NAVSEA
WARFARE CENTERS
Indian Head EOD Technology Division

CAD/PAD International Logistics Meeting (ILM)

CAD/PAD Propellant Stability Programs

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Agenda

- Purpose
- What are propellants?
- Propellant life cycle
- Why is propellant stability important?
- Propellant stability at Naval Surface Warfare Center Indian Head EOD Technology Division
- Risk
- Fleet takeaways!
- Questions?

Purpose

- The Cartridge Actuated Devices / Propellant Actuated Devices (CAD/PAD) propellant stability program monitors the stabilizer content of single and double base CAD/PAD propellants
  - Bulk government furnished material (GFM) propellant
  - Loaded end-item propellant
- Verifies propellants are safe for storage, manufacturing, handling, transportation, installation, and disposal
- Successful evaluations benefit end-users
  - Confirms material is stable prior to manufacturing end-items
  - Validate current life service life of applications

What Are Propellants?

- Propellants: chemical substances used to produce large volumes of hot gases
  - Produced gases are used to do **work**, and are used in systems such as:
    - Emergency escape systems (ejection seats!)
    - Fire extinguishing systems
    - Stores release and jettison systems
    - Cable cutting systems
  - For CAD/PAD items, the produced gas pressure is usually used for actuation of the next component in the ejection sequence

Bulk Propellants

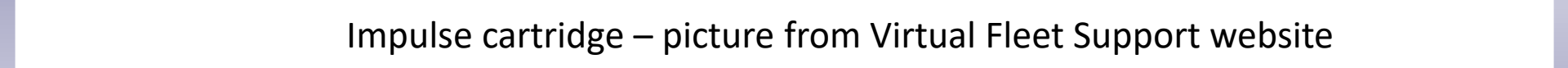
Flake propellants

Perforated propellants

Non-graphited, non-perforated propellants

All propellant pictures taken during propellant sample inspections at NSWC IHEODTD prior to 2012.

