Professional Development Short Course On:
Thermal & Fluid Systems Modeling

Instructor:
Matthew E. Moran, PE

ATI Course Schedule: http://www.ATIcourses.com/schedule.htm
Thermal & Fluid Systems Modeling
With Excel / VBA

June 16-18, 2009
Beltsville, Maryland
$1490 (8:30am - 4:30pm)
“Register 3 or More & Receive $100 Off The Course Tuition.”

Summary
This three-day course is for engineers, scientists, and others interested in developing custom thermal and fluid system models. Principles and practices are established for creating integrated models using Excel and its built-in programming environment, Visual Basic for Applications (VBA). Real-world techniques and tips not found in any other course, book, or other resource are revealed. Step-by-step implementation, instructor-led interactive examples, and integrated participant exercises solidify the concepts introduced. Application examples are demonstrated from the instructor's experience in unmanned underwater vehicles, LEO spacecraft, cryogenic propulsion systems, aerospace & military power systems, avionics thermal management, and other projects.

Instructor
Matthew E. Moran, PE is the owner of Isotherm Technologies LLC, a Senior Engineer at NASA, and an instructor in the graduate school at Walsh University. He has 27 years experience developing products and systems for aerospace, electronics, military, and power generation applications. He has created Excel/VBA thermal & fluid system models for the Air Force, Office of Naval Research, Missile Defense Agency, NASA, and other organizations. Matt is a Professional Engineer (Ohio), with a B.S. & graduate work in Mechanical Engineering, and an MBA in Systems Management. He has published 37 papers, and has 2 patents and 3 patents pending, in the areas of thermal systems, cryogenics, MEMS/microsystems, power generation systems, and electronics cooling.

What You Will Learn
• Exploit the full power of Excel for building thermal & fluid models.
• Master the built-in VBA programming environment.
• Implement advanced data I/O, manipulation, analysis, and display.
• Create full featured graphical interfaces and interactive content.
• Optimize performance for multi-parameter systems and designs.
• Integrate interdisciplinary capabilities into thermal & fluid models.

Course Outline
10. Adding Interdisciplinary Capabilities. Integrating other technical analyses. Financial/cost models.
16. Other Useful Tips & Tricks. Practical hands-on techniques & tips.
17. Application Topics. Tailored to participant interests.

This course will provide the knowledge and methods to create custom thermal & fluid system models for analyzing conceptual designs, performing system trades, and optimizing system performance with Excel/VBA.

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Description

These sample slides are excerpted from the 3-day short course entitled “Thermal & Fluid Systems Modeling with Excel/VBA”. The course provides in-depth details on the principles, practices, and implementation of Excel and its integrated programming environment, Visual Basic for Applications (VBA), for thermal and fluid modeling.

For upcoming public offerings of the course and other related information, please visit www.aticourses.com or www.isothermtech.com. To receive a monthly email newsletter that includes Excel/VBA techniques & tips, please send an email to info@isothermtech.com with “Newsletter” in the subject field, and your contact information in the body (a typical signature block is sufficient).
Course Summary

This course will provide the knowledge and methods to create custom thermal & fluid system models for...

- Analyzing conceptual designs
- Performing system trades
- Simulating operation
- Optimizing system performance

...with Excel/VBA.
Learning Objectives

• Exploit the full power of Excel for building thermal & fluid models
• Master the built-in VBA programming environment
• Implement advanced data I/O, manipulation, analysis, and display
• Create full featured graphical interfaces and interactive content
• Optimize performance for multi-parameter systems and designs
• Integrate interdisciplinary capabilities into thermal & fluid models
Topics: Design & Build

1. Excel/VBA Review
2. Identifying Scope & Capabilities
3. Quick Prototyping
4. Defining Model Structure
5. Designing Graphical User Interfaces
6. Building & Tuning the VBA Engine
7. Customizing Output Results
8. Exploiting Built-in Excel Functions
Topics: Refine & Optimize

9. Integrating External Data
10. Adding Interdisciplinary Capabilities
11. Unleashing GoalSeek & Solver
12. Incorporating Scenarios
13. Documentation, References, & Links
14. Formatting & Protection
15. Flexibility, Standardization, & Configuration Control
16. Other Useful Tips & Tricks
17. Application Topics
Modeling Options

