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EXPLOSIVES SAFETY RISK ASSESSMENTS AT PORTS

Lead Author & Presenter: Brandon Fryman (APT)
Co-Authors: Deb Satkowiak (IME), Bill Evans (APT), Jorge Flores (APT)

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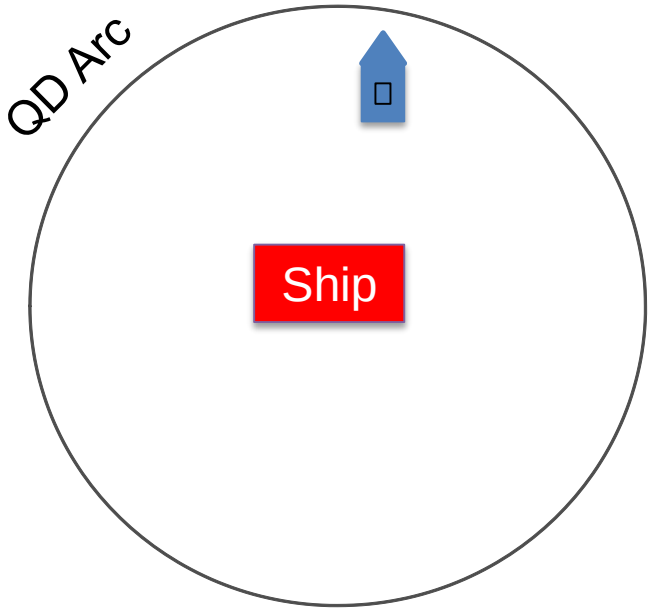
INTRODUCTION

- Ports in the U.S. and around the world are essential to the global explosives supply chain.
- Ships used in explosives transport can carry large amounts of explosives into ports.
- Often, the large amounts of explosives that ships carry make it impossible to meet quantity/distance (QD) rules when entering a port.
- One possible solution to this problem is the use of a quantitative risk assessment (QRA) to determine the level of safety at a port instead of QD rules.



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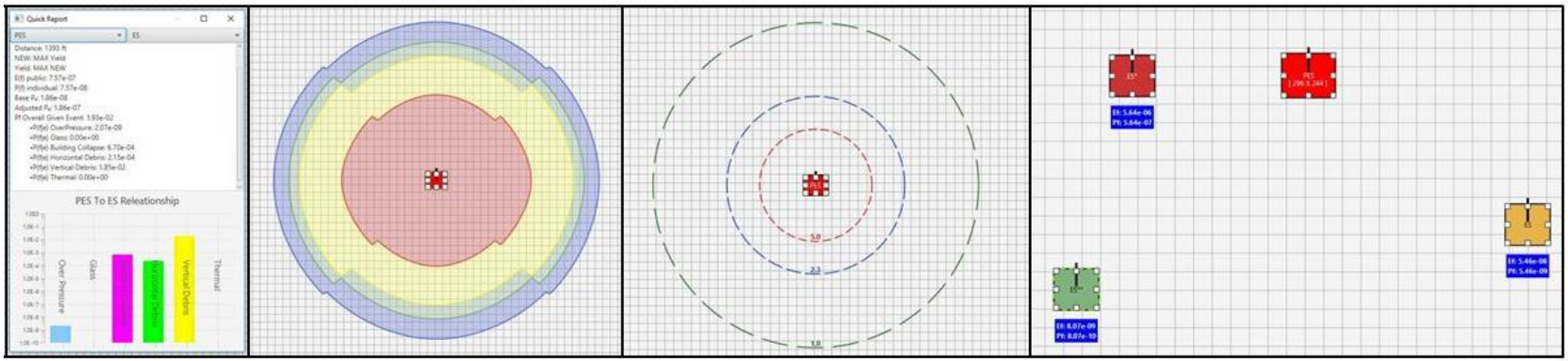
QUANTITATIVE RISK ASSESSMENT (QRA)

- Explosive QRAs are designed to quantify the risk of harm to people and assets from explosive operations.
- QRAs are becoming increasingly more common in the explosives industry and are a method, in addition to historic QD methodology, for determining the safety of explosive operations.
- In order to conduct a QRA, a tool that implements QRA methodology is essential.



