

A MODULAR STORE FOR DRUMS OF RADIOACTIVE WASTE

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ABSTRACT

Currently, the United Kingdom has no facility for the disposal of any waste above the low level category, indicating that all intermediate and high level waste, apart from spent fuel, has to be stored on the site of origin. To meet this storage requirement, nuclear sites are resorting to converting existing buildings or contemplating the construction of dedicated facilities, resulting in considerable cost implications. These financing aspects not only concern the construction strategy but also impinge on the ultimate decommissioning costs associated with each particular nuclear site.

This paper reports on an investigation to apply the commercially available interlocking hollow block system to the design of a store for drums of radioactive waste. This block system can be quickly, and cost effectively, erected and filled with a choice of dense material. Later, the store can be dismantled with a minimum of disposable radioactive waste and the complete facility re-erected at another location if required, considerably reducing both capital construction and decommissioning costs.

The investigation also encompassed a detailed review of the equipment required to place the drums of waste into the store, resulting in a scheme for a remotely operated vehicle that did not rely on umbilical control cables. The drum handler design included for 100% redundancy of all functions, meaning that whichever component failed, the handler was always recoverable to effect the necessary repair.

The ultimate aim of the waste drum store review was to produce a facility that was as safe as a conventionally constructed unit, but at a lower overall building and decommissioning cost.

INTRODUCTION

A modular Waste Drum Store is presented herein. The design was developed to address the increasing problem in the United Kingdom for the need to store intermediate level waste (ILW) on the site of origin, because of a lack of a national disposal facility. Due to spiraling costs of conventional on-site construction techniques, which are labor intensive, it was necessary to seek a new form of construction that entailed lower material and labor costs. To achieve that aim, a recently developed modular, hollow block system was considered for review in this Waste Drum Store concept. In addition, a special, low cost Drum Handler was also investigated, to ensure a safe and fully recoverable emplacement operation was completely feasible.

STORE SPECIFICATION

Prior to commencing the investigation, the authors produced a specification for the Drum Store and Handler, based on their knowledge of the UK nuclear sites and probable operational requirements. The main points of the specification were:

- Store to contain a nominal 100 drums of encapsulated waste, each drum having a capacity of 500 liters
- Activity of drums sufficient to warrant the equivalent of 300 mm of concrete shielding
- Drum size to be 800 mm diameter and 1200 mm high (See Fig 1)
- Each drum to have a weight of 1,500 kgs.
- Store to be constructed within an existing building and have a smooth concrete floor
- Design life of Store to be a minimum of 5 years
- Store construction to be such that it can be dismantled and re-used elsewhere

- Labyrinth entry (to avoid the use of moving shielded doors)
- Drums to be delivered singly with appropriate documentation
- Drum Handler to have 100% redundancy of all components
- Drum Handler to be operated by radio control from a remotely positioned control panel
- Operations within Store to be viewed by CCTV systems



Figure 1 - Standard Nirex Waste Drum

STORE DESIGN

This investigation commenced with a review of a recently developed interlocking hollow block system (1,2) and commercially available to special order. The advantages of this block system are numerous, e.g. each is light enough to be installed by two persons and once installed, they can be filled with a choice of dense material such as water, sand, lead or iron shot. The blocks can also be filled with cement grout although, obviously, such fill material cannot be recovered in the event the facility needs to be moved elsewhere. Each block is manufactured in polyethylene which is resistant to radiation (3) and ultra violet light, and they are designed with interlocking male & female edges to reduce radiation streaming (shine path) at the joints. They are available in a variety of sizes, the most popular being the Full and Corner Blocks and a Half-Length Block. An illustration of the Full and Corner Block is shown in Figure 2

