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Example of Modeling Methodologies Applied in SOARCA

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SAND2017-3373 C

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Hydrogen Deflagration

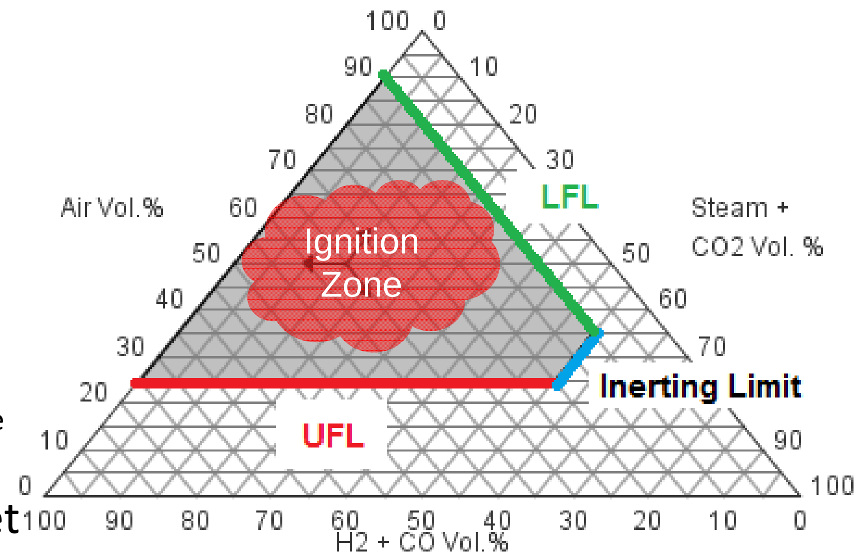
- Overview of the MELCOR Deflagration Modeling
  - Shapiro implementation of default limits
- Overview of the SOARCA Deflagration Modeling
  - Ignition source requirement
  - Application of a Kumar inspired methodology
    - Applies a directional component to ignition criteria
    - Temperature correction to combustion H_2 limit

MELCOR BurnPackage Methodology

- Burns in MELCOR involve the following determinations
  - Ignition Criteria – Mole fraction criteria permitting a burn to occur
    - Two limits may be defined (burns may also be disallowed in user specifies volumes)
      - Spontaneous deflagrations / Igniter initiated deflagrations
        - » Control function (CF) may be used to actuate an igniter
          - » Recent SOARCA modeling use the igniter CFs to incorporate all of the ignition criteria
  - Burn Rate – Moles of gases reacted during a time step (HECTR 1.5)
    - Burn Completeness – Mole fraction of combustible left at end of burn (solved at start of burn)
    - Burn Duration – Duration of a given burn (solved at the start of burn)
      - = Characteristic volume length / Flame Speed (HECTR Correlation)
    - Rate = (X(t) – BurnComplete)/(BurnDuration – TimeSpentBurning)
  - Propagation Criteria – Mole fraction criteria permitting a burn to transfer to another control volume
    - Propagation directional ignition criteria (4%/6%/9%)
    - Ignition criteria check after Const(def=0.0)*BurnDuration

