

Realistic Assessment of Hazard Division 1.3 Events

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Agenda

- Review of current QD methodology
- NATO AASTP-1 vs. US DOD 4145.26-M
- IBD comparisons from AASTP-1
- Accident and test review/comparison
- Practical implications

Current QD Methodology

- HD 1.1 and HD 1.3 based on NEWQD
- Primary hazard for HD 1.1
 - Detonation resulting in overpressure and fragmentation
 - All energetic material consumed in milliseconds
- Primary hazard for HD 1.3
 - Mass fire resulting in high levels of heat flux
 - Accidents and testing show that with adequate venting (no «choked flow»), propagation of fire takes minutes to hours
- Does weight-based QD provide a realistic assessment of the hazard from HD 1.3 materials?

Not a new
idea...

- Papers sponsored by the DDESB in 2010 and 2013 discuss the shortcomings of weight-based QD for HD 1.3 materials
- Both discuss the importance of choked flow
 - Proper construction with consideration for adequate venting to prevent an event similar to detonation
- Disparities in current weight-based QD calculation methods for HD 1.3 materials...

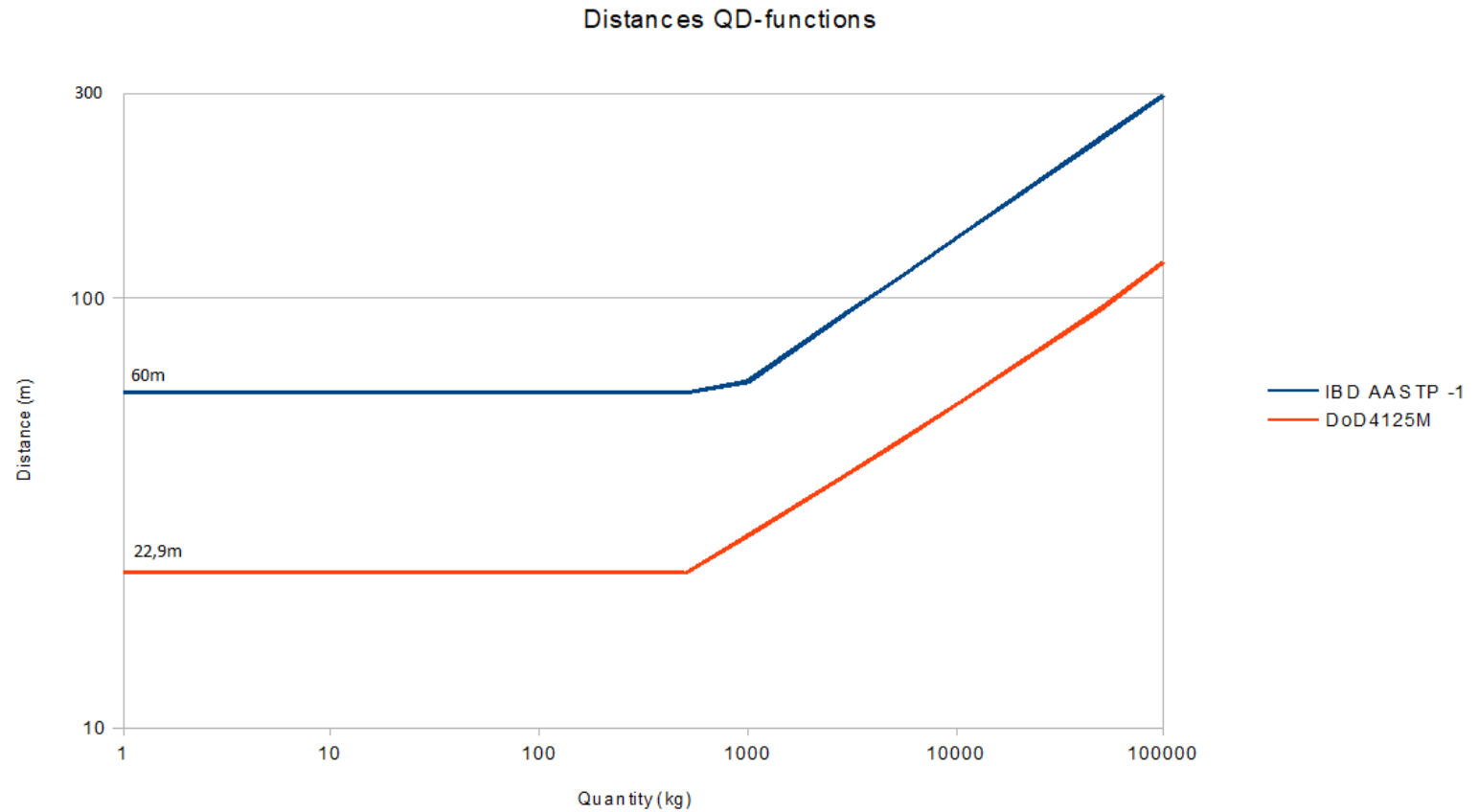
Weight-based
QD does not
account for...

