Source Term Factors

DOE SCAPA STWG

What is Source Term

- Source Term (ST) is a way to describe how much material needs to be modeled for airborne transport in atmospheric dispersion modeling
- The process of determining source term is based on experimental data and is selected as a balance between realism and conservatism

What is the Source Term (Cont'd)

- The phrase "source term" can be confusing
- The full equation actually provides the "respirable source term for a release to the external environment"
- There are other "source terms",
  - For example, "airborne source term" can capture the amount of both respirable and non-respirable material released to the environment and subject to deposition
  - Airborne source term is often used to calculate the impact of released material deposited on the ground near the event site.

Source Term

Source Term = (MAR)(DR)(ARF)(RF)(LPF)

MAR = Material At Risk

DR = Damage Ratio

ARF = Airborne Release Fraction

RF = Respirable Fraction

LPF = Leak Path Factor

ST=(**MAR**)(DR)(ARF)(RF)(LPF)

Material At Risk (MAR)

- How much material is available to be damaged or released before we apply any other factors
- Examples:
  - May be the entire content of a tank
  - May be the entire inventory of a material in a warehouse
  - May be an entire truckload of material

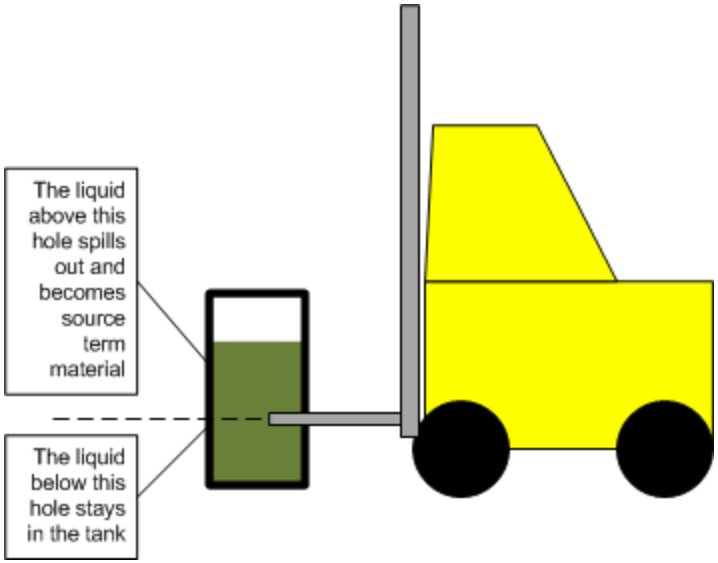
ST=(MAR)(DR)(ARF)(RF)(LPF)

Damage Ratio (DR)

- What fraction of the material is damaged by the event
- Physical Separation of containers might limit the amount released by any one event
- The event, packaging, and material properties all affect the damage ratio

Damage Ratio Examples

- A firecracker would not damage much of an anvil
- If a forklift tine punctures a tank of liquid, only the liquid above the hole will spill out



ST=(MAR)(DR)(**ARF**)(RF)(LPF)

Airborne Release Fraction (ARF)

- Within the damaged material, how much can go into the air versus being damaged in-place?
- Again, this is influenced by the event and the material properties
- If the material shatters into large shards but does not produce particulate that can be transported by the air, it has a very low ARF
- If the material is volatile or is already finely divided, it will have a relatively high ARF

ST=(MAR)(DR)(ARF)(**RF**)(LPF)

Respirable Fraction (RF)

- Of that airborne material, how much of it is finely divided enough to be inhaled?
- Some things like gases and vapors can all be inhaled
- People's bodies have ways to get rid of particulates that are coarser
- Very finely divided materials or very soluble materials can make their way past a person's natural defenses

ST=(MAR)(DR)(ARF)(RF)(LPF)

Leak Path Factor (LPF)