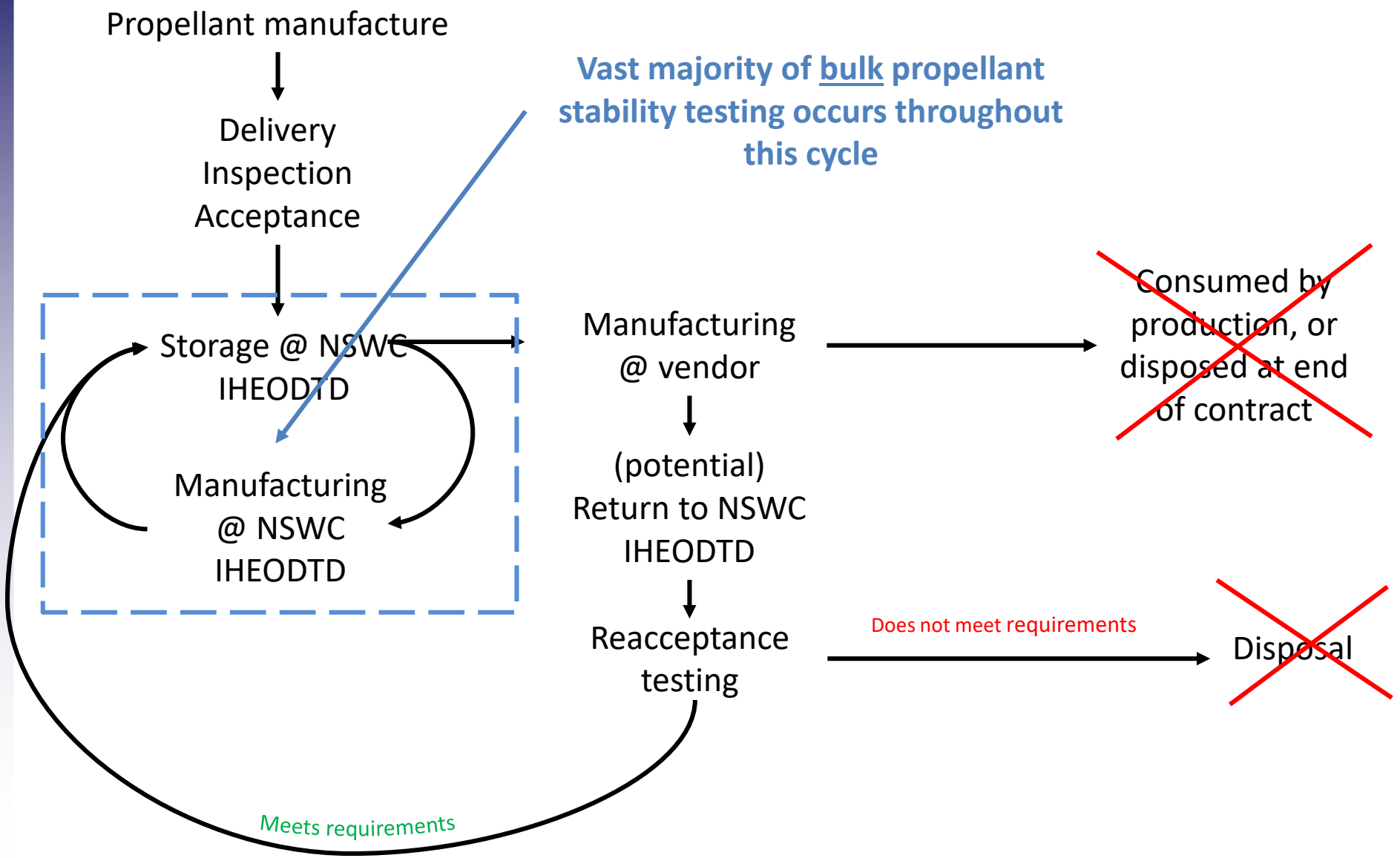
End Item Propellants



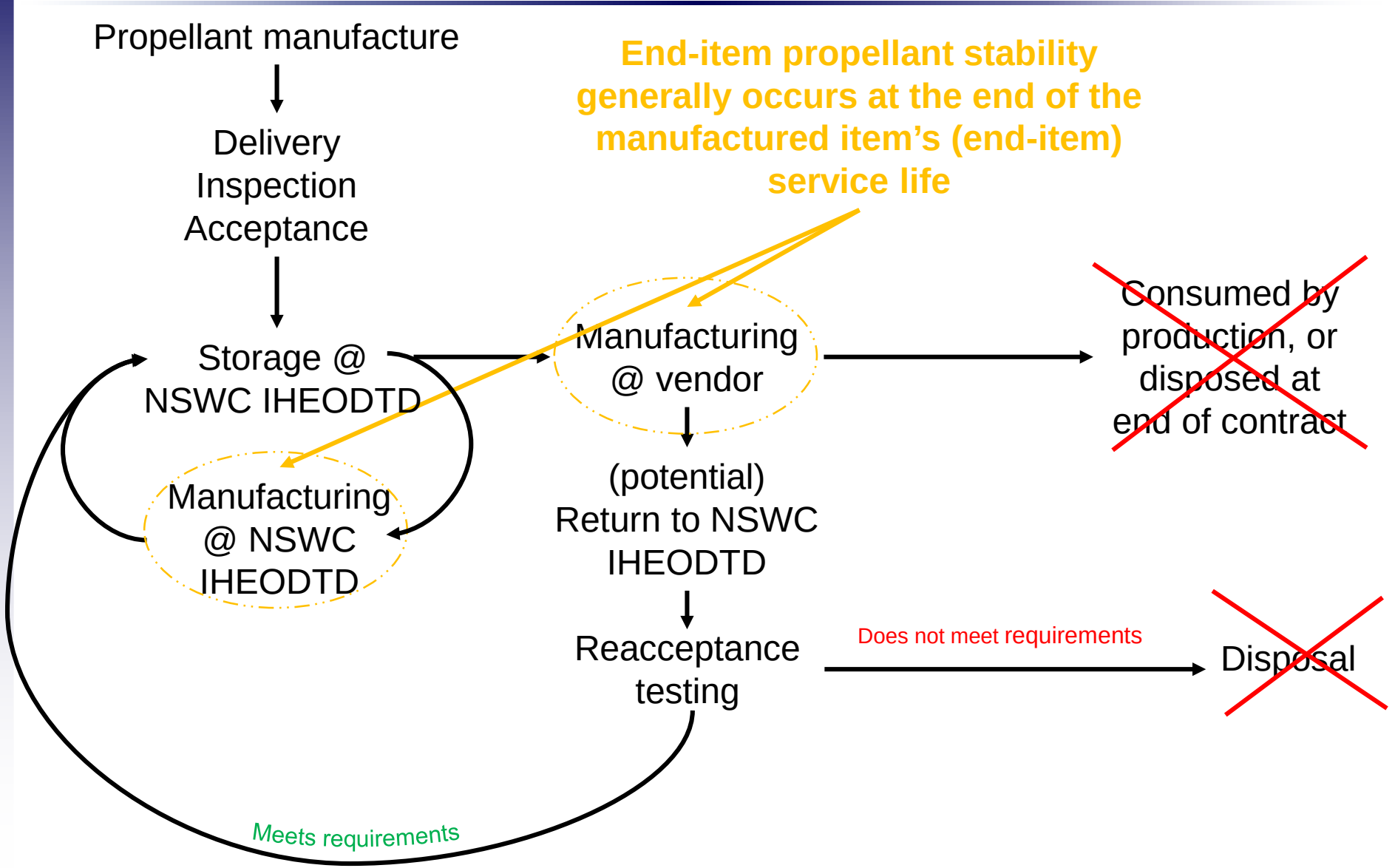
Impulse cartridge – picture from Virtual Fleet Support website