- Higher Complexity, Lower Ease of Use
- Higher Cost, Less Availability

- CFD codes
- Finite element, finite difference codes
- Application focused codes
- Custom or in-house programs
- Math computations s/w (incl Excel/VBA)
- Hand calculations

Increasing Model Fidelity, Decreasing Flexibility
Advantages of Excel/VBA

FEATURES & BENEFITS

• Flexibility & customization
• Built-in math functions
• Data I/O, manipulation & display
• Full featured GUI tools
• Integrated programming language & development environment
• Multi-parameter solver
• Ubiquitous installed user base
• Familiarity & ease of use
• Interdisciplinary capabilities (incl financial)
• Enable rapid exploration of design variations

TECHNICAL APPLICATIONS

• Automating, standardizing, & documenting repetitive calculations
• Performing what-ifs & inverse solutions
• Rapid analytical prototyping
• Exploring conceptual designs/systems
• System trades and parameter sensitivities
• Precursor, complementary, and/or check for more high fidelity analyses
• Multidisciplinary interactions (including costing)
Functions (Built-In)

- Excel has many useful built-in functions under a variety of categories
- These functions can be invoked from the worksheet side by selecting a cell and clicking the “fx” icon or “Insert-Function…” from the menu bar
- Many functions also exist on the VBA side, although the syntax may be different (check the VBA help menu)

TIP: Worksheet side functions can be accessed in VBA by using the syntax: “VBAvariable = Application.WorksheetFunction.FunctionName(Arg1, Arg2,...)”

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Graphics

• Objects can be placed anywhere on the sheet

• Fill patterns & colors can be added from the Drawing toolbar

• When an object is selected, editing circles appear around the object and can be used to size, rotate, or otherwise edit the object

• “Connectors” can be added that will follow the objects wherever they move

TIP: To prevent a graphic from being changed when cells are re-sized, right click on the graphic, select “Format Autoshape…”, select the “Properties” tab, and select “Don’t move or size with cells”
Visual Basic Editor

- **Project window** shows workbook objects, userforms, & modules
- **Properties window** shows properties of selected object
- **Main window** displays userform, VBA code modules, etc.
- **VBA menu bar** includes debugger and other VBA unique picks

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Project & Properties

Excel objects (workbooks, spreadsheets, etc.)

Userforms (see blank one to the right with toolbox for adding controls)

Modules (This is where the VBA code is contained)

Properties of selected object (a userform in this case)

THIS WINDOW DISPLAYS WHATEVER VBA OBJECT IS BEING EDITED (a userform in this case)

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## Functions vs Subs

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Function</th>
<th>Sub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass variables in</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pass variable out (incl array)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Modify worksheet objects &amp; properties (incl cell values)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Call from a cell</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Run on an event (e.g. click)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Accessible as a user defined function (“fx” icon)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Accessible as a macro</td>
<td>No</td>
<td>Yes*</td>
</tr>
</tbody>
</table>
### Object Structure

- **Excel uses an object oriented structure**
- **Objects can have a collection of sub-objects** (e.g. Workbook-Worksheets-Range)
- **Properties define the characteristics of an object** (e.g. Value)
- **Methods are member functions of the application object** (e.g. Activate)
- **Events are actions that can be taken on an object** (e.g. Open)

**Legend**
- Object and collection
- Object only

**Source:** Excel Help (VBA)
Object Oriented Programming

- Virtually any “object” in the Excel environment can have its properties accessed and its methods executed using the VBA Editor
  - In the properties window
  - With a sub procedure
- Properties can be read into a variable by setting the property equal to the variable name
- Some properties can be written to by setting the property equal to a value or variable
- Select “View-Object Browser” and choose “Application” under Classes to see the many objects that can be manipulated

NOTE: The scope of this course allows only a limited introduction to this extensive topic. Programming methods most applicable to engineering models will be the primary focus.

