Hazards30

26–27 November 2020, Virtual

On the 10^{-4} /yr criterion for blast overpressure

An alternative comparative approach for safer design

Steve Howell and Prankul Middha

26 November 2020

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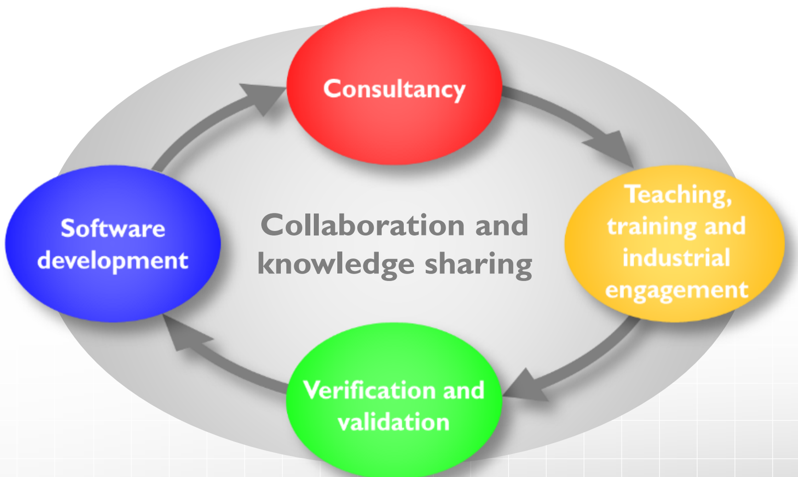
Abercus is an independent consultancy specialising in **advanced engineering simulation** within the energy sector – computational fluid dynamics (CFD), finite element analysis (FEA), the development of bespoke software tools and teaching/training.



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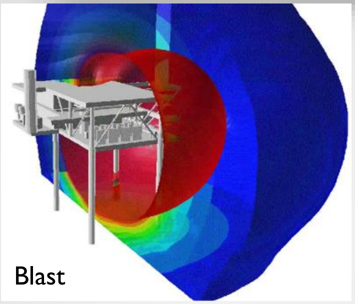
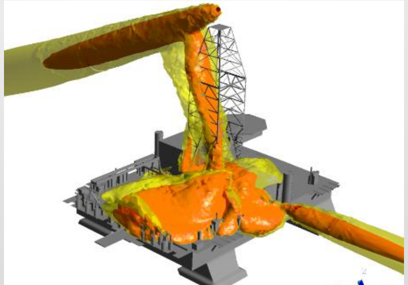
Technical safety



