COMMERCIAL APPLICATIONS OF DRY STORAGE TECHNOLOGY

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ABSTRACT

This paper briefly reviews the technical and cost aspects of the storage at Gentilly-I of 67 MgU of spent fuel. A similar approach is presently being taken for the dry storage of 300 MgU of Douglas Point Generating Station spent fuel. The fuel will be stored in 47 concrete canisters arranged in an array within a fenced area adjacent to the turbine building.

The role of AECL developed expertise and technology is highlighted, including licensing, safety, health physics and project management aspects required for successful project implementation. The paper considers the various alternatives surveyed and the ones retained. Detailed description of canister, canister field, basket, fuel handling operations and basket welding sequences in a shielded station are covered. The equipment costs, schedule and total project costs are reviewed.

The characteristics and projected costs of a canister program at an operating site for a canister similar to Gentilly I and Douglas Point and for another scenario involving a slightly larger canister are also given. Potential future advances in canister technology are also described, which all have the potential to further decrease dry storage cost.

1. INTRODUCTION

This paper briefly describes the early developments of dry spent fuel storage in canisters at Whiteshell and its first commercial application at the Gentilly-I prototype power reactor. A more detailed description of the equipment and methods intended for the Douglas Point spent fuel storage program is also provided. Cost figures for Douglas Point are given with projections for standard CANDU fuel.

2. EARLY DEVELOPMENTS OF CANISTERS

In Canada and abroad, spent fuel has been stored mainly in pools since the advent of nuclear plants. In the early seventies the Whiteshell Nuclear Research Establishment (WNRE) designed and tested several models of canisters for dry storage of nuclear spent fuel. These contained natural uranium fuel of various designs and burn-ups and are also licensed for the storage of the slightly enriched fuel from the WR-1 reactor. A total of three experimental canisters and 10 production canisters are presently operating 17 MgU of spent fuel stored at the Waste Management Area of the WNRE Laboratories. These canisters are presently licenced for a maximum thermal rating of 4.4 kW and can each hold up to 6,000 kgU of fuel, depending on enrichment and cooling periods.

3. THE GENTILLY-I CANISTER STORAGE PROGRAM

When the Gentilly-I prototype CANDU Boiling Light Water reactor was decommissioned in 1984, a decision was made to place the spent fuel in concrete canisters. This was the most economical approach. The Gentilly-I spent fuel had only an equivalent of 183 Effective Fuel Power Days and benefited from a minimum of 7 years of cooling; the decay heat and radiation field conditions were thus low in comparison to conditions experienced at WNRE. The Gentilly-I program stored 67 MgU in 11 canisters. Each canister was 6.0 m high, had a diameter of 2.6 m and was lined with 86.4 cm (34 in) O.D. carbon steel pipe. The canister thus provided a combined shielding of 0.86 m of concrete and 9.5 mm of steel.

The Gentilly-I basket was 545 mm high and had a maximum diameter of 810 mm and could store 38 bundles. A total of eight stainless steel baskets per canisters were stored for a total of 304 bundles per canisters. It is to be noted that unlike other CANDU fuel the Gentilly-I fuel had a central hole accommodating a Central Structural Tube for operations. The fuel in the basket was thus simply positioned with pins. Also, unlike other canisters, the ones in Gentilly-I were located in an auxiliary wing of the turbine Building which had once housed the standby power generators.

4. THE DOUGLAS POINT CANISTER STORAGE PROGRAM

The Douglas Point station was permanently shutdown in May 1984 and is now in a static state with all fuel temporarily stored in the pool. A quantity of 22,236 bundles, representing approximately 300 MgU is to be stored. Because of the success of the Gentilly-I program, the same concept for storage and fuel handling has been retained and only adapted to the exact Douglas Point fuel dimensions when required. The quantity of fuel being too large for storage inside the Turbine Building, the canisters were to be located outside in a closed packed array.

4.1 Safety and Licensing considerations

The primary Safety and Licensing concerns which must be addressed satisfactorily in any spent fuel storage facility are:

- adequate fuel cooling
- effective containment of radioactive release in the event of fuel failure
- adequate radiation shielding
- adequate physical security and ease of safeguard verification
- long term structural integrity

All the above elements are factored into the design of canisters and Fuel Handling as described below.