Impulse cartridge after dissection and propellant removal – picture taken at NSWC IHEODTD in June 2018

Propellant Life Cycle



Propellant Life Cycle (con't)



Why Does Propellant Stability Matter?

- Several factors affect the development, manufacture, fielding and sustainment of different propellant formulations
  - Mechanical properties
  - Performance requirements
  - Cost
  - Application requirements
  - Safety
- The CAD/PAD Propellant Stability programs are ultimately concerned about the safety of our propellants

Safe Propellant, Safer Navy

- There is some type of propellant in essentially every CAD/PAD item
  - Ejection seats, fire extinguishers, stores release systems…
- These items are manufactured, packaged, shipped, stored, handled, installed, removed, serviced, returned, etc., by multiple different organizations and people, and in a wide range of environments
- One of the easiest and most cost effective tests for propellants susceptible to destabilization is **stabilizer content**

Brief History of CAD/PAD PSTP

- Bulk propellant stability has been ongoing since the late 1970s
  - Importance was emphasized in August 1995 after the Building 518 fire

Photo taken after the building 518 fire

Brief History of CAD/PAD PSTP (con't)

- Current end-item stability test program originated in 2007 and is integrated into the ordnance assessment (OA) process
  - Importance emphasized in 2007 after the first PDRM rupture