QUANTITATIVE RISK ASSESSMENT (QRA)

- Safety Assessment for Explosives Risk (SAFER) and Institute of Makers of Explosives Safety Analysis for Risk (IMESAFR) are both readily available QRA tools.
- SAFER is the current U.S. Department of Defense (DoD) QRA tool that implements the QRA methodology presented in the Department of Defense Explosives Safety Board (DDESB) Technical Paper 14.
- IMESAFR[1] is a QRA tool sponsored by the Institute of Makers of Explosives (IME) that has been developed closely alongside the SAFER tool.

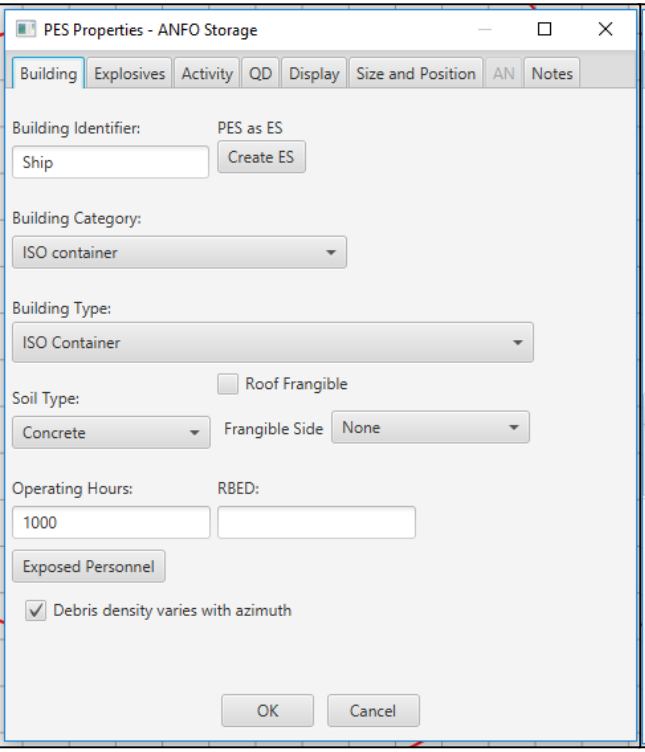
Institute of Makers of Explosives Safety Analysis for Risk
IMESAFR

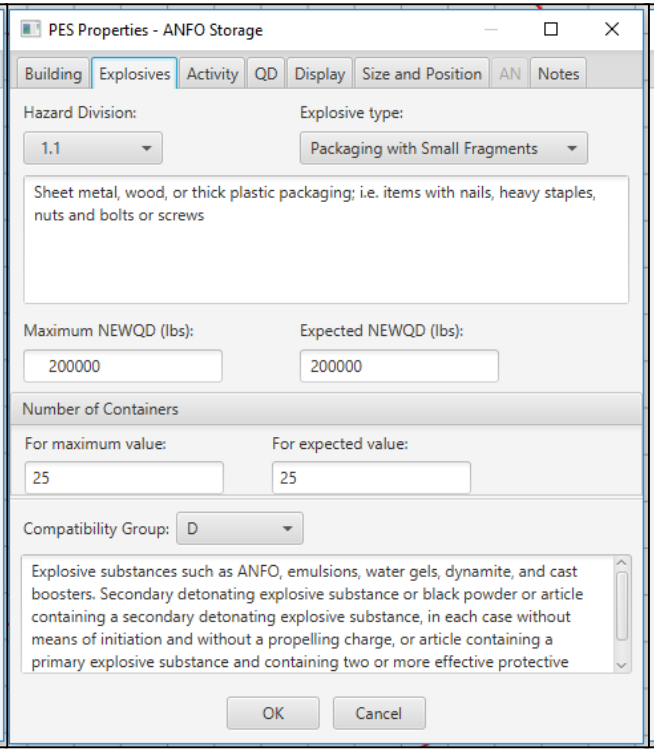
1 - “IMESAFR Overview” International Explosives Safety Symposium & Exposition 2018, Paper 20720; J. Tatom, B. Evans, J. Hoffman, C. Fritz, M. Duncan, M. Robinson