- Initiation energy
- Reaction rate
- Article in which the HD 1.3 material is embedded
- Energy density of the substance
- Critical diameter or total mass of the substance
- Confinement of buildings or technical equipment due to inadequate venting area (choked flow)
- Cause of fatalities (burns to personnel)

Subcategories of
HD 1.3 within
AASTP-1

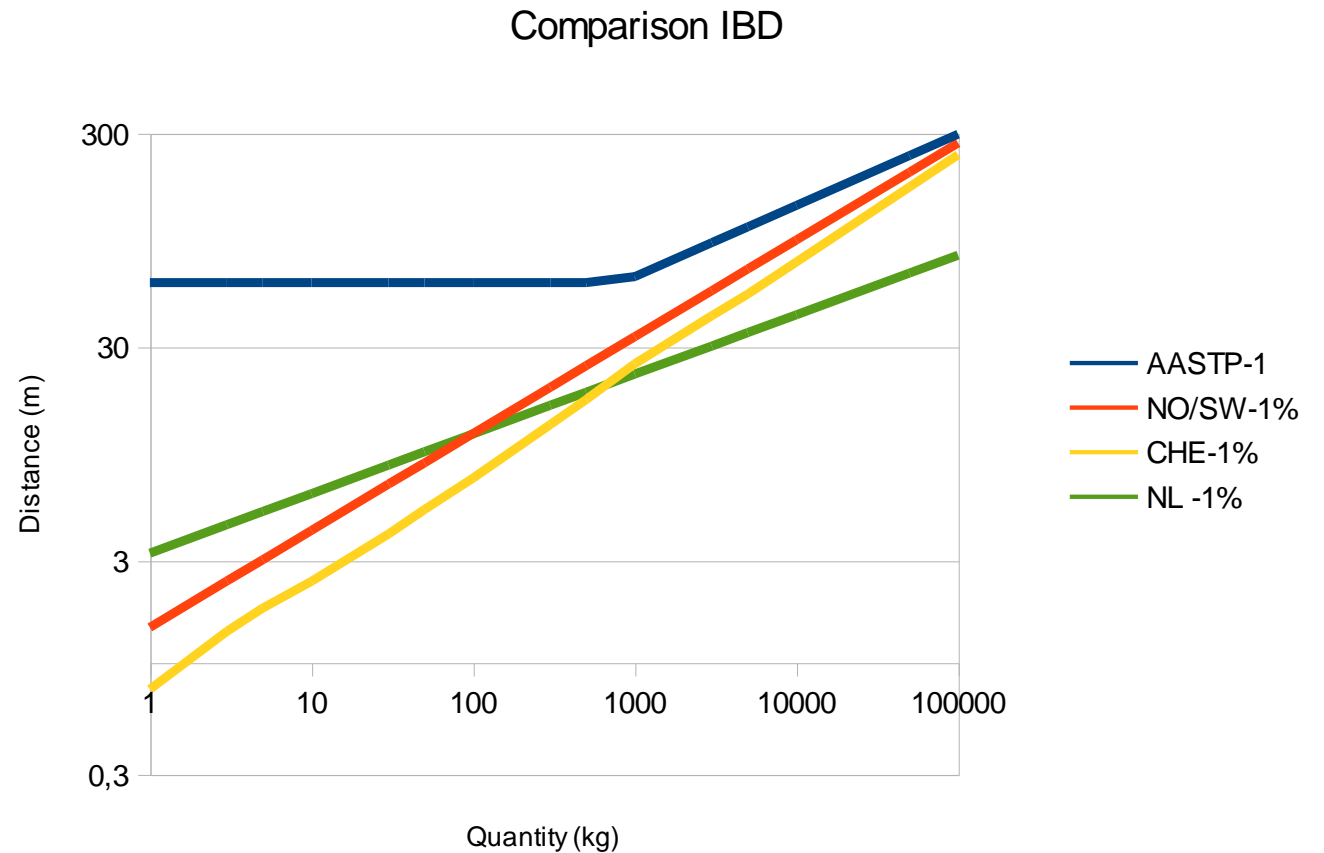
- HD 1.3.1: Explosives producing a mass fire effect
 - fireball with intense radiant heat
 - firebrands
 - some fragments where the firebrands may be massive fiery chunks of burning propellant
- HD 1.3.2: Items other than propellants that produce a moderate fire with moderate projections and firebrands
 - projections include fragments but these are less hazardous than those which characterize HD 1.2

