Marine Keel Cooler Optimization Tool

EML 4551C Senior Design

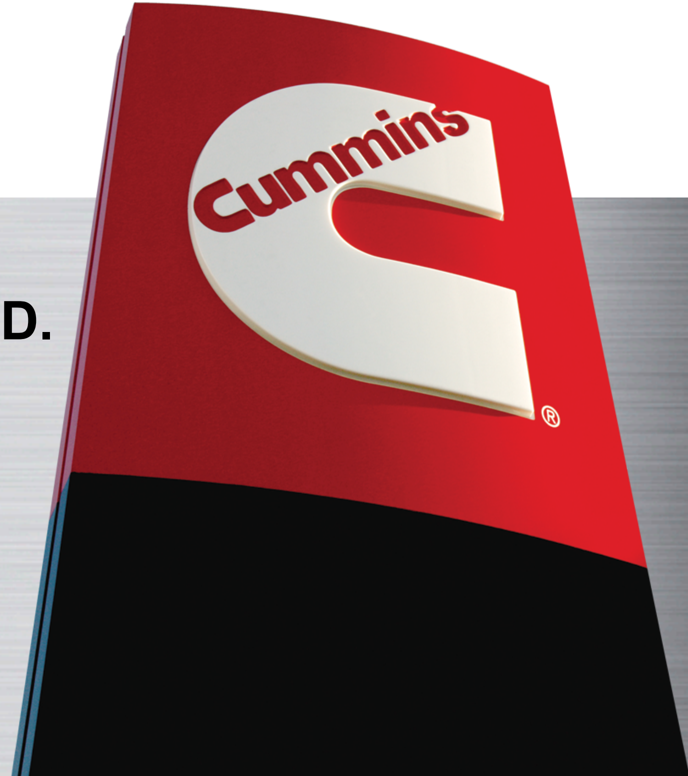
Sponsored by **Frank Ruggiero**

Faculty Advisor **Steven W. Van Sciver, Ph.D.**

Instructor **Nikhil Gupta, Ph.D.**

Team 3

Melissa Allende *Grady Beasley* *Stanko Gutalj*
James Haga *Jacob Ross*



Presented 20 October 2015

Overview

- Problem Statement and Goal
- Project Scope
- Background and Theory
- Design and Analysis
- Scheduling and Resource Allocation
- Results
- Conclusion

Problem Statement & Goal

- Problem Statement:

  "The current Cummins Keel Cooler Tool provides no feedback on a particular design and is limited in its capability"

- Project Goal:

  "Design a more versatile design tool which generates feedback and provides a more user friendly interface"

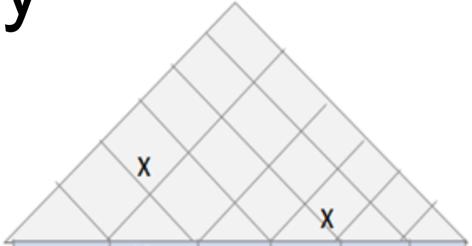
Project Scope

- The current design has no customer feedback
- Only provides user an output of “Pass/Fail” on design
- Needs to provide recommendations for design improvement
- The device needs to be able to evaluate the design of the keel cooler through the use of different materials (Currently only evaluates steel)
- Current tool is outdated and not user friendly

Project Scope

- Customer Characteristics
  - Evaluates through multiple materials
  - Accurate
  - Interactive feedback
  - Define optimal size
- Engineering Characteristics
  - Sharable
  - Programming Language
  - Minimize coding lines
  - Maximize processing time

House of Quality (HOQ)



Technical Requirements	Customer Priority	Programming language	Minimize coding lines	Shareable	Use equations	Range of inputs	Testability
Uses Multiple materials	4	1	1	1	4	4	4
Define optimal size	5	1	1	1	4	2	2
User friendly	4	4	4	4	1	2	2
Suggest alternatives	3	2	1	1	1	2	1
Accurate	5	1	2	1	4	1	4
Interactive feedback	4	2	2	1	1	4	2
Raw Score		44	46	37	67	61	65
Rank order		**5**	**4**	**6**	**1**	**3**	**2**