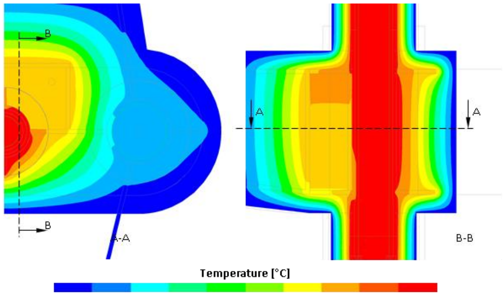
Blast

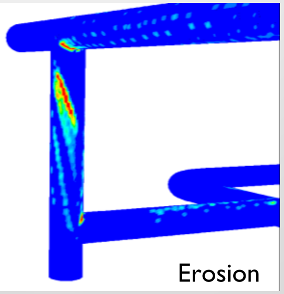


Deepwater Horizon : http://abercus.com/News_20110622.aspx

Flow assurance

Hydrate avoidance

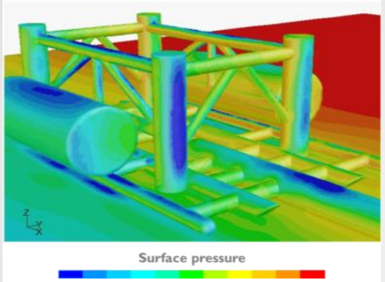


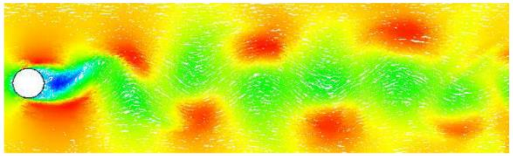


Erosion

Subsea engineering

Subsea stability





Flow induced vibration

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- Since the conception of the NORSOK Z-013 standard [1] in the late 1990's, the oil and gas industry has steadily moved towards a probabilistic approach for explosion risk assessment (ERA).
- In recent years, several parties have expressed concerns relating to this probabilistic approach [2,3].
- Abercus shares these concerns:
  - NORSOK Z-013 is not prescriptive – there is room for interpretation.
  - There is no British or International standard detailing the methodology.
  - Abercus has reviewed several probabilistic studies and, depending upon the input assumptions, the design blast loads may vary significantly.

[1] Risk and Emergency Preparedness Analysis, NORSOK standard Z-013 Annex F, Rev 3, 2010.
[2] A review of the Q9 equivalent cloud method for explosion modelling, J. Stewart & S. Gant - HSE, FABIG newsletter 75, 2019.
[3] Quantifying risk and how it all goes wrong, Keith Miller, Hazards 28, 2018.

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Introduction

- Abercus shares these concerns:
  - Abercus will participate in the PROBABLAST JIP which will launch early in 2021 with the aim of investigating whether there is an issue relating to inconsistency in the probabilistic approach across industry
    https://www.linkedin.com/groups/8980032/
- In the Norwegian sector, these concerns led to the RISP project
  - JIP: Risk informed decision support in development projects (RISP), Report LaC-P0647-R-0125, September 2019
    https://www.norskoljeoggass.no/contentassets/433b5a6a2ef54e429ead0f6934119d1d/final-main-risp--report-0647-r-0125-13122019-complete.pdf
  - Upcoming FABIG lunchtime webinar (9 December 2020):
    RISP-EX – A simplified tool for explosion load decision support
    https://www.fabig.com/events/lunchtime-webinar-rispex-simplified-tool-for-explosion-load-decision-support-linda-flottum-aker-solutions-jens-johansson-garstad-dnv-gl

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Introduction

- This paper considers some of the uncertainties in the inputs into the probabilistic methodology and whether an absolute acceptability criterion such as the 10^{-4} /yr criterion that is currently widely adopted is fit for purpose.
- Abercus proposes that instead of using an absolute acceptance criterion, a relative/comparative criterion could be used instead.
  - This would require the independent consideration of two separate models, a model of the actual asset of interest and a model of a similar notional asset that is used to define the acceptance criterion.
  - This approach has the **significant benefit** that any uncertainties associated with the input assumptions will be inherent in both models, so that when they are compared any error will, to a large degree, cancel out.

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Introduction

- There is a precedent for this approach, in another industry – this is an opportunity to learn from another industry:
  - In 2006, a comparative approach was introduced into the UK building regulations for the energy performance of new buildings.
  - Despite early skepticism, largely because it was a new approach that perhaps was not well understood by many in the industry at that time, the approach has now proven to be very successful for well over a decade.
  - This provides a precedent that could be adapted for determining design accidental loads for blast.
  - This paper is simply intended to raise the approach as a discussion point – feedback is welcome.

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Probabilistic explosion risk assessment

- A probabilistic explosion risk assessment in line with NORSOK Z-013 involves three steps:
  - CFD simulations – use computational fluid dynamics (CFD) to simulate a large number of deterministic gas dispersion and explosion consequences to form a database of representative scenarios for pre and post (delayed) ignition behaviour following a loss of containment of flammable material.
  - Probabilistic analysis – consider probabilities of release and ignition for each simulated scenario to construct exceedence data for blast loads.
  - Determine the blast loads – from the exceedence data, retrieve the blast load corresponding to the acceptability criterion (often 10^{-4}/yr).
- This paper focusses on the second and third points.

