IMESAFR Overview

John Tatom; A-P-T Research, Inc.; Huntsville, AL, USA

Bill Evans; A-P-T Research, Inc.; Huntsville, AL, USA

Josh Hoffman; Institute of Makers of Explosives; Washington, D.C., USA

Clint Fritz; Nelson Brothers; Birmingham, AL, USA

Michelle Duncan; A-P-T Research, Inc.; Huntsville, AL, USA

Mary Robinson; A-P-T Research, Inc.; Huntsville, AL, USA

Keywords: IMESAFR, quantitative risk assessment, explosives safety

Abstract

The Institute of Makers of Explosives (IME) has sponsored the development of a quantitative risk assessment (QRA) tool called IMESAFR (Institute of Makers of Explosives Safety Analysis for Risk). This software has been developed to assess risks in situations where quantity-distance (QD) cannot be met, and also for risk management.

The project has involved participation and collaboration from both U.S. and Canadian government regulatory entities since the inception. The Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), which regulates the storage of commercial explosives in the U.S., now accepts risk-based variance requests using IMESAFR and the "Risk Bank" method. ATF is evaluating moving to the use of numerical criteria for public individual and group risk. In Canada, the Natural Resources Canada – Explosives Regulatory Division (NRCan-ERD) is using IMESAFR for risk-based derogation requests when QD cannot be met. The Canadian Armed Forces (CAF) are now also using IMESAFR as part of their Ammunition and Explosives Risk Assessment Safety Case (AERASC) process.

IMESAFR v2.1 is the latest version of this software and contains an ammonium nitrate (AN) module as well as the standard TNT-based algorithms for predicting explosion effects and consequences. The program is anchored by data from recent Department of Defense (DoD) and ATF test programs, and IME has also proposed a three-part test series.

1. Background

The IMESAFR project began, in discussion form, in 2004. Work on creating the QRA models and actual software tool began in 2005.

1.1. Quantitative Risk Assessment - QRA

Although risk-based approaches to safety are not new and are in fact are commonplace when dealing with some hazardous materials (e.g., chemical or nuclear), the use of QRA for explosives safety is relatively new – especially in the U.S. An essential aspect of risk assessment is that the

probability of the event is considered, rather than only worrying about the consequences. But the consequences should be rigorously evaluated and tied to the specifics of the scenario in question, rather than having a one-size-fits-all method.

In 1997, the DoD began developing its approach to implementing QRA for explosives safety. The Risk-Based Explosives Safety Criteria Team (RBESCT) developed the Technical Paper 14 (TP-14) model (Ref. 1), implemented by the Safety Assessment for Explosives Risk (SAFER) tool. The RBESCT comprised representatives of the Department of Defense Explosives Safety Board (DDESB) and Services (Army, Navy, Air Force, Marines, and Coast Guard). Seeking a similar solution for the commercial explosives community in North America, IME looked to build upon the work of the RBESCT and develop IMESAFR for use by the industry.

1.2. Institute of Makers of Explosives - IME

IME is a nonprofit association founded in 1913 with the mission "to promote safety and security and the protection of employees, users, the public and the environment and encourage the adoption of uniform rules and regulations in the manufacture, transportation, storage, handling use and disposal of explosive materials." IME represents U.S. manufacturers and distributors of commercial explosives and oxidizers, and companies that provide related services. The ability to manufacture, use, transport, distribute, and commercial explosives safely and securely is critical to the explosives industry. Accordingly, IME has an interest in any guidance, standards, and best practices, and advocating at all levels of government the adoption of rules and regulations consistent with safety and security in the manufacture, transportation, storage, handling, use, and disposal of explosive materials.

IME established the American Table of Distances (ATD) over 100 years ago and since then it has been incorporated into many regulations to govern quantities and distances associated with the storage of explosives. In recognizing the evolution of explosive products, manufacturing processes, and storage practices, IME decided to pioneer a modern means to determine how and where to store commercial explosives to supplement the ATD. The decision was made by IME to pursue an approach that relied upon QRA. IME has since invested in the science of QRA, and its continued improvement, knowing it to be a critical component toward advancements in safely storing commercial explosives.

1.3. A-P-T Research, Inc. - APT

A-P-T Research, Inc. (APT) has been the support contractor for the RBESCT since its inception. APT works on the development of explosive effects and consequence models. When DDESB chose to implement a technology transfer to help IME begin the IMESAFR project, IME hired APT to support the project. APT has provided subject matter experts (SMEs) and software development capability to both teams. This history and relationship is depicted in Figure 1.

Figure 1 - IMESAFR Development History and Relationships

1.4. IMESAFR Project

1.4.1. General History, Including Regulatory Involvement

From the beginning of the project, IME and APT invited regulators to participate in the development of IMESAFR. ATF, Mine Safety and Health Administration (MSHA), Occupational Safety and Health Administration (OSHA), NRCan-ERD, and Canadian Explosives Research Laboratory (CERL) were involved from the first meeting. Regulatory participation was vital, as the goal of the IMESAFR project was not only to develop a QRA model, but also to establish the rules and requirements for application of IMESAFR, initially in the U.S. and Canada. To this end, it was essential to have regulatory buy-in on the approach, level of conservatism, and intended applications of IMESAFR.

