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COMPUTER CODES IN RAMP

HABIT

CODE FOR ASSESSING CONTROL ROOM HABITABILITY

Radiation Protection Branch
Office of Nuclear Regulatory Research
The United States Nuclear Regulatory Commission

HABIT TEAM*

- Kevin Lam (System Engineer)
- Richard McMullan (Fortran)
- Raymond Aurdos (Graphic)
- **Dan Pomykala (PM)**
- Wendy Chinchilla (Admin)
- Dr. Tom Spicer (Expert)
- Dr. Casper Sun (COR)
- Dr. Syed Haider (NRC PM)

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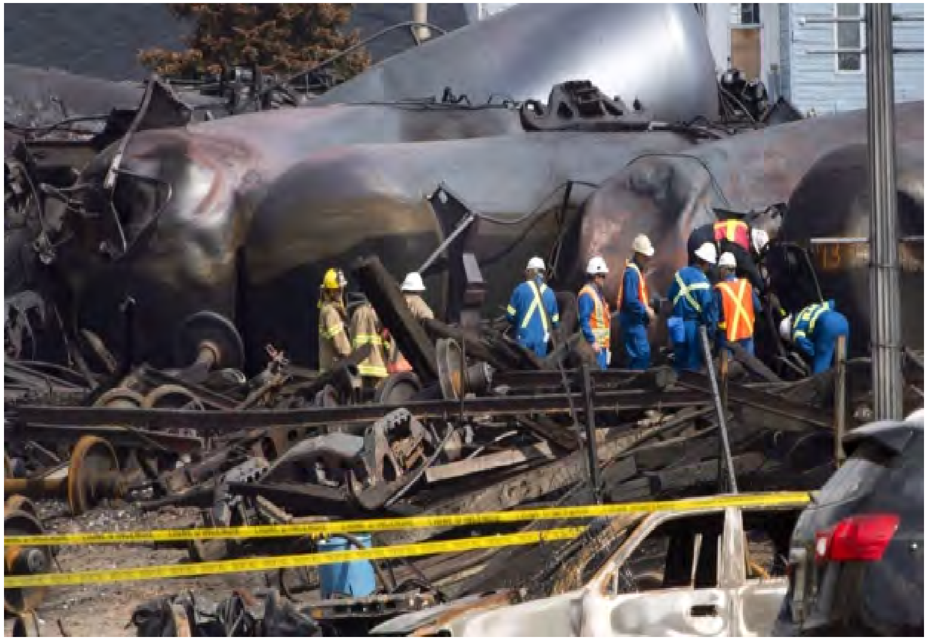
COMPUTER CODE FOR ASSESSING CONTROL ROOM HABITABILITY

Prepared for 2015 RAMP first annual meeting, Rockville, MD 20852: October 5th, 2015

Real ATD Pictures



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Habitable Issues

Non-radiological

Radiological

Conservation Equation

$$\frac{\partial \Phi}{\partial t} + \nabla \cdot (\mathbf{F} + \Phi \mathbf{V}) - H = 0$$

$$C(x,y,z,t) = \frac{Q}{2\pi\, u\, \sigma_y \sigma_z} . \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left[\exp\left(-\frac{(z-H_{eff})^2}{2\sigma_z^2}\right)\right] + \exp\left(-\frac{(z+H_{eff})^2}{2\sigma_z^2}\right)$$

HABIT Code Development

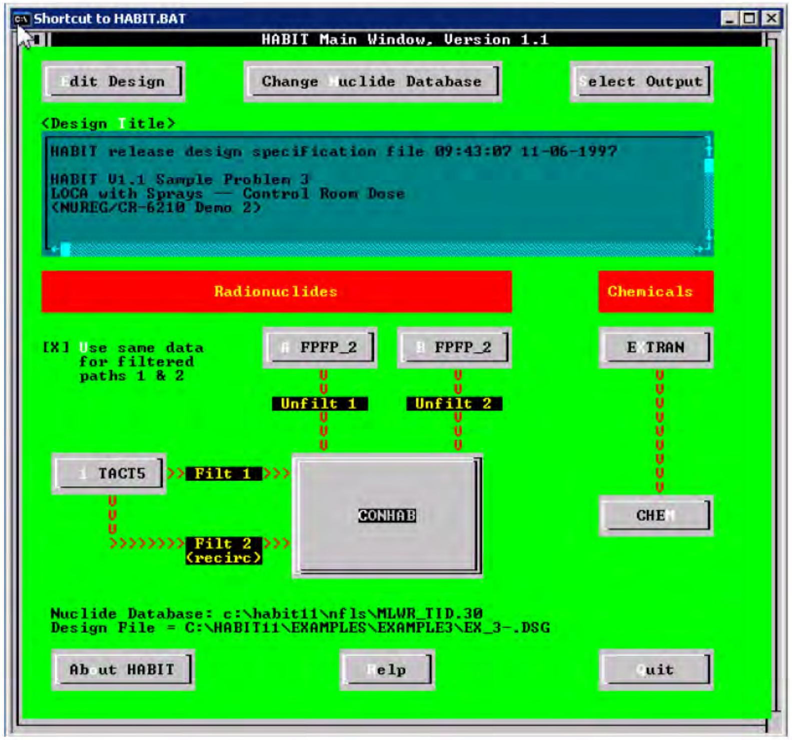
- **Phase I** (June 2014 – Feb. 2015):
  - Repaired **HABIT v1.1** FORTRAN source code
  - Developed User Manual and added interactive help screens
  - Complying Section 508 requirements
- **Phase II** (April 2015 – Sept. 2016):
  - Integrated DEGADIS and SLAB (D&S) dense gas models
  - New GUI and completed **HABIT v2.0 code**
  - V&V and built test cases examples
- **Phase III** (Oct 2016 – Present):
  - **Release HABIT v2.1** and update the User Manual
  - Renew NUREG/CR-6210 and RG 1.78
  - ATD benchmark (on the horizon)

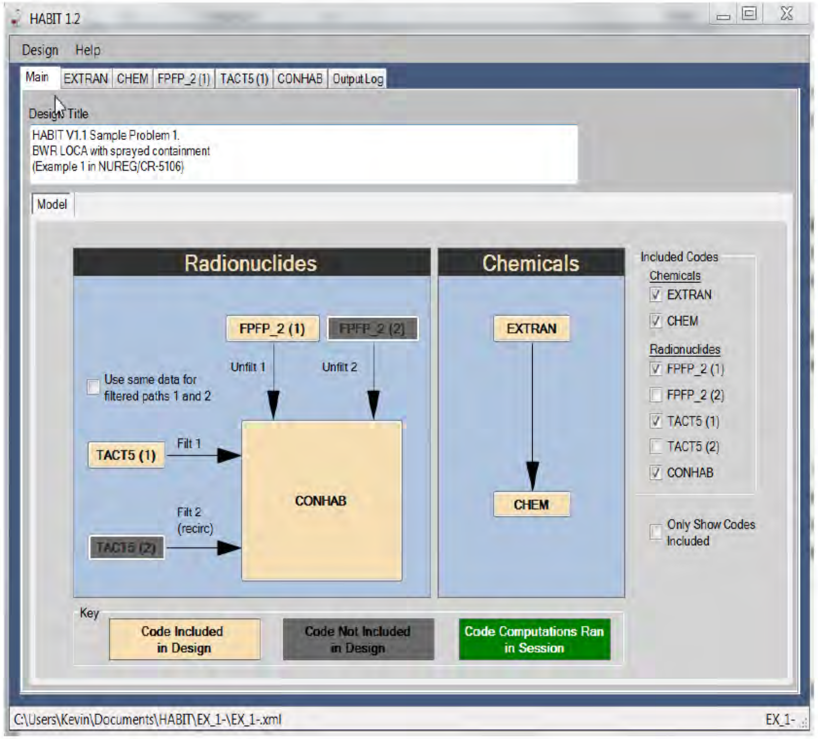
RG 1.78: Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release (2001)

PHASE-I (8 Months)

HABIT v1.1 & v1.2

Original	New





Validate FORTRAN modules and I/O data

- Impacts from identified "BUGS" and modifications made in HABIT 1.2
- Precision of reproduced identical results

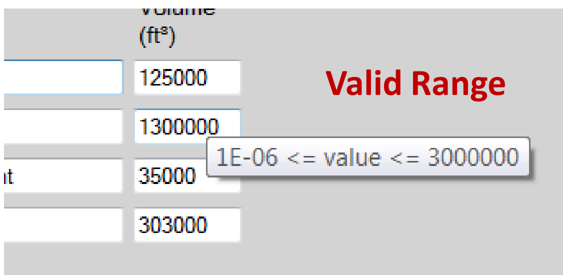
Add Microsoft compiling methods and new "User Manual"