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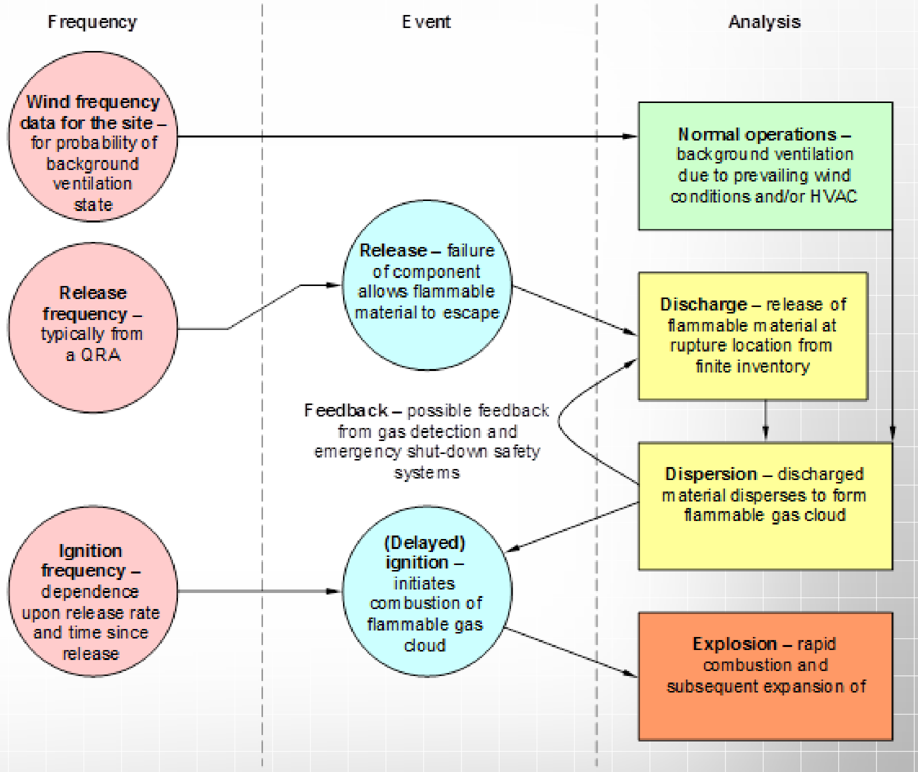
Probabilistic explosion risk assessment

Typical methodology

- A large number of deterministic representative scenarios (ventilation, dispersion and explosion) are simulated
- With an understanding of the frequencies of occurrence at each stage, exceedance data for the explosion loads can be compiled.



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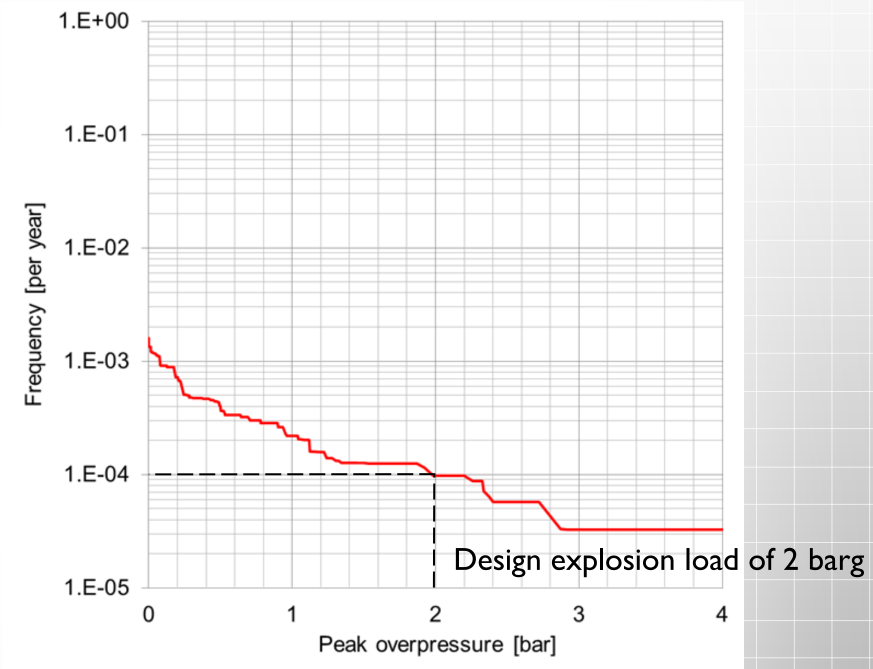
Probabilistic explosion risk assessment

