PITTSBURGH MINING RESEARCH DIVISION

BIP RA Stopping/Door System Research

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Refuge Alternative Partnership

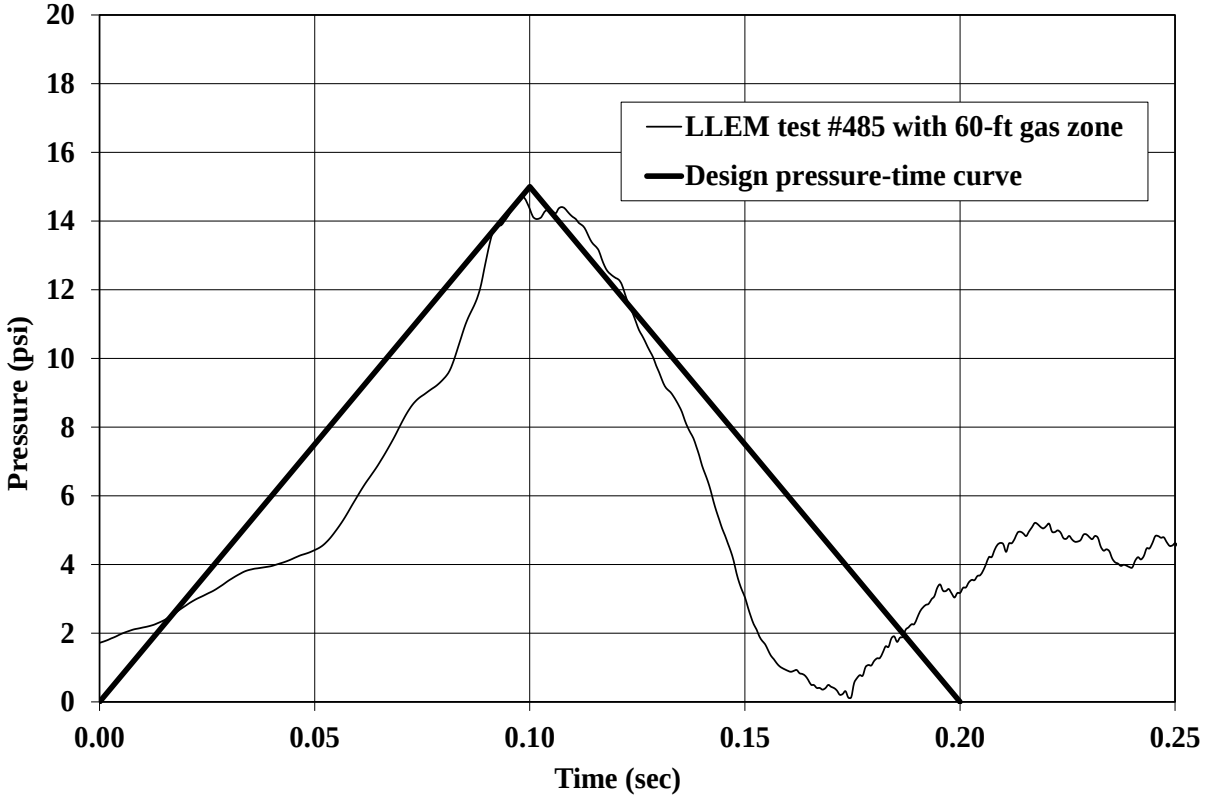
October 19, 2016

Pittsburgh, PA

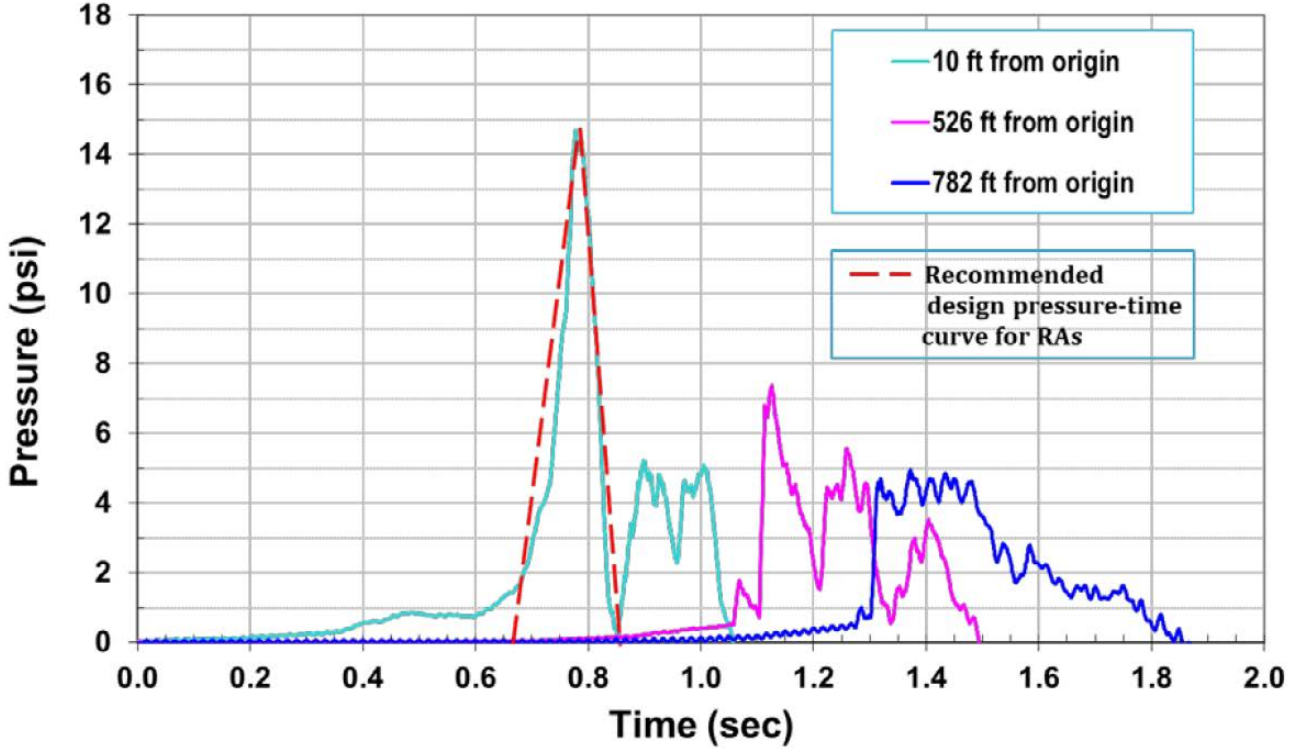
Outline

1. Introduction/background
2. Update
3. Planned Analysis/Test Methods
4. Summary

RA regulations specify a design load of 15-psi with a duration of 0.2 seconds



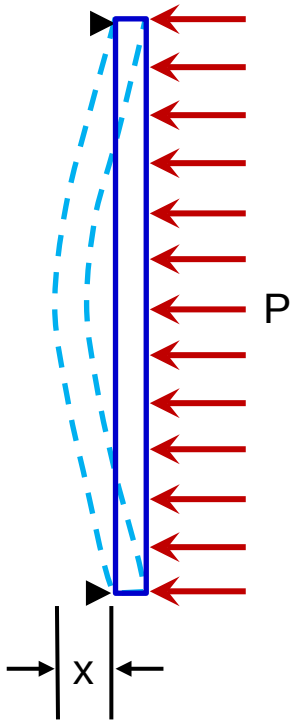
Actual blast pressure near RA may have a different peak pressure and “rise time” than design pressure

