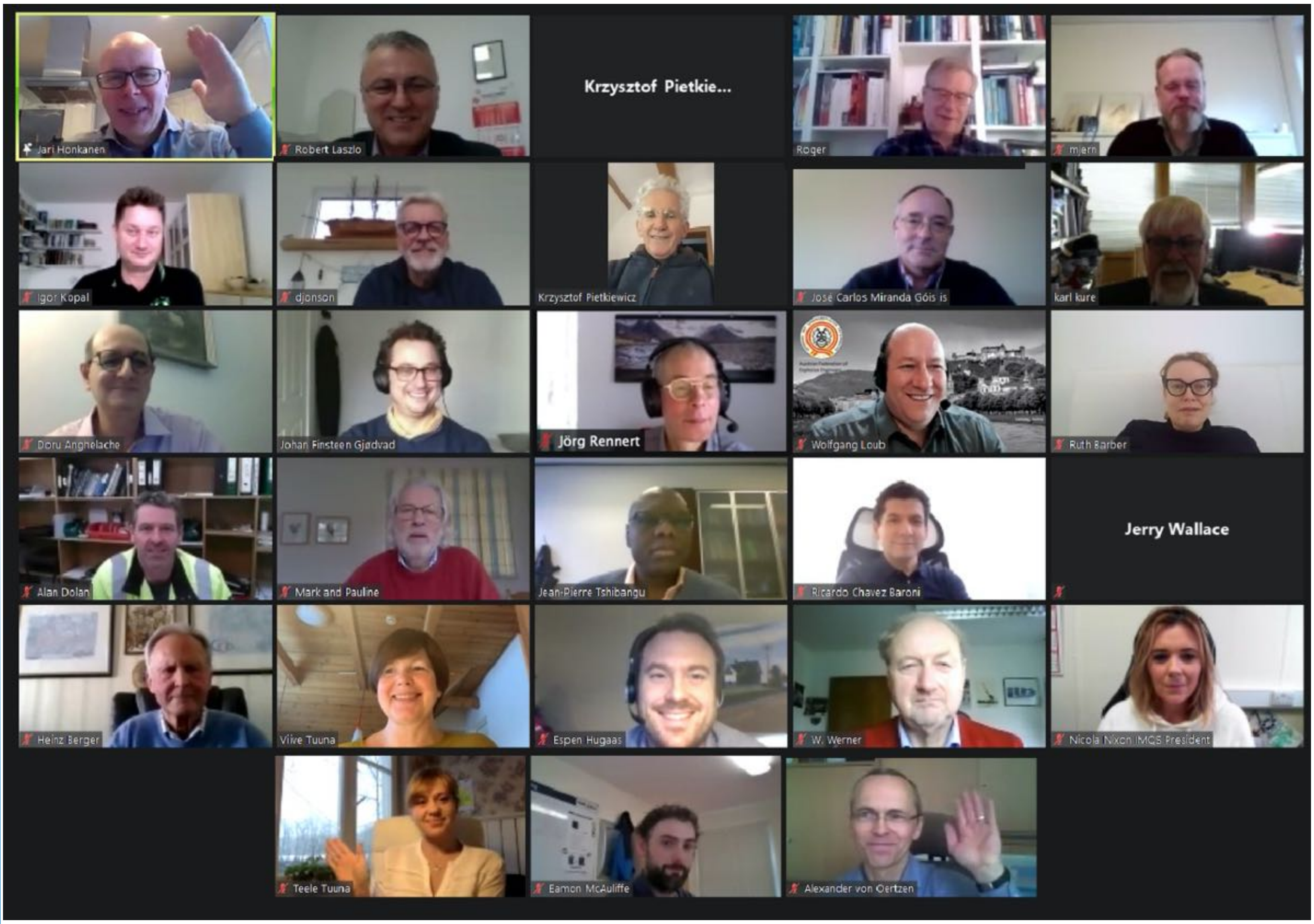
EFEE

NEWSLETTER



EFEE Environmental committee comparison of vibration standards part 2 – Project update

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A New Tool For Hole Deviation Control

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December 2020

The Presidents Voices..3

Updates from the 65th EFEE Council Meeting and 19th Annual General Meeting held on the 20th of November 2020..............6

EFEE Environmental committee comparison of vibration standards part 2 – Project update..9

Toxic fumes from detonation of emulsion explosives.............14

Repackaging of explosives: A task not anticipated in the Danish regulations...28

A New Tool For Hole Deviation Control...................................37

Next EFEE Conferences...49

Greetings from the ISEE...51

Upcoming International events..53

We in EFEE hope you will enjoy the present EFEE-Newsletter. The next edition will be published in February 2021. Please feel free to contact the EFEE secretariat or write to newsletter@efee.eu in case:

- You have a story you want to bring in the Newsletter
- You have a future event for the next EFEE Newsletter upcoming events list
- You want to advertise in an upcoming Newsletter edition

or any other matter.

Viive Tuuna, Chairman of the Newsletter Committee and the Vice President of EFEE and

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

EFEE

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Dear EFEE members, the Presidents voices

My last day as the President of EFEE was 20th of November and my last official task was to run the Annual General Meeting on that day. A new board was elected for EFEE in this meeting and thus my 2-year long term finished as our constitution dictates.

I had of course high ambitions when I started my term in 2018. However, it is surprising how the time flies and two years goe by quite fast. The EFEE board has normally 4 meetings in a year, so the presidency lasts normally only a period of 8 meetings. Mine lasted 10 meetings because the AGM was delayed half a year due to COVID. Looking back this short period now, I am glad to note that I was able to meet at least some of those goals I had set for myself.

My first priority was to arrange a successful conference in 2019 in Helsinki, as the conference took place in my home country Finland and I was personally responsible for many arrangements. I would like to thank the whole Tyler Events team for hard work and good co-operation in all arrangements concerning the 10th Conference – we delivered a truly great event together!

Another important goal for me was to develop the administration and management of our association, so that we would be positioned better to face the requirements and challenges of the future. I have had an excellent hard-working board to run during my term and the good co-operation from everyone has made it possible to develop the administration of EFEE even further during these two years. We have for example re-arranged roles and tasks within the board to even out the workload and to remove obstacles for equality in nominating candidates for all board positions in the future. We have also made agreements with two contractors supporting the EFEE administration in the future. The first one is for marketing of advertisements and memberships with Tyler Events, which is also our main conference organizer. The second is for administration and running of PECCS training program with Spark & Stone Concept (Ms. Teele Tuuna). Therefore, I am proud to hand over a really strong and well-balanced board and administration to the next President of EFEE, Mr. Doru Anghelache from Romania, who also served as the Vice President during my whole term.

My sincere thanks and gratitude to Doru and all others who served in the board of EFEE during my two years! I could not have made any of this without your hard work and support. I am especially grateful to Igor Kopal, who supported and instructed me excellently as the Immediate Past President.

Jari Honkanen, Immediate Past President of EFEE

Dear colleagues,

As a newly elected President, I must start my first address by complimenting Jari for his leadership during a very difficult year in 2020 and before that.

As you know, to keep up with these difficult times, we have altered the way we conduct our meetings. Through the use of social media platforms, we have been able to hold our regular meetings online and have successfully run all planned activities despite the physical meetings being cancelled one by one. Notwithstanding the physical distance, these meetings have provided us with a sense of togetherness and support during a much needed time.

As recent news of upcoming vaccines have lifted our spirits, I want to start my term looking positively towards the future.

Already past President Jari Honkanen pointed out the achievements during his longer than 2 year presidency. I myself have to make sure to live up to his legacy and deliver as President of EFEE with the same consistency which his mandate has accustomed us all. I'm very pleased to see that despite all the difficulties, EFEE has continued to develop and be an authoritative voice of the explosives industry in Europe and beyond.

One of my fondest memories with EFEE goes back to 2003, when I was on a business trip in Czech Republic while working for Austin Detonator. I was invited to participate in the EFEE Conference held in Prague. As this was my first ever attendance, I remember being impressed with the people I've met and the high standard of the conference.

Since then, I have made all efforts to participate in the EFEE Conferences. Later, in 2015, after the Telford Council and the AGM, I became a board member representing EFEE Corporate members, as well as President of the Romanian Association of Explosives and Blasting Engineers – A.R.D.E. Therefore, 2015 is a reference year for me due to these milestones and I am incredibly honoured to now serve as EFEE's newly president.

To borrow a page from Jari's book, I want to take this first opportunity to introduce myself to those who do not know me. My background is Mining Engineering and I have graduated from the Technical University in Petrosani, Romania, in 1991. My first job was with the National Lignite Mining Company « OLTENIA », DRAGOTESTI Lignite Mine, where, along the years, I was responsible with development, support, production and have held various HSEQ positions.

I have been serving the explosives industry since 2003, when a new Austin Powder company was established in Romania. Later, starting with 2005, I started working for RomNitro Explosives S.R.L. – Bucharest, Romania, company sole shareholder Nitromak - dnx Ankara, Turkey, as a General Manager, then in 2010 as a Commercial Director of EPC Explo Romania S.R.L. (subsidiary of EPC GROUPE) and in 2014 as a Commercial Manager

(Procurement, Sales and Logistics) of SSE Explo Romania S.R.L. (part of Société Suisse des Explosifs),

At the end of 2018, I returned to the Austin family as the Administrator of the Romanian business entity and completed in the first half of 2020 the sale and transfer of part of the business to SSE Explo Romania S.R.L. Today I am the Managing Partner of Nitro Nobel GROUP S.R.L., company established in 2010.

As Jari mentioned when he took over the EFEE Presidency, the most important task for the President is to lead, unite and support the board, council and committees in all their endeavours and to work for EFEE and generally for our industry. I would like to echo those words and similarly invite you to share any ideas you might have on how we can develop the federation. It is an ambition of mine to lead with the same spirit of co-operation and openness which Jari has instilled in the federation. I am also grateful for his support as an Immediate Past President.

I must congratulate Mrs. Viive Tuuna, representing Estonian Association of Mining Enterprises (Eesti Mäetööstuse Ettevõtete Liit (EMTEL), who has been elected as the new Vice President of EFEE, and I wanted to give a warm welcome to Espen Hugaas from Norsk Forening for Fjellsprengningsteknikk (NFF) who has recently been elected as a new board member.

My special thanks to Roger Holmberg, our General Secretary, one of the most important pillars of EFEE since many years. He is a model that continues to inspire all of us.

Thank you everyone for your continued support and I hope to do my best over the next two years in the service of all of you.

Doru Anghelache, President of EFEE

Updates from the 65th EFEE Council Meeting and 19th Annual General Meeting held on the 20th of November 2020

Dear EFEE Members,

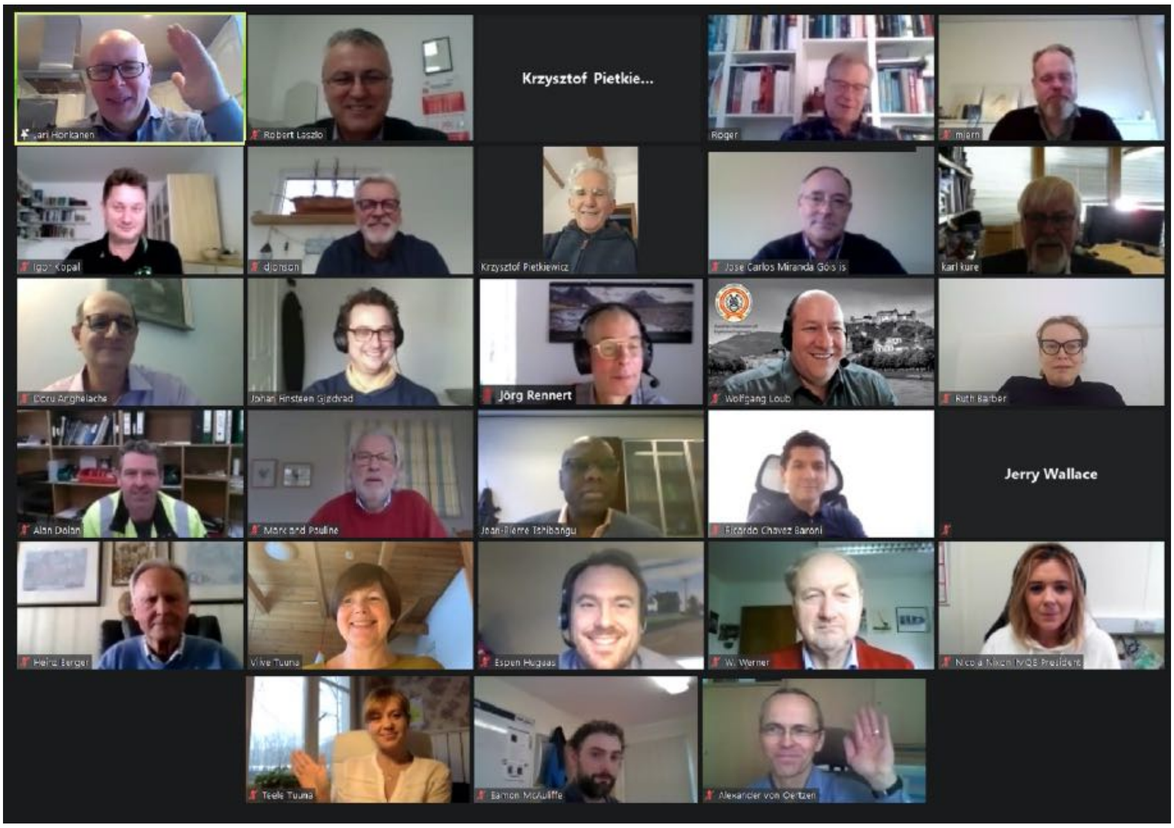
We wanted to commence this newsletter by highlighting some of the key updates regarding EFFEE from the 65th Council Meeting and 19th Annual General Meeting, both held over Zoom on the 20th November 2020. Considering the online format of the meetings, the two session were well-attended by our members, with only a few absences recorded.

We are pleased to inform you that EFEE has approved one new Corporate member, 42 new individual members, 2 student members and one honorary member since its last Council meeting in Helsinki in 2019. At the Annual General Meeting, Doru Anghelache has been unanimously elected as President, Viive Tuuna has been unanimously elected as Vice-President, Jörg Rennert has been unanimously elected as Treasurer, and Johan Gjødvad, Igor Kopal, Mathias Jern and Espen Hugaas have been unanimously elected as Board Members and Jari Honkanen will continue in the EFEE Board as the Immediate Past Presidet. In addition, Robert Laszlo, Mathias Jern and Tomi Kouvonen will be representing Corporate Members 2020-2022, and Teele Tuuna was chosen to represent Individuals for the 2020-2022.

Regarding the 2019 Finance and Audit reports, Committee Chairman Walter Werner and Proxy Auditor Donald Jonson have confirmed the correctness of EFEE's finances in 2019. Furthermore, the 2020 budget has been unanimously approved at the AGM. It has also been decided that the Vice President will continue as Chairman of the Newsletter Committee and that the Immediate Past President will handle the Membership & Marketing Committee. We are also happy to report that the Council accepted Jari Honkanen's proposal for the expert specialist team, the administration team and for the role of chairman of the Shotfiring Committee. It has been decided that Robert Laszlo will act as the Vice Chairman of the Shotfiring Committee and will take over as chairman after Karl Kure retires from this position. Considering the evolution of the pandemic, the Council has also voted to change the location of the 11th EFEE World Conference to be held in Maastricht, the Netherlands. The new chairman of the Conference committee will be Igor Kopal.

As before, we want to thank all the participants to the meetings for their time and our members for their continued interest and support.

Doru Anghelache, President of EFEE



Some of the participants from the EFEE Annual General Meeting in Zoom.

Participants from the EFEE Board Meeting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EFEE Environmental committee comparison of vibration standards part 2 – Project update

Comparing world standards for blast vibration monitoring with building response and involvement of international experts.

In the early days of 2018, the Environmental Committee of EFEE undertook a detailed comparison of the large differences between blast vibrations standards throughout the world. The project was inspired and lead by Mathias Jern (Nitro Consult) and Johan Finsteen Gjødvad (Sigicom) who were able to draw upon their thirty plus years of consulting on vibration monitoring.