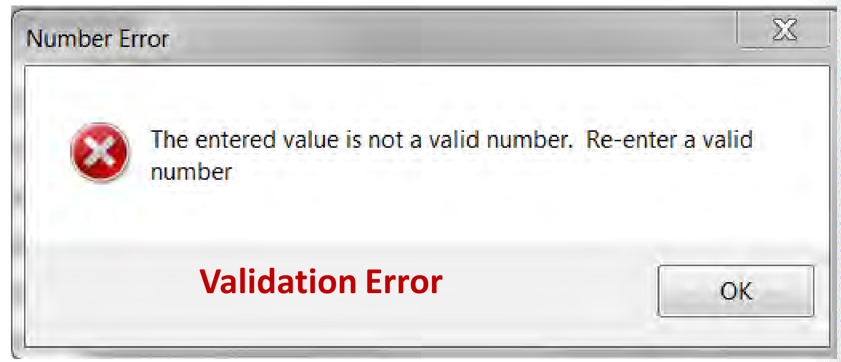
What's New in HABIT

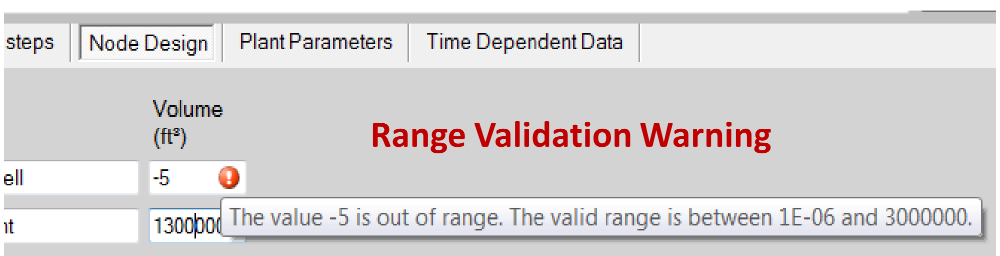
- **Used Intel Visual FORTRAN compiler for compatibility with Windows 7 (64-bit)**
  - Added User Manual and interactive tooltips
  - Backwards compatible for old I/O designed (.DSG) files
- **Used Microsoft .NET technology for graphical user interface (GUI) development**
  - Section 508 Compliance (e.g., color blinder or muted use of color, and JAWS)
  - Data plot and save in XML and ASCII

HABIT New Tooltips

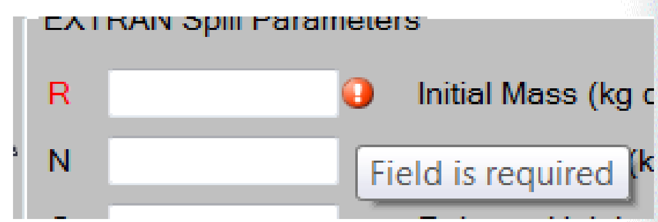
Tooltips provide a convenient way to see the expected range for fields and provide validations to prevent entering bad data.







Required Field Warning



PHASE-II

April 2015 - Sept 2016

- **Integrate HABIT-DEGADIS-SLAB codes**
- **Program BMW criteria and test cases for dense-gas model importance**

ANL: ATD Code Comparison and Selected Models

Model	Developer	Purpose	Scenarios	Type
ALOHA 5.4.3	EPA/NOAA	Dense gas and neutrally buoyant gas dispersions	Leak from pipeline or tank, evaporating puddle, direct open source	Source-term model
DEGADIS 2.1	University of Arkansas	Dense gas and neutrally buoyant gas dispersions	Elevated or ground-level area source, vertical jet leak	Non-source-term model
HABIT 1.1	**PNNL**	**Neutrally buoyant gas dispersions**	**Liquid or gas tank burst and leak**	**Source-term model**
SCIPUFF 2.2	Titan Research and Technology	Dense gas and neutrally buoyant gas dispersions	Moving and stack sources, gaseous and particulate materials	Non-source-term model
SLAB	LLNL	Dense gas and neutrally buoyant gas dispersions	Open evaporating pool, horizontal and vertical jet/stack, instantaneous volume liqiud sources	Non-source-term model

Source: Table E.1: ANL/EVS/TM-13.3 (April 2013)

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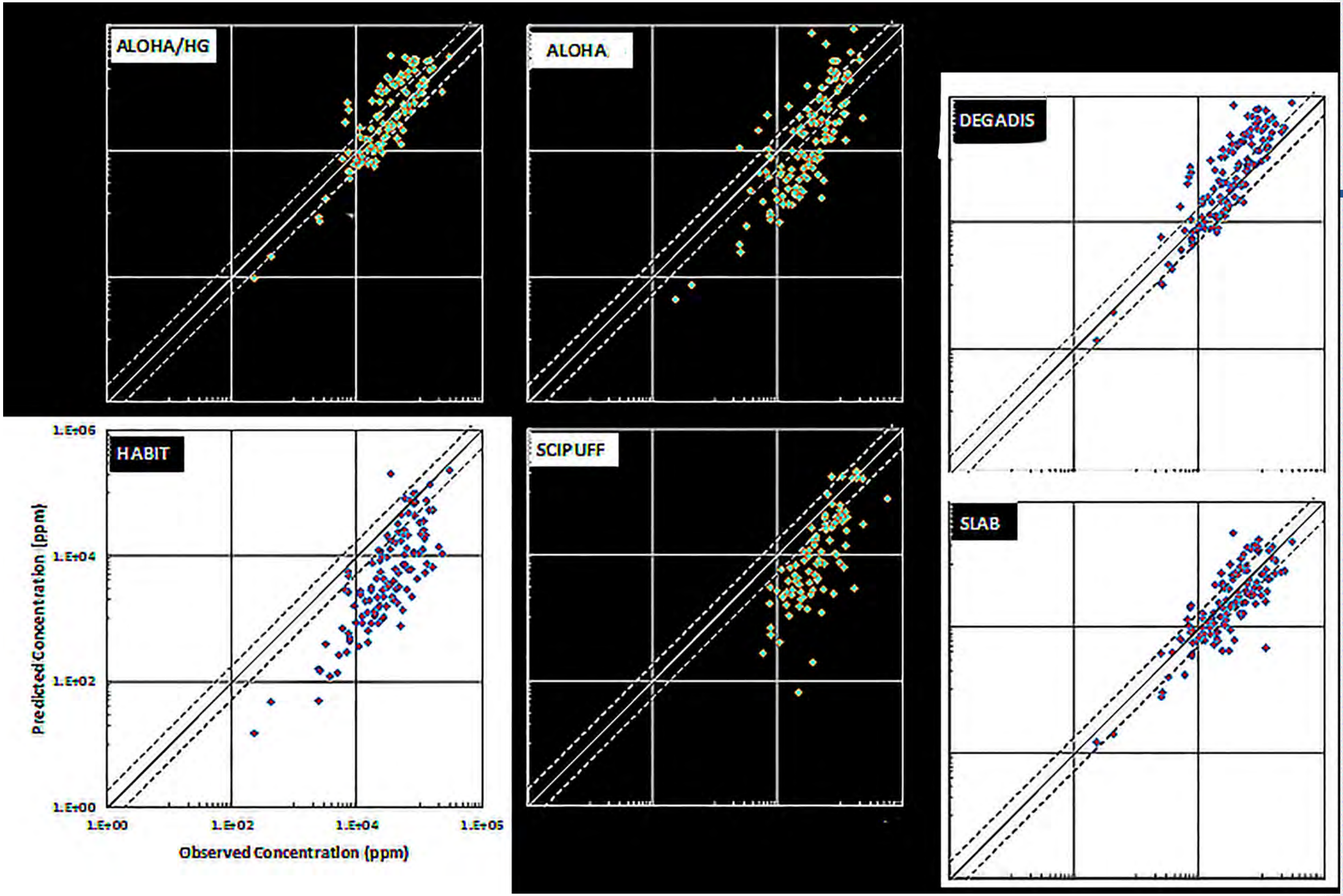
ATD Experimental Data (Hanna et al.1991)

