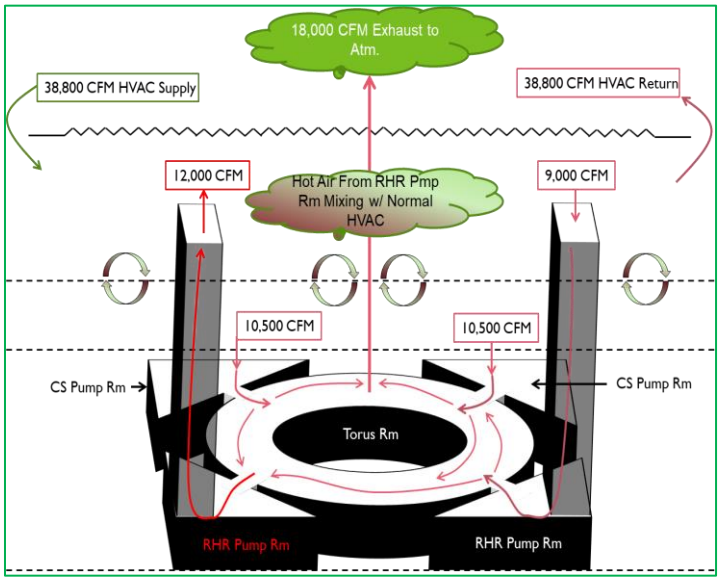
GOTHIC™ for Ventilation, Filtration and Radiological Analysis
Analysis Division

Introduction

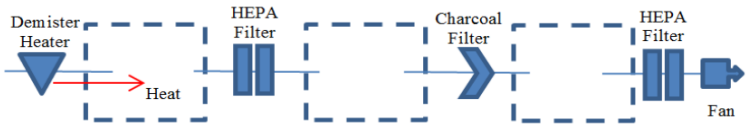
GOTHIC is an industry trusted tool for providing engineering solutions for a variety of applications, including fission product tracking, dry aerosol transport and ventilation assessments. The software provides an integrated analysis environment that includes a graphical user interface (GUI) for constructing analysis models, a numerical solver that includes parallel processing capabilities and a post-processor for evaluating simulation results. It solves the conservation equations for mass, momentum and energy for multicomponent, multi-phase flow in lumped parameter and multi-dimensional geometries (1, 2, or full 3D), including the effects of turbulence, diffusion and buoyancy.

GOTHIC has been developed over 30+ years to become a hybrid tool that bridges the gap between traditional system level thermal hydraulics analysis tools and computational fluid dynamics (CFD) analysis tools. GOTHIC's full treatment of the fluid-fluid shear as well as molecular and turbulent diffusion is consistent with that found in a CFD type code, except that GOTHIC relies on wall functions (e.g., correlations for heat transfer coefficients and friction factors) rather than trying to resolve the boundary layer. As a result, GOTHIC can apply much larger computational cells than CFD type codes. The significant reduction in mesh density is one reason that GOTHIC is generally much more computationally efficient than CFD. GOTHIC has a large user base and an established pedigree for a wide range of applications. Also, all development has been performed under a Nuclear Quality Assurance program that complies with 10CFR 50, Appendix B and applicable portions of ASME NQA-1.



Ventilation and Filtration Assessments

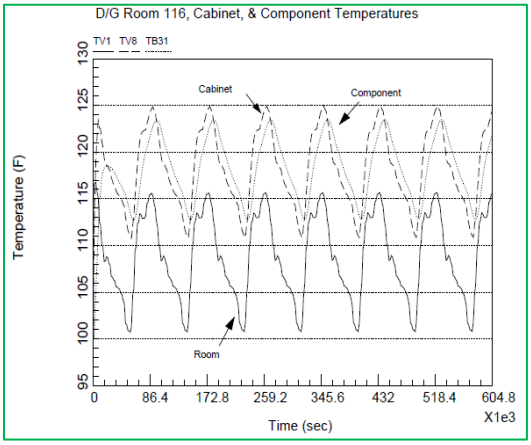
GOTHIC has been used for assessing both forced and natural convection conditions for a wide range of applications, including:



- Tracking concentration of hazardous gases and chemicals for habitability and safety assessments
- Determining ventilation and filtration requirements and optimizing location and arrangement of these systems
- Room heat-up, including diverse and FLEXible coping strategies for Extended Loss of AC Power (FLEX/ELAP)
- Equipment Qualification (EQ)

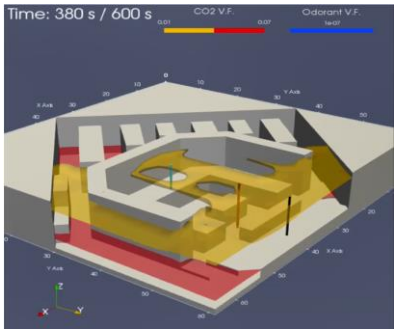
Past experience by Zachry Nuclear includes:

- Buoyancy-driven ventilation flows for RHR Pump Room cooling
- Evaluating alternative cooling strategies for cooling both trains of Class 1E Electrical Equipment with one train of HVAC to avoid plant shutdown
- Assessing time to reach limiting temperatures inside equipment, electrical and server cabinets
- Demonstrating operability of a component in a diesel room cabinet for various failure scenarios using 3D modeling of ventilation flow and heat transfer
- Fire, smoke and exhaust propagation
- Dousing sprays and filter performance



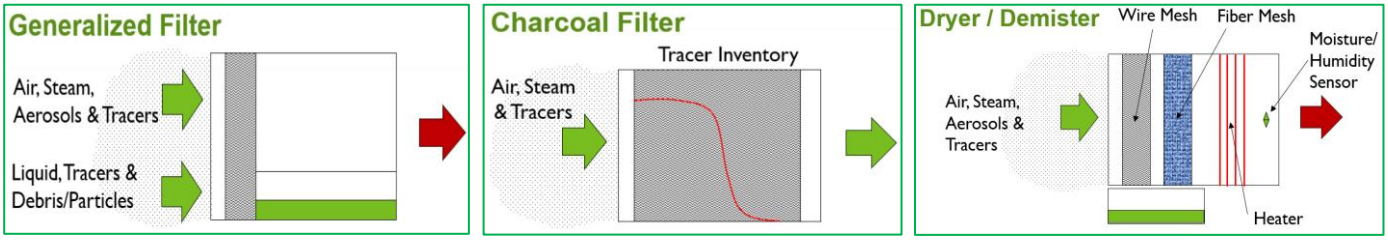
GOTHIC™ incorporates technology developed for the electric power industry under the sponsorship of EPRI, the Electric Power Research Institute.

Particle and Aerosol Tracking



A distinctive feature of GOTHIC is the ability to track many different fields/substances in a simulation. Conservation equations are solved for three (or more) primary fields, including continuous liquid, steam, N non-condensing gases, and any number of M interacting dispersed droplet/aerosol fields. Optional secondary fields are also available to represent ice, mist/fog as well as any number of X solid particle components, Y dissolved gases and Z tracers (including decay and formation of daughter products) that can be tracked in the vapor, liquid and drop fields. A drop/aerosol field in GOTHIC can represent solid particles and/or water, allowing for the simulation of dry aerosols such as dust or other particulates.