Exceedance curves and the 10^{-4} criterion

- The exceedance curves show the predicted frequency for explosion loading at a target of interest
- For a specified allowable frequency, the design load is read from the curve and can be used as the basis of the structural design.



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Probabilistic explosion risk assessment

Uncertainties

- There are many areas of uncertainty, including but not limited to:
  - Release frequency data.
  - Ignition probability models (time dependent or steady state).
  - Scenario selection and resolution (ventilation, dispersion and explosion).
  - Representation of detection and emergency shutdown and blowdown.
  - Mapping of dispersion results to explosion analysis (Q9 vs FLAM vs real clouds).
  - Variance between alternative CFD tools.
  - User variance when using a specific CFD tool.
- Initial feedback from PROBABLAST JIP – these uncertainties are acknowledged by many parties.

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Probabilistic explosion risk assessment

Uncertainties

- When exceedance data is presented, however, it is usually only a single set of exceedance data that is provided.
  - Sensitivities are usually not presented, or may not have been considered.
  - Abercus has previously argued that these sensitivities should be transparent and properly understood [4].

[4] New paradigms for determining structural design loads for blast, Steve Howell and Prankul Middha, Hazards 28, 2018.

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Uncertainties in the probabilistic approach

Sensitivity to assumptions

- This paper considers two important inputs into the probabilistic assessment:
  - Release frequency data assumed for the gas dispersion analysis.
  - Ignition frequency model assumed for the explosion analysis.
- Abercus has recently independently reviewed several probabilistic studies and, depending upon the assumptions for these input frequencies, the design blast load may vary significantly – from several barg to zero!!!

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Uncertainties in the probabilistic approach

Sensitivity to assumptions – release frequency

- In a recent project review, Abercus had an immediate concern that the 10^{-4} /yr blast overpressures predicted at the key target of interest seemed rather low.
- After a review of the CFD model and associated congestion factors, which all looked sensible, focus was turned to the release frequencies assumed for the analysis.

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Uncertainties in the probabilistic approach

Sensitivity to assumptions – release frequency

Hole size [mm]	< 19	19-50	50-75	75-100	100-150	>150	Total
Source 1	1.35×10^{-2}	4.33×10^{-3}	3.49×10^{-3}	4.59×10^{-5}	9.17×10^{-5}	2.76×10^{-4}	2.18×10^{-2}
Source 2	1.62×10^{-2}	1.08×10^{-2}	9.13×10^{-4}	9.13×10^{-4}	1.82×10^{-3}	2.14×10^{-3}	3.29×10^{-2}
Source 3	5.40×10^{-2}	1.15×10^{-2}	3.08×10^{-3}	1.10×10^{-3}	1.78×10^{-3}	5.33×10^{-3}	7.68×10^{-2}
Source 4	1.92×10^{-2}	9.69×10^{-3}	7.81×10^{-4}	7.81×10^{-4}	1.17×10^{-4}	3.49×10^{-4}	3.09×10^{-2}

- The actual numbers presented in this table have been modified from the project report in order to protect the anonymity of the project. They do, however, remain in proportion to those presented in the project report.

- Source 1 is the release frequency data assumed for the original assessment.
- Source 2 is equivalent data independently retrieved by Abercus as part of the review.
  - Note that both Source 1 and Source 2 ultimately derive from the same source data, the HCR database.
- Source 3 and Source 4 is data retrieved from two previous Abercus projects for comparison.

