Introduction to Computational Fluid Dynamics (CFD) for Combustion

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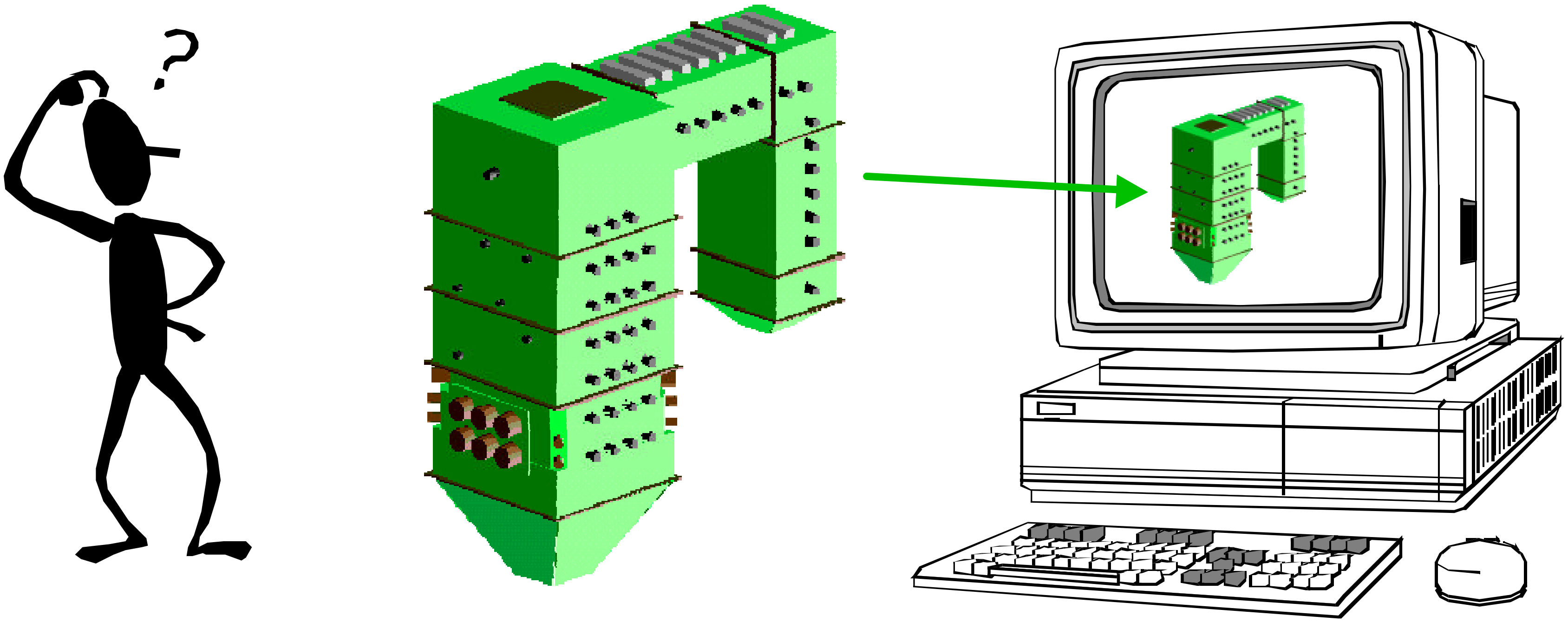
What is CFD?



- CFD stands for Computational Fluid Dynamics
- CFD uses computers to represent (or model) the physical and chemical processes occurring in a furnace

Why Use CFD?

- CFD can be used to:
  - » Improve understanding of furnace behavior & interactions
  - » Evaluate furnace or new technology performance
  - » Provide conceptual designs
  - » Identify potential operational problems
  - » Guide experiments
- CFD is more cost-effective than physical testing
- CFD provides more complete information than testing
- CFD does NOT make decisions for engineers, but does help them be more informed

