EFEE NEWSLETTER

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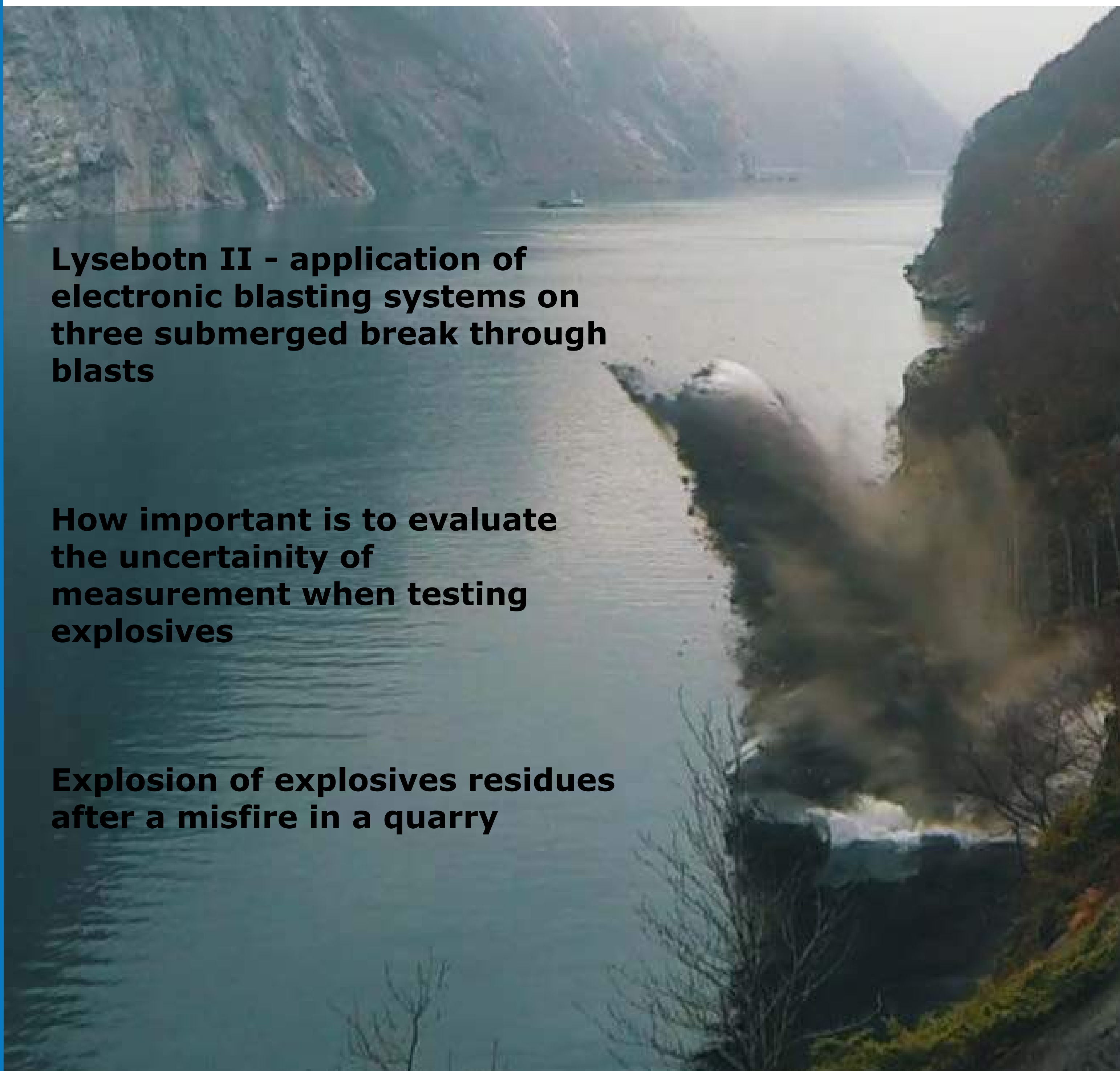

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February 2018

NEWSLETTER

February 2018

We in EFEE hope you will enjoy the present EFEE-Newsletter. The next edition will be published in May 2018. Please feel free to contact the EFEE secretariat in case:

- You have a story you want to bublish in the Newsletter
- You have a future event for the next EFEE Newsletter Upcoming events list
- You wish to advertise in EFEE Newsletter

Or any other matter.

Jari Honkanen, Chairman of the Newsletter Committee and the Vice President of EFEE and

Teele Tuuna, Editor of EFEE Newsletter - newsletter@efee.eu

Dear EFEE members, the President´s voice

It is the New Year 2018, which means a lot of new beginnings and some old ones, which still needs to be worked on. Doing something better certainly should feature on our list - of New Year resolutions. I would like to take this opportunity to extend my best New Year wishes to all of you - our National Associations, Corporate members, Individual members, Honorary members as well as to our so far two Student members, to have a good and successful year 2018. In this year our federation is going to have some very important and challenging events, so please let me briefly describe and summarize those events for you.

We are really very happy that since the beginning of August 2016, when we noted very good news from Sweden and our application for PECCS project application (Pan-European Competency Certificate for Shotfirers / Blast designers by European Federation of Explosives Engineers) was approved for funding, the project moves steadily ahead as scheduled. The project has 8 partners: Estonia, Sweden, Norway, Portugal, Germany, United Kingdom, Romania and France. An official website of this project, www.shotfirer.eu, was also created, this is where you can find out all the relevant and important details.

At the same time we have written a letter to all National Associations, about the PECCS project regarding the future of the explosives shotfirer certifications in the European Union, in the hope of their support. The outcomes of this project are: learning materials with examining questions, exercises, a course based on these materials and an online learning program which will be available on the internet for free on www.shotfirer.eu. The PECCS project will complete a course with training means, which consists of about 1000 text sheets, pictures and drawings, exercises and an exam. The first test course for this materials already took place in Stockholm, Sweden, with the help from the PECCS contractor (BEF) between 11th -15th of December 2017.

The next test courses will be organized in France, Paris (23rd – 27th April, 2018) and in Germany, Dresden, (10-14th Sept, 2018). For authorities, who are issuing blasting certificates in Europe today and for the teachers/instructors, who are training blasters today, there will be no attendance fee for the test courses. All participants will receive a certificate of attendance. For registration to any of our test courses, or for more information, please visit project website www.shofirer.eu or contact us over the following email, info@shotfirer.eu

The autumn Council meeting for EFEE will take place on 7th and 8th September in Dresden, Germany to celebrate and commemorate the 30 years of EFEE. The reason to choose Germany for hosting this very important event for our federation is quite simple. EFEE was founded on 20th October 1988 in Aachen, Germany. Five nations were represented at this day for founding EFEE: Finland (Raimo Vuolio), the Netherlands (Henk Grünfeld and Joep Peeters), Switzerland (Didier Fardel and Hans Gysin), UK (Ken Broadhurst and Mike Groves) and Germany with nearly the complete board of the German association.

After long discussions regarding the English name of the organization, with suggestions as "European Explosives Engineering Institute", the name was finally decided to be the present name "European Federation of Explosives Engineers" (EFEE).

Besides the regular EFEE Board meetings, Council meetings and Annual General Meeting scheduled for this year, our federation participates also on meetings of Notified Bodies for Explosives as well as on meetings of Explosives Working Group. EFEE is regularly represented on both types of meetings by Jörg Rennert who makes a great work for our federation.

I´m very delighted to introduce you the first issue of EFEE Newsletter in this year. Please do not finish reading our Newsletter with my foreword but kindly continue to read - all the interesting articles are prepared especially for you in this Newsletter.

Igor Kopal, President of EFEE

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Reduced fees on workshops in conjunction with EFEE conferences.

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Gain access to list of European standards on vibrations and air blast through the member section of the EFEE website.

Gain information of and possibilities to influence the EU shot firing procedures and attend standing committees like EU-directives, Environmental and Newsletter.

Supporting of professional explosives engineers.

Network of professional explosives engineers.

A possibility to be part of the EFEE Council and influence the EU explosives society.

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Information on conferences and professional courses.

SAFEX information on incidents in the explosives industry.

Corporate Members also have the benefit of a 25% discount on ads in the EFEE Newsletters

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LYSEBOTN II – APPLICATION OF ELECTRONIC BLASTING SYSTEMS ON THREE SUBMERGED BREAK THROUGH BLASTS

SUMMARY

Lysebotn kraftverk (Hydro Power plant) is located in the inner most of Lysefjorden in South west of Norway. The hydro power plant has been in operation for more than 60 years. In 2012, it was decided by the owner to build a new power plant, Lysebotn II, at the same location to avoid taking existing facilities out of production for renovation. The construction of Lysebotn II started in 2013 and the new power plant is scheduled to be ready for production in 2018. As part of the development of Lysebotn II, it is necessary to use the "ancient" Norwegian technique of underwater tunnel piercing. The technique is to construct an intake tunnel under a water magazine and leave a short plug of solid rock that will be blasted when infrastructure in the rest of the power plant is ready. The technique has been widely used in Norway for more than 100 years, but in the past 20-25 years the number of underwater tunnel piercings has decreased as there are fewer hydro power developments now than before. An underwater piercing is a critical part of a hydro power plant development, and therefore, comprehensive measures are taken to ensure that the result is successful. The final brake through blasts at Lysebotn II (two intake tunnels and one outlet tunnel) were all, as the first time in Norway, initiated with electronic detonators to ensure the initiation.

INTRODUCTION

Lysebotn kraftverk

Lysebotn Kraftverk (hydro power plant) is the heart of the Lyse Group and has supplied the nearby region with electric power for more than 60 years. The construction of the power plant started after the second world war and the first part was finished in 1953. After this, an extension was made and by the time it was complete in 1964 it was the largest hydro power plant in all of Norway. When the powerplant was due for renovation, it was decided that a new power plant was to be constructed, namely the Lysebotn II.

Lysebotn II

When the Lyse Group decided to renew and renovate the old Lysebotn power plant, they had two options: Either to shut down the existing plant and do the necessary renovation or to construct an entire new power plant. The decision was the latter. By chosing this option, the existing plant could be in operation during the construction phase and in the end, a brand new and modern plant would take over the production. Implenia Norge AS won the contract in constructing the new power plant. The construction work started in 2013.

All in all, since the works started about 11 000 meters of new tunnels have been constructed in addition to a new power plant located 1,5 km into the mountain. All excavation of tunnels and caverns have been done by conventional drill and blast. Of the 11 kms of new tunnels, about 9 kms are new waterways. The works will be finished in 2018 and production of electric power can commence later that year. The Lysebotn II power plant will have an installed capacity of 370 MW which is 160 MW more then the old plant. Lysebotn II will take use of the same catchment area as the existing plant (*Sødal, Nilsen, Lauvdal, 2015*) and the total vertical drop from is approx. 685 meters (*Lyse, 2016*).

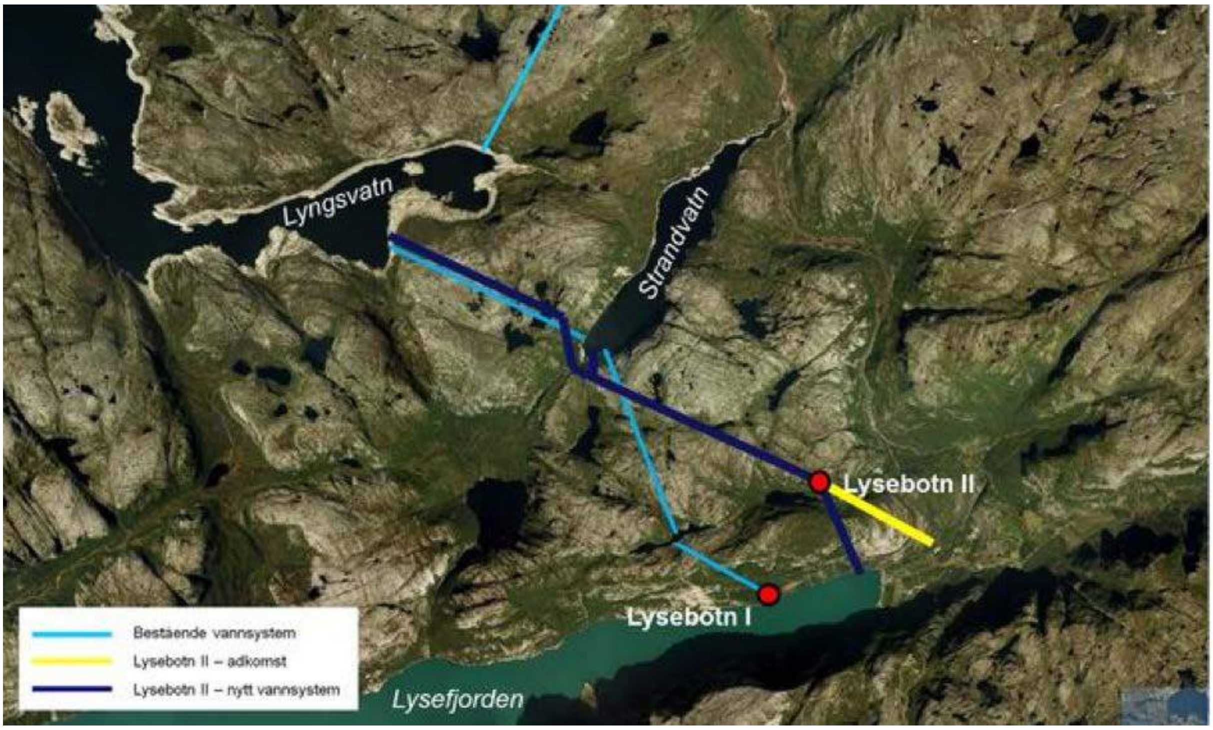

Figure 1: Lysebotn I (old plant) and Lysebotn II new plant. Overview (Sødal, Nilsen, Lauvdal, 2015)

The construction of the new power plant required planning and performing three submerged tunnel piercings: the new intakes in lake Lyngsvatn and lake Strandvatn, and the outlet in the Lysefjorden.