AASTP-1 vs. DOD 4145.26-M



- Both are weight based (NEWQD)
- AASTP-1 uses cube root
- 4145.26-M uses exponential function
- AASTP-1: 41% longer QD

Disparities within AASTP-1



- Four models in AASTP-1 from NATO, Norway/Sweden, Switzerland, and the Netherlands
- Four different answers...

Accident

- 0.5 kg of black powder injured a Norwegian EOD officer due to failure to secure the fuze
 - Event occurred $\sim 0.7\text{m}$ (arms length) away
- Resulted in superficial burns to his face
- Is the 60m IBD required by AASTP-1 or the 22.9m IBD required by DOD 4145.26-M warranted based on this accident?
- Black powder has a relatively low energy density ($\sim 3\text{MJ/kg}$)
 - Weight-based QD does not account for the energy density of different HD 1.3 materials

Finnish Test

- Finnish Ministry of Defense tested behavior of HD 1.3 propellant in two 40-foot ISO containers
- Observed the flame jet and fireball resulting from ignition of propellant in one of the containers
- Measured the time for the contents of the second container to ignite

16 tons of
HD 1.3
propellant



Flame jet formation

Fireball formation



| NO-SW | SUI-Fast | SUI-Slow | NL | UK | US |
|-----------------------|---------------------|--------------------|-----------------------|-----------------------|----------------------|
| 88m | 101 | 25 | 32 | 23 | 48 |
| 3,8Q ^{0,325} | 4Q ^(1/3) | Q ^(1/3) | 0,45Q ^{0,44} | 1,7Q ^{0,268} | 1,5Q ^{0,36} |

Comparison of calculations for IBD and fireball diameter

- Fireball diameter prediction model calculations for 16 tons of propellant according to AASTP-4 Part II
- Again, four different answers...
- IBD for 16 tons of propellant
- Five different answers...most conservative model yields a QD 328% longer than the least conservative model

| NO-SW 1% lethality | SUI 1% lethality | NL 1% lethality | US DOD 4145.26-M | NATO AASTP-1 |
|--------------------|------------------|-----------------|------------------|--------------|
| 117m | 94m | 49m | 66m | 161m |