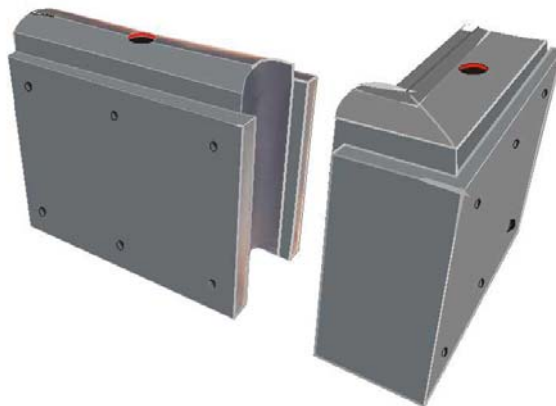


Figure 2 - Interlocking Wall and Corner Blocks

This interlocking block system has been subject to a series of development tests to establish both its structural stability and efficiency of the block joints in the context of radiation resistance. (4,5) The stability tests indicated that an empty block could withstand a vertical load of 25 tonnes, that is 5 times the design load, without the block failing structurally. There was considerable distortion of the block but a majority of the original dimensions were retrieved on removal of the load. The 5 tonnes design load represented a stack of 8 blocks (6 meters high) filled with concrete but with the bottom block empty. The radiation testing used a Co^{60} source aimed at both the centre of a block surface and at the joint between two blocks. The shielding efficiency of the joints was found to be excellent.

Having viewed the above test results and determined that this interlocking block system had potential to meet the requirements of a Drum Store, the next investigation undertaken was to inspect the physical dimensions of the blocks and how they might be employed on this project. An interesting feature of the block system is that they have been designed around a format of 1000mm long x 750 mm high x 500 mm thick, that being the overall size of the Full Wall Block, the basis of the system, (on which the structural and radiation tests were done). The 500 mm thickness remains a constant dimension throughout the system, the variables being length and height. The producers of the interlocking block system have envisaged that the greatest demand will be for Full Wall, Full Corner and Half-Length Wall Blocks although others can be produced if the demand is sufficient. In the three examples provided, the height of all three blocks would be the same at 750 mm. As this system is produced by a hot rotational moulding process, there are no construction joins and the dimensional repeatability of the finished product is assured.

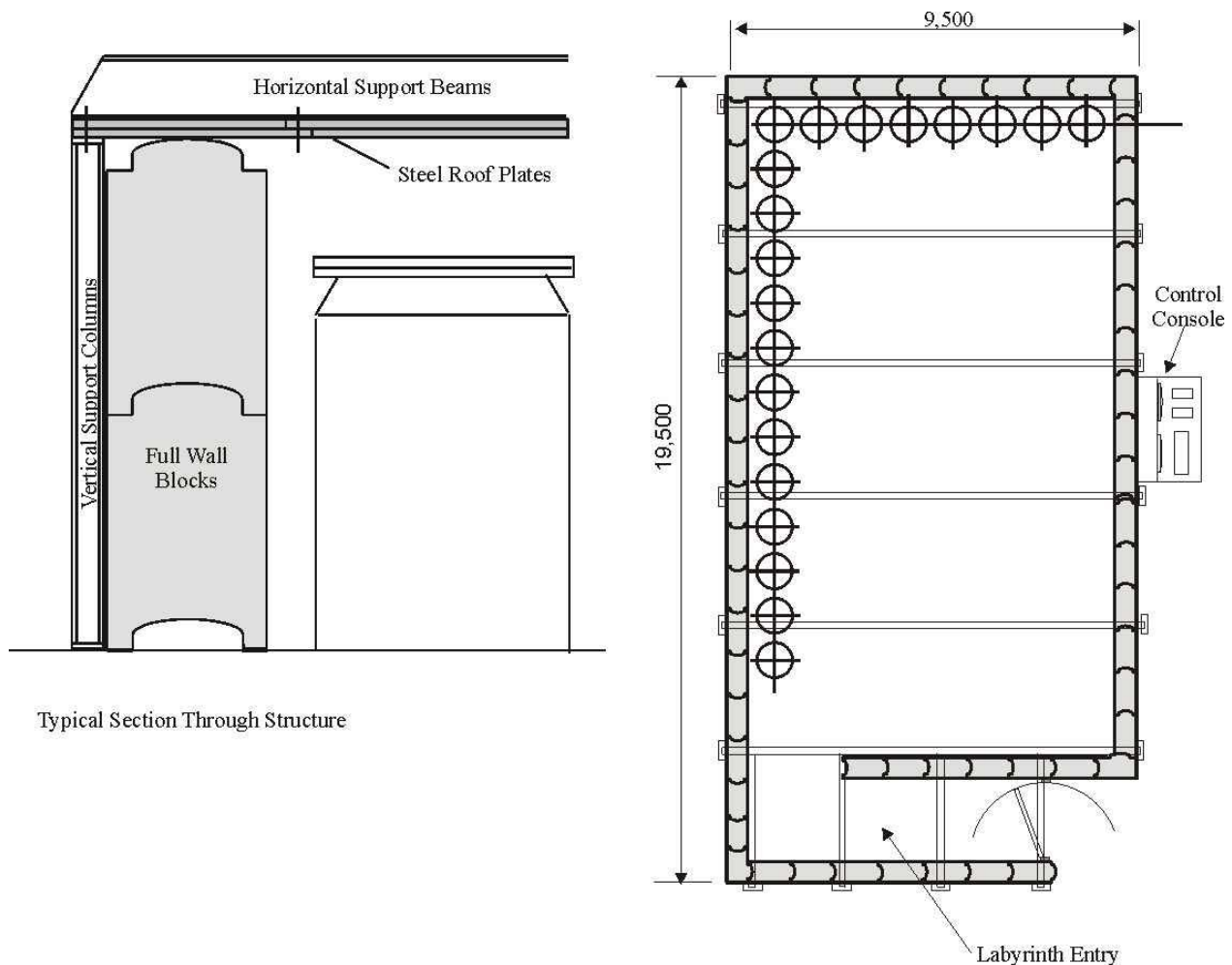
At this stage in the investigation, it became necessary to look at the detail of the walls and roof structures of the Drum Store. It was obvious that to contemplate using the block system for the Store Roof would require a substantial support structure at an extra cost which would off-set the advantage of using the system for the walls. It was decided, therefore, that the roof should be designed as a steel plate structure supported by intermittent cross beams, these beams would rest on vertical columns fixed to the ground, outside the block walls. Such an arrangement would ensure that no roof loads would have to be sustained by the blocks. The configuration of external cross beams and vertical columns meant that the internal space of the Drum Store was free of any obstructions, an ideal situation for a facility employing a radio controlled vehicle to handle the drums.

