Validating Computational Fluid Dynamics Models of Super Computing Environments

Clair Christofersen
Mentor – Aaron Andersen
August 2, 2012
Personal Background

• Undergraduate Student at Miami University
  – Major: Integrated Mathematics Education
  – Minor: Mechanical Engineering

• Related Interests:
  – Mechanical Engineering and Cooling Systems
  – Calculus Applications
  – Planning for Environmental Efficiency
Project Summary

GOAL: Optimize Energy Efficiency of NWSC

- Determine the accuracy of the TileFlow™ model from 2011 intern Jared Baker
  - Software Limitations
  - Model to Real World Comparisons

- Modify model to best represent the actual final design of NWSC’s super computing room
  - Ensure cohesiveness between temperature and airflow results

- Test-run model to select most efficient methods of cooling the center
  - With & Without Hot Aisle Containment, With & Without RDHX
  - Close dampers in perforated tiles
  - 2 Fans Running, 3 Fans Running, 4 Fans Running
  - Increasing Server Inlet Temperature
NWSC Efficiency

• High and Dry Cheyenne
  – Natural cooling 96% of year
    • Evaporative cooling
    • Outside Air
  – 10% renewable energy from wind

• Achieved LEED Gold Certification
  – Strong Power Usage Efficiency (PUE) ratio

• Sustainable Design
  – High raised floors for sufficient air flow
  – Chilled beam system for effective office cooling
  – Water consumption reduced by 4.2 million gal/yr due to cooling tower and low flow plumbing
  – Natural lighting from window placement

SOURCE - http://www.nwsc.ucar.edu/sustainability
Jared’s Preliminary Models

- Fully air-cooled (1)
  Water-air cooled (2)
  Fully water cooled (3)

- Water-air cooled showed lowest total heat rejection (most efficient option)
Water-Air Cooled Selection

• Liquid Cooling (Rear Door Heat Xchangers)
  – Yellowstone HPC 1.55 PFLOPS, 63 compute cabinets
  – RDHX removes 30 kW per cabinet & eliminates 100% of heat generated in each cabinet

• Air Cooling (Hot Aisle Containment)
  – GLADE, Data Analysis & Visualization (DAV) Clusters
  – Hot Aisle Containment to avoid mixture of hot and cold air
Altering the Model

Place Yellowstone HPC on right, GLADE & DAV Clusters on left (different cooling needs)

FLIP Yellowstone 90 degrees (simplified installation)
Altering the Model (cont’d)

• Placement and number of perforate tiles, wrong type of perforated tile in TileFlow
  – Damper vs. no damper
  – Affects CFM per tile

• Appropriate supplied airflow
  – 4 Air Handler Units (AHU), each supplies 49000 cubic feet per minute (cfm)
  – When dampers close, each unit supplies 35800 cfm

• Appropriate drop ceiling openings
  – Affects pressure drop
A Model That Matches Cohesive Results Between TileFlow and Actual Measurements

Temperature Relationship

- expected limitations from leakage and under floor obstructions

Airflow Relationship

- CRAC units inside TileFlow™ are at a specified airflow rate
  - **No differential pressure control**
Test Run: Without RDHX

**Hot Spot** – server inlet temperature > 82 °F

RESULT: Hot Spots in ALL Inlet Temperature Areas

No RDHX in Liquid Cooled Section
Test Run: With RDHX

RESULT: No Hot Spots, Possibly Cooler Inlet Temperature Than Needed

RDHX in Liquid Cooled Section

Temperature in F

55.0 65.0 75.0 85.0 95.0
**ΔT: Temperature Differential**

- T return – T supply
- Higher ΔT → Greater Efficiency  
  - Reduces the amount of fan or pumping energy required to move the same amount of energy around
- Much higher return temp w/ Hot Aisle Containment

---

**Test Run: With & Without Hot Aisle Containment**

- **No Hot Aisle Containment in Air Cooled Section**
  - RESULT: Hot Spots in Inlet Temperature Areas

- **Hot Aisle Containment in Air Cooled Section**
  - RESULT: All Hot Air Contained, Flow to Return Ducts for Cooling
Simulation: No Hot Aisle Containment
Findings & Conclusions

• Better for installation purposes to flip Yellowstone HPC 90 degrees

• Important to **accurately** consider ceiling and floor openings when developing TileFlow model

• Closing dampers on perforated tiles around Yellowstone reduced fan wall use by 40%
  – No effect on inlet temperatures

• Hot Aisle Containment for GLADE & DAV Clusters

• RDHX for 1.5 PFLOP equipment (Yellowstone HPC)
Future Work

• Determine “Sweet Spot” Server Inlet Temperature
  – Lowest kW use without allowing hot spots

• Find greatest fan wall efficiency
  – 2 fans at highest CFM, 3 fans at medium CFM, 4 fans at lowest CFM
Questions?