Additionally, IME wanted to maintain a close working relationship with DDESB to make sure a collaborative arrangement was established. Therefore, the DDESB has a representative on what became known as the IMESAFR Development Team, and IME likewise participated in RBESCT meetings.

More recently, ATF and IME founded the IMESAFR Science Panel (ISP), which they co-chair.[1]

1.4.2. List of Release Dates and Versions

Beginning in 2005, the IMESAFR Development Team developed a list of adaptations and additions necessary to create a software tool for industry, using SAFER as a starting point. Released in January 2007, IMESAFR v1.0 shared algorithms with SAFER v3.0. While similar, IMESAFR contained differences including explosives, activities, environmental factors, and available potential explosion site (PES) types. (Ref. 2, 3)

[1] McNeill, S., Hsu, N., Tatom, J., Evans, B., *IMESAFR Science Panel*, Minutes of International Explosives Safety Symposium & Exposition 2018, NDIA Paper No. 20722, 6-10 August 2018, San Diego, CA

IMESAFR was updated to IMESAFR v1.1, which was released February 2009. This version included algorithm updates provided in SAFER v3.1, as well as updates to create a more intuitive graphical user interface (GUI).

In February 2011, IMESAFR v1.2 was released to the public with bug fixes, additional updates from SAFER v3.1, and other enhancement features. This version allowed the importing of User Defined Explosive Articles (UDEAs) and allowed pressure-reduction credit for an exposed site (ES) due to the presence of barricades, under certain conditions. (Ref. 4)

The next version of IMESAFR v2.0, was released to the public in January 2013. This included major updates to the interface, including an interface based on a Geographical Information System (GIS) (i.e., a map-based GUI). Users now had the ability to place structures and roads on a map, visualize risk, and generate other informative details, such as debris contours.

Four years later, in October 2017, the AN engine within IMESAFR was released for public use.[2] This engine allowed risk assessments involving AN rather than just using the existing the TNT engine to model AN as a TNT equivalence. Another enhancement of this version included two additional PES structures associated with storage of AN. (Ref. 5)

In April 2018, IMESAFR v2.1 was released to the public. This version included a full development platform update, algorithm update, and additional new features. These features included updates to barricades, user-friendly keyboard shortcuts, parametric studies, and user-defined risk color coding. More information on features IMESAFR v2.1 is provided in Section 2.1.

1.4.3. Overview of User Base

IMESAFR has a history of international users spanning industry, government, and academic sectors. Between 2013 and 2017, IMESAFR v2.0 training was provided to over 300 individuals, 28% of which were outside of the U.S. and Canada, including citizens of Mexico, Belgium, Germany, Spain, and Australia.

[2] Swisdak, M., Evans, W., *Ammonium Nitrate Modeling in the AN Module of IMESAFR*, Minutes of International Explosives Safety Symposium & Exposition, NDIA Paper No. 20701, 6-10 August 2018, San Diego, CA

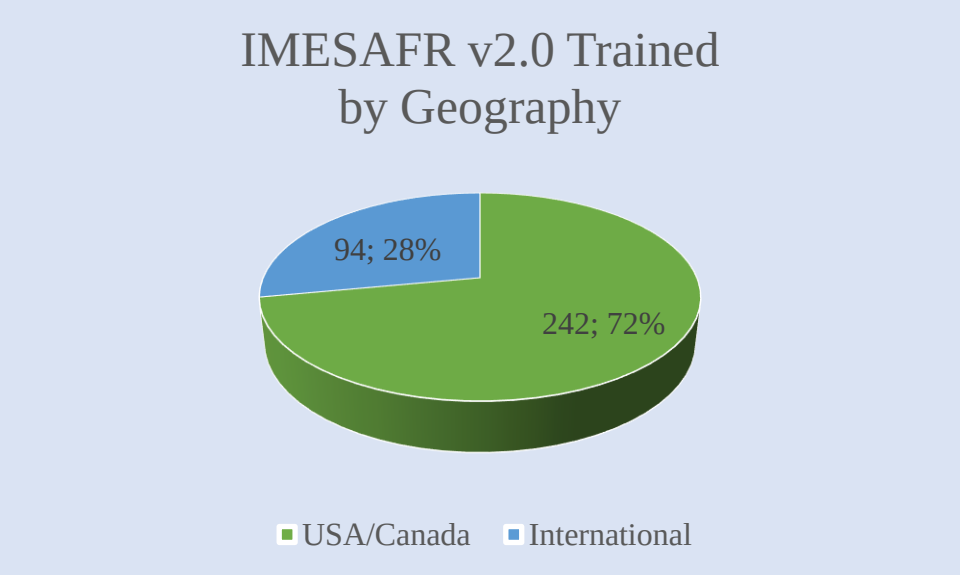

Figure 2 - IMESAFR v2.0 Trained by Geography

Notably, 43% of those trained to use IMESAFR v2.0 were government regulators, as shown in Figure 3.

