Protective Construction Design Criteria for HD 1.3

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CI7, Explosion Effects and Consequences

Overview

- **Discuss the complexity of HD 1.3 system reactions**
- **Consider the limitations of existing HD 1.3 Protective Construction (PC) design criteria**
- **Discuss the utility of NFPA fire rating system for PC applications**
- **Design considerations for HD 1.3 thermal effects across penetrations in DoD operating cells**

- **Applicable explosives safety standards for storage and operations defined in:**
  - **DoD Manual 6055.09-M, "DoD Ammunition and Explosives Safety Standards"**
    - Manage risks with DoD-titled ammunitions and explosives (AE) by providing protection criteria to minimize serious injury, loss of life, and damage to property
  - **Hazard Class/Division (HD) 1.3 covers broad range of AE**
    - Grenades, gun propellants, large diameter rocket motors
    - Although HD 1.3 systems are known as a predominantly mass fire hazard, the underlying science shows it is much more complex

- **Explosives safety protective construction requirements**
  - **UFC 3-340-02, "Structures to Resist the Effects of Accidental Explosions"**
    - Provides design criteria for HD 1.1 (mass detonating)
    - No design criteria for HD 1.3
- **Protective construction structure types**
  - **Shelters: protect acceptor system (assets and people)**
  - **Barriers**
  - **Containment structures: limit/prevent release of hazards of donor**
    - Most HD 1.3 PC falls into the category of containment
      - Complete containment (no structural failure, controlled release of hazards)
      - Partial containment (frangible surface failure, controlled release of hazards)
      - Need design load basis
        - Internal pressure histories
        - Fragments if high speed or massive
        - Thermals

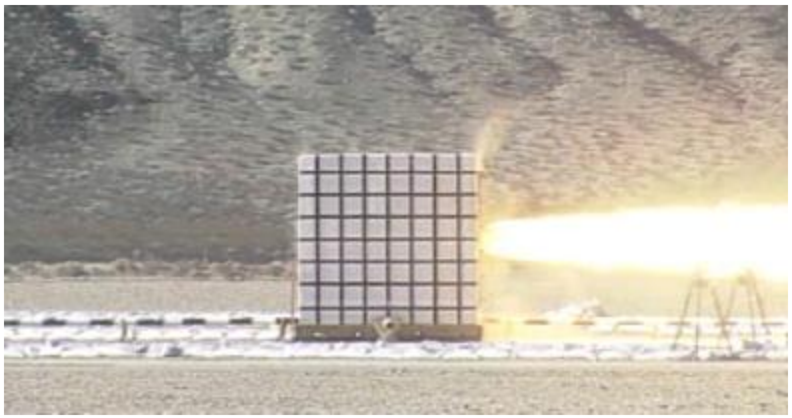
Reaction Effects of HD 1.3 Systems

- **Must consider HD 1.3 a system**
  - **Hazards potential/reaction effects dependencies**
    - Stimulus
      - Combustion/fire initiation, shock, etc
    - Sample properties
      - Chemistry
      - Geometry
      - Physical condition
    - Environment
      - Confinement
      - Condition
  - **Range of reaction responses**
    - No reaction, mild burning, deflagration, explosion, detonation
      - Possible effects: flames, fireball, heat flux, gas pressure, fragments, debris

- **Naval Air Warfare Center Weapons Division Kasun Testing**
  - **Combustion of M1 gun propellant in Kasun-type 2m cube reinforced concrete structure**
    - Choked flow condition occurs when
      - High loading density; Loading density = [weight of energetic] / [chamber volume]
      - Low vent area ratio; VAR = [vent area] / $[\text{chamber volume}]^{2/3}$
      - Occurs when internal pressure exceeds 2X atmospheric pressure
      - Leads to rapid pressure rise until structure bursts
        - Occurs over a matter of seconds (quasi-static structural response)
        - Large debris projected far distances
        - Untenable design scenario
    - For M1 gun propellant, based on testing and review of historical data
      - Choked flow avoided when loading density < 0.02 g/cc (1.24 lb/ft^3)
        - Quantitative relationship to vent ratio to be further developed
      - Choked flow occurred for loading density > 0.05 g/cc
      - For HD 1.1, UFC 3-340-02 recommends containment structure loading density < 0.15 lb/ft^3
        - Would similar guidance be appropriate/possible for HD 1.3?