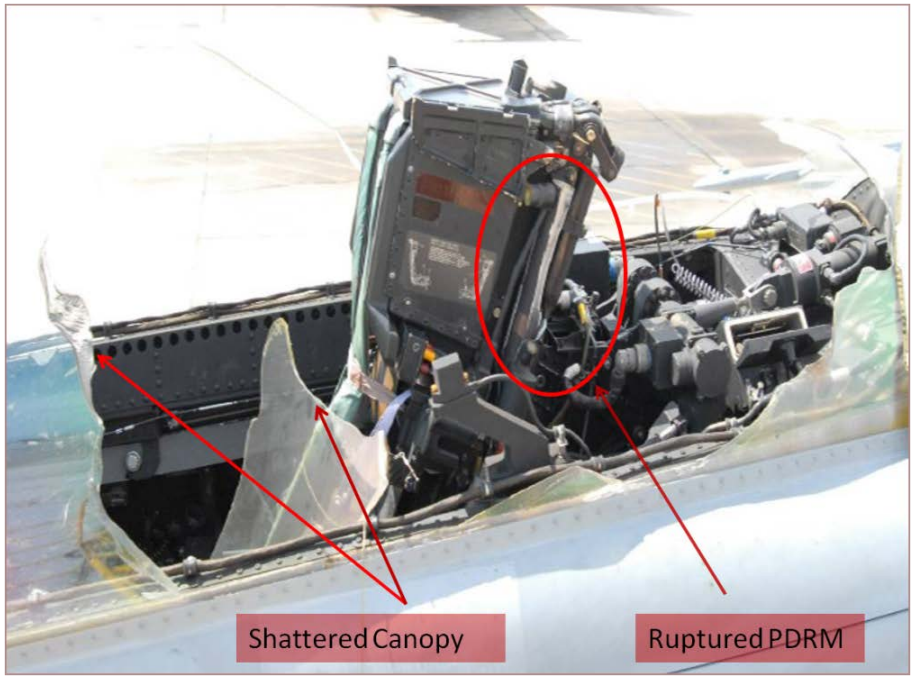


Photo taken after the July 2007 PDRM incident

Brief History of CAD/PAD PSTP (con't)

- Current end-item stability test program originated in 2007 and is integrated into the Ordnance Assessment (OA) process
  - Importance emphasized in 2007 after the first PDRM rupture
  - Reiterated again in 2017 with the second PDRM rupture

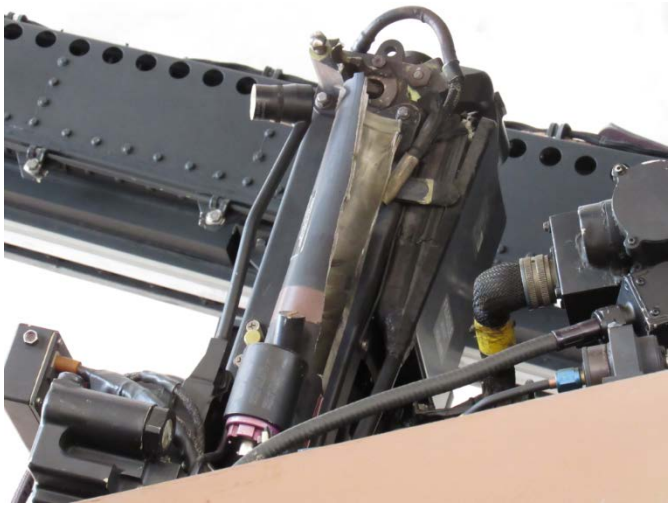


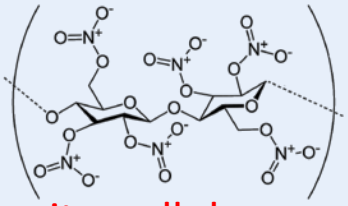
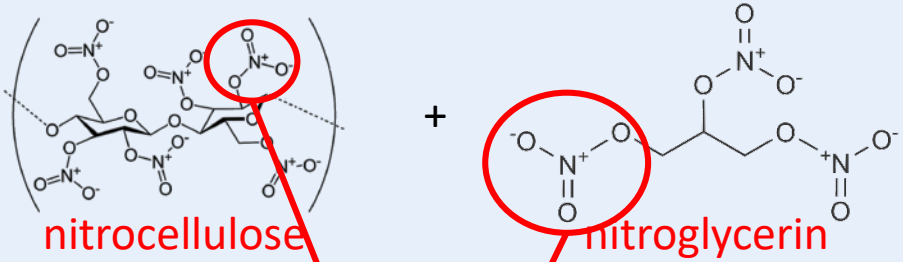
Photo taken after the 2017 PDRM rupture

Do All Propellants Need Stability Testing?