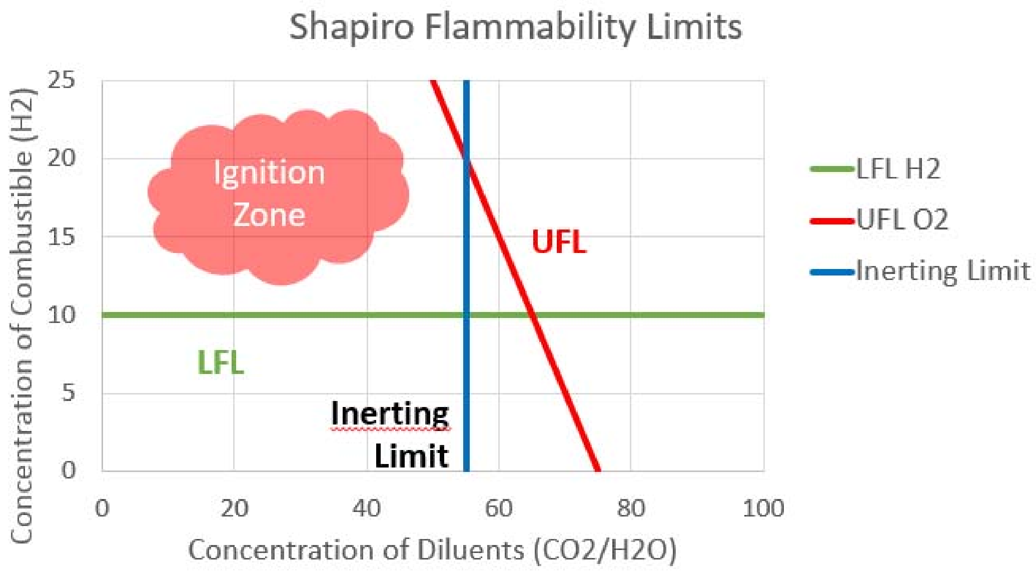
MELCOR BurnPackage Ignition Criteria

- Shapiro Model – Spontaneous Combustion
  - Constant limits
    - Lower Flammabiltiy Limit (LFL)
      - 10% H_2 (+CO adjusted)
    - Upper Flammabiilty Limit (UFL)
      - 5% O_2
    - Inerting Limit
      - 55% CO_2 + H_2O
    - Control volume mole fractions are evaluated against these limits
- Note the use of "Air" implies set N_2/O_2 concentrations



Shapiro Model

- Shapiro Model – Depicted on an XY plot
  - LFL – 10% Hydrogen
  - UFL –5% Oxygen (for 80/20 N2/O2 – 5% Oxygen corresponds to 25% "Air")
  - Inerting Limit 55%