Reaction Effects of HD 1.3 Systems

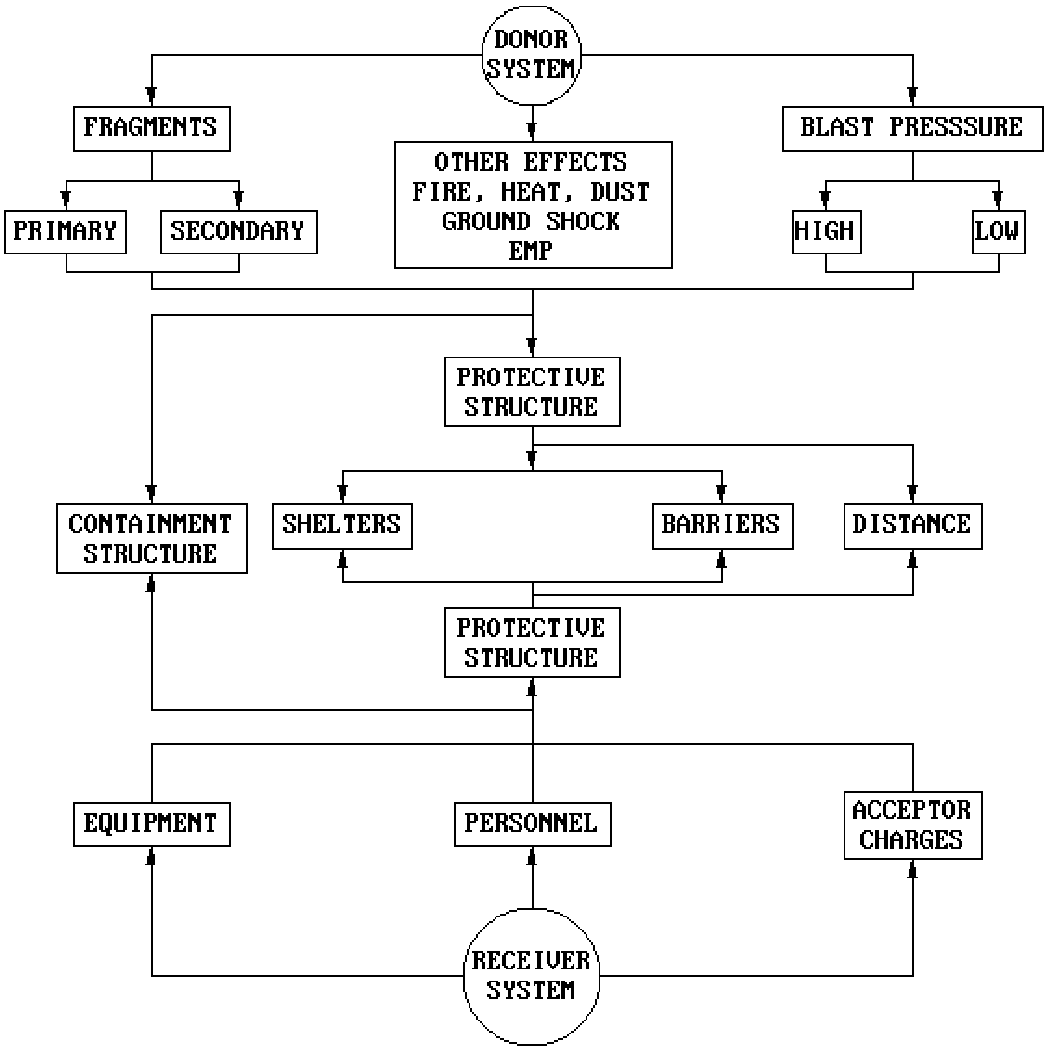
- **NAWCWD Kasun Test 2 (@ T = 1.5, 2, & 17s)**



