DEVELOPING AN ALBERTA FLARE CALPUFF MODEL

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Why do we need a Flare Model?

- Flares are different than stacks
- Current dispersion models are made for stacks with a constant exit height and constant exit diameter, but for a flare these change with the flow rate and wind
- All regulatory dispersion models can handle steady, continuous emissions from stacks
- Non-routine flares typically have predictions that exceed the AAAQO

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What is Non-Routine Flaring?

- Planned Flaring
  - Maintenance
    - well tests
    - vessel and pipeline blowdowns
  - Occur less than 720 hours/year
- Unplanned Flaring
  - Process upsets
  - Emergencies
  - Occur less than 88 hours/year

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Who is Funding?

- Alberta Upstream Petroleum Research Fund (AUPRF)
  - PTAC
    - Petroleum Technology Alliance Canada
  - CAPP
    - Canadian Association of Petroleum Producers

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Who is doing work?

- **Zelt Professional Services Inc.** (Brian Zelt)
  - Programming and documentation
- **Michael Zelensky (ERCB)**
  - Combustion equations
- **TRC (**Francoise Robe, David Strimaitis, Joe Scire)
  - CALPUFF and related code update
- **Z^2** We have worked together to produce:
  - ERCBflare
  - ERCBincin
  - ERCBH2S
  - Risk based criteria for non-routine flares

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Why do we need a Flare Model for CALPUFF?

- Non-routine sour gas flare SO_2 dispersion predictions often exceed Alberta Ambient Air Quality Objectives (AAAQO) using available "stack" models
  - Is the current modelling over simplified?
- CALPUFF can handle transient sources but not flares with parameters that change with the wind
- Risk based criteria for non-routine flaring requires realistic predictions
  - For example 99^{th} percentile prediction at a receptor must not exceed the AAAQO
- Air Quality Management Programs require realistic predictions of when and where exceedances occur

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Why …

- Current models do not realistically model flares
- Difficult to make non-routine flare SO_2 dispersion acceptable without expensive flare system changes
- Flare source parameters sensitivity to meteorological conditions and flaring rate needs to be accounted for
- Risk-based criteria require accurate predictions for all conditions
- Flaring Management Programs more effective if exceedances properly identified

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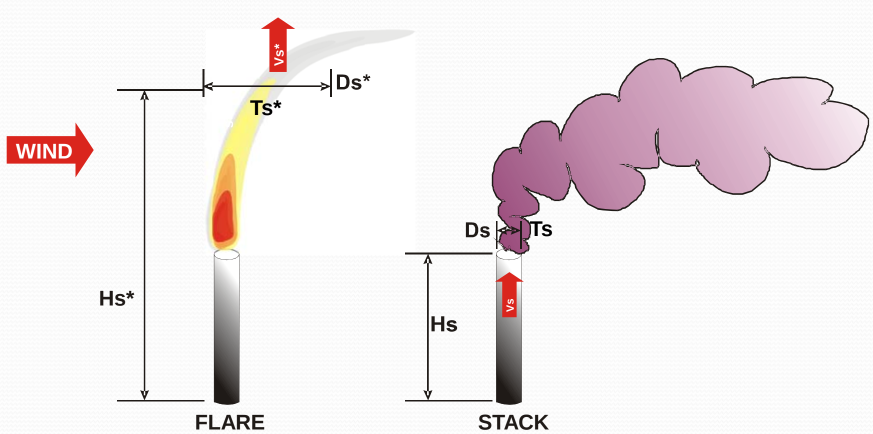
Source Parameters for Flares and Stacks



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Stack Exit Parameters Input to CALPUFF

CONSTANT IN TIME

1. Height (m)
2. Diameter (m)

VARIABLE IN TIME

3. Temperature (K)
4. Velocity (m/s)
5. Emission rate (g/s)

Flares use Pseudo-Parameters

- *Pseudo – supposed, but not real*
- Calculated to allow for combustion of flared gas
  - conserve energy (buoyancy) and momentum
  - varying degrees of simplifications used
- **VARIABLE IN TIME**
  1. Effective height of flame
  2. Pseudo-diameter
  3. Pseudo-temperature
  4. Pseudo-velocity
  5. Emission rate / Efficiency
  6. Location