The next investigation involved a review of the competitive methods of construction, i.e. concrete block, poured concrete structure, steel plate and hollow interlocking plastic block. This investigation included material and building costs, speed of construction and, therefore, dose uptake, contamination factors, decommissioning, and disposal costs. It was assumed that all forms would require the same steel plate roof. The least expensive material costs were found in the concrete block wall, although very labor intensive and, therefore, the highest dose commitment. The highest material costs were associated with the steel plate wall, which also demanded many labor hours to install. The poured concrete wall, where it is required to construct formwork and employ reinforcing was also expensive in labor and dose commitment. The interlocking block wall was less expensive than the steel wall but competitive with the poured concrete material costs, although the on-site labor costs were significantly lower. Taking decommissioning into account, it was assumed that both the interlocking block system and the steel plate wall could be protected with a sprayed on coating and that on removal of the coating, the revealed surfaces would be easily decontaminated if required. Both steel and interlocking blocks could, therefore, be considered for re-use, spreading the costs over a number of applications. The porous concrete, however, even if protected with a strippable coating, must be classed as disposable radioactive waste after the removal of the coating. The decommissioning of the concrete block or poured walls was a labor intensive, dust producing operation generating much radioactively contaminated waste for disposal. In summary, the interlocking block system appeared to have distinct advantages over the other forms of construction, including cleanliness, low labor hours and therefore low dose uptake times, very low waste for disposal, ease of decommissioning and an ability to be employed elsewhere after minimal decontamination.

As a result of these deliberations, a sketch was prepared of the Drum Store structure (See Figure 3) where it can be seen that a two block high arrangement is sufficient to enclose the 1200 mm high drum. This would still leave a working clearance, providing the support beams are mounted externally as discussed above. The Half-Length Wall Block is an essential feature of the design, inasmuch as it permits the second row of blocks to be offset horizontally from the first row, providing a more stable structure. The holes provided in the blocks have a dual purpose. The first is to allow them to receive lifting eyes for raising the blocks into a high location, and second, they can be used in conjunction with set screws and standard fixing brackets, or any other support structure, to provide a stable locating facility for the assembly. The fixing brackets are designed to fix block to block, block to floor, and block to vertical support structure.