- **Existing guidance/design tools are limited**
  - **UFC 3-340-02 provides no HD 1.3 design criteria**
  - **USACE HNDED-CS-93-7 Design Guide for HD 1.3 PC**
    - Simple procedures to determine fireball volume and gas pressures
    - Does not quantitatively account for confinement
      - Confinement can increase reaction violence (fireball volume, rate of pressurization)
      - Results in overly conservative design
  - **No approved explosion effects prediction tools available currently**
    - For HD 1.1, confined blast effects can be calculated using CONBLAST or BlastX computer programs.
      - None available for HD 1.3
  - **NFPA 495 Explosive Materials Code recommends a process hazards analysis at all stages of lifecycle**
    - f(stimulus, sample, environment)

Protective Construction

Figure 1-1 Explosive protective system



- **DoD Explosives Operating Rooms & HD 1.3**
  - **Necessary at different points along the munition's lifecycle**
  - **Complete or partial confinement structures**
    - Partial has at least one frangible surface (usually exterior wall or roof)
      - Per UFC 3-340-02, frangible surfaces fail at < 25 psf
    - Explosion products/gases must be vented regardless of level of containment
    - Can develop significant pressures if venting is low/ loading density is high
  - **Containment structure design considerations (pressure)**
    - Need rate of pressurization to develop p(t)
      - f(stimulus, sample, environment)
    - Complete containment – p(t) must be conservative if structural elements are being designed to resist; must avoid rupture, avoid high loading density
    - Partial containment – allow for frangible surface failures, use lighter construction

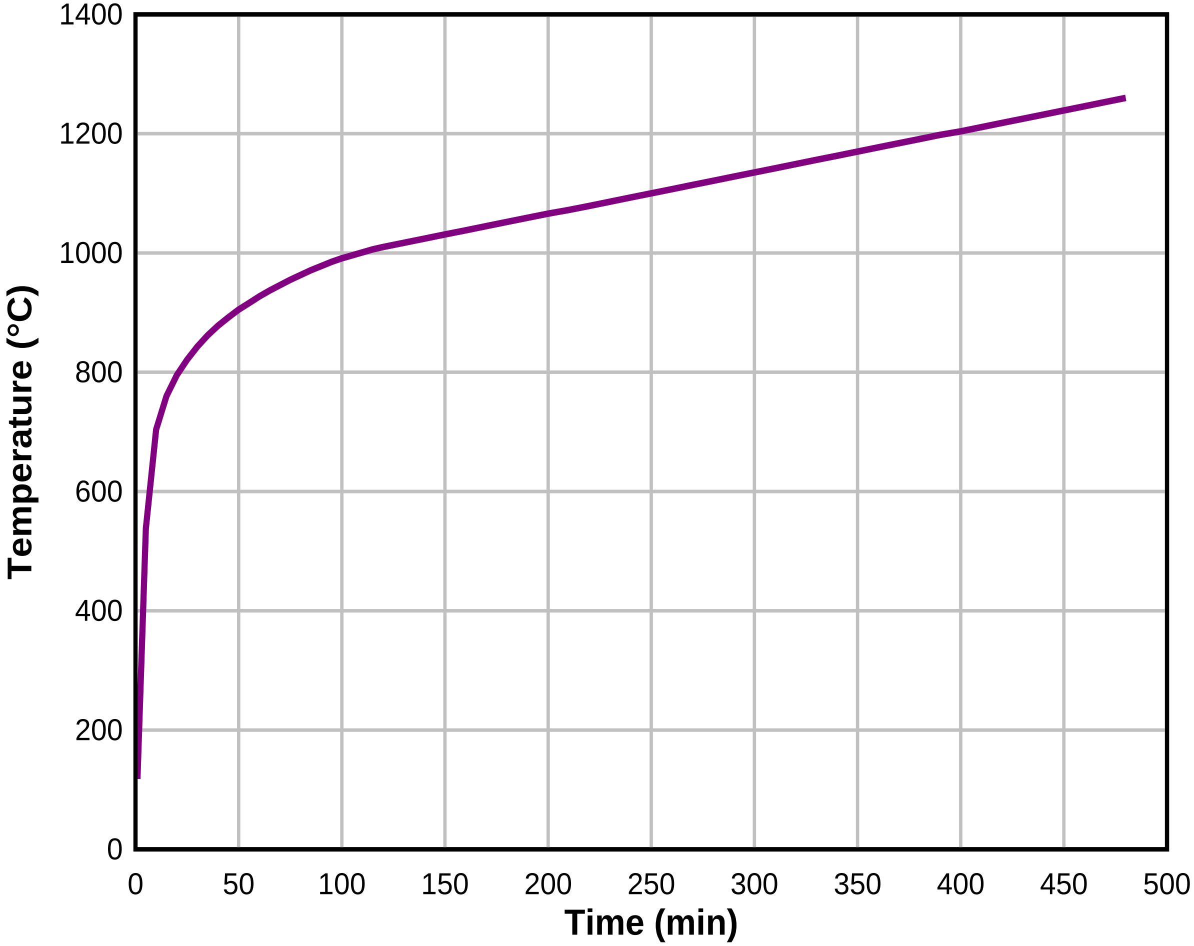
- **DoD Explosives Operating Rooms & HD 1.3**
  - **Containment structure design considerations (fire/thermal)**
    - General approach has been to determine volume of fireball, compare to chamber volume, provide vents as needed to channel out of chamber
    - Fireball volume f(stimulus, sample, environment)
  - **Multi-room structures**
    - Rooms requiring protection adjacent to operating rooms
      - How to prevent fire/thermal effects from passing through penetrations?