ERCBflare.xls Pseudo-Parameters

- Combustion efficiency calculated from U of A correlations
- 25% of heat released lost through radiation
  (less than 75% of heat is released to plume rise)
- Buoyancy flux at site pressure and
  nearly constant with ambient temperature
- Temperature calculated at lower flammability limits with heat losses
- Pseudo-diameter and Pseudo-velocity calculated from Temperature, buoyancy and momentum flux
- Effective height and location uses Brzustowski flare model
  - Stack-tip downwash may occur at high wind speeds

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Brzustowski Flare Model

- Used in AP 5-21
- Determines vertical and horizontal position of flame
- Dependent on flared gas momentum,
  crosswind momentum and lower flammability limit
- Effective height changes with:
  - wind speed, ambient temperature, flaring rate and gas composition
- ERCBflare currently uses the average wind speed and temperature to determine an effective height used for all meteorological conditions

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How will predictions change?

- Based on β-ERCBflare with variable source parameters into ERCBSCREEN:
  - Predictions for wind speeds <3.5 m/s decrease
  - Predictions for wind speeds >3.5 m/s increase
  - Maximum parallel airflow prediction now occur at high wind speeds
  - Maximum complex terrain prediction often occur at low wind speeds, but depends on terrain

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How are we doing it?

- **ERCBflare** will be enhanced to:
  - Accept non-routine flaring inputs to define exponential blowdown
  - ~~Produce screening source parameters that vary with~~
    - ~~Meteorological Conditions~~
    - ~~Transient Flaring Rate~~
  - ~~Run 54 screening meteorological conditions~~
  - ~~Determine if screening predictions are acceptable~~
- ~~If screening not acceptable, then …~~

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How are we doing it?

- **ERCBflare** (basis) will be modified:
  - User interface
  - Method to retrieve MM5/CALMET meteorological file for site at stack-top
  - Method to produce ABFlare.DAT variable source file
- **CALPUFF** will be modified:
  - To read ABFlare.DAT to predict SO_2 dispersion from flares with source parameters that vary with
    - Meteorological conditions
    - Transient flaring rate
- **Post processor** of CALPUFF output risk based criteria

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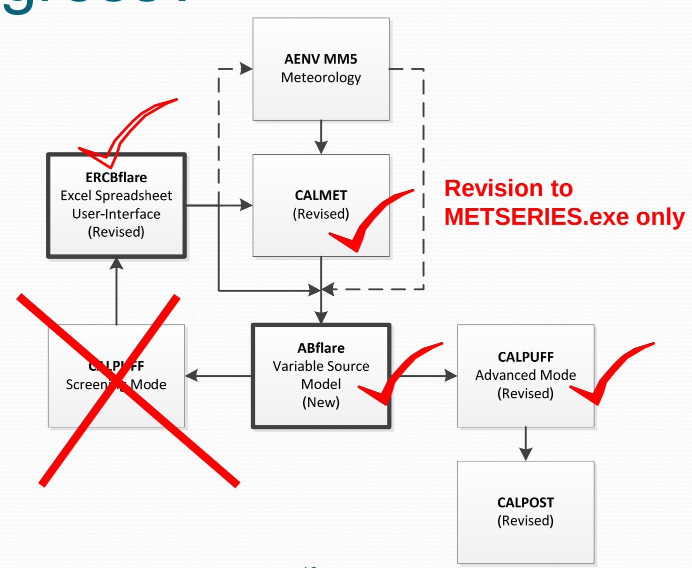
Progress?



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When

- Phase One - Code Development
  - January 1, 2011 to June 30, 2011
- Phase Two - Model Testing
  - July 1, 2011 to September 30, 2011 …?
- Phase Three – Documentation
  - October 1, 2011 to December 31, 2011 …?

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Blowdown Model

- Based upon an exponential pressure relief
- A portion of the volume remains in vessels
- Inputs are:
  - Initial pressure, temperature and gas composition, contained volume, orifice sizes
  - Initial flowrate and total volume released calculated
  - Fraction of volume released
  - Step duration
- Blowdown model creates a series of puffs to be modelled in CALPUFF