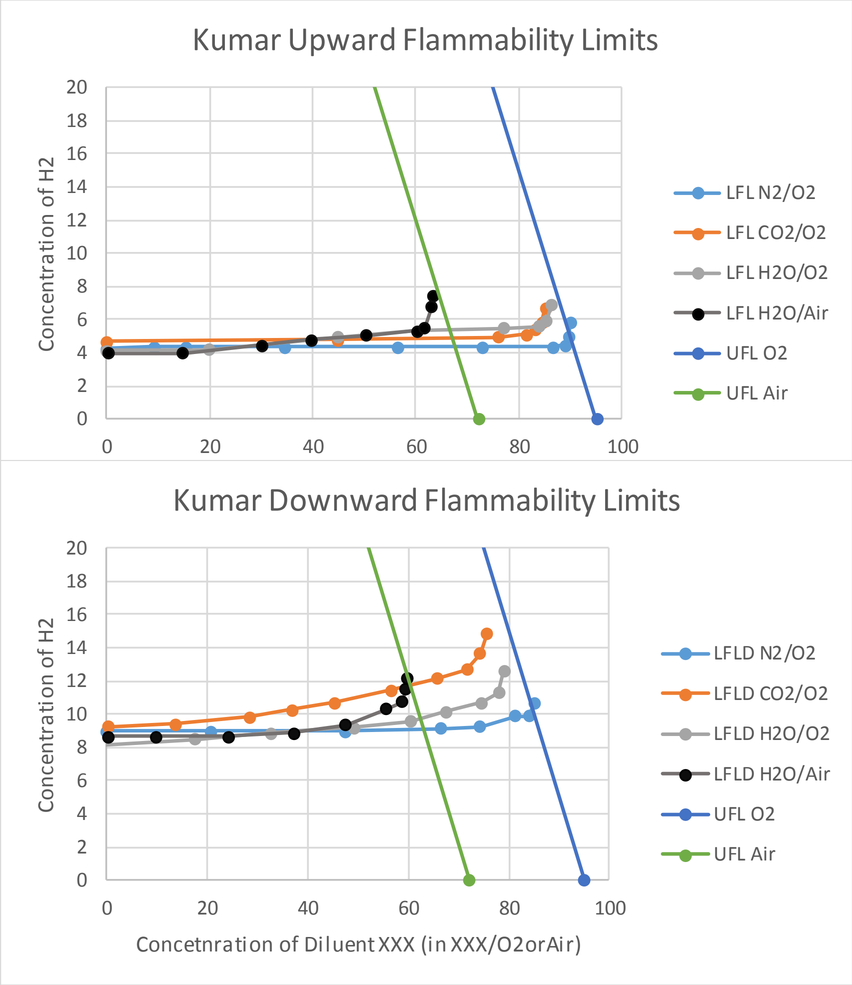
Kumar-Inspired Model

- Integrating directionality (up/down/horizontal) with ignition criteria
  - Performed for Uncertainty Analysis sampling in recent SOARCA studies
    - Uniform distribution for the three possible directions
  - Lower flammability limits vary with regard to relevant flame direction
    - Data from Kumar* was employed
      - Tabular functions using the diluent mole fractions to determine lower flammability limits
    - Upward directional flame front requires less hydrogen then downward traveling flame fronts
    - Horizontal is taken as the average between upward and downward propagation
  - Lower flammability limits vary with atmospheric temperature
- Known ignition sources employed
  - Disable spontaneous ignition criteria
  - Adjust igniter ignition criteria to reduced ignition criteria (maintain CO/H_2O ratio)
  - Create control function logic which combines ignition criteria and ignition source
    - H_2 + CO limit; O_2 limit
    - Hot jet temperature at break site
    - Debris in cavity

Imposing Data

- Kumar investigated various systems to determine up/downward limits
  - $H_2 - N_2 - O_2$
  - $H_2 - CO_2 - O_2$
  - $H_2 - H_2O - O_2$
  - $H_2 - H_2O - Air$

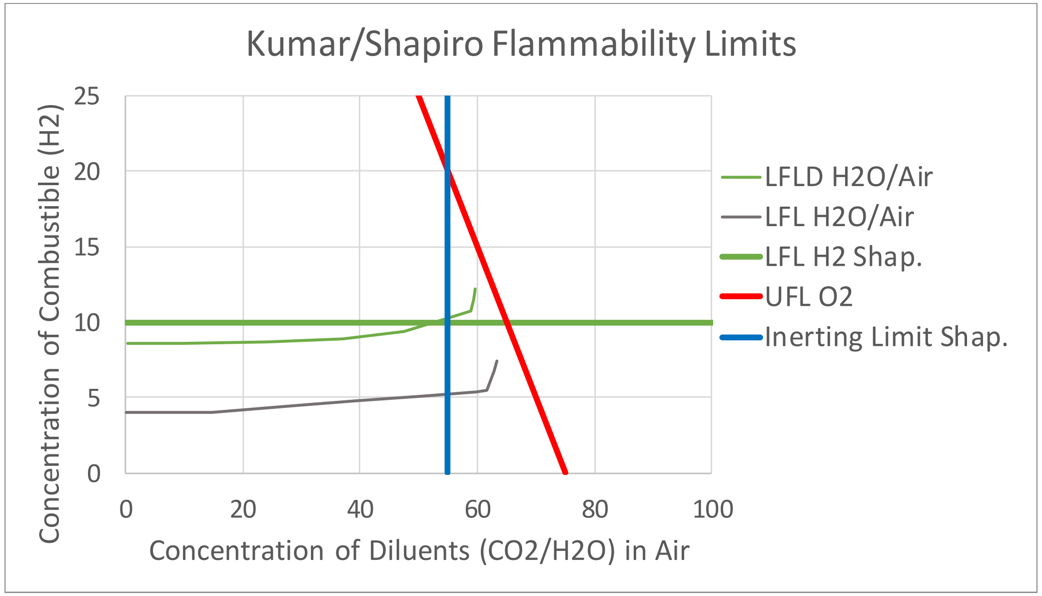
- Kumar purports N_2 may be treated as a diluent in context of paper



