DECOMMISSIONING AND RECONSTRUCTION OF THE FAST REACTOR FUEL REPROCESSING PLANT, DOUNREAY

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Abstract

DECOMMISSIONING AND RECONSTRUCTION OF THE FAST REACTOR FUEL REPROCESSING PLANT, DOUNREAY.

The conversion of the Fast Reactor Irradiated Fuel Reprocessing Plant at Dounreay from its original function of servicing the Dounreay Experimental Fast Reactor (15 MW(e)) fuel cycle to that of reprocessing fuel from the Dounreay Prototype Fast Reactor (250 MW(e)) led to an extensive modification exercise. This necessitated entry into, decontamination, and rebuilding of the greater part of the plant; many areas were in effect decommissioned and then new facilities constructed on the same location. In cell plant conditions at the beginning of the exercise ranged down from radiation areas at above 1000 R/h gamma, and contamination levels 500 R/h beta-gamma and 1000 counts/s alpha. This exercise consequently proved to be the largest of its kind undertaken to date in the United Kingdom, and demonstrated the ability to decommission active plant facilities. It also generated much valuable experience and led to the demonstration of novel techniques in this field. The FR reprocessing plant was designed and built in the late '50s to reprocess the irradiated driver core fuel from the DFR reactor, and also to handle the breeder fuel elements prior to their transfer to the Windscale thermal reactor fuel reprocessing plant. It was decided in 1971/72 to modify the DFR reprocessing plants for the reprocessing of the PFR mixed oxide fuel. In order to achieve these modifications it was necessary to effect personnel entry into all sections of the active plant other than the DFR fuel disassembly cave and the DFR fuel dissolver cell. Several different types of cell were entered; namely – HA (beta-gamma) fuel breakdown caves, HA dissolver cells, and both HA and LA extraction cells. The conditions varied from total in cave or cell contamination to cells containing mainly internally contaminated vessels. The radiological hazards embraced variously high gamma radiation levels and high plutonium contamination levels. The extent of the work varied from complete cell strip out – and in some cases demolition – to limited relocation and addition of process equipment. The above features, taken together, determined the objective adopted, either: (i) conversion to a contamination-free working area, or (ii) acceptance of limited contamination and radiation levels and working in air line suits.

1. INTRODUCTION

The Dounreay NPDE has extensive facilities associated with both Fast Reactor and Materials Testing Reactor fuel cycles together with supporting fuel development and post-irradiation examination laboratories. These facilities are small in scale due to the high fissile content of the materials handled, but the overall throughput in terms of value or activity is equivalent to much larger thermal reactor fuel cycle plants.

The various buildings are grouped into one plant area and have been operating actively for nearly 20 years. Taken in conjunction with the DFR reactor, the site had all the essential features of an early version of a Nuclear Power Park.

Over the 20 years of operation of the facilities, the function of some of the plants and buildings has changed, as well as the operating methods, - in line with improved techniques, changes in throughput, and improvements to meet different operational and safety standards. This paper discusses the decommissioning of sections of the Fast Reactor Fuel Reprocessing Plant as a first step in its conversion from having an enriched uranium capability to one including uranium/plutonium mixed oxide reprocessing.

The Dounreay Fast Reactor Reprocessing Plant was designed and built in the late '50's in order to serve the Dounreay Experimental Fast Reactor (60 MW(th)). It embraced 'head end' irradiated fuel handling and breakdown facilities, dissolution equipment and solvent extraction systems. The enriched uranium (75% U_5) metallic core fuel was processed to a high purity uranyl nitrate solution for subsequent refabrication in the Billet Production Plant. The active liquor effluent was segregated at source, the Highly Active was routed direct to underground storage tanks, and the Low Active to delay tanks prior to sea discharge. The breeder/blanket natural uranium metal fuel was merely broken down for transfer as irradiated fuel to the Windscale plant; it not being considered appropriate to utilise the necessarily limited geometry plant on low concentration fissile materials.

The decision was made in 1971/72 to modify the DFR fuel reprocessing plant for the processing of PFR mixed oxide fuel. This decision was based mainly on the need to prove fuel performance aspects of plutonium recycle in power producing fast reactors and to demonstrate a full fuel cycle. It also recognised the value, in terms of operational experience and development information, of such an exercise in the design of fuel reprocessing plant for a larger scale system. It was recognised that the extent of the detailed modifications would be large. The prime factors dictating the scope of the modifications were, in addition to providing for an increase in throughput/capacity;

a. Improved containment, both primary vessel and cell;

b. Rearrangement of the solvent extraction equipment to accommodate the two macrosolute flowsheet;

c. Provision of new cave facilities for the far more complex PFR fuel assembly breakdown;

d. Provision of a new dissolver and feed liquor clarification equipment;

e. Increased 'head end' radiation shielding;

f. Increased liquor tankage to improve fissile material accountancy for both fuel cycle evaluation and to meet 'safeguards' requirements;

g. Improved ventilation arrangements;

h. The incorporation of operational improvements identified as being desirable over 15 years of operation.