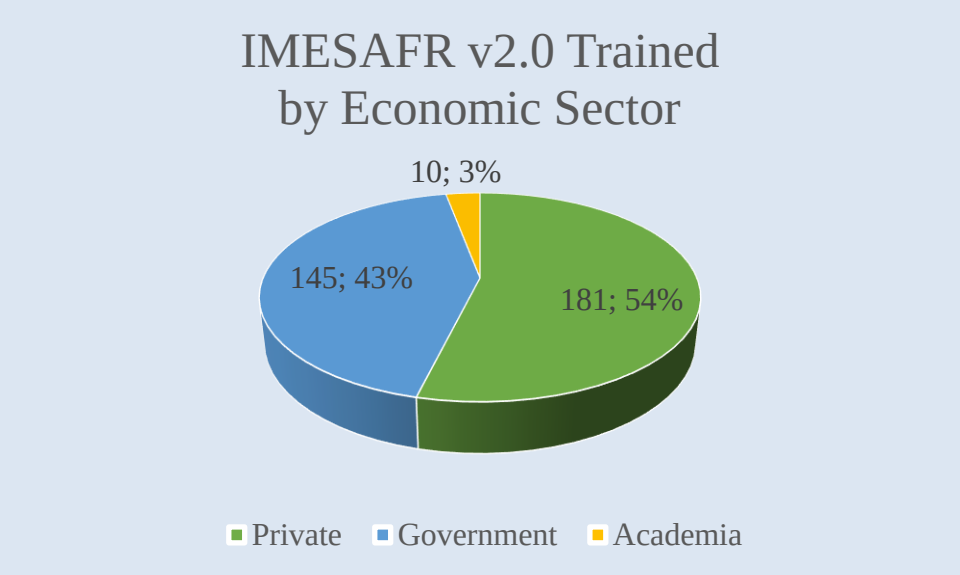

Figure 3 - IMESAFR v2.0 Trained by Economic Sector

Since its public release in April 2018, nearly 40 individuals have been trained to use IMESAFR v2.1. Of those individuals, most have been U.S. or Canadian citizens, as shown in Figure 2.

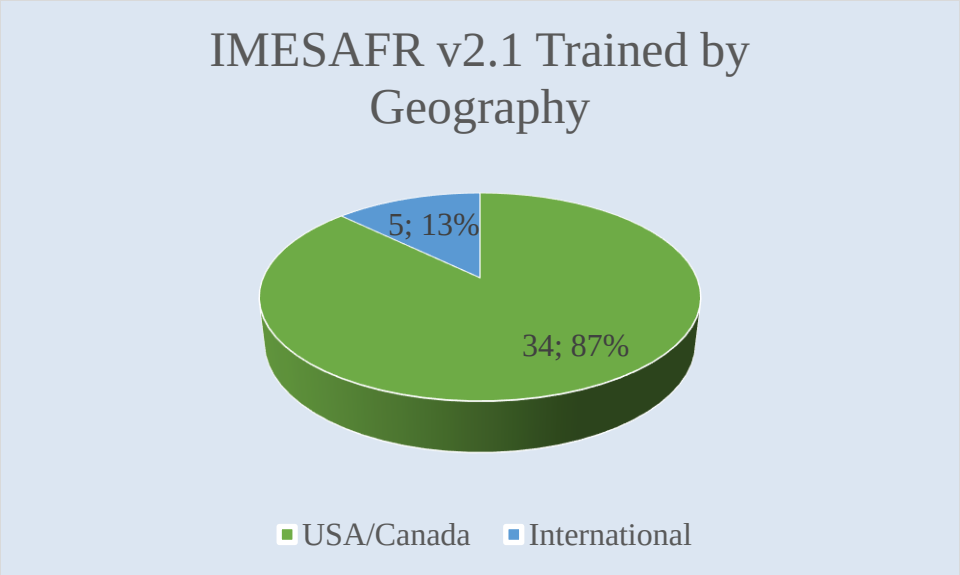

Figure 2 - IMESAFR v2.1 Trained by Geography

Those who have trained outside of the U.S. and Canada include citizens from Spain, Finland, and Australia. As of July 2018, nearly half of those trained to use IMESAFR v2.1 were government regulators, as shown in Figure 3.