Parameter	Burro	Coyote	Desert Tortoise	Goldfish	Hanford (continuous)	Hanford (Instantaneous)	Maplin Sands	Prairie Grass	Thorney Island (continuous)	Thorney Is. (instantaneous)
Number of trials	8	3	4	3	5	6	4, 8[a]	44	2	9
Location	China Lake, Calif.	China Lake, Calif.	Nevada Test Site, Nev.	Nevada Test Site, Nev.	Richland, Wash.	Richland, Wash.	Maplin Sands, U.K.	Near O'Neill, Neb.	Thorney Island, U.K.	Thorney Island, U.K.
Period	Jun.-Sep. 1980	Sep.-Oct. 1981	Aug.-Sep. 1983	Aug. 1986	Sep.-Nov. 1967	Sep.-Nov. 1967	Sep. 1980, Sep.-Oct. 1980	Jul.-Aug. 1956	Jun. 1984	Aug. 1982-Jun. 1983
Material	LNG	LNG	NH_3	HF	Krypton-85	Krypton-85	LNG, LPG	SO_2	Freon-12, N_2	Freon-12, N_2
Type of release	Boiling liquid (dense gas)	Boiling liquid (dense gas)	2-phase jet (dense gas)	2-phase jet (dense gas)	Gas (non-buoyant)	Gas (non-buoyant)	Boiling liquid (dense gas)	Gas jet (non-buoyant)	Gas (dense gas)	Gas (dense gas)
Total mass (kg)	10,700-17,300	6,500-12,700	10,000 - 36,800	3,500-3,800	11-24[b]	10[b]	2,000-6,600, 1,500-8,400	23-63	4,800	3,150-8,700
Release duration (s)	79-190	65-98	126-381	125-360	598-1,191	(instantaneous)	100-230, 90-360	600	460	(instantaneous)
Surface	Water	Water	Soil	Soil	Soil	Soil	Water	Soil	Soil	Soil
Surface roughness (m)	0.0002	0.0002	0.003	0.003	0.03	0.03	0.0003	0.006	0.01	0.005-0.018
P-G stability class	C-E	C-D	D-E	D	C-F	C-F	D, C-D	A-F	E-F	D-F
Max. distance (m)	140-800	300-400	800	1,000-3,000	800	800	180-650, 250-650	800	472	410-580
Min. averaging time (s)	1	1	1	66.6-88.3	38.4	4.8	3	(dosage)	30	0.6
Max. averaging time (s)	40-140	50-90	80-300	66.6-88.3	269-845	4.8	3	600	30	0.6

[a] The first and second values denote LNG and LPG, respectively, if any.

[b] Curies, rather than kg, are used as a measure of the amount of this radioactive tracer released.



"Predicted (V)" and "Observed (H)" Concentrations (ppm)

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Modules Selected

- **DEGADIS (Thomas Spicer)** solves the gas concentrations by gravity-driven, over flat terrain, then into the entrainment layers.
- **SLAB (Donald Ermak)** solves gas concentrations by mass, energy, and momentum balances at downwind locations.

Both Models can perform for release from:
pool evaporation, jets, and explosion scenarios.

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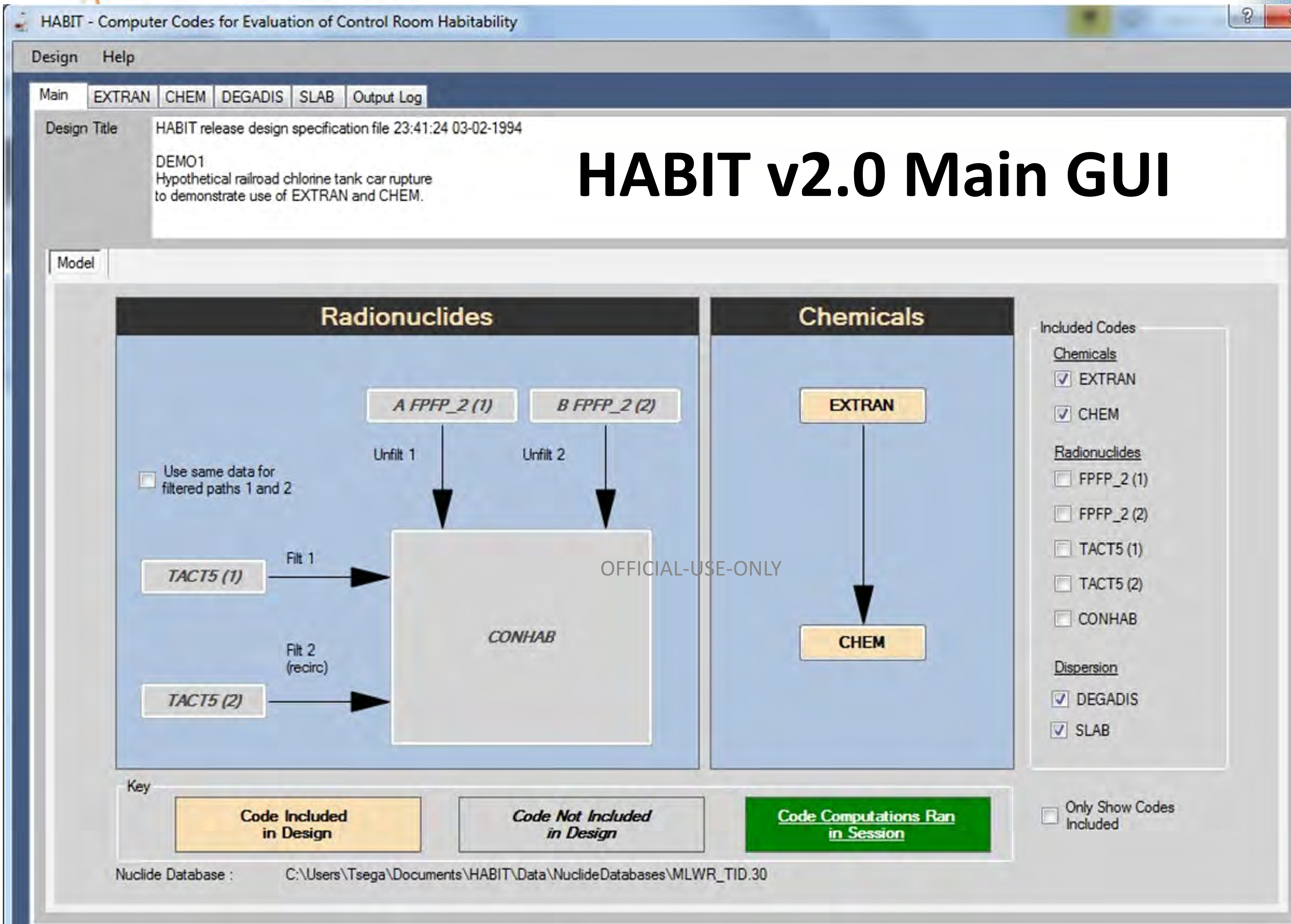
Model Evaluations:

Is an equitable comparison possible?

- Models have varying starting points (e.g. some have full source emissions algorithms and others require input of source emission rate),
- Models have varying ending points (i.e., the output files are not consistent with each other),
- Most models have been ‘calibrated’ with some of the field data sets,
- Models are not applicable to all source scenarios (i.e., some models claim to be applicable to a wider range of scenarios than justified by their scientific modules), and
- Model developers some state that it is necessary to consult with them during any applications of their model.

HABIT v2.0 Main GUI



BMW Criteria

Britter and McQuaid found that denser-than-air effects are important if:

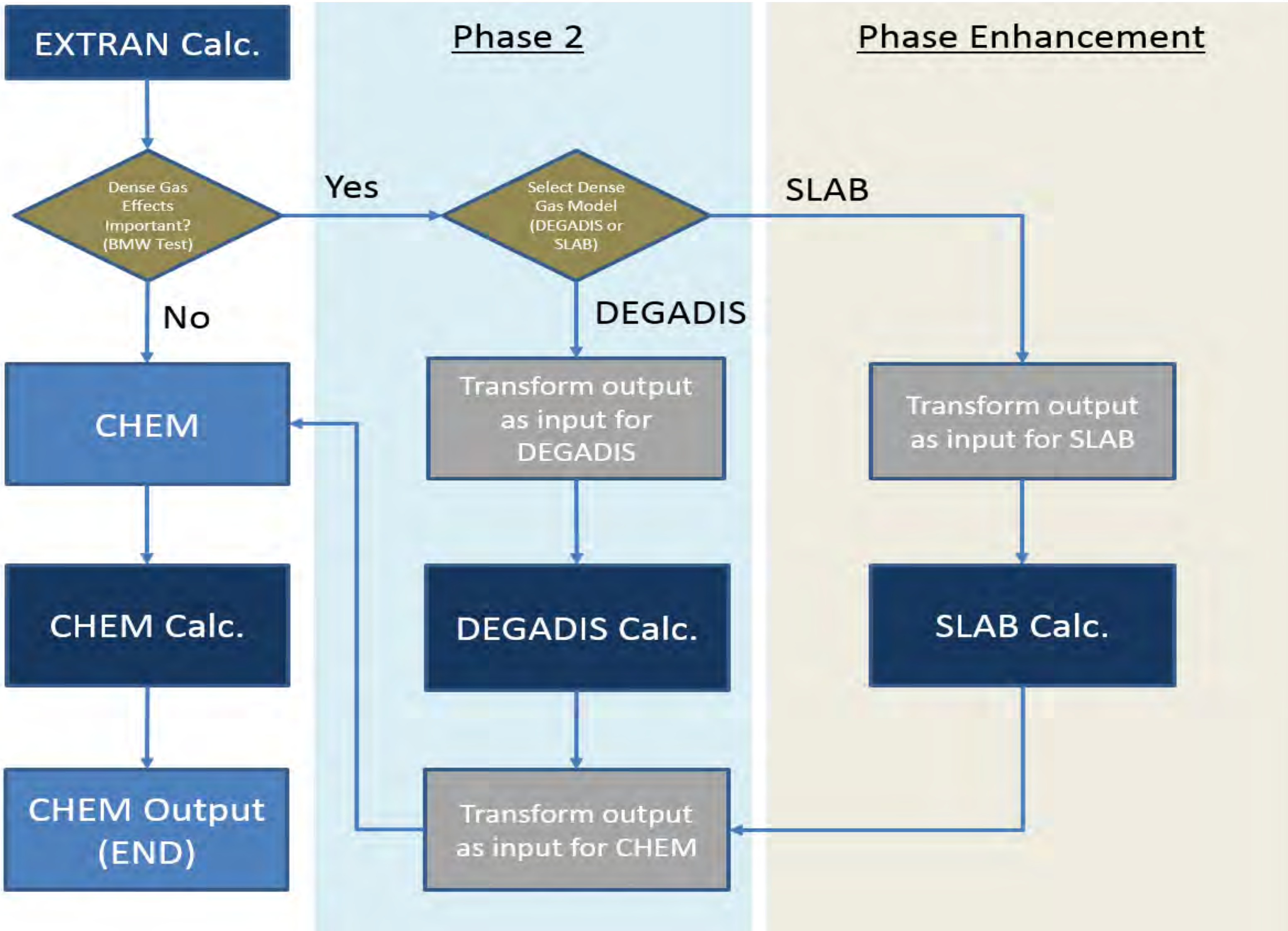
$$\frac{g(dm/\rho_s)}{D_s u_r^3}\left(\frac{\rho_s - \rho_a}{\rho_a}\right) > 0.15^3 = 0.0034$$