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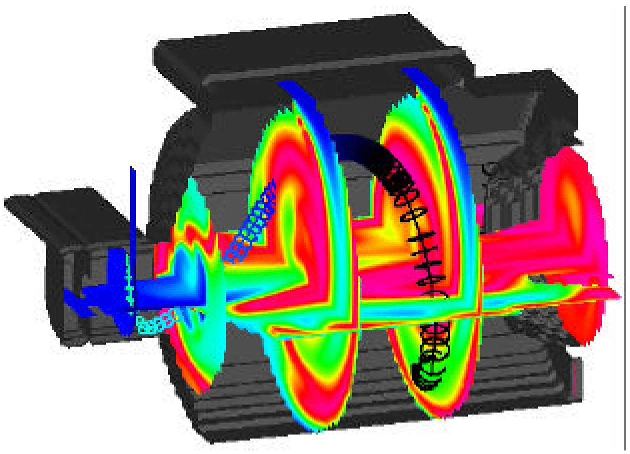
How Does CFD Work?

- The CFD model represents the furnace:
  - » Geometry (furnace walls, burners, air ports, cooling tubes, etc)
  - » Operating conditions (fuel flow, air flow, surface conditions, etc)
  - » Combustion processes
    - – Flow patterns
    - – Turbulent mixing
    - – Gas-phase chemical reactions
    - – Heterogeneous particle reactions
    - – Particle dispersion and deposition
    - – Radiative and convective heat transfer
  - » Pollutant formation and destruction (NOx, SOx, CO, etc)



- The CFD model solves equations which represent the combustion processes

How Accurate is CFD Modeling?

- CFD model accuracy depends on
  - » Accuracy of the furnace inputs
    - – Geometry
    - – Operating conditions
    - – Fuel, air and surface properties
  - » Accuracy of the numerical methods used to solve the equations
  - » Accurate representation of physical and chemical processes
- Model accuracy is usually limited by the accuracy to which furnace operating conditions and properties are known
- Validation of CFD models for full-scale furnaces is difficult due to a paucity of reliable measured data

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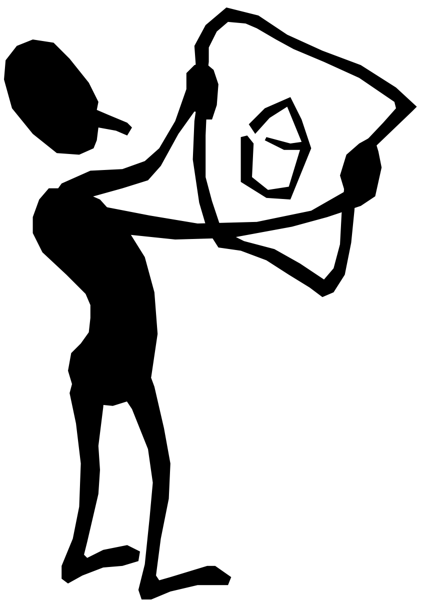
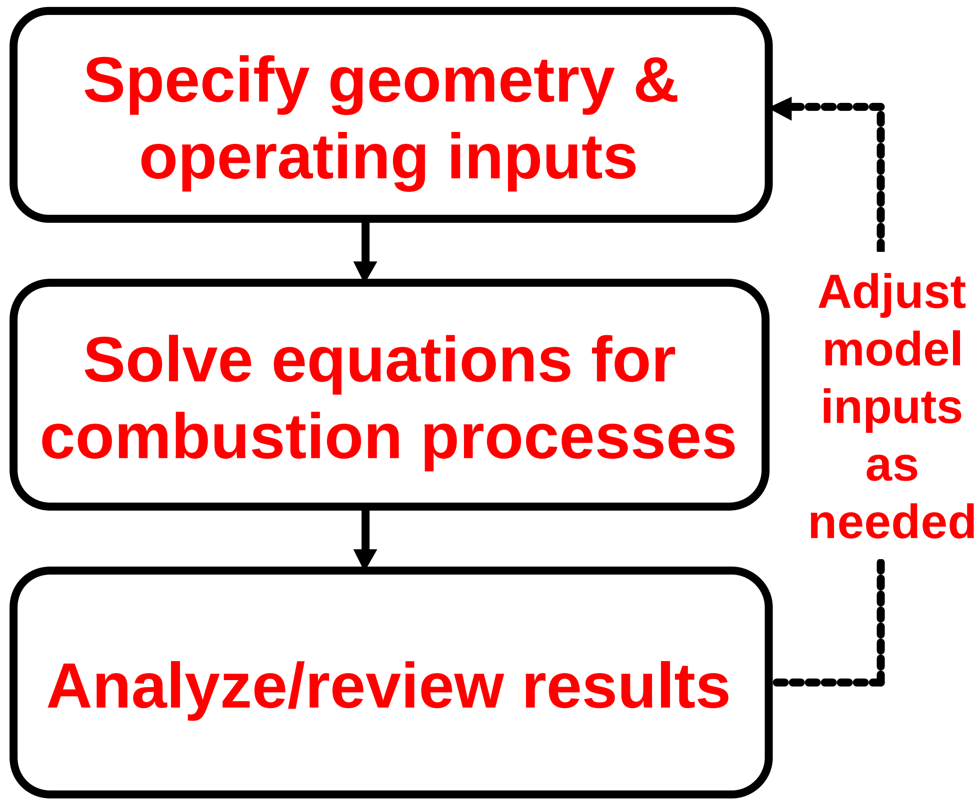
CFD Modeling Approach