First phase of the project

In the first part of the project, national vibration standards were compared using a survey combined with interviews of professionals in the field around the world. Results were presented at two conferences, namely the EFEE conference in Helsinki 2019 and the ISEE conference in Denver 2020. The first part did not conclude but rather observed and compared details. One of the main findings was a confirmation of the huge difference between the different standards. These differences included the wide differences in both restrictions and how the issue is addressed through measurement. The observed differences were quite substantial, confirming that the different national vibration standards vary a lot when it comes to the allowed vibration levels.

Figure 1 Arial overview over the Aitik mine in northern Sweden, the green ring indicating the approximate area of blasting and the blue buildings for possible monitoring.

Allowable vibrations levels vary by up to a factor of 10 for the exact same blast. There are also large differences in where the monitors are placed, which directions that are monitored, which frequency content are recorded, how the dominating frequency of the vibration is determined etc.

Second phase of the project

The described differences create challenges in comparison of results from vibration monitoring between different countries. How can such differences be explained and/or defended? It is obviously a problem from an academic perspective but also from a practical view in a more and more international world where both blasters, consultants and contractors work all over the world and hence must address the problem of vibration from blasting in different countries with different standards. Such large differences also challenge the standards of correctness.

Therefore, the next and present part of the project, part 2, was launched to provide more insight concerning the implications of these differences through actual measurement. Here the aim is to better understand how large the differences are between the different standards and to some degree why these differences exist:

- *Are the large differences in allowed vibration levels from different countries the result of different acceptance levels of risk for damage to buildings?*
- *How does the wide range of required transducer attachment affect measurement? How are they mounted, where and why? And is there a difference in measured vibrations due to these differences?*
- *Is the purpose of the standard the same? It might be to protect buildings and other constructions from cracking due to vibrations. Or is it to keep disturbance at an acceptable level both relating to neighbours and to the society. Or is the motive to give equally restrictive rules to all blasting companies making it less attractive to take large risks to gain competitive advantages?*
- *Can cracking potential be assessed by comparing blast response of existing cracks during the blasts to that produced by normal environmental response or by calculating strains from relative displacements. In other words, how do standards compare to actual building responses.*

Figure 2 From the left; Johan and Mathias during visit to the Aitik mine test site.

Objectives of the different standards are not fully known. The way a standard is written is in its nature normally limited when it comes to background, history, and explanation of the content, hence it's almost impossible to grasp the full reason for these large differences. Where possible this historical context will be compared but most importantly the actual differences will be compared.

The aim of the second part the EFEE project

The aim is to measure vibrations from blasting using some of the representative national standards to be able to compare them properly.

Initially the standards that will be compared are USBM (USA), BS (UK), DIN (DE), SS (SE), Decree of 22 September 1994 (FR). The compared standards represent the most used stands in the world or standards that are representative for a type of standards in a region.

A guidance committee of national experts, with knowledge of the use of and developmental history of their standard has been assembled to oversee the second phase.They are involved to guide and validate the methods of monitoring and data analysis are correct. The aim is not only to base the monitoring on what is described in the standard but also the actual practice in the different countries.

Monitoring will be performed by mounting equipment according to the normal practice of the different countries guided by the national experts connected to the project. In addition to comparison of measured response to allowable excitation, building response will also be measured through three methods. First is the traditional comparison of upper story response to the ground excitation.

Second, building strains will be calculated from relative building displacements measured in two locations. And thirdly crack response will be compared to both blasts induced ground motion and climatological effects to determine the relative importance of the measured response.

Apart from the data which is to be collected during the project comparison will also be made with results from a similar Norwegian study by Norwegian Geotechnical Institute, which is mainly focusing on the Norwegian standard.

Since these tests will not involve direct observation of cracking, two other building performance measures will be employed. Stain is being monitored because it is judged by many to be the parameter which most directly relates to material sensitivity by physical principles. Crack response is being monitored because no measurement is either large or small or good or bad without comparison. This as strain judged by many is seen as a good unit to monitor the well-being of a building or structure. Strain is a good common indicator which can be used to challenge the results from the standards. This as the results of the standards this way can be compare to the actual material properties of a structure.

Status of the project.

Until now two online workshops have been completed. The initial workshop gathered the experts, presented how the project was planned, the standards to be monitored by and compared, the equipment to be used and the planed site for monitoring.

Figure 3 Screenshot from the workshop, where participants from around the globe are giving input to the project.

The project is very fortunate to have a group of skilled and renowned experts attached to the project. The project is very thankful that they want to spend time on this project and contribute with their comments and commitment. The involved experts are listed below.

The project is very thankful that Boliden have let us monitor on their mine and have been very well guided and assisted in the mine by our contact Mr. Torbjörn Krigsman. Finally, the Second workshop included a presentation by Mr Syed Alley Hassan,

Dr. Robert Farnfield (UK)	Dr. Vitor Luconi Rosenhaim (BR)
M.Sc. Karin Noren-Cosgriff (NO)	Dr. Thierry Bernard (FR)
Prof. Charles Dowding (US)	Mining Eng. Kenneth Eltschlager (US)
Dr. Catherine T. Aimone-Martin (US)	Dr. Nathan Rouse (US)
Dipl.-Geogr. Johannes Kutschera (DE)	Dr. Chanping Yi (SE/CH)

Table 1 The group of experts connected to the project.

The second workshop awaited a site visit to the open pit mine where the monitoring is to take place. Namely, Europe's largest open pit mine the Aitik mine. The discussion was focused on proposed positions for monitoring and alternatives. The Aitik mine is situated North of the Polar circle close to the Swedish town of Gällivare.

from Luleå Technical University (LTU). Syed presented his master thesis, which will be part of the EFEE vib2 project. EFEEs Environmental committee and the project are grateful to LTU and Professor Daniel Johansson and Dr. Chanping Yi to establishing the contact to Syed.

Vibration monitors will be placed on the foundation of the selected building, in the soil in front of the building and (if possible) on the top floor of the building. In addition, if possible, crack sensors and velocity transducers for strain calculation will also be placed on the selected building blasting area. Several blasts will be monitored. Monitoring will be done with Sigicoms instrument C22 which has the ability for GPS-clock synchronization between the monitors. This ability also gives the opportunity to analyze relative displacement, wavelength, and strain in the structures. The project is grateful that Sigicom has promised to provide both Geophones and crack-gauges to the project.

If you want to know more about the project you can contact either Johan Finsteen Gjødvad or Mathias Jern which are responsible for the project on the behalf of EFEE.

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Toxic fumes from detonation of emulsion explosives

U. Nyberg, D. Johansson and N. Petropoulos

Luleå University of Technology, Sweden

ABSTRACT: This article deals with toxic fume measurements of CO, NOx and Velocity of Detonation VoD in a 35 m^3 detonation test chamber. Pure and blended emulsions were tested in this study. Formation of toxic fumes from detonation of emulsion explosives in thick walled mortar confiners were compared with data from thin walled glass confinements with otherwise similar dimensions. Furthermore, intentional deviation in oxygen balance of ± 5 % for pure emulsion explosives and decoupled pure emulsion explosives in dry respectively wet blast holes are tested. Production of toxic fumes is dependent on the type of explosives, charge diameter and oxygen balance. In general, pure emulsion generates lower toxicity than blend emulsion, concentration of toxic fumes relative charge weight decreases with charge diameter and the tested deviation from oxygen balance have significant effect on generation of CO and NOx.

1 INTRODUCTION

Swebrec at Luleå University of Technology have during 2015 and 2016 measured toxic fumes from detonation of pure and blended emulsion explosives in a detonation test chamber. The studies have been made possible through founding by the stakeholders LKAB and Kimit AB, Boliden AB and Forcit AB and by Vinnova - SIP STRIM (a Swedish innovation agency). It is a continuation of a pilot study that was carried out in 2014 which was partly financed by LKAB fund for promoting research and education at LTU. *The project aims to improve the knowledge of production of toxic fumes from detonation of emulsion explosives in rock blasting both for surface mining and underground mining and to minimize the staff exposure to toxic fumes.*

In a study by Bakke et.al (2004), the cumulative exposure to nitrogen dioxide was found to be a major risk factor for lung function decreases based on Spiro-metric measurements of 651 male construction workers during 1989-2002 for an average of 6 years. Bakke et al. (2004) also concludes that "Contact with blasting fumes should be avoided, diesel exhaust emission should be reduced and respiratory devices should be used to protect the workers against dust and nitrogen dioxide exposure".

This paper is based on a work, Nyberg et al. (2017), on toxic fumes generated by detonation of i) pure emulsion ii) pure emulsion with 5% Al additives, iii) pure emulsion with 30 % dry AN-prills additives, iv) oxygen un-balanced pure emulsion and v) pure emulsion in dry and wet holes with decoupled charges.

The field work was done in Swebrec:s 35 m^3 detonation test chamber for maximum 5 kg TNT placed at FOI Grindsjön in co-operation with stakeholder's experts and researchers from Luleå University of Technology.

1 METHODOLOGY

1.1 Test setup

The tests were divided in 4 rounds, see Table 1-1. The difference between the rounds can be seen, from wall thicknesses, hole inner diameters and length of confinements. The explosives were initiated with shock tubes and standard pyrotechnic caps, 8-12 grams of plastic explosive with energy = 4.7 MJ/kg, density = 1500 kg/m^3 and VoD = 7680 m/s, Helte etal. (2006). The 1st round comprises tests with pure and blended emulsion in 8 glass- and 2 PVC (thin walled confiners) and was a validation of the results from a pilot study, Nyberg et al. (2015). In the second round, 8 charges in thick walled mortar confiners, Johansson (2010), were tested with pure emulsion and emulsion with additives (aluminium). This round also included a supplement to the detonation test chamber with an additional 150 l stainless steel vessel installed outside the blast chamber in order to evaluate the effect of the chamber material properties. The third round dealt with intentional deviations of ± 5 % in explosive's oxygen balance and tests with ANFO- explosives in Ø50 mm mortar confiners which served as a reference. The 4th round dealt with oxygen balanced and decoupled string emulsion Ø22 mm in Ø50 holes. Here both Dry String (DS) and Water coupled String (WS) were tested with mortar cylinders as confiners.The decoupling ($Ø_{hole}/Ø_{expl.}$)reduces the shock waves

substantially, which could be seen as a fairly practical case for cautious blasting, see Figure 1-1.

Figure 1-1: Decoupled string emulsion Ø22 mm in Ø50 hole and a VoD probe in a mortar confinement.

Round	Conf.	Wall mm	Hole $Ø_i$ mm	Length mm	No. tests
1	Glass, PVC	1.8-4.2	27.0-80.0	≥8.1$Ø_i$	10
2	Mortar	35-63	19.6-75.0	≥8.5$Ø_i$	8
3	Mortar	35-59	32.1-75.0	≥9.8$Ø_i$	14
4	Mortar	50	50.0	≥9.8$Ø_i$	6

Table 1-1: Confinement data. Decupling ration is 1 except for round 4 with ratio 2.27.

the composition for pure emulsion explosives E682 and with additives of 5 % Al and 30 % dry AN-prills are presented. The AN-prills additives are porous with sizes between 1 to 2 mm. The droplet size is 2-10 µm and Al particles are recycled 0.1-0.3 mm. The composition of the explosives for Glass- (G) and Mortar (M) can be found in Table 1-3. The emulsion explosives are sensitized with approximately 3% glass micro spheres with density 0.20 g/cc (3M K20). The density of ANFO was 816 kg/m3.

Content	E682	E682+ 5% Al	E682+ 30%AN
Oxidant %	94.00	95.30	91.50
Oil %	4.00	2.70	6.50
Emulsifier %	2.00	2.00	2.00
Density kg/m³ (G)	1170	1170	1150
Density kg/m³ (M)	1155	1130	1165
Oxygen balance %	0.09	-0.01	-0.02

Table 1-2: Explosive composition for round 1 and 2 with tests in Glass (G) and Mortar (M) confiners.

Content	E682 Neg.	E682 Pos.	E682 String
Oxidant %	89.76	95.54	94.00
Oil %	5.30	2.52	4.00
Emulsifier %	1.94	1.94	2.00
Density kg/m³ (M)	1170	1141	1150 (Target)
Oxygen balance %	- 5.09%	+ 5.03%	0 (Target)

Table 1-3. The emulsion explosives are sensitized with approximately 3% glass micro spheres with density 0.20 g/cc (3M K20). The density of ANFO was 816 kg/m3.

Table 1-3: Explosive composition in mortar confiners for round 3 with negative and positive oxygen balanced emulsion explosives and for round 4 with oxygen balanced string emulsion.

1.2 Measurements

The measurements were done from a hole in a lid from one of the modified camera windows (see Figure 1-2) and a separate 150l stainless steel vessel connected to the chamber for comparison (not shown in the Figure). Before each test, the chamber had normal fresh air and atmospheric pressure at P_1.

The explosives were placed in the centre of the test chamber and the two upper valves were closed as well as the lower one and the door. After detonation, the peak pressure in the chamber increased to P_2 and the detonation products were blowing out from the measurement holes until the pressure was reduced to $P_1 \approx P_2$. In that moment the recording starts at time $T_0 \approx$ 1-3 minute after detonation. The recording instrument was a flu gas analyser ecom EN2 with a flow rate of 2l per minute. The explosive products were pumped via the standard instrument pipe or a PTFE inert tube connected to the instrument. The electrochemical sensors had following specification in terms of range, accuracy and (resolution); O_2: 0-21 ± 0.3 vol. % (0.1%), CO: 0-4000 ± 20 ppm (1 ppm), NO: 0- 5000 ± 5 ppm (1 ppm), NO2: 0-1000 ± 5 ppm (1 ppm) and the IR sensor for CO_2: 0- 20 % with resolution 0.1 vol. %. The data-sampling rate was set to 1 sample per second for a period of 50-60 minutes. This is in general oversampling, but suitable for the first peak and the drops at the beginning of the recording.

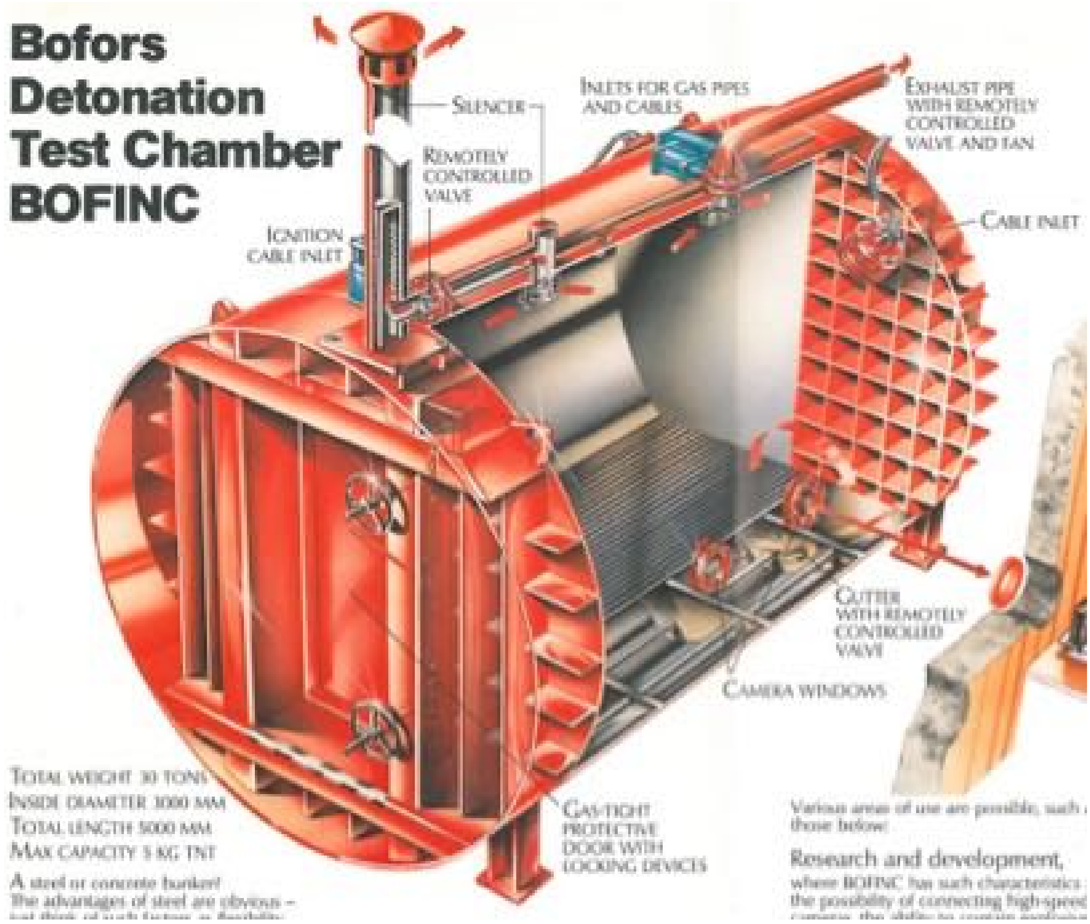

Figure 1-2: Test chamber for toxic fume measurements. Data sampling from modified camera windows and a 150 l stainless steel vessel (not shown).