4.2 Basket and Canister design

Various internal layout and partitioning of fuel were analysed and a geometry having 54 bundles per basket was retained. This geometry offered the largest amount of bundles stored and the maximum amount of clearance for fuel insertion into the basket. The Douglas Point basket is exclusively made of stainless steel and is identical in dimensions to the Gentilly-I basket, except that two drilled plates are used to position the fuel in the basket instead of locating pins. The use of a Gentilly-I basket implied that the same canister as Gentilly-I could be used again. However, for Douglas Point, the canister height was slightly increased and some of the available space at the bottom is also used to store a ninth basket. Seismic, thermal and basket drop stress calculations all showed this simple modification to be acceptable. A reduction of six canisters was thus achieved.

The fuel to be stored contains some three year cooled fuel (with high gamma activity) and a large quantity of fuel having cooling periods exceeding 10 years. This offered the opportunity of providing for extra shielding within the basket by having an outer shielding ring of 24 bundles of 10 years or more of cooling as seen in figure 1. The remaining 30 bundles, located in the inner rings positions, are chosen to be fuel with 3 to 10 years of cooling. To provide for supplementary shielding at the top of the canister, the last basket to be inserted in a canister will contain only fuel with 10 or more years of cooling. This fuel arrangement is expected to reduce significantly the man-rem burden by the operating personnel.

4.3 Canister Site Design

A total quantity of 47 canisters (46 used plus one spare) will be located on the site. The spare canister is intended essentially for incident recovery from loading or long-term operation and may also be used for test purposes. The canisters are arranged in four rows of 12 canisters as seen in figure 2 and are serviced by a gantry crane. The canisters are spaced approximately one meter apart and base slabs of reinforced concrete of 7.3 m by 7.3 m (24 ft X 24 ft) and 61 cm (2 ft) thick are used to support 4 canisters. The canister array is of 14.6 m by 44 m (48 ft by 144 ft) only and the fenced area is of 70 m by 71 m (230 ft X 235 ft). The canister site is adjacent to the East end of the Turbine Building wall.

4.4 Fuel Handling Operations

The fuel handling (F/H) operations are identical to the ones at Gentilly-I and essentially consist of loading the baskets, welding them in a shielded station and transporting the baskets to the canister with an on-site flask. Due to the experienced brittleness of the Douglas Point fuel, all F/H operations will be done manually. Before loading the baskets, the trays are checked to make sure of the appropriate age of the fuel. The fuel on the tray is then positionned vertically with a suitable mechanism and then taken manually to the basket. Fuel with a cooling period of 3 to 10 years is first loaded vertically into the basket; this is followed by the loading of the outside ring, which has fuel with cooling periods of 10 years or more. A simple support mechanism is placed under the bundle to prevent it from free-falling when the fuel bundle grapple is disengaged. Baskets dedicated to be the last one in the canister will only be filled with fuel having 10 years or more of cooling by following essentially the same method. Once the basket is filled, a basket cover is installed on the basket with the same tool as was used at Gentilly-I. The basket is then temporarily stored in the pool until such time that the canister loading operations can begin. This basket loading cycle is then repeated.

When canister loading approval is received, the filled baskets are taken out of the pool through a chute and into a shielded welding station installed on the pool side. The basket is first brought to a drying station where warm air is circulated through the fuel and returned to the plant active ventilation system. The basket cover is then welded to the basket base at the bottom end and at the top end of the cover. This is done with a circular fillet weld, using a remote Metal Inert Gas (MIG) welding technique. The basket is then pulled out of the shielded station and into a flask for transportation to the canister site by truck. The flask is lifted to the top of the canister array by the gantry crane. The canister plug is raised and slid alongside with the flask. The basket is then lowered into the canister. When all baskets are loaded, the canister top is welded on and an IAEA seal is applied. It is expected that with two flasks, the cycle time will be brought from 2.5 hours for Gentilly-I (one flask) to 1.5 hours for Douglas Point.

4.5 Thermal and Shielding Considerations

On average, the Douglas Point canisters will only have heat releases of less than 1.5 kW while the value obtained at Gentilly-I was even lower at less than 0.5 kW. This represents only a fraction of the thermal licence limit of 4.4 kW for such canisters. Detailed thermal calculations were made for a windless summer day having a 24 hours ambient temperature of $30^{o}C$; the results are reported in Table I.