For puffs or instantaneous gas releases, denser-than-air effects are important if:

$$\frac{g(m/\rho_s)^{1/3}}{u_r^2}\left(\frac{\rho_s - \rho_a}{\rho_a}\right) > 0.2^2 = 0.04$$

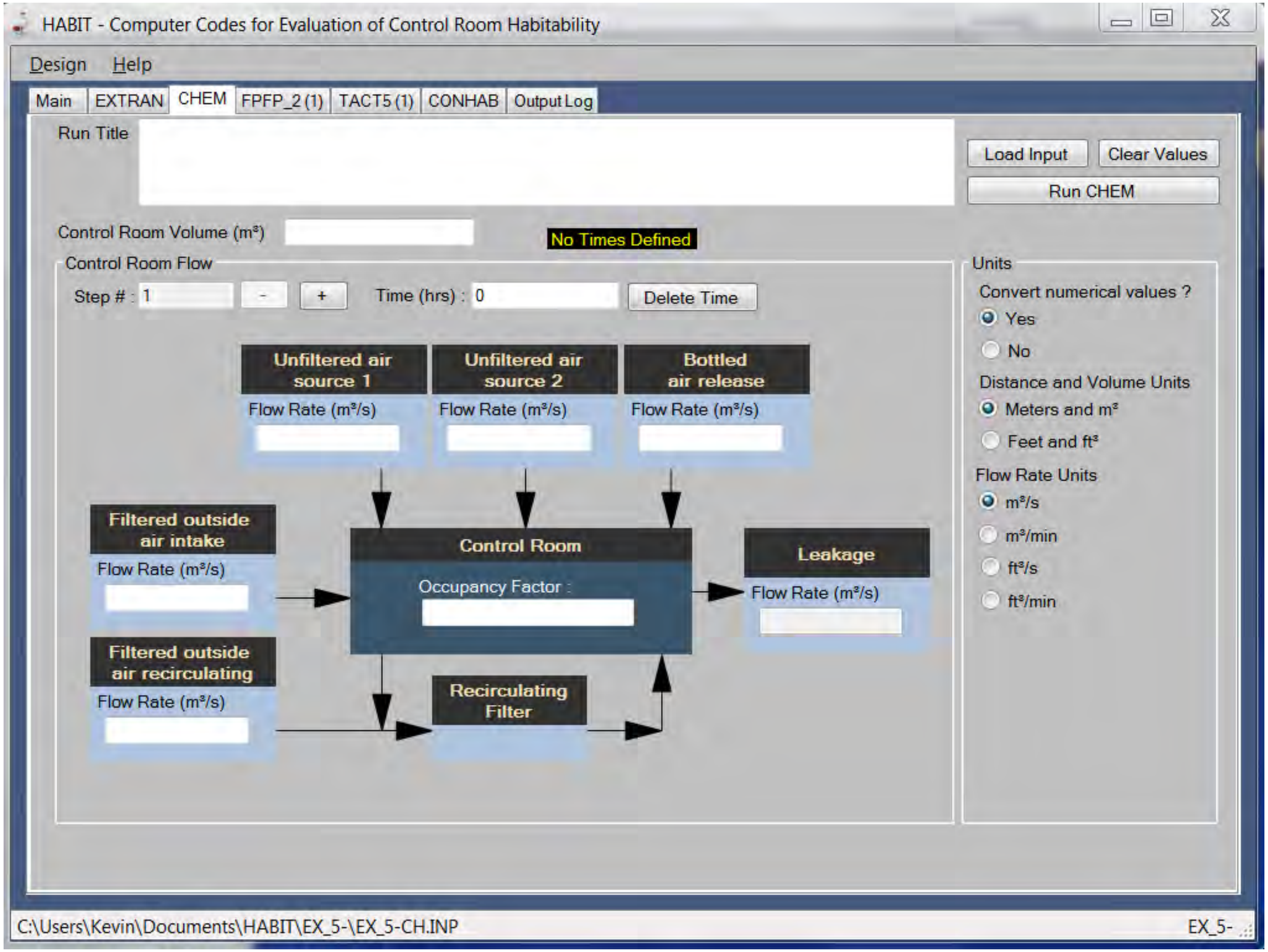
Where g is the acceleration due to gravity and ρ_a is the ambient air density.

Flowchart

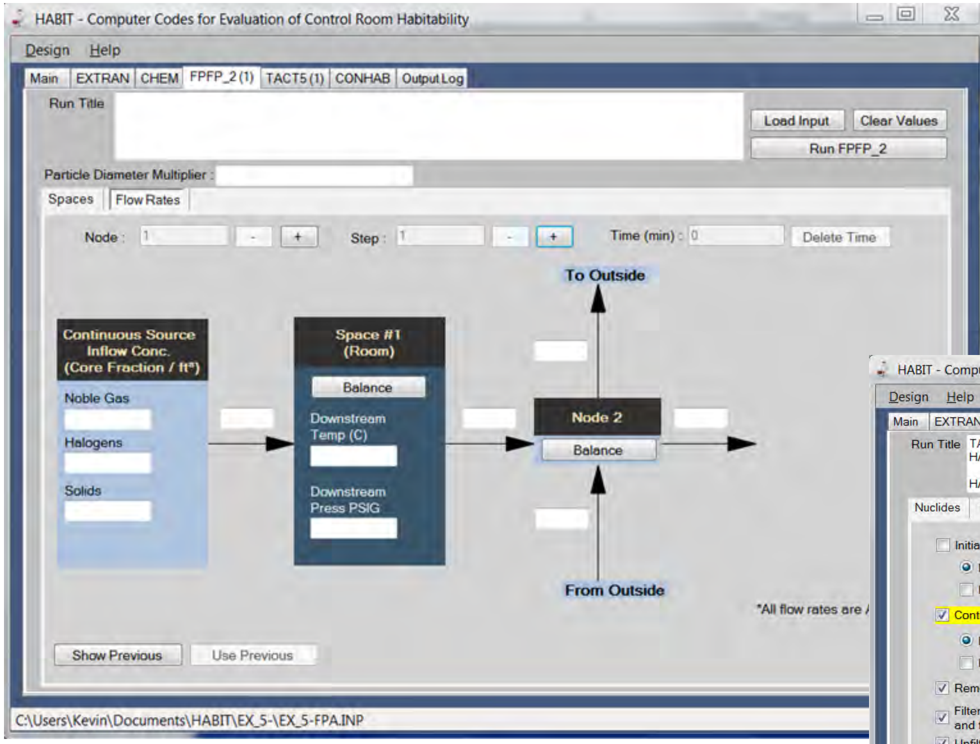


Phase 2
Phase Enhancement
EXTRAN Calc.
Dense Gas Effects Important? (BMW Test)
Yes
No
Select Dense Gas Model (DEGADIS or SLAB)
SLAB
DEGADIS
CHEM
Transform output as input for DEGADIS
Transform output as input for SLAB
CHEM Calc.
DEGADIS Calc.
SLAB Calc.
CHEM Output (END)
Transform output as input for CHEM