2. THE PLANT

2.1 The DFR Reprocessing Plant Facilities

The DFR reprocessing plant was housed in a building 130 ft long by 85 ft wide by 40 ft high, divided essentially into two on its long E - W axis. The larger part (south) embraced the caves, cells, their service and sampling systems and the access area, this is termed the 'Active Area'. The smaller part included the instrument and control, and the inactive feed system area, defined as a 'Contamination Control Zone' and operated at clean area (white) activity levels. (Fig 1). The active caves and cells ranged in biological shielding thickness from 4 ft concrete down to 9 inch brick, and this area was traversed by 15 ton capacity over-head crane.

The plant was originally designed to process the enriched uranium alloy core fuel which was broken down in the Core Cave by mechanical stripping of the niobium cladding and charged as slugs to the dissolver.

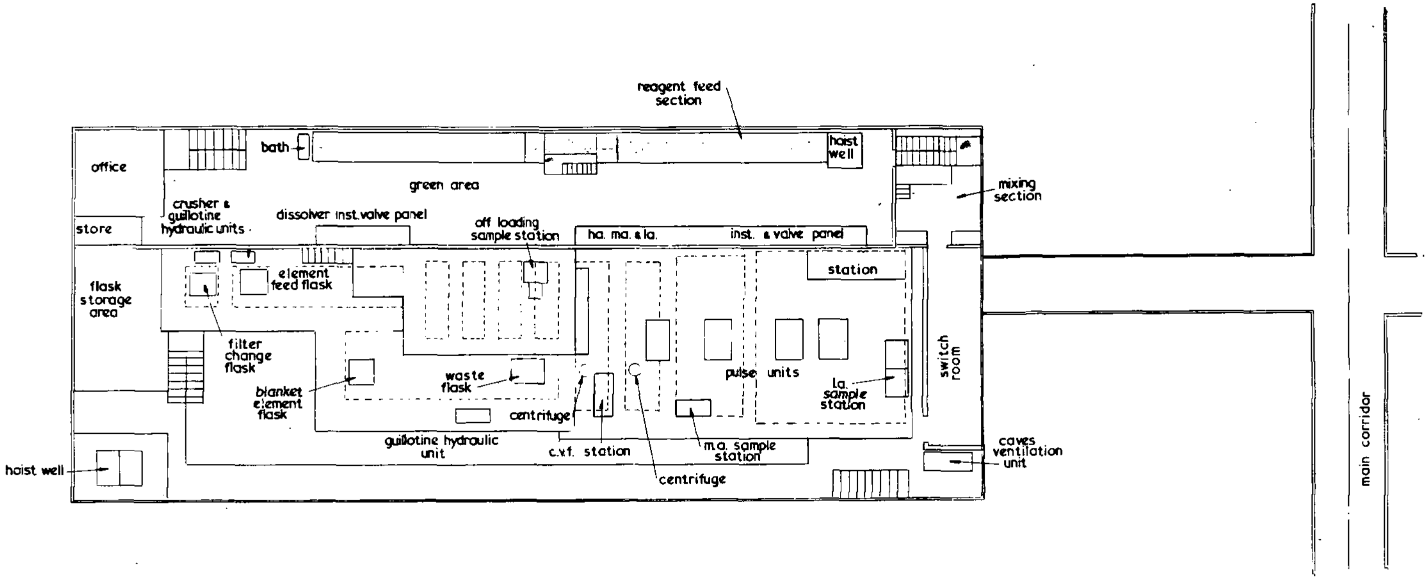


FIG.1. DFR irradiated fuel reprocessing plant (1960–1975).

The fuel slugs were dissolved in nitric acid and the liquor fed to a solvent extraction plant based on the Purex (TBP/OK) flow-sheet. The solvent extraction equipment consisted of mixer-settlers confined to a basic 4 inch geometry to avoid criticality.

The Head End plant was equipped with a 4 ft concrete shielded, zinc-bromide window, master slave manipulator cave communicating with four dissolver cells by way of a shielded tunnel. Only two of those cells (nos 3 and 4) were originally equipped with continuous dissolvers of stainless steel construction. The dissolved active feed liquor was then fed to one of two High Active extraction cells, the second being a fully equipped spare, and then to a Medium and finally a Low Active Cell. Three cycles of solvent extraction resulted in Fission Product Decontamination Factors of 10^7 to 10^8 being achieved, the first cycle contributing about 10^4 to 10^5. The Low Active Cell was equipped with a fourth plutonium separation and purification cycle, passing its product stream to an above cell evaporation and off-loading glove box system. The plutonium cycle has not been in regular use due to the low plutonium levels of the highly enriched core fuel. A separate cave was employed for the breeder fuel.

Plant liquor transfers were generally by gravity with remote 'air lift' and vacuum siphon systems to provide additional head at discrete points in the high active plant. The high active cells were completely sealed and inaccessible. The medium and low active cells included pumping arrangements, located either within the cells or in shielded 'bulge' local extensions. Personnel access was not necessary for routine operations but was required for maintenance, plant washdown, and occasional fault analysis and rectification.

The plant was extensively modified and improved over the years including first the installation of a titanium dissolver and a recirculating off-gas scrubbing system in the spare dissolver cells (DC1 & 2) and then a major change in the head end process wherein a chop/leach technique was adopted for fuel breakdown. This necessitated the replacement of the unused (DC 3) continuous dissolver by a leach dissolver fabricated from titanium and its coupling into the off-gas recirculating scrubber system. The plant was also modified to accept MTR active feed liquor transferred from the dissolution section of the neighbouring MTR reprocessing plant.

