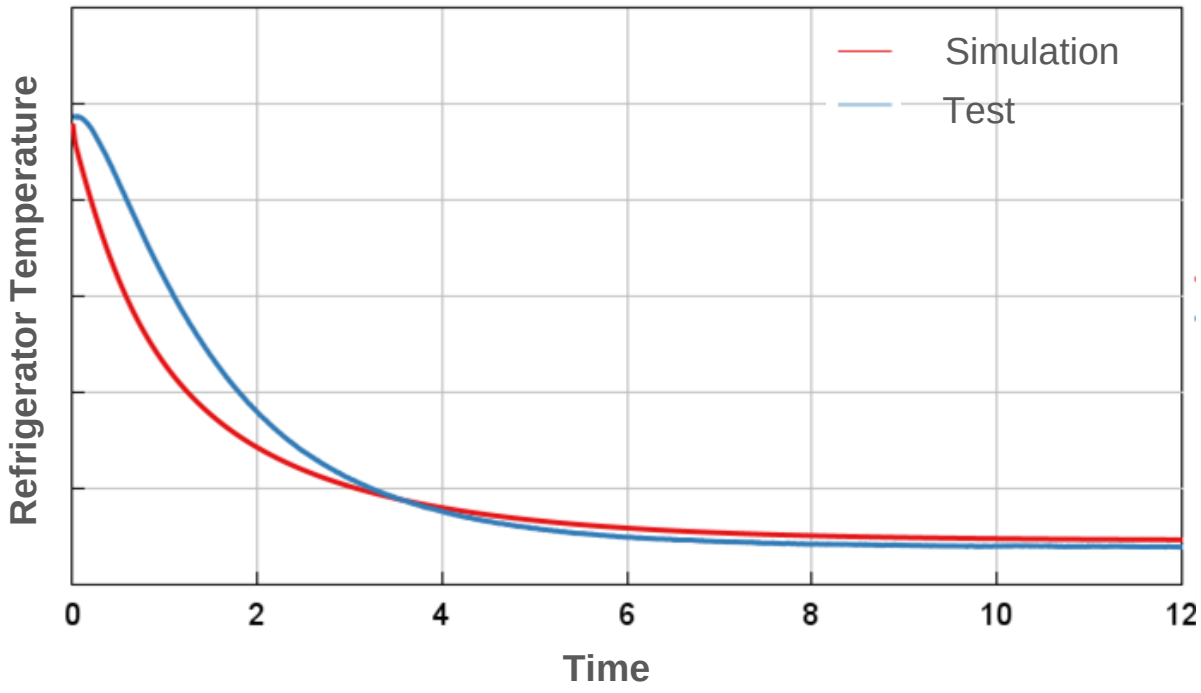




- ➔ Test data includes Fan power in addition to Compressor Power which constitutes to higher power consumption than simulation
- ➔ Good Correlation between simulation & test data

Whirlpool Corporation Confidential

# Pull Down Test Results | Compartment Temperatures




- ➔ Initial Pull Down phase results can be improved with accurate modelling of thermal masses to reduce gap between simulation & test data
- ➔ Good Correlation between simulation & test data

Whirlpool Corporation Confidential

# Results Summary & Next Actions for Model Improvements

- ➔ Transient System Models are successfully built in GT-SUITE to virtualize Energy Consumption & Pull Down test of a Refrigerator
- ➔ GT-SUITE has shown stable performance for both Energy & Pull Down test
- ➔ Simulation models are faster compared to real test scenario (Pull Down Test - 27:1 times faster)
- ➔ Models can be further improved with:
  - ◆ Accurate HTCs on each wall face (Internal & External)
  - ◆ Accurate inputs regarding isentropic efficiency & discharge temperature
  - ◆ Accurate inputs regarding thermal mass surface area of thermal mass present in system
- ➔ Detailed Sensor modelling planned to improve correlation of simulation with Energy test data
- ➔ Explore GT-SUITE capabilities to optimize control algorithms for integrated plant model

Whirlpool Corporation Confidential

Whirlpool
KitchenAid
JENNAIR
MAYTAG
AMANA
BRASTEMP
Consul
insinkerator
GLADIATOR
acros
SWASH
everydrop
affresh
APPLIANCE CARE

Whirlpool Corporation Confidential