Shielding calculations indicated that the 500 mm thick blocks filled with dry sand would provide the equivalent of the 300 mm of concrete specified, based upon the direct comparison of the density of the two materials. The developers of this interlocking block system advocate employing kiln dried sand as it flows more easily when filling and emptying the blocks using a vacuum transfer system. They also recommend installing the blocks empty and filling in-situ. The Full Wall & Corner Blocks weigh some 33 kg. empty permitting 2 persons to lift each block comfortably, particularly where only two rows high are required. . In preparing the roof shielding calculations the authors decided that a slight relaxation on the required thickness was permissible as the radiation 'shine' would be directly upwards where no personnel or public would be endangered. These calculations showed that a steel plate roof of 60 mm would suffice and for ease of construction, the roof was formed of two 30 mm plates with steps in the vertical joins. The entrance to the Drum Store is via a labyrinth door of suitable width to accommodate the Drum Handler described later in this review. The free space at the entrance end of the stored drums has been provided to allow the Drum Handler to position the last drums into the Store and to be able to exit with ease. The labyrinth door will be provided with an automatically opening door, interlocked with the Drum Handler so that the door is only opened when the Handler is approaching. It will not be able to be opened by the operating personnel.

No dedicated ventilation has been provided in the Store as it has been assumed that it will already be installed within an existing building with adequate flow to ventilate the Store. The resultant Drum Store design, which is shown in outline form in Figure 3, is some 19.5 metres long by 9.5 metres wide and 1.8 metres high containing 104 drums at approximately 1 metre pitch. The design utilizes 123 Full, 8 Full Corner and 10 Half-Length Blocks in its construction as well as numerous fixing plates.



One area of concern arising from the proposed use of the interlocking block system was that of the floor condition. Any alignment errors caused by a bad surface will be magnified after a number of blocks have been installed, particularly if the construction is many blocks high. It is, therefore, necessary to ensure the floor surface is flat and free from significant imperfections. The authors recommend laying an epoxy/cement layer over any existing imperfect floor to obtain the preferred finish. Epoxy/cement mixes are currently available which can be poured and which are self-leveling. All that is required prior to pouring the mix is a boundary shuttering of some 30 mm or so high to contain the product until curing has finished. It is also recommended that this treatment should cover the complete area of the store to provide a level surface for the blocks but also to ensure the movement of the Drum Handler is unimpeded throughout its areas of operation.

Having determined the outline form of the Drum Store consideration was given to construction methods and risk analysis. The resultant design of the Store, and particularly the suspended steel plate roof, required some thought on its safe installation. Following the construction of the block walls, each vertical support column must be fixed into position, bolted to both the vertical wall blocks and the floor. A short scaffolding support structure needs building inside the Store area to the roof level and the first 30 mm roof plate lowered into position on to the scaffolding structure. The second 30 mm plate should then be placed on the first and the bolts holding one plate to the other installed. The first horizontal support beam can then be positioned so that it is resting on and bolted to the vertical columns. Finally, the horizontal beam must be attached to the roof plates with the appropriate screws, after which the scaffolding can be removed and reconstructed under the next section for a repeat performance. This procedure then continues until the complete roof has been installed. It should be noted that each roof plate overlaps its adjoining plate so that there is no direct radiation 'shine' path. The preceding description is a summary of a detailed installation procedure which was prepared during this investigation and which was combined with a full risk analysis of the proposed construction methods.

An illustration of the complete Drum Store is shown in Figure 4

DRUM HANDLER

There are a number of remotely operated vehicles available that can be adapted to carry drums weighing 1500 kgs. into the store. However, all employ the umbilical cable principle to carry both power and control signals to the vehicle. The use of the umbilical cable for vehicle recovery requires robust structures to absorb the loads that would be generated by the cable itself, particularly when negotiating corners. A simple pull on the umbilical to retrieve a vehicle carrying a 1500 kg. drum, demands sophisticated cable management systems and increases the risk of cable damage. These available vehicles have very little built-in component redundancy and become, therefore, high risk aspects of the Drum Store design.