Over 10 tonne of enriched uranium DFR core fuel was processed through the plant with an associated fission product activity of about 10^8 Ci. Additionally over 22 t of breeder fuel

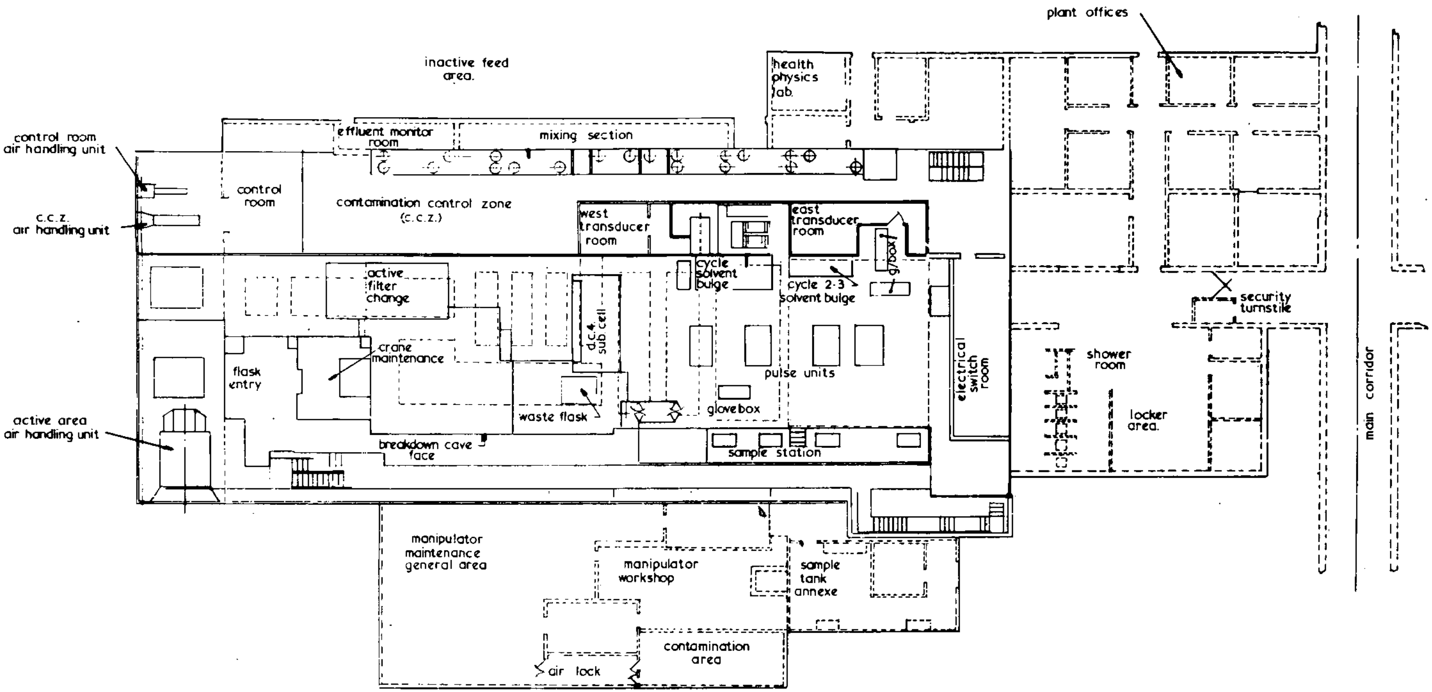
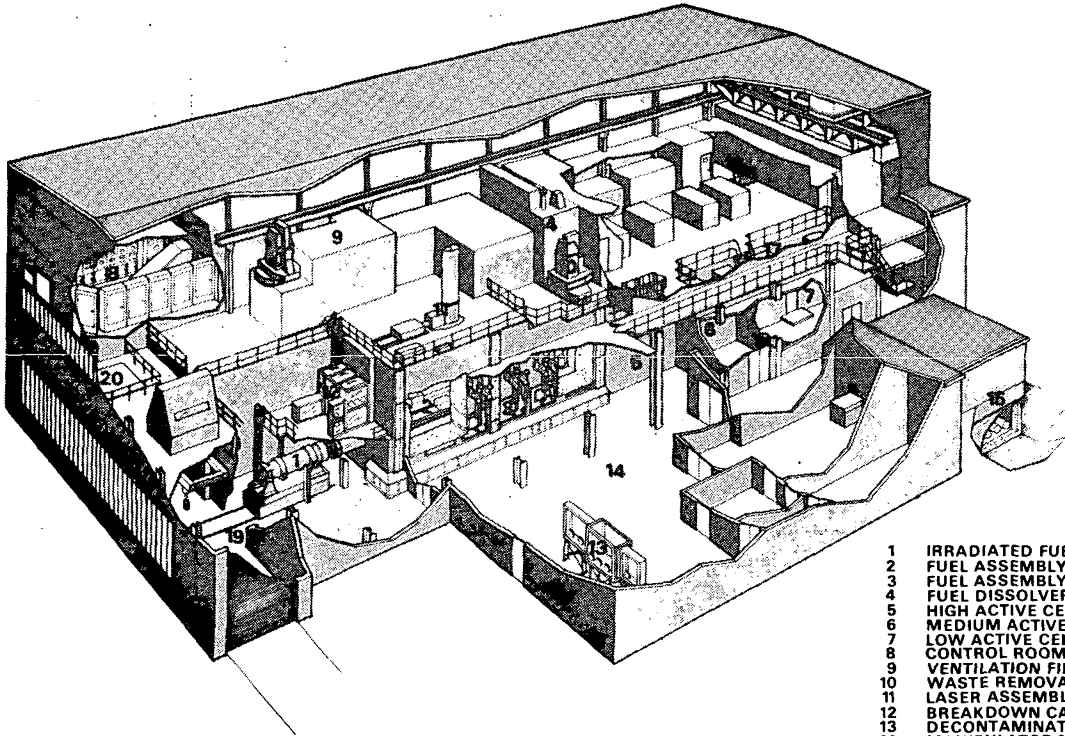