SOARCA Compared to Default MELCOR Model

- Applies the Air data set for upward/downward and computes horizontal limit as the average from the up and downward ignition criteria limits

- Increases overall envelope supporting deflagrations
- Fidelity near inerting limit



Temperature Enhancement

- From Kumar
  - Up/downward augmentation to ignition criteria

$LFL_{dir,aug} = LFL_{dir,Kumar} + C_{dir} * \Delta T_{atm,Kumar}$

C_{dir} = -1%/100C for downward and -0.5%/100C for upward

$\Delta T_{atm,Kumar}$ = Delta between the present atmosphere temperature and the temperature at which the limit was determined

$\Delta T_{atm,Kumar} = (T_{atm} - 295.15)$

Fission Product Distribution with UA

- Discuss sources for modeling in SOARCA and SOARCA UA
- Show probability density function for gaseous iodine
- Discuss input generation and deck management used to perform UA

SOARCA Fission Product Classes Definition

- Modeling methodology draws from the following resources
  - Phebus experiments
    - Cs_2MoO_4 used across all of SOARCA
    - Gaseous iodine (I_2, methyl iodine neglected) only applied in SOARCA UA
      - Prior best-estimate SOARCA studies assume chemical form CsI only for iodine

        NUREG/CR-7155, "SOARCA Project – Uncertainty Analysis of the Unmitigated LTSBO of the Peach Bottom Atomic Power Station, Draft Report"
  - VERCORS, ORNL VI&HI, Phebus, and the CORSOR/ORNL-Booth release models
    - Modification of the Booth-ORNL model parameters

      NUREG/CR-7008, "MELCOR Best Practices as Applied in the SOARCA Project"

      Modification of CORSOR/Booth Parameters in MELCOR
  - NUREG-1465
    - Assumed gap fractions

Modeling Fission Products

- Pre-defined mass for all classes
  - No application of the class combination model
    - Prescriptive containment concentrations are being directly specified within the fuel
  - User must combines decay heat tables appropriately
  - Specify radioactive mass for Cs (CsOH), CsI, Mo, Cs_2MoO_4
- SOARCA practice
  - Class 2 – 5% of available Cs (all placed into the fuel gap)
  - Class 4 – 0%
  - Class 16 – All Iodine combined (5% placed into the fuel gap)
  - Class 17 – Remaining Cs combined to form Cs_2MoO_4
    - Specifying radioactive mass in the fuel
  - Class 7 – Mo decremented by formation of Cs_2MoO_4

SOARCA UA Fission Product Class Definition

- Pre-defined approximate compositions definition
  - Phebus test results provided evidence of the chemical form Cs_2MoO_4 and persistence of gaseous iodine which are used in the SOARCA UA
  - Combination n for iodine speciation
    - Average peak percentage of iodine observed as gaseous FTP0-3
    - 5th average over experiment