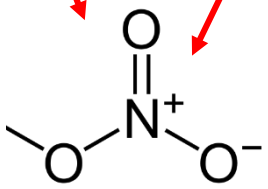
- Several different types of propellants, depending on their formulation
  - Single base: nitrocellulose-based
    - Used in impulse cartridges
  - Double base: nitrocellulose and nitroglycerin-based
    - Used in rocket motors
  - Triple base: nitrocellulose, nitroglycerin, and nitroguanidine-based
  - Composite: usually ammonium perchlorate or ammonium nitrate-based
    - Used in impulse cartridges
- CAD/PAD propellants are single or double base propellants, or composite: only the single and double base propellants require stability testing for us because…

Nitrate Esters, Featured in Nitrocellulose and Nitroglycerin

- CAD/PAD Propellant Stability Programs monitor and test the single and double base propellants

Single base propellants:	 nitrocellulose
Double base propellants:	 nitrocellulose + nitroglycerin

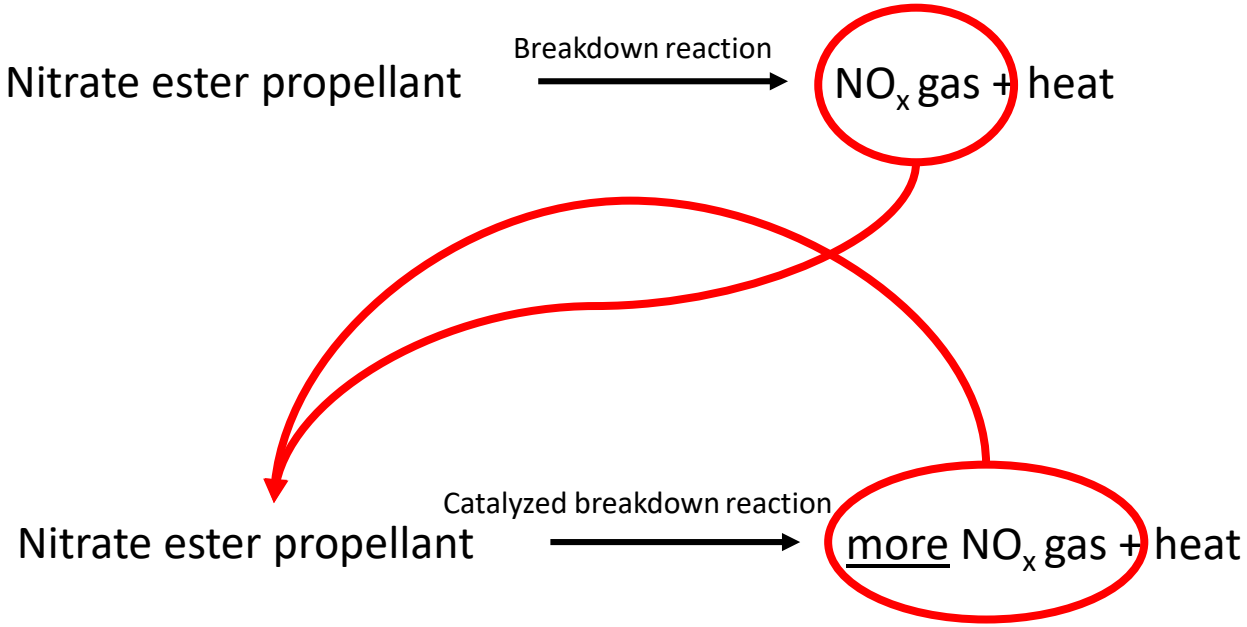
Nitrate ester group



Nitrate Ester Breakdown Reactions

- Nitrate esters (and all chemicals) undergo chemical breakdown reactions throughout their lifetime
- This reaction produces nitrogen oxide gases (NO_x) and heat
- The produced gases and heat then feed back into the reaction and perpetuate it