FIG.2. Fast reactor fuel reprocessing plant Dounreay.



1 IRRADIATED FUEL TRANSFER FLASK
2 FUEL ASSEMBLY BREAKDOWN CAVE
3 FUEL ASSEMBLY BREAKDOWN CAVE OPERATING FACE
4 FUEL DISSOLVER CELL
5 HIGH ACTIVE CELLS 1 & 2 SOLVENT EXTRACTION
6 MEDIUM ACTIVE CELL SOLVENT EXTRACTION
7 LOW ACTIVE CELL SOLVENT EXTRACTION
8 CONTROL ROOM
9 VENTILATION FILTER UNIT
10 WASTE REMOVAL FLASK
11 LASER ASSEMBLY
12 BREAKDOWN CAVE MAINTENANCE BOOTH
13 DECONTAMINATION BOXES
14 MANIPULATOR MAINTENANCE AREA
15 SAMPLE TANK ANNEXE
16 MIXER SETTLER PULSE UNITS
17 ANALYTICAL SAMPLE STATION
18 SOLVENT EXTRACTION CELLS ACCESS AREAS
19 VEHICLE ACCESS BAY
20 WASTE FLASK TRANSFER HATCH

FIG. 3. Fast reactor fuel reprocessing building.

was also stripped and the fuel transferred to Windscale. The solvent extraction section also reprocessed over ½t of enriched uranium from about 12 t of MTR fuel with an activity of about 10^7 Ci. In addition, special campaigns were conducted to recover plutonium from Pu enriched pins, and from irradiated experimental oxide fuels irradiated in DFR.

2.2 The Modified Plant

The requirements for the PFR mixed oxide reprocessing led essentially to an extension of the whole plant and individual extensions to facilities within the existing plant. It also led to additional equipment being installed, and existing equipment being rearranged, within some of the cells. It also led to some cells being either completely re-equipped or totally demolished in order for that site to accommodate a completely new facility.

The total modification work leading to the new plant (Figs 2,3) can be summarised as:

a. Fuel Receipt Bay. Increase the lifting capacity.

b. DFR Breeder Cave. Demolish, and construct the new PFR Irradiated Fuel Cave on its site.

c. Dissolver Cell 4. Gut the cell and demolish the upper section; equip with the new PFR dissolver, charge system, liquor clarification system, and tankage. Extend it to accommodate further first cycle tankage.

d. Dissolver Cell 1. Gut the cell; utilise it for the new active ventilation system including a shielded remote filter changing cell, and leave a section free for future equipment.

e. Dissolver Cell 2. Install improved recirculating scrubber pumping system and couple into new PFR dissolver.

f. Conveyor Tunnel. Gut and utilise for active ventilation ducting.

g. High Active Extraction Cell 1. Improve the solvent extraction system, carry out a detailed examination of the equipment (for corrosion), and piping modifications.

h. High Active Extraction Cell 2. As HAC 1.

i. Medium Active Extraction Cell. Improve and revise the layout of the extraction system, and install extra tankage and instrumentation.

j. Low Active Extraction Cell. Improve and revise the internal layout, install new instrumentation, change the solvent pumping system, remove the old low capacity plutonium cycle, install a new product transfer system (to the Evaporation and Storage plant), and extend to accommodate extra tankage.

k. Demolish the old ventilation and filtration system.

l. Isolate and remove the redundant plutonium glove box facilities.

m. Extensive out of cell work associated with the above.

To achieve the degree of modification it was necessary to 'enter' all sections of the plant other than the DFR Core Cave and the DFR Leach Dissolver cell (DC 3). Previous experience within the plant, and even more so in the MTR Reprocessing Plant, indicated that such a modification exercise would be practicable within an acceptable time-scale and personnel radiation exposure.

To minimise the DFR fuel cycle inventory, reprocessing was required during the modification exercise. The modification programme was consequently phased and interrupted twice for fairly extensive DFR reprocessing campaigns. These interruptions necessitated detailed equipment checks, preparation of modified safety documentation and recommissioning of the part modified plant before the campaigns commenced. They also necessitated further decontamination work before the modification programme could recommence.

3. THE DECOMMISSIONING EXERCISE

3.1 General Approach

The plant modifications were so extensive that they could only be realised by personnel access. The cave and cells were all contaminated to varying extents with both fission product and plutonium activity. The contaminants were widely distributed in areas such as the cave and conveyor tunnel, and were predominantly located within the primary vessel containment in some of the extraction cell situations (eg the Medium

Active Cell). These two situations were approached in different ways as explained below.