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Uncertainties in the probabilistic approach

Sensitivity to assumptions – release frequency

- Both Source 1 and Source 2 ultimately derive from the same source data, the HCR database, however there are clear differences in the data compiled for this project.
- Most significantly, the data for Source 1 is around one order of magnitude lower than that for Source 2 for releases with a hole size of 75 mm or greater – as highlighted by the red values in the table on the previous slide.
- Exceedence curves for blast overpressure at a principal target of interest are presented for the four sources of release frequency data on the next slide.

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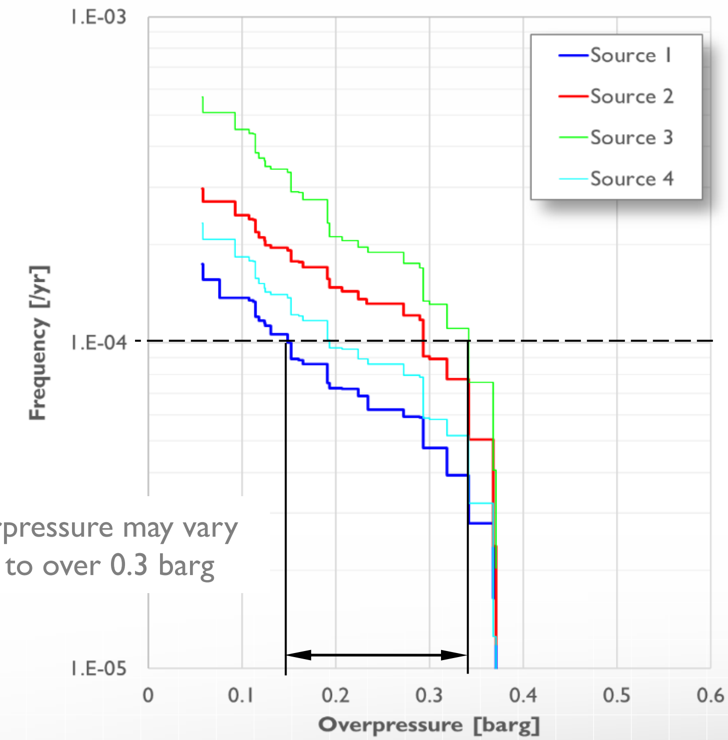
Uncertainties in the probabilistic approach

Sensitivity to assumptions – release frequency



The 10^{-4} /yr overpressure may vary from 0.15 barg to over 0.3 barg

Exceedance curves for peak overpressure for four alternative sources of release frequency data

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Uncertainties in the probabilistic approach

Sensitivity to assumptions – ignition frequency

- In the UK sector, the input ignition frequencies are often derived from the UKOOA ignition model [5].
- However, within this model there is scope to interpret aspects of the model differently.
- Exceedence curves at a principal target of interest for a previous Abercus assessment is presented for six alternative formulations for ignition frequency, each of which is permissible according to the UKOOA model.

[5] IP Research Report, Ignition probability review, model development and look up correlations, Energy Institute, 2006.

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Uncertainties in the probabilistic approach

Sensitivity to assumptions – ignition frequency

Ignition methodology	Probability of ignition	Probability of explosion given ignition	Time dependence
A	UKOOA 25	Fixed at 20%	UKOOA
B	UKOOA 25	Cox, Lees and Ang	UKOOA
C	UKOOA 25	Ignored	UKOOA
D	UKOOA 25	Fixed at 20%	Ignored
E	UKOOA 25	Cox, Lees and Ang	Ignored
F	UKOOA 25	Ignored	Ignored