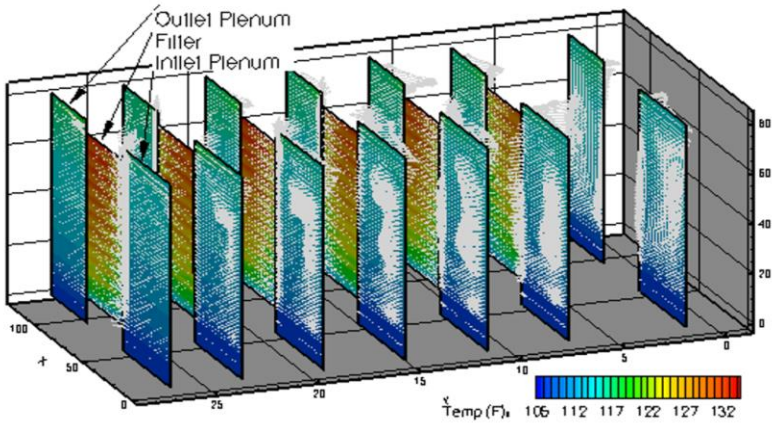
The dispersed drop/aerosols are based on aerosol mechanics, including consideration of the size distribution, agglomeration, formation (or entrainment) and deposition. For each drop/aerosol field, conservation equations for mass, energy, momentum, interfacial area and number density are solved. This allows each field to move with its own velocity, momentum and temperature. The drop/aerosol inventory for each field in each computational volume or cell evolves during a simulation based on the transport, phase change and interactions with other drop/aerosol fields and with surfaces. The number concentration and size distribution are computed separately for each field, thus allowing aerosols with a wide range of sizes to be tracked in a single application. In addition to the solid particle capability, another distinctive feature of GOTHIC is the ability to track user defined tracer elements (including radioactive decay and daughtering of nuclides) in the liquid, vapor and droplet fields as well as surfaces and filters. This capability allows GOTHIC to model fission product transport and release or the removal of particulates or harmful toxins from exhaust gases using a spray scrubber or some other type of filtration system. GOTHIC includes component models for fans, filters, charcoal filters, dryers/demisters, dampers, *etc*. The aerosols and other filtered material is removed or accumulated in these components.



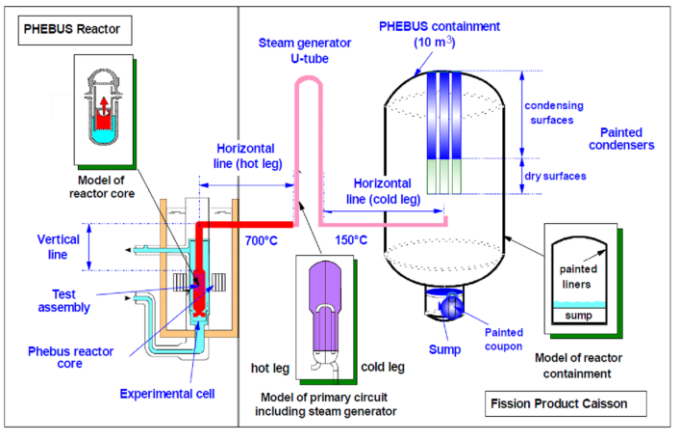
Recent enhancements to the software provide options to transfer tracers between phases with condensation or evaporation, convert from one tracer to another on radioactive decay and tracer transport by molecular and turbulent diffusion. This has application for tracking tritium or other materials that can change phase. The tracers can also be used to track concentration of iodine species and other chemicals (including [H+] and [OH-] for pH analysis).