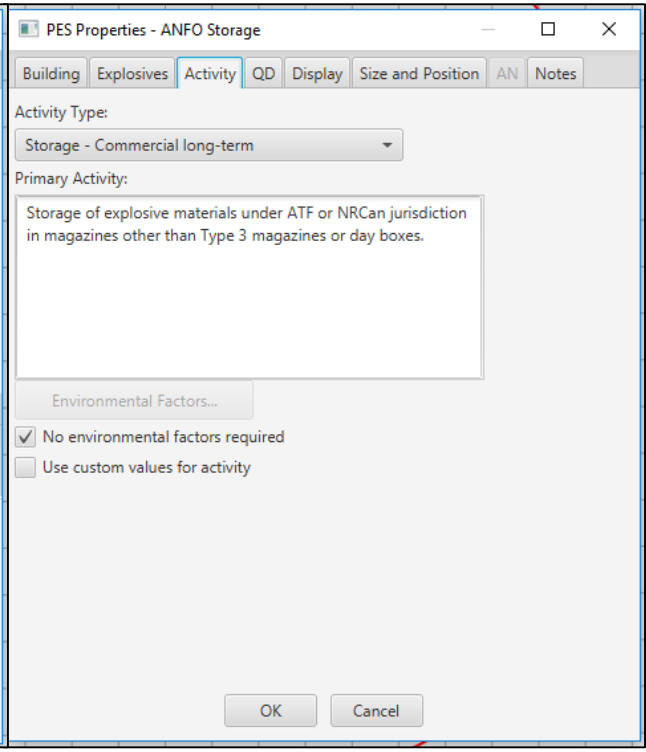
GUIDELINES FOR A QRA AT A PORT

- IME has drafted a document titled “Guidelines for IMESAFR-Based QRAs for Ports.”
- The guidelines presented in this document include a caveat that a QRA at a port should only be conducted on port operations that handle closed shipping containers.
- For standard loading and unloading operations at a port, a QRA is not that different from a standard QRA of a fixed facility.
- The first analysis that should be completed for port scenarios is a standard annual risk analysis.
- The details of the potential explosion site (PES) (the ship in a port operation) and the exposed sites (ESs) must be identified for input into the QRA.
- Example PES and ES inputs are shown on the next two slides.

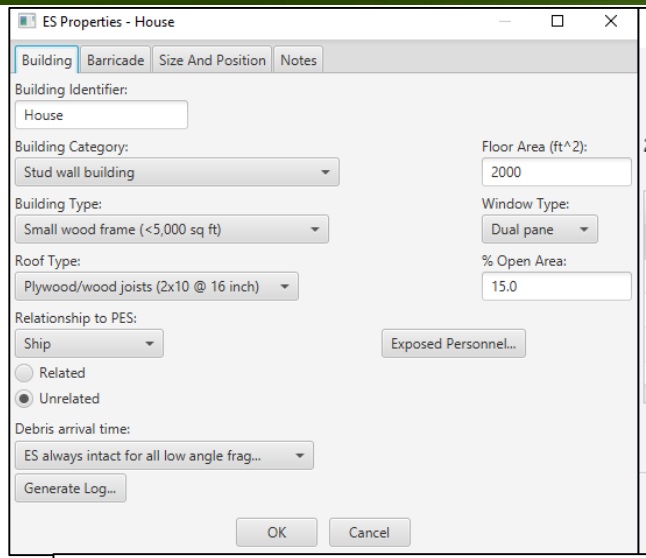
GUIDELINES FOR A QRA AT A PORT - PES INPUTS