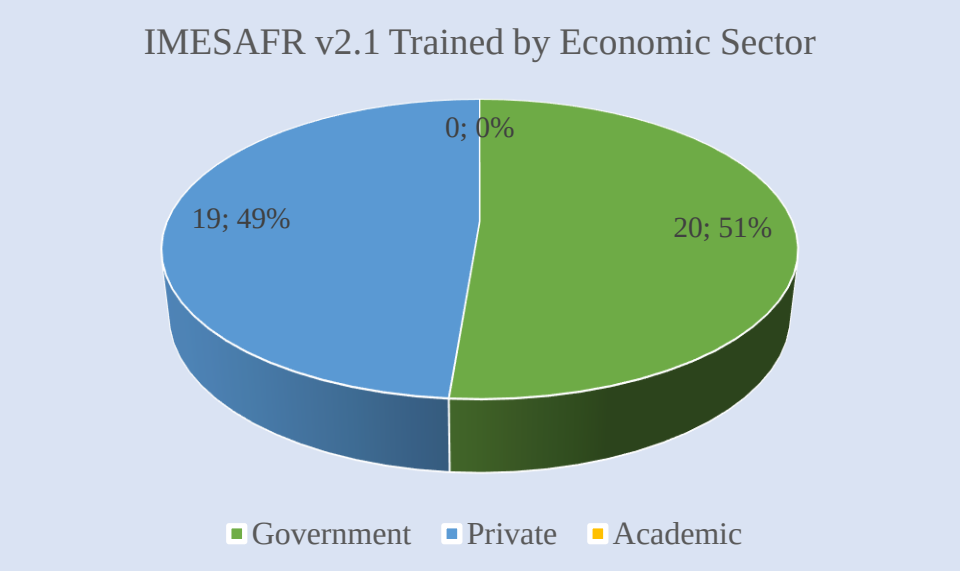

Figure 3 - IMESAFR v2.1 Trained by Economic Sector

1.5. Previously Presented Papers

Numerous IMESAFR papers have been previously presented, including the following:

- "Development and Application of Quantitative Risk Assessment Methodology," SAFEX Topical Papers Series, Paper No. 09/15, L. Santis, M. Swisdak, J. Tatom.
- "IMESAFR Version 2.0: A Next Generation Tool for Managing Risk Associated with Commercial Explosives Operations – 2014 Update," Visfotak Explosives Safety & Technology Society Journal, Volume 9, 2015; J. Tatom, M. Swisdak, L. Santis, T. Ross.
- "SciPan 5 Program Description and Data Summary," TR-NAVFAC EXWC-CI-1507, 2015; M. Anderson, R. Conway, J. Tatom, L. Cotton.
- "IMESAFR Sensitivity Studies," Proceedings of the 40th Annual Conference on Explosives and Blasting Technique (ISEE), Denver, CO, February 2014, T-14-00400; T. Ross, J. Tatom, L. Santis.
- "A New Way of Looking at Risk and QD Compliance," Proceedings of the 38th Annual Conference on Explosives and Blasting Technique (ISEE), Nashville, TN, February 2013; L. Santis, J. Tatom, M. Swisdak.
- "Features of IMESAFR V2.0," Chief Inspectors of Explosives (CIE) Conference 2013; J. Tatom.
- "A Proposed Test Program to Improve Explosive Risk Management," Proceedings of the 38th Annual Conference on Explosives and Blasting Technique (ISEE), Nashville, TN, February 2013; M. Swisdak, J. Tatom, L. Santis, D. Leidel.
- "IMESAFR Version 2.0: A Next Generation Tool for Managing Risk Associated with Commercial Explosives Operations," Parari 2011; J. Tatom, M. Swisdak, L. Santis.
- "An Updated Comparison of the Quin Site Explosive Event Results to IMESAFR Consequence Predictions," Parari 2011; J. Tatom, M. Swisdak, L. Santis.
- "A Comparison of the Quin Site Explosive Event Results to IMESAFR Consequence Predictions," SAFEX 2011; Proceedings from the 33rd DDESB Explosives Safety Seminar, Palm Springs, CA, August 2008; J. Tatom, M. Swisdak, L. Santis.
- "The Status of Risk Assessment in the Commercial Explosives Community," Proceedings from the 33rd DDESB Explosives Safety Seminar, Palm Springs, CA, August 2008; J. Tatom, L. Santis, M. Hardwick, D. Leidel
- "A New Tool for Managing Risk Associated with Commercial Explosives Operations," Minutes of the Eight Annual Australian Explosive Ordnance Symposium, Melbourne, Australia November 2007; J. Tatom, L. Santis.
- "A New Tool for Managing Risk with Commercial Explosive Operations," Proceedings of the 33rd Annual Conference on Explosives and Blasting Technique (ISEE), Nashville, TN, January 2007; L. Santis, M. Hardwick, D. Leidel, J. Tatom.
- "The Science and Testing Behind Quantitative Risk Assessment Models," Proceedings of the 33rd Annual Conference on Explosives and Blasting Technique (ISEE), Nashville, TN, January 2007; J. Tatom, M. Swisdak.

- "IMESAFR – A Tool for Managing Risk from Commercial Explosives Operations," Proceedings from the 32nd DDESB Explosives Safety Seminar, Philadelphia, PA, August 2006; L. Santis, M. Hardwick, D. Leidel, J. Tatom.
- "A Comparison of SAFER and IMESAFR Methods, Features, and Models," Proceedings from the 32nd DDESB Explosives Safety Seminar, Philadelphia, PA, August 2006; J. Tatom, M. Hardwick, L. Santis.