2 RESULTS

2.1 Velocity of detonation

In general Velocity of Detonation, VoD vary due to the type of explosives, type of confinements and charge diameters. VoD becomes unstable close to critical charge diameters and for large diameters it is close to ideal detonation conditions.

The VoD as a function of 1/charge diameter is shown in Figure **2-1**. The upper line represents the pure emulsion E682 and the lower emulsion E682 with 5% aluminium additives.

Vixen-I version 5.1 was used for the infinity charge diameter with slightly different pure emulsion (density of 1169 kg/m^3) and with 6 % aluminium additives (density of 1180 kg/m^3), Hansson (2009:1). Copper pipes were used for Ø100 mm, Esen et al. (2005). Fitting to similar pure emulsion VoD data in PVC pipes by Nie et al. (2000) shows no significant difference to the one in the figure below.

Further measurements for charge diameters over Ø100 mm could confirm or exclude the linear fit of the VoD models.

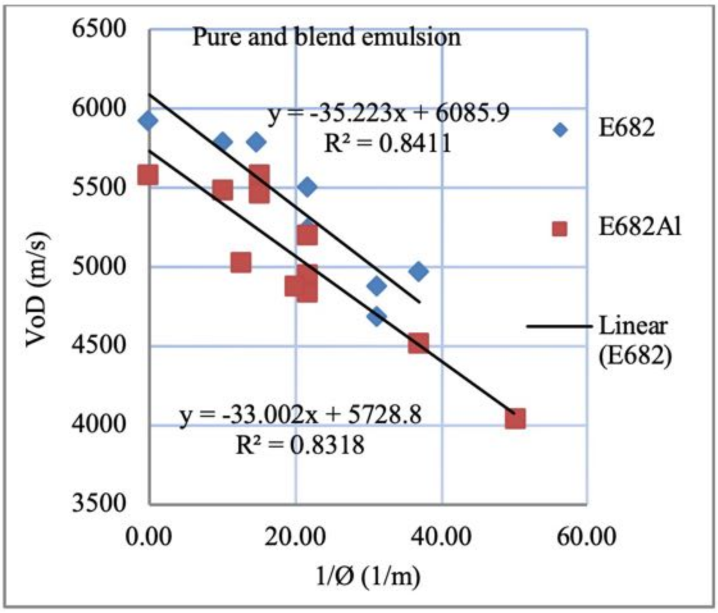

Figure 2-1: VoD data for pure and blend emulsion explosives.

Figure 2-2 shows VoD for negative (- 5%) and positive (+5%) oxygen balance for pure emulsion E682 and an oxygen balanced reference ANFO explosives in thick walled mortar confinements. The oxygen balance is not a critical factor for VoD according to these data and the blasting performance is not significantly affected by the unbalanced emulsion explosives. The VoD for ANFO is, as expected, significant lower than for the emulsion explosives.

There is no significant effect on VoD of short time exposure of water in decoupled blast holes for the tested string emulsion, Figure **2-3**. For example Rowland et al. (2001) was testing the effect of emulsion loaded in pipes with water for up to 2 months and there was no visible effect on the emulsion and VoD.

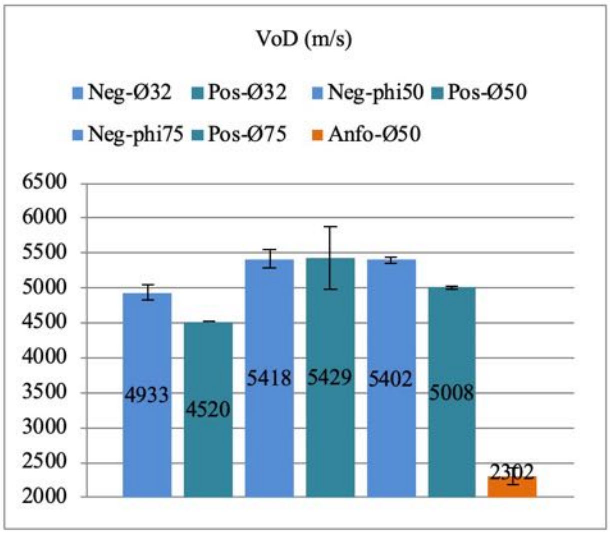

Figure 2-2: VoD for fully coupled negative- and positive oxygen balanced emulsion and ANFO in mortar confiners (N=2).

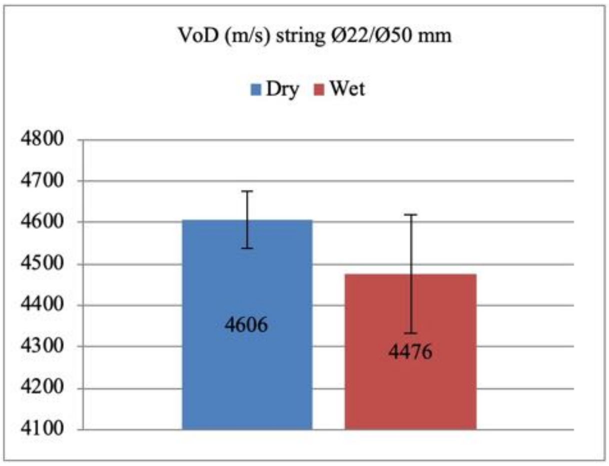

Figure 2-3: VoD for dry and wet holes for decoupled and oxygen balanced string emulsion in mortar confiners. For wet holes (N= 2) and for the dry holes (N= 3).

2.2 Toxic fumes

The produced volumes of toxic fumes V (l/kg explosives) are estimated based on recordings of peak ppm for NOx and CO, Figure **2-4**, from a flue gas analyser and the 35 m^3 test chamber and some missing produced volume δ based on explosive mass roughly 900 l/kg, eqn. 1,

(1) $V\ (l/kg) = 10^3 \cdot (ppm/10^6) \cdot (35+\delta)/m.$

Dips in the recordings are related to change in the measuring point i.e. sampling in the small 150 l vessel which was connected to the blasting chamber. Dilution did sometimes cause lower ppm-values in the vessel. Data by for example Maranda et al. (2011) shows that concentration of CO remains constant and concentration of NO and NO_2 vary linearly with time due to secondary reaction of detonation products.

Figure **2-5** to Figure **2-8** show trends for pure and blend (Al- or AN-additives) emulsion explosives of decreasing CO- and NOx values with increasing charge diameters in glass and mortar confinements. Comparison of toxic fumes from glass confiners with mortar confiners is difficult due to missing repetitions though there are some values indicating lower toxicity for the mortar confiners. According to Roberts (1992) heavier confinements reduces NO_2.

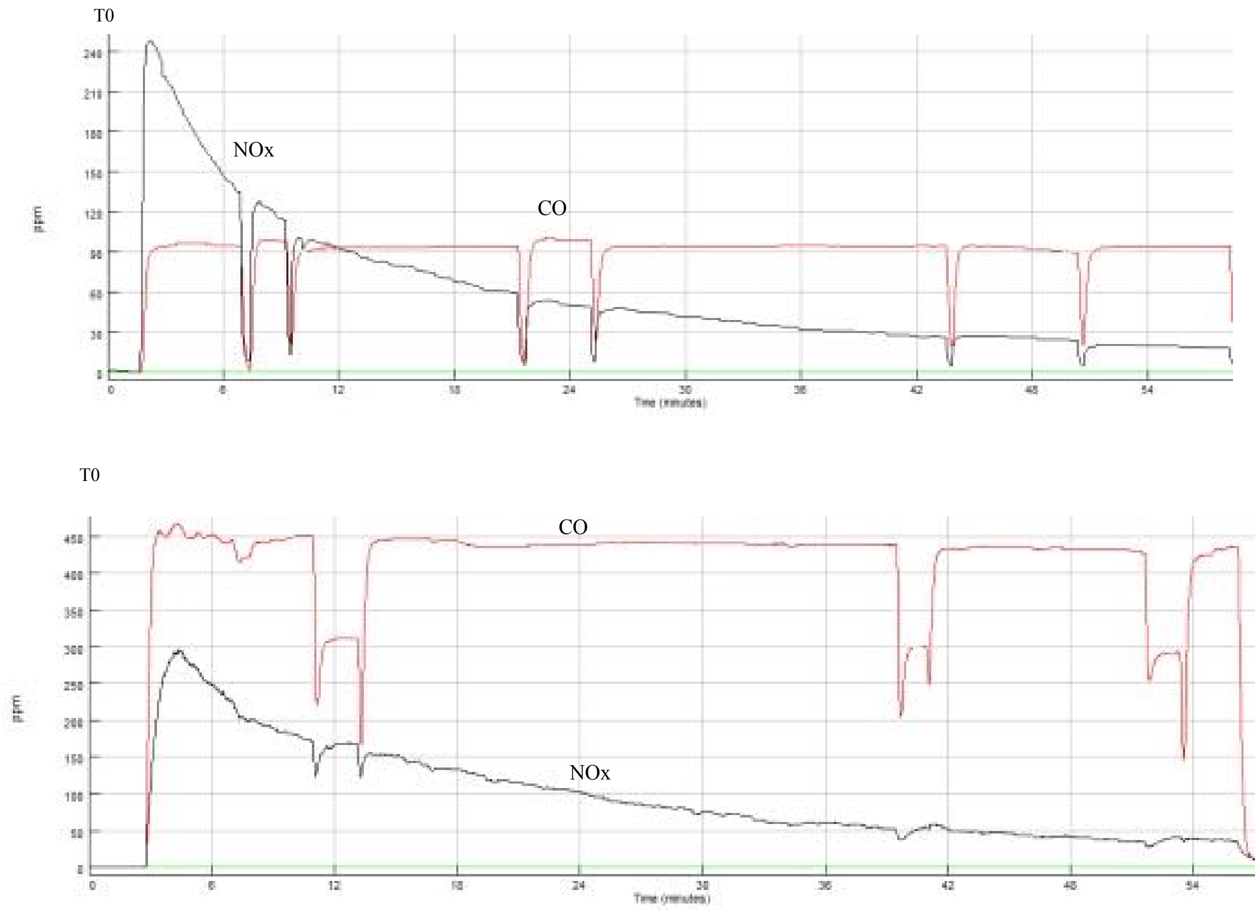

Figure 2-4: Time recordings of ppm for CO (red line) and NOx (black line). The upper figure shows pure emulsion with 5% Al additives (≈ 1.19 kg) and the lower shows ANFO Ø50mm
(≈ 0.78 kg).

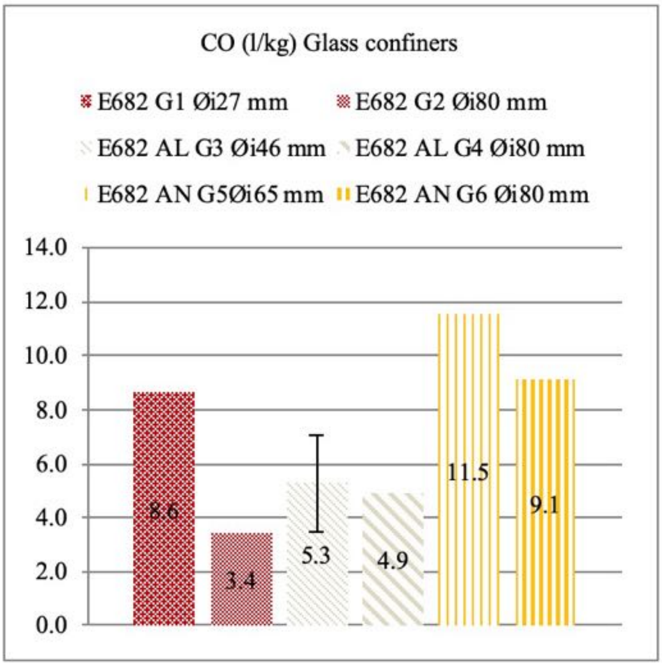

Figure 2-5: Measured CO for pure and blend emulsion (N=2 for one diameter).

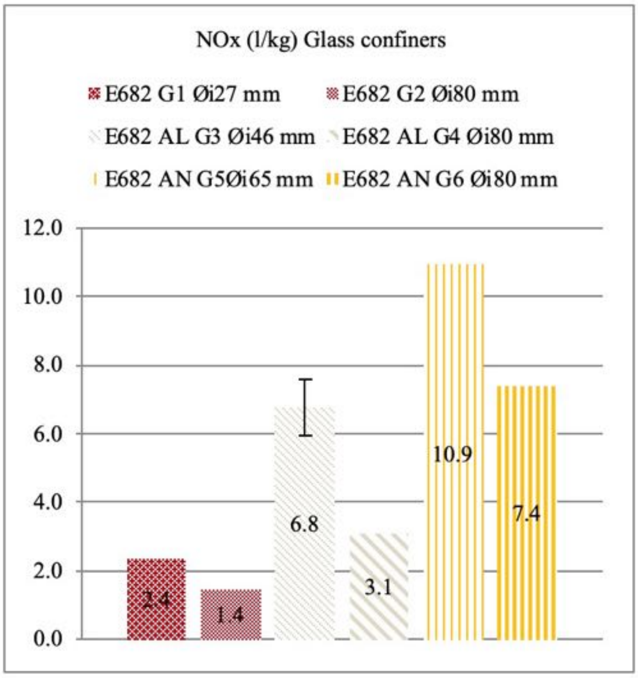

Figure 2-6: Measured NOx from pure and blend emulsion (N=2 for one diameter).

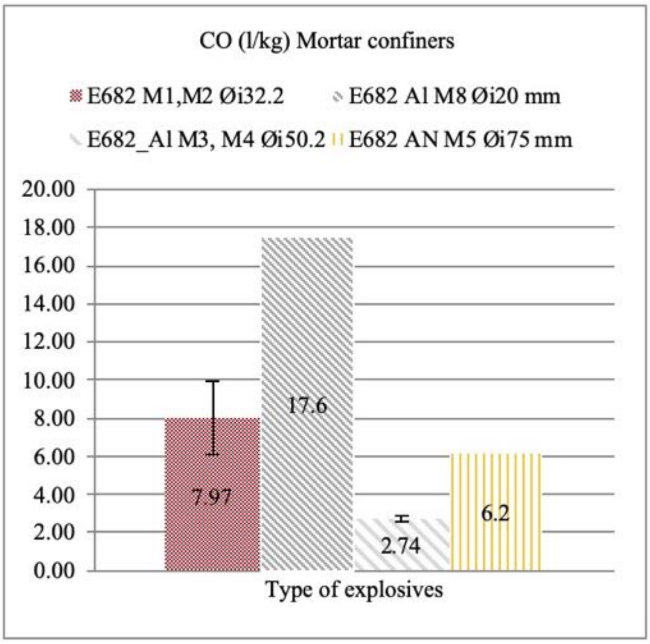

Figure 2-7: CO for pure and blend emulsion in fully coupled mortar confiners (N=2 for 2 diameters).

