Performance-Based Hazardous Area Classification (HAC) for Releases of Flammable Liquids

APPROACHES, CONSIDERATIONS, + LIMITATIONS

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Christopher is a Director in the Industrial + Process Safety Group whose primary responsibilities include the safe handling of hazardous materials, and leading and facilitating Dust Hazard and Process Hazard Analyses and Hazardous Area Classification Studies. He has experience in both creating and auditing Process Safety Management programs and EHS management systems.

As a Certified Safety Professional, Chris has extensive knowledge in OSHA, EPA, and NFPA regulations. Additional recent project experience includes developing quantitative risk assessments, performing job hazard analyses and industrial hygiene sampling.

Agenda

01 HAC Fundamentals

02 Prescriptive HAC

03 Hand Calculation Performance-Based HAC

04 Computer Modeling Performance-Based HAC

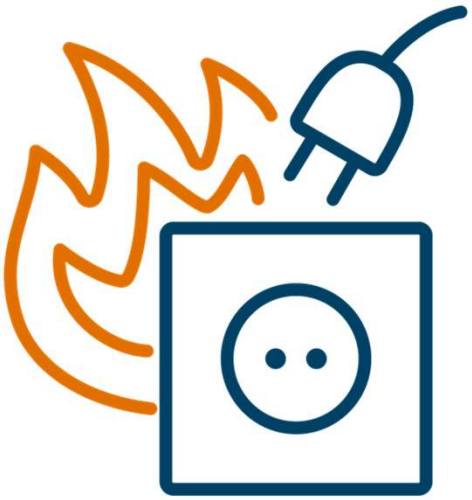
05 Key Takeaways

01 – HAC Fundamentals

HAC Fundamentals

HAC = **H**azardous **A**rea **C**lassification

- Practice of controlling ignition sources in areas with potential releases of flammable materials
  - **Flammable liquids *(and combustible liquids, if heated above flash point or atomized)***
  - Flammable gases
  - Combustible dusts
  - Combustible fibers/flyings
- Ignition sources
  - Electrical equipment and wiring
  - Heated surfaces
  - Hot work (e.g., welding, brazing, grinding, etc.)
  - Electrostatic discharge



HAC Fundamentals

- Governing code is NFPA 70: *National Electrical Code* (NEC) as referenced by:
  - IFC § 5003.9.4
  - NFPA 1 § 60.5.1.10.1
- NEC recognizes two (2) nomenclature systems for HAC
  - Division System (NEC § 500) – ***Most commonly used in the US***
  - Zone System (NEC § 505)
- NEC classifies hazardous area using four-pronged approach
  - **Class**: Type of flammable material present ***(Flammable Liquids = Class I)***
  - **Division or Zone**: Likelihood that flammable material is present
    - **Division 1 & Zone 0/1:** During normal operations
    - **Division 2 & Zone 2:** During abnormal operations
  - **Group**: Ignitability of material ***(Flammable Liquidsrange from Group A – D)***
  - **T-Code**: Maximum allowable equipment temperature around flammable

02 – Prescriptive HAC

Prescriptive HAC

NEC Informational Notes

- NEC prescribes HAC “shall” be performed but does not prescribe “how” to perform HAC
- NEC § 500.4 and NEC § 505.4 list “Informational Notes” for “how” to perform HAC (non-exhaustive list):
  - NFPA 30: *Flammable and Combustible Liquids Code*
  - NFPA 497: *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*
- **NFPA 497 is so commonly used that it is sometimes viewed as a “code” – but it is a recommended practice**

Prescriptive HAC

General Prescriptive HAC Approach

- Identify flammable material release points (normal, abnormal)
  - **Normal**: Open vessel, routinely operated sample/bleed valve, conservation vent, drum/tote filling, etc.
  - **Abnormal**: Pipe union, valve stem packing, equipment/ instrument fitting, pump/compressor seal, etc.
- Characterize area ventilation as “adequate” or “inadequate”
  - **Adequate**: 1 CFM/ft^2, 6 ACH, or other criterion to maintain vapor concentration < 25% of LFL
  - **Inadequate**: Ventilation that does not meet the “Adequate” definition
- Categorize relative magnitude of equipment size, flow rate, and pressure ***(in some cases)***
- Identify “closest” scenario/diagram (e.g., NFPA 497 Section 5.10)