Technical Rank scale:
4 Highest
2 Medium
1 lowest

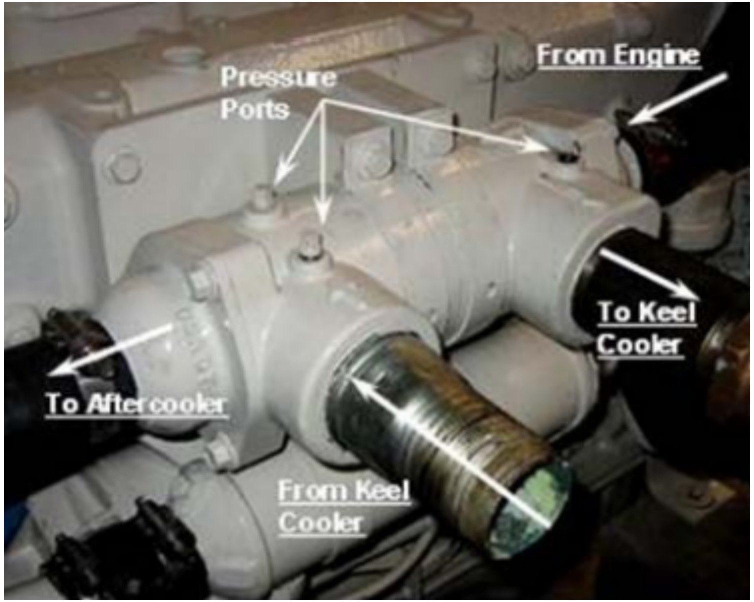
Customer Priority:
Ranks from 1 to 5 where 5 is the highest

Background and Theory

- A properly designed and installed cooling system is essential for satisfactory engine life and performance
- Keel cooling is a cooling system which utilizes a group of tubes, pipes or channels attached to the outside of the hull below the waterline
- Cummins Marine one of the Markets within Cummins Inc. is specialized in diesel engines outfitted to provide power in marine vessel applications
- Since cooling of engine is not possible to thoroughly rely on charged air circulation, an alternate system must be used

Background and Theory

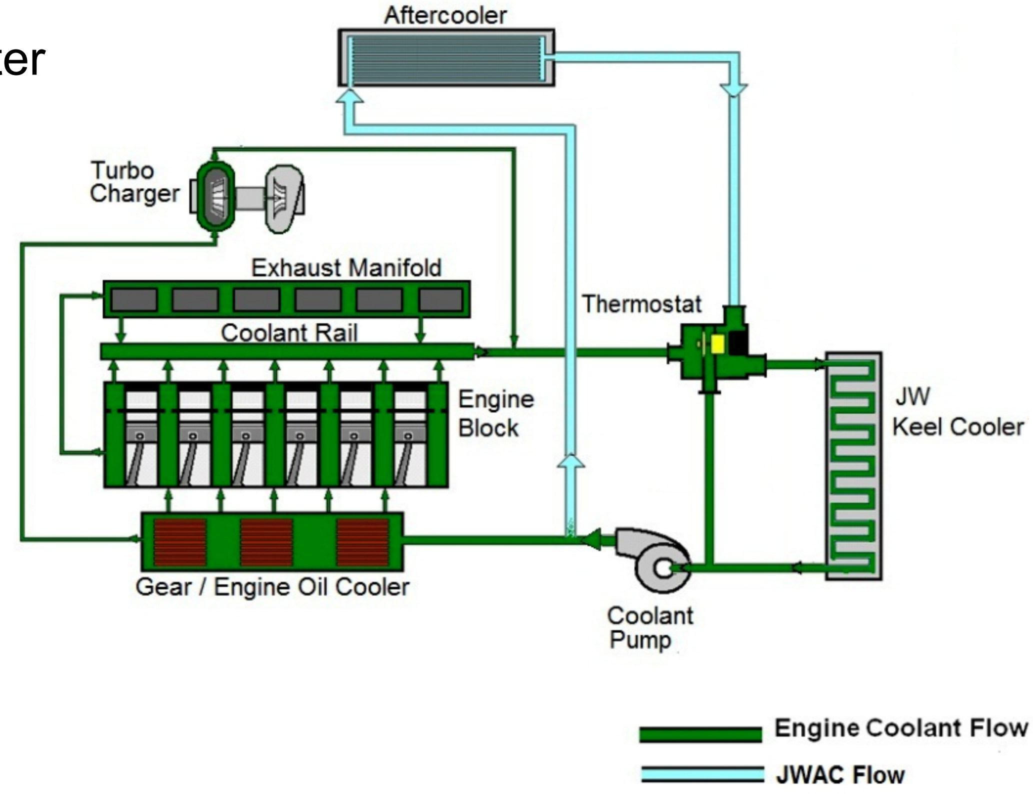
- Cummins Marine Requires a design optimization tool as well as a design validation tool for keel cooling systems
- A predictive tool is require for the Marine Application Engineers to ensure engine installation quality assurance