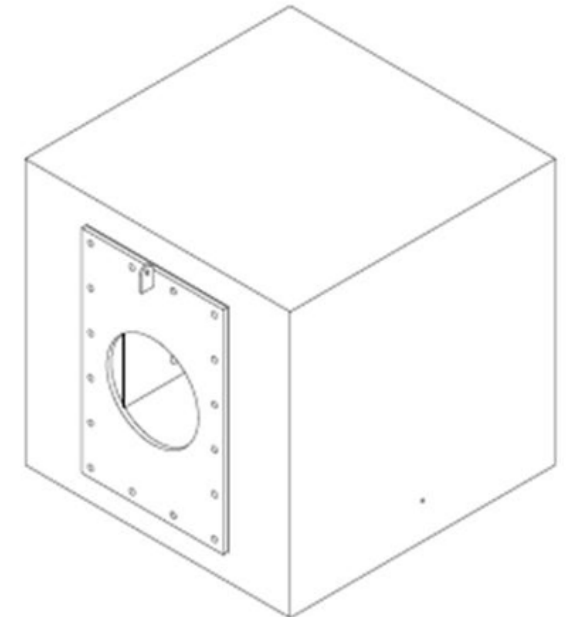
DDESB Choked flow tests

- Between 2011-2013, the DDESB conducted a series of tests to evaluate choked flow effects



Test Structure for Current Project

- Similar Construction to Kasun
 - Door modified to ensure seals and insertion of vent
 - 79 cm (vent area ratio – 0.06)
 - Unchoked Flow
 - 39 cm (vent area ratio – 0.01)
 - Choked Flow
- HD 1.3 Material
 - M1 gun propellant
 - NC
 - Large Surface Area
- 4 Tests
 - Loading Densities
 - 0.01 g/cc
 - 2 → Unchoked Flow
 - 0.05 g/cc
 - 2 → Choked Flow



Fireball/flame jet calculations from AASTP-4 Part II

| Test 1- Unchoked flow | Test 2- Unchoked flow | Test 3- Choked flow | Test 4- Choked flow |
|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| 130kg propellant | 533kg propellant | 120kg propellant | 503kg propellant |
| Predicted flame jet 21.5m | Predicted flame jet 32.2m | Predicted flame jet 21m | Predicted flame jet 31.5m |
| Predicted fireball* 3.8-20m | Predicted fireball* 7.1-33m | Predicted fireball* 3.7-20m | Predicted fireball* 7.0-32m |

Predicted fireball and flame jet from DDESB tests, (* the range of predicted fireball diameters represents different models given in AASTP-4 part II for different reaction rates)

- Choked flow, 503kg

DDESB Tests

- Rupture of structure



Realistic Hazard Assessment

- Rocket motor production facility at Nammo Raufoss AS
- Building 108 is sited for 9500kg HD 1.3
- IBD with weight-based QD is 55.5m
- Building is constructed with reinforced concrete walls/roof with a light venting wall to prevent choked flow
- Building is divided into numerous rooms/cells
 - Not possible for all 9500kg to ignite simultaneously

Building 108 layout

| BEGRENSNINGER | | | |
|--|---------------------|------------------------|--------------------------------|
| ROM NR: | ROMBESKRIVELSE | MAKS ANTALL OPERATØRER | MAKS DRIVSTOFF |
| 1 | TENNERE | 2 | MAKS 27 TENNER OG 0,5 Kg BKNO3 |
| 3 | LAGER TENNERE | • | MAKS 400 TENNERE OG 4 Kg BKNO3 |
| 4* | PAKKING | 4 | 1700 |
| 5* | MONTERING / PAKKING | 6 | 1900 |
| 6* | MELLOMLAGER | 4 | 2100 |
| 9* | LAKKERING | 2 | 650 |
| 10 | RØNTGEN | 2 | 700 |
| 11 | MELLOMLAGER | 2 | 2850 |
| 14 | MONTASJE | 4 | 3200, 30 stk TENNERE |
| 15 | MONTASJE | 4 | 1500, 30 stk TENNERE |
| 19 | LAGER TENNERE | • | MAKS 400 TENNERE |
| 20 | TEST BUNKER | • | 125 |
| - | FRYSERI | - | - |
| MERKNAD* | | TØRKEKAMMER / LAKK | 2 x (3) |
| * SAMLET MENGDEN DRIVSTOFF I BYGNINGEN SKAL IKKE OVERSTIGE 9,5 TONN. | | | |
| * VED KJØRING AV KALDE KOMPONENTER | | | |

MERKNAD:

- Tenner på tennlager skal ligge i godkjent emballasje med merking.