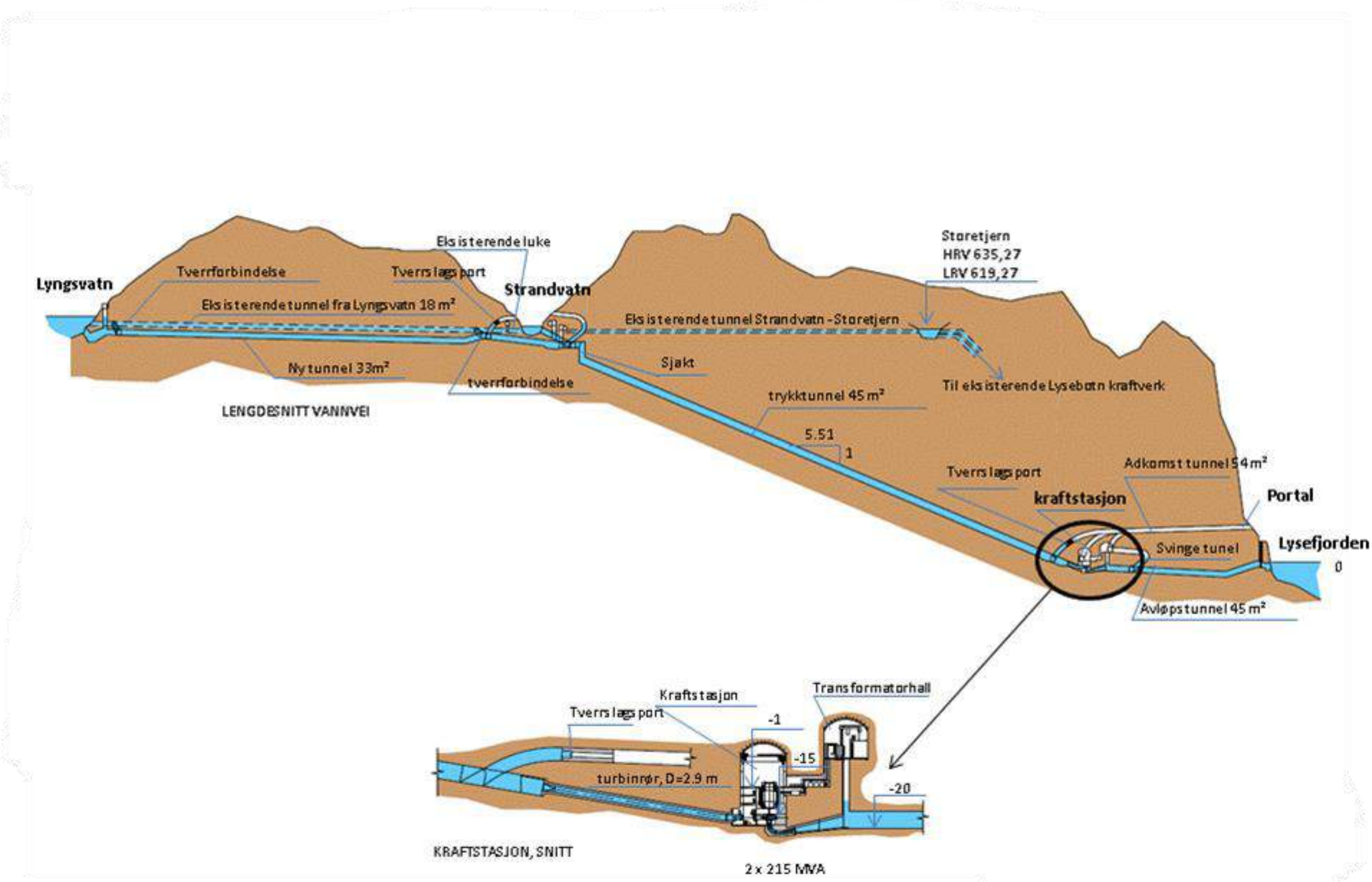

Figure 2: Longitudinal section of Lysebotn II. (Sødal, Nilsen, Lauvdal, 2015)

UNDERWATER TUNNEL PIERCINGS IN NORWAY – «THE NORWEGIAN METHOD»

History

The topography of Norway has made it obvious to take advantage of the many naturally elevated water systems and use them as magazines for hydropower production. To lead the water into a power plant, a tunnel is constructed under a reservoir to drain it from the bottom. Underwater tunnel piercings is a common method that has been used in Norway for a long time. The first one is probably from the time around 1890 when a tunnel was blasted under the Demmevatn lake near the Hardangerjøkulen glacier. The purpose of this tunnel was not hydro power production, but rather a measure to control flooding in the springtime. Ten years later, the first underwater tunnel piercing for hydropower purpose was blasted. Since then, many piercings have been performed on a wide variety of depths. Especially in the time span between 1960 and late 1980s, during the «hydro power boom», such blasting operations were common. It is uncertain exactly how many piercings have been done, but most likely around 600. The deepest ones have been performed when constructing landing of subsea oil and gas pipes along the west coast of Norway.

The deepest ones have been successfully blasted on depths up to 200 meters.

Methods of piercings

Underwater tunnel piercing can be divided into two main categories: Open system and closed system. The open system type of piercing is, as the name reveals, open with a connection to the atmosphere trough a shaft or acess tunnel. In such a system, the water can flow in with little resistance and the momentum of the water can flush the blasted rock material a long way into the tunnel system. To prevent this from happening, it is therefore common to fill up the tunnel and shaft with water before the blast. The level of filling is adapted to the water level in the reservoir. It is also important to avoid water all the way up to the blast itself. If the blast is initiated directly into water, a high amplitude pressure wave will pass through the water at potentially damage gate constructions downstream.

The closed system type of piercing means that there is no direct contact through to the atmosphere. Normally, this is performed by closing the intake gate upstream the gate shaft. The tunnel between the gate and the blast is considered to be a closed volume.

Depending of the water pressure on the outside of the blast and the length of tunnel between the blast and the gate, this method have been applied sometimes with a dry tunnel with no overpressure in the closed volume. Other times, air has been added to establish a certain level of air overpressure on the inside.

However, it is as common to add some water inside this closed volume to work as a barrier that will lower the velocity of water and rock material that flows into the tunnel after the blast. A certain level of water will also make it easier to increase the air pressure on the inside by reducing the volume of air.

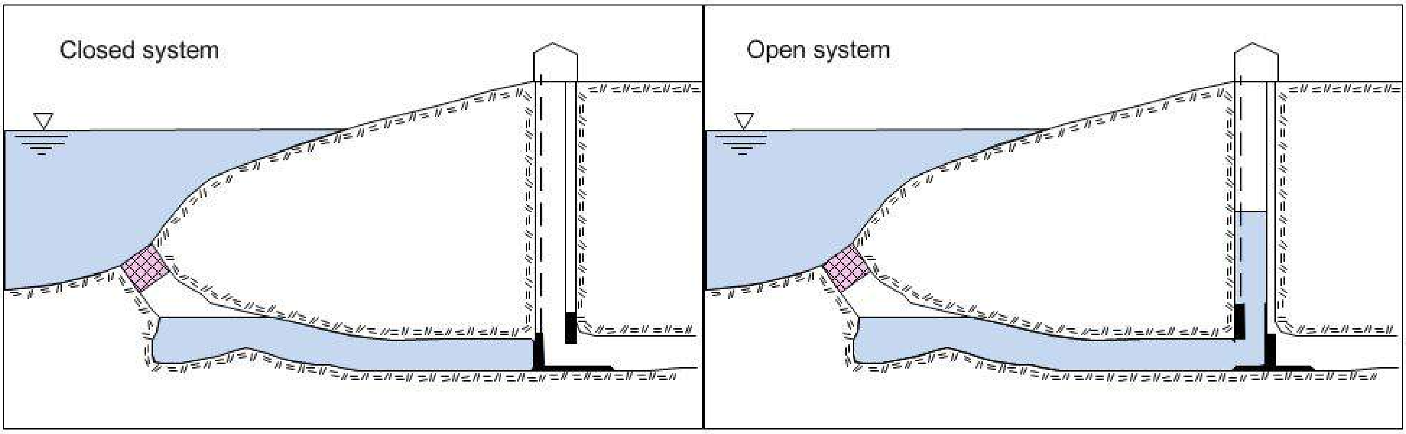

Figure 3: The two main types of underwater tunnel piercings. Closed system (right) and open system (left)

The break through blast into a reservoir (piercing) is considered a critical part of the construction of a hydro power plant. Therefore, a number of measures are taken to make sure that the blast is successfully carried out and that the result is an opening into the reservoir that is in line with the dimensions of the rest of the power plant. It is of great importance that the products used (explosives and ignition system) are performing as planned. Compared to a normal tunnel blast, the break trough blast is substantially overcharged. If the blast is to be put under air overpressure, it is important that both the explosives and detonators are designed for this.

Also, one would arrange for each blast hole to have at least two separate points of ignition. In addition there will be arranged for certain connection from the blast to the blasting machine. Up until the 1990s it was common to apply electric detonators on break through blasts. The electric detonators are to some point possible to measure and probe for errors, but on the other hand, the potential of current leakage and stray currents lead to a transition to non-electric detonators to address the danger of premature detonation. However, the non-electric detonators are not possible to measure and the primary control measure is visual inspection.

The rule of thumb is to double up in every connection point with extra connectors and two separate lines of ignition.

THE BREAK THROUGH BLASTS AT LYSEBOTN II.

When planning the break through blasts at the Lysebotn II project, Implenia Norge AS together with Orica Norway AS decided in an early phase to use electronic blasting system (EBS) on all three blasts. By using electronic detonators, there is both a high level of control and also inherent safety measures against stray currents. In addition there was the benefit of a high flexibility in delay times. Standard electronic detonators (Uni tronic™ 600) had the sufficient specifications regarding static pressures that was expected on the blasts. The detonators could be measured all the time from charging to blasting. All blast were planned and performed at depths where regular dynamite pipe charges (Eurodyn Magnasplit) could be applied.

Outlet Lysefjorden.

The outlet tunnel from the power plant to the fjord is about 1250 meters. From the surface, an access tunnel was blasted in a spiral down to a cavern 8 meters above the outlet tunnel. From here a gate shaft was constructed. The distance from the gate shaft to the break through blast was 70 meters. The water pressure outside the blast was 2-4 mWc in the top and 10- 12 mWc at the bottom of the blast. The blast was drilled horisontally from the inside out to the fjord. Due to the rock conditions, the longest blast holes was up to 11 meters at the bottom of the blast. The shape of the blast was circular with a diameter of 6,7 meters on the inside. Because of the relatively shallow water on the outside of the blast, it was decided to perform the blast as an open system piercing with no water added to the tunnel. A temporary concrete plug was casted upstream to the gate shaft to prevent water from flooding back to the power station that was still under construction at the time of the blast. It was expected that the water would flush into the tunnel and up the gate shaft, so all infrastructure in the cavern above the shaft was either removed or secured. In total, 800 kg of dynamite, 228 electronic detonators were used (two dets/hole). In addition, a wooden plug was used to lock the charges in the blast holes. The blast was initiated at noon on January 25th 2017.

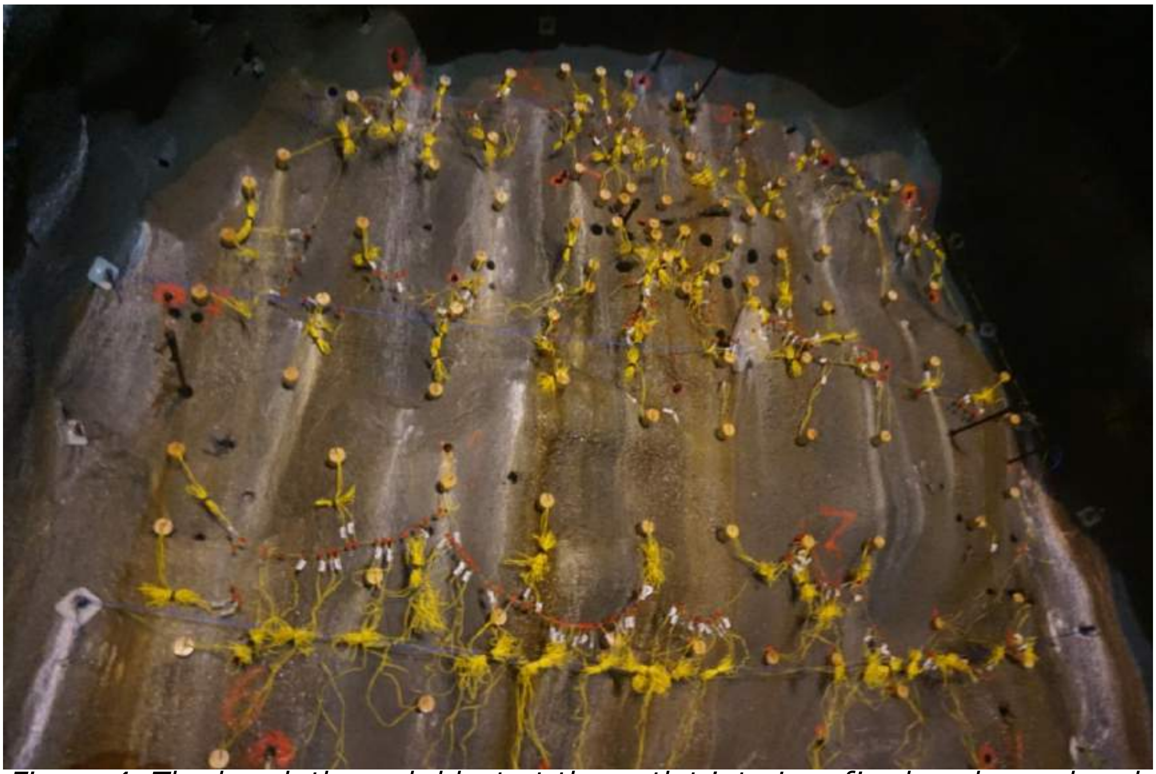

Figure 4. The break through blast at the outlet into Lysefjorden charged and hooked up. Photo: Espen Hugaas

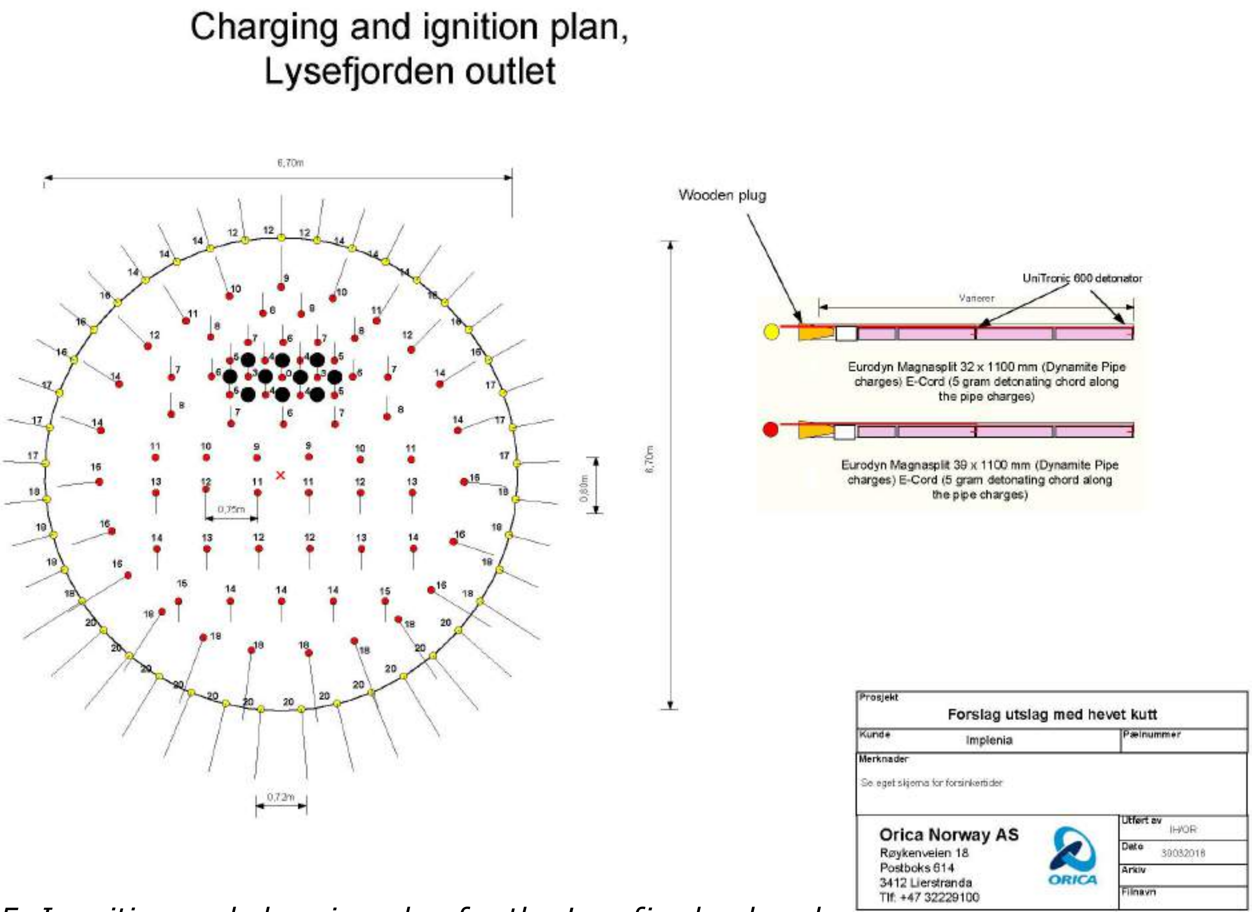

Figure 5. Ingnition and charging plan for the Lysefjorden break piercing

Intake lake Lyngsvatn

A new intake tunnel was constructed in parallel to the existing intake tunnel. The piercing at Lake Lyngsvatn was the deepest of the three with potentially 50 mWc over the break through blast. However, the blast was planned so that it could be performed at as low as possible water level in the reservoir, but this again had to be adapted to the operation of the existing power plant. It was decided that the blast was to be performed as a closed system piercing with water inside the closed volume. A wide range of different scenarios were considered and calculated to make sure that the pressure levels from the inflow of water would not exceed the limits of the gate construction.

