IME
institute of makers of explosives

Guidelines for IMESAFR-Based QRAs for Ports

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Introduction

International export and import of commercial explosives has been commonplace for many years. From a North American perspective, the volume of such shipments continues to grow for two primary reasons:

- There are fewer manufacturers of primary and molecular explosives in North America, so such materials need to be sourced from Europe, South America and/or Asia, and
- Large explosives companies operate globally and increasingly have global supply chains.

Against this trend of more/larger shipments be exported or imported through North American ports is the countervailing trend towards ports reducing allowed quantities or even closing ports to explosive imports and exports under the rationale that such imports and export create heightened risk at the ports. This is despite the absence of actual incidents involving shipments of commercial explosives through ports (the well-known incidents all involve munitions, Ammonium Nitrate, or practices long-since ceased by industry). As a safety and security association, the Institute of Makers of Explosives (IME) is concerned that any arbitrary reduction in allowable net explosives weights through a given port shifts risk to additional ships, creates more handling, and/or necessitates greater surface transportation.

Over the past few years, Quantity/Distance (Q/D) has been used as a rationale for reducing/eliminating the shipment of explosives through certain ports due to the proximity of certain ports to of populated areas. This is a very conservative approach and is arguably not valid for transportation scenarios (this is the only transportation mode where Q/D is applied). IME has been active in championing the use of IMESAFR/ Quantitative Risk Assessment (QRA) as a scientifically-based, conservative option for making objective and transparent decisions regarding the shipment of explosives through ports.

The purpose of these guidelines is to provide explosive companies, ports and regulators with a conservative yet balanced method to assess the risk of importing and exporting commercial explosives through North American Ports. These Guidelines will also suggest the acceptance of tolerable risk targets (QRA without risk targets is like hockey without nets: a potentially interesting but, in the end, meaningless exercise). The Individual and Group Risk targets are the draft IME guideline values. The Individual Risk Target is widely used globally and has been proposed by IME to the U.S. Bureau of

Alcohol, Tobacco, Firearms & Explosives (ATF)[1]. The Group Risk Target has been agreed by the IMESAFR Science Panel (ISP)[2], which is preparing a support document prior to submitting it to ATF for consideration.

These guidelines address only shipments in containers. Also, the guidelines are only valid for port operations handling closed containers.[3] Shipments of explosives which are not containerized and the handling of explosive materials outside of closed containers are not covered by these guidelines. In addition, these guidelines assume that once off-loaded from the vessel to a transport vehicle, the explosives will immediately leave the area of activity, and there will be no accumulation of explosive material in any area of the port.

Scenarios Considered

There are essentially three scenarios:

1. Roll On Roll Off (RoRo)

In this scenario, neither the explosives nor the container they are in are handled except to drive onto the vessel at the loading end and drive off at the unloading end.

2. In Transit

This is similar to Scenario 1 except that the container(s) remain(s) on the vessel the entire time in port (i.e. they are destined for another port) with no handling of container or contents.

3. Normal On- and/or Off-Loading

Standard loading/unloading containers from vessels with the caveats stated above.

QRA Considerations

The three scenarios outlined above will be covered from both the Individual and Group Risk perspectives.

1. General Considerations

With the qualifications limiting the validity of these guidelines (e.g. handling only closed containers), there are perhaps no "without-warning" explosion scenarios. The safe handling characteristic of commercial explosives was illustrated by an IME Member Company (Orica), where pressurized air guns were used to fire pentolite boosters (HD 1.1D explosive) and propellant grains (HD 1.3) at steel plates at several times free fall velocities without generating any initiations. The impacts of cased/palletized material in containers will be much more elastic (less energy transferred at a slower rate), so even at

[1] At the request of ATF, the IMESAFR Science Panel oversaw a Peer Review of the IMESAFR Probability of Event before formally accepting this criterion. The final report was accepted in August 2018.
[2] The ISP is an independent body that includes representatives from U.S. and Canadian Governments as well as academia and private industry.
[3] More information on IME's best practices can be found in SLP-24, *Recommendations for Handling 50 Metric Tons or More of Commercial Division 1.1 or 1.2 Break-Bulk and Containerized Explosive Materials in Transportation at Commercial Waterfront Facilities in the United States*, www.ime.org.

maximum crane height, a container can be dropped with a negligible chance of initiating the contained product. This is the worst-case potential without-warning scenario, consequently it is arguable that only with-warning scenarios, such as fire, need to be considered (see below). All fire scenarios will allow time for evacuation, even with sensitive Class 1.1 materials. Therefore, all Class 1 loading/unloading operations at ports should be covered by an Emergency Response Plan that includes an evacuation plan for roads, residences, etc. at risk from an explosion.

To ensure that any Port QRA is conservative, IME recommends that the following scenarios be included:

i) Without-warning scenario: the worst-case event as discussed above would be a single container dropped from a significant height and initiating the full container load. The event frequency would be the IMESAFR default (conservative in this case) for loading/unloading
ii) With-warning scenario: e.g. a fire scenario involving the entire inventory. The event frequency would be the IMESAFR default for long term commercial storage and, if credible, evacuation could be considered as a mitigating factor to reduce exposure.