It was for the above reasons that the authors decided to review the requirements of a Drum Handler and to undertake a design scheme of their own. This scheme encompasses the 100% redundancy strategy for a radio controlled unit, i.e. all components, including the heavy duty battery, are provided with stand-by back-up components. The stand-by components can be selected, when required, via a radio signal. The main and stand-by components can be selected, when required, via an appropriate radio signal.

The first component chosen, after the battery, was the propulsion system, for both forward and rearwards motion. The authors found that a method that had most promise was the caravan or trailer moving appliance, which employed a radio controlled motor driving each wheel through a friction roller. This arrangement permits the owner to park the caravan in confined areas driving each wheel individually. In fact, tests revealed that the independent control of each wheel permitted the caravan to turn in its own length by driving one wheel in one direction and the opposite wheel in the other direction, with the jockey wheel swiveling as required. All under the authority of the hand held radio control unit. The authors decided that a similar arrangement should be used on the Drum Handler but that an additional pair of drive motors is required on each wheel in the event of a motor failure. Each set of motors is provided with separate radio control units and in the event of any motor failure, that pair will be deactivated and allowed to freewheel. The other pair of motors will then be activated and used to recover the situation.

The wheels chosen for the drive system are large in diameter and have hard rubber tyres suitable for a roller friction drive and the load being supported. These are mounted at the rear of the vehicle absorbing the majority of the drum weight, while the system chosen to act the part of the swiveling jockey wheel on a caravan is a pair of low profile castor wheels positioned at the front of the vehicle. It is possible with this combination of wheels to drive the Drum Handler through very sharp bends, if required. Both rear drive wheels and the front castors are suitable for concrete

floors with small imperfections. The next problem to be encountered was the lifting of the waste drum. The drum has been designed by the UK disposal authority, Nirex, to be lifted under the top flange (See Figure 1) The Drum Handler described here accommodates this lifting arrangement with a pair of forks which locate under the drum flange, prior to the forks being tilted backwards to lift the bottom rim of the drum off the floor. This tilting movement is achieved by powering an electric actuator, which is mounted alongside a stand-by actuator, all controlled by separate radio signals.

Also carried on board the Drum Handler are forward and rearward facing CCTV cameras, which are duplicated to meet the 100% redundancy case, to aid the remotely positioned operator. Other fixed units, plus lighting, within the Drum Store structure, augment these on-board cameras. As the Drum Store is an effective barrier to the penetration of radio and CCTV signals, a relay is positioned in the roof of the Store. This relay receives signals from the control console outside the Store, transfers them through the roof structure and transmits the signals to the receiver, also duplicated to cover possible breakdown, on the Drum Handler. Similarly, signals from the Handler will be relayed back to the control console. The control console is positioned some distance from the drum path to produce the minimum dose uptake exposure to the operator. He can view and control all movements of the Drum Handler from this point, viewing through the various VDU's provided. All of the technology proposed for this Drum Handler is readily available commercially and is already in regular use in current popular television programs and sports broadcasting.

It will be seen that with all the components on the Drum Handler supported by back-up components, there is very little argument for a second Drum Handler, as all operations will be capable of being terminated before it is necessary to send the Drum Handler off for repair. The need for a second Drum Handler will depend on the travel speed of the Drum Handler, the on-board battery life between charges, the rate of arrival of the waste drums and the estimated time that the inoperative Handler will be away for repairs. All of these factors will be established in the next phase of this project, the detail development program. A pictorial view of the proposed Drum Handler is shown in Figure 4.