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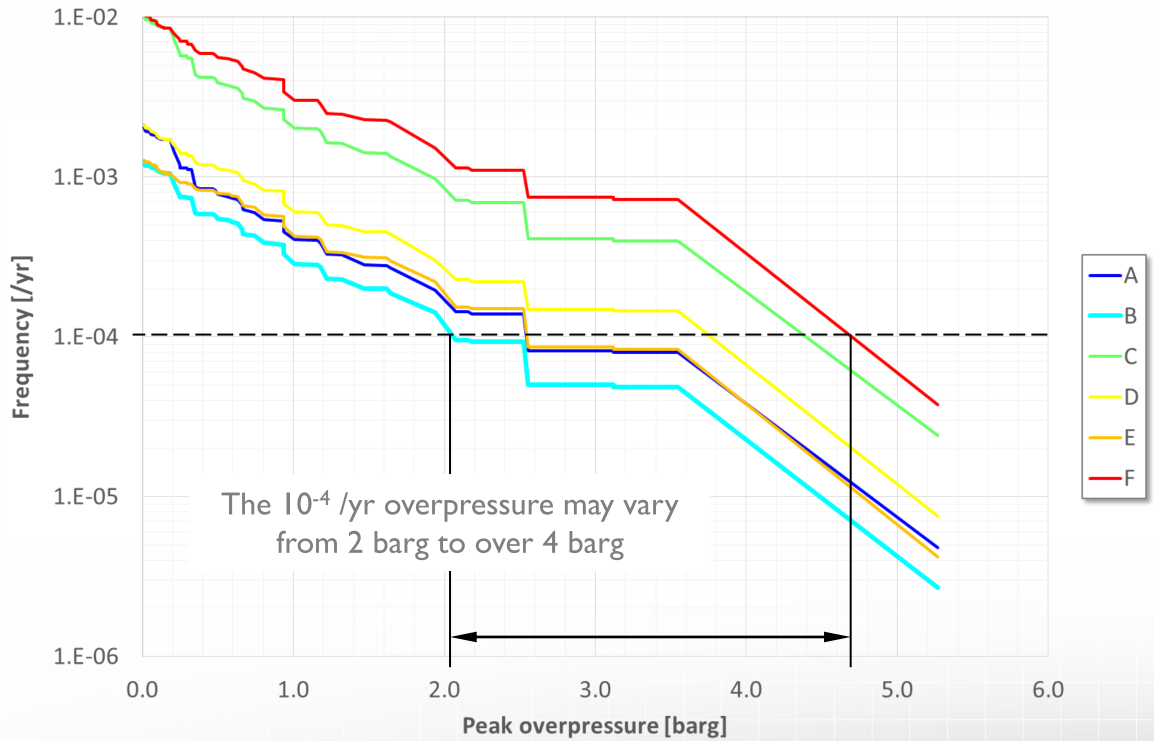
Uncertainties in the probabilistic approach

Sensitivity to assumptions – ignition frequency



Exceedance curves for peak overpressure for six alternative ignition frequency methods

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Uncertainties in the probabilistic approach

Sensitivity to assumptions

- With this level of sensitivity to the underlying input assumptions, we should ask the question: is a probabilistic approach based upon an absolute acceptance criterion fit for purpose?

- Can we learn from other industries to develop an approach that could reduce the effect of these uncertainties when determining design accidental loads?

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Energy performance of buildings

- Twenty years ago, there were two competing dynamic simulation tools that could be used to predict the energy use in buildings.
- However, the predictions from each tool could differ due to the methodologies employed by the tools.
- Perhaps twenty years ago, that did not matter – the tools could still be used to explore trends and reduce energy use.
- But then, in 2002, the EU published a directive on the energy performance of buildings which required member states to implement an energy use calculation by law.
- Correspondingly, in 2006, the UK government updated the building regulations (Part L2A in England/Section 6 in Scotland).