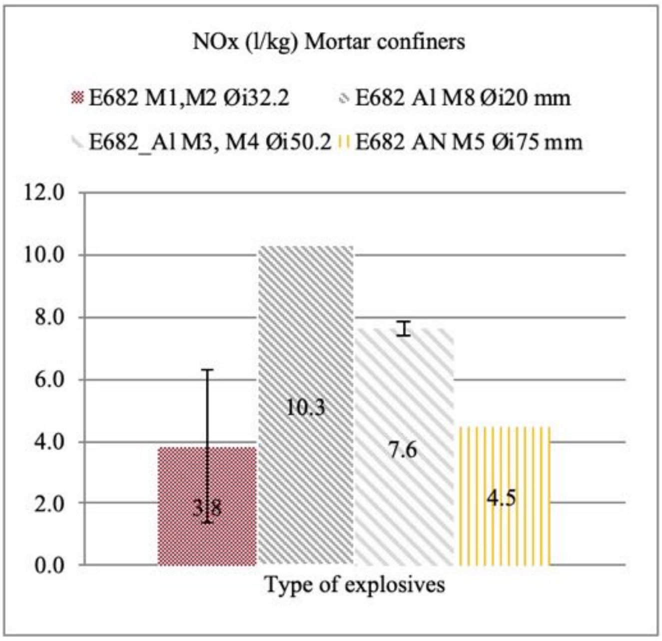

Figure 2-8: NOx for pure and blend emulsion for fully coupled charges (N=2 for 2 diameters).

The effects of oxygen balance on toxic fumes are shown in Figure **2-9** and Figure 2-10 for tests in mortar confiners for fully coupled charges. The explosives were manufactured with -5 % and + 5% oxygen in order to encourage possible conditions which could be similar to the ones in mining conditions.

The CO values are higher for the negative balanced explosives and lower for NOx i.e. for oxygen balance OB < 0 CO are produced and for OB > 0 NOx is produced. There is decreasing values for CO with increasing charge diameters for positive oxygen balance which is not the case for negative oxygen balance. For NOx both positive and negative oxygen balance shows decreasing values with increasing diameters.

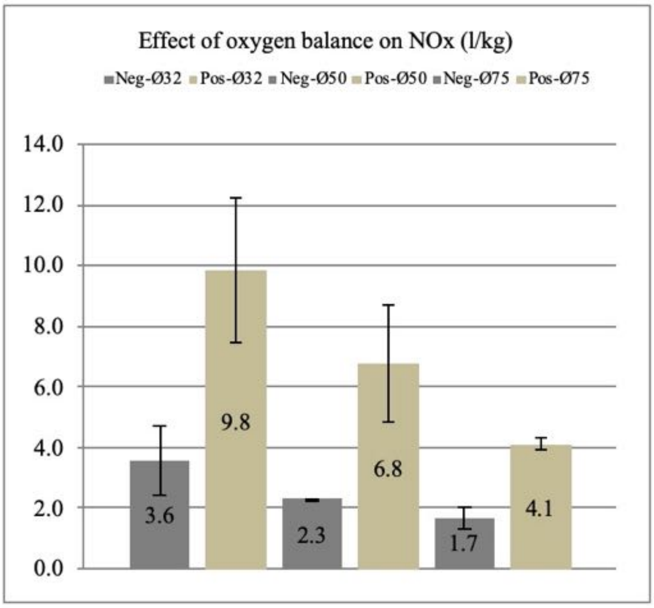

Figure 2-10: NOx for pure emulsion E682 with negative and positive oxygen balance for fully coupled charges in mortar confiners (N=2).

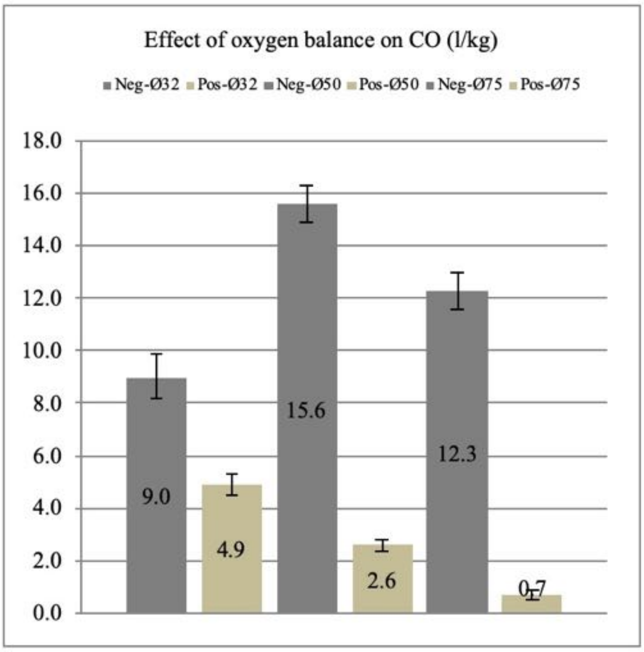

Figure 2-9: Carbon oxide for pure emulsion E682 with negative and positive oxygen balance for fully coupled charges in mortar confiners (N=2).

As earlier mentioned, two cases with string emulsions were tested in wet- and dry holes. The results can be seen in Figure 2-11 and Figure 2-12. For the shots in wet holes, water was filled just before blasting into the volume between the charges and the mortar hole walls in order to simulate typical blasting conditions, see Figure **1-1**. The long time effect of water filled blast holes is not studied in this work.

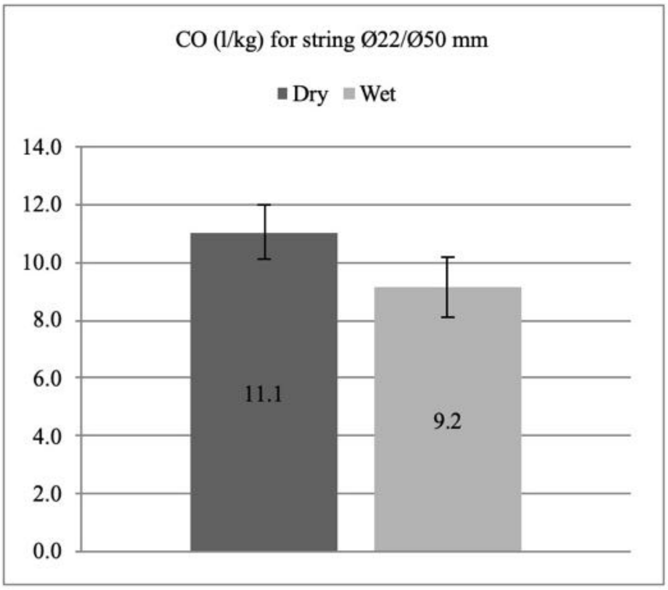

Figure 2-11: CO for pure string emulsion in decoupled dry- and wet holes in mortar confiners (N=3).

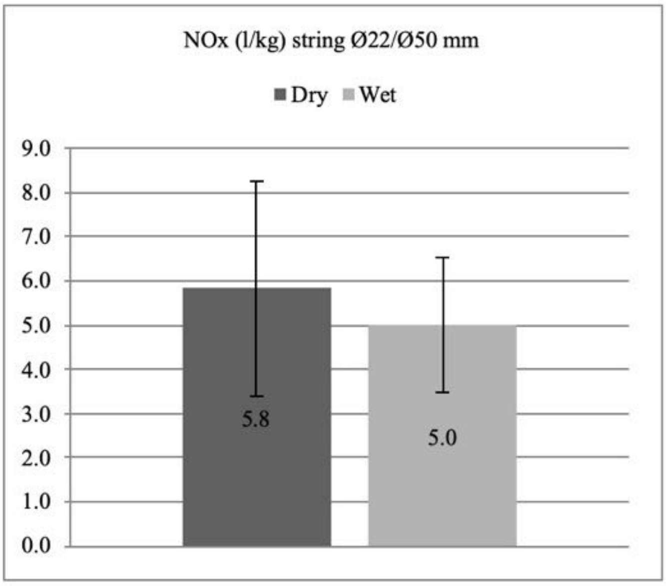

Figure 2-12: NOx for pure string emulsion in decoupled dry- and wet holes in mortar confiners (N=3).

For fully coupled charges in glass and mortar confinements all the quantities measured for emulsion are lower than the ones for ANFO. See the relative data for diameters approximately Øi50 mm in Figure 2-13.

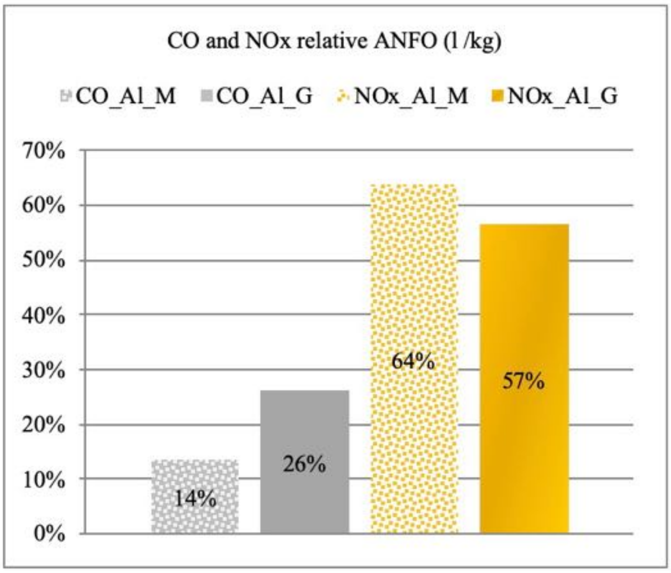

Figure 2-13: CO and NOx relative relative ANFO for fully coupled charges of emulsion with 5% Al additives and in Mortar (M) and Glass (G) confiners. The charge diameters are approximately Ø50 mm.

A comparison with a pilot study, Nyberg et al. (2015) can be seenin Figure **2-14** and Figure **2-15**. All confiners are made of glass with one exception which is PVC which generates extra CO due to burning of the PVC pipes. As pointed out earlier in this paper larger charge diameters generate lower values ($l/kg_{expl.}$) of CO and NOx which in general has larger data scatter. Minor deviations in mixing, densities and charging procedure is assumed to have no strong effect on the results. Emulsion explosives with ANprills additives generate the highest values of CO and additives with both Al and ANprills higher NOx concentrations.

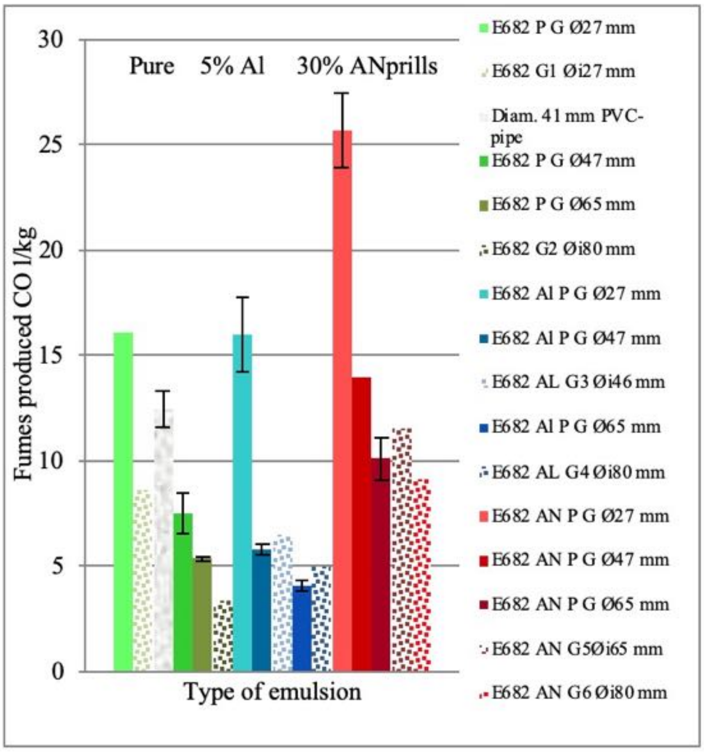

Figure 2-14: Data from the Pilot study in Glass confiners (P G) together with actual data.

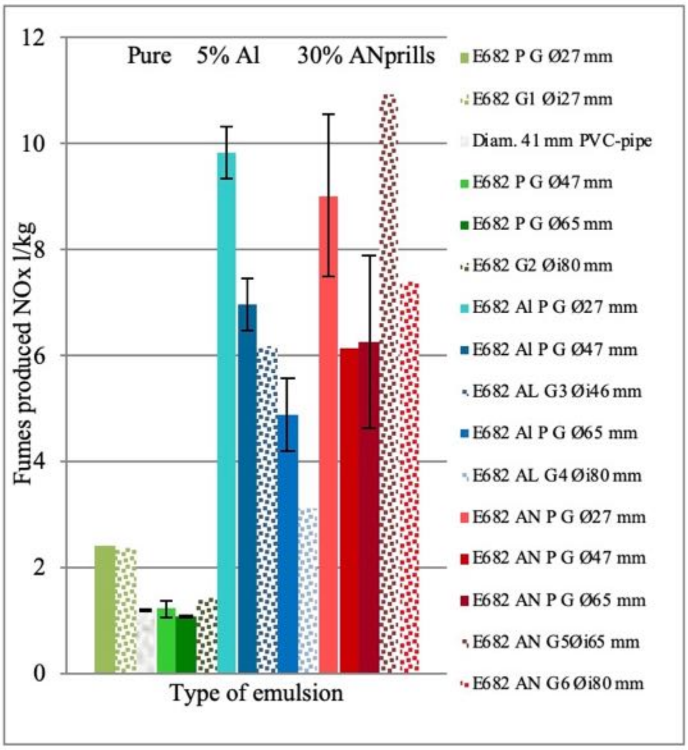

Figure 2-15: Data from the Pilot study in Glass confiners (P G) together with the actual data.

3 DISCUSSIONS AND CONCLUSIONS

The main interest in this paper is to show the potential for reduction of toxic fumes from detonation of typical Swedish emulsion explosives especially CO and the cumulative staff exposure to NOx which appear to be a major risk factor for lung function decreases. Sources such as emissions from diesel vehicles are not considered here, but are sometimes the dominating source for emission of CO and NOx.

The results of the tested fresh (manufactured less than a week before tests - no recrystallization) noncommercial emulsion explosives E682, E682+5% Al and E682+ 30% ANprills and a reference ANFO indicates that the type of explosives is one of the major factors for formation of toxic fumes ($l/kg_{expl.}$) from detonation which confirms the conclusions by Katsabanis & Taylor (2013). The formation of CO is similar for pure emulsion and with 5% Al-additives but with increased toxicity for additives of 30 % ANprills. Formation of NOx is higher for both Al- and ANprills additives compared to pure emulsion which can be used as guidance for improvements of air quality in mining and tunnelling.

The uncertainty in data is the production of NO_x; for the time dependent measurements (approximately 45-60 minutes) in general CO remains constant, NO are consumed with an early high reaction rate and NO_2 are produced by secondary reactions and with losses. Some of our results are in accordance with earlier tests by for example Persson & Persson (1980) and Harris et al. (2003). The reduction of NO_2 with time could be explained by solution with water, effect of dust and adsorption to surfaces.

As expected there is a clear effect on toxicity of ± 5 % oxygen balance and a diameter effect even if the number of repetitions is limited. For + 5 % oxygen balance CO decreases with increasing diameters but not for - 5 % oxygen balance. CO is also in general higher for negative balance. For NOx we measure the opposite. The values are in general lower for negative oxygen balance but with the same dependence on diameters; the values are lower for larger charge diameters. These results again enable adjustments in the explosive formulation in order to reduce some of the toxic fume components.

In Tunnelling and mining the blast holes are sometimes filled/partly filled with water. A special case is the so called decoupled charges and our data shows no significant effect of water on detonation velocity VoD or toxic fumes for Ø22 mm string emulsion in Ø50 mm holes. The long time effect of these emulsion explosives in contact with water is not studied here.