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Putting Excel & VBA Together

Guidelines for integrating Excel & VBA in thermal & fluid systems models:

• Use Excel as the interface between the model and the user
  – Input & output management
  – Decompose subsystems and/or components in separate worksheets
  – Customize for intuitiveness & performance

• Use VBA as the numerical/algorithms engine:
  – Calculations, iteration, decision flow, loops, etc.
  – Custom userforms
Model Definition

END USER(S) & CONFIGURATION CONTROL
- Who will be using the model?
  - only the developer
  - one well defined customer/user
  - user group
  - corporate wide distribution
  - unlimited distribution

SCOPE & REQUIREMENTS
- What results do they need?
  - single point design
  - design trades
  - system simulation
  - system optimization

CAPABILITIES & INTERFACES
- What parameters do they want to vary?
  - raw inputs
  - statistical variations
  - design perturbations

STANDARDS & WORK FLOW
- Who is developing the model?
  - one person
  - 2 or 3 people
  - more than 10 people
  - multiple organizations
System Decomposition

- Systems can be decomposed in Excel using different worksheets.
- If more than two levels are needed, can use the syntax: 1.1, 1.1.1, 1.1.1.1, etc.
- Other Excel tools to aid in documenting and navigating within system models: Diagrams, Navigation Objects, and Outlines.

**NOTE:** Can also add a parent level by creating & linking multiple workbooks.
Start-Up Control

- The way a workbook is displayed when it opens can be controlled
- Open the VBA Editor
- Double click on “This Workbook” in the VBA Project window
- Select “Workbook” in the first drop down window, and “Open” in the second
- Add code to control how the workbook opens
- Other events can have code attached by selecting them from the second drop down menu (e.g. closing the workbook)

The above code displays a startup message, makes Sheet1 active, zooms in to fill the screen with columns A to M, and selects cell A1
Hyperlinks

To hyperlink an image or cell to a target location:

1. Right click on the selected image or cell & select “Hyperlink”
2. Choose what type of link you want to create and its location
User Forms

- User Forms are created on the VBA side by selecting “Insert-UserForm”
- A Forms folder appears in the Project window containing a new UserForm
- ActiveX controls can be added by selecting them and dragging on the UserForm to place them

TIP: The name of the UserForm and all objects on it can be modified within the Properties window
Scenarios

- Excel “Scenarios” tool can be used to explore and document changes to system/design parameters
- Can be automated with VBA to add design points with the push of a button
- All named variables for a given design can also be output
Sensitivity Analysis

- Analysis of the sensitivity of various model parameters can be done quickly in Excel
- Use model to generate a table of performance results while varying one parameter at a time
- Plot results to explore sensitivity of performance to key parameters
- A similar approach can be used to investigate process variability in parameters (e.g. manufacturing tolerances)
Goal Seek

- Goal Seek is a simple and easy tool for finding a desired value based on changing one variable.
- Helpful for running quick “what-if” calculations.
- Allows user to explore design boundaries as a function of one variable at a time.
- Example: What flow velocity will yield the maximum allowable pressure drop?
Solver

- Solver is a very powerful tool for multi-parameter optimization
- Unfortunately, documentation in Excel is not comprehensive
- Can be run in real time or automated using VBA
- Note: must select “VBA-Tools-References” and check “Solver” if automated (not covered in this course)
- Is actually a third-party add-in from Frontline Systems
- Many other 3rd party optimization Add-Ins are available
Interdisciplinary Models

Example of functions from one model:

- Partial Pressure of Water Using Antoine Eqn (and Dew Point) Function WaterPP(CellTemp)...
- Voltage Per Cell Function Vcell(CurrentDens, CellResist, RT_nFAnode, iOAnode, TafelSlopeCathode, iOCathode, LimitingCurrent, Voc)...
- Stress Calculation for Wall Thickness of a Tank Function WallT(units, material, pressure, diam, safetyfactor)...
- Wall Thickness Calculation for Buckling Load (Refr: John F. Harvey, 1985) Function BuckleThick(units, material, pressure, diam, length, safetyfactor)...
- Spherical Tank Internal Surface Area Function SphArea(diameter)...
- Spherical Tank Mass Function SphMass(units, diameter, wallthick, material)
- Heat Leak Into Spherical Tank Function SphHeat(units, diami, MLIfactor, area%, sinktemp, fluidtemp, MLIIlayers, foamthick, wallthick)...
- Assignment of Fluid ID # for Gaspak Properties Function FluidID(fluid)...