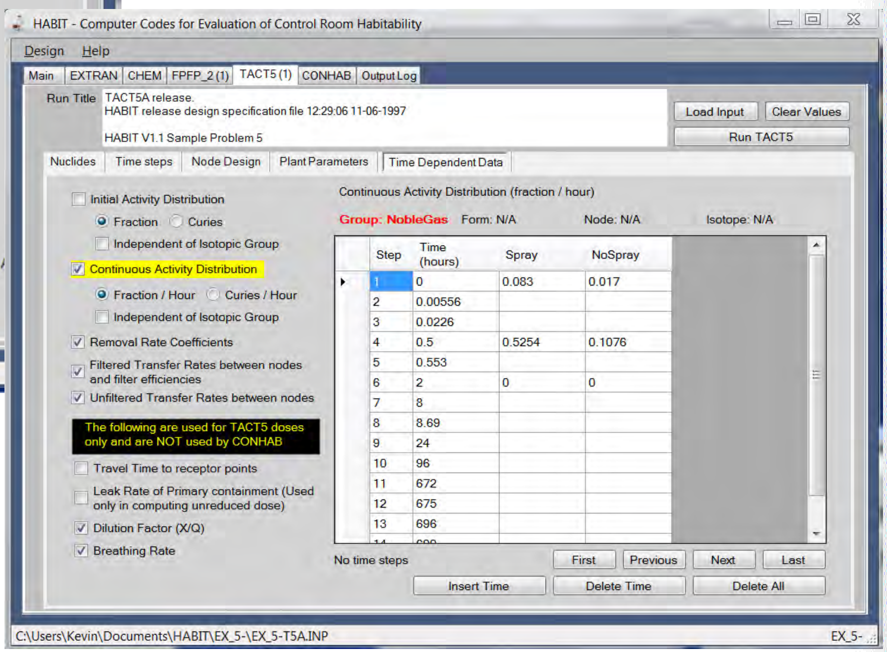
CHEM(ical) Module



Radiological Modules

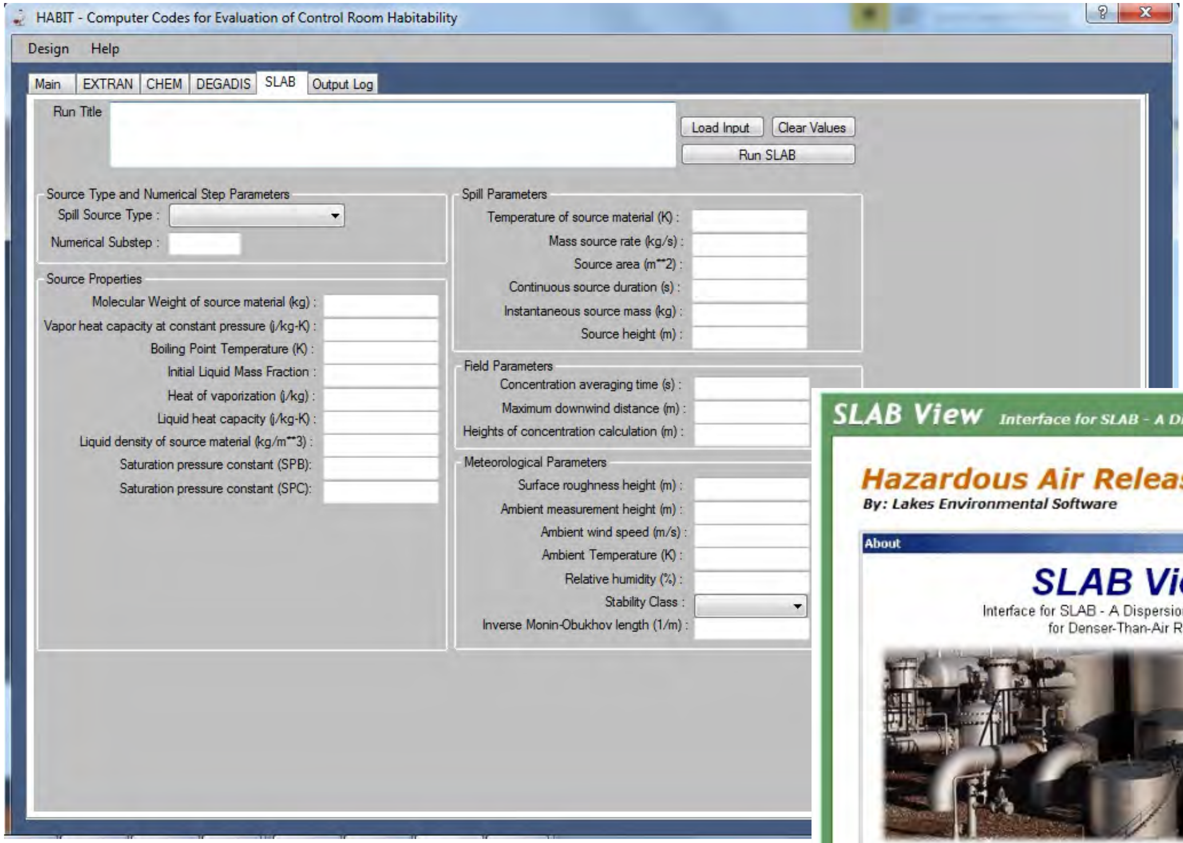


TACT Module

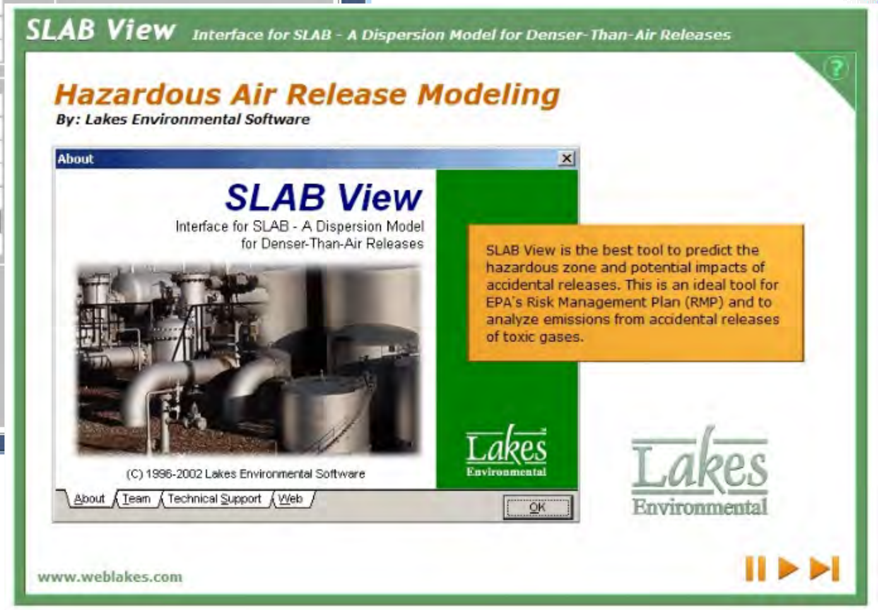


FPFP Module

SLAB (GUI)