2. Status of IMESAFR v2.1

2.1. New Standard Features

IMESAFR v2.1 includes updates to both the interface and algorithms. Interface updates include the ability to consider a PES as an ES, display contours based on predefined ESs, enter a barricade blocking vertical debris, and blocking side impact debris when defining a barricade. This version also allows users to define color coding for risk, pressure arcs, and contours. Algorithm updates include the use of Mass Bin G to account for non-hazardous, low kinetic energy pieces of debris, as well as accounting for a frangible roof, frangible wall, or a combination of the two. IMESAFR v2.1 also includes updates to its QD interface to better handle IME Safety Library Publication 2 (SLP2) rules (i.e., the ATD). IMESAFR features logic to determine separation failures and appropriate aggregation according to ATF Table of Distances regulations including Inhabited Building Distance (IBD) and Public Traffic Route (PTR).

2.2. AN Capabilities

The AN module within IMESAFR v2.1 characterizes events associated with AN. Instead of using a TNT-equivalency, the AN module produces a prediction based on a more representative waveform.

APT was contracted by IME to work with the IME AN Working Group to develop the AN module for IMESAFR v2.0. Research behind the development of the module includes the use of data provided by IME members to ensure a thorough understanding of the blast wave characteristics of AN explosions and the effect AN explosions have on donor structures. Where adequate experimental and test data were not available, the model is "physics-based" (and also uses numerical modeling to provide "synthetic empirical data" to supplement the available). IMESAFR v2.1 includes the AN Engine as well as the PES types introduced in v2.0 for the AN module, overhead silo and railcar.

For a user to access the AN module, certain conditions must be met. The user must select a representative combination of PES, activity type, and explosive type to access the module. The user must then accept (check a box) that the conditions under which AN is stored/handled meet relevant guidelines and standards, which in turn validates the use of default event frequencies. Once accessed, the user can select the initiation mechanism: fire, contamination, or projectile/shock. Each mechanism defines the probability of event (P_e), upper-bound multiplier, and the percent contribution of the AN event. These values can be edited by the user. The user also can set the conservativism of the velocity scaling factor, and whether to consider the effects created by unreacted AN. The default selections for these last two factors are the conservative

options, although the effects of unreacted AN are complex and the "conservative option" may not be the more conservative for all scenarios/at all distances.

3. Status of Regulatory Acceptance

As mentioned previously, IMESAFR was developed with input from regulators from the beginning of the project. As this software tool has matured and acceptance of QRA-based methods has expanded, regulatory usage has increased. This increase satisfies a goal of this project: explosives safety software models available to regulators that provide a much better picture of risk, and therefore safety, than previously available. Moving forward, regulations need to be evaluated and, in some cases, modernized.

3.1. United States

3.1.1. Bureau of Alcohol, Tobacco, Firearms and Explosives - ATF

In the U.S., storage of commercial explosives is regulated by ATF. As participants in the development of IMESAFR, ATF has been heavily involved with determining how the existing standards can be modified, or how exceptions to them can be made, based on QRA. ATF grants "variances" from traditional QD siting requirements, similar to waivers in DoD vernacular. However, unlike waivers in the DoD, the industry cannot choose to have a variance – they must be granted one by ATF.

3.1.1.1. Risk Bank

The current approach used by ATF for granting risk-based variances is the "Risk Bank" method. Rather than comparing the numerical risk values from IMESAFR against a numerical criterion, the industry applicant demonstrates that the risks associated with their desired scenario is no greater than the risks associated with the "equivalent" QD-compliant scenario (i.e., the scenario with either the quantity lowered or the distance increased to meet ATD). IMESAFR is used to evaluate both scenarios, ensuring an "apples to apples" comparison.

ATF approved the first variance from the ATD based on QRA in April 2015. The facility for which this variance was granted was assessed with IMESAFR, and the scenario desired by the applicant provided considerably less risk than the QD-compliant arrangement they would have otherwise been required to implement. Since that time, ATF has granted eight more IMESAFR-based variances to American industry.

3.1.1.2. Numerical Criteria

The Risk Bank concept is "fair" in the sense the risk can be no higher than that associated with QD compliance. However, there is no guarantee that the risk from a Risk Bank-approved scenario is tolerably low when judged numerically. That is, if the QD-compliant scenario has high risk (which is admittedly not normally the case), then the variance might still be associated with more risk than desirable. Therefore, ideally ATF would establish numerical criteria to be sure that the risks were tolerable. IME has proposed numerical risk criteria to ATF, and the IMESAFR Science Panel (ISP) has been considering numerical values and implementation

details. ATF has been evaluating the probability of event methodology in IMESAFR; a decision on numerical criteria is expected in late 2018.

3.1.2. United States Coast Guard - USCG

In order to load/unload explosive material at a port in the U.S., a permit is required from the U.S. Coast Guard (USCG). Traditionally, this permit is granted based on passing QD rules for operations at a port. However, USCG Captains of the Ports (COTPs) have policy and precedence available to approve/disapprove requested quantities of explosives that do not meet QD requirements. To obtain approval from a COTP, IMESAFR can be used to submit a waiver request. Part of this process is to inform affected parties of the risks involved and obtain buy-in from them. USCG Headquarters also encourages USCG COTPs to use IMESAFR when incoming shipments do not meet QD.