Ideally, one would increase the pressure in the closed volume before the blast to such a level that the addition of gases from the explosives would bring the inside pressure almost up to the level of the outside static pressure from the body of water. (Solvik, 1995) However, this must also be adapted to the system limits of explosives and detonators. From the gate shaft, the intake tunnel was blasted on a declining angle for about 80 meters before levelling out near the position of the blast (120 meters from the shaft). Directly under the blast, an extra volume was excavated to collect rock debris from the blast.

The break through blast was drilled with a circular cross section with the area of 25 m^2. The length of drill holes was in average 4,5 meters. In total, 76 holes were charged. A total of 550 kgs of dynamite pipe charges and 152 detonators were used (two in each hole). Since the time of firing was in the middle of February, the water level in the lake was estimated to be 20 meters above the blast. It was installed valves for air and water through the gate construction to control the level of water and air inside the closed volume. The geometry of the tunnel between the gate and the blast mad it easy to compress air simply by adding water.

To keep control over this process, a system for reading the water level under the blast was created, and in addition, a pipe for air was laid all the way to the blast. A manometer on this pipe would then tell the pressure in the closed air pocket under the blast. In the event that extra air had to be added or pressure had to be released, this pipe would be used for that purpose. Scaffolding was installed as a working platform when charging and hooking up the detonators. The break through blast was drilled vertically up into the lake. Wooden plugs was used to secure the collars and lock the charges inside the holes. All detonator leg wires were secured and a firing cable was connected. After charging and removing of the scaffold.

Figure 6. Scaffolding installed under the lake Lyngsvatn break through blast. Photo: Espen Hugaas

The 9 day long process of water filling began. (67 cubic meters of water per hour through a pipe more than 3 kms long). All the time when water filling was ongoing, the detonators were measured to make sure that nothing had happened that could affect the blast. The blast was fired on February 16th 2016.

Intake lake Strandvatn

Like at Lake Lyngsvatn, an intake tunnel was constructed under lake Strandvatn in parallel to the existing tunnel. A zone with bad ground conditions lead to a correction of the position of the point of the break through blast. The geometry of the tunnel system upstream the gate shaft was different to the lake Lyngsvatn intake. From the gate, the tunnel floor ascended slightly and the distance from the gate to the blast was about 185 meters. The blast itself was planned to be identical to the Lyngsvatn blast, but severely worse ground conditions made drilling hard and the result was a smaller cross section then planned.

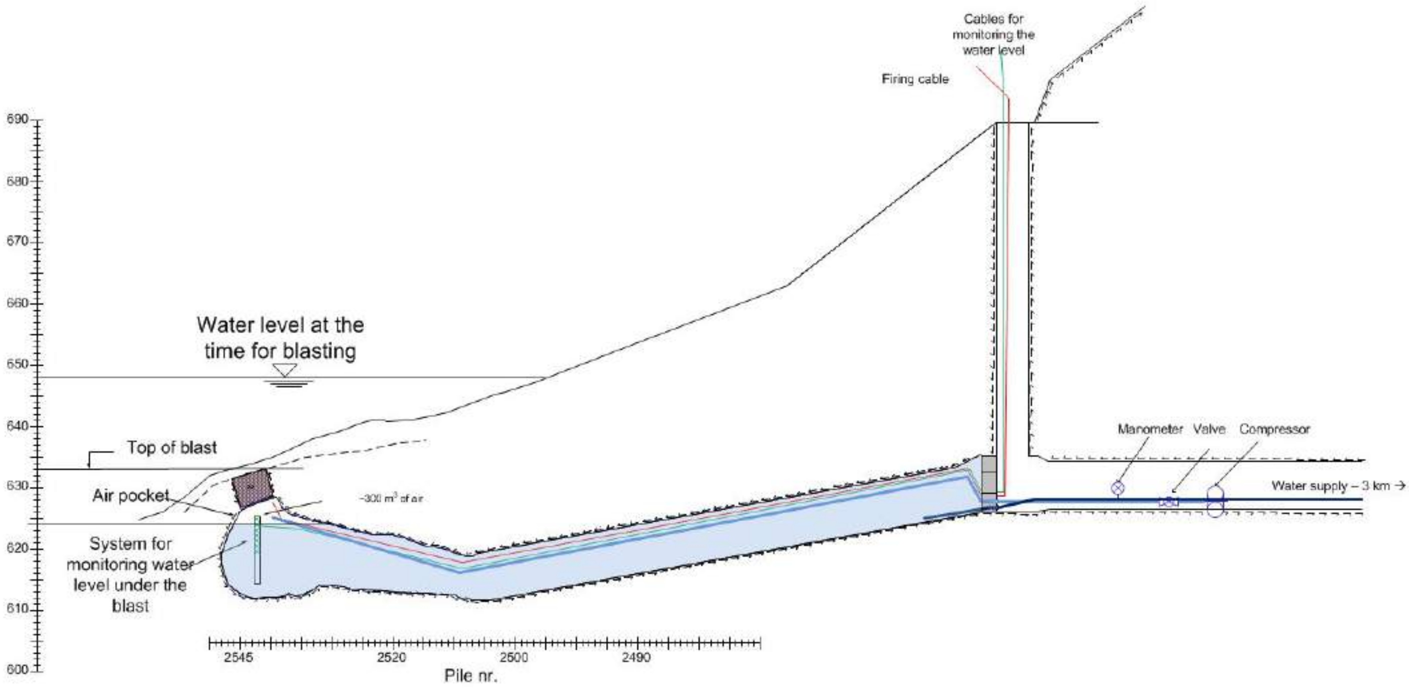

Figure 7: Cross section of the situation and instrumentation at the break through blast at lake Lyngsvatn.

However, the opening would in any case be sufficient for the capacity of the power plant. The charging work was identical to the Lyngsvatn intake, (scaffolding as working platform) and water and air levels were controlled by the same measures. The outside water pressure was lower than at the Lyngsvatn blast (7-8 mWc). The break through blast at lake Strandvatn was performed on March 9th 2017.

Blast results

All three underwater tunnel piercings were to be considered successfully performed. There were no problems during charging and water filling. Both the Lysefjorden outlet and the Strandvatn intake had to be blasted with blast holes considerably longer than originally planned, but this did not affect the end results.

Figure 8. Detonators are connected to bus wire and secured to the wooden plugs that locks the blast holes. Photo: Espen Hugaas

Figure 9: No doubt that the blast in the outlet tunnel broke out into Lysefjorden (Lyse TV, 2017)

Figure 10. From the inspection after the piercing into Lysefjorden. (Photo: Stillframe from inspection movie, 2017)

Figure 11: The fumes from the blast breaks the ice at lake Lyngsvatn (right) and laje Strandvatn (left) Photo: Espen Hugaas

Use of electronic blasting systems

By using electronic blasting systems on critical blasting operations such as underwater tunnel piercings, enhance the level of certainty of blast performance. The electronic detonators are fully measurable both when considering the number of detonators that are connected to the blast circuit and when controlling the level of current leakage. Compared to non-electric detonators, the electronic detonators gives a more clear and easy way of working at the face. On a break through blast charged with non-electric detonators, one have to pay close attention to the two shock-tubes coming out of each blast hole to make sure that these are connected in two separate bunches, and that each bunch have double bunch connectors. With the electronic detonators, all detonators are connected to the same common bus wire that is continuously monitored so that any faulty detonators or current leakage can be addressed immediately. On the break through blast at the Lysebotn II project, only one firing cable was used. This was considered to be sufficient as the charging process as well as the water filling process was accompanied by continuously monitoring of the blast circuit. However, there is also possible to apply two completely separate firing lines for increased certainty.

CONCLUSION

When performing break through blast on underwater tunnel piercings it is of great importance that the blast result is according to the plan. A misfire has to be avoided. In this perspective, it is natural to use the most suitable tools to achieve a high level of certainty. The use of electronic blasting systems are a subject for debate in the light of regular tunneling operations due to extra costs. However, on critical blasts such as described in this text, there is no doubt that it is the correct approach.

Olaf Rømcke, Civil Engineer, Orica Norway AS
Espen Hugaas, Civil Engineer, Orica Norway AS

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HOW IMPORTANT IS TO EVALUATE THE UNCERTAINTY OF MEASUREMENT WHEN TESTING CIVIL USE EXPLOSIVES

Recently Romania adopted the European legislation regarding the explosives for civil use Directive 93/15 CEE. In the annex of the directive are established the essential safety requirements which shall be tested applying the harmonized European standards. For this reason the testing facilities shall be updated and the paper describes the researches made in INSEMEX in the Laboratory for Explosives and Blasting Techniques to achieve the level of the requirements provided by the European standard for determination of the resistance to hydrostatic pressure of explosives.

To certify a product means to establish its compliance with a series of specifications. The documentation of the product covers the parameters to le met by the designed product so as to be operational, reliable, healthy and safe for man and environment, cost efficient and so on.

The purpose of tests and measurements is to evaluate a product and say whether the item in question is in compliance or not with the specification.

At the moment when we reports the final result of measurement of a physical dimension, it is compulsory to have a quantitative type indication on the quality of the result so that the persons which are going to use the result can evaluate its trustworthy ness. Consequently is necessary to have available a procedure easy to use, easy to understand and agreed to by everyone for being able to characterize the quality of the result gained after a measurement, i.e. the evaluation and the expression of its uncertainty.

The idea of „uncertainty" as a numerically expressed attribute is relatively new in the history of measurements, although the error and the analysis of errors represent concepts which have been part of the science of measurements (i.e. of metrology) for a long time and it is widely recognized the fact that after all known or the supposed components of error have been evaluated and the suitable corrections have been applied, a certain level of uncertainty regarding the validity of the result stays, i.e. we have a doubt on how correct this result, might show the value of the measured dimension.

If no information is available on the uncertainty of measurement or whether these information is not correct, we can get a limit situation when a product is considered as being in compliance but actually, this product doesn't exactly meet the stated parameter, i.e. the product is non-compliant and cannot be used safety on it shall display a diminished technical and economic efficiency.

The certification of products for the regulated fields of activity (here also being included the for explosives civil use) involves a high responsibility in issuing the test reports, and the certificates of conformity, and the decision to declare a product as compliant or non compliant shall be grounded on accurate information. The certification of a non-compliant explosive may generate hazardous situations; the rejection of a compliant explosive may generate economic losses.

The same as when the almost universal use of the I.S. has given coherence to all scientific measurements, a concord on the evaluation and express of the uncertainty of measurement allows an easy and correct understanding of a wide range of measurements made for scientific, engineering, trade, industry and legislative purposes.

The ideal method to evaluate and express the uncertainty of a result should have a general character, i.e. applicable to all types of measurements and to all data used during measurements.

The dimension used to express uncertainty shall:

- be logical by itself, it shall derive directly from its component parts, irrespective of the group size of these parts or of their division into sub-component parts;
- have a transferable character, i.e. a the direct use of a result or of a component of an evaluated uncertainty to evaluate the uncertainty of another measurement where the same result is being used.

It is necessary quite often in many industrial applications that the result of a measurement be surrounded by a range which covers the largest part of the distribution of values possible to be assigned to the dimension subjected to measurement.

The ideal method to evaluate and express the uncertainty of measurements shall have to provide such a range with a suitable trustworthy ness or covering probability.

Generally, the uncertainty of measurement covers several component parts which can be divided into two categories in connection to the method used to estimate their numerical dimensions:

A. are the ones evaluated by statistical methods.
B. are the ones evaluated by other methods.

The isn't always an univocal correspondence between the classification with A or B categories and the classification with „random" and „systematic" uncertainties used in the past.

The phrase „systematic uncertainty" should be avoided since it may lead to misinterpretations.

A detailed report of the uncertainty should include the full list of its components and should state. The method used to get the numerical dimensions for each component.

The composed uncertainty shall be characterized by the numerical dimension gained by applying the usual method for combining the available options. The composed uncertainty together with its component parts shall be expressed as „standard deviations".

Whether it is necessary to multiply the composed uncertainty with a certain coefficient to get the global uncertainty, them it is always necessary to state that coefficient.

When we do measurements and make reference to international standards, further details on the result of the measurement and on its uncertainty are necessary. Several measurements are being performed with periodically calibrated instruments or with instruments found under the incidence of legal metrologic inspection, whether the

Several measurements are being performed with periodically calibrated instruments or with instruments found under the incidence of legal metrologic inspection, whether the instruments meet the requirements stated in provisions or in the current normative documents, then the uncertainties of their indications may be inferred from these specifications or from the normative documents.

The basic principle is the following one; when one reports the result of a measurement together with its uncertainty, one should provide several information than normal or shouldn't state „non-applicable”. For example, one should:

a) describe clearly the methods used to calculate the results of measurements and its uncertainty based on the experimental observation and on the input data;
b) give a presentation of all the component parts of the uncertainty and give a full explanation of the manner used to evaluate each component part;
c) give a presentation of the experimental data so that each important stage be easily monitored and the calculation manner be repeated independently whenever necessary;
d) determine all the significant corrections and the constants used during the analysis together with their origins.

Beside the equipment and the staff training the competence of a testing house depends on the idea that it can be clearly stated the trust level of the measurement result, i.e. the calculation of the uncertainty of measurement, together with its indication as an absolute or percentage value, together with the values stated for the measurand.

The mathematical - statistical machinery said by [1] or [2], is very laborious (a lot of working hours) and its implementation in the everyday measurement may not be so easy for the working staff of the testing houses; this is the reason why software for these purposes have been designed.

The Laboratory for Explosives and Blasting Techniques (LETI) from INSEMEX carries out a series of testing, analyses, verifications on the products part of the „civil” use explosives. This field has been regulated by the Law no. 126/1995 concerning the rules of explosive materials with the subsequent changes and additions and by the Directive 93/15/EEC, taken by the Romanian legislation under the HG (Government Decision) no.207/2005.

The organization of LETI meets the requirements of the standard SR EN ISO/CEI 17025 „General requirements for the competences of the testing and calibration laboratories” and uses a well documented, accredited quality system.

LETI has developed 6 packages of testing procedures grounded according to their specific character (in all 32 testing procedures) according to the essential safety requirements stated in the Annex to the Directive 93/15/EEC.

Also, part of these testing procedures includes operating procedures (24) which are used during the preparatory operations.

For carrying out all these testing we have here specific instrumentation and testing apparatus, some of them quite rave or even unique at national level.