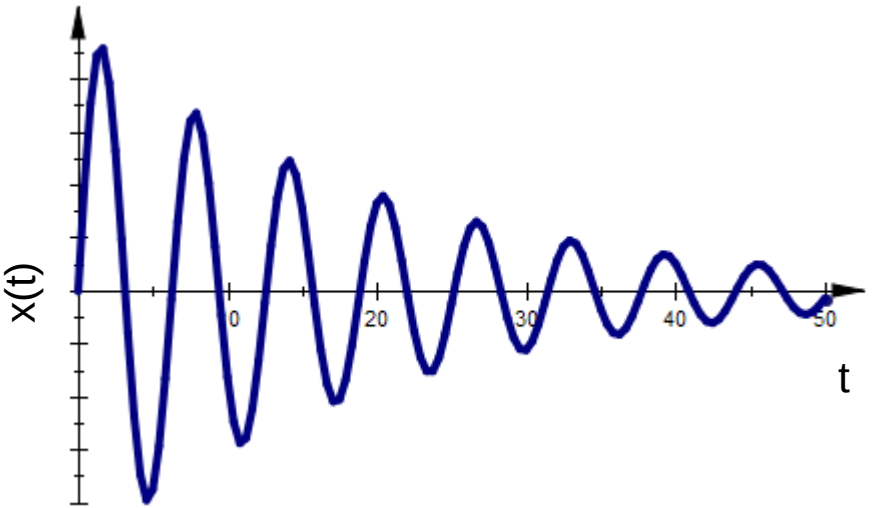


From RI 9698: Facilitating the Use of Built-in-place Refuge Alternatives in Mines

Response due to impulsive (high speed) loading is different than response due to quasi-static (slow speed) loading

- Dynamic response will include both positive and negative loading

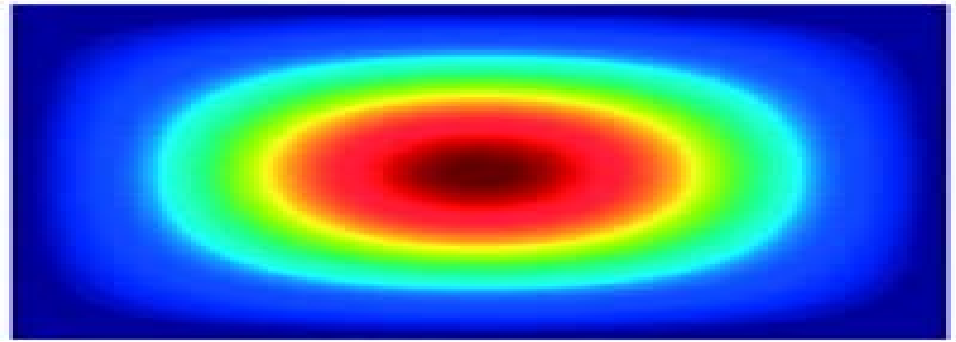




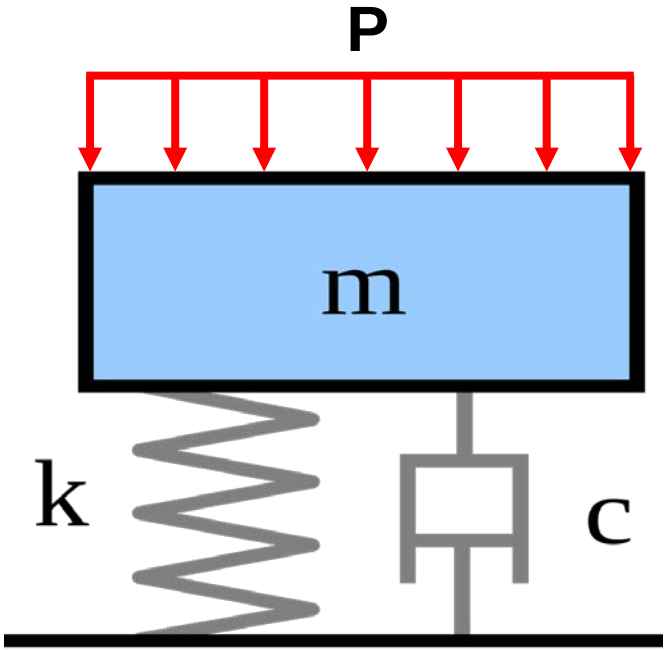
The stopping/door must not leak after being subjected to overpressure

- Stopping alone may not be a concern
- All door components must withstand dynamic pressure
  - Door “skin”
  - Latching mechanism
  - Hinges
  - Seal