When as in this case some of the contents of blasting fumes is known, models for prediction of toxic fumes and ventilation requirements can be used for dimensioning of the mine ventilation system, Euler and Katsabanis (1991) and the re-entry time can be minimized, Gillies et al. (2004).

4 ACKNOWLEDGEMENTS

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Repackaging of explosives: A task not anticipated in the Danish regulations

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ABSTRACT: Royal Arctic Line (RAL) is a shipping company owned by the Government of Greenland that has an exclusive concession for the transportation of all sea cargo to and from Greenland, including explosives. Cargo is shipped in standard containers from the Danish port of Aalborg. Due to the geography of Greenland, with many small, widely dispersed settlements, the explosives must be repacked into separate containers for each settlement. Due to the Danish regulations on explosives, this repackaging must take place under the same conditions as long-term storage of explosives, which entails that the warehouse used must be turned into a bunker, at great expense to RAL. NIRAS suggested the Danish Emergency Management Agency (DEMA) to allow the use of a quantitative risk based approach instead; a first in Denmark. A number of scenarios that could lead to an accidental explosion were defined, and the probability and consequence spectrum of each scenario was determined using bowtie-analyses. The consequences, in terms of fatalities, were assessed based on typical amounts of explosives, the number of persons in the terminal and neighbouring buildings, and empirical blast and fragment lethality criteria. The risk was shown to be below the risk acceptance criteria for the three required personnel groups, directly involved employees, other employees and uninvolved third parties. Furthermore the risk was also shown to be below the acceptance criteria for risk to the society by means of an F-N diagram.

DEMA has accepted the quantitative risk analysis method and final approval should be forthcoming.

1. INTRODUCTION

Greenland is the World's largest island, comparable in size to western Europe. It is an autonomous self-governing part of the Kingdom of Denmark. Greenland is sparsely populated, with most of the inhabitants living in small settlements spread out along the west coast. Due to the large distances and rugged terrain, there is no road network connecting the towns and settlements and all goods have to be transported by ship, boat or by air.

Apart from the inland ice sheet, Greenland mainly consists of exposed bedrock, why there is a need for explosives for construction, quarrying and mining. Goods transportation by sea, including explosives, is carried out by the shipping line Royal Arctic Line (RAL), which is owned by the government of Greenland. RAL is operating by royal concession, meaning that it is generally the only carrier to provide goods transport to Greenland. RAL operates out of the Danish port of Aalborg. Due to the lack of port facilities in most of the Greenlandic settlements, goods are transported in standard ISO shipping containers with the RAL ships being equipped with cranes to unload containers directly onto the quay.

Due to the large distances and relatively small amounts of goods, each ship will do a tour, stopping at several settlements and setting off a number of containers at each stop. This means that all cargo, including explosives, must be divided into containers based on their destination, at the latest at the port of departure.

At the other end of the supply chain, transport of explosives from the supplier to the port in Aalborg also present a set of challenges. Due to transport restrictions, e.g. at the ferry between Helsingborg and Elsinore, and ADR requirements, it is not economically feasible to pack the containers for each settlement at the factory and transport them to the port for direct embarkation.

Therefore, any explosives destined for Greenland must be repacked into containers according to their destination at the RAL warehouse in Aalborg.

2. LEGAL REQUIREMENTS AND INFLUENCE ON RAL

The Danish code for handling explosives specifies that explosives can be stored for up to 48 hours under constant observation as part of a transport process, or up to 60 hours in a freight terminal without further measures required. However, the Danish Emergency Management Agency (DEMA), who oversee the code, have specified that repackaging does not fall under these provisions and any repackaging requires the same conditions as long-term storage of explosives. The rules are based on NATO storage requirements (AASTP-1).

The facilities for repackaging therefore have to comply with the regulations for long-term storage of explosives, which means that RAL has the option of finding a new location for repackaging or turning their warehouse into a veritable bunker, as the required safety distances are not available.

The first option, finding a new site, has been examined, but as Denmark is a quite developed country, there are no areas of the required size without towns, villages or major roads nearby. The second option, turning the warehouse into a bunker stems from the DEMA practice of allowing shorter safety distances, if an engineering assessment show that the facility is constructed so that the consequences to neighbours will be similar or less than if the safety distances had been upheld.

3. RISK BASED APPROACH

DEMA has previously indicated, that a risk based approach, taking the probability of an explosion into account, could be used. Such an approach would generally require the estimation of the probability and consequences of a number of explosion scenarios, calculating the associated risks and comparing these to a set of acceptance criteria.

3.1. Acceptance criteria

As a risk based approach has not previously been used for approval of explosives storage facilities, there is no precedence for which criteria to use. The authority to determine the criteria lies with the Ministry of Justice. DEMA has suggested the criteria shown in Table 1 based on similar criteria for sites containing dangerous substances in accordance with Directive 2012/18/EU (the Seveso III Directive).

Table 1. Risk based acceptance criteria proposed by DEMA.

		Acceptance criteria
Individual risk		
	Persons directly involved in work with explosives	Rules for general labour safety (Rules set forth by the Danish Working Environment Authority)
	Other persons employed in the same business	10^{-5} fatalities per year
	Third person	10^{-6} fatalities per year
Risk to society		A curve of accumulated frequencies where the frequency for 1 fatality is 10^{-4} per year and which decreases in relation to the square of the number of deaths. The frequency for 1,000 fatalities must be 0.

Table 1. Risk based acceptance criteria proposed by DEMA.

3.2. Probability assessment using bowtie analysis

The probability assessment is carried out using a bowtie analysis, which is a general risk analysis method described in ISO 31010.

A bowtie diagram should generally be interpreted from left to right. The unwanted condition, i.e. explosion, is displayed in the centre of the bowtie. The left hand side of the bowtie consists of a fault tree, where the preconditions for an explosion are examined and the right side consists of an event tree, where the possible outcomes are examined.

Barriers can be introduced into the bowtie. On the left hand side of the bowtie, barriers can be any measure that will reduce the probability of an incident and on the right hand side, barriers are any measure that reduces the consequences. Furthermore, different conditions can be introduced in the event tree on the right side of the bowtie.

A bowtie analysis is performed for each scenario. An example bowtie diagram is presented in Figure 1.

Further information about the bowtie methodology can be found in risk analysis literature.

Each of the initial conditions, barriers and event tree branches in the bowtie diagram must be supplied with either a frequency or probability of occurrence. These input parameters must be individually assessed based on the actual conditions on the site, historical data, engineering assessments or expert judgement. The estimated frequencies and probabilities are combined using Boolean logic to give an estimate of the probability of each outcome.

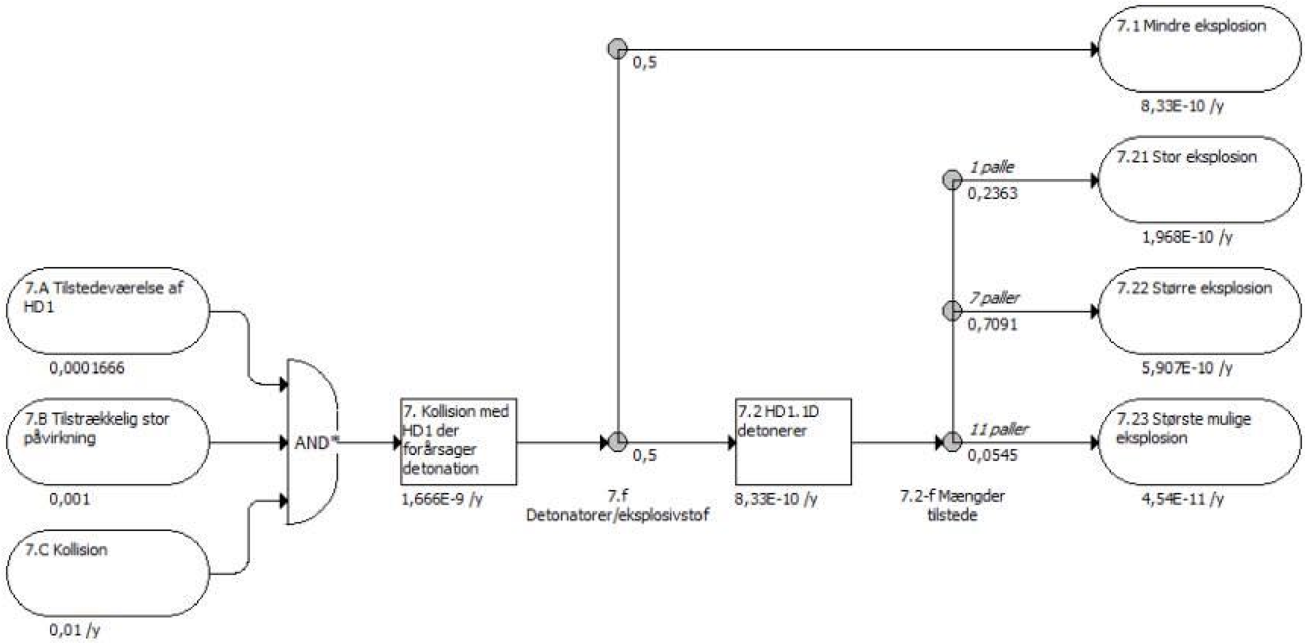

Figure 1. Example of a bowtie diagram.

In order to limit the total number of possible outcomes, a few representative consequence magnitudes can be chosen.

Generally, frequencies based of factual data of the input parameters are sought but in areas with little or no data to support the estimation, conservative assumptions have been made.

3.3.Consequence assessment

The consequences are investigated in terms of the number of fatalities. These fatalities come from either direct exposure to blast pressure, exposure to primary or secondary fragments (e.g. glass from window panes) or exposure to falling structural elements from being inside a building that collapses.

The number of people at various locations in the warehouse, adjoining administration building, and at neighbouring facilities has been estimated.

Fatalities from direct blast exposure is taken as anyone exposed to a blast pressure of 193 kPa or more. 193 kPa corresponds to a survival rate of at least 99 % according to UFC 3-340-02.

Fatalities from fragments are estimated based on the expected number of persons outdoors within fragment range and the number of persons estimated to be near windows in buildings subjected to a pressure of more than 2 kPa.

Fatalities from exposure to falling structural elements is estimated based on the expected number of persons in buildings subjected to a blast pressure of 35 kPa or more. 35 kPa corresponds to "severe damage" according to Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs. Severe damage is defined as "partial collapse and/or failure of some bearing members".

Furthermore, fatalities are divided into those directly involved, other employees at RAL and 3rd persons, as specified by the acceptance criteria.

In general, the number of fatalities is estimated as a worst case figure.

3.4.Scenarios

The scenarios for investigation were found in a workshop with participation from RAL staff members, including the Head of Security and specialists from NIRAS. The workshop resulted in ten scenarios, for which a risk contribution was thought possible.

4. EXAMPLE CALCULATION

An example could consist of an incident where goods containing detonators is dropped inside the warehouse, either due to eccentric lifting, poorly stacked goods on the pallet or sudden forklift breakdown.

The bowtie diagram for the example can be seen in Figure 2.

The conditions and probabilities from the right hand side of the bowtie make up 6 outcomes which combined with fatality consequence assessments result in the risk presented in Table 2.

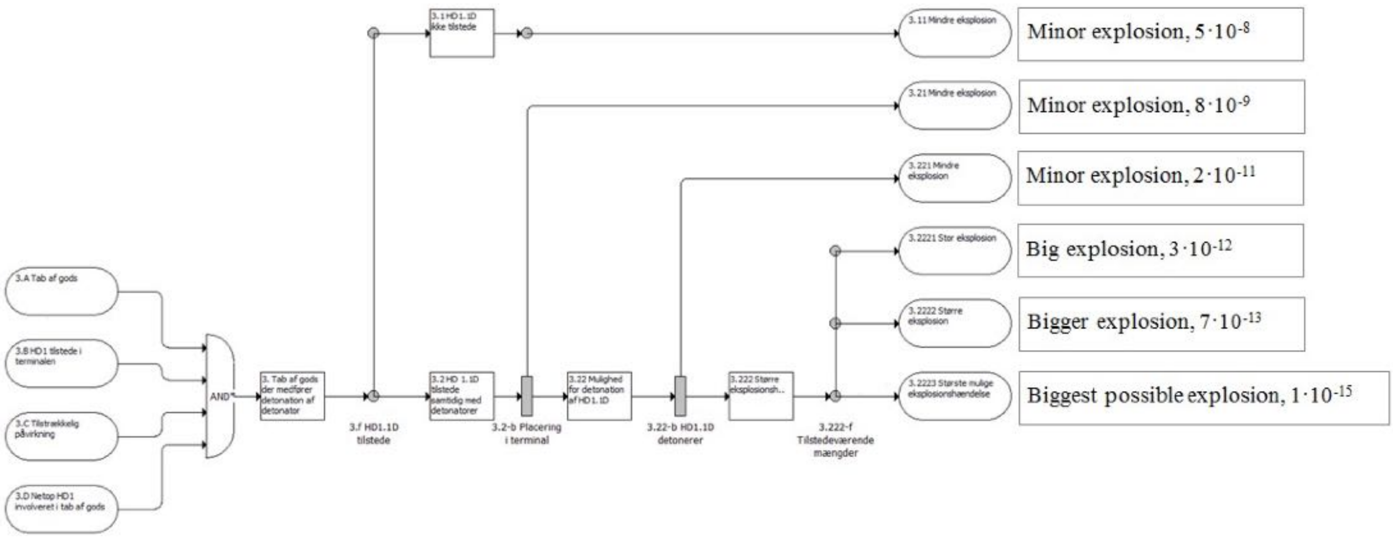

Figure 2. Bowtie diagram for the example scenario. Presented values are examples.

The investigation comprised scenarios within handling and transporting explosives, from their arrival by truck to the loading onto the ship, as well as any imaginable external influence during their stay at the terminal.

The sums calculated in Table 2 can be considered as the risk contribution for the personnel group in question from the specific scenario. Similar risks are calculated for all scenarios.

Outcome	Probability, Incidents /year	Fatalities, Directly involved	Risk, Directly involved	Fatalities, Other employees	Risk, Other employees	Fatalities, 3rd person	Risk, 3rd person
Minor explosion	$5 \cdot 10^{-8}$	1	$5 \cdot 10^{-8}$	0	0	0	0
Minor explosion	$8 \cdot 10^{-9}$	1	$8 \cdot 10^{-9}$	0	0	0	0
Minor explosion	$2 \cdot 10^{-11}$	1	$2 \cdot 10^{-11}$	0	0	0	0
Big explosion	$3 \cdot 10^{-12}$	1	$3 \cdot 10^{-12}$	10	$3 \cdot 10^{-11}$	3	$9 \cdot 10^{-12}$
Bigger explosion	$7 \cdot 10^{-13}$	1	$7 \cdot 10^{-13}$	15	$1 \cdot 10^{-11}$	10	$7 \cdot 10^{-12}$
Biggest possible	$1 \cdot 10^{-15}$	1	$1 \cdot 10^{-15}$	60	$6 \cdot 10^{-14}$	40	$4 \cdot 10^{-14}$

Table 2. Calculation of risk for the example scenario. Presented values are examples.

5. RESULTS

The risks from each scenario are summed up to obtain the total risk.

A risk of e.g. $2.1 \cdot 10^{-9}$ corresponds to an estimated 2.1 fatalities every 1,000,000,000 years.