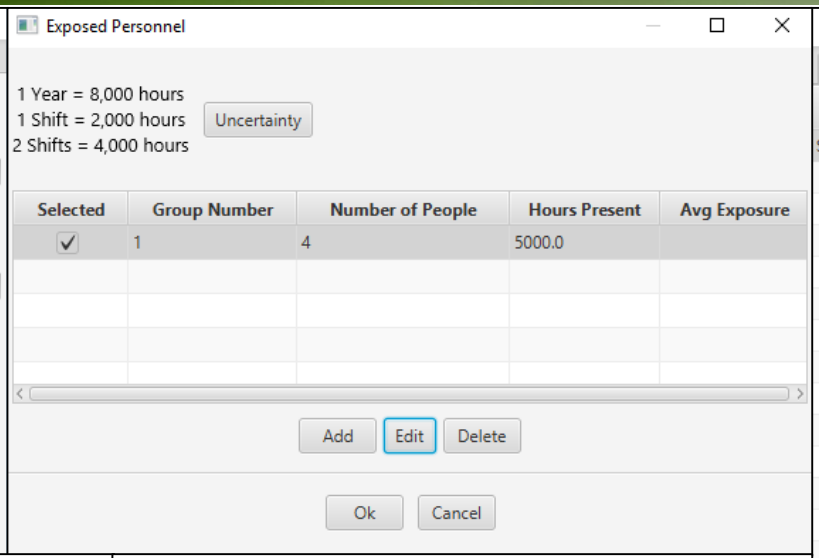


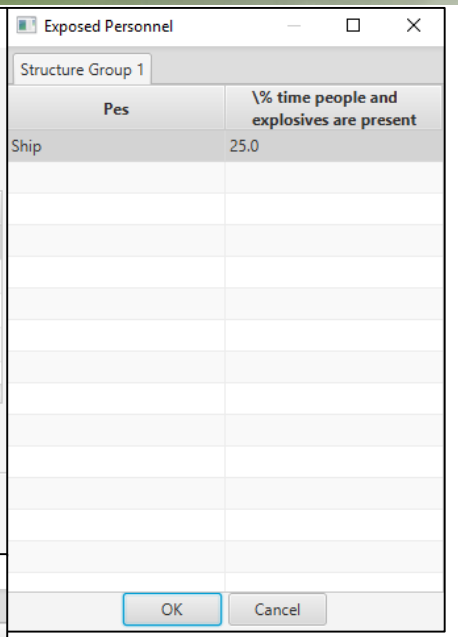


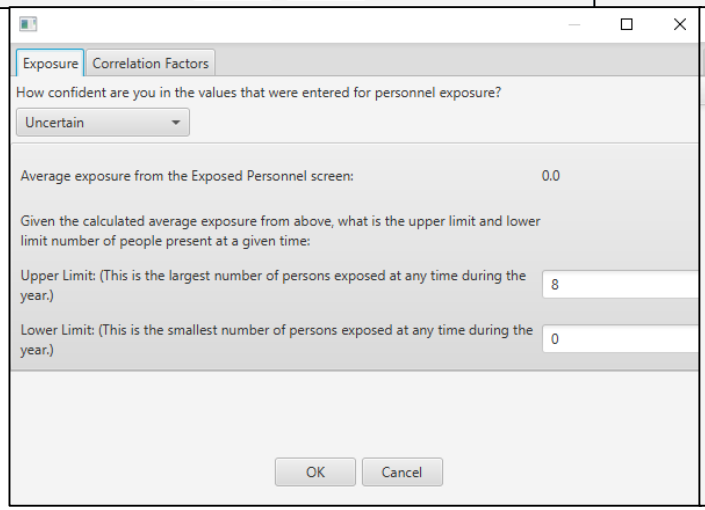


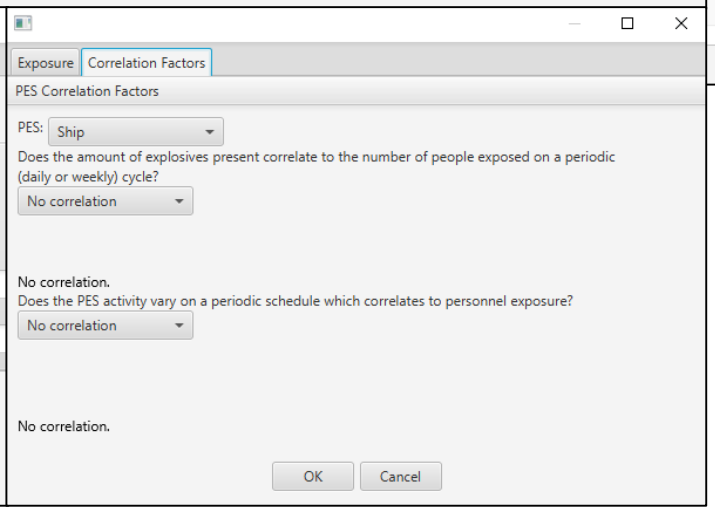
GUIDELINES FOR A QRA AT A PORT - ES INPUTS











GUIDELINES FOR A QRA AT A PORT

- In IMESAFR, there are two PES models that can generally be applied to port operations:
  - *Ship* model
  - *ISO Container* model
- The *Ship* model should generally be used when large amounts of explosives are stored below deck. This model allows the entire ship to turn into debris following an explosion.
- The *ISO Container* model should generally be used when explosives are stored above deck. In this model, only the ISO containers would become debris. The debris that would be generated by the deck of the ship is accounted for by setting the soil type to *Concrete.*

GUIDELINES FOR A QRA AT A PORT

- Generally, it is mandated that explosives are located above deck, so the *ISO Container* model will be the appropriate choice.
- Ammonium nitrate (AN) will almost always be shipped below deck, so the *Ship* model would be appropriate.