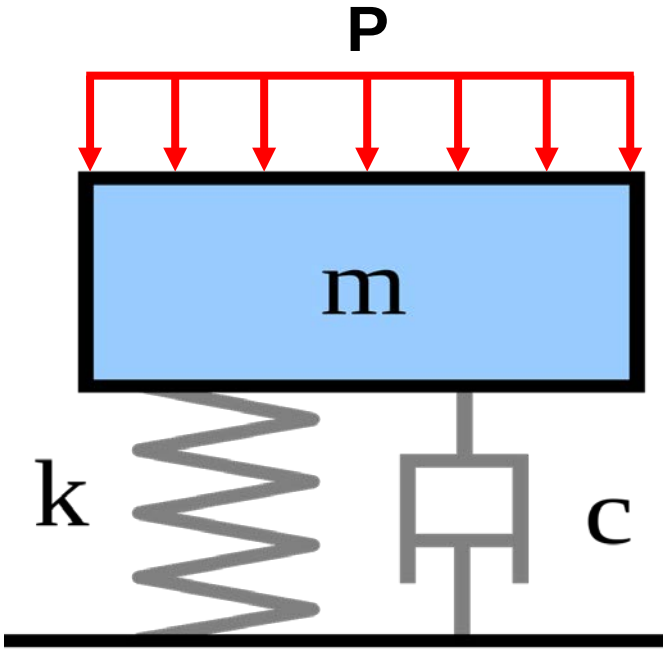
USACE Protective Design Center uses of single-degree-of-freedom analysis for design of blast-resistant structures



The structure is modeled a simple spring-mass-damper system; the response to a blast load can be solved using this simple model

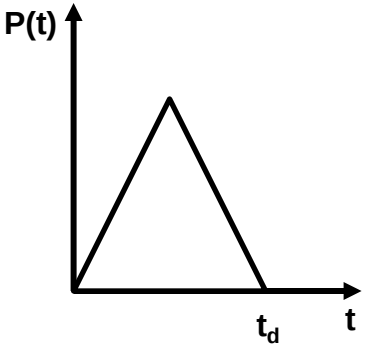


The stresses on the structure are then calculated based on the maximum deflection

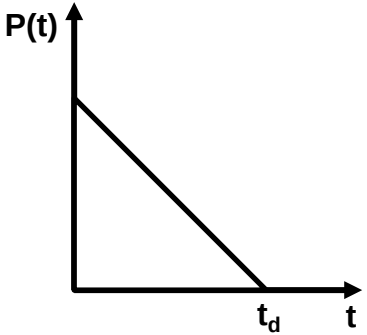


The response of a structure to a pulse depends on the shape and duration of the pulse, and the natural period of the structure

Dynamic Load Factor (DLF)[1]: The ratio of the dynamic deflection to the deflection which would have resulted from the static application of the load[1]



An isosceles pulse has a maximum DLF of 1.5

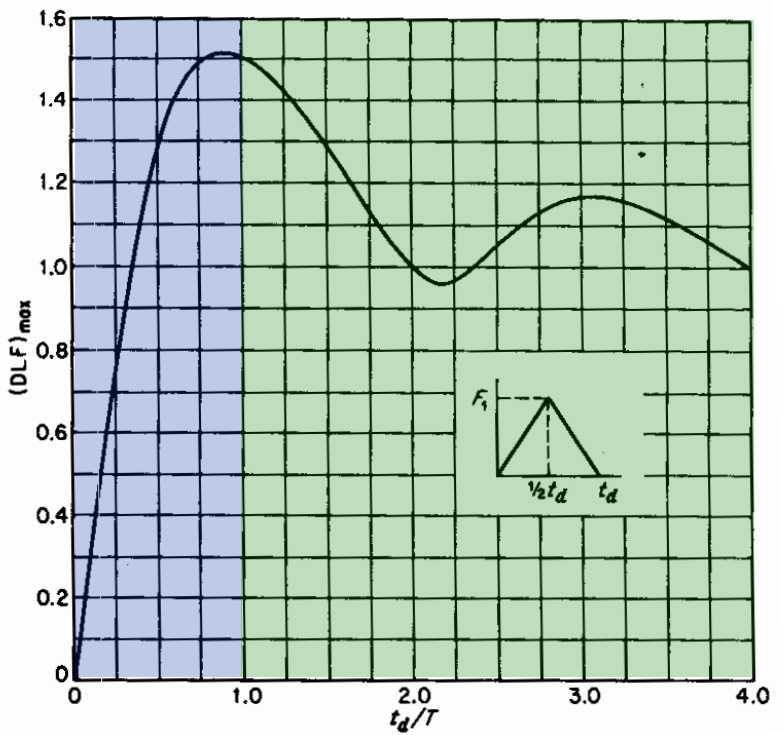


A right triangle pulse has a maximum DLF of 2.0

[1]Biggs, J.M. (1964). *Introduction to Structural Dynamics.* New York, NY: McGraw-Hill Book Company.