Scenario	Risk, Directly involved	Risk, Other employees	Risk, 3rd persons
Scenario 1	$1.1 \cdot 10^{-6}$	$1.1 \cdot 10^{-8}$	$5.2 \cdot 10^{-9}$
Scenario 2	$8.8 \cdot 10^{-9}$	$1.7 \cdot 10^{-7}$	$8.1 \cdot 10^{-8}$
Scenario 3	$3.8 \cdot 10^{-8}$	$3.6 \cdot 10^{-10}$	$1.7 \cdot 10^{-10}$
Scenario 4	$3.0 \cdot 10^{-9}$	$5.6 \cdot 10^{-8}$	$2.8 \cdot 10^{-8}$
Scenario 5	$2.1 \cdot 10^{-9}$	$2.6 \cdot 10^{-8}$	$1.2 \cdot 10^{-8}$
Scenario 6	$3.0 \cdot 10^{-9}$	$2.8 \cdot 10^{-11}$	$1.4 \cdot 10^{-11}$
Scenario 7	$1.7 \cdot 10^{-9}$	$6.2 \cdot 10^{-8}$	$4.3 \cdot 10^{-8}$
Scenario 8	$1.8 \cdot 10^{-10}$	$2.9 \cdot 10^{-9}$	$4.4 \cdot 10^{-9}$
Scenario 9	$8.0 \cdot 10^{-9}$	$1.3 \cdot 10^{-7}$	$2.0 \cdot 10^{-7}$
Scenario 10	$2.0 \cdot 10^{-9}$	$3.4 \cdot 10^{-8}$	$5.1 \cdot 10^{-8}$
Total risk	$1.2 \cdot 10^{-6}$	$4.9 \cdot 10^{-7}$	$4.2 \cdot 10^{-7}$

Table 3. Total risk summed up over all scenarios.

By comparison with the acceptance criteria in Table 1, it can be seen that the calculated risk levels fall within the acceptable levels.

5.1.Risk to society

Risk to society is presented in the form of a F-N diagram, where the abscissa denotes the number of fatalities and the ordinate the accumulated frequency. The F-N diagram is presented in Figure 3.

From Figure 3 it can be seen that the risk to society also falls within the acceptable levels.

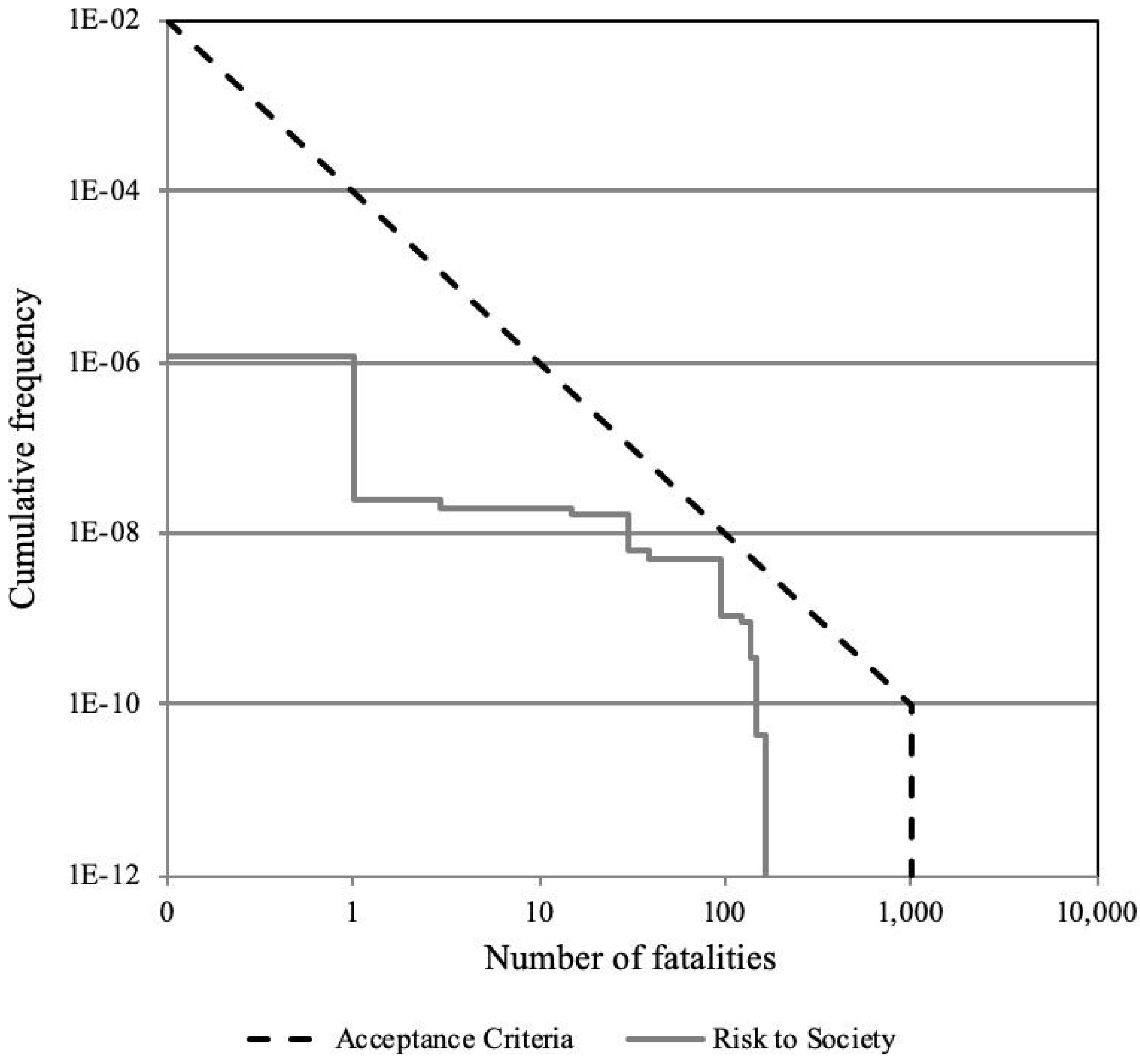

Figure 3. Risk to society from all scenarios. The acceptance criteria corresponds to the one mentioned in Table 1.

6. CONCLUSIONS

Due to authority demands and logistical reasons, RAL had to find a new location for repacking explosives or turn their warehouse into a veritable bunker. Instead, RAL chose to have a risk analysis of the repacking of explosives made.

Ten possible scenarios that might lead to an unintended explosion at the RAL warehouse in Aalborg have been investigated with respect to the risk they impose to individuals at or near the warehouse and to society in general.

The risk levels were shown to be below the acceptance criteria and the results has been forwarded to DEMA for approval. DEMA has approved the method but final approval has not yet been awarded, as the acceptance criteria has to be approved by the Ministry of Justice as well.

This is the first time the probability of an incident is incorporated in a risk analysis with respect to explosives storage and handling in Denmark.

The incorporation of probabilities into risk assessments regarding storage of explosives in Denmark, might make it possible to obtain approval for more storage facilities in locations better suited for the end users in the future.

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Zero local emissions
Less noise and heating of surfaces
Improved energy efficiency
Lower operating expenses
Higher performance and
improved time efficiency
Normet's emulsion explosives chargers with battery electric architecture SmartDrive ensure safe and more pleasant operation with zero local emission tramming and explosives charging in underground face, with less heat, less noise exposure and cleaner air at the work face. The charging of explosives can be done with batteries only or the machine can be plugged to the grid, when it also charges the batteries.
INNOVATING FOR
PERFORMANCE

A New Tool For Hole Deviation Control
A Statistical Analysis

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ABSTRACT: This scientific document explores the analyses, processes and studies around the development of an electronic tool to measure deviations in boreholes with inclinations and azimuths within in a range of 360 degrees. The proximity of explosives charges near free faces or concentrations of high powder factor due to unpredicted drilling deviations are one of the main causes of fly-rocks, ground vibrations and poor or excessive fragmentation. These points affect directly safety distances (humans and equipment), operation production and costs. For this results a borehole deviation system, based on magnetic sensors and accelerometers, with an economic price, was developed with modern technology and tested along existent tools in the market. The main idea was to study statistically the results from each methodology and prove the accuracy of the new system. For that was used a residue analysis for the validation of the data from the several sources and was proved the validity of this new methodology. The normality tests for statistics residues analysis proves that it is possible to infer that the model has null residual mean and a small residual error. This document intents to show the importance of the constant investigation of measurement tools, benefits of this new methodology, the use of updated technology and the production improvements of friendly and easy to use tools.

1. INTRODUCTION

Today's mining situation is at a very excited point. The gradual cultural change that is being observed along the majority of mining operations allows the implementation of new techniques and knowledges. Since companies are being honest on what they are doing they are suffering restructuration's based on lessons and errors from the past (MineMagazine, 2018). The way to approach problems is also different and the market is thirsty of new technologies and ready to invest in innovation, automation and technology. The miners blinkers were removed and technology from other industrial sectors is now being accepted into the mining industry. David Cormack, Delloite Australia Mining Consulting Leader, says, *"We are seeing a huge interest and traction on how to use technology to optimise more effectively and efficiently and to future-proof companies against potential commodity downturns"*. This market reaction, the interest from companies on doing things differently and the focus on manage risks to avoid reputational damages and financial loss (Paul Singh, 1996) was the kick-off motivation for the development of the project presented on this article.

This research study had as objective the development of a different product (named O-PitDev), based on actual and available technologies, for borehole deviation measurement. A statistical analysis was conducted for the comparison of the results from this new methodology and two others already existent in the market. The results were very satisfactory since after following a very rigorous testing strategy, there was statistical proof that the data is equal.

2. BACKGROUND

2.1 Drilling

The drilling process is an indispensable procedure when talking about blasting with explosives (Lutz Jr., 2000). The drilling practice is about making holes in a rock mass, using predefined parameters such as diameter, length, angle, azimuth, among others. When speaking of blasting operations specifically, the main objective of this drilling procedure is to create holes in which explosive is placed in order to get a fragmented rock after the blast.

During the evolution of the mining industry, the drilling process was optimized and became much more complex, involving new drilling methods for different applications, improved drilling machines and new methodology and technology for measure the drilling performance and accuracy.

2.2 Deviation Issues

The drilling process and its necessities are normally associated to the production demands and time schedule of a mining operation. If the demand it's too high or not well planned it can lead to problems on the drilling accuracy causing, consequently, higher drilling costs, fragmentation issues, floor irregularities, safety issues (fly rocks) or serious damage to the instruments (Harris, 1999).

It's considered a hole deviation when the drilling process doesn't follow the planned hole trajectory, due to unintentional problems. These issues can be related with the rock type and geology, drill rig type, drill rods used and, frequently, due to the driller's technique (Miranda & Leite, 2018).

Drilling issues, like the one's described above, can lead to typical errors like wrong positioning of the drilling rig on the borehole collar, angular error during the drilling procedure and bending deviations due to the tendency of the steel rod to bend while the bit is progressing inside the rock mass (Giles & Roller, 2012).

On the Figure 1, the authors represent the typical errors referred above: collar position errors where the driller positioned the drilling rig incorrectly; angular errors, where the planned angle it's different from the real one and, finally, bending errors, where the rod suffered a curvature while progressing inside of the rock. Both too short and too long holes are drill erros and can be caused by operator mistakes or issues in drill rigs.

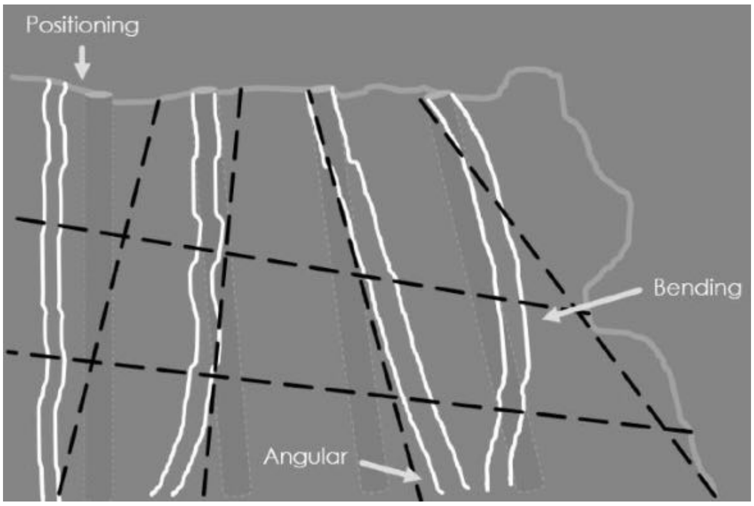


Figure 1. Drilling errors

2.2.1 Drilling Survey

The survey of a hole allows to obtain real information about the geometry of the hole enabling to analyse common problems in blasting process and, consequently, avoid them.

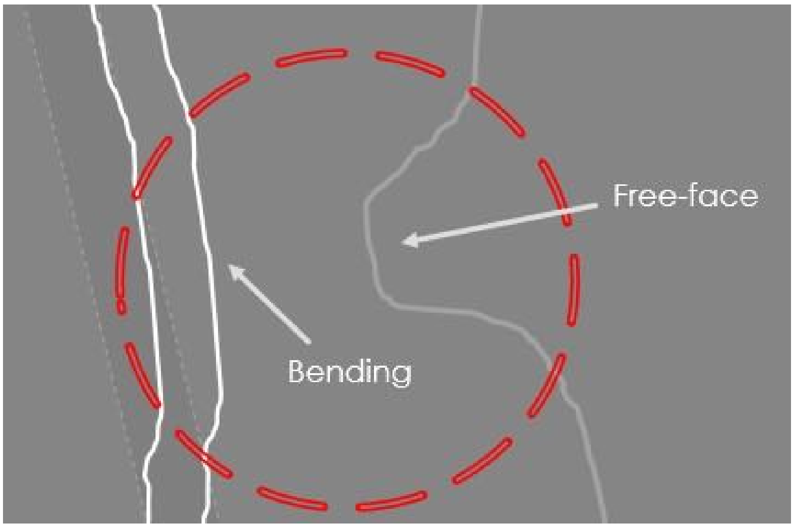


Figure 2. Example of a detected deviation problem

For example, on Figure 2, the survey allowed to recognize that the hole suffered a bending approaching it to the free face causing the risk to produce fly-rocks. These actions, including the continuous measurement of borehole deviations, will lead to a best blast performance, quality control that ends up positively affecting all the mining production.

2.3 Drilling Deviation Tools

There are three to four main devices in the market that are used for drilling deviations control. These equipment manufactures develop handheld devices for this purpose.

These devices can be used in metal or non-metal environments, supported by bars or cables, to measure upholes and downholes, with accuracies varying from ± 0.25º to ± 0.1º on inclinations and ±1º for azimuths (Miranda, Leite, Brito, Frank, & Carvalho, 2019)

3. DEVELOPMENT

3.1 Development

The development procedure was organized in several phases. On the R&D stage it was investigated the elements needed to obtain a working product from the point of view of electronics, waterproof system, hard case, technology, user experience, phone app and probe accessories. During the product design and testing phase several prototypes were tested and designed until the definition of the optimum one. On the administrative side, testing and certifications institutions were contacted in order to ensure publicly the quality of the system.

Internal and intensive tests related with waterproof and impact were conducted in order to ensure the correct behaviour of the system. Apart from the laboratory tests, field trials in several environments, -20ºC/-4ºF up to 40ºC/104ºF, dry, wet and iced environment, were executed to evaluate the response of the tool on real and daily conditions.

3.2 Probe Electronics

The sensors are essential part of this equipment, as they have the important function of feeding crucial information to determine heading and inclination of the hole and thus provide a real representation of the hole. Taking that into account, the accuracy of the sensors is very important for the probe to work as intended.

The authors chose to utilize am IMU (Inertial Motion Sensor) from a reputable vendor that ofers 9-axis absolute orientation sensing. Additionally was used an ARM micro controller to provide data processing and Bluetooth connectivity to a smartphone so the data could be download from the probe.

3.3 Probe Design

The operation of a borehole measurement device consists basically of a set of electronic elements and sensors that, in combination, calculate the direction and inclination of a hole. Because they consist of fragile elements, sensors and electronic, these need protection, resistant to external contacts, friction and fluid actions to remain intact and in operation when introduced through a hole.

The majority of capsules from these kind of devices, inclinometers and sensors, are made of stainless steel - studied by Silva in the field of Geotechnics (Silva, 2008). Stainless steel has its famous resistance to corrosion, giving a longer life than other materials and elements.

However, despite its main characteristic, there are several other advantages of using stainless steel (Frank, 2009), such as: physical (mechanical) resistance equal to or greater than common steel; easy cleaning; low surface tension; hygienic appearance; inert material (does not react to contact with other materials); high durability; ease of modulation and welding; stability in extreme temperatures; visual beauty (modernity, cleanliness and brightness); great value for money and; recyclable material.

