TECHNICAL UNDERPINNING OF THE EARLY PHASE MONITORING OF A PLUME RELEASE FROM AWE

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ABSTRACT

The Atomic Weapons Establishment (AWE), in line with most large nuclear establishments in the United Kingdom, has robust and well rehearsed responses to reasonably foreseeable incident scenarios. The requirements for this response capability are laid down in legislation.

Two studies have been undertaken to technically underpin the early phase monitoring of a plume release from AWE. One study reviewed the commonly used plume models and radiological monitoring instrumentation available at AWE for early phase response to an airborne release scenario. This study concentrated on balancing the requirement for accurate results and optimising the time taken to collect the data necessary for important decisions. The second study involved a physically scaled model of one section of the AWE Aldermaston site, whose near field effects were investigated in a wind tunnel.

The studies have been combined to produce recommendations for appropriate early phase monitoring and highlighted the effect that complex buildings structures have on the cavity wake region.

INTRODUCTION

The Atomic Weapons Establishment (AWE) has for a long time had emergency response arrangements in place for dealing with an incident that might involve the release of a plume of radioactive material into the environment. There was, however, no demonstrable evidence technically underpinning the arrangements, although they appeared theoretically sound.

Many reports have been written on the subject of emergency response to nuclear accidents. Unfortunately, AWE is different from most nuclear sites, in that it is a large industrial complex in close proximity to high density population centres and is not at a coastal site. This situation makes modelling the dispersion of radioactive material (material), in the unlikely event of a nuclear accident, more difficult.

PLUME MODELLING UTILISED

When material is released into the atmosphere, the airborne particulate and gases form a plume that is transported in the downwind direction and expands in the horizontal and vertical planes due to diffusion controlled by turbulent eddies in the atmosphere. Transport in the vertical plane is inhibited when a plume reaches the “Boundary Layer Inversion” or the ground level, where it is reflected.

Due to these mechanisms, amongst others, the atmospheric dispersion of a plume is complex and depends on many variables that are equally difficult to determine. Various mathematical models have been developed to emulate the atmospheric dispersion characteristics of a plume, such as the Gaussian and the Diffusivity (K-profile) models, and their various refinements. The Gaussian models are by far the simplest and provide results comparable to those determined from the more complex models. The Gaussian plume diffusion model assumes that the concentration of dispersed material can be likened to a Gaussian distribution, described by the standard deviations σ_y and σ_z in the horizontal and vertical planes respectively.

Thus, a mathematical model depicting the plume can be derived taking into account factors such as the Meteorological Classification, Surface Roughness and the alterations to its composition due to material removal by various mechanisms [such as dry, wet and occult deposition and radioactive decay]. Special effects such as plume rise due to momentum or thermal buoyancy, plume release height and entrainment effects on the released material due to building wakes may also be modelled if appropriate.

In the ‘early phase’ of an incident, involving the release of material, detailed reliable knowledge of parameters influencing dispersion and deposition will be limited. Consequently, a simple model is required to allow a quick determination of affected areas and suitable monitoring locations. To assist in this, AWE now utilises an adaptation of the Gaussian plume diffusion model and other pertinent information. Unfortunately, this type of model is not appropriate for near field monitoring at AWE due to the strong influence of entrainment in these regions.

MODELLING FOR RAPID RESPONSE MONITORING

A wind tunnel study investigation focused on the influence of building structures at AWE Aldermaston on plume dispersion in the near field.

A 1:350 scale model of the major structures within a large section of the Aldermaston site was constructed after careful consideration of the similarity rules. A significant amount of effort was put into ensuring that the appropriate scaling laws were obeyed. For numerous reasons, only one atmospheric condition was simulated, that being a neutrally stratified boundary layer, corresponding Meteorological Classification category D. These atmospheric conditions are encountered for approximately 60% of the time at AWE. The flow in the wind tunnel had been previously characterised.

Two experimental methods were used to investigate the cavity wake region, determine ground level concentrations and plume width at the 50% concentration values:

- Flow visualisation using smoke, laser illumination and image data capture.
- Gas tracer tests using a neutral buoyancy gas.

Data on Cavity wake regions - The quantitative flow visualisation and some of the gas tracer studies confirmed that for structures that were within the region of another structure's cavity wake region, the dimensions of the cavity regions were within 10-20% of the predictions. An area was observed where the cavity wake regions of a number of structures effectively overlapped producing a highly complex recirculation flow where the standard predictions do not accurately fit.