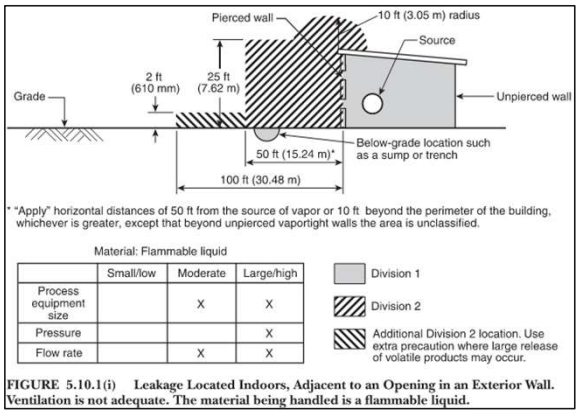


FIGURE 5.10.1(i) Leakage Located Indoors, Adjacent to an Opening in an Exterior Wall. Ventilation is not adequate. The material being handled is a flammable liquid.

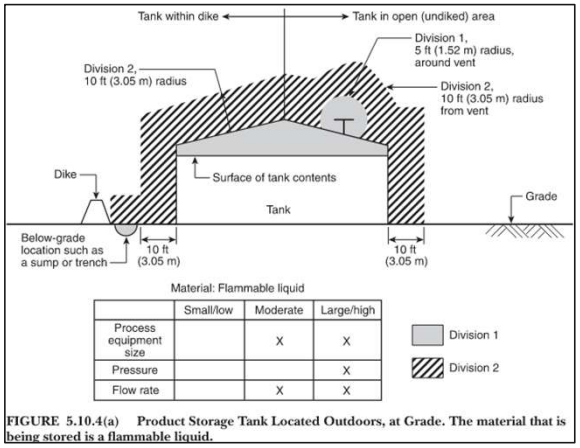


FIGURE 5.10.4(a) Product Storage Tank Located Outdoors, at Grade. The material that is being stored is a flammable liquid.

Prescriptive HAC

Potential Limitations

Non-Exhaustive Range of Assumed Operating + Release Conditions	+ May overestimate HAC boundaries for small-scale operations (i.e., laboratories, pilot plants, etc.) + May underestimate HAC boundaries (i.e., ultra high-pressure operations, large liquid releases, etc.)
Ventilation “Adequacy” Criteria (1 CFM/ft² or 6 ACH) only considers Area Footprint	+ Ability of ventilation to effectively dilute also depends on material properties and release conditions + Layout of supply inlets and exhaust intakes can greatly influence ventilation effectiveness
Application of “Sound Engineering Judgment” in refining HAC Boundary can Widely Vary	+ “…because all cases are not the same, sound engineering judgment is required.” (NFPA 497-2024 § 5.8.5)