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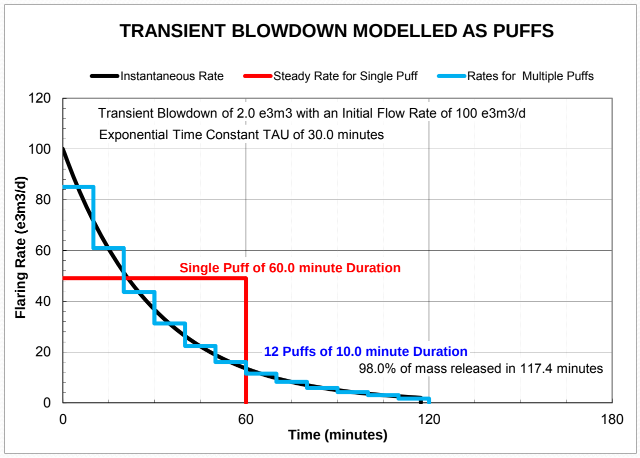
Blowdown Model



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Combustion Calculations

- Stand alone module for combustion calculations
- CALPUFF-like input file
- Reads meteorological time series at stack-top
- Allows for:
  - Blowdown inputs, user specified blowdown or user source
  - Meteorologically variable combustion or static meteorology
  - Emission rate of
    - Maximum SO_2 (100% conversion efficiency)
    - Actual SO_2 (conversion efficiency)
    - Uncombusted H_2S (conversion efficiency)

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Combustion Calculations

- Allows for…
  - Blowdown average raw and fuel gas composition
  - Variable H_2S gas blowdown composition is handled through user-blowdown input
  - Fuel gas ratio either static (Qmax) or proportional to blowdown
- Creates an VariableFlare.dat file(s) for CALPUFF

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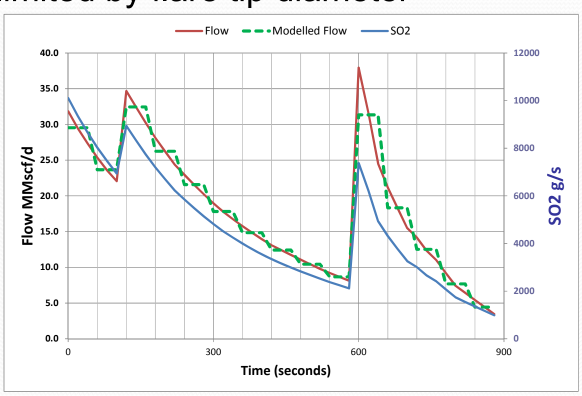
Example Application of ABFlare

- Facility blowdown with multiple vessels in 15 minutes
- Variable H2S depending upon vessel
- Flow limited by flare tip diameter



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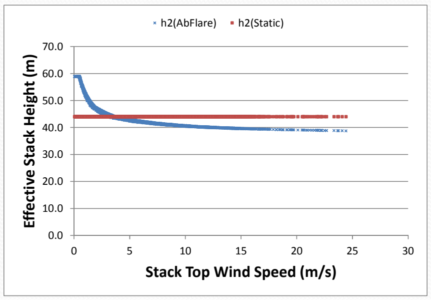
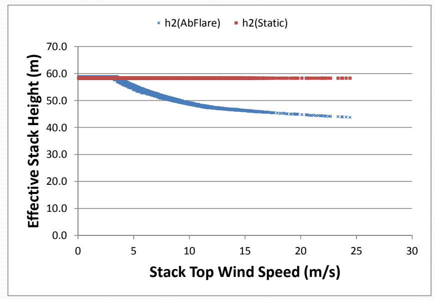
Effective Height *vs* Windspeed





Low Release Rate **High Release Rate**

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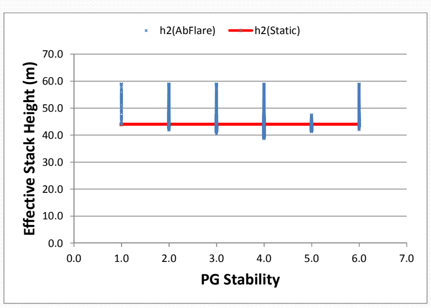
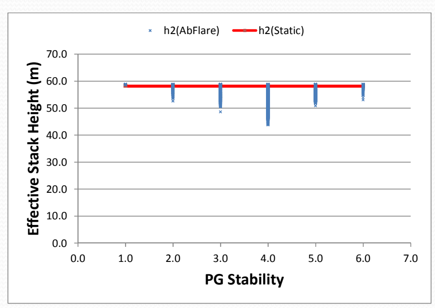
Effective Height *vs* Stability





Low Release Rate **High Release Rate**

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