GUIDELINES FOR A QRA AT A PORT

Exposure

The times at which port operations occur should be carefully considered. Operations that occur at night will greatly alter the exposure at ESs when compared to operations that occur during the day.

GUIDELINES FOR A QRA AT A PORT

Net Explosive Weight (NEW)

The amount of explosives for operations needs to be defined for a QRA. The maximum possible size of a shipment should be used for all operations in the year.

Annual Activity Hours

The amount of annual activity hours for port operations should be calculated by multiplying the estimated maximum number of shipments in a year by the amount of time each operation takes.

HOURLY RISK ASSESSMENTS

- Often times an hourly risk assessment can be justified and will often be required by a regulator reviewing a QRA for a port.
- Hourly risk assessments are beneficial for scenarios that include few loading and unloading operations in a year, which leads to few hours of activity per year.
- For example, a port could only have 100 hours of activity in a year, which would mean 8,660 hours with no activity. In such scenarios, the annual risk is offset by a very large number of hours where the risk is zero.
- To calculate the hourly risk, hourly exposure and hourly probability of event must be determined. IMESAFR is able to calculate an hourly risk once these inputs are determined.

The benefit of an hourly risk assessment is that it only considers the time when an activity occurs.

HOURLY RISK ASSESSMENTS

Exposure

- If operations are carried out at a fixed time, which is normal for most port scenarios, then the occupancy/traffic data should be used for the surrounding ESs at that time. If operations occur at random times, then the average occupancy/traffic data should be used.
- Personnel should be entered into IMESAFR as present at each ES for one hour and the explosive activity should be entered as occurring one hour per year. The percent time that people and explosives are present should be entered as 100% of the time.
- IMESAFR presents the probability of event (P_e) for all activities as the probability of event in a year.
- To complete an hourly analysis, the P_e for an hour must be determined.

HOURLY RISK ASSESSMENTS

Probability of Event

- IMESAFR presents a baseline probability of event (P_e) for all activities as the probability of event in a year.
- To complete an hourly analysis, the P_e for an hour must be determined.
- An hourly P_e can be determined by adjusting the annual baseline P_e.
- The annual baseline P_e value utilized by IMESAFR is based on a typical number of operating hours per year.
- The annual P_e value is divided by the typical number of hours for the activity to determine an hourly P_e.
- An example hourly P_e calculation for commercial loading and unloading:

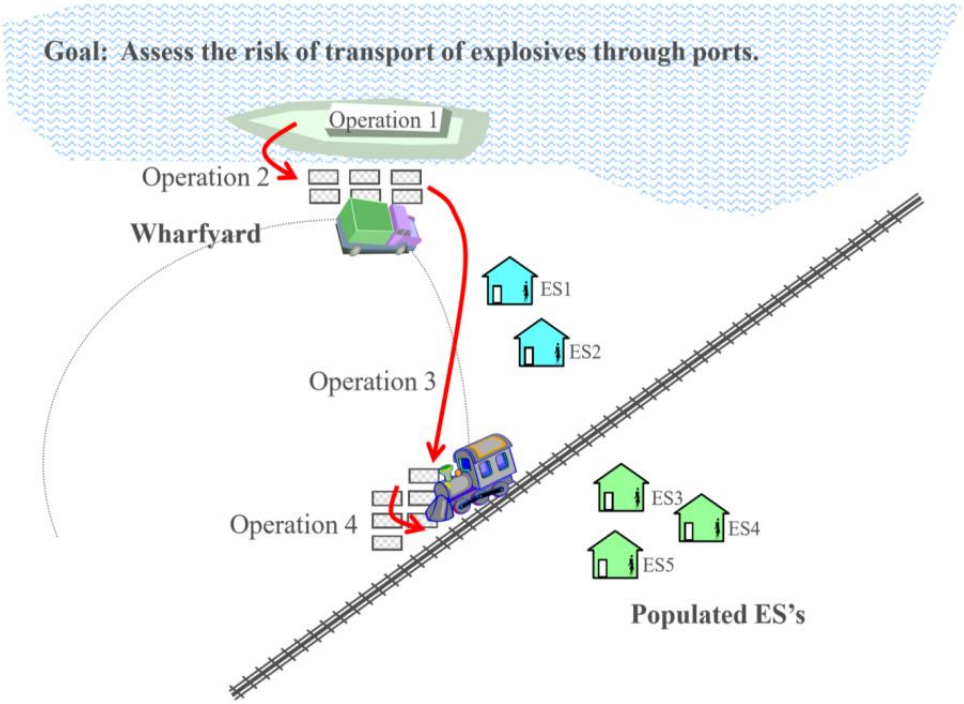
$$Annual\ P_e = 1.90E-05, based\ on\ 1{,}560\ hours$$