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Energy performance of buildings

- Since 2006, the UK building regulations have required that the energy performance of new buildings other than dwellings must be calculated using the National Calculation Method (NCM) [6].
- Perhaps recognizing that it might be impossible to reconcile the two existing dynamic simulation codes, (or even predictions from either code from different users), the NCM uses a comparative approach to set the acceptability criterion for energy use and the associated carbon dioxide emissions due to the use of the building…

[6] Website for UK's national calculation method for non domestic buildings, http://www.uk-ncm.org.uk/

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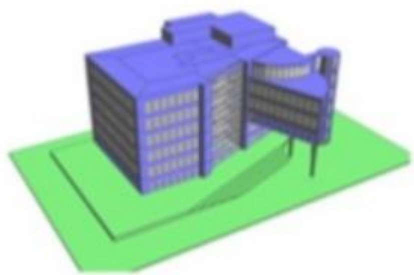
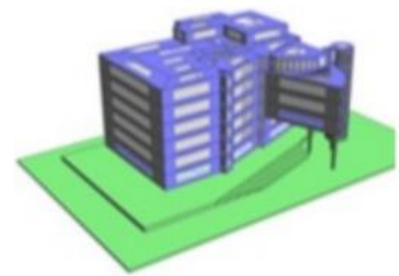
National calculation method (NCM)

- For each dynamic simulation tool, an accurate representation of the **actual building** is constructed by the user, and then a **notional building** is automatically generated by the tool:

Actual building



Notional building (2007)



Comparison of the notional building with the actual building for Section 6 (energy performance requirement for Scottish building regulations) [7]

[7] Impact of building regulations 2010 on users of dynamic simulation, https://www.slideshare.net/IESVE/sesg-seminar-presentation-11175600 (retrieved 17 January 2020)

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National calculation method (NCM)

- For each dynamic simulation tool, an accurate representation of the **actual building** is constructed by the user, and then a **notional building** is automatically generated by the tool.
- The notional building has:
  - Rooflights (at least in the 2006/7 building regulations)
  - Fixed proportion of glazing in the facades
  - Construction materials (U-values) fixed by the NCM.
- Normally the user would not get to see the notional building – this is created automatically in the background and cannot be interfered with by the user.

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National calculation method (NCM)

- The simulation tools calculate two emission rates for carbon dioxide emissions due to the use of the building:
  - The Building Emission Rate (BER) for the actual building
  - The Notional Emissions Rate (NER) for the notional building
- A Target Emission Rate (TER) is calculated:

$$TER = NER \times (1 - IF) \times (1 - LZC), \quad \text{where:}$$

  - the improvement factor (IF) is either 15% or 20%, depending upon whether the actual building is naturally ventilated or mechanically ventilated/air conditioned
  - the low/zero carbon benchmark (LZC) is equal to 10%.
- In order to comply with the building regulations, the BER must not exceed the TER.

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National calculation method (NCM)

- The NCM methodology has several benefits:
  - It is detailed by an independent authority and compliance must be assessed by using an accredited software tool.
  - It is a robust comparative approach where compliance is achieved by comparison with a **relative criterion**, the TER, which depends upon the building under consideration rather than an absolute criterion that applies to all buildings.
  - The compliance criterion, the TER, is determined by simulating the energy performance of the notional building and that simulation uses many of the same input assumptions as the simulation for the actual building.
  - As a consequence, **any uncertainties associated with the input assumptions will be inherent in both models, so that when they are compared any error will, to a large degree, cancel out.**

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National calculation method (NCM)

- There are only a few accredited software tool that can be used for building regulation compliance:
  - Several (~3) commercially available physics-based dynamic simulation tools that simulate the energy performance of a building in some detail.
  - A simplified tool called SBEM (Simplified Building Energy Model) developed by the UK Government.
  - Dynamic simulation is perhaps analogous to the use of CFD, whereas SBEM is more akin to the use of an integral model.
- In addition, compliance can only be achieved if the individual undertaking the assessment is an accredited user of the chosen software. A central database of accredited assessors is maintained and is freely accessible.