The standard risk 'output' for IMESAFR is the probability of fatality per year. For port operations, where the actual loading/unloading time is a small fraction of a year, an unacceptably high risk during these activities can be masked by the zero risk over the rest of the year – yielding an acceptable annual risk. There are essentially two ways of dealing with this: 1) have a risk aversion target (also known as catastrophic risk target) to deal with the worst-case scenario or, 2) as is preferred in port operations, calculate the hourly risk when operations are conducted and measure them against hourly risk targets.

2. Risk Targets

Annual Individual Risk: 1 e-06, i.e. for the person most at risk, the fatality rate is less than 1 per 1,000,000 years.

Annual Group Risk: 1 e-05, i.e. the total fatality rate will be less than 10 people per 1,000,000 years.

Annual Group Risk (As Low As Reasonably Practicable (ALARP) Region): 1 e-04, i.e. the total fatality rate will be less than 100 people per 1,000,000 years. This is acceptable for short durations or under special circumstances. However, measures should be in place to reduce this to 1 e-05 in a timely fashion.

These are all annual risk targets. To conservatively generate the hourly risk targets, divide these numbers by the relevant value 8,760 (the number of hours per standard year). This is very conservative, and it might be appropriate to do the analysis on a 'shift-year basis' i.e., divide the Annual Risk criteria by the baseline hours for that activity, e.g., 8,760 for long term commercial storage and 1,560 for loading/unloading).

3. RoRo Operations: Individual and Group Risk

Most jurisdictions do not require Q/D restrictions for RoRo operations and therefore QRA Guidelines are not required. Should a regulator or Port Authority require a QRA, the Guidelines under "Normal Loading/Unloading Operations" can be used. Please note that these will be very conservative for RoRo operations, so a further discount to event frequency would be warranted. An hourly risk calculation is almost never warranted for this scenario. This is essentially a transport scenario, which IMESAFR is not designed to cover, so there is no default event frequency available. Therefore, the analyst must

determine a user-defined event frequency. This will almost certainly be a single container event and evacuation should be allowed as a mitigating factor.

4. In Transit: Individual and Group Risk

This may be treated as normal storage. (The IMESAFR user is instructed to select long term commercial storage event frequency). As there are many initiation mechanisms present for commercial long term storage that are not present for on-vessel storage, a discount to the standard event frequency is generally justified. An hourly risk calculation is generally not warranted for this scenario but can be carried out if required using the default event frequency for long term storage and standard risk criteria, all divided by 8,760 to convert to hourly criteria.

5. Normal Loading/Unloading Operations

This is the case where the analysis can become complex and conservative assumptions/approaches can result in a punitively conservative result. This is especially true when an hourly risk-based calculation is carried out, which can be warranted for this scenario.

The first analysis that should be done is a standard annual risk analysis using the following inputs:

- All shipments should be assumed to be the maximum size intended.
- The frequency should be the intended maximum number of shipments/year.
- Activity hours should be a conservative estimate based on maximum number of shipments x duration of loading/unloading.
- Adjust risk for any operations restricted to a specific time period; for example midnight to 5 AM is a specified operational time period for many ports. During restricted non-business operational hours, there is less traffic density, less occupancy in businesses, etc.
- Two scenarios should be analyzed, the with and without-warning scenarios described above. Note that the two scenarios should have different numbers of activity hours. The with-warning scenario should include all hours that the vessel is in port, including loading/unloading; the without-warning scenario should include only the actual loading/unloading hours for explosives.

If either analysis fails, unless the number of activity hours is very high (which IME considers to be more than 1,000 hours per year), then it is probably pointless to continue the analysis/QRA process. This is especially true if the fail is for Individual Risk, as Group Risk is the normal issue for Port QRAs. For a standard analysis which is a borderline pass on a low number of activity hours, there is probably an uncomfortably high $P_{f|e}$ and/or too many people too close. This means that if the regulator requests an hourly-based analysis, it will fail the risk assessment. But a clean pass for a standard annual analysis on both Individual Risk and Group Risk should meet all regulatory requirements. However, a regulatory authority may have additional requirements, such as an hourly risk assessment or catastrophic risk aversion criterion.

Catastrophic risk aversion is very simple both in concept and calculation. The concept demonstrates that there is a number of fatalities (or damage to facilities, monetary loss, etc.) which is the maximum acceptable to stakeholders, such as regulators, society, shareholders, etc. A worst-case scenario analysis is done and measured against the selected relevant criteria; for this activity, it will normally be fatalities. This approach should be preferred to the hourly assessment approach but requires the regulatory

authority to have catastrophic risk aversion criteria defined, which is rare. For this reason, the much more problematic hourly risk assessment is more prevalent.