A further factor dictating the approach to decontamination was the degree of modifications or new installation required. Some areas were completely demolished and rebuilt (DFR blanket cave), or were completely gutted leaving only the cell fabric into which the new equipment was to be installed. In these situations the reconstruction was effected under clean area (negligible contamination/low radiation) conditions by personnel wearing normal DNE working clothing.

Other areas were subject to lower levels of strip-out, and the re-installation was effected under higher contamination levels and with varying radiation levels. This necessitated pressurised air line suit working and varying degrees of radiation exposure control.

The plutonium contaminated gloveboxes were partially decontaminated and then disposed of by techniques involving foam filling. They were then transferred to other facilities for breaking up and final treatment.

3.2 Dissolver and Extraction Cells

The active extraction cells had gamma radiation levels of about 100 R/h at 3 ft from the process vessels. Local beams existed at over 1000 R/h. The equipment and cell internals were also contaminated with plutonium alpha activity and fission product beta activity to produce swabs well in excess of 1000 cps*alpha and 100 mR/h beta-gamma.

The basic approach was to wash out the vessel and pipe work internals with nitric acid and steam (non salt bearing media) to buffer tankage in the HA liquor storage and evaporation plant. This was effected using installed wash down piping and by employing other suitable process or service pipe branches. This was continued over many days or weeks until the activity level in the effluent was reduced to a level that would not prejudice the statutory site sea disposal authorisation. More agressive washing media was then employed, including sulphuric acid, caustic, and nitric acid/sodium fluoride solutions.

The washing out was continued until remote radiation monitoring indicated that it was reasonable to open up access into the cell. More extensive remote radiation and contamination monitoring was then carried out. It was then usual

* cps = counts/s

practice to reduce the contamination levels by hosing down the cell and internal vessels with high pressure (10 000 lbf/in^2) water blasting equipment, this being done from the cell access doorway.

General cell radiation levels were then below the 1 to 20 R/h range and this permitted short term entries to establish radiation source areas. The exact sequences of operation followed from this point depended upon the detailed situation and were varied as the work progressed. Generally, if the radiation were emanating from a redundant vessel or line it was locally shielded and then cut out and removed from the cell and disposed of as waste. If it arose from a section of plant scheduled to continue in use, it was either subject to further washing - by making special provisions - or was shielded, removed, and then cleaned to low levels in the Decontamination Centre.

3.3 Cave Facilities

The situation within the cave type facilities was quite different in that the bulk of the activity was not confined to primary vessel containment. There was consequently no comprehensive built in liquor washing system.

Initial radiation levels within the cave and conveyor tunnel were again high, in excess of 100 R/h gamma (500 R/h beta-gamma) in some areas. The bulk of this radiation was emanating from contamination distributed amongst the operating equipment, that contamination also contained significant plutonium alpha activity.

The approach to this type of situation was to clear up, sweep up and swab all accessible surfaces using remote handling equipment - the manipulators in the case of the cave. The waste arisings were then flasked out to the HA waste stores. Following this, remote access was improved, in the case of the cave by high pressure hosing the man entry facility.

The equipment and bench work was then cut out using electric arc cutting employing the manipulators. Following the removal of the higher radiation source areas limited man entry became possible to assist in the gutting and removal. Following this stage a dramatic reduction of the contamination and radiation levels was achieved by high pressure water jetting, initially done remotely but later by hand-held guns. Gutting and decontamination was continued, and wall embedded sources shielded.

Removal of the structural concrete shielding then followed where necessary. This was most frequently done by diamond drilling 4 inch stitch holes or by pneumatic drilling, and then breaking out large sections by hydraulic jack wedging and/or pneumatic drilling. In the case of the cave the demolition was so extensive that a specialist contractor was called in to employ thermal lancing techniques. These last operations sorely taxed the containment, ventilation and personnel protection arrangements but were completed safely in a fraction of the time that otherwise would have been necessary, and at a fraction of the radiation exposure.

3.4 Results

Following the decontamination and decommissioning the fully stripped out areas were reduced to accessible contamination levels below '5 cps' and radiation levels below 10 mR/h. Care was required to ensure that the defined inaccessible areas remained protected.

The active cell areas were reduced to contamination levels generally below 1000 cps and radiation levels generally below 50, occasionally 100, mR/h. Higher localised areas existed in some of the cells and careful control was required to ensure that they kept inaccessible.

The above levels were dictated by the fact that the plant areas were to be re-instated as active facilities. It is noted that while that led, in most cases, to something just short of complete decommissioning - such would have been easier. This is because most of the features that gave the more significant problems towards the end of the exercise, and which could have been removed, were required to be left installed or in place as part of the new plant.

A selection of special features of the exercise are now discussed below.

3.5 Ventilation

As entry was being made into previously inaccessible low ventilation, highly contaminated areas of the plant, special procedures were necessary.

The provision of local containment was recognised as the best starting point in that any activity releases would be confined to a small volume and there would also be reduced ventilation demands. All cell access entry areas and working areas in highly contaminated areas were consequently equipped with local containment constructed of timber and hardboard, plaster-board or corrugated iron; all suitably treated to facilitate later decontamination. Some additional internal plastic curtaining was employed to localise potential release. Frame supported PVC tents were only employed in the lower activity areas, eg the digging out of contaminated floor concrete.