Effect of Structures on ground level releases - Reduced ground level concentrations (g.l.cs) relative to those predicted by a Gaussian model and relative to base line tests carried out without the structures present were observed for ground level releases impinging on building structures, reduction factors in g.l.cs of up to 3.2 were observed within 500m of the release point (near field). The plume concentration profile for g.l.cs around some of the larger structures were non Gaussian within 100 to 200m of the structure, in line with predictions. For the structures investigated there were plume broadening factors observed from 1.3 to greater than 2.

Effect of Structures on elevated releases - Ground level concentrations were found to increase in the near field as a consequence of the structures, with centreline concentrations being increased by factors ranging from 5 to 68 from those predicted by a Gaussian model and relative to base line tests carried out without the structures present. The highest increases were found to be within 300m of the release point when influenced by the largest structure on the site, with the airflow at 45° to the building aspect. For tracer releases into airflows perpendicular to the building aspect, plume widths were not significantly broadened with respect to the un-perturbed flow. When the airflow was at 45° to the building aspect, plume widths were increased, with factors of up to 3 being encountered. It was also determined that the amount of material entrained into the cavity wake region is sensitive to the release height. A 10% change in height resulted in a g.l.c increase of up to 150% at 265m from the source. However, the plume broadening effects did not appear to be sensitive to the release height.

PRACTICAL INTERPRETATION OF THE MODEL FOR RAPID RESPONSE

The information obtained from the modelling has enabled a criterion to be developed for circumstances where rapid response monitoring deployment would be feasible and where it may not. The model has further enabled decisions to be formulated on the most appropriate monitoring locations to rapidly confirm or deny, when coupled with other salient information, a plume release from a building. This decision can pay specific attention to the cavity wake region and plume widening, due to down wind obstructions.

OVERVIEW OF AWE'S ARRANGEMENTS

The arrangements currently in place and continually being developed consist of three teams as detailed below:

(i) **Team One** the rapid response team made up of one health physics supervisor and one surveyor.

(ii) **Teams Two and Three** the district monitoring teams each made up of one health physics supervisor and two surveyors.

Each of these teams has identical monitoring, sampling and analysis equipment, as well as Personal Protective Equipment (PPE) and communications equipment. All teams shall perform District Monitoring duties in line with specific requirements, but shall have initial deployments as below.

The rapid response team will be deployed in close proximity to the building suspected of having a release, to confirm or deny a plume release.

The first District Monitoring Team, to be dispatched will be sent to a region close to the site perimeter fence, avoiding the plume area displayed on one of the NRPB plume overlays, entering the plume deposition area delineated by the 1% line. Their first task will be to monitor the area inside of the perimeter fence, to determine if it is likely that an off-site release has occurred.

The second District Monitoring Team will be dispatched off-site to pre-determined monitoring locations, where various monitoring can be undertaken. Monitoring will be undertaken at pre-determined locations, to assist with locality accuracy, recorded against location and then transmitted back to a member of Health Physics at AWE Aldermaston.

The result for the source term can then be entered into a further computer programme, along with the release height, which allows an estimate to be determined of the distance from any release that specific countermeasures are appropriate. This distance will of course, using these crude data, have significant uncertainties.

CONCLUSION

At AWE Aldermaston, district monitoring and rapid response arrangements offer the quickest, and currently most appropriate, way of obtaining qualitative and quantitative results following a plume release.

Bearing in mind that this work was only undertaken for a single weather condition and with limited wind directions a number of conclusions can be drawn.

- The amount of material from an elevated release deposited downwind of a structure is increased relative to the un-perturbed flow and for a number of situations near field monitoring within the cavity wake region of downwind structures may produce useful results to confirm a release. However, for some ground and elevated release scenarios, the NRPB (Pasquill-Gifford) overlay system will under predict the plume width in the near field.
- The ground level concentration data showed that where increases or decreases occur they are not confined to the cavity wake region and extend for a significant distance downwind.

Thus, near field rapid response monitoring results are useful for confirming that a release to atmosphere has occurred, but not for accurate determination of quantitative results about the plume spread and source term. However, far field monitoring results allow interpolation of approximate (order of magnitude) source terms.

With the approach used by AWE it is possible to confirm the release or otherwise of a plume; provide an estimate and then refinements of a release source term; determine areas of contamination; and

(i) advise on the extent of countermeasure requirements.