Utviklingsopdrag: Ved gjennomføring av slike oppdrag skal det ikke være annen produksjon eller kritt i rommet. Rekvistisjon og prosess skal være tilgjengelig!

Kruttvekt (kg kritt i produktet) se egen liste.

BESØKENDE:

Max 10 besøkende pr. rom. Det tas hensyn til aktuell produksjon, og om nødvendig må antallet være lavere.

"SPESIALTEGN"

- SAMLINGSPLASS
- ROM MED DRIVSTOFF
- PUNKTAVSUG
- ROM UTEN DRIVSTOFF
- OPERATØR

NAMMO AS
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 Street address: Enggata 31, NO-2800 Raufoss, Norway
 E-mail: info@nammo.com Telephone: +47 61 13 36 00 Telefax: +47 61 13 36 20

BYGNING NR. 108
MASKIN LAYOUT

| | | | | | | |
|---------------------------------|----------|--------|--------|----------------|------------|------|
| Format | Bygn.nr. | Gr.nr. | Målt | Tegnl. | 15.03.2017 | HCL |
| A3 | 108 | B | -1:200 | Kontrollert | | |
| Utløsende evd./anl/tek/råd/jng. | | | | Filnavn: | NAMMO/M108 | |
| | | | | Tegningsnummer | ML 07 | Rev. |
| | | | | | | - |

LØST-TEK

Light walls for venting in event of accident

Weight-based
QD vs. flame
jet and fireball
calculations

| | HD 1.3 NEWQD | Required IBD, 4145.26-M QD value | Calculated Flame Jet total length (length along ground: 2/3 total length) $L=5.49*NEQ^{0.28}$ | Calculated Fireball Diameter, $D_{FIRE}=3.97*(NEW*1.2)^{1/3}$ |
|---------|-----------------|---|---|---|
| Room 4 | 1700 | 32,8 | 44,1 (29,4) | 50,4 |
| Room 5 | 1900 | 33,9 | 45,5 (30,4) | 52,3 |
| Room 6 | 2100 | 35,0 | 46,8 (31,2) | 54,1 |
| Room 9 | 650 | 24,7 | 33,7 (22,5) | 36,6 |
| Room 10 | 700 | 25,2 | 34,4 (23,0) | 37,5 |
| Room 11 | 2800 | 38,1 | 50,7 (33,8) | 59,5 |
| Room 14 | 3200 | 39,7 | 52,7 (35,1) | 62,2 |
| Room 15 | 1500 | 31,6 | 42,6 (28,4) | 48,3 |
| Room 20 | 125 | 22,9 | 21,3 (14,2) | 21,1 |
| Room 23 | 1300 | 30,3 | 40,9 (27,3) | 46,1 |
| Total | 9500 | 55,6 | 71,4 (47,6) | 84,1 |

