British Nuclear Group

28 February 2007

Sellafield Legacy Wastes Update

NuSAC (2007) P5 Open Paper

Dave Mason, Andrew Buchan

1 Background

This paper provides the background to, and summarises the progress in a number of areas related to the most significant legacy wastes at Sellafield. The aim of this paper is to provide NUSAC members with an overview of the issues related to the waste characterisation, retrieval and processing which will be required to achieve remediation. It provides updates on the progress with Legacy Wastes reported in the previous papers NuSAC (2006) P4 Closed and NuSAC (2006) P7 Open. It should be noted that these previous papers primarily provided a detailed update of the management of high and medium active liquors at Sellafield. This paper provides a more detailed background to the legacy waste facilities and the challenges facing these remediation projects. The paper does not consider the decommissioning or demolition of residual civil structures.

A number of fuel ponds, silos and resulting waste materials are considered:

- Pile Fuel Storage Pond
- First Magnox Pond
- Magnox Fuel Cladding Silo
- Pile Fuel Cladding Silo

2 Terms

ALARP	As Low As Reasonably Practicable
BNFL	British Nuclear Fuels Limited
BNGSL	British Nuclear Group Sellafield Limited
BEP	Box Encapsulation Plant
BEPO	British Experimental Pile “0”
BEPPS1	Box Encapsulation Plant Product Store 1
BPEO	Best Practicable Environmental Option
BPM	Best Practicable Means
DTI	Department for Trade and Industry
EA	Environment Agency
ERP	Early Remediation Project
FHP	Fuel Handling Plant
HMG	Her Majesty’s Government
HSE	Health and Safety Executive
HWM	Historic Waste Management
ILW	Intermediate Level Waste
LoC	Letter of Compliance
LLW	Low Level Waste
LLWR	Low Level Waste Repository
LP&S	Legacy Ponds and Silos
LSTP	Local Sludge Treatment Plant
LTP	Lifetime Plan
MEP	Magnox Encapsulation Plant
MBGWS	Miscellaneous Beta-Gamma Waste Store
NDA	Nuclear Decommissioning Authority
NII	Nuclear Installations Inspectorate
NTWP	Near Term Work Plan
POCO	Post Operational Clean Out
SEP	Silo Emptying Plant
SIXEP	Site Ion Exchange Plant
SPP1	Solids Packaging Plant 1
WEP	Waste Encapsulation Plant
WPEP	Waste Packaging Encapsulation Plant

3 Context

The Legacy Ponds and Silos area at Sellafield comprises four key legacy plants; namely the Pile Fuel and First Magnox Fuel Ponds and the Pile Fuel Cladding and Magnox Fuel Cladding Silos. The remediation strategies described in this paper offer the potential for British Nuclear Group Sellafield Limited to address the requirements of the Licence Specification dates as issued by the HSE in 2001. (Refs 1 to 3)
These require the following:

Pile Fuel Storage Pond (August 2009)
"At least 90% of the total volume of potentially mobile Intermediate level waste which has been accumulated as sludge…shall be stored as sludge/slurry form within modern stainless steel containment"

First Magnox Pond (August 2010)
"At least 90% of the total volume of potentially mobile Intermediate level waste which has been accumulated as sludge…shall be stored as sludge/slurry form within modern stainless steel containment"

Magnox Fuel Cladding Silo (August 2020)
"At least 80% of the total volume of all Intermediate Level Waste sludges originating from operations prior to 1 August 2000 and which have been accumulated as radioactive waste shall be stored in a safe passive form

Pile Fuel Cladding Silo (August 2016)
"The licensee shall not accumulate the contents of the …silo ….except in a place and manner approved by the executive"

This paper is based upon the Lifetime Plan 2006 and underpinning technical information available at the time of writing.

4 Pile Fuel Storage Pond

The pile fuel storage pond served the two Windscale pile reactors and was used to store and de-can pile fuel. The Pond has been used subsequently to store Magnox and oxide fuel and other irradiated materials. The pond is now hydraulically isolated from the two reactor water ducts. The Pond is 100 m by 25 m by 7 m deep containing 14 million litres water and 183 skips. The pond has been in use from the early 1950 and is the oldest active water retaining structure on Sellafield site. A summary of the materials, quantities and proposed treatment strategies is outlined in Table 1 below.