The response of a structure to a pulse depends on the shape and duration of the pulse, and the natural period of the structure

- Actual DLF depends on the ratio of pulse time to structure's natural period



$\frac{t_d}{T} < 1$ Structure is "slow" relative to pulse
(Structure has low stiffness relative to mass)

$\frac{t_d}{T} > 1$ Structure is "fast" relative to pulse
(Structure has high stiffness relative to mass)

Biggs, J.M. (1964). *Introduction to Structural Dynamics (pp. 47).* New York, NY: McGraw-Hill Book Company.

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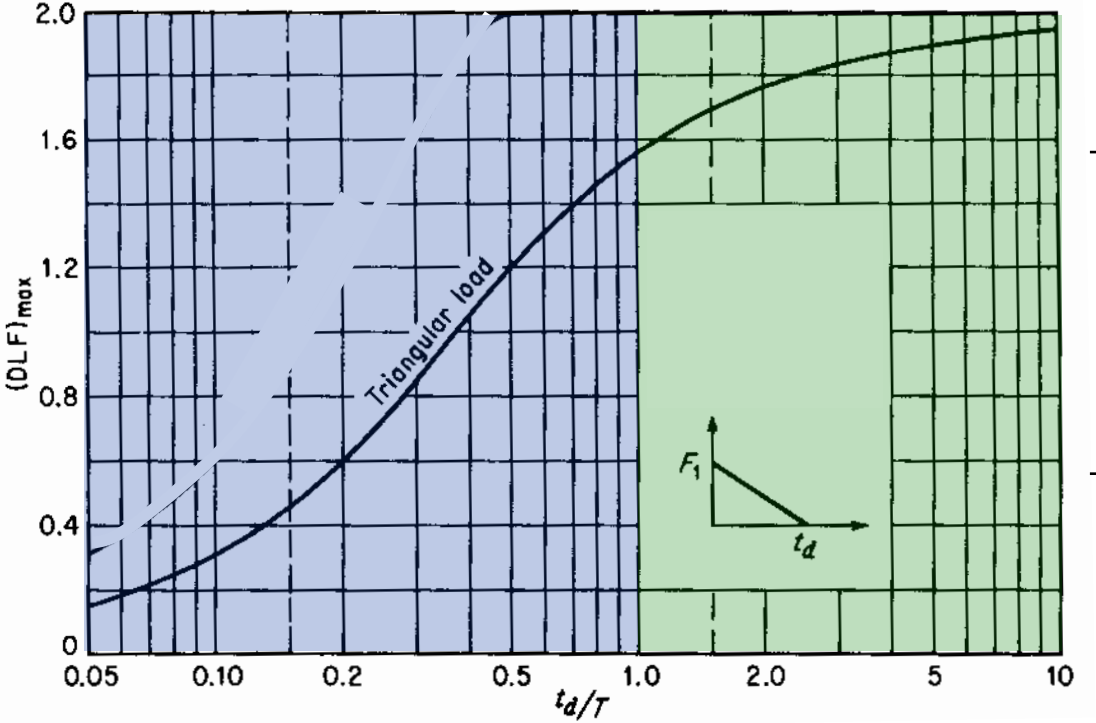

$\frac{t_d}{T} < 1$ Structure is "slow" relative to pulse (Structure has low stiffness relative to mass)