As it was not practicable to increase the total ventilation extract from the plant, it was decided to fit axial booster fans to four of the six 'space' extract louvres and to run 18 and 24 inch flexible ducts from their inlets to the containment areas being worked in if they could not adequately be ventilated by the local cell extract.

Very soon after the start of the exercise the use of respirators for routine respiratory protection in the highly contaminated areas was abandoned, the air line fed pressurised PVC suit provided a far improved working environment. Respirators were then restricted to those operators supporting the air line workers, and as a general issue protection at times when the release risk was considered to be higher than usual.

With these precautions there have been no cases over the five years of any person inhaling significant activity, either beta-gamma or alpha. There have been a few cases of releases in excess of 10 MPC·h over a shift recorded on the static monitors but these did not lead to personnel exposure. A problem area has been the relatively low sensitivity of the alpha-in-air alarm instrumentation and the slow response in discriminating between plutonium alpha activity and the less toxic radon/thoron. This has been aggravated not only by the High Radon accumulations in the Caithness air under certain weather conditions, but also by the employment of 'by-product' gypsum in some of the earlier re-plastering work. This problem is now being overcome with the development of reliable discriminating instrumentation.

TABLE I

PERSONNEL DOSE RECORDS

Year	1972	1973	1974	1975	1976
Man·years	77	69	82	88	97
Rems	290	222	186	133	83
Average	3.77	3.22	2.27	1.51	0.86

TABLE II

WASTE GENERATION 1972-1976 (excluding waste arisings from reprocessing campaigns)

Year	Volume ... m^3 (as generated)								
	High Active Silo Disposal			Low Active Waste Disposal			High "Alpha" Waste		
	Plant & Equipment	Rubble	Process Arisings	Plant & Equipment	Rubble	Process Arisings	Plant & Equipment	Process Arisings	
1972	1.0	0.1	0.4	) 70	150	150	0.1	0.1	DFR Reprocessing
1973	0.35	nil	0.5	)					
1974	0.2	0.1	0.5	41	53	115	0.1	3.0	DFR Reprocessing
1975	0.2	nil	0.2	32	32	35	1.5	0.3	
1976	0.75	0.3	1.9	62	110	60		1.0	
Sub Total	2.5	0.5	3.5	205	345	360	1.7	5.3	
Total		6.5			910			7.0	
Occupied Volume in Waste Facility	2.5	0.5	2.5	150	300	200	1.7	4.4	
		5.5			650			6.1	

3.6 Radiation Exposure

The control of radiation exposure has been very dependent upon area surveying and up-to-date information on personal exposure records. Increased emphasis has been placed on radiation exposure during the 5 year interval of the exercise. It is over this period that very positive steps have been taken to reduce the personal exposures down from 5 rem per year. In spite of some early doubts this plant modification programme has not prejudiced this scheme.

Area radiation monitoring has been good and, with one exception, totally effective in terms of the objectives. In only one case has a major radiation source not been detected other than by a personal radiation instrument (an excessive dose did not result). In that particular case (DC 4) it was a very narrow beam and it was most likely that it was not revealed until the workman made it accessible consequent upon his stripping out of equipment.

Exposure records have been kept up to date - effectively to the hour - by running a cumulative total of film badge recorded dose with the addition of subsequent exposures assessed by Quartz Fibre Electrometer dose readings. Safety is built into this system due to the leakage characteristics of the QFE's. This has required a high level of personal discipline in recording QFE doses, and a high degree of updating and revising following the issue of each set of fortnightly film results.

Recognised higher exposure risk jobs are covered more comprehensively with special procedures involving the wearing of cumulative dose warning instrumentation and periodic withdrawal from the jobs for dose checking. Such air-line suit working situations have demonstrated the need for improved cummunications, and such have progressively been introduced.

Radiation exposure records are presented in Table I. These cover all those workers involved in decontamination, decommissioning, operations and the installation work. Significant total dose reductions would in fact be expected if the exercise had been confined only to decommissioning.

The progressive decline reflects the fact that the decontamination exercise was effective. It is of note that the last major reprocessing run carried out in the winter of 1974/75 had far lower exposure per unit throughput than previous runs, and the extent of that in itself more than justified the decontamination exposures up to that date.

3.7. Waste Arisings

The waste generated in the exercise was far greater than would be associated with a decontamination exercise and partial decommissioning. This reflects the fact that much of the protective and operational materials (eg swabs, plastic sheeting, disposal jigs) were associated with the re-installation phase of the programme, and that the two active reprocessing campaigns resulted in extra waste arisings.

The solid waste arisings are presented in Table II. The volumes referred to are those recorded as the material left the plant. The 'consolidated' figures refer to the waste storage capacity occupied, the reduction arising from 'self compaction' due to the collapsing of bags etc containing appreciable voidage. The total activity of the High Active (HA) Waste has been estimated as 3 600 Ci, and that of the Low Active (LA) as 40 Ci.

The HA waste is broadly that with over 750 mR/h radiation levels, or if also 'alpha active' that over 75 mR/h; it is subject to retrievable silo storage. The low active waste embraces all other materials with lower radiation and with no significant transuranic content; it is subject to contained 'waste pit' ground burial. The high alpha waste is that with significant transuranic content, of low gamma radiation; it has in the past, and over this exercise, been transferred to AERE Harwell for treatment and/or sea disposal.