Table 1: Pile Fuel Storage Pond Inventory and Strategy

Inventory Type	LTP 2006 Strategy
Oxide Fuel	Waste characterisation facility then Oxide Fuel Storage
Sludges	Retrieve to Corral, LSTP buffer tanks, dewater & grout. Transport to BEPPS1 for wash and store.
Metal Fuel	BEP treatment BEPPS1storage
ILW Isotopes	To waste characterisation facility then BEP/BEPPS1
ILW Magnox Swarf	To MEP
ILW Zircalloy liners	To MBGWS
Activated Items	Mostly LLW to LLWR (except 60Co)

Recent progress
The planned commencement of residual oxide fuel transfer to alternative storage during 2004/5 was prevented by non-availability of a waste characterisation facility. An alternative approach was developed to allow fuel to be moved within the pond in a consolidation exercise to maximise operational flexibility. The strategy for metal fuel retrieval and treatment is currently under development. In preparation for sludge retrieval, with attendant increase in pond water activity levels, a local effluent treatment plant has been installed within the pond itself. A modular unit incorporating a sand bed filter and an ion exchange unit, operable on either once through or recirculation basis, was installed using a mobile crane in late 2006 and is currently undergoing commissioning. Preparations are in hand regarding the sludge retrieval equipment and receiving tanks.

5 First Magnox Pond

The first Magnox pond was built and commissioned in 1959 for the receipt, storage and decanning of irradiated Magnox fuel. In 1974 the Magnox reprocessing plant underwent a lengthy reprocessing shut down which led to the fuel being stored under water in the pond for abnormally long periods of time. This resulted in excessive corrosion of fuel cladding and fuel, giving rise to formation of sludge, comprising corrosion products, within the ponds. The presence of sludge in the pond led to poor underwater visibility and deteriorating radiological conditions throughout the plant.

In 1986 pond purging and sludge exports were diverted from the original settling tank to the new purpose built settling tanks, which in turn exported sludge and pond water to the Site Ion Exchange Plant (SIXEP).

Following a gradual reduction in decanning operations, bulk receipt of fuel from Magnox Stations ended in 1986 when the new Fuel Handling Plant (FHP) became operational. However some fuel was received from Calder Hall up to 1994. Between 1959 and 1986 over 25,000 tonnes of fuel were successfully processed through the facility, including Pile/BEPO fuel. Decanning operations ceased in 1988. The building is showing varying degrees of ageing effects. Concerns raised in 2000 over the structural condition of the plant, following a periodic safety review, led to all retrieval operations being suspended, including operation of the skip handler. As a result, the plant was placed under a control and surveillance regime, whilst the retrievals/decommissioning strategies were reviewed.

Project Strategy

The first Magnox pond still contains significant volumes of historical waste including fuel, sludge and intermediate level (beta/gamma) waste. This radioactive inventory presents a significant risk to the workforce and public, and is required to be retrieved to ultimately remove the hazard. The first Magnox pond strategy is in line with the Legacy Ponds and Silos (LP&S) Early Remediation Project (ERP). That is to progressively reduce the risk associated with the facility. This objective is met by retrieving waste from the pond and treating/processing waste to a safer form and safely storing above ground, in a suitable store, for an interim period. The ERP achieves inventory removal and risk reduction faster than the earlier Historic Waste Management (HWM) project and is intended to address the Regulatory Instrument requirements. The Project Strategy will take account of the constraints within the plant i.e. condition of structures, plant and equipment, dose rates, crane lifting capacities, limited availability of export options, number and positioning of pond skips (pond management to facilitate sludge retrieval operations). A summary of the materials, quantities and proposed treatment strategies is outlined in Table 2 below.

Table 2: First Magnox Pond Inventory and Strategy

Inventory Type	Lifetime Plan 2006 Strategy
Fuel Debris	Fuel mass to FHP starting 2010,Remainder to BEP (mixed with MBGW)-shipped in skips through export building
Sludges	Retrieve to SPP1 buffer tks via corral, dewater & compact, grout. Transport to BEPPS for wash and store.
Loose MBGW	BEP treatment BEPPS1 storage
Skips	To BEP/BEPPS1 containing MBGW/fuel
Zeolites	To BEP/BEPPS1
Wet Bay ILW	Preferred Route is selected as MBGWS and WEP