Additionally, given that the largest percentage of U.S. manufacturing states do *not* have ports, safe entry of explosives at any given port likely has a *nationwide* economic impact, which is a cost-benefit factor directed to be considered by USCG policy.[3]

IMESAFR-based QRA solutions have been implemented at specific ports by individual COTPs (Ref. 6), and USCG Headquarters encourages the use of QRA, but they have stated that they look to ATF to establish policies related to commercial explosives.

3.2. International

3.2.1. Canada

3.2.1.1. Explosives Regulations - ERD

NRCan-ERD was the first Competent Authority to grant a QD derogation (the equivalent to an ATF variance) based on an IMESAFR-supported QRA. ERD had been granting derogations based on QRAs since the 1990s, but the advent of IMESAFR made the generation of such QRAs easier for the explosives companies, as well as much more rigorous, consistent, and easy to review from the regulatory perspective.

Canadian regulators quickly recognized the value/potential for a commercial explosives equivalent to SAFER and had people (John Buszard from ERD and Bert von Rosen from CERL) on the IMESAFR Development Team from early in the process.[4] ERD, CERL, and ATF have provided great assistance in the development of IMESAFR and have all been strong proponents of removing over-conservatism from the model.

ERD has referenced IMESAFR in both regulations and guidelines for many years and requires IMESAFR, or equivalent, analyses to support QRAs for QD derogations. ERD recognizes that there is no equivalent to IMESAFR available but for obvious reasons cannot mandate the use of

[3] Fryman, B., Evans, B., Flores J., Satkowiak D., *Explosives Safety Risk Assessments at Ports*, Minutes International Explosives Safety Symposium & Exposition 2018, NDIA Paper No. 20718, 6-10 August 2018, San Diego, CA 2018
[4] Mr. von Rosen remains on the Development Team and is also a charter member of the IMESAFR Science Panel. Mr. Buszard has retired from ERD and not been replaced; however, ERD has an open invitation from the IME to do so.

a single program or product for any purpose. The new Canadian Explosives Act (still in draft as of the writing of this paper) continues the practice of referencing IMESAFR as an acceptable tool and requiring the use of IMESAFR, or equivalent, for some applications.

The newest of these requirements is for QRAs for ports and wharves using new guidelines written by ERD. This has become a hot topic in both the U.S. and Canada.[5] ERD has written a new set of guidelines for QRAs for ports and wharves. These guidelines are in the final approval phase of the lengthy Canadian regulatory process before becoming an official document. The guidelines reference IMESAFR as an acceptable tool and requires the use of a tool such as IMESAFR to quantify the risk. The guidelines also reference the IME Guidelines for Port QRAs. But most importantly, the guidelines provide numerical targets for both individual and group risk. These are the "standard," so far as that exists: 1E-06 for Public Individual Risk and 1E-05 for Public Group Risk. ERD will also consider other preventative or mitigative factors (e.g., credible evacuation) included in a QRA. It is expected that these numerical risk criteria for ports and wharves will become the de facto risk targets for all applications (the individual risk target is already essentially that). They will also become a useful tool in discussions with other regulators in potentially setting numerical risk targets in other jurisdictions.

3.2.1.2. Canadian Armed Forces - CAF

In a country as large and relatively sparsely populated as Canada, it is generally possible to find areas for large stores of explosives or munitions. However, it is not possible to dictate where the next "task" will be to ensure that there will be no QD issues. Both statements are true for both commercial explosives companies and the CAF. On the commercial side, explosives are seldom used where there are no people; even remote mines soon generate a local population and infrastructure. On the military side, deployment goes where needs dictate and, again, this will seldom be to areas where there is no population. Therefore, the CAF have recognized a need for a quantitative risk tool for cases where QD is not possible and rapid decisions must be made.

CAF has decided that IMESAFR could be such a tool and sent several of its members to the April 2018 IMESAFR v2.1 training course in Ottawa. CAF was impressed with the tool and has decided to adopt it for their QRA needs. IMESAFR trainers were impressed with the capabilities of the CAF trainees and, at the completion of the course, invited the senior member of the trainees to join the IMESAFR Development Team and, possibly, the ISP. That person is transferring to another position, but the CAF will nominate a person to join these IME groups.

This in some ways completes the circle. The DoD recognized a similar need and out of that came SAFER, which spawned IMESAFR when the IME saw potential for the commercial explosives industry. Now IMESAFR is being adopted by the military of another NATO country, while SAFER evolves into a very U.S./site-specific risk management tool.