For this equipment, the stainless-steel type AISI 304 was selected. Through several tests with previous prototypes, it was concluded that the stainless-steel isolates the radiofrequency required to communicate the data between the equipment and the receivers installed on the PC and on the mobile phone. Therefore, in this version it was necessary to install an external antenna for connectivity between both.

The probe has been designed to have gravity in its favor on its descent to the bottom of the hole and to have enough weight and density to overcome the surface tension and thrust of fluids that may be present in the holes. It is understood that stainless steel meets these requirements, considering that it is a material of considerable density (7,85 g/cm^3) (Solução completa em Usinagem, 2018).

4. FIELD TESTS RESULTS – STATISTICAL ANALYSIS

4.2 Field Procedure

The tests were conducted by O-Pitblast and FORCIT between February 11th and 15th in 3 different mines in Finland. All tests were performed along with the use of 2 well-known hole measuring equipment (traditional device 1 and traditional device 2) to compare the resulting data between the 3 devices.

The test procedure followed consisted on the measurement of 1 hole 20 times and 4 holes measured 5 times each, with each tool.

Hole	Number of measurements	Measurement Device
1	20	TD1 / TD2 / O-PitDev
2	5	TD1 / TD2 / O-PitDev
3	5	TD1 / TD2 / O-PitDev
4	5	TD1 / TD2 / O-PitDev
5	5	TD1 / TD2 / O-PitDev

Table 1. Measurement procedure

The field procedure included:

- Registration of holes position;
- Measurement of hole’s profile with both traditional devices;
- Measurement of hole’s profile with the new system according to the following methodology:
- Deployment of the new system in the bottom of the borehole;
- Measurement of the offset;
- Record the first time of the first measure in the bottom of the hole;
- Pull the probe until the borehole collar making stops at each 2 meters – 6,56 ft - and collect the time at those stops;
- Match both information from phone app and probe – time, angle and azimuth.

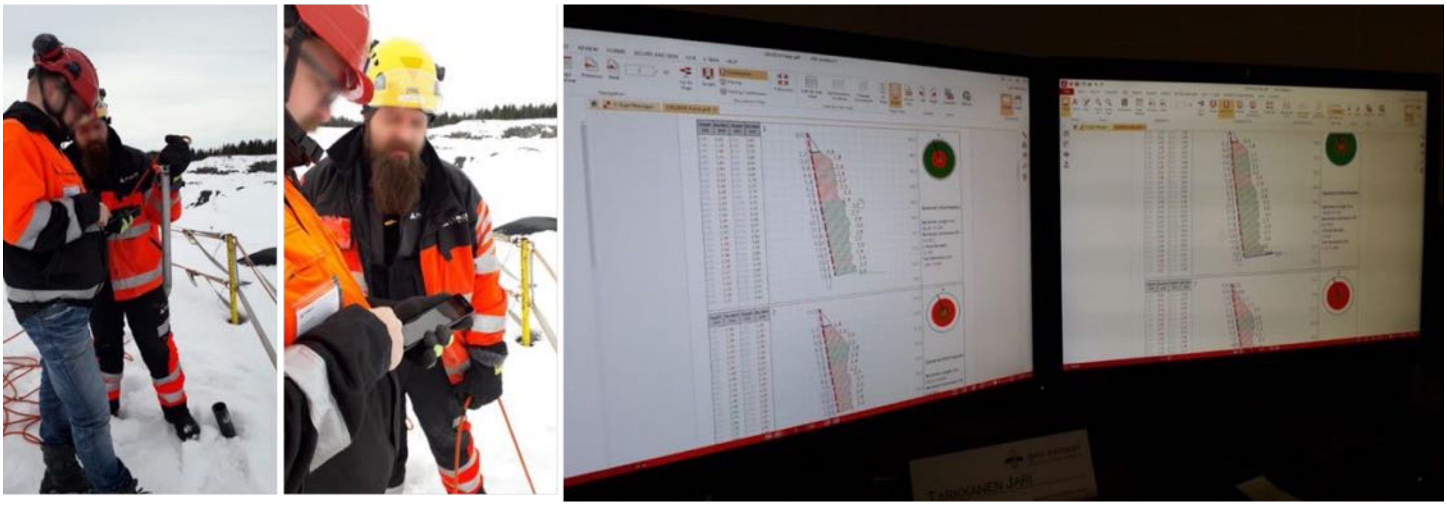


Figure 3. Field Tests

After the field procedure, either with smartphone technology or with the other devices with the same propose, the operator got the information of the real inclination, heading and depth of the borehole. With this information and with a blast design software, it was possible to analyse different data such as:

- Critical profiles: rows too near/far from the free face;
- Critical burden;
- Projection risks: hole not drilled correctly (their inclination/azimuth is wrong) causing fly rock risks;
- Burden distribution;
- Deviation values;
- Real angle: possibility to see if the planned hole and the real one has the same angle;
- Toe error: generation of toe due to a wrong drilling.

4.3 Statistical Analysis

In order to compare the results, the authors of this paper made a residue analysis (Miranda & Leite, 2018). The first step was to apply an ANOVA (parametric test for comparison between two or more samples)[1], but before it, was analysed the box-plot for the residue of the angle and azimuth in the three devices - Figure 5.

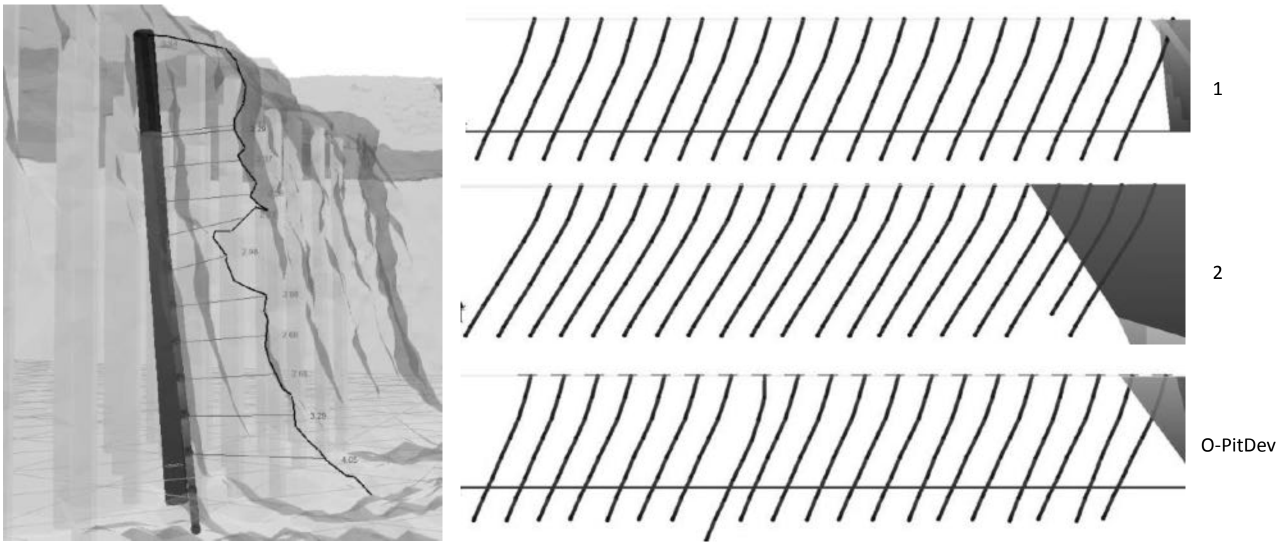


Figure 4. Field Results - Comparison between equipment

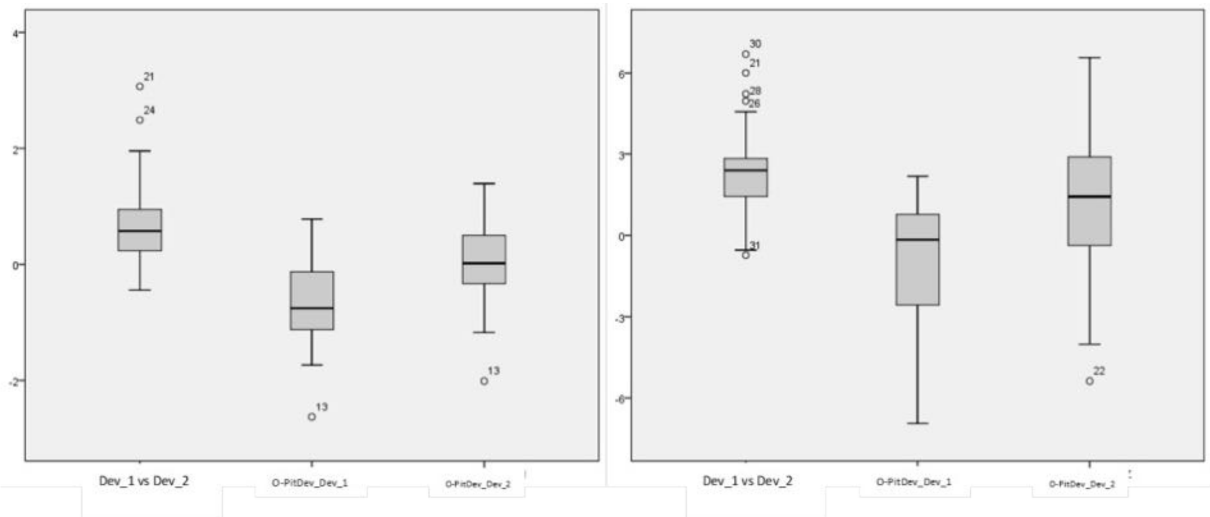


Figure 5. Boxplot of residue in all devices

Was possible to identify the presence of outliers and, using the 3 sigmas analysis (Gama, Carvalho, Faceli, Lorena, & Oliveira, 2017) the outliers were removed and new boxplot was generated - Figure 6.

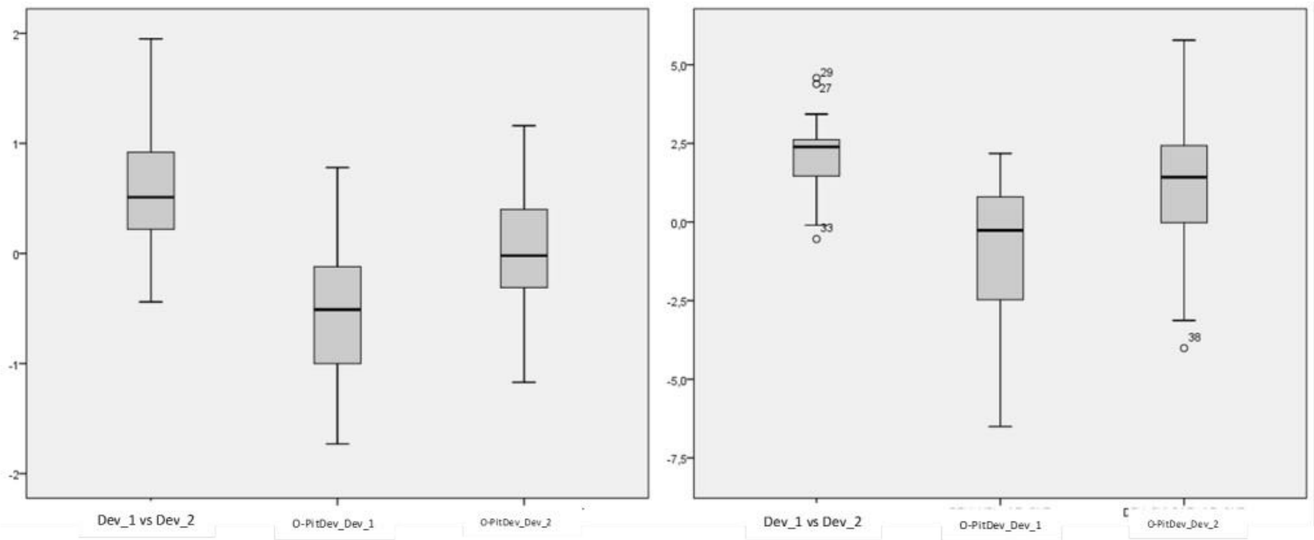
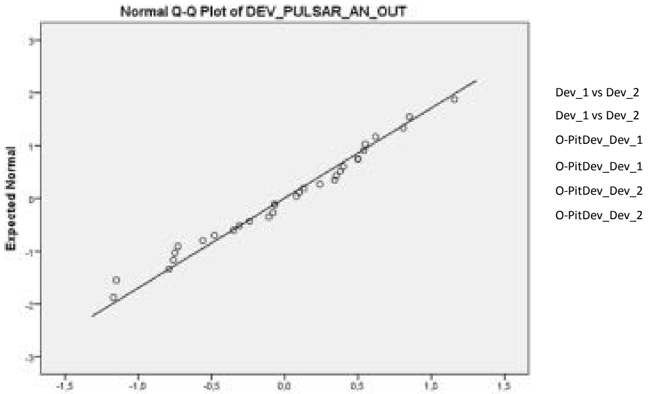
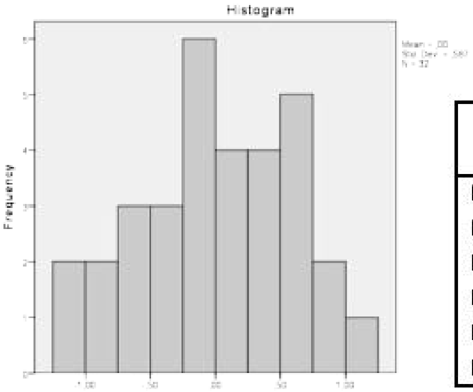


Figure 6: Boxplot after outliers removed

The visually examination is not conclusive, then, ANOVA analysis was applied. To use this kind of analysis is mandatory to verify the normality of the data and homogeneity of the variance. A normality test was done (Kolmogorov-Smirnov and Shapiro-Wilk) and histogram and Q-Q plot was analysed. The results are showed on Figure 7.





Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MDL_PULSAR_AN_OUT	,072	32	,200*	,984	32	,902
MDL_PULSAR_AZ_OUT	,155	32	,050	,958	32	,250
DEV_MDL_AN_OUT	,131	32	,175	,966	32	,399
DEV_MDL_AZ_OUT	,125	32	,200*	,932	32	,044
DEV_PULSAR_AN_OUT	,096	32	,200*	,977	32	,695
DEV_PULSAR_AZ_OUT	,080	32	,200*	,988	32	,968

Figure 7. Normality test

The tests results demonstrated the normality of the data (for an usual level of significance). The second one was to evaluate the homogeneity of the variance - Figure 8.

Angle Residue

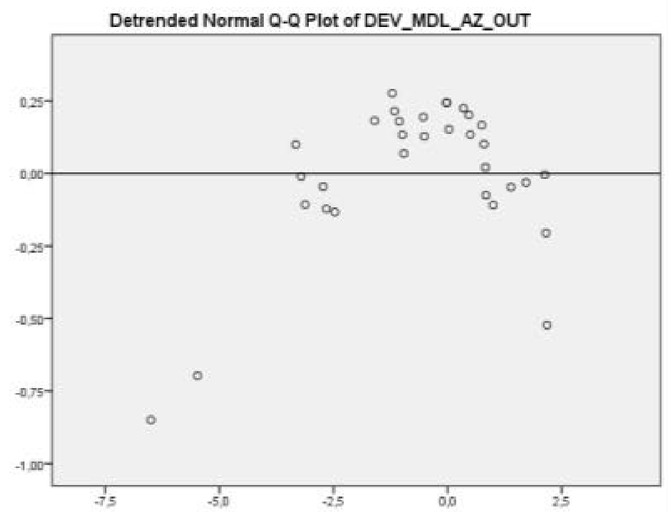
Levene Statistic	df1	df2	Sig.
,513	2	113	,600

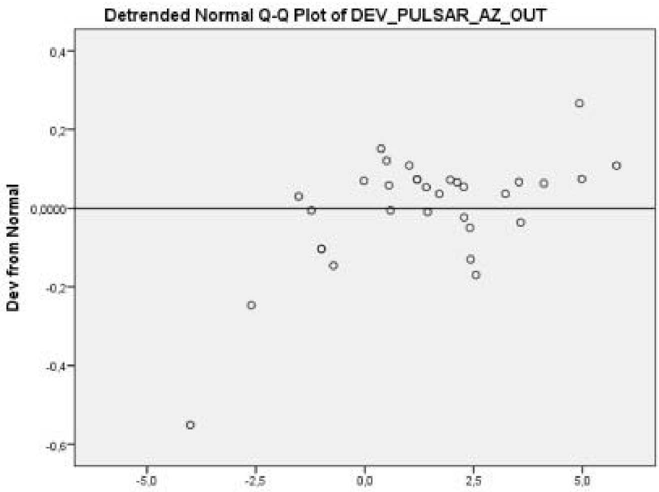
Azimuth Residue

Levene Statistic	df1	df2	Sig.
7,836	2	111	,001

Figure 8. Test of the homogeneity of the variance

It was possible to conclude that the variance of the residue of the angle is homogeneous (p-value higher than 0.05), but not for the azimuth residue. It is conceivable to use not only the hypothesis test but all available data to draw this conclusion (Moreira, Macedo, Costa, & Moutinho, 2011). When evaluated the detrended normal Q-Q chart for the residue two by two it is possible to conclude that no clear trends are observed - Figure 9.