$$Hourly\ P_e = \frac{1.90E-05}{1{,}560\ hours} = 1.22E-08$$

- This hourly P_e value can be entered in IMESAFR as a custom P_e value.

SEQUENTIAL OPERATIONS PROTOCOL

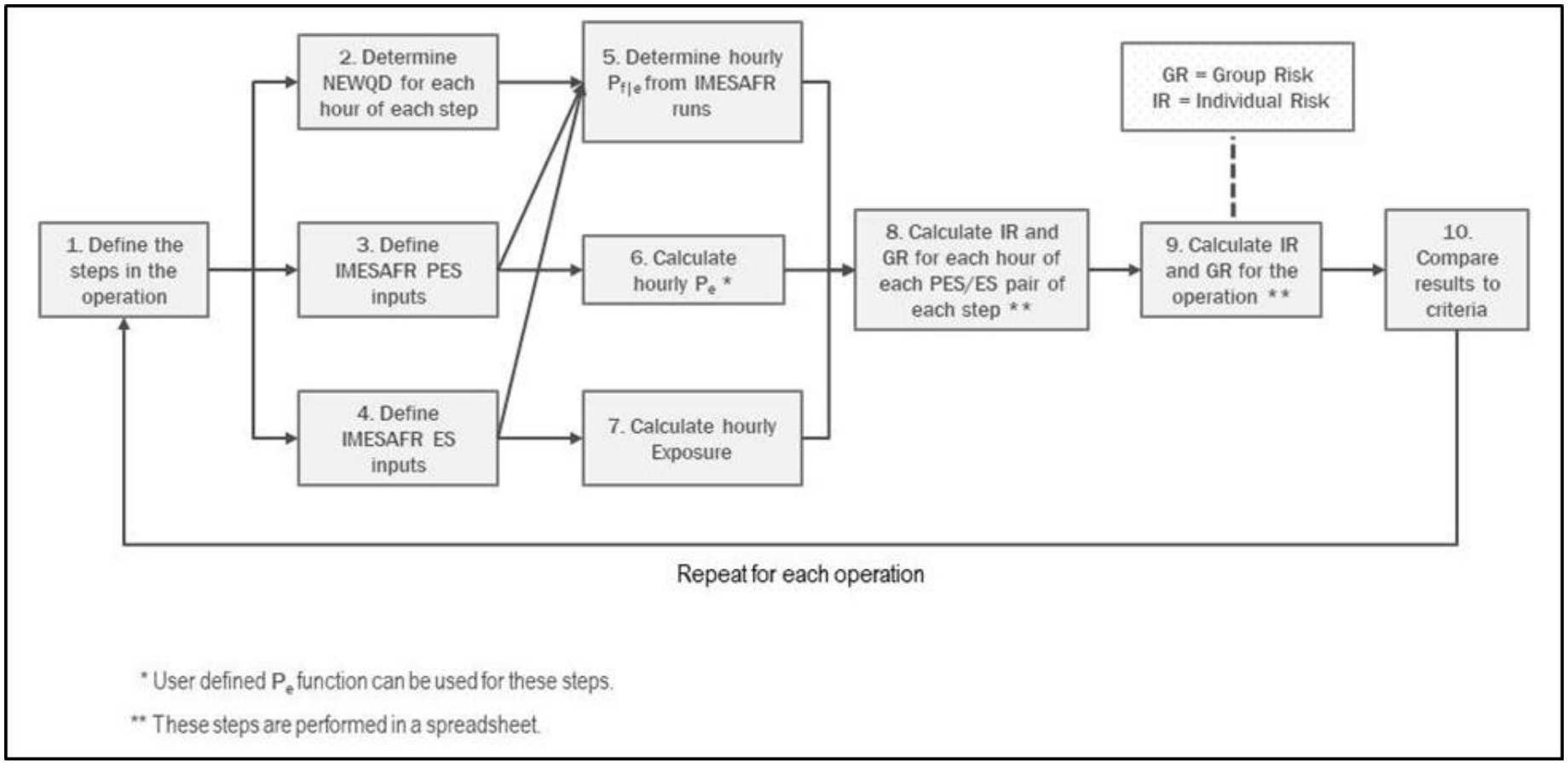
- In some port scenarios, explosives may be transported several times from ships, to trucks, trains, and storage facilities.
- In these scenarios, explosives are increasing and decreasing at each location over a certain period of time.
- This creates a unique scenario that requires the risk at each location to be evaluated over time, then aggregated to determine the overall risk from operations.