- How well does the building trap, confine or contain the potential airborne hazardous material?
- Buildings can provide filtration
- Buildings can reduce the effect of winds that would cause material to go airborne
- Some buildings may have features like exhaust fans that reduce the exposure of the personnel inside but deliberately release more material outside

Special Filters in Leak Paths

- Some buildings will have very deliberately designed filtration systems that greatly reduce the Leak Path Factor
- Some of the best are High Efficiency Particulate Air (HEPA) filter systems
- HEPA filters are at least 99.97% efficient in removing a particular size of very small particle

Respirable Release Fraction (RRF)

RRF=(ARF)(RF)

ST=(MAR)(DR)(**RRF**)(LPF)

- RRF is simply RF multiplied by ARF
- RRF is a shorthand way of keeping the other two closely related factors together in a quick-to-use manner

Release Fraction

Release Fraction= (DR)(ARF)(RF)(LPF)

Source Term = (MAR)(Release Fraction)

- Release Fraction is a term used in DOE-STD-1027
  - that, in turn, came from NRC in NUREG-1140
- Like Respirable Release Fraction, Release Fraction is a shorthand way of keeping the other factors together in a quick-to-use manner
- Be careful about the letters RF. They could mean Respirable Fraction or they could mean Release Fraction

Source Term Example

- Hypothetical warehouse
- Forklift carries two drums of finely-divided powdered hazardous material (500kg ea.).
- Turns corner too fast, one drum falls off.
- That drum breaks off the lid, spilling all contents.

Source Term Example (Cont'd.)

Source Term = (MAR)(DR)(ARF)(RF)(LPF)

MAR = 1000 kg

DR = one half (.5)

ARF = 10% (0.1)

RF = 10% (0.1)

LPF = 10% (0.1)

Source Term = (1000kg)(0.5)(0.1)(0.1)(0.1)

Source Term = 0.5kg

Airborne Release Rate (ARR)

- Another way to describe a source terms for longer lasting events
- This applies a per-unit-of-time aspect to the source term

Margins of Safety

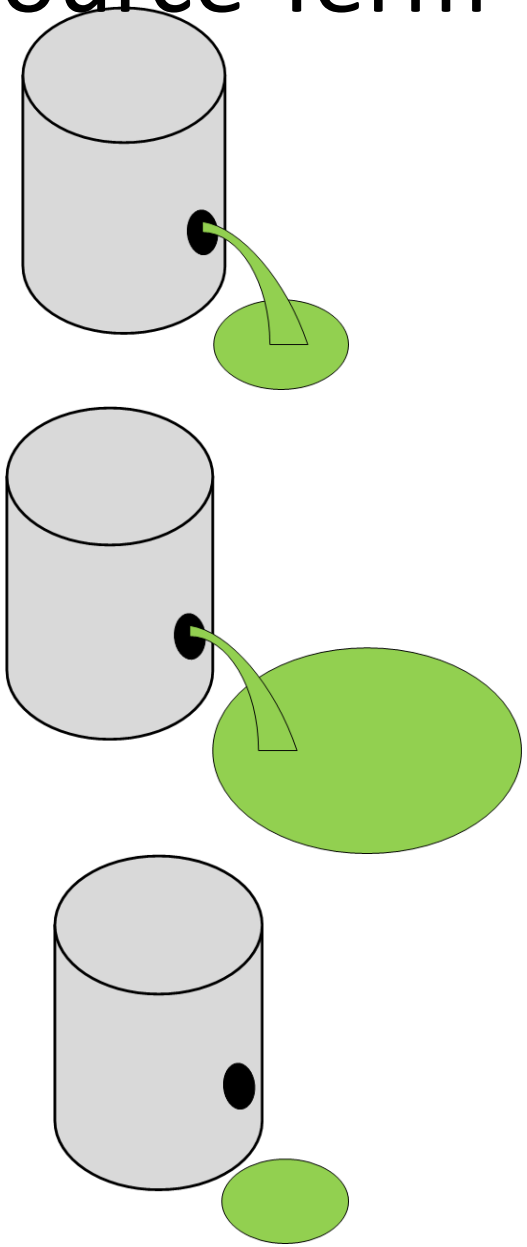
- Often each factor chosen is conservative and has some safety margin (sometimes very large) built in to accommodate uncertainty
- If all five factors a margin of safety ranging from 110% to 100:1, then you can easily end up with very exaggerated source term
- It is not uncommon to see <u>very</u> large margins of safety in each source term factor