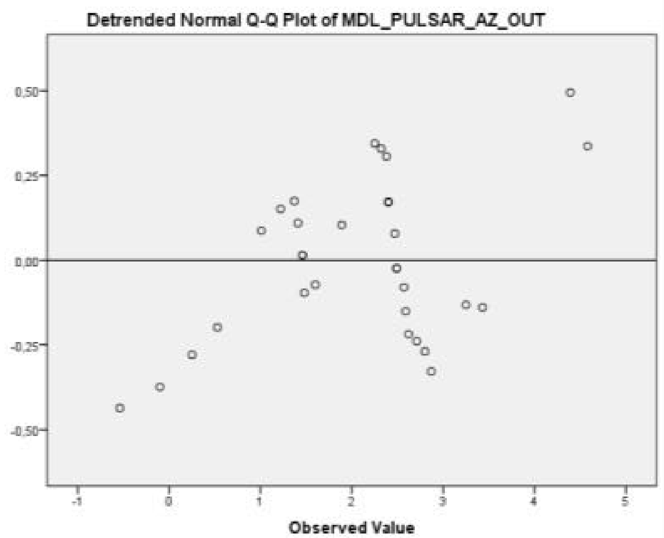


Figure 9. Q-Q chart for the pair of data

After to check the normality of the data and the homogeneity of the variance it was possible to conclude that *ANOVA* was adequate to be used. The results indicated that the data doesn't came from the same sample for both, angle and azimuth residues - Figure 10.

Was possible also to verify that when compared both traditional devices (angle and azimuth residues) the zero was outside of the confidence interval range. That was enough to conclude that the traditional devices measured different data.

ANOVA

Angle Residue

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26,203	2	13,101	36,246	,000
Within Groups	40,844	113	,361		
Total	67,047	115			

ANOVA

Azimuth Residue

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	211,394	2	105,697	22,387	,000
Within Groups	524,060	111	4,721		
Total	735,454	113			

Figure 10. ANOVA test for samples

This situation means that the data is different, and new analysis was necessary. The next step was to compare the data two by two in order to identify if any pair of data comes from the same sample. A descriptive exploration was done - Figure 11.

The new system presented a identical values for angle when compared with the device 1 and identical azimuth when compared with the traditional device 2. The angle error when compared with the device 1 was less than the angle error between the traditional devices.

Descriptives

			Statistic	Std. Error
Dev_1 vs Dev_2	Mean		,5784	,09760
	95% Confidence Interval for Mean	Lower Bound	,3794	
		Upper Bound	,7775	
	5% Trimmed Mean		,5682	
	Median		,5750	
	Variance		,305	
O-PitDev_Dev_1	Mean		-,5819	,10993
	95% Confidence Interval for Mean	Lower Bound	-,8061	
		Upper Bound	-,3577	
	5% Trimmed Mean		-,5979	
	Median		-,7500	
	Variance		,387	
O-PitDev_Dev_2	Mean		-,0044	,10375
	95% Confidence Interval for Mean	Lower Bound	-,2160	
		Upper Bound	,2072	
	5% Trimmed Mean		,0017	
	Median		,0050	
	Variance		,344	

			Statistic	Std. Error
Dev_1 vs Dev_2	Mean		2,0766	,20000
	95% Confidence Interval for Mean	Lower Bound	1,6687	
		Upper Bound	2,4845	
	5% Trimmed Mean		2,0776	
	Median		2,3900	
	Variance		1,280	
O-PitDev_Dev_1	Mean		-,7003	,37610
	95% Confidence Interval for Mean	Lower Bound	-1,4674	
		Upper Bound	,0667	
	5% Trimmed Mean		-,5590	
	Median		-,2650	
	Variance		4,526	
O-PitDev_Dev_2	Mean		1,3766	,39225
	95% Confidence Interval for Mean	Lower Bound	,5766	
		Upper Bound	2,1766	
	5% Trimmed Mean		1,4187	
	Median		1,4250	
	Variance		4,924	

Figure 11. Descriptive analysis of the data

To validate (statistically) that the data from the new device is identically to traditional devices two conditions must be validated: the normal distribution of residue and the zero within the confidence interval for mean (Miranda V. G., 2016). As showed above on Figure 7 was possible to accept the normality of the data.

The azimuth error when compared with the traditional device 2 was less than the azimuth error between both traditional devices. A resume is presented on Figure 12.

Angle residue	New System	Traditional Device 1	Traditional Device 2
New System	0.00 º	0.36 º	0.00 º
Traditional Device 1	0.36 º	0.00 º	0.38 º
Traditional Device 2	0.00 º	0.38 º	0.00 º

Azimuth residue	New System	Traditional Device 1	Traditional Device 2
New System	0.00 º	0.00 º	0.57 º
Traditional Device 1	0.00 º	0.00 º	1.66 º
Traditional Device 2	0.57 º	1.66 º	0.00 º

Figure 12. Angle and Azimuth Analysis

It was possible to conclude that the new system has a similar behavior when compared with traditional devices and presented same angle measurements that the traditional device 1 and same azimuth measurements that traditional device 2, and the mistake in comparison with both traditional devices was less than error between both devices.

The charts and tables above showed information from part of the data, but all data presented similar behavior.

Was possible to conclude that, statistically, the measurements of the new system are trustworthy and have a level of precision good enough if compared with the two traditional devices disponible on the market.

Is possible see a resume of all residues - Figure 13.

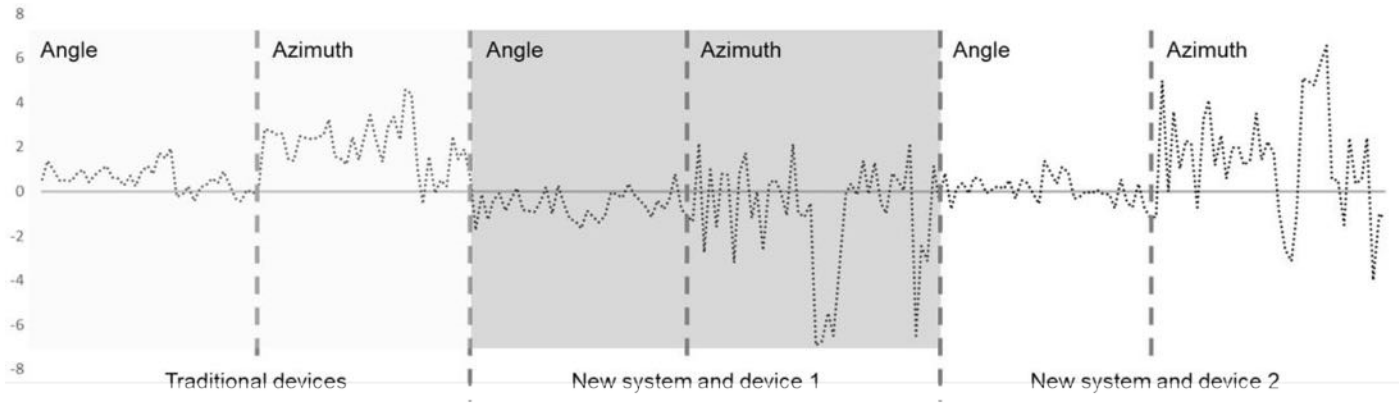


Figure 13. Resume of all residues

5. CONCLUSION

The statistical analysis of the data from field test proved that the new system, when compared with the traditional devices available on market, was capable to measure hole's deviations with an excellent level of confidence. Due to the use of new sensors widely available on the market was possible develop a new system not only reliable technology but cheaper. The market is definitely open for this kind of technologies which are changing the mindset of the miners since they are been used for production improvements, safety control and cost reductions. As usually more tests are necessary to continually prove the efficacy and quality of this kind of research and development projects. An important limitation of the prototype used in this research was the sensibility of the sensors to magnetic field, for this, the researchers are now developing the second phase of the prototype to be used in metal mines. Human errors play an important role on the borehole survey quality. To minimize this to the maximum the same person was the one carrying out the 3 procedures for the 3 products. Future studies for accuracy will be done inside pipes where initial and final position it is known.

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The coronavirus has stopped meetings and events in its tracks, leading to an unprecedented time for the industry - but we will undoubtedly recover. Right now, conferences are nearly impossible to hold - both logistically, due to travel restrictions, and as a matter of public health and safety.

A phenomenal global effort to develop vaccines for the protection against coronavirus is coming to the final stages, progress with vaccines and preliminary positive results following large scale global clinical trials, demonstrate that it will be possible to use the vaccine to fight coronavirus, brining much needed optimism for the future of conferences.

The health, safety and well-being of our conference participants, speakers and exhibitors are the top priorities for EFEE when considering the destination for the next EFEE World Conference. With social distancing guidelines in place and the requirements of local health and safety authorities to follow in the hosting country, the destination for the conference and particularly the conference venue will now have to meet all of these requirements, which previously have not had to be considered.

After careful consideration it was decided during the EFEE 65 thCouncil meeting that the location for the next 11th EFEE World Conference will be Maastricht in the Netherlands. The conference will take place from Sunday 19th to Tuesday 21st September 2021. The Maastricht Exhibition and Conference Centre, (MECC) is the right choice for the conference venue having just completed a full refurbishment, the MECC offers considerable conference space enabling social distancing throughout the exhibition, technical rooms and catering areas.

The NH conference hotel is adjacent to the MECC and just a minutes' walk away. Bedrooms have been held at a preferential rate and will be available to book as part of the registration process.

Maastricht is a city and a municipality situated in the southeaster Netherlands. It is the capital and largest city of the province of Limburg. Maastricht is located on both sides of the Meuse, at the point where the Jeker joins it. It is adjacent to the border with Belgium. Maastricht is known in the Netherlands and beyond for its lively squares, narrow streets, and historic buildings. The city has 1,677 national heritage buildings, more than any Dutch city outside Amsterdam.

Maastricht's main sights include:

- Meuse river, with several parks and promenades along the river, and some interesting bridges,
- City fortifications,
- Binnenstad: inner-city district with pedestrianized shopping streets including Grote and Kleine Staat, and high-end shopping streets Stokstraat and Maastrichter Smedenstraat.

12th EFEE Conference will take place in 2023 in Dublin, Ireland which is offering world-class conference venues in the heart of Ireland´s capital city. It is conveniently located at the gateway to Europe, Ireland is easily accessible for overseas delegates. Dublin is situated on a bay on the east coast, at the mouth of the River Liffey, it lies within the province of Leinster. It is bordered on the south by the Dublin Mountains, a part of the Wicklow Mountains range.

13th EFEE Conference will take place in Bucharest, Romania. Bucharest is the capital and largest city in Romania, as well as its cultural, industrial, and financial centre. Known for its wide, tree-lined boulevards and glorious Belle Epoque buildings, Bucharest is a bustling metropolis. The city's elegant architecture and the sophistication of its elite earned the city the nickname of "Little Paris".

EFEE looks forward to bringing you a safe and successful conference in Maarstricht. We will be contacting authors and exhibitors in the coming weeks, however, if you have any immediate queries please contact info@efee2021.com or visit efee2021.com

Igor Kopal, Chairman of Conference Committee

James Tyler, Tyler Events






Greetings from the ISEE.

As you will be aware, we have taken the decision to cancel the 2021 Annual Conference, scheduled to be held in Orlando in early February 2021. This was a very difficult decision for the Board to make, but we felt that we could not provide a quality conference under the prevailing conditions.

Our Annual Conference is very important to us for many reasons. It provides an essential education and training opportunity for the industry for people who need training hours to retain blasting licences either at the Blasters Weekend or throughout the conference.

The technical sessions give authors the chance to share their knowledge and experience to those of us who want to keep abreast of technical developments in the industry. Some see this as the key to a successful conference. Others get the most benefit out of the networking opportunities that the conference provides by bringing people together from around the industry and the world, sharing experiences and asking questions of industry experts in a casual setting. The Industry Exhibits give everyone the opportunity to see how the industry is developing and the chance to catch up with old friends and make new ones in a casual setting.

The developing situation with the pandemic meant that it would be impossible to hold anything resembling a normal conference. The information that we were given by the hotel meant that our capacity would have been a fraction of that available under normal circumstances. The exhibits would have limited capacity and size, social events would be curbed and general movement around the hotel would be difficult. International travel conditions are uncertain. Up to 40% of our attendees come from outside the US, meaning that attendance would be reduced. All in all, we could not see how we could hold a good event under these circumstances.

Underpinning all this is the prerequisite that all our members and staff are safe and healthy. We did not want to host an event that may expose people to a virus that can have major impacts on their lives. If only one person were to be affected, that would be one too many.

Based on all these things the Board made the difficult decision to cancel the 2021 conference. It was hard and on a personal level, I will miss this event enormously. It has been an important part of my year for nearly three decades.

Time that would normally be spent by Staff on conference planning has now been used to develop alternative training opportunities such as the Webinar Series that has been running in the last quarter of 2020.

We are also starting to plan for the next Annual Conference to be held in Las Vegas from 30 January – 2 February 2022. All the things we have learned in recent years, including 2020, will be brought together to make this a fantastic event. We are confident that we will be able to get together and continue to provide the industry with a valuable and enjoyable forum to learn and develop.

With my very best wishes to you all for the remainder of 2020 and into 2021. I look forward to meeting as many of you as possible in Las Vegas in 2022

Alastair Torrance.
President, ISEE

Upcoming International Events

15TH INTERNATIONAL CONFERENCE ON
DRILLING AND BLASTING TECHNOLOGY–2020
Cancelled and moved to spring 2021
Velence, Hungary
http://www.mare.info.hu/en

MINExpo INTERNATIONAL 2020
Postponed Until Sept. 2021
Las Vegas, Nevada, USA
https://www.minexpo.com/

ISEE 47th Annual Conference on Explosives and Blasting Technique
Cancelled and moved to 2022
Orlando Florida, USA
https://www.isee.org/conferences/2021-conference

SME Annual Conference
1-5 March 3, 2021,
In virtual format
www.smeannualconference.com

SAFEX International Congress
New date 5-10 September, 2021
Salzburg, Austria
https://www.safex-international.org/safex/news-safex-congress-xx-in-salzburg.html?sid=1580472102

WORLD TUNNEL CONGRESS 2021
UNDERGROUND SOLUTIONS FOR A WORLD IN CHANGE
Postponed to 2022
Bella Center Copenhagen, Denmark
https://www.wtc2021.dk/

HILLHEAD 2021
June, 22-24, 2021
Hillhead Quarry
Buxton. UK
https://www.hillhead.com

EFEE 11th World Conference on Explosives and Blasting
September 19-21, 2021
Maastricht, Netherlands
www.efee2021.com

FRAGBLAST 13
October 17-22, 2021
Hangzou, China
www.fragblast13.org.cn

26th World Mining Congress
Postponed to 25-29 June 2023.
Brisbane, Australia
https://wmc2022.org/