03 – Hand Calculation Performance-Based HAC

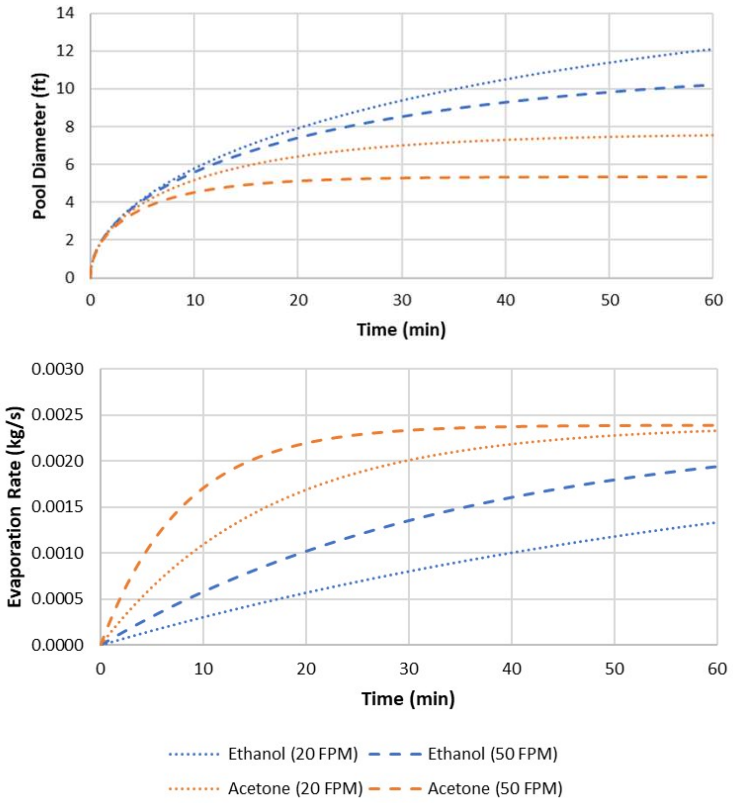
Hand Calculation Performance-Based HAC

- International Electrotechnical Commission (IEC) 60079-10-1: C*lassification of Areas – Explosive Gas Atmospheres* recognized as a hand calculation method for performance-based HAC
- ANSI/ISA US-adopted version of IEC 60079-10-1 referenced as “Informational Note” in NEC § 505.4
  - NFPA 2 also started referencing IEC 60079-10-1 for various HAC requirements in the 2022 edition
- IEC 60079-10-1 semi-quantifies interaction between hazardous release and ventilation conditions
  - Quantifies release rate based on material properties, release source, and process conditions
  - Quantifies ventilation conditions based on local air speed and anticipated uptime
- IEC 60079-10-1 usable for the following release types:
  - Flammable liquids
  - Compressed flammable gases
  - Liquefied flammable gases

Hand Calculation Performance-Based HAC

Flammable Liquid HAC Indoor Release Example

- Indoor liquid leak from valve stem packing ***(unconfined 3-gal spill over 60 mins)***
  - **Liquids** = Ethanol and Acetone
  - **Hole Size** = 0.25 mm^2
  - **System Pressure** = 15 psig
  - **Release & Ambient Temperature** = 77°F
  - **Local Air Speeds** = 20 FPM and 50 FPM



Hand Calculation Performance-Based HAC

Flammable Liquid HAC Indoor Release Example

HAC Summary Table (IEC 60079-10-1 Methodology)

Liquid	Hole Size	System Pressure	System & Ambient Temperature	Local Air Speed	HAC After 5 Minutes	HAC After 15 minutes
Ethanol	0.25 mm^2	15 psig	77°F	**20 FPM**	**Unclassified**	**Class I, Division 2**
Ethanol	0.25 mm^2	15 psig	77°F	**50 FPM**	**Unclassified**	**Class I, Division 2**
Acetone	0.25 mm^2	15 psig	77°F	**20 FPM**	**Class I, Division 2**	**Class I, Division 2**
Acetone	0.25 mm^2	15 psig	77°F	**50 FPM**	**Class I, Division 2**	**Class I, Division 2**

NOTE: Application of IEC 60079-10-1 in determining physical extent of classified areas (e.g., 15 ft) is relatively limited for indoor release scenarios, and deferring back to prescriptive methods is common.

Hand Calculation Performance-Based HAC

Flammable Liquid HAC Potential Recommendations

- + Limit potential pool size
  - − Secondary containment and/or drainage
  - − Caps/plugs/locks for valves open to atmosphere
  - − Leak detection and process shutoff (requires robust supervision if not automated)
  - − Splash guards around high-pressure leak points (limits spray distance and controls misting)
- + Increase air velocity in release area
  - − Increase ventilation rate
  - − Improve ventilation layout to increase local air velocity around release source
  - − Implement local exhaust ventilation for open systems

04 – Computer Modeling Performance-Based HAC

Computer Modeling Performance-Based HAC

- Computer modeling offers wider range of performance-based HAC options than hand calculations
  - Comes at increased cost, time, and information required
- Free-Field Empirical Modeling
  - Employs empirical correlations validated against experimental data
  - Models gas/vapor dispersion, fires, and explosions in **outdoor** release scenarios
  - Does **not** consider equipment/infrastructure layout or other obstructions
- Computational Fluid Dynamics (CFD) Modeling
  - Advanced numerical analysis of Navier-Stokes equations
  - Models gas/vapor dispersion in complex 3D geometries
    - 3D equipment and infrastructure models must be provided
    - 3D LIDAR scans of areas can be performed if as-built models are not already available
  - CFD Models can take ***days*** to ***weeks*** to resolve depending on complexity

05 – Key Takeaways

Key Takeaways

HAC Technique	Pros	Cons
Prescriptive	Fastest/cheapest option and widespread AHJ understanding	Non-exhaustive representative scenarios and potential for overestimate/underestimation
IEC 60079-10-1	Cheapest performance-based option and works well for outdoor releases	Limited applicability for indoor releases
Free-Field Empirical Modeling	More rigorous characterization of outdoor releases than IEC 60079-10-1	Not applicable for indoor releases or for complex outdoor 3D geometries
CFD Modeling	Most rigorous approach and considers complex 3D geometries	Most time-intensive, expensive, and information-intensive method

Questions?

Thank You

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