Recent progress

As part of the skip handler reinstatement work, a Gantry Refurbishment System has been installed providing a working platform allowing steel work and crane rails to be inspected and refurbished. A skip of fuel has been transferred from the pond to the Fuel Handling Plant and successfully reprocessed through the chemical separation plants to demonstrate the potential availability of this as a treatment route for fuel in this condition. Refurbishment projects have been implemented to allow export of fuel on a routine basis. Another trial involving export of a container of pond sludge for in-drum encapsulation in WEP has taken place to demonstrate the technical viability of a sludge encapsulation process. Clearance of an adjacent site in preparation for the construction of the retrieved sludge holding tanks (SPP1) is underway. Emergency pumping systems have been installed to enable any leakage from redundant high risk pipework to be returned to the main pond, progress has also been made in the isolation strategies for these high risk lines, this will significantly reduce the risks of gross leakage from the pond.

6 Magnox Fuel Cladding Silo

The Magnox fuel cladding silo stores Intermediate Level Waste, primarily Magnox fuel cladding underwater. The silo consists of 6 original compartments which have been added to in a series of extensions; the facility now comprises 22 compartments. Whilst improvements in containment and ventilation standards have been incorporated into the later extensions to the building, it is considered prudent to retrieve the silo contents to safe passive storage in a timely manner. The building structure is inevitably subject to deterioration with time and the hazards associated with hydrogen evolution resulting from thermal excursion and chronic release will require management for the life of the building. To manage the risk of hydrogen excursions during storage, active safety systems utilising ventilation and inert gas blanketing are employed. In the past, loss of containment has occurred from the original silo and the risks posed by containment of the active liquor created by storage of radioactive material underwater in an ageing concrete structure will persist until the inventory is removed. The current situation is considered intolerable and the only way to eliminate these hazards is to remove the solid waste in a controlled manner, accelerating the process where practicable to do so. As the solid inventory in groups of compartments is removed, the active liquor, which would present the overriding immediate hazard in the event of a loss of containment, can also be progressively removed and processed.

Waste Retrieval

Waste will be grabbed and withdrawn into a purpose built 300te, mobile shielded cave (Silo Emptying Plant SEP) for sorting, size reduction and consigning to a $3m^3$ skip. The filled waste skips will be exported in heavily shielded 50Te flasks, via the existing rail infrastructure. Deployment systems will be required to allow the grab to access material not directly below the charge holes of the compartments. The operations will need to be supported by a large amount of ancillary equipment - special skips, flasks, stands, etc. All of this equipment will require suitable storage and handling facilities. The building is undergoing engineering modifications to allow deployment of the SEP machines. This work is broadly either structural improvement and relocation of items that clash with the proposed new plant, or installation of equipment to support the SEP programme, such as new cranes. Interfacing plants will be required to handle the waste from this process. This will include Magnox swarf and sludge, beta-gamma waste items and excess liquor generated during the retrievals process. Further facilities will be required to store ancillary equipment and to carry out maintenance.

Hazards and Hazard Management

The process of removing waste from the compartments will introduce some new potential hazards or exacerbate a number of existing hazards. It is accepted that there may be some relatively short term increase in risk, due to the hazards introduced by the processes and engineering changes involved. In principle, this is considered acceptable, due to the overriding requirement to remove the inventory from the plant as soon as practicable.

Generally, many hazards associated with retrievals can ultimately lead to a loss of containment, with potential for increased dose to operators and public . However, this must be viewed against the urgency placed upon removal of the inventory, due in part to the age of the structure and the limitations of the containment engineering. The hazards are being captured and addressed via specific hazard management strategies that consider both current storage and retrievals management requirements.

It has been accepted by stakeholders that an accelerated programme of risk reduction is essential, given the age of the structure and inevitable deterioration of the earlier blocks of compartments. In 2003, after extensive optioneering, an air-based strategy was confirmed as the reference design. To support this, three SEP machines have been constructed, designed for air-based retrieval, and, after considering the hazards and programme challenges of a strategy change back to a fully inerted process, it is considered appropriate to continue to develop an air based strategy, sufficiently robust to provide confidence that all foreseeable hazards can be managed, while removing the building inventory to an acceptable timescale. The constraints introduced by the building structure, with its legacy of 40 years of handling ILW, require weighing against the theoretical benefits of the options available. The practical difficulties of installing and operating a fully inerted system appropriate for waste retrieval have proven to be insurmountable within an acceptable time frame. It is inappropriate to consider the current inerting system as an indicator of the viability of such a scheme.