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NCM as a precedent for explosion

- The NORSOK Z013 standard was first released in the late 1990s at a time when computational fluid dynamics was still a niche technology with relatively few practitioners – it has now been around for 20 years and has not changed significantly in that time.
- During the same period there have been continual advances in both computer hardware and engineering simulation tools, and the use of simulation technologies such as finite element analysis and computational fluid dynamics continues to increase apace.
- The NORSOK Z013 standard is perhaps due a review and the NCM could provide a precedent for the probabilistic explosion approach moving forward.

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NCM as a precedent for explosion

- A relative acceptance criterion analogous to the TER, based upon models of an actual asset and a notional asset and a required margin of improvement, could allow input uncertainties to largely cancel out, reducing inconsistency.
- Of course, this change in approach would need some thought and the definition of the notional asset for an explosion assessment would require agreement. For example:
  - Representative levels of congestion and confinement would need to be agreed for a 2020 notional standard – wellhead, process area, utility…
  - For the NCM, the BER and TER are scalar quantities, but for an explosion assessment, how could the blast load for the actual and notional facilities be compared? Directly, everywhere across the asset, or another measure.

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NCM as a precedent for explosion

- Abercus believes that the NORSOK Z013 approach is due an overhaul and that the NCM could provide a good model for many aspects of a new probabilistic explosion approach based upon relative acceptance criteria.
- Abercus also believes that this should be given an urgent focus by industry – the sooner we recognize the concerns that have been raised with the current approach by many different parties, the sooner we can start to address them, improve the consistency of the methodology and produce safer assets.

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Other recent initiatives

RISP/RISP-Ex

- In an effort to eliminate inconsistencies between different parties, a JIP is already ongoing in Norway – Risk Informed decision Support in development Projects (RISP):
  - This approach reduces the emphasis on simulating a large number of scenarios with CFD and avoids the possibility of user inconsistency
  - Using knowledge gained over the past 40 years, a software tool RISP-Ex is being developed to provide DALs that are used in the decision making process with respect to explosion hazards – using a look-up approach
  - The JIP recognises that RISP is a simplified methodology, but it is a consistent approach so that the DAL predictions returned by RISP-Ex will not depend upon which party has undertaken the work.

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Other recent initiatives

RISP/RISP-Ex

- RISP-Ex could, in future, offer an alternative methodology to CFD-based probabilistic ERA with respect to determination of DALs, especially where *standard* design is being pursued.
- For novel designs, and while RISP-Ex is becoming established, CFD-based probabilistic ERA is still likely to be needed.
  - JIP: Risk informed decision support in development projects (RISP), Report LaC-P0647-R-0125, September 2019
    https://www.norskoljeoggass.no/contentassets/433b5a6a2ef54e429ead0f6934119d1d/final-main-risp--report-0647-r-0125-13122019-complete.pdf
  - Upcoming FABIG lunchtime webinar (9 December 2020):
    RISP-EX – A simplified tool for explosion load decision support
    https://www.fabig.com/events/lunchtime-webinar-rispex-simplified-tool-for-explosion-load-decision-support-linda-flottum-aker-solutions-jens-johansson-garstad-dnv-gl

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Other recent initiatives

PROBABLAST JIP

- A joint industry project, PROBABLAST JIP, has been established to carry out a blind probabilistic ERA inter-comparison exercise
- The project work is divided into three phases:

Phase	Objective
A	Identify whether there is an issue regarding inconsistency in approach across the industry
B	Share experience and learnings in the public domain
C	Help develop good practice guidelines (eventual goal)

- Many of the leading safety consultancies have already agreed to participate in the blind study and submit data anonymously.

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Other recent initiatives

PROBABLAST JIP

- NAFEMS, the international association for the engineering modelling, analysis and simulation community, will receive data anonymously from participants.
- The UK Health and Safety Executive (HSE) will provide an independent review of the submitted benchmark data.
- Interested parties with relevant experience of CFD-based probabilistic ERA are welcome, indeed encouraged, to join this effort – please do get in touch and join the JIP. You can register your interest at the PROBABLAST JIP LinkedIn page: https://www.linkedin.com/groups/8980032/.

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