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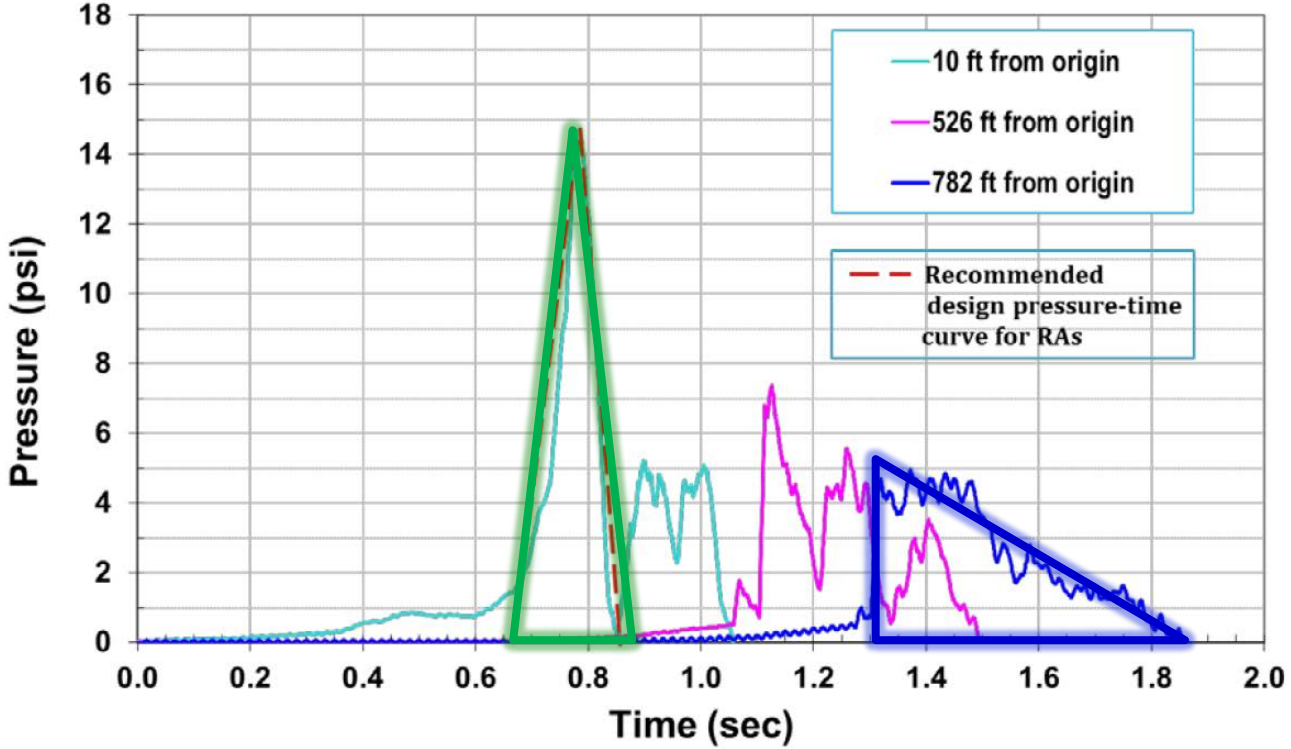
Biggs, J.M. (1964). *Introduction to Structural Dynamics (pp. 46).* New York, NY: McGraw-Hill Book Company.

The pressure-time curve near the blast is much different than the pressure time curve away from the blast



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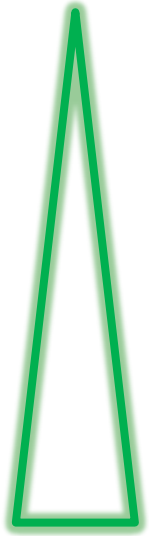
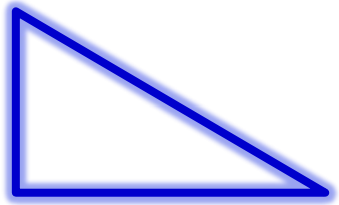


NEAR: 15-psi isosceles triangle with a duration of 200 ms



FAR: 5-psi right triangle with a duration of 600 ms

Prior NIOSH research is directly applicable to BIP RA stopping design, multiple internal and external (contract) efforts

CDC Workplace Safety and Health

RI 9659

REPORT OF INVESTIGATIONS/2002

Evaluation of Explosion-Resistant Seals, Stoppings, and Overcast for Ventilation Control in Underground Coal Mining