An hourly risk assessment requirement can be justified if there is a low number of hours per year of loading/unloading activity, which is generally the case. This is because the calculated risk is the weighted average of a very large number of hours where the risk is "0" and a much smaller number of hours where the risk is not zero. So, if the activity occurs for 100 hours per year, then there are 8,660 hours of zero risk. Consequently, the risk can be quite high during the 100 hours of actual activity and still provide acceptable annual risk numbers. An hourly risk assessment simply considers only the time (which can be reduced to a "snapshot" of 1 hour) when the activity occurs. This approach is not what IMESAFR is designed to do, and although it is certainly capable of doing this type of analysis, the numbers generated will be substantially conservative.

One of the reasons that this type of analysis is overly conservative is due to the tendency to make this both an hourly and worst-case scenario analysis. As will be emphasized below, this is rarely valid and will almost inevitably result in a "fail." The other reason that these analyses tend to be overly conservative is "hidden," i.e., IMESAFR multiplies the "raw" values it generates by an Uncertainty Factor. The Uncertainty calculation is very complex and is itself overly conservative. It is noted that the ISP has already identified some overly conservative factors and will be reviewing the Uncertainty calculations in the next year. In addition, the assumptions used in the hourly assessment tend to cover a significant range for many of the input variables which results in an abnormally large Uncertainty multiplier.

There is nothing wrong in principle in doing an hourly assessment for this type of operation. However, IMESAFR is designed to be the best available tool for assessing annual risk, not hourly risk. While all the algorithms still work correctly, all of the in-built conservatism in the model/algorithms, assumptions and uncertainty calculations will generate very conservative results. This may be appropriate in specific scenarios where a high level of risk aversion is warranted but, in most cases, it will generate overly conservative results that will limit both ports and companies from carrying out very reasonable, low-risk activities.

Therefore, IME is making the following recommendations for port assessments. These recommendations are aimed at analyses where an hourly risk assessment is required and are intended to provide an accurate assessment that balances the over-conservatism of this approach with realistic inputs and parameters:

a) **Never do both an hourly-based assessment and a catastrophic risk aversion assessment**. If one makes all worst-case assumptions for populations at potential risk, then the generated risk must be measured against a catastrophic risk criterion. An hourly assessment should be done against an average level of populations at risk/occupancy. If these activities only occur during certain hours, then populations/occupancies should be the averages for these periods. Note that this can increase the Uncertainty multiplier while also decreasing the baseline risk.
b) **Turn off Uncertainty in IMESAFR**. This will often significantly reduce the calculated risk (it is easy to generate scenarios where this effect can be an order of magnitude or more). Reality will always have some uncertainty so a narrow pass with Uncertainty turned off should, at the minimum, require some further risk reduction processes to be put into place. On the other

hand, a narrow fail that passes by a factor of more than 10 with Uncertainty turned off should probably be reviewed with that consideration in mind.

c) **Evacuation**. When looking at with warning scenarios, fire on board is the overwhelming scenario of concern and historically fire scenarios provide 30 minutes or more for evacuation, closing roads, etc. Reducing exposure, i.e., the number of people in range, reduces risk as effectively as reducing the event frequency or consequences. The effectiveness of evacuation depends on population/vehicle density, type of buildings to be evacuated, effectiveness/training of the local first responders and having an effective ERP in place.

d) **Event frequency default value**. There is an excellent case to be made that the default loading/unloading P_e value in IMESAFR is too high for activities only involving containers containing Class 1 material. The default value is based on historical data where the activity is loading/unloading cases or pallets of product, sometimes handling individual units of product. The container, which is never open during the process, provides a significant level of protection to the product inside. It is recommended that the event frequency default value for long term commercial storage be used. After all, this activity is more like a short movement of a magazine, not the loading/unloading of product within the magazine/container. Note that there is no known incident where this activity has resulted in an explosion in a port.

e) **Risk target.** The recommended value for the Individual Risk remains the best risk target; however, it is recommended that the ALARP value for Group Risk (1 e-04) be used. This lower risk target balances some of the over-conservatism of an hourly assessment. It would be reasonable to tie this to other risk reduction processes, e.g. an ERP including evacuation.

For internal evaluations, the user can determine which option or options provide a more accurate assessment. For assessments for regulators, the final say will always lie with the regulator. However, these recommendations are reasonable ways of using a conservative approach to a port QRA while obtaining more realistic results.

Conclusions

For many ports, any Q/D analysis will severely limit, or even prohibit, loading/unloading activities for Class 1 materials. Such limitations have occurred despite the historical record that indicates that this is, in fact, a very low risk activity. QRA offers a subjective, balanced approach to risk analysis, and IMESAFR is the best tool to support a QRA. A normal IMESAFR-based QRA can be inadequately conservative if the port activity is low; therefore regulators often request an hourly-based assessment. While this provides a better indication of the “instantaneous risk” during loading/unloading, it also normally drives the analysis to generate overly conservative results. It is with these considerations that IME has proposed options that will make the IMESAFR analysis more realistic.