It is considered acceptable that there will be short term increases in risk inherent in the long term risk reduction strategy. Such increases will be appropriately justified and managed through such mechanisms as ALARP, BPM and BPEO

There remains a substantial amount of work, to provide the required levels of confidence that such a safety case can be delivered and it can be expected that a certain amount of confirmatory work will run over into the early phases of retrievals. The difficulty in providing a deterministic safety case has led to the development of a multi-legged safety argument, which will continue to be strengthened as further understanding is gained.

Key Outstanding issues

There are, at this stage of the project, areas of uncertainty that will be addressed as the project progresses and matures. These include:

- Understanding the potential risks of held-up volumes of hydrogen within the waste and vessels, voids etc.
- Understanding of the management of released volumes and ullage conditions to minimise the potential for an overpressure event. This includes elimination of ignition sources, modelling of released hydrogen, effects of enhanced and reconfigured ventilation schemes.
- Consequences of an overpressure event - loss of containment and impact on retrievals - and definition of the bounding case with comparison against the withstand ability of the silo compartments and ductwork.
- Optimisation of the configuration of ventilation systems for retrievals, liquor management and routing, and maintenance of cooling and level measurement capabilities during retrievals.

Recent progress
The redundant west end crane in the Magnox Swarf Storage Silos has been replaced, and the new crane is undergoing final commissioning. This is a necessary step to enable removal of redundant equipment from the building and the installation of the silo emptying machines. Substantial improvements have been made in respect of several aspects of the building infrastructure: Compartment 7 operating floor contamination has been removed allowing a significant mass of temporary shielding to be removed thus facilitating the installation of retrieval equipment, enhancement of ventilation systems, additional hydrogen monitoring and analysis has been carried out to underpin key factors for both continued storage and air based retrieval safety cases. The Liquor activity reduction Trial Phase 2 commenced with a further 50m3 of liquor transferred to SIXEP, this demonstrates the re-establishment of the liquor processing routes and enables the performance of the effluent treatment plant to be established for the types of liquors which will be generated during waste retrieval activities. Waste processing plants are being re-engineered to allow the solid wastes arising from silo emptying to be characterised prior to encapsulation.

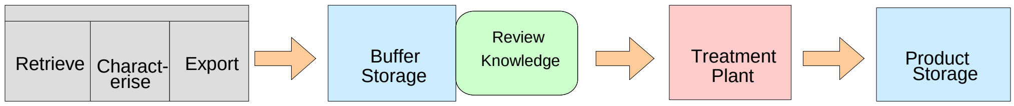
7 Pile Fuel Cladding Silo

The Pile fuel cladding silo contains historical miscellaneous ILW generated on the Windscale and Chapelcross sites between 1951 and 1964 with some sporadic tipping up to 1968. Tipping of waste into the silo stopped once the wet silos came on line. Since cessation of tipping, the silo has essentially been held under a care and maintenance regime with the concrete and steel structures continuing to provide containment and bulk shielding for the stored waste.

It has been recognised that this is not a sustainable situation due to the fact that the structure was not designed to modern standards for waste storage. This has led to an interim situation whereby there is a reliance on active engineered safety systems to maintain safety. There are legislative and strategic drivers that require the retrieval of waste from the silo and other facilities at Sellafield over the coming years and to convert it to a product form suitable for long term storage and ultimate disposal. The silo structure can then go through final POCO, de-commissioning and ultimately be dismantled.

The NII has issued a Specification (Ref.1) requiring that by August 2016 the ‘contents which have been accumulated as radioactive waste’ shall not be accumulated ‘except in a place and manner approved by the Executive’. British Nuclear Group interprets this requirement as the removal of 95% of the waste from the Silo by the given date and stored in a manner that uses passive safety features to maintain nuclear safety. The exact nature and current condition of the pile fuel cladding silo waste is not fully understood and will not be until some of it has been removed and investigated. Hence, there is no immediately identifiable single treatment process available to convert all the waste to a final disposable form. The project strategy therefore is to remove the waste and consign it to a buffer store whilst the information attained during removal is used to develop an appropriate treatment process or identify the correct route using existing plant/process (see Figure 1).