3.2.2. Beyond North America

The rest of the world is behind North America mainly for one obvious reason: SAFER was developed for the U.S. DoD and IMESAFR was developed for the U.S. explosives industry,

[5]Fryman, B., Evans, B., Flores J., Satkowiak D., *Explosives Safety Risk Assessments at Ports*, International Explosives Safety Symposium & Exposition 2018, NDIA Paper No. 20718, 6-10 August 2018, San Diego, CA 2018

which automatically spills over to Canada, given that the border barely exists for most IME member companies. No other country has accepted IMESAFR as a QRA tool to the extent Canada has. The U.S. (ATF) has accepted IMESAFR-driven QRAs to support requests for variances but are currently using an approval system (Risk Bank) that is more complicated that numerical criteria, and may soon be replaced, as previously described. However, the rest of the world is very interested in IMESAFR and other international regulators have been trained in IMESAFR and are considering IMESAFR-based QRAs to grant exemptions from QD requirements. While there are countries around the world considering IMESAFR in some fashion, the main interests are in Europe and Australia, which are covered in this paper.

3.2.2.1. Europe

Europe is an obvious candidate for the adoption of IMESAFR. The continent is fairly densely populated, making QD a potential issue. Many of the regulatory agencies are technically sophisticated and most of the countries use risk tools for the management of other hazardous goods.

The Nordics area has already embraced QRA as the use of Amrisk (or Ammorisk) has been accepted for many years for commercial explosives sites where QD is an issue. This is most broadly true for Norway and Sweden. All the region's Competent Authorities are now aware of IMESAFR and have trained people in it. The global explosives companies that have a very large presence in the regional explosives market are pushing for a conversion to IMESAFR and are being listened to. Elsewhere, Germany, the UK, and Ireland have all accepted IMESAFR-based QRAs for various explosives activities. The most interesting use of IMESAFR in Europe – and one that is accepted across the European Union (EU) – is to demonstrate compliance to the Seveso rules for upper-tier risk explosives manufacturing sites – or for other upper-tier risk sites (e.g., mines) where significant quantities of explosives are stored. It is now also extended to large AN stores, for which the AN Module will become the standard tool.[6] This is a relatively new application for IMESAFR but one which is likely be standardized in the EU – plus the UK, Brexit or not – into broad acceptance of IMESAFR as a risk management tool for energetic materials.

3.2.2.2. Australia

Australia is like Canada – if at opposite ends of the survivable temperature extremes – in that it is a very large country, occupied by relatively few people, and with a very large and important mining sector. But like Canada, explosives get used where people are located, or people move to where explosives are used, so QD is not always as easy to attain as might be expected. Also, Australia is a major manufacturer and importer of AN, which is often stored in very large inventories close to significant populations. While AN does not require QD for protection of people, there have been enough AN transport fires leading to explosions in Australia (and elsewhere) that no one is under the impression that no requirement for QD is a synonym for no risk. Further, the vast majority of "explosives" used in Australia are classified as UN3375 Ammonium Nitrate Emulsion (ANE), i.e., a 5.1 oxidizer requiring no QD. So, while Australia

[6] Swisdak, M., Evans, W., *Ammonium Nitrate Modeling in the AN Module of IMESAFR*, Minutes of International Explosives Safety Symposium & Exposition, NDIA Paper No. 20701, 6-10 August 2018, San Diego, CA

has very few issues with QD for 1.1 or 1.5 explosives, explosive companies and regulators recognize that with large amounts of AN and ANEs stored close to populations, there is a significant risk to be managed in these instances.

Another key point about regulation in Australia is that it is concentrated at the state level, with only a very loose federal overarching responsibility. Mining is concentrated in four states: New South Wales (NSW), Western Australia (WA), Queensland (QLD), and South Australia (SA). Each of the various state regulators take different views on risk management, including the use of IMESAFR. NSW is the most sophisticated of the states for risk management in general, but this has not been fully transmitted to the management of explosives and AN risk. SA is the most conservative of the states and is essentially a regulator, not a risk manager, with respect to explosives and AN. WA and, especially, QLD are the most progressive regulators for using risk management for inventories of all explosives, especially Hazardous Division (HD) 5.1 materials. This is particularly true for QLD, where the risk from 5.1 materials in populous areas is widespread. QLD is asking explosives companies to demonstrate that these non-explosive sites are acceptably low risk and expects IMESAFR to be used as a tool in this analysis. There is a large and growing base of IMESAFR-trained people, both industry and regulators, in Australia, with a growing acceptance that IMESAFR is an invaluable tool in the management of risk, especially where QD is not required. It can confidently be expected that the use and acceptance of IMESAFR will grow in Australia.

4. Testing Program

IME commissioned a "maturity matrix" study on IMESAFR in 2011; such a study is intended to identify areas within the model that are in the most need of additional empirical data anchor points. This led to a proposed IME test program intended to address such areas. (Ref. 7) This program also considered which elements of IMESAFR were not in common with DoD explosives safety considerations (and thus would not likely be the subject of a DoD test program). The test program identified three key areas: elevated AN/ANE storage bins, perforating guns (used in oil and gas operations), and relatively low quantities in smaller magazines. Additionally, as IMESAFR's AN Module was developed, testing was proposed for rail cars.