Nitrate Ester Breakdown Reactions – Without Stabilizers

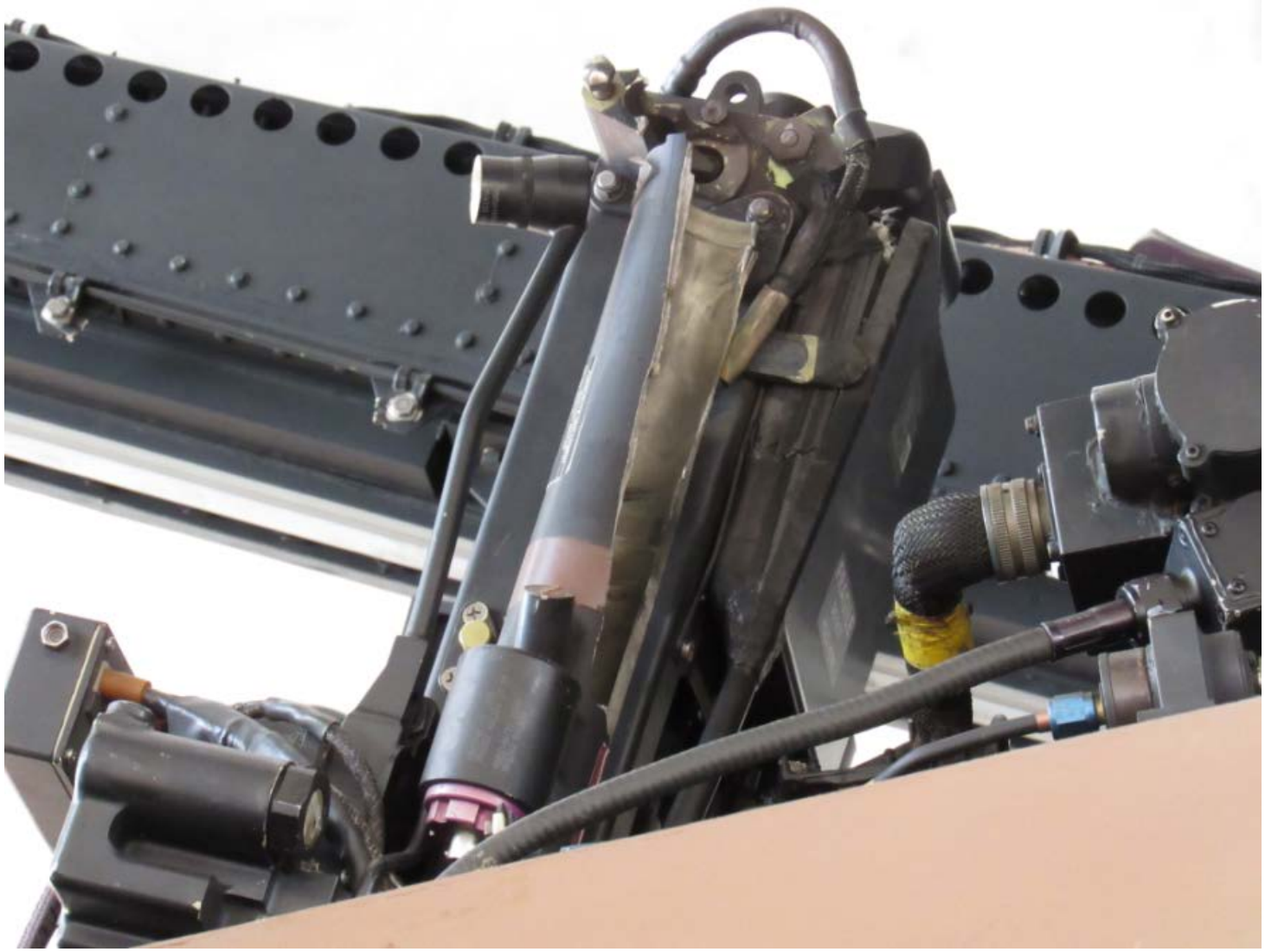


This reaction will continue until the nitrate esters are depleted from the propellant.