The two prime objectives over the exercise were to minimise the alpha content of the HA (beta-gamma) waste and the quantity of liquid waste requiring interim storage. These were achieved by minimising cross contamination and by aqueous media decontamination. A third objective was to minimise the volume of waste requiring silo storage, again achieved in the same way.

Reference to Table II indicates that a high degree of success was realised in this. For instance the vast amount of rubble generated in the demolition of the unlined blanket cave was practically all disposed of as LA waste, in spite of the high gamma and alpha activity levels originally present in the cave. In that case the beta/gamma: alpha ratio was such that by the time the walls had been washed free of penetrating radiation source material sufficient for the required access, the alpha activity was negligible.

The volumes of liquid effluent were very high at times, primarily during high pressure hosing and over protracted vessel wash out exercises. The techniques adopted were designed to minimise volumes forwarded for HAL storage (with or without evaporation) and only to move to the large wash volume regime once it became possible to divert to the Low Active Drain. The liquor diverted to HA storage contained about 2000 Ci of Fission Product beta activity, and that discharged to the LA drain for direct sea disposal contained about 5000 Ci 'beta' and 10 Ci 'alpha'. The controlling isotope on sea discharge was the ^{90}Sr, 200 Ci of this was discharged over the 5 years.

The exercise produced a steady fissile material book 'gain' of a few grams per quarter due to the waste assay procedure and techniques. A real gain of 2½ kg 75% U_5 uranium was, however, realised. This was material that had in the past been consigned to an inaccessible plant area (the cave-dissolver Conveyor Tunnel) and had not previously been readily recoverable.

3.8. Resources

The number of people involved in the exercise has fluctuated over the 5 years. The extent of their involvement in decontamination/decommissioning has varied considerably, effort also being devoted to operations, the modifications themselves, the preparations for the 'new plant' operations, and training. Comprehensive records are, however, available and a detailed analysis has been started to break down the effort, and radiation usage, between the main plant areas. It should be noted that it was decided not to reduce individual dose exposures merely by dilution or sharing amongst an expanded decommissioning team.

4. DISCUSSION

4.1 Summary

The major decommissioning part of the exercise took four years but some decontamination work is still proceeding to accommodate final installation work. The exercise has not been continuous having been interrupted by reprocessing, campaigns, and delayed by being phased in with the concurrent modification work. The work involved was more demanding than a pure decommissioning exercise. It is noted, however, that the extra demands resulted in the waste being disposed of to lower category facilities than might otherwise have been the case.

4.2 Observations

Many aspects of the exercise deserve particular mention, apart from those generally discussed above. Some of the points were anticipated and were re-inforced by the experience, others evolved as the work proceeded. These are discussed briefly below:

a. Manpower. It was demonstrated many times that it was best to employ personnel who normally work in the plant rather than staff from other areas, except where special skills are called for. This undoubtedly reduces the total dose commitment and leads to less self-created problems, it also reduces the time taken in training and briefing.

b. Planning. The work is undoubtedly best organised by those with a good and detailed knowledge of the plant. The organisers should also have some familiarity with the history of the plant and also unrestricted access to detailed historical information. The availability of comprehensive plant layout, and vessel detail drawings makes the planning arrangements more appropriate to the task, supporting photographic records are of immense value here. Undoubtedly the greatest asset is a scale model of the facility, indeed if none are available it may be considered worthwhile to construct them from plant drawings, checking them against plant knowledge and updating on the basis of observation during the exercise. In some circumstances it would be worthwhile having two models of a facility, one to retain as the starting point record, and one to demolish in line with the progress. Reliable progress recording is essential if wasted effort in high radiation areas is to be avoided, this must include the detail of work undertaken and also the radiation/contamination survey and liquor activity results.

c. Design. Active plants should be designed with eventual decommissioning in mind. Access is normally provided, even in highly active facilities, in order to assist in the plant preparation and pre-operational commissioning. That is not, however, necessarily appropriate to a gamma active situation. Some of the design features to incorporate include: the elimination of mild-steel supports and ladders; the provision of built-in wash lines into the active vessel system - particlar attention being given to lutes and liquor traps; the extensive use of stainless steel cladding; the continuity of the primary vessel containment system; the provision of a ventilation system that can accommodate the eventual opening of a 'sealed cell'; and a spacious plant layout - particularly in cell piping - to aid movement in cumbersome protective clothing and to make 'distance' a viable radiation exposure counter-measure.

d. Techniques. The available waste services or disposal arrangements very much dictate the techniques employed. In terms of this exercise the preferred activity removal system was an aqueous medium leading to long term liquor storage or sea disposal. Thermic lancing proved valuable for removal of massive shielding and even remote separation of active vessels; but it does require extensive decontamination first, and then the provision of adequate filtered ventilation systems. Diamond drilling is extremely noisy but once set up needs little close attention; it does however give rise to large amounts of slurry - and together with pneumatic drilling - gives rise to extreme dust levels. High pressure water jetting proved to be one of the most valuable techniques, first introduced into this exercise in 1972; subject to there being adequate liquor collection and disposal arrangements the technique is self cleaning and does not generate an aerosol or airborne release problem. Hacksawing of process piping was resorted to in that it required little skilled knowledge, but electric arc cutting was used extensively where fairly widespread surgery was being undertaken; hydraulic crimping and separation was also introduced to advantage in some circumstances. It was always necessary to consider whether a cut line should be left open or be sealed; a common sealing technique was to fit an expoxy resin filled cap.