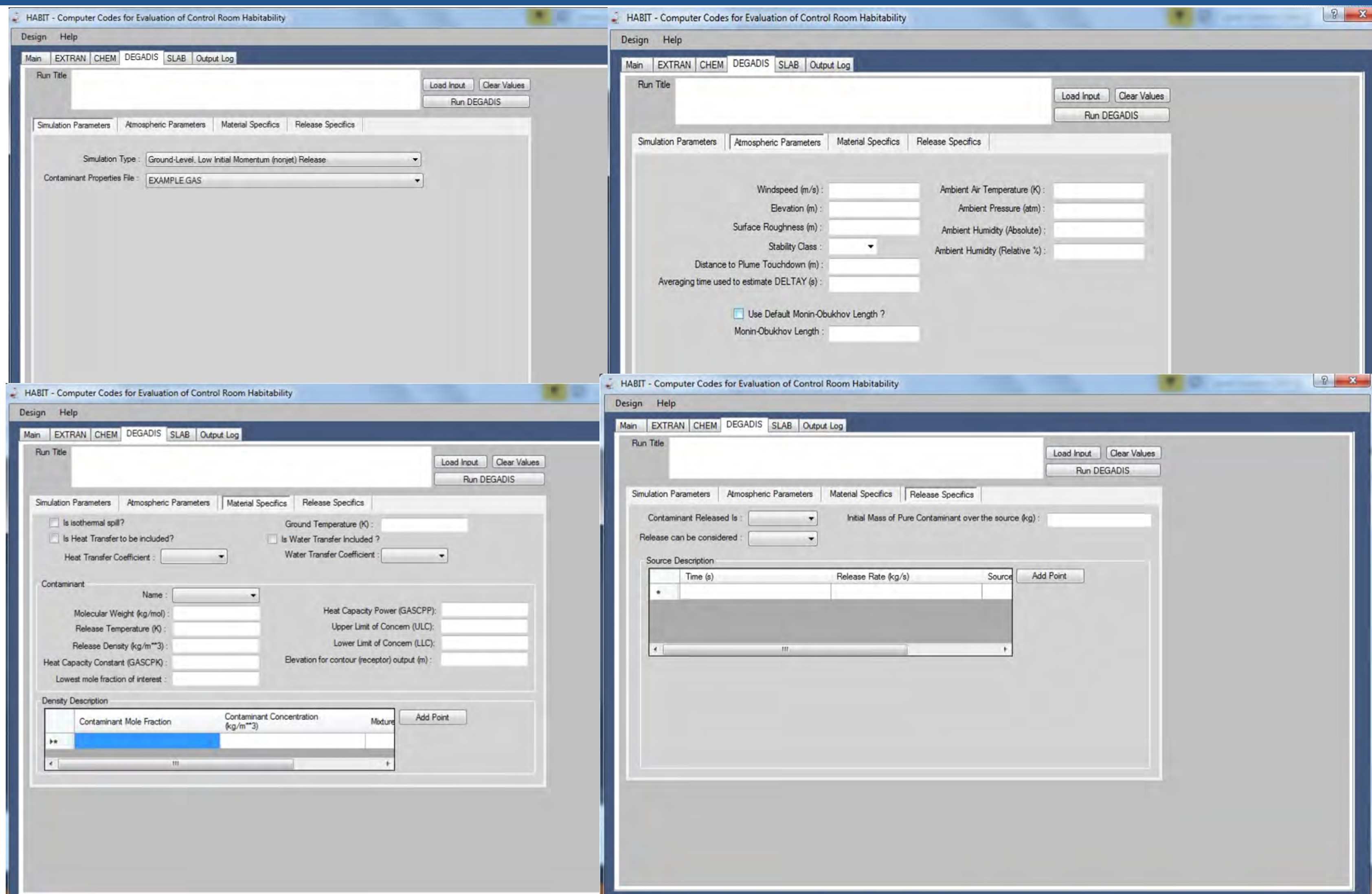


HABIT - Computer Codes for Evaluation of Control Room Habitability
Design
Help
Main
EXTRAN
CHEM
DEGADIS
SLAB
Output Log
Run Title
Load Input
Clear Values
Run SLAB
Source Type and Numerical Step Parameters
Spill Source Type :
Numerical Substep :
Source Properties
Molecular Weight of source material (kg) :
Vapor heat capacity at constant pressure (j/kg-K) :
Boiling Point Temperature (K) :
Initial Liquid Mass Fraction :
Heat of vaporization (j/kg) :
Liquid heat capacity (j/kg-K) :
Liquid density of source material (kg/m**3) :
Saturation pressure constant (SPB):
Saturation pressure constant (SPC):
Spill Parameters
Temperature of source material (K) :
Mass source rate (kg/s) :
Source area (m**2) :
Continuous source duration (s) :
Instantaneous source mass (kg) :
Source height (m) :
Field Parameters
Concentration averaging time (s) :
Maximum downwind distance (m) :
Heights of concentration calculation (m) :
Meteorological Parameters
Surface roughness height (m) :
Ambient measurement height (m) :
Ambient wind speed (m/s) :
Ambient Temperature (K) :
Relative humidity (%) :
Stability Class :
Inverse Monin-Obukhov length (1/m) :



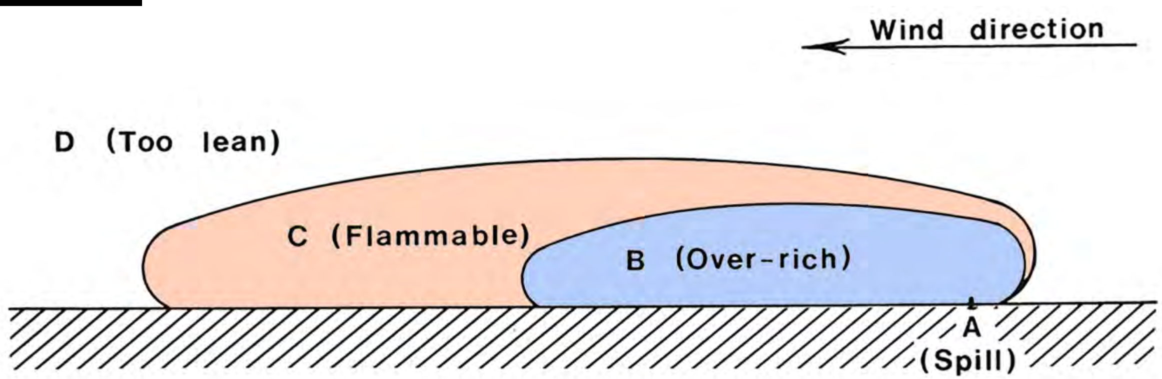
SLAB View Interface for SLAB - A Dispersion Model for Denser-Than-Air Releases
Hazardous Air Release Modeling
By: Lakes Environmental Software
About
SLAB View
Interface for SLAB - A Dispersion Model for Denser-Than-Air Releases
(C) 1996-2002 Lakes Environmental Software
About
Team
Technical Support
Web
OK
Lakes Environmental
SLAB View is the best tool to predict the hazardous zone and potential impacts of accidental releases. This is an ideal tool for EPA's Risk Management Plan (RMP) and to analyze emissions from accidental releases of toxic gases.
Lakes Environmental
www.weblakes.com

DEDAGIS: GUI


HABIT - Computer Codes for Evaluation of Control Room Habitability
Design
Help
Main
EXTRAN
CHEM
DEGADIS
SLAB
Output Log
Run Title
Load Input
Clear Values
Run DEGADIS
Simulation Parameters
Atmospheric Parameters
Material Specifics
Release Specifics
Simulation Type :
Ground-Level, Low Initial Momentum (nonjet) Release
Contaminant Properties File :
EXAMPLE.GAS
Windspeed (m/s) :
Elevation (m) :
Surface Roughness (m) :
Stability Class :
Distance to Plume Touchdown (m) :
Averaging time used to estimate DELTAY (s) :
Ambient Air Temperature (K) :
Ambient Pressure (atm) :
Ambient Humidity (Absolute) :
Ambient Humidity (Relative %) :
Use Default Monin-Obukhov Length ?
Monin-Obukhov Length :
Is isothermal spill?
Is Heat Transfer to be included?
Heat Transfer Coefficient :
Ground Temperature (K) :
Is Water Transfer Included ?
Water Transfer Coefficient :
Contaminant
Name :
Molecular Weight (kg/mol) :
Release Temperature (K) :
Release Density (kg/m**3) :
Heat Capacity Constant (GASCPK) :
Lowest mole fraction of interest :
Heat Capacity Power (GASCPP):
Upper Limit of Concern (ULC):
Lower Limit of Concern (LLC):
Elevation for contour (receptor) output (m) :
Density Description
Contaminant Mole Fraction
Contaminant Concentration (kg/m**3)
Mixture
Add Point
Contaminant Released Is :
Release can be considered :
Initial Mass of Pure Contaminant over the source (kg) :
Source Description
Time (s)
Release Rate (kg/s)
Source

DEGADIS' 4 Modules

- Simulation Processes
- Atmospheric Processes
- Chemical Specifications
- Release Specifications



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I/O Input Fields

- Chemical properties
- Meteorological conditions
- BMW parameters
- Spill scenario and conditions