This instrumentation covers the evaluation of the uncertainty of measurement for the measuring chains applied.

Even if some resting give results with the logic order, 1 or 0, and no numerical dimensions (for ex. the tested explosive shall initiate or not in certain conditions) the carrying out of these testing in volves preliminary measurements whose uncertainty may affect the logic result 1 or 0 (ignition; non-ignition) with wrong conclusions for the tested product.

For the purpose of evaluation of the measurement uncertainty which occurs during testing of explosive materials (high explosives, detonating cords and detonators) together with the well known testing procedures and by knowing the parameters of the apparatus, there have been drawn out the „Measurement data sheets”.

An example for such a sheet is shown below. The example refers to the „Determination of sensitivity to the transmission of detonation”.

Measurement data sheet

1. Name of testing/measurement

Determination of sensitivity to the transmission of detonation.

2. Testing/measurement procedure

PI-ETI-02.3. Determination of sensitivity to the transmission of detonation of encartridged explosives.

3. Tested/measured item

AGP powder explosion proof explosive.

4. Preparation of the test item.

The test item means 18 cartridges of explosive, weighting 100±5 g, with a diameter of 30±1 mm, in their original package; 6 cartridges for each test.

5. Environment conditions

No special environment conditions.

6. Principle of the measurement method

The cartridges are set down at a pre-settled distance among them (measured longitudinally).

The explosion of, first cartridge shall have to propagate to the rest of cartridges; it shall have to be complete and it shall have to leave no traces of explosive or package.

7. Measurement chain

- 6 cartridges are set down equidistantly in straight line (the distance between the ends of the 2 cartridges being equal to the diameter of the cartridges) on a level led sand bed;
- The distance between cartridges is measured with the help of a caliper rule.

- The first cartridge is primed at the free end with the help of a detonator no.8 (pyrotechnical or electric detonator) or with the help of another detonator with similar parameters;

- The leading wires of the electric detonator are connected to the detonating cable;

- The detonating cable is connected to the exploder;

- The cartridges are fired;

- The result is checked out.

8. Results

TC = full transmission of detonation.

NT = no transmission of detonation.

9. Balance of the uncertainty of measurement (See table no.1)

10. Manner used to record the result of the measurement and of the uncertainty of measurement.

- TC/NT.

- The results of the measurements cannot be established from a quantitative point of view; they are susceptible to be differentiated from a qualitative point of view.

These sheets record the measuring method used during the testing in question. Finally, if one knows the value of balance of uncertainty, measures to keep the uncertainty of measurement within acceptable limits can be taken. Also it is possible to remove the wrong results difficult to trace in other circumstances.

Consequently, we get a database so we can proceed to the next stage, i.e. modeling the used measuring methods on a PC.

The implementation of the mathematical machinery stated by GUM (2), makes necessary the use of an adequate software.

We searched for the available software on the internet and found several companies in the United States, West and Central Europe, New Zeeland suitable to provide such software.

We made comparisons among all these software and purchased the one which meets the requirements and the practical needs for the testing and measurements carried out in the Laboratory for Explosives and Blasting Techniques at INSEMEX.

Considering the specific character involved by testing of civil use explosives and of the electric detonators, the experts from the Laboratory for Explosives and Blasting Methods have considered a software capable to manage a large database and capable to include the whole mathematical machinery stated by GUM. The performances – price ratio, the possibility for further updating and the exempt of import customs duty pointed to the software presented by Metro data GmbH-Germany.

To meet the needs of the laboratory and considering the project in operation within the framework of the National Research Program „CALIST", we bought the full version in English of „GUM WORK BENCH 1.3." made by Metro data GmbH Germany.

No.	Element that influence uncertainty	Description of influence over uncertainty, Observations	Type		Influence			Probability of occurrence 0÷1
			Systematic	Random	Major	Minor	Insignificant	
1.	Equipment for measuring the distance between cartridges.	Accuracy of measurement caliper rule.	X			X		1
2.	Collinear laying down of cartridges	The measured value is an interval when the symmetry axes of cartridges are not collinear.	X			X		$1 \bullet 10^{-1}$
3.	Reading accuracy of the operator	Probability to mistake reading the lines on the ruler of the caliper.		X		X		$1 \bullet 10^{-1}$
4.	Packing manner of cartridges	The explosives of cartridge in paraffin paper have the end often the cartridge with a deviation from cylindricity due to the fold.		X		X		$1 \bullet 10^{-1}$

Table no.1

To save the recorded data, GUM WORK BENCH 1.3. – Metro data GmbH Germany generates an evaluation report on uncertainty divided info several sections:

1. Title and description.
2. Equation of uncertainty.
3. (Quantitative) Data base for all the dimensions of the equations.
4. A description of observations (text and mathematic form).
5. Establishing a correlation among dimensions.
6. The budget of uncertainty.
7. Results

- Value [absolute];
- Extended uncertainty [absolute] or [%]:
- Covering rate (2) – for a normal distribution.
- Covering level %, normal, rectangular, triangular, trapezoidal with halo: 0,3; 0,5; 0,7.

	Dimension
	Value
	Standard uncertainty
	Freedom
	Sensitivity coefficient
	Contributions to uncertainty
	Percentage from uncertainty

This software allows a versatile handling of the mathematical and the statistical apparatus stated by GUM [2] and offers several possibilities for modeling the phenomena depending on how extended the database is, depending on how control over the dimensions that come up in the budget of uncertainty is being kept.

With the help of the technical sheet, we can determine all the parameters which describe the balance of uncertainty of measurement (quant sized in the model of the equation of uncertainty).

At the end of 2005 we carried out a study report with the help of GUM WORK BENCH 3.1. We evaluated the uncertainty of measurement for certain testing usually made by our laboratory (testing to measure the detonation velocity of detonating cords, testing to measure the mass of explosive necessary for carrying out the testing to determine the resistance to friction).

There follows an example on how to determine the model of the equation of uncertainty necessary for measuring the mass of explosive to carry out the testing with the view to determining the resistance to friction:

- Testing procedure PI-ETI-3.4. „Establishing sensitivity to friction of high explosives and the core of the detonating core.
- Test item: RIOCORD ANTIGRISU 6 g/m – detonating cord;
- Apparatus for use: analytical balance with an accuracy of 0.1 mg.

Model of equation:

$$m_x = m_s + \delta m_D + \delta_m + \delta m_c + \delta_B$$

List of dimensions:

Dimension	Measuring unit	Definition
m_x	g	Mass of explosive
m_s	g	Pointer of the balance (weight)
δm_D	g	Deviation of the mass indication compared to the standard measurement (because of decalibration as time passes by)
δ_m	g	Difference noticed compared to the standard (correction made by the operator)
δm_c	g	Correction for the eccentric location on scales and because of magnetic effect.
δ_B	g	Correction of floatability (compensating the effect of Archimedean's law – measurements is performed in vacuum not in air)

CONCLUSION

With the model of the equatio and the budget of uncertainty established for a certain type of measurement, the staff of the laboratory uses an efficient software; consequently the complex problems of mathematical statistics turns info a routine everyday operation.

This application can be used for any type of measurement of any physical phenomenon whether it is possible to determine exactly the equation which models the uncertainty of measurement.

Attila Kovacs – Eng. PhD.,

Florin Rădoi – Eng., Edward Gheorghiosu – Eng. INSEMEX Petrosani

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[9] *** SR EN 13763-1, ,, *Explozivi pentru uz civil. Capse detonante şi relee întârzietoare. Partea 1: Cerinţe",* Decembrie 2004.

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Explosion of explosives residues after a misfire in a quarry

Basic information

- July 2016, afternoon shift in a quarry, after processing of approximately 80% material from a previous blast (app. two months ago).
- Explosion occurred at disintegration of rock pile by a hydraulic hammer on wheel excavator.
- Injury of operator of this excavator.
- Breakage of a front glass of excavator cabin and protective net.
- Residues were found at the explosion site.

Performed acts

- Explosion site investigation, ensuring of case related documentation.
- There was ordered:
  - to liquidate a misfire immediatly
  - to adopt a measurements to avoid any similar working injuries,
  - hearing of the injured operator (the only direct participant), the master blaster and the head of the quarry.

Probable cause of accident according to company findings

- Probable cause of this accident was hitting of an initiation explosive cartridge (including a detonator) in one of snake boreholes (horizontal boreholes) by a hydraulic hammer.
- There were discovered 6 snake boreholes (horizontal boreholes) with a misfire, containing in total 60 kg of explosives (10 kg of dynamite and 50 kg of emulsion explosives) and 5 detonators. Probable reason of this misfire was cutting off a shock tube (rock fall) or fault of nonelectric detonator resulting into a misfire of several next detonators.

Solution and measurement

Company elaborated technological procedure for a misfire liquidation.

Misfire liquidation:

- part of free explosives residues was liquidated at an explosion site,
- part of explosives residues was transferred into a magazine, stored as fault product and later officially liquidated,

- blasting original (misfired) boreholes after a renewal of initiation cartridge.

Measurements:

- Standard use of a head boreholes with sub drilling.
- Only exceptional use of snake boreholes (horizontal boreholes).
- Increased control of firing line.

Sanctions and fines

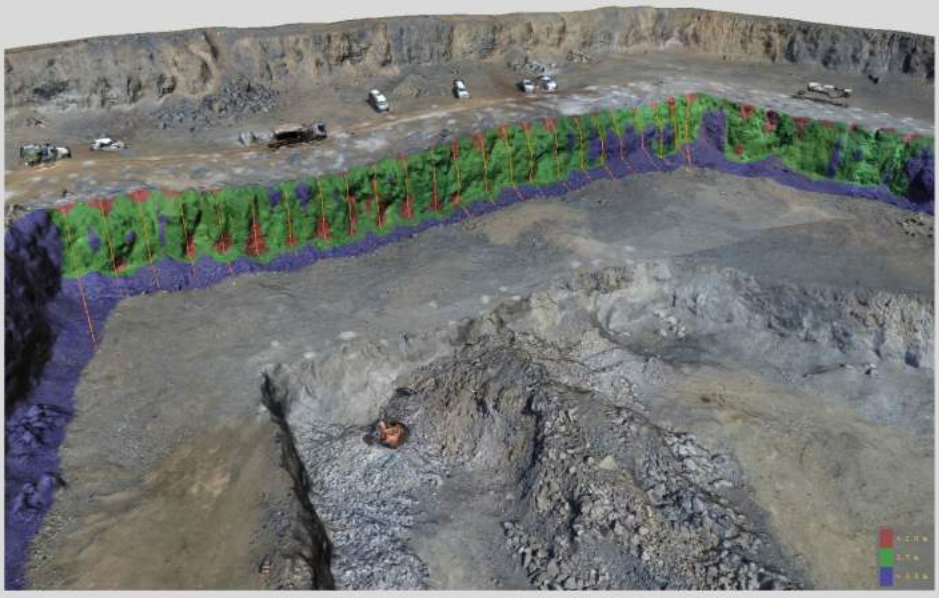
- Fine to the head of quarry for insufficient execution of obligatory workplace controls by technicians and for recording of this controls.
- Fine to the master blaster for discrepancies in blast records and in registry of misfires

Doc. Ing. Tomas Dosoudil, Csc - District Mining Authority for the Regions of Hradec Kralove and Pardubice,, Czech Republic

BlastMetriX UAV

Aerial 3D imaging

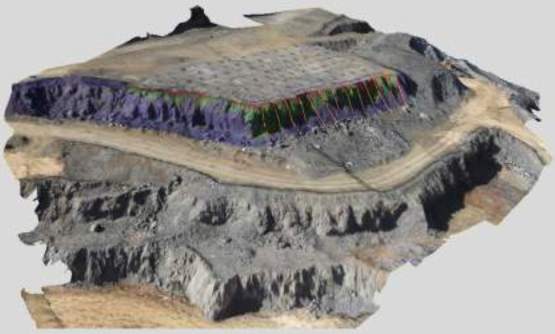
Blast Design and Blast Analysis with 3D images



3D images from drones are a perfect survey of large blast sites. Poor blasting results are often caused by inaccuracy of the front row hole placement and suboptimal blast pattern geometry.

Features

- Face profiles (burden diagrams and maps)
- Volume to blast
- Pre-post blast comparison
- Quantification of muckpile (movement, volume, swell)
- Power trough
- Seamless data flow



3GSM Software & Measurement 3GSM.at

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Meeting the Explosives Working Group

This year's annual meeting of the Explosives Working Group took place in Brussels on 20th October 2017 with the EFEE taking part as a permanent observer as in the past years. The Explosives Working Group is coordinated by the Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs of the EUROPEAN COMMISSION with its head Federico Musso. The following points were part of this year's agenda:

Update on the implementation of the Action Plan on Enhancing the Security of Explosives

- DG HOME involves much stronger the European Police Agency EUROPOL
- Counter Terrorism Package should ensure security of public places
- Increased focus on substances used as explosives precursors

This working group is compiling measures for improving and enhancing safety when handling explosives. When looking at what has happened in the past month, this is becoming more and more important. The industry regards it as crucial to take part in the process actively and attentively so that decisions on the required measures are practice-oriented as far as possible.

Report on the last meeting of the AdCo group on Explosives for Civil Uses

- Industry attendance by UEPG, FEEM and CBI-EIG
- FEEM confirmed a change within the industry from packed explosives towards emulsions and Ammonium nitrate
- Members States set up a survey on Article 16 – 2014/28/EU: Licence / Authorisation

EFEE took the opportunity and participated in the meeting of the of the AdCo group on Explosives for Civil Uses on the 26th of October 2017. During the meeting, EFEE introduced itself and gave an outlook on the tasks and goals pursued by EFEE. Through the attending in this meeting, EFEE had the opportunity to get more information about the work of the AdCo group on Explosives for Civil Uses. Furthermore, there was the possibility for EFEE to come up with some input for the work of this AdCo group from the point of view of the users of explosives.

Update on the transposition by Member States of Directive 2014/28/EU on the harmonisation of the laws of the Member States relating to the making available on the market and supervision of explosives for civil uses

- The last two EU Member States have transposed the Directive a few months ago and notified the European Commission. Previously, the Commission had to apply pressure on Germany and started an infringement procedure against Croatia to ensure transposition.

Revision of the Q&A document – (more information you will find in the end of this article)

- Need to update the Q&A document
- Three questions added to the document, e.g. if a quarry/mine mixes explosives on site for own use, would it fall under the definition of a manufacturer referring to article 5.1 and 5.2 of the Explosives for civil use Directive?

13. Interpretation of "use for own purposes" pursuant to the Explosives Directive

14. Date of application of rules on explosives traceability

15. The case when a quarry or mine mixes its own explosive on site for blasting on its own site: does it fall under the definition of a manufacturer using an explosive for own purposes?

The UK representative referring to question number 15 raised the proportionality principle for the many small quarries and family-owned business to avoid additional burden and costs.

It should be noted that the discussion on this topic is not new. It has already been made clear in previous documents that the fact that quarry mixes its own explosive on site for blasting on its own site is also subject to the regulations. The repeated discussion on this topic is often due to a different interpretation of this regulation.

Applicability of traceability provisions to explosives in transfer

- Transit: Explosives originating from a non-EU country and destined to another non-EU country, i.e. not being placed on the EU market but transported through EU territory do not fall under the scope of the EU traceability system.
- Transfer: The transfer procedure pursuant to Article 11 of Directive 2014/28/EU applies also to explosives manufactured in the EU and shipped for export outside the EU. The transfer procedure is necessary for the physical movement of the explosives from the manufacturing site to the point of export (where the explosives leave the EU territory). The traceability provisions do however not apply to explosives manufactured for export, if the conditions as per Article 3(2) of Directive 2008/43/EC are met.
- EU Transfer: Transport of goods from one EU Member States to another EU Member States without leaving EU territory during transport, e.g. Greek goods delivered to Belgium cannot be transported through Serbia or any other non-EU territory
- Transit transport on roads is well monitored and includes electronic transit declaration. For rail transit, a simplified paper version is used which does not provide the same level of control.