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

IC 9515
INFORMATION CIRCULAR/2009

Compendium of Structural Testing Data for 20-psi Coal Mine Seals

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

ERDC/GSL TR-14-31

Geotechnical and Structures Laboratory

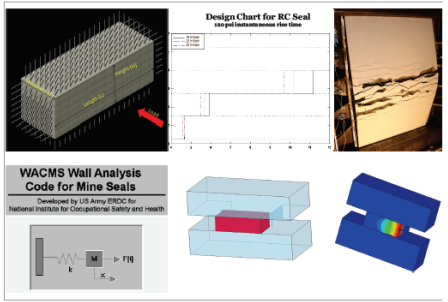
US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
INNOVATIVE SOLUTIONS for a safer, better world

Structural Analysis and Design of Seals for Coal Mine Safety

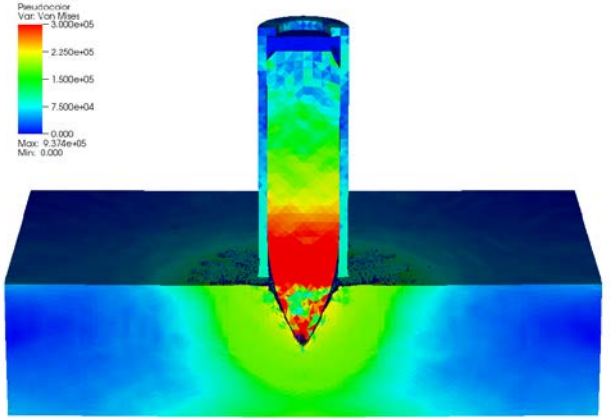
Gordon W. McMahon, Jose A. Rullán-Rodríguez, Matthew S. Holmer, Robert E. Walker, James L. O'Daniel, James R. Britt, and Richard K. Zipf

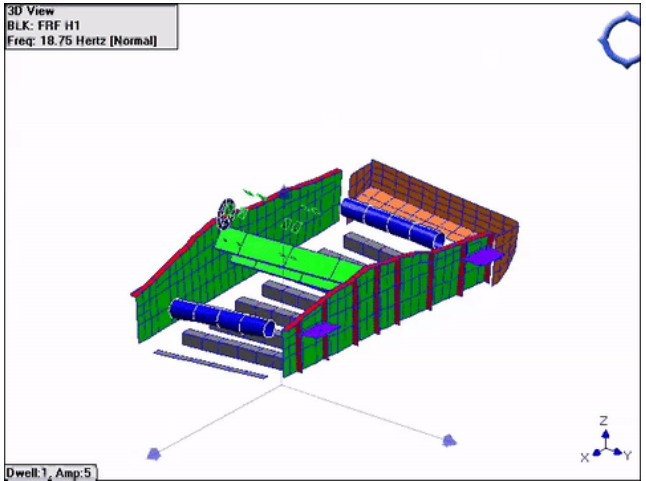
July 2014



Analysis of BIP RA stopping/door systems requires a complex approach

- Finite element (FE) analysis
  - Linear and non-linear static analysis
  - Transient, linear and non-linear dynamic analysis w/ pressure and impact load
- Model validation testing
  - Non-destructive strain gauge testing with static loading
  - Modal analysis to validate dynamic behavior





Analysis of BIP RA stopping/door systems requires a complex approach

- Static (possibly destructive) testing w/ 15-psi design curve
  - Hydrostatic test facility required
  - Test for leaks before and after
- Dynamic testing
  - Blast test facility required
  - Projectile test apparatus (cinder block launcher) required
  - Test for leaks before and after testing

In summary …

- Stopping/door must withstand design pressure and dynamic blast loads
  - Use US Army Corps of Engineers seal design procedure
- Door skin, hinges, and latching mechanisms must be examined
- Approach will utilize combination of FE analysis, FE model validation testing, design load testing, and dynamic testing
- ANSYS FE software and work station purchased
- Two people attended US Army Corps of Engineers Protective Design Center Blast Resistant Structural Design course in August 2016
- Prior NIOSH work directly applicable
- FE analysis pushed back to 2017

Questions?

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www.cdc.gov/niosh/mining