- Excel is inherently “blind” to the discipline being modeled
- This flexibility allows the developer to integrate other technical disciplines into the model wherever and however is most effective
- The interaction between disciplines is especially valuable to simulate (e.g. “multiphysics”)
Collaboration Lessons Learned

- Agree to modeling strategy & approach upfront, and enforce it
- Insure all contributors have the skills to implement adopted techniques
- If possible, have individual contributors work on separate subsystem worksheets
- Have a single person do system integration of the workbook
- Implement configuration & version control techniques
- Consider using file storage & management systems that “check-out” documents to insure only one person is working on it at any given time
- Look to the “open source” development community for more advanced techniques (e.g. Apache, Linux, Open Office, etc.)
Distribution & Version Control

- Use a version numbering system to save modifications
  - Development versions can be saved as 1.1, 1.2, 1.3, etc. (archive these if necessary)
  - Released versions can be saved as 1.0, 2.0, 3.0, etc. (keep copies of these on hand for support questions)

- Examples
  - ThermalModel_v2.5 is a development version
  - ThermalModel_v3.0 is the third release
Exporting & Importing Modules

- VBA modules can be exported to a file for archiving or to use for a library of standard codes.
- Click on the module to be exported, then select “File-Export File…”
- The text file can be imported into any VBA module folder by selecting “File-Import File…”
Flexibility & Extensibility

Excel is an ideal environment for allowing users to add custom content to a standardized model.

Some examples:
- Add price sheets
- Link model outputs to custom calculations
- Provide worksheet sections for user customization
- Allow addition of selected macros

By using the protection settings, developer can control which features to allow user to customize.
# Example: Simple Calc Sheet

## FORCED CONVECTION: FLAT PLATE

![Diagram of a flat plate with fluid flow](image.png)

### Description:
Forced convection over a flat plate where bulk fluid is flowing parallel to the plate.

### Assumptions:
Fluid properties evaluated at film temp (avg of plate & fluid temps)

### Equations:
\[
Nu = \frac{hL}{k} = 0.664 \frac{Pr^{1/3}}{Re^{1/2}} \text{ for } Re < 5 \times 10^5
\]
\[
Nu = \frac{hL}{k} = 0.036 Pr^{1/3} (Re^{0.8} - 23,200) \text{ for } Re > 5 \times 10^5
\]
\[
Re = \frac{VL}{\nu}
\]
\[
q = h(T_p - T_f)
\]

### References:

<table>
<thead>
<tr>
<th>INPUTS</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>L Plate Length</td>
<td>10</td>
<td>ft</td>
</tr>
<tr>
<td>Tp Plate Temp</td>
<td>97</td>
<td>F</td>
</tr>
<tr>
<td>V Fluid velocity</td>
<td>0.6</td>
<td>ft/s</td>
</tr>
<tr>
<td>Tr Fluid Temp</td>
<td>72</td>
<td>F</td>
</tr>
<tr>
<td>Pr Fluid Prandtl Number</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>(\nu) Fluid Kinematic Viscosity</td>
<td>1.60E-05</td>
<td>m^2/s</td>
</tr>
<tr>
<td>(k) Fluid Thermal Conductivity</td>
<td>0.025</td>
<td>W/m-k</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OUTPUTS</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tm Film Temp</td>
<td>29.16666667</td>
<td>°C</td>
</tr>
<tr>
<td>Re Reynolds Number</td>
<td>34838.64</td>
<td>m/s</td>
</tr>
<tr>
<td>Nu Nusselt Number</td>
<td>110.5651159</td>
<td></td>
</tr>
<tr>
<td>h Heat Transfer Coeff</td>
<td>0.159715764</td>
<td>Btu/hr-ft^2-F</td>
</tr>
<tr>
<td>q Heat Flux</td>
<td>3.995356895</td>
<td>Btu/hr-ft^2</td>
</tr>
</tbody>
</table>
Example: Another Calc Sheet