Some Factors Change with Time

- For example, an explosion next to a tank of volatile liquid
- First there is a blast-dispersion and then there is an evaporating liquid dispersion (evaporation rates and explosive dispersal are whole other topics)
- This may require two or more sets of calculations but some computer models can do both with one set of user inputs

Another Time-Dependant Source Term Example

- A spill from a tank
- The size of the surface area of the spill pool affects the source term
- The evaporating pool grows as the spill continues
- The tank empties and the pool shrinks again



Some of the Factors Can Interrelate

- For example, the building that provides filtration drives down the leak path factor but what comes through the filtration may have a higher respirable fraction because the bigger non-respirable particles would filter out first

Sources for Source Term Factors

- Most of the sources for source term factors comes from published results of experiments
- Often the experiments do not match the exact scenario that we need to analyze but will be the “best fit” from the sources that can be found
- Often published source term factors come from just one or two measured results from very expensive one-time experiments . . . Thus the large safety factors at each step of the process
- DOE-HDBK-3010-94, Airborne Release Fraction Rates provides a compendium of summarized experimental data for source term factors

Units of Source Term

- Sometimes ST units are a total number of whatever is released
  - e.g., 100 lb, 100 Ci, or 20 kg
  - This is usually done for short lasting releases or instantaneous releases
- Sometimes ST units are expressed per unit of time
  - e.g., 20 lb/hr, 100 Ci/sec or 20 tons/year
  - This is usually done for continuous or long-lasting releases

Types of Units

- Chemicals are usually described in units of mass or weight (lb, kg, ton, etc.)
- Radiological materials may either be described in units of mass or in units of activity (Ci, Bq)
- Hazardous Biological materials may be described in units of mass or in Colony Forming Units (CFU's)

Different Material/Event Combinations Produce Different Factors for Each Part o f the Equation

- A solid piece of metal that falls or is struck will produce very little airborne material
- Same piece of metal in a fire and it might produce much more metal-oxide
- Blow the same piece of metal up with explosives and it will produce even more metal particulate
- Replace the piece of metal with a volatile liquid and all the numbers would be different again

Criticality Source Terms

- During a criticality, the source term is not the fuel material, the source term is the product of the reaction of the fuel material
- The type of fuel, the fuels configuration and the type of event that initiates the criticality all affect what and how much material is produced as criticality source term
- The types of products of reaction are generally described as noble gases or radioiodine

DOE-HDBK3010-94 Ch. 6

- Provides source term information for criticalities
- Scenarios include
  - Solutions (fissile materials dissolved in a liquid solvent)
  - Fully Moderated/Reflected* Solids (bulk metal or other solids like powders that undergo criticality when moderated or reflected)
  - Bare, Dry Solids (Bare and Dry Solids that may be reflected but have no moderation (i.e., not immersed in liquid)
  - Large Storage Arrays - Driving together by external forces large amounts of material (i.e., reactor fuel storage arrays)

**Moderation and reflection are things that happen to moving neutrons caused by the neutron's environment and they each influence how the neutrons affect fissile material in the area*

Some Scenario Factors Affect Consequence Like Source Term Does

- Examples:
  - Fires and explosions can “loft” the plume skyward and allow the plume to become more dilute (and less dangerous) as they come back down
  - Deposition is a way to describe how material can be deposited on surfaces where the plume travels
  - Chemistry: released materials can undergo chemical changes while they travel
  - Radiological Decay: some short-lived materials can change very quickly during a release