- **Fire/thermal effects across penetrations/openings in DoD operating rooms**
  - **NFPA/fire rated firestops**
    - NFPA 221 Standard on Firewalls requires the use of firestop systems/devices at all penetrations through firewalls; commercially available
      - Pipes, cables/cable trays, exhaust vents, wires, etc.

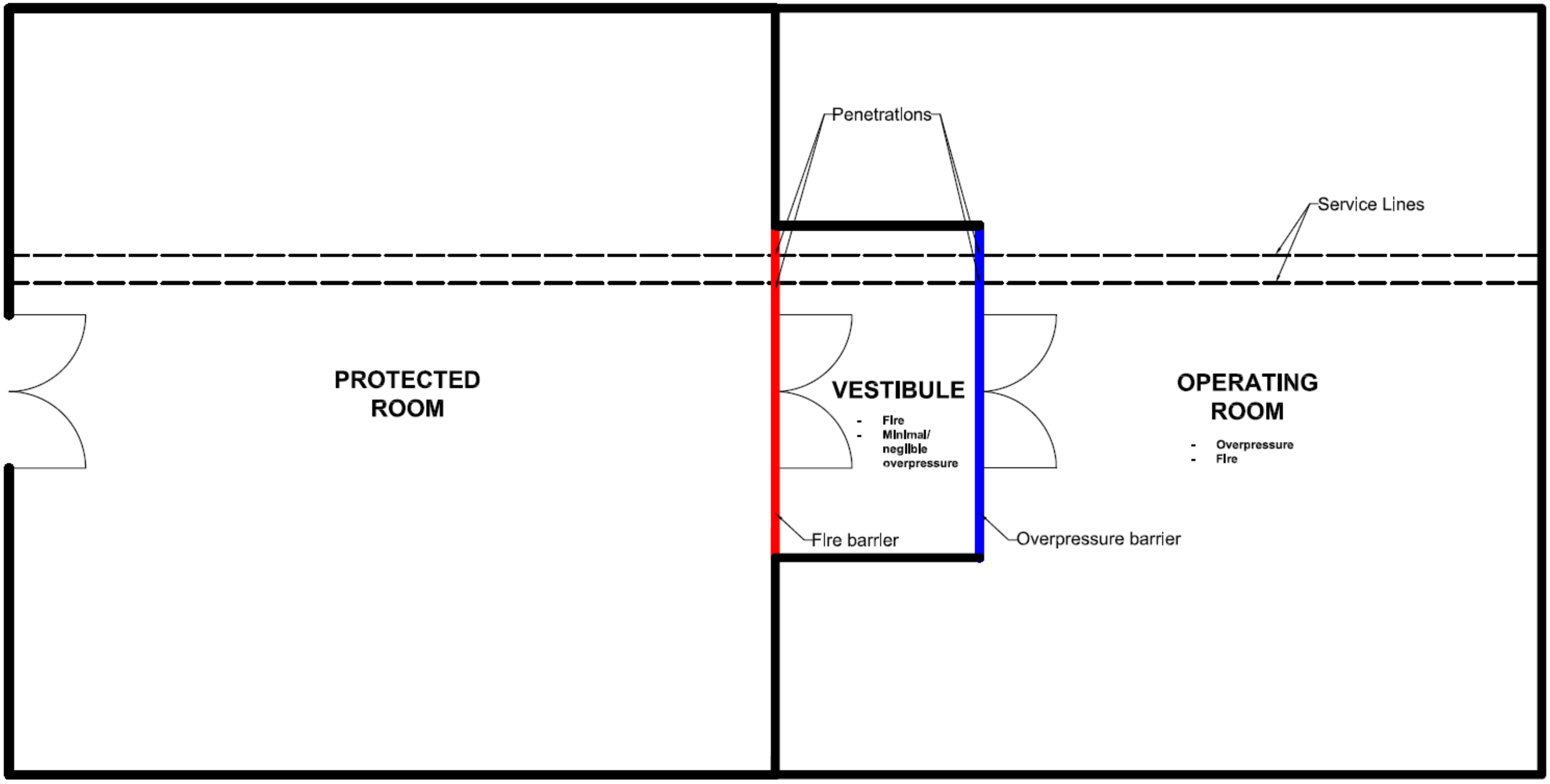
- **Fire/thermal effects across penetrations/openings in DoD operating rooms**
  - **NFPA 80 Standard for Fire Doors and Other Opening Protectives**
    - Fire doors, fire windows, fire curtains, elevator hoistways, etc.
  - **Are NFPA fire ratings suitable for HD 1.3 fire/thermal hazards?**
    - NFPA fire ratings are based on standard tests
      - Ex., NFPA 252 Standard Methods of Fire Tests of Fire Door Assemblies
        - Prescribes a standard Temperature-time (T-t) curve for furnace structure
        - Tests not conducted under positive pressure

• Fire/thermal effects across penetrations/openings in DoD operating rooms

- **Standard NFPA Temperature-time curve**
  - Based on 'severe' fire scenario
  - Max temps comparable to what can be expected in an HD 1.3 reaction
  - Rise time may be not be quick enough; thermal shock



- Fire/thermal effects across penetrations/openings in DoD operating rooms
  - Decouple hazards using Vestibules



Conclusions

- **UFC 3-340-02 provides no HD 1.3 design criteria, alternatively available guidance is limited and conservative, lots of development still needed**
- **HD 1.3 reaction violence is complex to predict**
  - **f(stimulus, sample, environment)**
- **Protective construction**
  - **Design basis should integrate process analysis**
  - **Engineering load prediction tools still needed!**
  - **Operating rooms**
    - Complete containment - maintain low loading density
    - Partial containment: lots of venting/frangible surfaces, lightweight
  - **NFPA fire rated devices/assemblies**
    - Effects of thermal shock need investigation
    - Could be useful in low pressure environments or with Vestibules