### Natural (Free) Convection: Vertical Plane

**Inputs**

<table>
<thead>
<tr>
<th>L</th>
<th>0.0254 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ</td>
<td>0 degrees</td>
</tr>
<tr>
<td>T_p</td>
<td>80 °C</td>
</tr>
<tr>
<td>T_r</td>
<td>25 °C</td>
</tr>
<tr>
<td>Pr</td>
<td>0.71</td>
</tr>
<tr>
<td>( \beta )</td>
<td>1.17E+08 1/°C-m³</td>
</tr>
<tr>
<td>( \nu )</td>
<td>1.67E-05 m²/s</td>
</tr>
<tr>
<td>( k )</td>
<td>0.026 W/m·°C</td>
</tr>
</tbody>
</table>

**Outputs**

<table>
<thead>
<tr>
<th>T_m</th>
<th>52.5 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr</td>
<td>1.05E+05</td>
</tr>
<tr>
<td>Nu</td>
<td>9</td>
</tr>
<tr>
<td>h</td>
<td>9.4 W/m²·°C</td>
</tr>
<tr>
<td>q</td>
<td>516.9 W/m²</td>
</tr>
</tbody>
</table>

**Equations:**

\[
Nu = \frac{h l}{k} - C (Gr Pr)^\beta \\
Gr = \left( \frac{\rho_f - \rho_i}{\rho_f(T_p - T_r)} \right)^{\frac{3}{2}} \left( T_p - T_r \right)^{\frac{1}{2}} \\
\beta = \frac{\rho_f - \rho_i}{\rho_f(T_p - T_r)} \\
h = k(T_p - T_r) \\
q = h(T_p - T_r) \\
\]

**References:**

4. Eckert & Jackson, "Analysis of Turbulent Free Convection Boundary Layer on a Flat Plate", NACA Rept. 1015, 1951
Example: Multilayer Insulation
Example: SOTV Spacecraft

<table>
<thead>
<tr>
<th>Launch Vehicle:</th>
<th>Atlas V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Hydrogen Tank</td>
<td></td>
</tr>
<tr>
<td>LH2 Mass (kg):</td>
<td>5000 OK</td>
</tr>
<tr>
<td>LH2 Temp (K):</td>
<td>21.0 OK</td>
</tr>
<tr>
<td>Heat Leak (W):</td>
<td>8.97</td>
</tr>
<tr>
<td>Tank Shape:</td>
<td>Cylindrical</td>
</tr>
<tr>
<td>Tank Vol. (m³):</td>
<td>72.50</td>
</tr>
<tr>
<td>Max Diam (m):</td>
<td>4.316</td>
</tr>
<tr>
<td>Max Length (m):</td>
<td>7.663</td>
</tr>
<tr>
<td>Tank Mass (kg):</td>
<td>1620</td>
</tr>
<tr>
<td>MLI Mass (kg):</td>
<td>456</td>
</tr>
<tr>
<td>Total Mass (kg):</td>
<td>7076</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radiator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sink Temp (K):</td>
</tr>
<tr>
<td>Radiator Temp (K):</td>
</tr>
<tr>
<td>Radiative Area (m²):</td>
</tr>
<tr>
<td>Mass (kg):</td>
</tr>
</tbody>
</table>

**SYSTEM RESULTS**

| Efficiency (%): | 0.14 |
| % of Carnot: | 7.72 |

**Solar Concentrator**

| Efficiency (%): | 80.0 OK |
| Solar Flux (W/m²): | 1360 |
| Diameter (m): | 3.52 |
| Power to TASHE (W): | 8395 |

**TASHE & Resonator**

| PV Power Out (W): | 2202 |
| Operating Temp (K): | 1103 |
| Rejection Temp (K): | 292 |
| Rejected Heat (W): | 3367 |
| Mass (kg): | 42 |
| Efficiency (%): | 26.23 |
| % of Carnot: | 35.67 |
### Example: Cryo Tank Design