Flame jet/fireball > weight-based QD

Safety zones vs. weight-based QD

Explosives Safety
Submittal Drawing

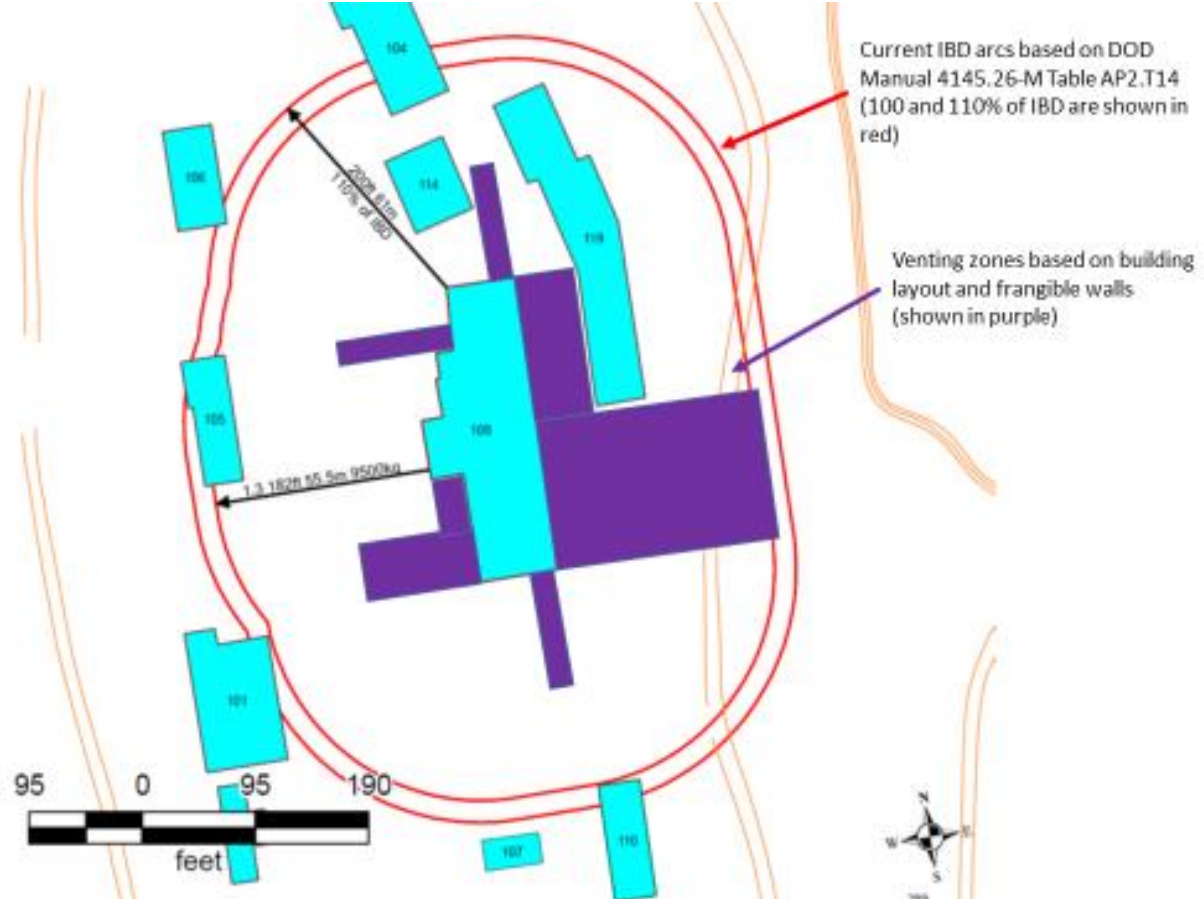
Facility Number:
108

Base/Location:
NARA

Analysis Date:
11/15/2017
DOD2013MAY13

Review Date:

PCS 
ES 
Hazardous Buildings (yellow) 
Parking Areas 
Buildings 
Rail (shown in blue) 



AASTP-1 comments on venting

- *«A building with marked asymmetry of construction such as an igloo or building with protective roof and walls, but with one relatively weak wall or a door, induces very directional effects from the flames and the projection of burning packages.»*
- Unfortunately, there is no specific quantitative guidance in the form of calculations

Conclusions

- Comparison of QD calculation methods shows high variability
- Engineering analysis should be conducted to produce a more realistic picture of the risk associated the quantity and type of HD 1.3 materials
- Sufficient ventilation to prevent choked flow and consideration for hazard zones associated with directional flame jets/fireballs and ejected burning material is critical
- Reliance purely on weight-based QD tables can lead to being both overly conservative in some cases and overconfidence in others
- Assessing the risks associated with HD 1.3 materials requires further study