	E	F	G	H	I	J	K	L
1	Liquid Tank Burst-**DEGADIS**	Liquid Tank Leak-**DEGADIS**	Gas Tank Burst-**DEGADIS**	Gas Tank Leak-**DEGADIS**	Liquid Tank Burst-**SLAB**	Liquid Tank Leak-**SLAB**	Gas Tank Burst-**SLAB**	Gas Tank Leak-**SLAB**
2	u0 (m/s) = U_a	u0 (m/s) = U_a	u0 (m/s) = U_a	u0 (m/s) = U_a	UA (m/s) = U_a	UA (m/s) = U_a	UA (m/s) = U_a	UA (m/s) = U_a
3	z0 (m) = 10 m	z0 (m) = 10 m	z0 (m) = 10 m	z0 (m) = 10 m	ZA = 10 m	ZA = 10 m	ZA = 10 m	ZA = 10 m
4	istab (A=1,B=2, etc.) (A-F)so class G would be best approximated with class F.	istab (A=1,B=2, etc.) (A-F)so class G would be best approximated with	istab (A=1,B=2, etc.) (A-F)so class G would be best approximated with class F.	istab (A=1,B=2, etc.) (A-F)so class G would be best approximated with class F.	STAB (A=1,B=2, etc.)(A-F)class G would be best approximated with class	STAB (A=1,B=2, etc.)(A-F)class G would be best approximated with class F.	STAB (A=1,B=2, etc.)(A-F)class G would be best approximated with	STAB (A=1,B=2, etc.)(A-F)class G would be best
5	tamb (K) = T_a + 273.15	tamb (K) = T_a + 273.15	tamb (K) = T_a + 273.15	tamb (K) = T_a + 273.15	TA (K) = T_a + 273.15	TA (K) = T_a + 273.15	TA (K) = T_a + 273.15	TA (K) = T_a + 273.15
6	pamb (atm) = P_a/760	pamb (atm) = P_a/760	pamb (atm) = P_a/760	pamb (atm) = P_a/760	NOT USED	NOT USED	NOT USED	NOT USED
7	R_s (W/m^2)	R_s (W/m^2)	R_s (W/m^2)	R_s (W/m^2)	R_s (W/m^2)	R_s (W/m^2)	R_s (W/m^2)	R_s (W/m^2)
8	cc (tenths)	cc (tenths)	cc (tenths)	cc (tenths)	cc (tenths)	cc (tenths)	cc (tenths)	cc (tenths)
9	T_g (°C)	T_g (°C)	T_g (°C)	T_g (°C)	T_g (°C)	T_g (°C)	T_g (°C)	T_g (°C)
10	z_R (m)	z_R (m)	z_R (m)	z_R (m)	ZO (m)	ZO (m)	ZO (m)	ZO (m)
11	relhum (%)	relhum (%)	relhum (%)	relhum (%)	RH (%)	RH (%)	RH (%)	RH (%)
12	**oodist = 0,** Offset distance for a vertical jet release will not be used.	**oodist = 0,** Offset distance for a vertical jet release will not be used.	**oodist = 0,** Offset distance for a vertical jet release will not be used.	**oodist = 0,** Offset distance for a vertical jet release will not be used.	Not Used	Not Used	Not Used	Not Used
13	**indvel=1,** default Monin-Obukhov length is used.	**indvel=1,** default Monin-Obukhov length is used.	**indvel=1,** default Monin-Obukhov length is used.	**indvel=1,** default Monin-Obukhov length is used.	**ALA=0,**Monin-Obukhov length	**ALA=0,**Monin-Obukhov length	**ALA=0,**Monin-Obukhov length	**ALA=0,**Monin-Obukhov length
14	**frml = 0,**A user input value of the Monin-Obukhov length will not be used.	**frml = 0,**A user input value of the Monin-Obukhov length will not be used.	**frml = 0,**A user input value of the Monin-Obukhov length will not be used.	**frml = 0,**A user input value of the Monin-Obukhov length will not be used.	Not Used	Not Used	Not Used	Not Used
15	**humid = 0,** ambient humidity will be based on relative humidity.	**humid = 0,** ambient humidity will be based on relative humidity.	**humid = 0,** ambient humidity will be based on relative humidity.	**humid = 0,** ambient humidity will be based on relative humidity.	Not Used	Not Used	Not Used	Not Used
16	Not Used	Not Used	Not Used	Not Used	SPC =0	SPC =0	SPC =0	SPC =0
17								
18								
19								

1.Meteorological Input Params | 2.Spill Parameters | 3.Chemical Paramters | Legend

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HABIT PHASE-III

Work-in-Progress

Code Enhancements

- Adjustable GUI to maximize use of the monitor size
- Better and faster I/O data transfer and retrieval
- Consolidate common input HABIT-DEGADIS-SLAB
- Determine control-room “Intake-Height” key parameters

Code V&V

- Preform ALOHA-HABIT benchmark tests
- Implement D&S spill scenarios and modeling
- Add “Jack Rabbit” chlorine jet releases data

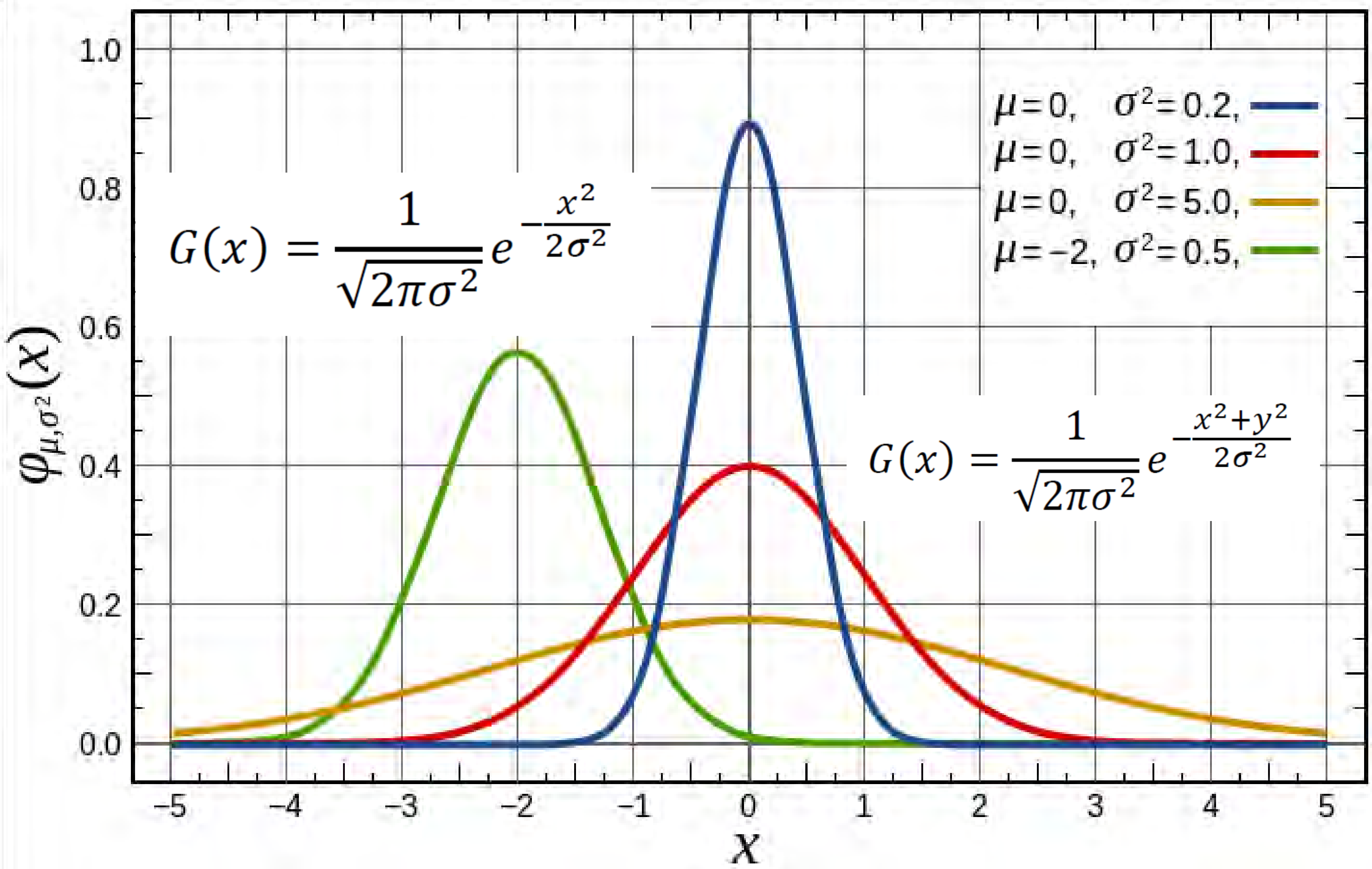
Intake-High Impact Assessment (Gaussian Model)

$$\sigma_y = A\,x^a \qquad A = 0{,}08\,(6\,m^{-0{,}3} + 1 - \ln \frac{H}{z_0}) \qquad a = 0.367\,(2{,}5 - m)$$