SEQUENTIAL OPERATIONS PROTOCOL

- A Sequential Operations Protocol (SOP) is designed to handle these complex operations with hourly changes to explosives at multiple locations.
- An SOP and a QRA tool are used together to evaluate the risk from operations.
- A sequential operation involves chains of activities, broken down into operation and steps, that must be analyzed hour by hour.
- For an analysis following an SOP, a “step” is a single activity, occurring over one or more hours, involving explosives at one PES. An “operation” is defined as a series of steps.
- The risk analysis process in an SOP is a 10-step process.

SEQUENTIAL OPERATIONS PROTOCOL



ANNUAL CRITERIA

- Determining the risk using a QRA is a valuable effort, but it is necessary to have tolerable risk criteria with which to compare this risk.
- IME's "Guidelines for IMESAFR-Based QRAs for Ports" has suggested several annual public risk targets:

Pass/Fail Criterion

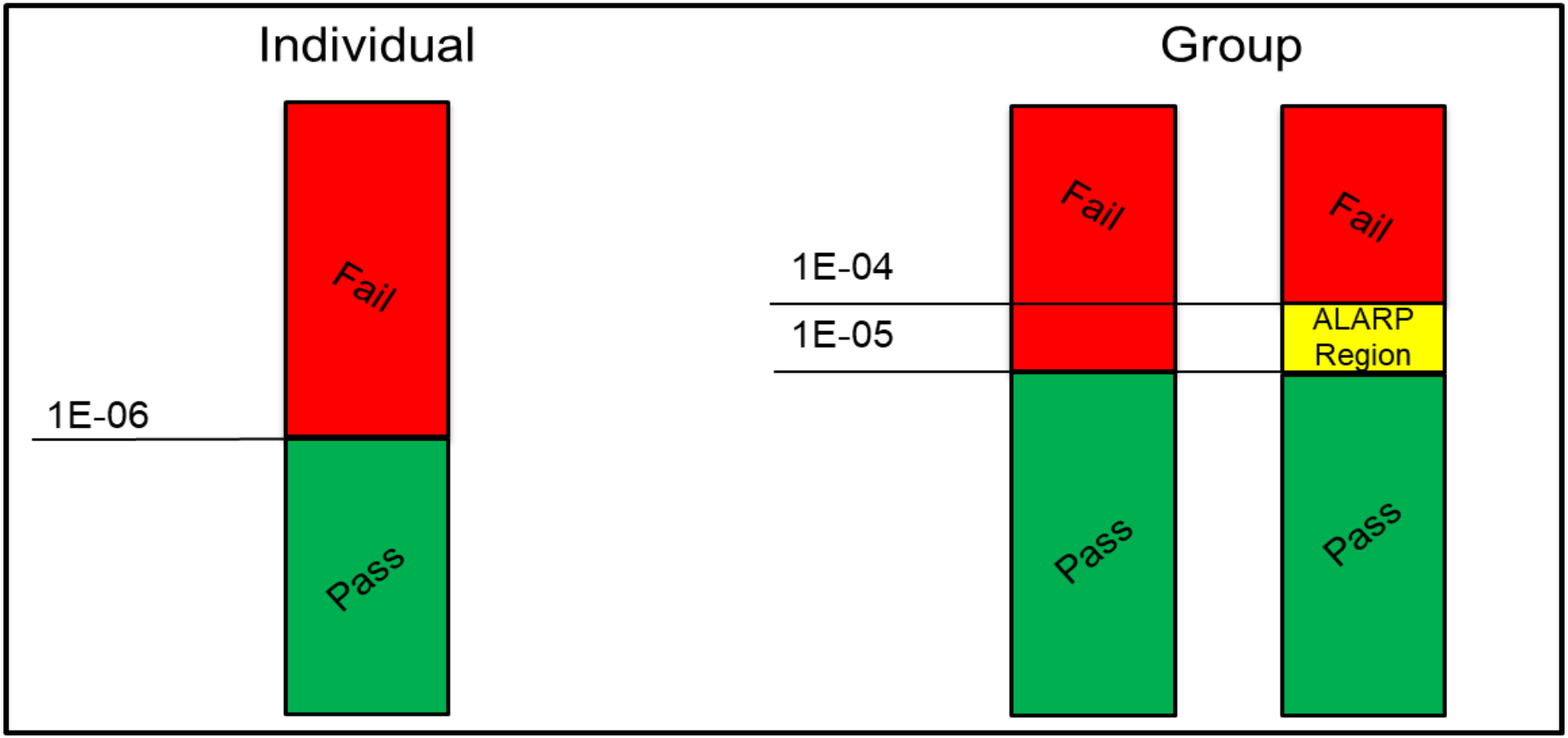
- Annual Individual Risk: 1E-06, i.e., for the person most at risk, the fatality rate is less than 1 per million years.
- Annual Group Risk: 1E-05, i.e., the total fatality rate will be less than 10 people per million years.