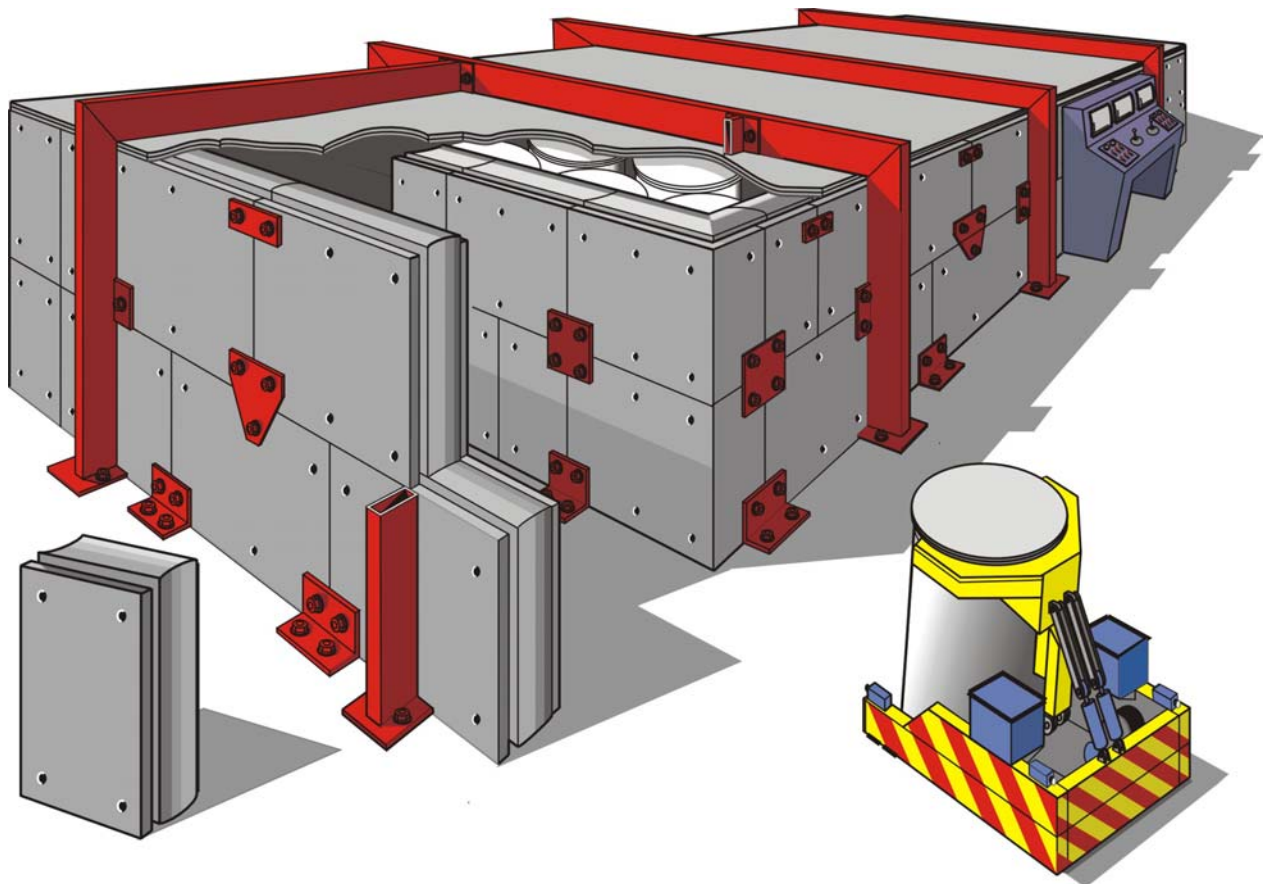


Figure 4 - Illustration of Drum Store and Drum Handler

CONCLUSIONS

The aim of this review, to investigate the possible use of an interlocking block system to construct a Store for waste drums, has been fulfilled. The conclusions of the authors was unanimous in deciding that the block system provided a quicker construction than conventional techniques, with a lower intensity of labor, lower material costs and, therefore, lower overall costs. All of which indicates a lower radiation dose uptake by the construction workers. The block system also provides a means of extending the Store capacity if required. The ability to dismantle the facility and move it to another location is a significant advantage, as is the lower decommissioning costs. The fact that any possible contamination on the blocks can be effectively removed, compared to the impossibility of decontaminating concrete, also indicated that significant savings in disposal costs will result.

With regard to the Drum Handler, the investigation proved that it is possible to provide a vehicle which avoids the use of an umbilical cable and is fully radio controlled. The authors agree, however, that the next aim is to detail design, manufacture of a prototype and undertake the development work required to prove its viability to the nuclear industry.

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