LTA Thermostat Housing

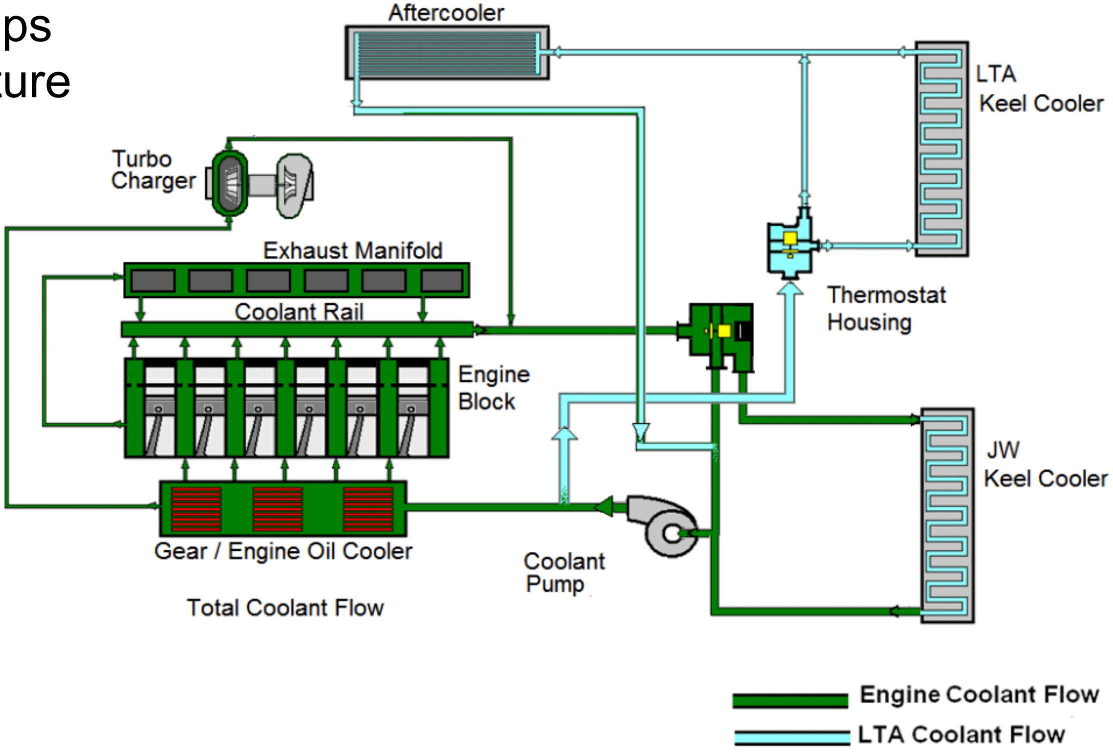
Background and Theory

- Jacket Water After Cooler (JWAC) QSK19



Background and Theory

- 1 Pump 2 Loops
  Low Temperature
  After Cooler
  (1P2L LTA)
  QSK19



Design and Analysis

- Steps for Design:
  1. Choose the right programming language
     - *Can we make the program work?*
  2. Identify the user and current inputs/outputs
     - *Who will be utilizing the program?*
     - *What are the user inputs?*
     - *What are the expected outputs?*
  3. Structure the program correctly
     - *Is the program intuitive and self-explanatory?*
     - *Establish standards for quality*

Design and Analysis

1. Choosing a Coding Language
    - *C, Java, Matlab*
    - *Judging criteria*
        - ✓ *Knowledge*
        - ✓ *Structure*
        - ✓ *Aesthetics*
        - ✓ *Relevance*

Table 1: Decision Matrix

Program:	Knowledge	Structure	Aesthetics	Relevance	Total:
C	9	10	1	10	8.5
Java	2	7	8	8	4.2
Matlab	8	1	8	6	6.4

C was chosen due to Team Member familiarity and ease to convert to other languages if necessary

Design and Analysis

2. Identify the User
    - Primary users will be Marine Application Engineers and Boat builders in shipyards
        - Two purposed: ***Validation*** and ***Design***
    - Uses same user inputs as the current program but adds custom engine option as well as design mode inputs
    - Outputs: **2 Modes 3 Ouputs**
        - **Design Mode:** Allows users to input custom parameters and outputs design specifications
        - **Validation Mode:** Allows users to input current specifications and outputs either **"Pass"** or **"Fail"** with design optimization suggestions