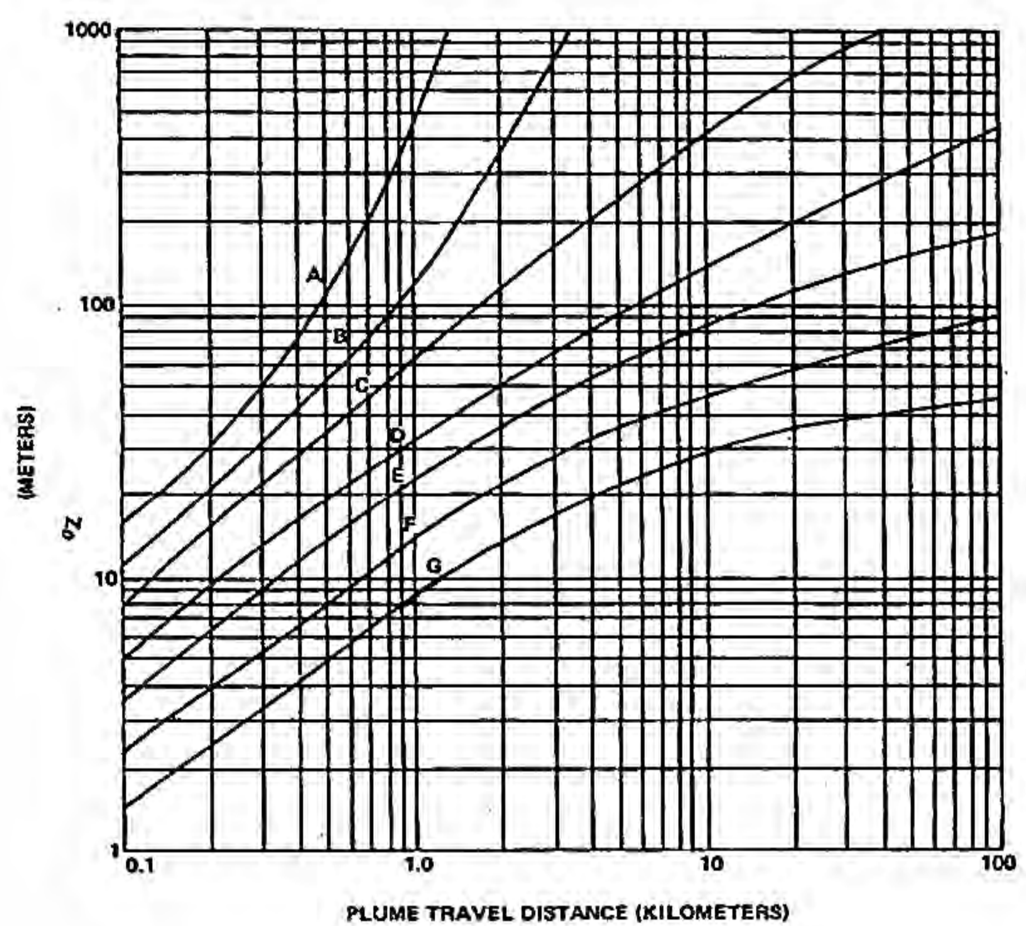
$$\sigma_z = B\,x^b \qquad B = 0{,}38\,m^{1.3}\,(8{,}7 - \ln \frac{H}{z_0}) \qquad b = 1{,}55\,\exp(-2{,}35\,m)$$

$$c_{od,xyz} = \frac{q_{od}}{2\pi \bar{u}\,\sigma_y \sigma_z} \exp\left[-\frac{y^2}{2\sigma_y^2}\right]\left\{\exp\left[-\frac{(z-H)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+H)^2}{2\sigma_z^2}\right]\right\}$$

Normal Gaussian Function



Height (σ_z) Coef. Vs. Distance for ATD 7 Classifications



Concentration in σ_z direction:

- Decreases with stability classes (A>F)
- Increases with downwind distance

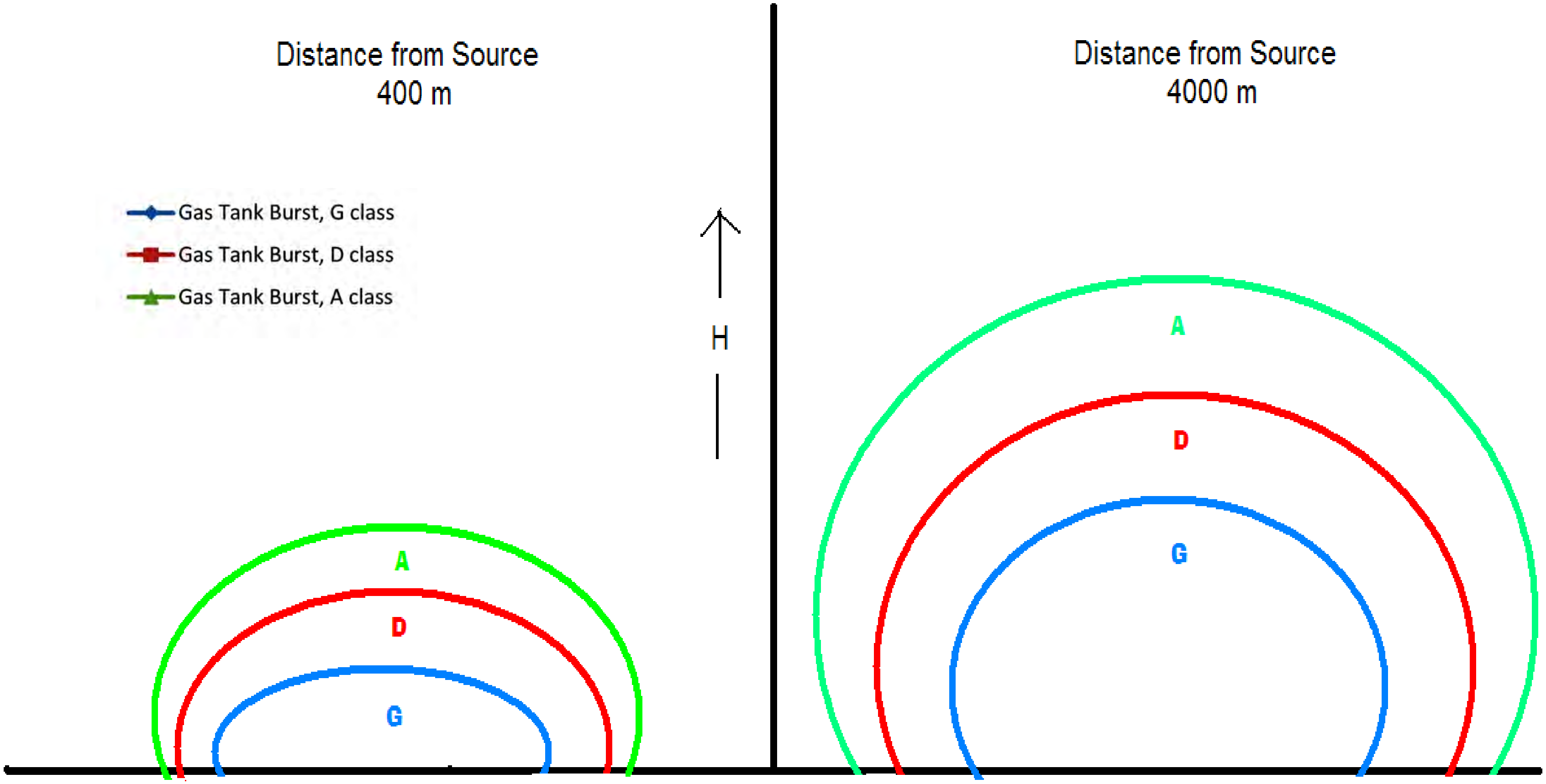
RG 1.145: Atmospheric dispersion models for potential accident consequence assessment at nuclear power plants (1982)

Specific σ_z Coefficients

Differences between σ_z used in HABIT and ALOHA codes

Stability Class	A (very unstable)			D (neutral)			G (very stable)		
Wind Speed (m/s)	1	3	5	1	3	5	1	3	5
HABIT σ_z									
Distance = 400 m	87	97	156	30	52	133	26	50	133
Distance = 4,000 m	1000	1000	1000	86	226	590	40	213	585
ALOHA σ_z									
Distance = 400 m	83	83	83	15	15	15	4	4	4
Distance = 4,000 m	1000	1000	1000	78	78	78	19	19	19

Dispersion Sizes at Specific ATD-Classes and Distances



Stylized Representation of Changing Puff Volume Limits with Stability Class

Summary

- HABIT v1.1 (1995) was reengineered from EXTRAN (1991) and can't run by Windows 7.
- HABIT v1.2 like its v1.1 and run by Windows 7.
- HABIT v2.0 (1995): D&S dense models added with radiological assessment functions.
- **HABIT v2.1 (2016): State of the Art and ready for ATD benchmarking.**

Where is HABIT Code?

- HABIT v1.1 (1995) is available at RSICC/ORNL).

- **Version 2.1 (2016) is available at RAMP.**


thank you
danke
рахмат
謝謝
spas
ngiyabonga
teşekkür ederim
Баярлалаа
mersi
kia ora
barka
welalin
tack
mahalo
tapadh leat
спасибо
faafetai lava
vinaka
спасибі
blagodaram
dank je
misaotra
matondo
paldies
grazzi
gracias
kiitos
dankie
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dankon
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asante
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obrigada
murakoze
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감사합니다
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