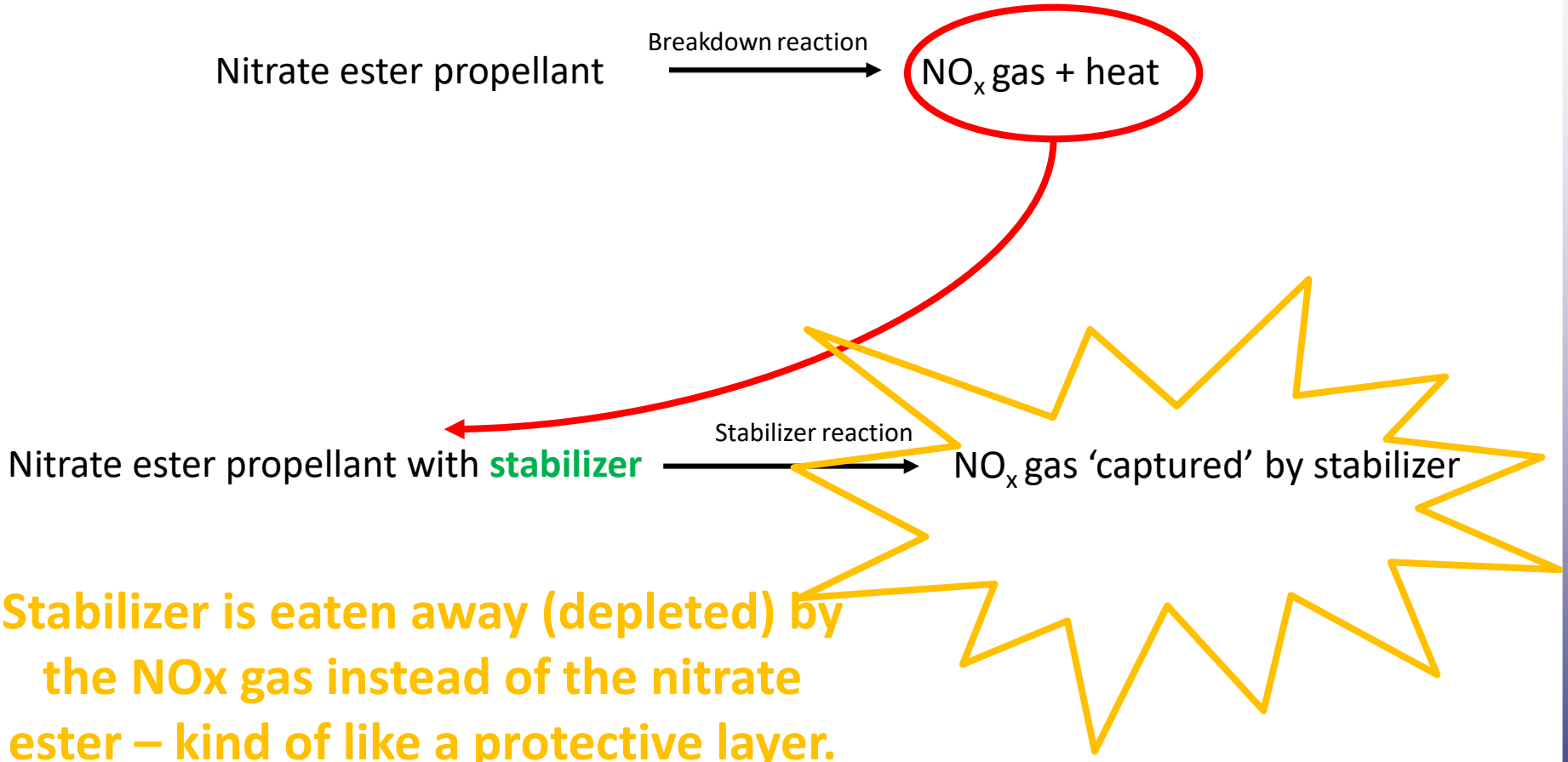
Nitrate Ester Degradation Continued

- If the degradation reaction continues, eventually all of the nitrate esters contained in the propellant will be reacted
- The volume of produced gas and heat will increase, which is detrimental in a small space
  - Cartridge case
  - Rocket motor case
- Worst possible outcome is auto-ignition of the propellant

Nitrate Ester Degradation Continued



Nitrate Ester Breakdown Reactions – With Stabilizers!