e. Personnel Protection. It was necessary to protect the operatives not only against radiological hazards, it was also necessary to ensure that the protection itself did not militate against good working conditions. It was found generally better to equip personnel with air line fed suits rather than rely on respirators, this was mainly to provide better working conditions. The use of intercommunication systems proved beneficial, not only for safety reasons, but also for in-cell inspections and on site planning; the coupling in of tape recorders also proved of some value. It was confirmed that the use of leaded clothing - mainly gloves - required careful considerations as its use often extended job times making the saving in extremity dose of little value set against the increase in whole-body exposure.

f. One last point to note is the condition that the cell is left in, either between a series of entries, or after the plant construction, or after an earlier modification exercise. In all such instances ad-hoc shielding can become a serious activity trap, which due to its weight gives great trouble in either decontamination or removal for disposal. A general principle is one of very high standards of 'house-keeping' with deviations being only by intent.

4.3 Conclusions

The exercise demonstrated the value of installed wash lines, or branches that could conveniently be utilised as such;

it also demonstrated the value of vessel and cell sump emptying facilities. The advantages of stainless steel lining, and impervious surfaces for concrete structures were both noted. The value of man entry facilities into High Active Plant areas was also noted, even where these were not used operationally.

The need for adequate local containment and extra ventilation was appreciated at the outset, and was re-inforced as the exercise proceeded.

Adequate control and personnel radiation exposure was demonstrated, as was the need for special communications systems for in cell pressurised suit working situations. This involved TV coverage and special umbilical line microphone links; designed for a special communications net including the monitoring of audible radiation dose instruments.

The value of thermic lancing was demonstrated, and the associated hazards were identified. It is concluded that this is a valuable technique if employed in conjunction with more conventional methods.

The exercise demonstrated that it is practicable to decommission and demolish a plutonium contaminated gamma active facility. Although this exercise was not intended to revert the area back to a green field site, it was complicated by the necessarily selective approach. Much of the 700 m^3 of solid waste arose due to the modification work, but even so the much larger part of it consisted of the plant structure. The liquid waste requiring storage was minimal and is commensurate with a complete decommissioning exercise.

Acknowledgements

The contribution of all those involved in this exercise is recognised. The personal commitment and individual application has been noted, and without that the job would have been far less effectively carried out.

DISCUSSION

M. RODRIGUEZ PARRA: What, roughly, is the proportion of equipment that may be re-used in a new facility?

T.R. BARRETT: Apart from the cave, which was completely gutted and demolished, about 20% of the 'vessels' belonging to the chemical plant equipment were discarded. That leaves 80% which were retained, and to these we have added about the same amount again.

M. RODRIGUEZ PARRA: What sort of equipment was considered fit for re-use?

T.R. BARRETT: The equipment being re-used consists mainly of the solvent extraction mixer-settler boxes and liquor tankage. Some of the more highly active mixer-settlers were removed and modified and then refitted, either in the same location or in a new section of the plant system. About 25% of the process piping was removed because of its high radiation levels, because it was redundant, because its routing was no longer appropriate, or in order to improve access.

M. RODRIGUEZ PARRA: How much time elapses between the beginning of decommissioning and the time when new equipment can be installed?

T.R. BARRETT: The time lapse before re-installation depends very much on the area of the plant being considered. Typically it could be three to six months for a HA cell (dissolver and first cycle extraction) after it had been sealed and in use for many years, and as little as two to three weeks for a LA cell (low $\beta\gamma$ but high α). As a result of the initial effectiveness of decontamination it was generally possible to re-enter and continue installation in the HA cells after the intermediate reprocessing campaigns within one month.

H. RABOLD: You mentioned the use of various acids for the decontamination of equipment. Could you comment on the decontamination effect that can be achieved with the different solutions?

T.R. BARRETT: We have used various decontaminating solutions at Dounreay in the past, including citric acid, peroxide, permanganate, oxalic acid and so on. Our experience has been that these act too slowly to give the DF we require. We were prepared to use salt-containing solutions only when the radioactivity in the waste stream was relatively low. As we were working to a tight schedule – governed by the final date of completion and the intermediate campaigns – we decided to use cold nitric acid/sodium fluoride solutions in view of their high decontamination rate. We have examined the interiors of vessels decontaminated in this way and have seen no damage.

H.U. FREUND: Have you considered or tested other means of breaking concrete besides those you mentioned? More specifically, have you tried methods involving explosive blasting of bulk concrete?

T.R. BARRETT: We have used concrete surface removal equipment ('scrabblers') in other plant areas, but we did not choose that process here, either because we wished to avoid iron contamination, or needed to remove massive sections of concrete, or both. We decided not to use explosives within the plant because we felt that we would have difficulty in justifying their use in view of the safety problems that might arise: for one thing, neighbouring areas of the same plant were remaining highly active and untouched. Explosives were used, however, in other areas and facilities that were being modified as part of the same overall project – for instance the HA solid waste store.