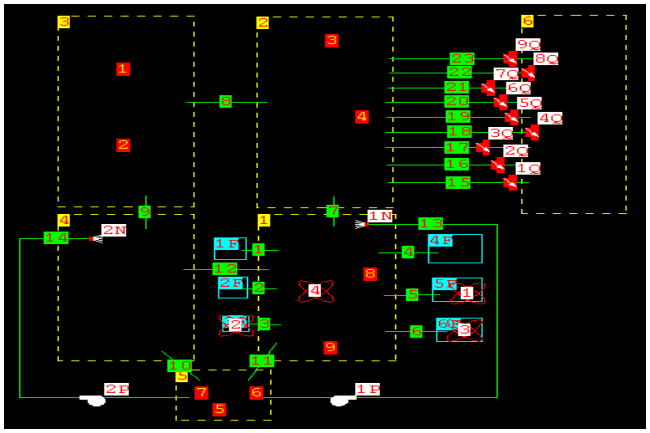
Radiological and Dose Analysis

The capabilities described in the previous section can be used for fission product tracking/retention as well as debris and dust transport. The figure to the right is from a 3D model of a charcoal filter where GOTHIC was used to analyze heating due to radioactive decay of Iodine collected by the filter. GOTHIC predicted the maximum charcoal temperature with natural convection cooling, confirming it was below safety limits for both iodine desorbtion and autoignition/combustion. The GOTHIC analysis and results were used to provided operational flexibility and reduced maintenance costs.



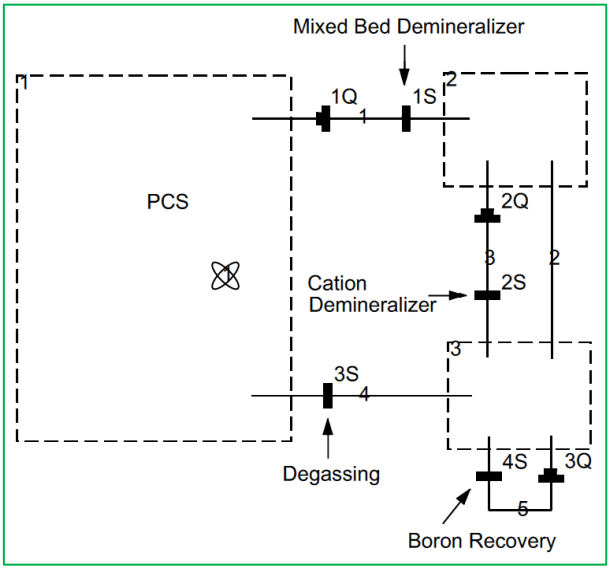
The fundamental aerosol models have been verified using analytical solutions and validated against applicable separate effects tests. Also, GOTHIC has been benchmarked to many integrated effects tests, including Phebus FP (Fission Product). A figure of the test facility and the corresponding GOTHIC model are shown below. The model tracks 98 tracers with radioactive decay and progeny formation, including various iodine isotopes (e.g., ^{129}I, ^{131}I, ^{132}I, ^{133}I and ^{134}I) in various forms (High volatile, Low volatile, Nonvolatile, Molecular). The iodine chemistry is calculated in a separate module that is coupled to GOTHIC. GOTHIC gives good agreement for the buildup and decay of suspended aerosols in Phebus Test 3.





The range of aerosol and radiological applications that GOTHIC has been used for includes:

- Source Term
  - Primary Coolant (Equilibrium) Activity
  - Non-Water Coolant Source/Leakage
- Conditions for Iodine Re-evolution
  - Sump/Suppression Pool Conditions and pH
  - RWST Conditions and pH
- Isotope Removal Mechanisms
  - Containment Sprayed and Unsprayed Region Mixing
  - Charcoal Filter Heating due to Iodine decay
- Radionuclide Transport and Decay
  - Post-LOCA Release
  - Transport between connected Compartments



ADAMS ML071581053 (titled “Best Practice Guidelines for the use of CFD in Nuclear Reactor Safety Applications”) poses guidelines for applying single phase CFD codes in nuclear reactor safety problems and GOTHIC is listed as a “*tool for 3D flows*” and “*dispersal and deposition of radionuclides.*”

Conclusions

GOTHIC is a general-purpose thermal-hydraulic analysis tool that includes both system level and CFD-like attributes. The software provides an integrated analysis environment that allows for fast, flexible creation or modification of models. The fundamental physical models, including aerosol modeling, along with the particle and isotope tracking, decay and reactor kinetics capabilities make GOTHIC well-suited to support radiological, dose, ventilation and dust/debris applications.

Contact Information

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