Stabilizer is eaten away (depleted) by the NOx gas instead of the nitrate ester – kind of like a protective layer.

And then there were Stabilizers

- Ultimately the breakdown reaction can't be stopped
- However, propellant formulations have been engineered to help slow down the breakdown reaction
  - Stabilizers are added to react with the produced gases instead of the nitrate esters
- The stability of propellants is predictable under a set of known, controlled conditions
  - Accordingly, following the storage, handling, installation, service life, and disposal guidelines is extremely important

For the fleet users: lots of factors go into determining the service life/handling, installation, storage, etc., guidelines: the stability of the propellants is one of them! You can help by making sure we get good surveillance samples back to test!

Testing for Stabilizer Content

- Bulk propellant:
  - Visual inspection
  - High Performance Liquid Chromatography (HPLC)
- End-item propellant:
  - Propellant download from application
  - Visual inspection
  - HPLC

Bulk Propellant Test Schedule

- The bulk propellant test schedule is determined by the stabilizer
  - Ethyl Centralite (EC): typically tested on a three year schedule
  - Diphenylamine (DPA): typically tested on a two year schedule
- Will test more frequently if test results come back low or indicative of rapidly depleting propellant

End-Item Propellant Test Schedule

- End-item propellant is tested concurrently with the OA program for the item
  - Generally a three-year schedule
- Will test more frequently for:
  - Known problem items
  - Service life extension support
  - Items that have never been stability tested

****Need service-returned assets to support these efforts!****

Factors that Affect Stabilizer Levels

- Several things can affect stabilizer levels, but the most critical factors are:
  - Moisture exposure
  - Heat exposure (thermal cycling, sustained heat, etc.)
- Try to mitigate the effects of these for both bulk propellants and their related end-items

Let's Talk about Risk

- Destabilized propellants can cause risks in manufacturing, storage, handling, transportation, installation, and disposal of both bulk propellants and end-item applications
- Color changes, over-pressurization, ruptured housing, auto-ignition
  - All preventable, unnecessary risks to the entire CAD/PAD community, industry base, and the warfighter
- (Relatively) small investment with a large return

One Final Example: PDRMs, again.

- PDRM rework program at NSWC IHEODTD
  - Energetics replaced, hardware reused
- Rework process is a manned operation
- January 31 2019:
  - Two motors from a 2009 lot were being reworked when operators experienced built-up pressure in the motor casing that caused the nozzle and the grid to pop off during removal
  - Propellant grains in each of the motors were green
- Prompted a shutdown to the rework line until the rework process could be re-evaluated for safety
  - Thorough investigation of the rework stock
- Ultimately determined to be caused by a combination of the storage practices and time spent in transit being returned to NSWC IHEODTD, and geographic location of installed time

This One's for the Fleet

We're here to support you – but we need your support in order to do that ☺

What can you do?

- Make sure you're following all of the guidelines on your parts – storage, handling, installation, shipping, etc. – check **Virtual Fleet Support!**
- Help us get the assets we need for testing: successful ordnance assessment/propellant stability evaluations benefit the end-users (and everyone!) but we have to have good, representative test assets.
  - **Propellant stability specific:** units from hot locations, with installed time data, please!
  - (mostly) undamaged units – the condition of the returned units affects our ability to test/evaluate them
- Remember that we're here for you: don't be afraid to get in touch if you have questions or concerns!

Comments, Questions, Thoughts, Ideas, etc.