Revision of the harmonised standards for civil explosives

- Results of the consultation on harmonised standards
- Discussion on a draft mandate for the revision of the harmonised standards

In addition, it should be noted that the standards are reviewed every two years. On 18.10.2016 the Commission launched a written consultation via a questionnaire within the Group of Experts on Explosives on the need to update the existing harmonised standards and/or develop new harmonised standards for civil explosives. The results of this written consultation you will find attached.

Update on the activities of the UN Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonised System of Classification and Labelling of Chemicals, Sub-Committee of Experts on the Transport of Dangerous Goods, regarding the development of an international traceability system This year's meeting of the Explosives Working Group was the last one led by Federico Musso. Federico Musso will take over another role in the European Commission from January 2018.

We would like to take this opportunity to say thank you Federico Musso for the very pleasant and trusting cooperation. We hope to be able to continue this cooperation between the Explosives Working Group and EFEE in the future and wish Federico Musso good luck for the new tasks and personally all the best.

Jörg Rennert, Member of the Board, EFEE

Pan European Competence Certificate for Shot firers and Blast designers - Project update

We are happy to announce that our first Testcourse has taken place. Twenty-two participants assembled at Fjällgatan 23, in Stockholm, on the morning of 12th December. Our course material was presented to a number of people from the rock blasting education establishment and to people who are active in the industry as rock blasters or authorities. Several European countries where represented.

Erasmus+

PECCS

BEF, the Swedish Rock Blasting Contractors Association together with EFEE is the project leader for PECCS, it is funded by Erasmus + program and our aim is to develop a competency certificate for Rock Blasters based on existing technical competence.

A common European education and technical qualification for Rock Blasters would make it easier for individuals in the industry to confirm their knowledge and experience throughout Europe. Today, the possibility to work is limited to those who wish to work abroad.

An European Competency Certificate would favor the mobility of labor in the whole of Europe.

The first PECCS Test course was extremely important for collecting feedback and responses to the material that has been developed so far.

BEF and all partners in the project were very grateful for the feedback and positive response that were given. The material was presented by each partner, representing each of thet chapters. All participants also received the material as a printed booklet. Discussions and constructive conversations followed after the presentations. Evaluations was also collected through a digital portal by feedback forms. The participants came from Sweden, Norway, Germany, France, Estonia and Finland.

BEF and all partners in the project would like to thank all the participants involved!

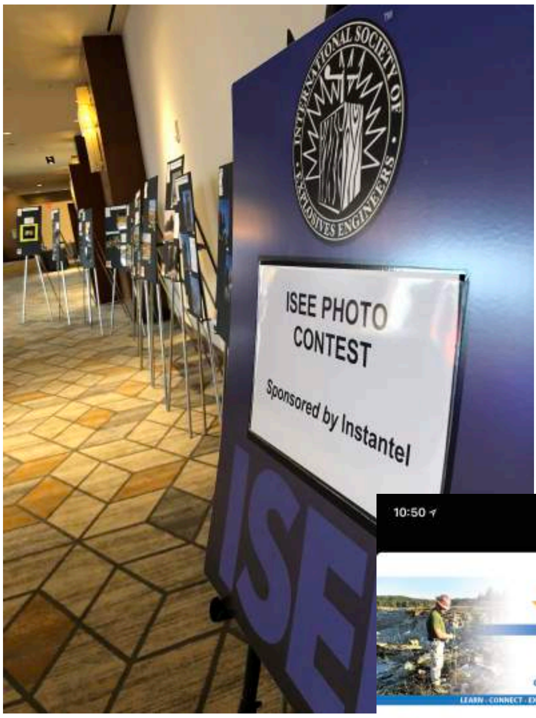
The second testcourse will be held in Paris, in April this year, from Monday the 23rd to Friday the 27th. For questions about the PECCS project and the upcoming events please contact Anette Broman, anette@bef.nu.
For more information go to www.shotfirer.eu

Anette Broman, PECCS, Project manager

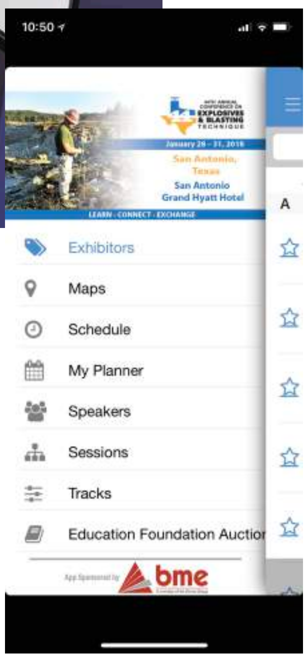
The participants of the Testcourse had the pleasure of meeting the Swedish Sancta Lucia. On December 13th every year, Sancta Lucia comes to us to give hope and light. She was accomplished by her fellow sister and gave all a memorable moment. Much appreciated!

The ISEE 44th Conference on Explosives and Blasting technique.

There's nothing wrong with having two barrels of explosives on the foyer of a Grand Hyatt Hotel in San Antonio, Texas, but only, if you are one of the visitors of ISEE 44th Annual Conference of Explosives and Blasting Technique. Being the biggest of its kind, the Conference still had more visitors than expected, more than 1700 attendees and participants from all over the world.



A Lot of interesting moments captured for the photo contest, a great number of new books in store, and a useful ISEE Conference app



This year the event had quite many surprises, especially for those, who have been visiting it for years. Besides having a fun gathering with live music and black magic instead of the formal Banquet Reception, the conference also included photos in Instagram and a marvellous app for free on Android and iOS. With that app you could create your own schedule, read about authors, check the opening hours of registration, bookstore and other and also follow up on the auction which was created to raise money for the Education Foundation ISEE Scholarship Fund, and more.

Many interesting exhibitors and quests

As important as safety is to the blasters, it's almost as important to welcome new, young specialists to this industry. Among all other events during the Conference, the Emerging Professionals Social was organised to enable all new faces of the industry to blend in and share ideas and contacts, held at Alamo.

In any way, San Antonio was a great place to have an event like this kind of like a city within the city – also known as the River Walk – San Antonio offered great possibilities to meet up with new contacts or old friends and share a nice Margarita or two.

I am sure, everybody is already looking forward to the 45th ISEE Conference in Nashville, Tennessee.

The event also put a lot of attention on the real blasters who work with explosives daily. Right before the beginning of the conference, almost 300 blasters gathered for the Blasters Weekend, especially for the seminar, which offered a full day of good presentations, practical examples and information about modern equipment and development of blasting technique. But this number of participants couldn't be compared with the great number of people who came to listen to the opening speech by Mike Mullane, a former astronaut who talked about safety through very practical example – the disaster of the Challenger space shuttle.

San Antonio had a lot to offer, Riverwalk and Alamo from the left

Teele Tuuna, Editor of EFEE Newsletter

Preface for an article reprint, from EFEE Newsletter, November 2017 edition: "MODELING THE DANGER OF INJURY WHEN FRAGMENTS OF MATERIAL RESULT FROM THE DETONATION OF EXPLOSIVE CHARGES"

On behalf of the Institute of Makers of Explosives and APT Research, Inc. (APT), we encourage the international use of quantitative risk assessment and Institute of Makers of Explosives Safety Analysis for Risk (IMESAFR©) by global industry members and regulatory authorities.

The authors of this article have consulted IME and APT, and, in recognition of IME and APT's copyrighted intellectual property, have adopted our request for revisions to this article and acknowledgement of our work.

We are pleased to share our research and programs with the commercial explosives industry, and encourage use of IMESAFR in explosive operations. Should you wish to copy or disseminate this article or our work in whole or in part, please contact us prior to doing so.

We are not responsible for the conclusions of the authors, and refer you to our own materials for further information.

Debra S. Satkowiak
President, Institute of Makers of Explosives

MODELING THE DANGER OF INJURY WHEN FRAGMENTS OF MATERIAL RESULT FROM THE DETONATION OF EXPLOSIVE CHARGES

Abstract

The paper shows a summary of the results of research undertaken in the field of modelling the dangers of injury / destruction when fragments of material resulting from the detonation of explosive charges are jettisoned on workers and / or industrial objectives from the explosives testing center. So, American scientific practice from the moment is (FRMS type) developed to improve the performance of the specialized software from the security of explosives for civil use type IMESAFR (ex. Version 2.0) which was acquired in the NUCLEU project- PN 16 43 02 15/2016- 2017, using different probability functions dedicated to this field type PDF (Probability Density Functions) in order to shape the graphic-analytical phenomenon when fragments of material resulting from the detonation of explosive charges are jettisoned.

Overview on the mechanisms of formation of fragments of the material resulting from the detonation of explosive charges

Detonation of explosives

Detonation is a physical-chemical process, characterized by a high reaction speed and by the formation of large quantities of gases, at high temperatures, which leads to the generation of high forces of breaking and dislocation of rocks. To interpret the physical phenomenon of detonation, worldwide were expressed various theories, one of them being the hydrodynamic theory. It was accepted unanimously, considering the similarity of its mode of propagation by explosives with the propagation of the pressurized fluid. The detonation mechanism comprises three steps: **I.** The mechanical compression of each molecule of the explosive substance carried by a dynamic pulse; **II.** The thermal decomposition of each layer in the structure of the explosive, up to high temperatures, when given the rapidity of the chemical reaction, the dynamic compression process being carried out without heat exchange in the environment (adiabatic compression); III. The exo-thermal decomposition of the explosive due to the action of high temperatures.

The formation of craters:

In figure No. 1 is presented schematically a crater produced by the detonation of an explosive (explosive charge [1]). Dimensions associated to a crater are the following:

D2 = the apparent diameter of the crater;
D1 = the actual diameter of the crater;
h1 = the actual depth of the crater;
h = berm height.

Craters are formed when there is a detonation of explosive charges that is placed as follows: below ground level (closed space); on the ground (air-ground interface); suspended in the air. Regardless of the location of the explosive charge, the crater is the destructive effect of a blasting. When initiating the explosive charge, in his mass, there is a violent decomposition reaction, the detonation wave which results is propagated at a speed of 2000 – 8000 m/s. In the detonation wave front is developed a pressure that can reach 104 MPa and it is transmitted in the environment in the form of a shock wave, having the same direction of propagation as the detonation wave.

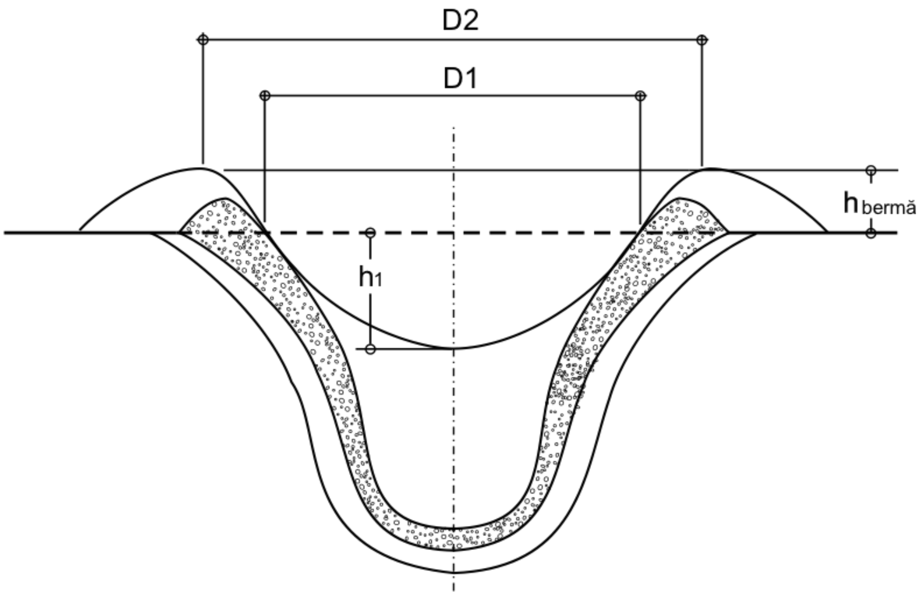


Fig. 1. Defining the size of a crater

The material resulting from an explosion type event considers three types of fragments: primary, secondary and scrap resulting from the crater formed[2]. The primary fragments are coming from the body of the explosive detonated, and secondarily from the structure of the storage room (eg. roof, end walls, side and rear)[3]. Also, other residues that are generated in the impact crater formation are fragments from the ground or the foundation structure of the storage room. In the event of an explosion type event there may result a large number of individual fragments (of the order of thousands) that can be uniquely identified by its mass and speed of the main parameters (and implicitly by the kinetic energy)[4]. The model type QRA (Quantitative Risk Assessment) consecrated to quantitative risk assessment, provides opportunities for an analysis of the whole volume of fragments designed, based on a dynamic model of meshing of the mass, using the distribution pattern of recurrent Bin n, (1). to provide a general overview of the 10 classes of results (Bini, i=1,10)[5].

RM – the residual material mass of fragment

DM – the fragment mass of material dispersion

Thus, Bin1/Bin10 represents the fragments with the high / low mass and level significant / low of damage and / or destruction of the human component and / or structures[8].

Table 1 shows the results obtained for the ten classes (Bin1÷Bin10) corresponding to level of damage / destruction (via kinetic energy) at the odds of maximum, medium and minimum, and average weight of each fragment designed depending on the type of material.

$$Bin\ n: DAM_n = RM_n + \left(\sum_{i=1}^{n-1}(DM_{[i,n]})\right) + \left(\sum_{i=2}^{n-1}(B11DM_{[i,n]})\right) \qquad (1)^6$$

where[7]:

DAM – dynamic adjustment of the mass of the material fragment

n – the order of meshing of the fragment mass of material

Class (Bin_{in} n=1,10)	Bin_1	Bin_2	Bin_3	Bin_4	Bin_5	Bin_6	Bin_7	Bin_8	Bin_9	Bin_{10}
Minimum kinetic energy (m-Kg)	100K	30K	10K	3K	1K	300	100	30	10	3
Average kinetic energy (m-Kg)	173K	54K	17K	5K	1,7K	547	173	54	17	5
The maximum kinetic energy (m-Kg)	≥300K	100K	30K	10K	3K	1K	300	100	30	10
The average weight of fragments of steel (Kg)	16,19352	6,75864	2,875824	1,206576	0,512568	0,214553	0,090266	0,038647	0,017191	0,006441
The average weight of concrete fragments (Kg)	34,20144	14,2884	6,07824	2,544696	1,079568	0,4536	0,190512	0,081648	0,036288	0,013608

Table 1[9].

Description of the primary fragments

The primary fragments result from explosive destruction and its packaging after detonation, and their design mechanism by modelling is based on the number of fragments, by their mass and by the maximum range of throwing. (Figure no.2)[10].