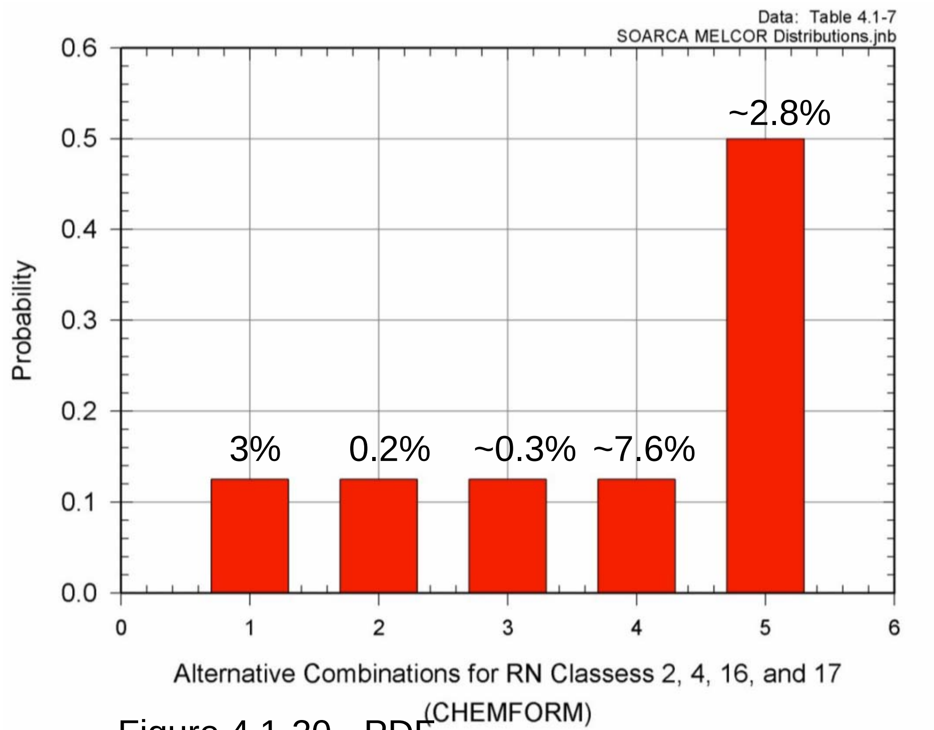
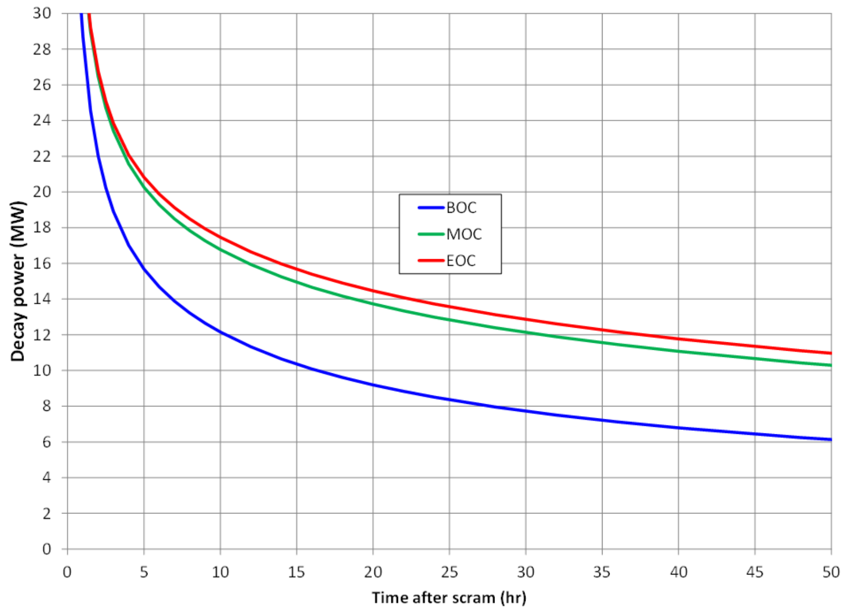