#### Units
- **English**
- **SI (metric)**

#### Sink Temperature
- Area 1: 300.0 K
- Area 2: 300.0 K
- Area 3: 300 K

#### % Tot Area
- 100 %
- 0 %
- 0 %

#### Isofoam
- 0.000 m
- 0.000 m
- 0.000 m

#### Section MLI Layers
- All
- None
- None

#### Misc. Factors
- Design
- Cond. factor: 14.6 %
- Mass factor: 10 %

#### C-C Overwrap (outer diam only)
- MLI factor: 174 %

#### Calculated Tank Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid density</td>
<td>75.410 kg/m³</td>
</tr>
<tr>
<td>Internal volume</td>
<td>6.77 m³</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>0.1500 cm</td>
</tr>
<tr>
<td>Dry mass</td>
<td>114.34 kg</td>
</tr>
<tr>
<td>Misciss</td>
<td>11.43 kg</td>
</tr>
<tr>
<td>MLI mass</td>
<td>144.21 kg</td>
</tr>
<tr>
<td>Heat leak</td>
<td>2.34 W</td>
</tr>
<tr>
<td>Conduction</td>
<td>0.34 W</td>
</tr>
<tr>
<td>Max outer diameter</td>
<td>1.296 m</td>
</tr>
<tr>
<td>Max outer length</td>
<td>9.24 m</td>
</tr>
<tr>
<td>Min inner diameter</td>
<td>N/A m</td>
</tr>
<tr>
<td>% Fluid mass</td>
<td>79.90%</td>
</tr>
<tr>
<td>Optim. Target</td>
<td>2.34</td>
</tr>
<tr>
<td>Active Cooling system mass</td>
<td>521.4 kg</td>
</tr>
<tr>
<td>Power in @20K</td>
<td>608.2 W</td>
</tr>
</tbody>
</table>

### Design

- **Tank press:** 345.0 kPa
- **Ullage:** 2 %
- **Aluminum (6061-T6):**

- **MEOP:** 551.6 kPa
- **Safety Factor:** 1.50

- **Stiffening rings:** 10
- **Thickness:** 0.25 cm
- **Cross section area:** 0.012 cm²
- **Length between:** 4.967 m

- **Cylinder Length:** 7.9 m
- **Inside Diameter:** 1.00 m
- **Inside Diameter:** 2.35 m
- **Internal Area:** 28.1 m²
- **Internal Area:** 17.3 m²
- **Inside Length:** 11.5 m
- **End Diameter:** 0.25 m
- **Outer Diameter:** 1.00 m
- **Inner Diameter:** 0.50 m
- **Internal Area:** 55.1 m²

- **% Area Ends:** 3.36 %
- **% Area Outer Cyl:** 64.4 %
- **% Area Inner Cyl:** 32.2 %
Example: Fuel Cell

- **HOST VEHICLE**
- **WATER STORAGE**
- **HUMIDITY**
  - 80°C
  - 797 rpm
- **PREHEATER**
  - -165°C
  - 75°C
- **LOX TANK**
  - Vaporizer
  - 50.00 kg LOX
  - 0.64 kg dry mass
  - 0.80 W heat leak
  - 0.52 m max OD
  - 1.16 m max length
  - 0 W

- **FUEL CELL**
  - 11.1 g/min (O2)
  - 126.3 g/min (H2O)
  - 80°C
  - 2.0 atm

- **Hydrogen out**
  - 1.4 g/min (H2)
  - 28.6 g/min (H2O)

- **Electrical Power**
  - 10000 W
  - Cell Voltage: 0.500 V
  - Net Current: 19999 A

- **Residual Heat**
  - 38519 W

- **Cooling Water**

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Instructor Bio

Matthew E. Moran is the owner of Isotherm Technologies LLC (isothermtech.com), a senior engineer at NASA, and an instructor in the graduate school at Walsh University. Matt also teaches engineering analysis seminars throughout the U.S. He has been a co-founder or key contributor to the start up of five high tech businesses; and has worked with hundreds of organizations of varying size, type and industry sector.

Matt has 27 years experience developing products and systems for aerospace, electronics, military, and power generation applications. He has created Excel/VBA thermal & fluid system models for the Air Force, Office of Naval Research, Missile Defense Agency, NASA, and other organizations.

Matt is a Professional Engineer (Ohio), with a B.S. & graduate work in Mechanical Engineering, and an MBA in Systems Management. He has published 37 papers, and has 2 patents and 3 patents pending, in the areas of thermal systems, cryogenics, MEMS/microsystems, power generation systems, and electronics cooling.