The number of explosive products (Nw) is determined by the relation (2):

$$N_w = \frac{W_1}{NEW \times QD_1} \qquad (2)^{11}$$

where:

W1 – amount of explosives of the explosive product No.1

NEW – net explosive quantity of a single product (V. Table 2)

QD1 – distance depending on the amount of explosives

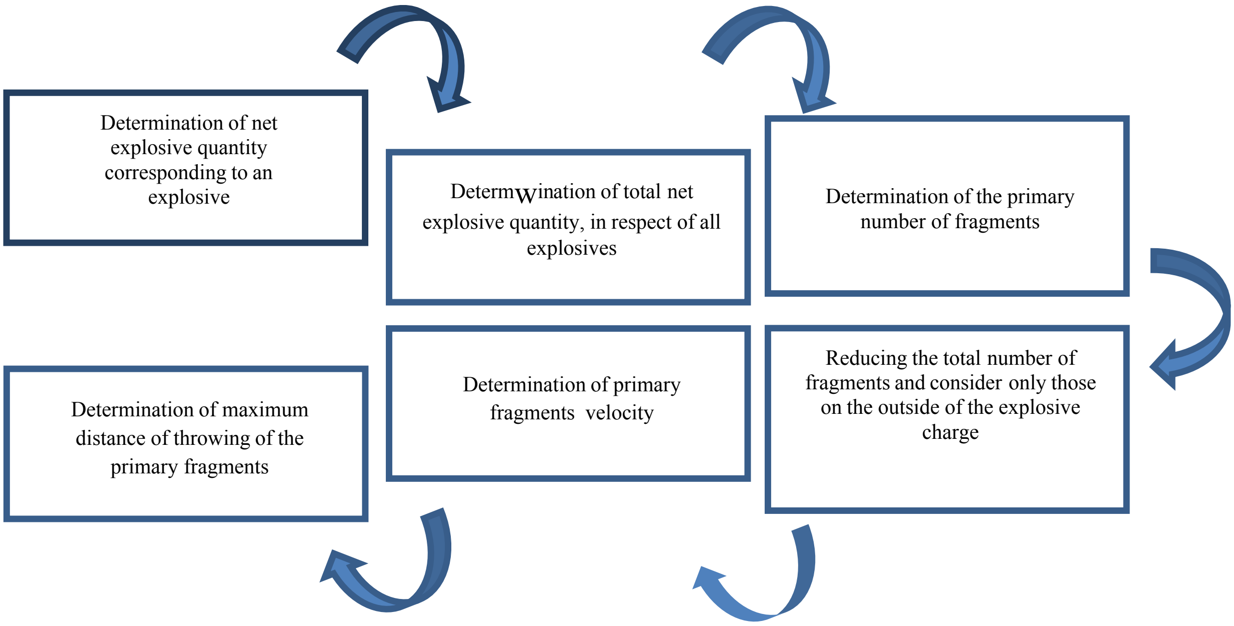


Fig.2. Process diagram for primary fragments projection[12]

Explosive charges	**NEW specific for a single type of explosive product (Kg)**	**Fragments derived from a single product Mass Bin$_n$, n=1÷10**									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
explosive charges with small fragments	0,4536	0	0	0	0	0	0	0	1	5	10
Explosive charges without primer fragments	0,4536	0	0	0	0	0	0	0	0	0	0
metallic container with explosive charge	4.536	0	0	0	0	0	0	80	4.111	796	319
Explosive charge confined in the metal pipe	3,901	0	0	0	0	0	0	4	19	44	79

Table 2.[13]

Further are displayed in tables the maximum range values of action / projection of the primary fragments (Rmax), which is determined for each fragment, according to the average weight, of the suitable bin and the initial rate (v. Table 3)[14].

explosive charges	V (m/s)	R_s(m)	R_M(m)
explosive charges with small fragments	1219,2	569,976	683,9712
Explosive charges without primer fragments	NA	NA	NA
metallic container with explosive charge	1219,2	569,976	683,9712
Explosive charge confined in the metal pipe	1219,2	569,976	683,9712

Table 3[14].

The value Rmax is set at the maximum value for the projection, whether for one explosive product (RS) or for multiple products (RM), depending on the amount of explosives considered, W1. In case of W1 lower than the net quantity of explosive from the explosive product it is used the value of RS, and where W1 is greater than this quantity, then it is used the value of RM. Usually, the value of RM is 20% higher than Rs, taking into consideration the known spraying debris[15].

In the event of an explosion type event, product within a potentially explosive structure type PES (for storing explosives for civil uses), results a very large amount of primary fragments whose number and the initial speed is determined according to the data of presented in tables No.2 and 3. Also, the components of the PES structure, remaining after the explosion, can block and remove the primary fragments resulting from this event. At the same time, it is necessary to determine the fraction of primary fragment blocked by structural components of PES (roof, front wall, rear wall and side walls).

Thus, to determine the number of primary fragments which may be blocked by various components of the structure of the PES, they must be divided depending on the angle of projection, namely: large angular throw fragments (hitting the roof) and lower angular throw fragments (the lower) (hitting the walls). The lower angular fragments are divided, at their turn, further in side impact fragments and horizontal fragments displaced in a direction nearly horizontal[16]. Also, side impact fragments have an arched trajectory, to ES-type structure (the structure exposed to explosion), but it can be blocked, in the end, the wall of this structure, by artificial obstacles (Figure 3)[17].

The primary fragments are divided as follows, 25% of the total number of the fragments is considered to be high angle fragments, 7.5% of the total is considered to be fragments of the side impact, and 67.5% is considered to be horizontal fragments. Setting these values are based on interpretation of test data, including high-speed video analysis. The primary fragments are divided into fragments that can be blocked or contained by each structure type PES.

The side impact fragments and the horizontal fragments are potentially blocked by the front wall, sidewalls and the components of the rear wall structure type PES, while high angle fragments are assumed to be potentially blocked by the roof component (Figure 4)[18].

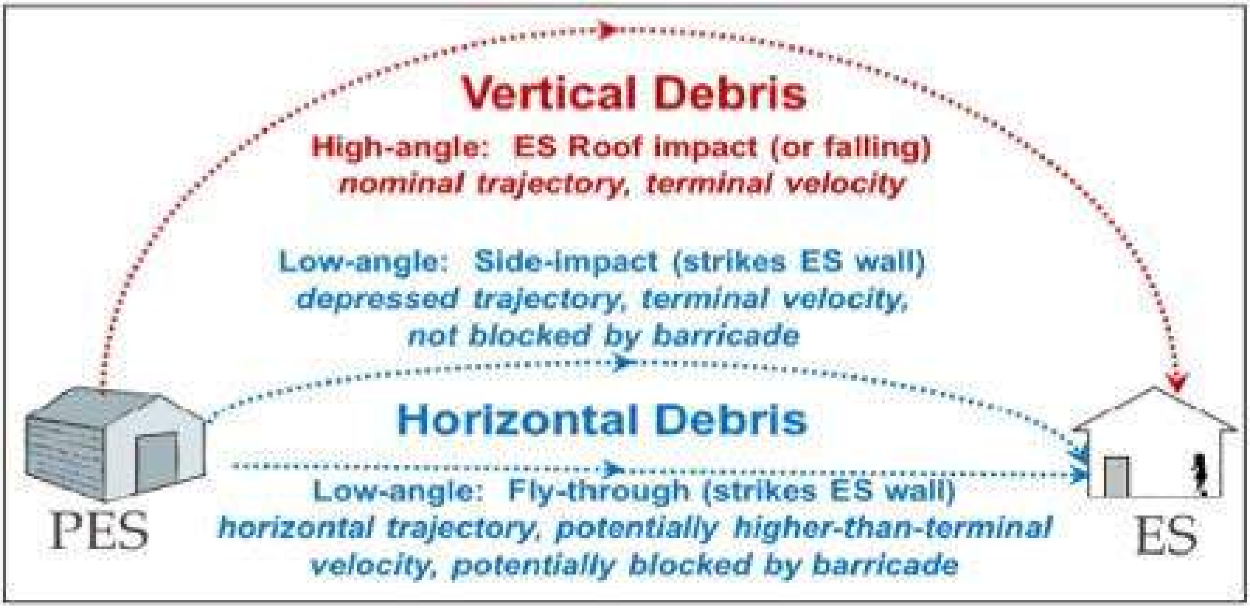


Fig.3 [17]*.* The design trajectories of primary fragments.(figure courtesy of APT Research)

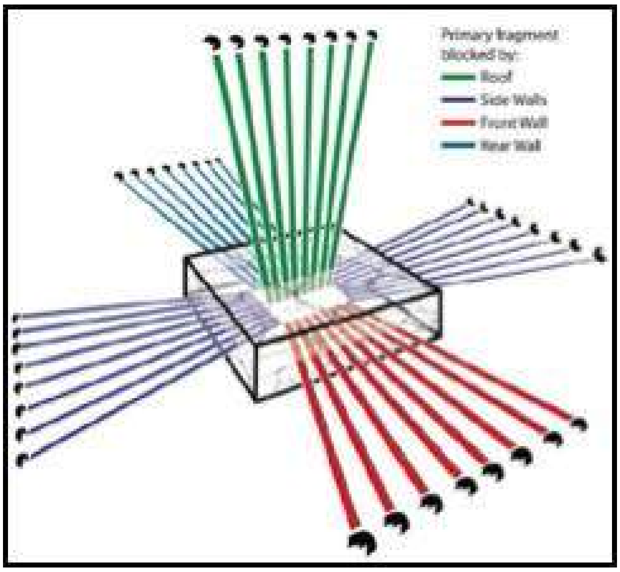


Fig. 4 [18]*.* Blocking the primary fragments. (figure courtesy of APT Research)

Density estimation of the material fragments projected

The configuration estimating of the path travelled by the material thrown away, can be done by using the methodologies results within various research conducted in this domain and requires well-grounded scientific knowledge on the main parameters evaluated, namely: the speed of impact and the mass of material fragment projected. It would be ideal for determining the position and speed of impact, specific to each fragment of discarded material, to use physical laws based on differential equations that characterize the wave phenomena, however, at the moment, there do not exist proven scientific results for a specific scenario related to an explosion type event.

The number of fragments and individual characteristics of mass and speed are dependent both on the type of material (eg. steel or concrete), and the characteristics of explosives used to testing. Thus, the conceptual models can be developed for the production of trajectory calculations for the intervals of fragment of mass, launch angle and speed. However, Monte Carlo simulations are sensitive to present ranges assigned to each variable trajectory. Also, these models require running a series of simulations at the time of analysis, requiring extensive resources of time and the calculation result being one detailed and based only on assumptions. Where, test results of explosives accident statistics, validated simulation data are available, then type models Fast-Running Models (FRMs) can be created for the analysis of hazards in a simplified manner, without using difficulty complex physical models based on the equation of state. So, American scientific practice from the moment (type FRMs), developed for specialized software in the field of explosives for civil uses security type IMESAFR 2.0 which was acquired in the Program NUCLEU-Project PN 16 43 02 15/2016-2017, using different probability density functions dedicated to this field type PDF (Probability Density Functions) for graphic-analytical model of the phenomenon of projecting portions of the material, which result from such explosion events. This PDF is obtained by pre-processing, simulation and / or analysis of test data in a dedicated equation (closed form), after the pre-set density function can generate immediate results. Figure No. 5 shows an example of simulation test data, by a number of data-points that have been translated into a closed-form equation[20].

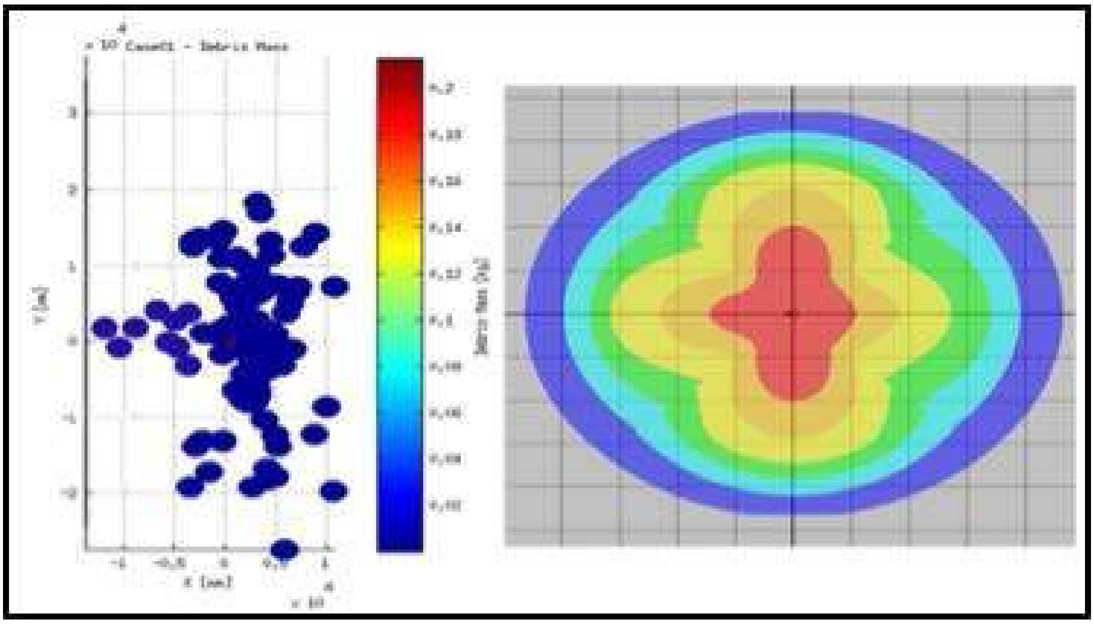


Fig. 5 [20]. Representative test transposition date in PDF. (figure courtesy of APT Research)

This PDF serves as a contour map, almost instantaneous forecasting projected portions of the material density. To represent different types of models based on the use of probability density functions, it can be designed with different levels of complexity. Thus, PDFs are composed of elements "down-range" type and azimuth (cross-range). "Down-range" component reproduces the shape of the origin of the blast outwards in any radial direction. This essential component distance determines the design portions of the material from the original location in which the explosive charge detonation occurs, and the range of their greater density. Cross range component determines the form of the tool when moving radially at a constant distance from the origin (azimuthal direction or cross-range). In the following, there will be detailed the two components of PDFs modelling practice often used in explosives security.

The most common PDFs are the uniform distributions in all directions from the origin (that is, no azimuthal variation). These distributions may be used effectively for modelling safety are evenly distributed or random in all directions around the site of an explosion such as both pieces of material resulting from the destruction of the roof that are thrown up and scattered, as well as fragments of wall structures of the various arcuate shape. The first example is a function of the type Gauss - normal of distribution (ex. a bell-shaped curve) used as component down-range without azimuthal variation, producing a distribution parameter type bi-variant Normal (BVN), characterized by the highest density at the origin which resembles a hill (Figure 6)[21].

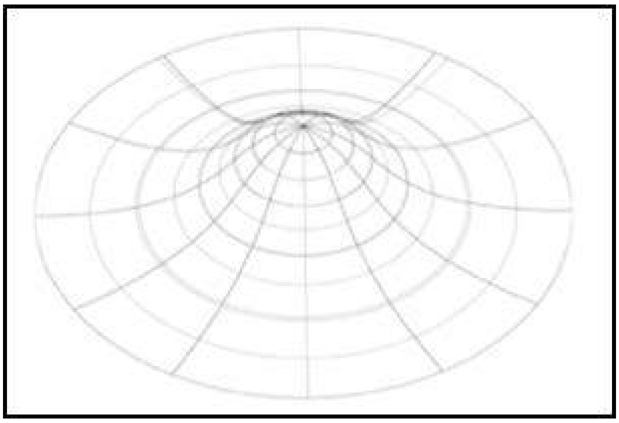


Fig. 6[21]. Distribution type Bi-Standard version (BVN). (figure courtesy of APT Research)

The shape of PDF- for the distribution of BVN is given by the following equation:

$$P_i = \frac{1}{2\pi\sigma^2} e^{\left(\frac{-r^2}{2\sigma^2}\right)} \quad (3)^{22}$$

where:

Pi - the probability of a single piece designed in a certain area;

σ - the standard deviation of the distance *"down-range"* ;

r - the range from the origin to the point of interest.