Figure 1 – Pile Fuel Cladding Silo: Waste Retrieval & Treatment Strategy



This approach provides timely hazard reduction whilst providing the flexibility to investigate the nature of the waste and hence identify whether;

- a new treatment plant is required or,
- the waste may can be treated via existing facilities or,
- a combination of both can be employed.

The advantages of the approach are as follows:

- Early risk reduction is achieved by removing the waste from the silo and storing it in a modern facility in small discrete units.
- The waste is transferred into packages which provide passive protection against waste fire (i.e. containment). The consequences of a fire event are therefore reduced significantly (limited to a single package).
- During retrievals, a degree of waste characterisation will reduce the uncertainty regarding the silo inventory and its current condition. If necessary, further waste conditioning could be carried out at a later stage.
- The information gained will be used during the design and development of the final product and process options. This will minimise the safety, environmental and technical risks associated with the product and process to meet the necessary storage and transfer criteria.
- Retrievals is decoupled from the waste treatment process so that removal of waste from the silo cannot be compromised by the downstream waste treatment plant (e.g. due to throughput issues). This improves confidence in the project’s ability to meet the 2016 completion date for emptying the majority of the bulk waste from the silo.

The ultimate aim is to develop an immobilised product suitable for disposal in a Nirex repository. A surface storage phase may be required for a period of time depending on the availability of the final repository, however the aim is for minimal rework before the waste packages are consigned to the facility.

Recent Progress
The silo is inerted under an argon blanket, with improvements made to reduce the vulnerability to seismic and other external hazards. Completion of plugging and sealing the charge hole openings in the silo roof has been carried out, along with the demolition of the 'tunnel' above the silo. An adjacent external shield wall has also been dismantled reducing the seismic risk. Retrieval plant design is currently underway for mechanical retrieval of the silo waste. Characterisation and container requirements for both buffer and final storage are currently being assessed. Work is ongoing to further underpin the inventory of materials stored in the facility, this may allow some of the pessimism to be reduced from the safety case and allow engineered systems for retrieval and transfer of wastes to be optimised.

8 Waste Matrix Development

There are a number of projects within the strategy at varying stages of maturity, each strongly focussed on the relevant License Instrument(s). Finalisation of viable product forms, acceptable to stakeholders and compatible with the resource and time constraints is a key continuing challenge. Each project within the strategy is on-track with the appraisal and evaluation of the options. Positive progress continues in these areas and there is significant agreement with NIREX and the Regulators on the way forward for the majority of waste forms, however, there are a number of technical issues and tensions between the stakeholders requiring resolution. Notable amongst these product issues is finding an acceptable solution for the reactive metals and fuel residues arising from the Ponds and Silos.

The product form challenges for silo wastes are compounded by the heterogeneous nature of the waste, with the constraint that the waste treatment processes must have the appropriate operability and throughput to achieve the specifications. Parameters currently being explored are segregation and characterisation requirements (for both silos) and the water content of the waste (for wet Magnox silo). The latter is important because it will largely determine the ongoing corrosion rate in the product and hence the confidence in the long term integrity of the product for disposal. There is increased acceptance that the need for early reduction of the present waste hazard is paramount and that the timeframe will be jeopardised if fully stable, disposable products are to be underpinned to the highest confidence levels. Thus, in order to deliver early hazard reduction, products may fall short of the ideal, with the attendant possibility that some remedial rework may be required prior to consignment to ultimate long term storage. Containerised buffer storage remains as a fall back position.

The cost and technical viability of recovering/treating residual metal fuel from the legacy ponds are aspects of an on-going issue, contributing to the assessment of whether fuel is categorised as waste or should be reprocessed. Both ponds projects are evaluating the range of options in order to arrive at fuel strategies with a time base consistent with the sludge retrieval programmes.

9 Funding issues

British Nuclear Group Sellafield Limited were asked by the NDA in late 2006 to consider what work might be performed at the Sellafield, Calder Hall, LLWR and Capenhurst sites to meet specific assumed funding levels, whilst at all times maintaining safety standards. NDA and Government have considered British Nuclear Group Sellafield Limited's submissions (along with all of the NDA owned Site's submissions) and have announced the Approved Site Funding Levels. These are broadly in line with those assumed by British Nuclear Group Sellafield Limited in constructing the 2007LTP. Whilst the Annual Sellafield Funding Level does represent a considerable challenge to the Site, it does present a reasonable basis to commence delivery of the 2007/08 planned activities. This will be reviewed throughout 2007/08 with the NDA.