4.1. Tests Conducted

IME and ATF have supported two large debris recovery efforts (in addition to Explosive Safety Knowledge Improvement Operation (ESKIMORE) testing)[7] to supply anchor data to IMESAFR models: National Ground Intelligence Center (NGIC) Iron Warrior IV[8] (conducted by U.S. Army Engineer Research and Development Center (ERDC) at Dugway Proving Ground (DPG), and

[7] Conway, B., *Overview of AMO-CAT*, Minutes of 2018 International Explosives Safety Symposium & Exposition, NDIA Paper No. 21246, 6-10 August 2018, San Diego, CA 2018
[8] Tatom, John W., *Iron Warrior IV Debris Recovery*, Minutes of 2018 International Explosives Safety Symposium & Exposition, NDIA Paper No. 20724, 6-10 August 2018, San Diego, CA 2018

Combating Terrorism Technical Support Office's (CTTSO) "Derailed"[9] (conducted by Sandia at DPG).

4.2. Planned Tests

IME and ATF hope to jointly conduct an overhead bin test and a perforating gun test program by 2020.

5. Future Plans

QRA is the future of explosives storage in the U.S. QD methodology is not well-suited to assess actual risks associated with activities around storage of explosives. The required use of QD in inspections has led to overly restrictive limits that are not based on scientific assessment of the risks to public safety. The commercial explosives industry will be much better served by a modern, science-based system for understanding, evaluating, and minimizing the potential risks associated with explosives storage.

That being said, IME is pleased to be able to include QD compliance features in IMESAFR. The QD Module will better handle the inclusion of SLP 2 QD rules (i.e., the ATD) in IMESAFR. This allows the user to site storage of explosives using distances in compliance with the quantity of explosives. In the same interface, the user can see the quantitative risk for that siting. IME has proposed to ATF the acceptance of a numerical criterion of 1E-6 for tolerable annual risk to an individual member of the public.

ATF has already accepted IMESAFR-based variances from ATD. IME is not opposed to regulation that is realistically achievable, aligns with IME best practices, and improves safety and security. Good regulations and good business practices often have the same goals.

IMESAFR v2.1 is commercially available for use internationally. There is an increasing demand for QRA tools from the international community. This international demand will require the inclusion of other regulatory tables in future IMESAFR updates. IME and APT will continue to work together to add new features and allow the user much more control over the realistic treatment of real-world scenarios, such as the ability to populate effective height and distance for a barricade – and have it treated accurately in the model. As many regulatory agencies are becoming more technically sophisticated, the acceptance of tools like IMESAFR will be a complement to other risk tools for the management of hazardous materials.

IMESAFR is intended to provide a conservative assessment of the average and most probable level of risk over a period of time. The amount of conservatism in IMESAFR is inversely related to the amount of available data. If there were very few or no data points available to anchor an algorithm, the models in IMESAFR are designed to err on the side of caution. However, when an algorithm has been corroborated by test or accident data, those models do not include the same level of conservatism. The inclusion of too much conservatism would prevent model results from comparing well with the empirical data anchor points, or reality. It is important that future testing be conducted to reduce conservatism and verify accuracy of data in IMESAFR. Several building

[9] Hoffman, J., Fryman, B., *IME Derailed Debris Collection*, Minutes of 2018 International Explosives Safety Symposium & Exposition, NDIA Paper No. 20737, 6-10 August 2018, San Diego, CA 2018

types unique to the commercial explosives industry and IMESAFR have been identified as needing further verification. Information on the breakup and debris-producing characteristics of these unique structures is required so that more realistic models can be included in IMESAFR.

IME is continually working to improve the output of IMESAFR to gain credibility with regulators. Current and future collaboration with regulators will make for a seamless transition to QRA.

References

1. DDESB Technical Paper 14, "Approved Methods and Algorithms for DoD Risk-Based Explosives Siting" Revision 4a, 17 March 2017.
2. Tatom, J., Hardwick, M., and Santis, L. "A Comparison of SAFER and IMESAFR Methods, Features, and Models", Minutes of the 32nd DDESB Explosives Safety Seminar, August 2006.
3. Santis, L., Hardwick, M., Leidel, D., and Tatom, J., "A New Tool for Managing Risk
4. Associated with Commercial Explosive Operations," Proceedings of the 32th Annual Conference on Explosives and Blasting Technique (ISEE), February 2007.
5. Swisdak, M., Tatom, J. and Santis, L., "A Comparison of the Quin Site Explosive Event Results to IMESAFR Consequence Predictions," Minutes of 10th Australian Ordnance Symposium (PARARI 2011), November 2011.
6. Tatom, J., Hardwick, M., and Leidel, D. "The Status of Risk Assessment in the Commercial Explosives Community," Proceedings from the 33rd DDESB Explosives Safety Seminar, Palm Springs, CA, August 2008.
7. Swisdak, M, Tatom, J, Santis, L., Leidel, D.,"A Proposed Test Program to Improve Explosive Risk Management," Proceedings of the 37th Annual Conference on Explosives and Blasting Technique (ISEE), February 2012.