The ISURF model

Probability density function BVN is useful for substantiating the basic scenarios, in which case is available a limited number of data and information, the danger of projecting fragments of material is assumed to be higher in the vicinity of the blast origin for the production location, as a result of the detonation of the charging material. However, there may be situations under which, a lot of the fragments are thrown out of origin. This aspect is especially true for primary fragments, the residues from the explosive charge and secondary arising from pieces of wall. When the model *"BVN down-range"* is used in these types of scenarios, the problem of the PDF is related to resolving over-prediction of throwing fragments near origin, in small amounts at intervals. Research conducted by the Institute of Explosives Manufacturers (IME) to develop specialized computer infrastructure for the security of explosives (IMESAFR), Research APT has developed a new function *"down-range"* to improve the model *"BVN down-range"*, resulting in a toroidal PDF with azimuthal variation (Figure 7)[23].

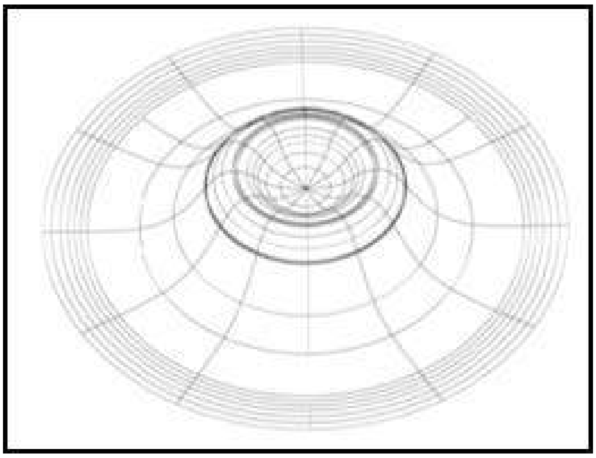


Fig.7. PDF toroidal without azimuthal variation, type ISURF[23] . (figure courtesy of APT Research)

Comparative analysis of the two established models for substantiating the scenarios of projecting the fragments of material resulting after the detonation of explosive charges, respectively: *Curve ''BVN down-range''* and *Curve "PDF* toroidal down-range'', points out that the areas occupied by the two curves are identical, and declaring the approximate representation of the same amount of total mass of the projected fragments[24]. It is also found that the model of the curve BVN is type conservative at certain intervals, compared with the curve PDF toroidal (Figure 8). The new component of the model PDF down-range is referred to as slope (Range) and it is given by initial ascending function of the new model – ISURF, (figure no.9). The complex shape of the model ISURF is provided by the three parameters mentioned, respectively a, b and c, which may have different values depending on: size of fragments thrown away of the resulting material type after detonation by explosive charge and type of structures used \ in the scenario of the explosion (ie. the wall or roof)[25].

The presentation chart of the model highlights the following elements of structure[26]:

- parameter "a" is the ratio of the horizontal coordinate of the maximum likelihood (Xpeak) and the maximum horizontal distance of throw (or "full-throw") the density of fragments (XMT), it is used to determine the maximum range;

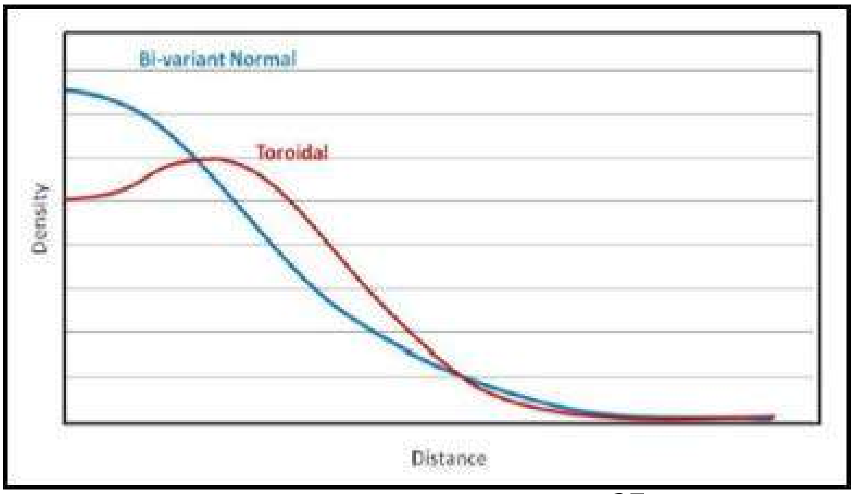


Fig. 8. Graph of curves *BVN down-range*[27] and *PDF toroidal down-range.* (figure courtesy of APT Research)

Knowing the percentage by calculating the area under the curve will result in the determination of both the inner face of the slope and the slope of the outer surface.

- parameter "b" the relation between probability density at origin (Y0) and the maximum probability density (Ypeak) is used to determine the maximum magnitude;

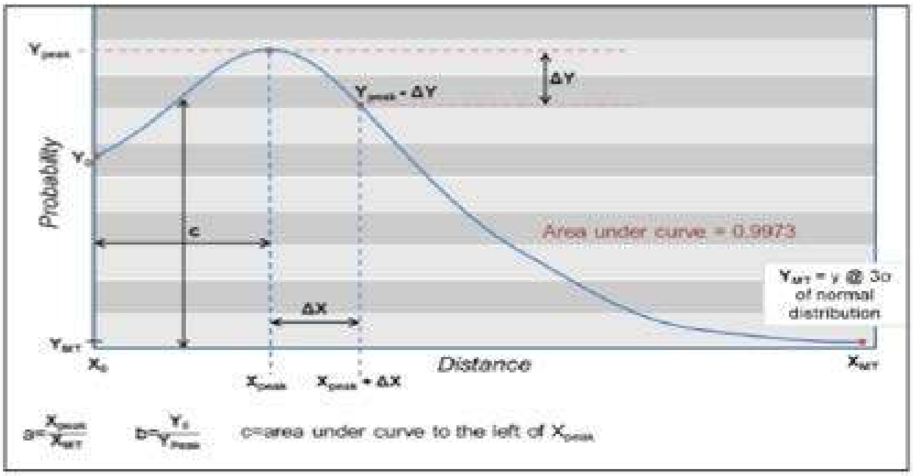


Fig. 9. Graphics details of the model ISURF down-range[28]. (figure courtesy of APT Research)

- parameter "c" is used for controlling the shape of curves which are joining the set points and represents the percentage of probability generated by the surface under the curve, which is bounded by the horizontal distance from the origin to the maximum value of the curve, determining the percentage of the area under the curve.

The ISURFGAD model

This model is characterized by a zero change in azimuth (they produce the same results in all directions), being used for modelling uniform of the directional hazard, both for fragments by the roof, the circular crater effect at warehouses of explosives and for scenarios of explosion where fragments are thrown in random directions. Because, in the case of centrally located loads in rectangular buildings, it has been observed that the density of the thrown material is strongly affected by the azimuth (debris of material tend to "move along the normal" and not in the "corners") generating an effect type Cloverleaf (PDF with azimuth zero – transversely range) shown in Figure 10, Figure No. 11 presents a new type of PDF (ISURFGAD) based on a model range transverse that take this type of effect into account[29].

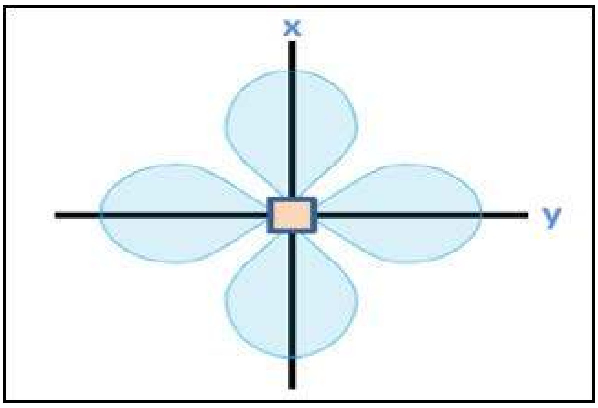


Fig.10. The model Cloverleaf of the dispersion of the fragments of material[32]. (figure courtesy of APT Research)

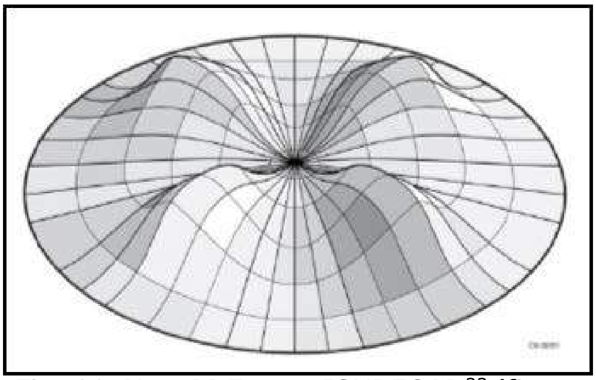


Fig. 11. New PDF-type ISURFGAD[33] (figure courtesy of APT Research)

PDF derivation type ISURFGAD is performed independently for functions down-range and the transverse radius. The function is represented for one dial of 900, probability density of the portions of the material characterized by independent parameters, respective interval of the range (r) and the throwing angle (θ), thus:

$$PDF = f(r) * g(\theta) \qquad (4)^{30}$$

in which[31]:

$f(r) = f_1 = A' + B'r + C'r^2 + D'r^3$, out of range $[0,R_{P+}]$

$f(r) = f_2 = k_1 exp[k_2*(r-R_{P+}]$, out of range $[R_{P+},R_{max}]$

$g(\theta) = [1/(2\pi R_c\sigma_\theta)]exp[-0,5(\theta/\sigma_\theta)^2]$

where:

R_{p+} - peak value of probability density

R_{max} - the maximum radius of the throwing portions of the material

R_C - the centroid radius

Human vulnerability assessment under the action of portions of the material resulting from the detonation of explosive charges

In previous sections were presented technical aspects of modelling portions of the material resulting from the detonation of explosive charges from structures type PES (for the storage of explosive materials) which can destroy structures exposed to explosion type events ES (for specific activities), with serious effects on the health and integrity of staff, and the population in surrounding areas[34]. For modelling the degree of damage to the human component using probability equation (of the impact between the human body and thrown fragment) configured based on Poisson probability distribution (5), respective:

$$P_{impact} = 1 - e^{-EN^*} \qquad (5)^{35}$$

where:

E - It is the human exposure (0.278 m^2)

N* - is the number of fragments which may damage the integrity of the human component

For solving the equation of probability, the model provides the estimation possibility of fatality areas with major and minor injuries based on the kinetic energy of the fragments projected (6), respectively[36]:

The lethality value is obtained from the curve shown in Figure No. 12, highlighting the likelihood of fatality for an event Pf|e compared with the kinetic energy of the fragments projected. Finally, the model calculates the overall probability of fatality caused by projected fragments, Pf(d), by summing the projecting path, corresponding to the angular projection, of the large fragments and to the displacement of small angular, and the total probability of death is obtained by using the additive rule applied in the case of events which are not mutually exclusive (7), respectively[38]:

$$P_{f(d)} = Valoarea\ de\ mortalitate \times P_{impact} \qquad (6)^{37}$$

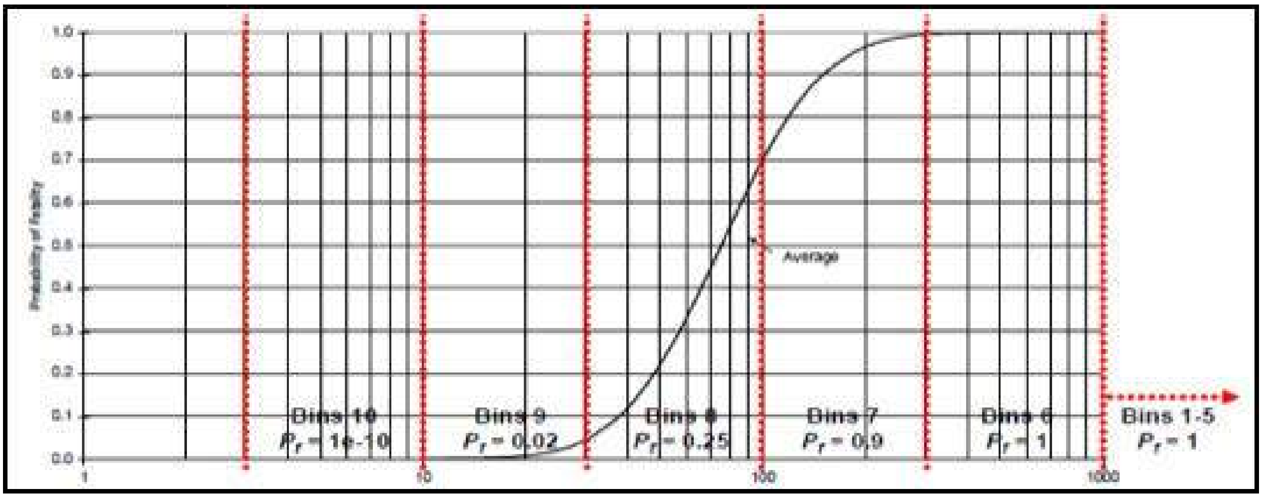


Fig.12. The probability of exposure of the human component by kinetic energy[39] (figure courtesy of APT Research)

$$P_{f(d)} = P_{f(d)unghi\ redus} + \left(1 - P_{f(d)unghi\ redus}\right) \times P_{f(d)unghi\ mare} \quad (7)$$

where:

Pf(d) - probability of death of a person due to the impact with a projected fragment.

Completely analogous is determined the likelihood of major damage/minor injuries Pmaji(d)/Pmini(d).

To substantiate the danger of the mechanism of thrown fragments is using a pattern type SCIFM (Simplified Cose-In Fatality Mechanism) all scenarios specific to this phenomenon (Figure No.13)[41].

Examples of application of the presented models

An example of surface PDF with the following characteristics: a = 0.330, b = 0.038, c = 50%, d = 10%, maximum range extender = 579 m and σ = 20^0,and it is presented in Figure No.14.