Specifying Geometry & Inputs

- Required geometry information includes
  - » Furnace dimensions
  - » Burner dimensions and locations
  - » Air and/or flue gas port dimensions and locations
  - » Cooling/process tube dimensions and locations
- Required operating information includes
  - » Surface properties
  - » Fuel composition, temperature, flow rate and distribution
  - » Air composition, temperature, flow rate and distribution
  - » Other gas composition, temperature, flow rate and distribution

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Computations

- CFD computations can be performed on a variety of computers ranging from desktop PCs to supercomputers
- Computational times range from several hours to several days depending on the size and complexity of the model
  - » Greater accuracy generally requires longer computing times
- There are a variety of CFD software packages available for different types of applications
  - » General purpose CFD software is available from several commercial vendors, but buyers must make sure the software is capable of accurately modeling the problem of interest
  - » Specialized, in-house CFD software is sometimes used by R&D or consulting companies to solve specific types of complex problems (such as coal combustion or jet engine combustion)

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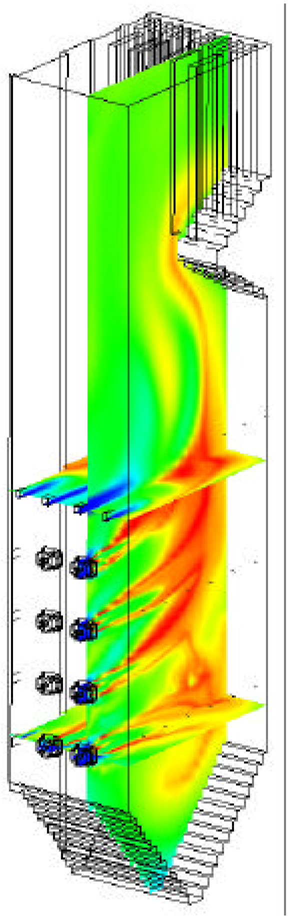
CFD Results

- Results available from CFD models include:
  - » Gas flow patterns, velocities and pressure drops
  - » Fuel and air mixing patterns
  - » Gas temperature profiles
  - » Species concentrations (e.g., CO, CO_2, H_2O, NOx, O_2, SO_2)
  - » Particle trajectories and deposition patterns
  - » Particle temperatures and compositions
  - » Surface temperatures and heat flux profiles
  - » Surface corrosion rates and slagging
- The tremendous amount of 3-D information to be analyzed requires graphical viewing



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Conclusion

- When used correctly, Computational Fluid Dynamics (CFD) is a cost-effective method for evaluating furnace performance, operational impacts & emissions
  - » CFD remains an expert-user tool – both the CFD software and modeling engineer must be qualified to solve the problem of interest
  - » CFD results should be used in conjunction with furnace observations, measurements (where reliable), experience and engineering judgment to provide optimal solutions
- For more information regarding CFD methodology or to determine if CFD is right for your problem, contact REI at info@reaction-eng.com or (801) 364-6925

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