

Title	CRR: 192/1998 Review of blast injury data and models
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Executive Summary	<p>The report has been produced for the Health and Safety Executive (HSE) by Medical Countermeasures Department, Chemical and Biological Defence Sector, DERA, Porton Down (CBD) under Order No. 3668IR74.006. CBD were tasked to carry out an assessment of parts of a methodology developed by WS Atkins Science and Technology for predicting the probability of fatality for the occupants of buildings affected by vapour cloud explosions. The parts to be assessed were those concerned with predicting the probability of injury.</p> <p>Specifically, CBD were to determine whether all relevant injury types, mechanisms and conditional probabilities had been addressed by the Atkins' model, and whether the most appropriate available injury criteria had been used to determine them.</p> <p>The two main approaches to predicting the probability of fatality for the occupants of buildings exposed to explosions are semi-empirical methods which rely on scaling the casualty data from historical explosions, and methods which model physical effects and injury mechanisms, and then use injury criteria to generate fatality probabilities ('ab-initio' approach). Both methods have known drawbacks - inadequately detailed statistical data for the semi-empirical methods, and inadequate or misleading injury criteria developed from first principles.</p> <p>WS Atkins used an ab-initio methodology, which aimed to model the physical events of vapour cloud explosions (VCE's) and the effects on buildings. The failure of the building or specific components was then used predict the consequent probability of fatality to occupants, using injury criteria available in public literature.</p> <p>CBD's search of its own archives, literature in the public domain and contact with some authors, revealed hitherto unrecognised sources of detailed historical casualty data. These searches and CBD's knowledge of human vulnerability, also revealed flaws in widely accepted and used injury criteria.</p> <p>Atkins' methodology did address the two injury mechanisms which have been shown by historical data to be the most important causes of fatality in occupants of buildings exposed to explosions: building collapse and flying debris.</p> <p>The injury criteria used by the Atkins model for predicting death from building collapse are undoubtedly over-pessimistic. Their model uses the most widely accepted injury criteria available in the world literature for prediction of fatality for impact from flying debris, but unfortunately, these criteria are so flawed that they render the subsequent calculations unsound. CBD's opinion is founded on comparison with detailed data from real events and by examining the original assumptions upon which the criteria were based. The methodology also covers a third possible cause - fatality due to glazing fragments - but grossly overestimates its importance. Flying glass is a major source of mortality from the Atkins predictions; it causes virtually no mortality amongst the casualties of actual explosions, although it is a major cause of injury.</p> <p>The Atkins methodology did not address four other potential causes of significant fatality in buildings. These are: translational injury within buildings; flying debris originating from sources outside buildings; burns, and primary blast lung injury. Of these, translational injury is a significant potential cause of fatality at the upper end of the range of overpressures considered by Atkins in their methodology. The probability of fatality from the other three mechanisms should be very low for most VCE's, but is not zero.</p> <p>The flaws in the individual injury criteria would probably result in inaccurate predictions of the total incidence of fatalities in building occupants. Overall, these</p>

	<p>probabilities should be markedly over pessimistic, despite the omission of some (lesser) potential causes of fatality. Atkins' comparison of their predictions with historical data underestimates the disparity between those data and their own predictions, since they are not aware of the sources of the most detailed data from WW II and terrorist bombing incidents. Consequently, the final Pressure-Impulse diagrams presented for use in predicting fatality are based on unsound assumptions and criteria.</p> <p>Atkins' conclusion that they have developed a workable methodology for predicting the probability of fatality for building occupants is not sustainable. Other methods must be used to predict the risk of fatality in buildings exposed to VCE's. The Atkins model is likely to over-estimate the incidence of fatalities.</p> <p>The best predictive methods currently available are semi-empirical ones which rely on the correlation of injury with damage to structures. Injury criteria in current use are too deeply flawed to form the basis for models relying solely on predictions from first principles. The most profitable approach for the future is likely to involve combining semi-empirical methods with criteria developed from first principles - improved casualty criteria which have been thoroughly validated against (or derived from) historical data.</p> <p>In addition, CBD's review highlighted the disparity between the typically large numbers of casualties from accidental and terrorist explosions who survive with injuries, and the relatively small numbers of casualties who die. Consequently, the human and financial cost of such explosions may be reflected poorly by predictive models which deal only with fatality.</p>
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