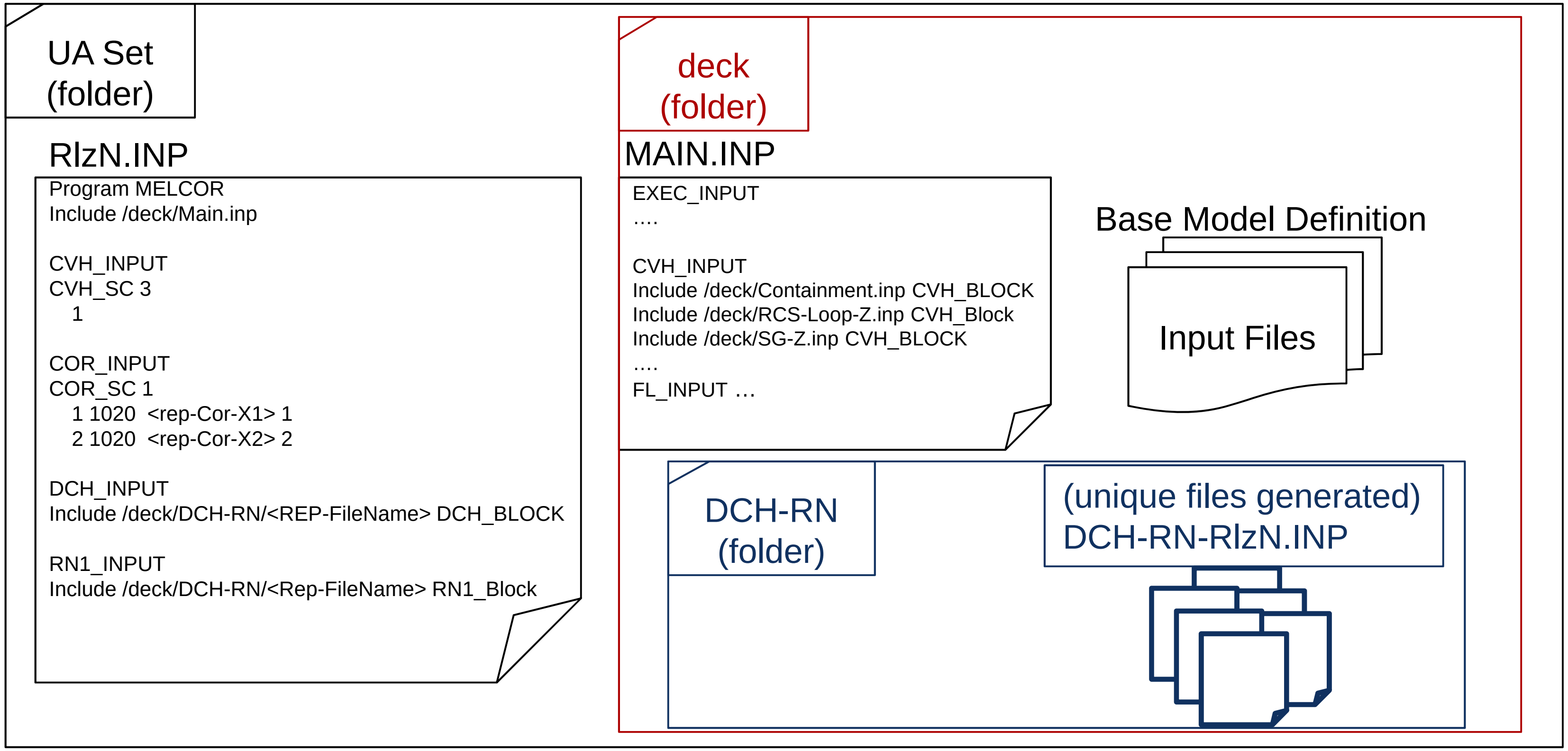
Figure 4.1-20 - PDF

SOARCA UA Total Decay Heat

- Sampled – Time at Cycle
  - Baseline decay heat power curves for scenario initiating at different times
  - Time of shutdown correspond to 7, 200, and 505 days for BOC, MOC, and EOC, respectively



Deck Organization Generation



DCH-RN File Set

- Specifies total decay heat
- Class specific decay heat
- Class radioactive mass

DCH_EL 'I2' 100.0 10 ! Sampled value for mass

1 0.0e0 10.E5 ! Time of Cycle

2 2.0e0 9.5E5

3 ..

Conclusions

- Discussed the following:
  - Implementation of a Kumar-inspired deflagration model
    - Overview of the default Burn Package treatment
    - Modification of the LFL using Kumar's data
  - Iodine class speciation
    - General SOARCA distribution of classes
    - SOARCA UA inclusion of Phebus results
  - Decay heat for different time of cycle
    - BOC, EOC, MOC
  - Possible deck configuration for UAs