10 Constraints

The above remediation and decommissioning projects represent very significant challenges in terms of size, complexity and degree of interaction.

British Nuclear Group Sellafield Ltd is committed to deliver these projects addressing the extremely challenging timescales set out in the three NII specifications. In order to achieve this, the following issues need to be considered:

Securing Continuity and Consistency of regulator approach

There is a need for a commitment to a well thought through and justified approach which continues throughout the project lifetime. This can be gained initially by early interaction with the regulator, and it is vital that through the development of the project that the regulators are kept adequately informed of changes in project strategy. It is fully recognised in decommissioning that there may be details which cannot be well characterised at the initial project phase. These need to be identified and mitigated as technical or project risks and these will be fully highlighted to the regulator. However, any potential significant changes in regulatory approach need to be signalled to the project so that their impact can be evaluated and their effect minimised. Equally, regulators need to commit to an approach such that options can be confidently closed with adequate justification, as opposed to keeping multiple options open incurring costs that can and have diverted resources.

Integrated regulatory approach throughout the project evolution

Each legacy project will comprise of many smaller interlinked projects which will require co-ordination of approach both within and between regulator bodies. Issues related to nuclear safety, conventional safety, environmental safety, nuclear safeguards and security will require co-ordination and the development of a mutually agreed and optimised approach within both the licensee and the regulators. Considerable effort has, and will continue to be expended, to enable the regulator to have an overview of the project, the integration of sub-projects and the views of other regulators.

Committed funding

The projects will require very large expenditure on resources and equipment, in order to deliver safe and reliable remediation, over many annual funding cycles. This will require integrated project costs to be evaluated to achieve the required end states. Much of the equipment costs will be expended in the early phases of the project to upgrade or install new items of plant to allow retrieval of bulk inventory. Much of the operational life of this plant will be shorter than conventional process plant, however in order to ensure reliable operation in duty and to cope with variability within waste streams, extensive commissioning will have to be carried out. In addition much of the equipment will be novel or bespoke, this may shift the expenditure profile forward when compared to that of traditional nuclear chemical plant.

Skills retention and development

Each project will require a significant team of engineering and technical resource to ensure successful development and delivery. These teams need to be assembled, retained and developed to ensure that the necessary skills can be delivered at the appropriate times. This will involve working with in house and supply chain resources. Skills and expertise will also need to be strengthened and maintained within the regulatory bodies. These requirements are set against a background of increased demand for a shrinking scientific and engineering skills base in the UK.

Clarity over waste matrix requirements

In order to develop waste retrieval strategies there needs to be clarity over the requirements for wastes which will be processed for interim storage or final disposal. Whilst there can be an inherent variability in the form of the materials be recovered, this can be reduced by extensive characterisation studies and any remaining variability can be accommodated as a technical risk within the retrieval and processing strategy. Uncertainty in waste matrix requirements or an over-riding need to achieve early hazard reduction progress could lead to wastes being stored in interim forms which are wastes are not optimal in terms of safety or future disposability e.g. in an ungrouted form, requiring further processing at some future date.

10 Conclusions

Legacy ponds and silos strategies have developed significantly, and key projects have been initiated. Good progress has been made in refurbishing existing equipment or installing new equipment to allow wastes to be safely and efficiently retrieved, characterised and processed. Work in the down stream waste plants is ongoing to ensure that feeds are consistent with waste matrix requirements and that suitable waste processing and storage facilities are available.

11 Recommendations

It is recommended that NuSAC note:

- The substantive progress that has been made in preparatory work for the decommissioning of Legacy Ponds and Silos

- That a pragmatic approach will be required to balance early Site risk reduction with the extent of waste form underpinning.

12 References

1. NII Licence Instrument 324, Letter to BNFL from W.W. Ascroft Hutton, Health & Safety Executive, 4th August 2000.
2. NII Licence Instrument 325, Letter to BNFL from W.W. Ascroft Hutton, Health & Safety Executive, 4th August 2000.
3. NII Licence Instrument 326, Letter to BNFL from W.W. Ascroft Hutton, Health & Safety Executive, 4th August 2000.