The results obtained after modelling the risk of injury from projected fragments of the material resulting from an explosion type event, can be highlighted graphic-analytical, both through the associated diagrams of

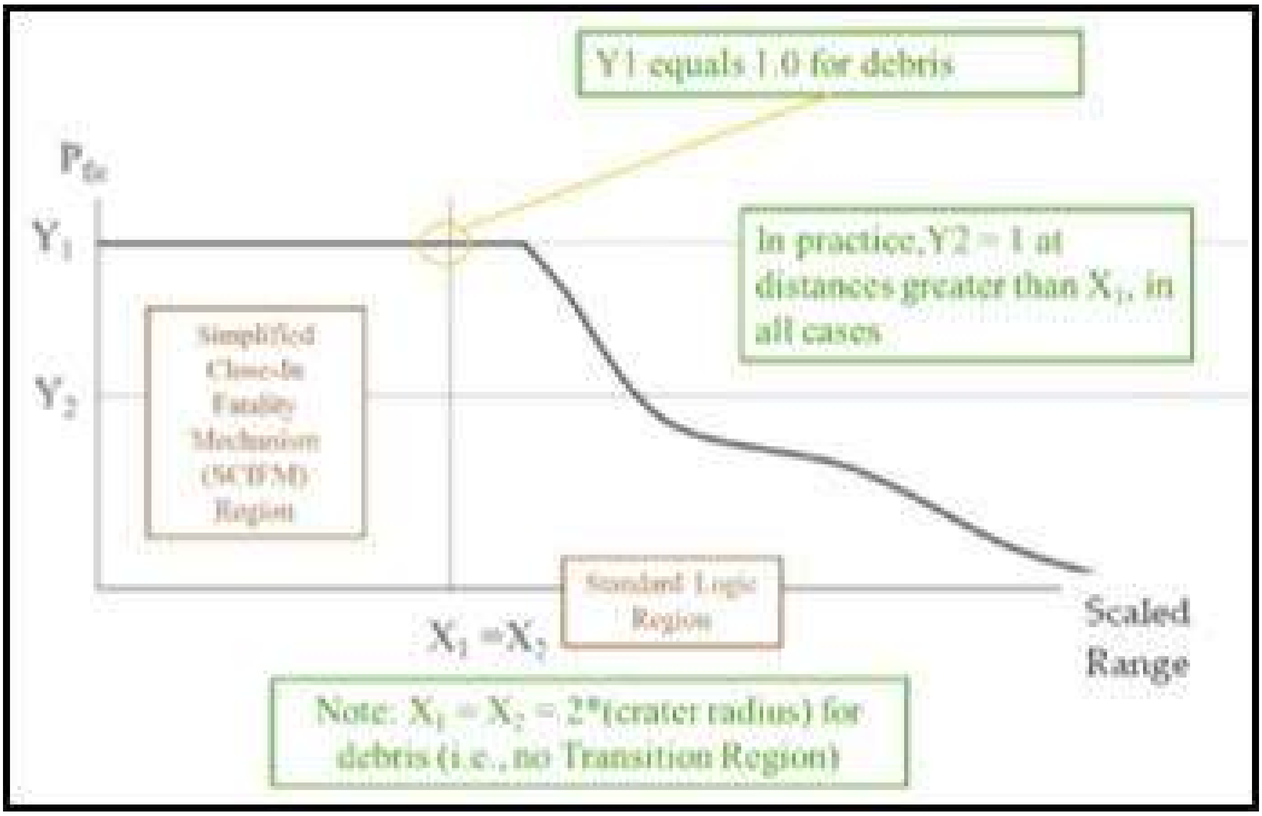


Fig. 13. The Model SCIFM for fragments projected[40] (figure courtesy of APT Research)

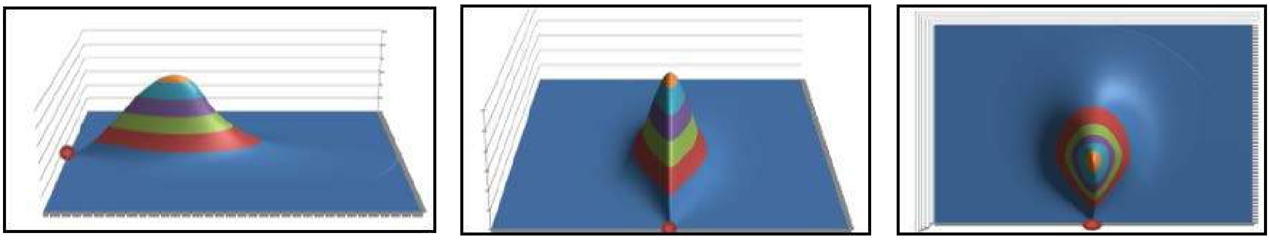


Fig. 14. PDF surface - ISURFGAD PDF[42] (figure courtesy of APT Research)

the contour maps of the destructive capacity, specific to the thrown fragments (kinetic energy of impact from fragments of the material), shown in Figure No. 15[43], and on the histograms of probability values of damage on the human component that define the following areas of interest, respectively: the area of fatality (the degree of mortality), area of major injuries (the extent of damage irreversible) and area of minor injuries (the extent of damage reversible), shown in Figure no.16.

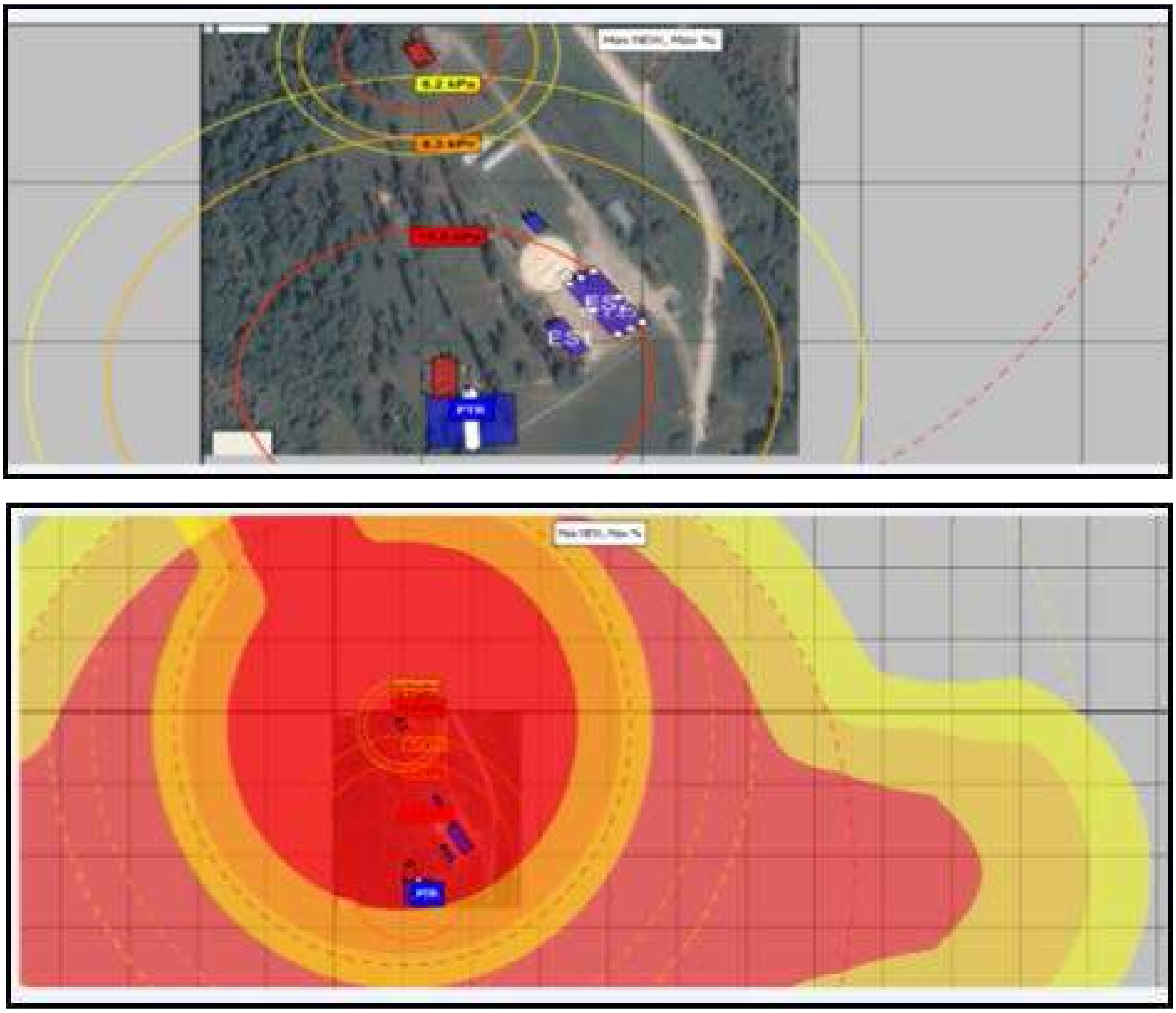


Fig. 15. Contour map for a deposit of explosives with a capacity of 1220 kg ETNT[44]

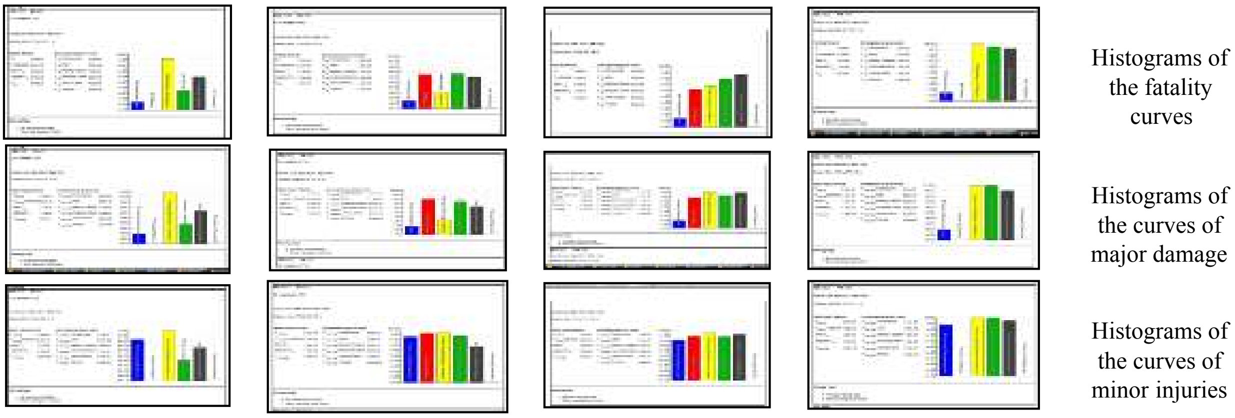


Fig. 16. Histograms of areas of damage on the human component and structures[45]

The results shown in Figures 15 and 16 are needed to establish the areas of interest, in the case of an explosion type event as a result of detonation of explosive charges, resulting in the following planning areas: **area of high mortality**, defined as the area in which it accrues the death of approx. 50% of the exposed population; **the area of irreversible injuries,** defined as the area in which the exposed population is suffering serious harm to somatic level and lung, serious illness, first and second degree burns. Light buildings, suffer major damage becoming unusable. Heavy structures may undergo minor damage; **attention area,** defined as the distance that the effects of the accident can be felt and can cause a mild illness, of short duration, or superficial burns easily curable. When explosion accidents occur, light buildings existing in the area of attention, may suffer minor damage.

Conclusions

Estimating the route configuration of the fragments of material projected can be achieved using model type Fast-Running Models (FRMs), created for hazard analysis in a simplified manner, using different functions for probability dedicated to this area (ex. model type ISURFGAD with the azimuthal variation), for graphic-analytical modelling of the phenomenon of projected pieces of material resulting from explosion type events.

The model of projecting the resulting material after an explosion considers three types of fragments: primary, secondary and scrap resulting from the area of the crater formed. Thus, primary fragments come from the detonated explosives body, and the secondary ones are coming from the structure of the storage room (ex. roof, front, side and rear walls). Also, the other debris of impact which are generated in the area of crater, are fragments coming from the ground or from the foundation structure of the storage room.

This paper has presented the technical aspects of material fragments modelling resulting from the detonation of explosive charges coming from potentially explosive structures, type PES (for the storage of explosive materials) which can destroy the structures exposed to explosion type, ES (for specific activities), with the serious effects on health and integrity of the working staff, and the population from surrounding areas.

The final results of modelling the risk of injury from projection of the material resulting from an explosion event, may be highlighted graphic-analytical, through the associated diagrams of the contour map and histograms of probability values of damage of the human component (death, major injuries and minor injuries).

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*** Program PNCDI – NUCLEU, Proiect PN 16 43 02 15/2016-2017„Cercetări privind creşterea gradului de securitate la infrastructurile tehnice destinate depozitării explozivilor de uz civil , INCD INSEMEX Petrosani.

*** Raport de expertiză tehnică privind *Evenimentul produs în data de 26.05.2008 la SC SPAROMEX SRL Victoria,* INCD INSEMEX Petrosani.

1 The explosive charge is the quantity of explosives prepared for detonation, in the view of displacement a volume of material (rack) for carrying out excavations.
2 Section 3.4 of the IMESAFR Technical Manual
3 Section 3.4 of the IMESAFR Technical Manual
4 Section 3.4.1 of the IMESAFR Technical Manual
5 Section 3 and then Appendix D of the IMESAFR Technical Manual
6 According to Appendix D of the IMESAFR Technical Manual
7 Page D-6 of the IMESAFR Technical Manual
8 According to the pages 39,40 of the IMESAFR Technical Manual
9 According to Table 11 of the IMESAFR Technical Manual and DDESB TP-14
10 Section 3.4.2 of the IMESAFR Technical Manual
11 According to Formula 9 of the IMESAFR Technical Manual
12 According to the Figure 25 of the IMESAFR Technical Manual
13 According to Table 12 of the IMESAFR Technical Manual
14 According to Table 13 of the IMESAFR Technical Manual
15 According to page 42 of the IMESAFR TM
16 Section 3.4.3 of the IMESAFR Technical Manual
17 Figure 26 of the IMESAFR Technical Manual
18 Figure 27 of the IMESAFR Technical Manual
19 According to page D-22 of the IMESAFR Technical Manual (Step 15)
20 Figure D5 from the IMESAFR Technical Manual
21 Figure 31 from the IMESAFR Technical Manual
22 As shown as Equation D29 from the IMESAFR Technical Manual
23 Figure 33 from IMESAFR Technical Manual
24 IMESAFR Technical Manual, page D-24
25 According to page D-25 of the IMESAFR Technical Manual
26 According to page D-26 of the IMESAFR Technical Manual
27 Figure D8 from the IMESAFR Technical Manual
28 Figure 32 from the IMESAFR Technical Manual
29 According to page D-26 of the IMESAFR Technical Manual
30 According to Equation D30 of the IMESAFR Technical Manual
31 According to pages D27-31 of the IMESAFR Technical Manual
32 Figure D-10 of the IMESAFR Technical Manual
33 Figure D-11 of the IMESAFR Technical Manual
34 Section 3.4.9 of the IMESAFR Technical Manual
35 Equation 10 of the IMESAFR Technical Manual
36 According to the page 55 of the IMESAFR Technical Manual
37 Equation 11 of the IMESAFR Technical Manual
38 Equation 12 from page 58 of the IMESAFR Technical Manual
39 Figure 37 of the IMESAFR Technical Manual
40 Figure 38 of the IMESAFR Technical Manual
41 According to the IMESAFR Technical Manual Appendix D
42 According to Figures D-12 and D-13 of the IMESAFR Technical Manual
43 IMESAFR User's Manual
44 Screen captures from IMESAFR v.2.0
45 Screen captures from IMESAFR v.2.0

Upcoming Events

2018 SME Annual Conference & Expo
February 25-28. 2018
Minneapolis, MN, USA
http://www.smemeetings.com/sme-ace-2018/

ITA-AITES World Tunnel Congress 2018
April 21-26, 2018
Dubai, United Arab Emirates
http://www.wtc2018.ae/

Fragblast 12
June 9-15, 2018
Luleå, Sweden
www.fragblast12.org
There will be a course for commercial explosives and mining company personnel particularly those that might be attending Fragblast 12 in Lulea, June 2018.
The course will be jointly run by the universities of Cambridge and Lulea and held on the campus of the latter for three days.
https://www.csc.cam.ac.uk/academic/shortcourses/det2018

25th WORLD MINING CONGRESS
June 19-22, 2018
Astana, Kazakhstan
www.wmc2018.org

HILLHEAD 2018
June 26-28, 2018
Derbyshire, UK
www.hillhead.com

Mining Expo International
September 6-8, 2018
Las Vegas, NV, USA
www.MiningExpoIntl.com

EFEE 10th World Conference on Explosives and Blasting
September 17-19, 2019
Helsinki, Finland
https://www.efee2019.com/