Design and Analysis

Current Program

Specification Sheet

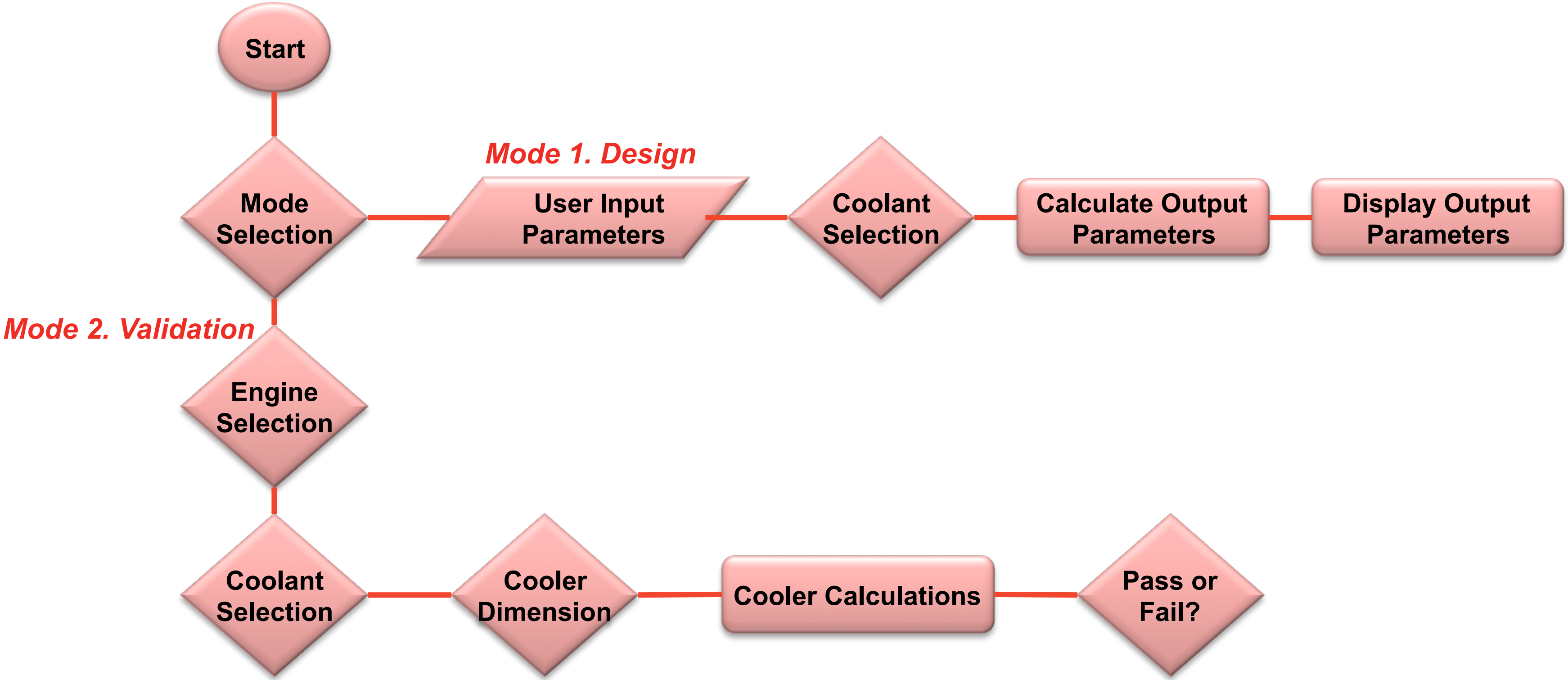
Engine Data			
Engine Model			from General Data Sheet
Engine Brake Horsepower	[BHP]		from Performance Data Sheet
Engine Speed	[rpm]		from Performance Data Sheet
Select a Cooling Circuit Type			from Performance Data Sheet
Total Circuit Heat Rejection	[BTU/min]		from Performance Data Sheet
Coolant Flow to Keel Cooler	[gpm]		from Performance Data Sheet
Engine Coolant Capacity	[gallons]		from General Data Sheet
Coolant Type (50/50 glycol or Water/DCA)		Make a Selection	50/50 Glycol solution preferred
Maximum Sea Water Temperature	[deg F]	85	Typical sea water temperature is between 75-85 deg. F
Design Speed	[knots]		Typical sizing speeds are: 1) Tugs/Pushboats: 1-2 knots 2) Generator set: 0.1-1 knots
Keel Cooler Data			
Standard Channel Size		Make a Selection	C depth (inches) × Weight Per Unit Length (pound force per foot)
Channel Width	[inches]		from standard steel channel tables
Channel Height	[inches]		from standard steel channel tables
Web Thickness	[inches]		from standard steel channel tables
Cross Sectional (Web) Area	[sq. inches]		from standard steel channel tables
Coolant Velocity	[ft/sec]		Best if kept between 2-8 ft/sec
Channel Material		**Steel**	
Total Installed Keel Cooler Length	[feet]		Increase cooler length or number of flow paths until **Pass/Fail** criteria is met
Thermal conductivity "k"	[BTU/hr-F-ft]	26.5	
Number of Flow Paths			
Results			
Actual KC Exterior Area	[sq. feet]		
Calculated Exterior Area	[sq. feet]		
Minimum Keel Cooler Length	[feet]		
Minimum Expansion Tank Capacity	[gallons]		from Installation Directions bulletin No. 3884744
Passing Criteria	**[Pass / Fail]**		Increase cooler length or number of flow paths until Pass/Fail criteria is met