As Low as Reasonably Possible (ALARP)

- Annual Group Risk: The fail line is defined as 1E-04, i.e., the total fatality rate will be less than 100 people per million years. The ALARP region is defined as an annual group risk between 1E-04 and 1E-05. This is acceptable for short durations or under special circumstances. However, measures should be in place to reduce this to 1E-05 in a timely fashion. Annual group risk under 1E-05 is considered passing.

ANNUAL CRITERIA

IME's "Guidelines for IMESAFR-Based QRAs for Ports" suggested annual public risk targets



HOURLY CRITERIA

- Regulatory agencies might be interested in hourly risk targets for operations that only occur a few times a year.
- If regulatory agencies decide to require hourly risk assessments, then associated hourly criteria should be investigated and established.
- One very conservative option for examining hourly risk is by dividing the annual risk targets presented previously by 8,760 hours.
- Determining an hourly risk target using this method is essentially saying that any one hour a port operation cannot have a higher risk than the average risk for annual operations.
- This method of looking at hourly risk is not recommended as a long-term solution, but if the risk from a port assessment falls below the hourly risk targets defined using this method, then there should be no question that the risk is tolerable.

REGULATORY ACCEPTANCE

- In December 2017, Natural Resources Canada (NRCan), Explosives Regulatory Division (ERD) published regulations that allow QRAs and established criteria. The criteria are:
  - Annual Individual Risk: 1E-06, i.e., for the person most at risk, the fatality rate is less than 1 per 1 million years.
  - Annual Group Risk: 1E-05, i.e., the total fatality rate will be less than 10 people per million years.
- U.S. Coast Guard (USCG), Captains of the Ports (COTPs) have policy and precedence available to approve/disapprove explosive quantities that don't meet QD requirements at ports based on QRA.
- To obtain approval from a COTP, IMESAFR can be used to submit a waiver request.

SUCCESS STORIES

- QRAs at ports are being put into practice in both the U.S. and Canada.
- QRAs have been accepted at both commercial and military ports when QD rules could not be met.
- One specific example is the U.S. Marine Corps Blount Island Command (BIC). BIC analysis utilizes the SOP discussed previously.

Sequence of Steps	Explosives Location
Step 1: **Train arrives (Operations begin)**	**Rail**
Step 2: **Rough terrain cargo handler takes container off rail and places on chassis hauler (in rail area)**	**Rail**
Step 3**: Chassis hauler moves container from rail area to crane**	**Chassis hauler**
Step 4: **Crane moves container from chassis hauler to ships hold**	**Ship**
Step 5: **KALMAR positions container in ships hold**	**Ship**
Step 6**: Loaded ship**	**Ship**

CONCLUSION

- QD limitations can lead to non-ideal solutions, such as multiple smaller shipments and increased handling, to meet QD rules that actually lead to an increase in the risk from operations.
- A QRA is an alternative methodology to provide a state-of-the-art examination of the risks for explosive port operations.
- QRAs can be performed on an annual basis that look at the average risk of all operations over a year, or on an hourly basis that only look at the risk during loading/unloading operations.
- The risk from very complex port operations can be assessed using SOP to perform the QRA.
- QRAs for ports are becoming more accepted in regulatory environments, led by NRCan ERD.