Design and Analysis

3. Program Structure
    - Divided into the main function with conditionally accessed sub-functions (modules)
        - Sub-functions contain engine information, variable parameters, and calculations
    - Logical structure of user input
        - User selects answers by typing corresponding numbers from the Engine Data Sheet
        - User to have option of returning to previous selection screen

Design and Analysis

3. Program Structure



Scheduling and Resource Allocation

- Trip to Cummins Marine Integration Center facilities – *Scheduled Spring 2016*
- Team expected to visit production facility – *Scheduled Spring 2016*
- First-hand look at production engine and keel cooler system
- Gain general assessment of keel cooled system:
  - ✓ Functionality
  - ✓ Typical dimensions/specifications on installed system

Scheduling and Resource Allocation

- **Work Breakdown**
  - *Program:*
    - Stage 1: Catalog constants/Values in program
    - Stage 2: Incorporate thermodynamic formulae in program
    - Stage 3: Test/Debug
    - Stage 4: Add functionality for multiple material
    - Stage 5: Test/Debug
  - *Testing Apparatus*:
    - Design Keel Cooler test section (sea channel)
    - Build test section to analyze program performance/predictive nature

Scheduling and Resource Allocation

- **Cost Breakdown**
  - *Program:*
    - Coded using free software available to team (no monetary cost, just time)
  - *Testing Apparatus*:
    - Square metal tubing- Steel: $13 ft. / Aluminum: $10 ft.
    - Round metal tubing- Steel: $ 5 ft. / Aluminum: $6.50 ft.
    - Pump- $100-500
    - Flanges- $2-50 (dependent on material, size, intricacy, etc.)
    - Fasteners- <$250
  - *Travel Expenses:* ≥ $400

Results

- **Possible Risks in Product Testing**
  - Building the testing equipment (validation keel cooler)
  - Proper Keel Cooler connections
  - Burns caused by the heat transfer from the engine
  - Possibility of causing engine failure by overheating engine $$$

Results

- **Possible Risks in Product Implementation**
  - If the product does not provide the correct read outs
  - Improper analysis could lead to an overheated engine (potential engine failure)
  - If proper engine cooling is not achieved, could lead to poor reputation/image of project sponsor and team
- **Risk Analysis**
  - **Concept Generation (No Risk)**
  - **Product Assembly (Low Risk)**
  - **Product Testing (Medium Risk)**
  - **Product Implementation (High Risk)**

Project Outlook

- Current Week:
  - *Prepare equations for coding*
  - *Determine outline for program*
  - *Create flow chart for code*
- Following Week:
  - *Continuation of above tasks*
  - *Establish basic architecture*
  - *Configuration design*

ID		Task Mode	Task Name	Duration	Start	Finish
14			pugh matrix	1 day	Fri 10/16/15	Fri 10/16/15
15			decision matrix	2 days	Sat 10/17/15	Mon 10/19/1
16			project prep	2 days	Mon 10/19/15	Tue 10/20/15
17			Midterm Report I	1 day	Tue 10/20/15	Tue 10/20/15
18			product architecture	11 days	Tue 10/20/15	Tue 11/3/15
19			Flow Chart	11 days	Tue 10/20/15	Tue 11/3/15
20			configuration design	11 days	Thu 11/5/15	Thu 11/19/15