Shielding calculations which includes neutron doses, were also made to evaluate the dose rates which may be reached at various locations in the Fuel Handling sequence. The results are given in Table II and are self explanatory.

5. DOUGLAS POINT PROGRAM SCHEDULE

The storage program has a duration of 22 months, starting in March 1986 and ending in December 1987. The main program milestones are given below:

Start of Program	March 1986
Construction License	September 1986
Start Basket Loading	January 1987
Start Canister Loading	May 1987
Complete Canister Loading	September 1987
Close-out	December 1987

As of October first, the purchase orders for baskets and canister site construction are issued and the construction licence for the canisters has been obtained from AECB.

6. FUEL STORAGE COSTS

The early WNRE experience indicates that costs of \$29.4/kgU were reached for the capital and loading costs of natural uranium fuel. In this case, the capital cost of the already amortized hot cells and other facilities were not included. For Gentilly-I, unit costs of \$64. per kgU were reached when all equipment used for the project are attributed to the project and unit costs of \$25. per kgU were obtained when a repeat job is considered. The present budget for Douglas Point is of \$7.3 M which corresponds to \$24. per kgU and includes all the costs to carry out the project. Present designs of canisters only uses about one third of the canister thermal license limit. Future applications for standard 102 mm diameter CANDU fuel are expected to use between 60% to 80% of the canister thermal capacity and substantially decrease costs into the range of $12 to $18 per kgU. Present and future designs of canisters are expected to have a lower present value cost per kgU than pools when considering a 30 years storage period.

7. FUTURE ADVANCES IN CANISTER TECHNOLOGY

The next fuel having the potential to be dry stored in Canada will be standard CANDU fuel. The dry storage of this fuel will be made after typical cooling periods of at least six years. If present Douglas Point baskets are used, a thermal loading of only 1.5 kW per canister would be reached. A significantly larger amount of fuel may be inserted into a similar canister than the Douglas Point one, without exceeding design limits. Other improvements to the dry storage concept may be made in the future to significantly reduce costs and minimize the storage space. These are:

- i) Integration of basketing operations to normal site fuel handling activities
- ii) Use of a manipulator device to load the fuel bundles from the trays to the basket.
- iii) Improve thermal conduction of various elements of the storage system.
- iv) Increase the quantity of fuel per canister to use a larger portion of the thermal dissipation capacity.
- v) Change of materials for baskets.

8. CONCLUSION

Spent fuel storage in canisters offers a secure and demonstrated way of storing fuel which can offer cost competitive solutions with respect to sequential pool construction. Canisters being modular units, they may be built as the fuel storage need arises, thus enhancing the cash flow position of the Utility with respect to the front-end construction expenses of pools. Also, eventual repairs or replacement of a canister represent a minor event compared to similar events happening at a pool. The design life of a canister being of 50 years, the move towards this particular option instead of a pool may well mean the deferment of 10 to 20 years of the large expenses that need to be incurred for transportation and ultimate disposal of fuel in an underground repository. The flexibility and cost competitiveness thus offered by canisters make them a choice candidate for interim fuel storage to be seriously considered.

TABLE I

MAXIMUM TEMPERATURE IN DOUGLAS POINT CANISTERS

LOCATION	MAXIMUM TEMPERATURE REACHED
DAILY AVERAGE AMBIENT AIR	30 ºC
CANISTER SURFACE	42 ºC
CANISTER LINER	73 ºC
BASKET WALL	97 ºC
HOTTEST PIN IN AVERAGE BASKET	108 ºC
HOTTEST PIN IN HOTTEST BASKET	125 ºC

TABLE II

MAXIMUM DOSE RATE AT VARIOUS LOCATIONS

LOCATION	DOSE RATE (mSv/h)
ON CONTACT WITH WELDING STATION	0.05 TO 0.1
ON CONTACT WITH TRANSFER FLASK	0.1 TO 0.22
ON CONTACT WITH ONE CANISTER	0.025 TO 0.064
IN BETWEEN 4 CANISTERS	0.1 TO 0.26
AT THE SITE FENCE	LOWER THAN 0.0025

DOUGLAS POINT SPENT FUEL STORAGE PROGRAM

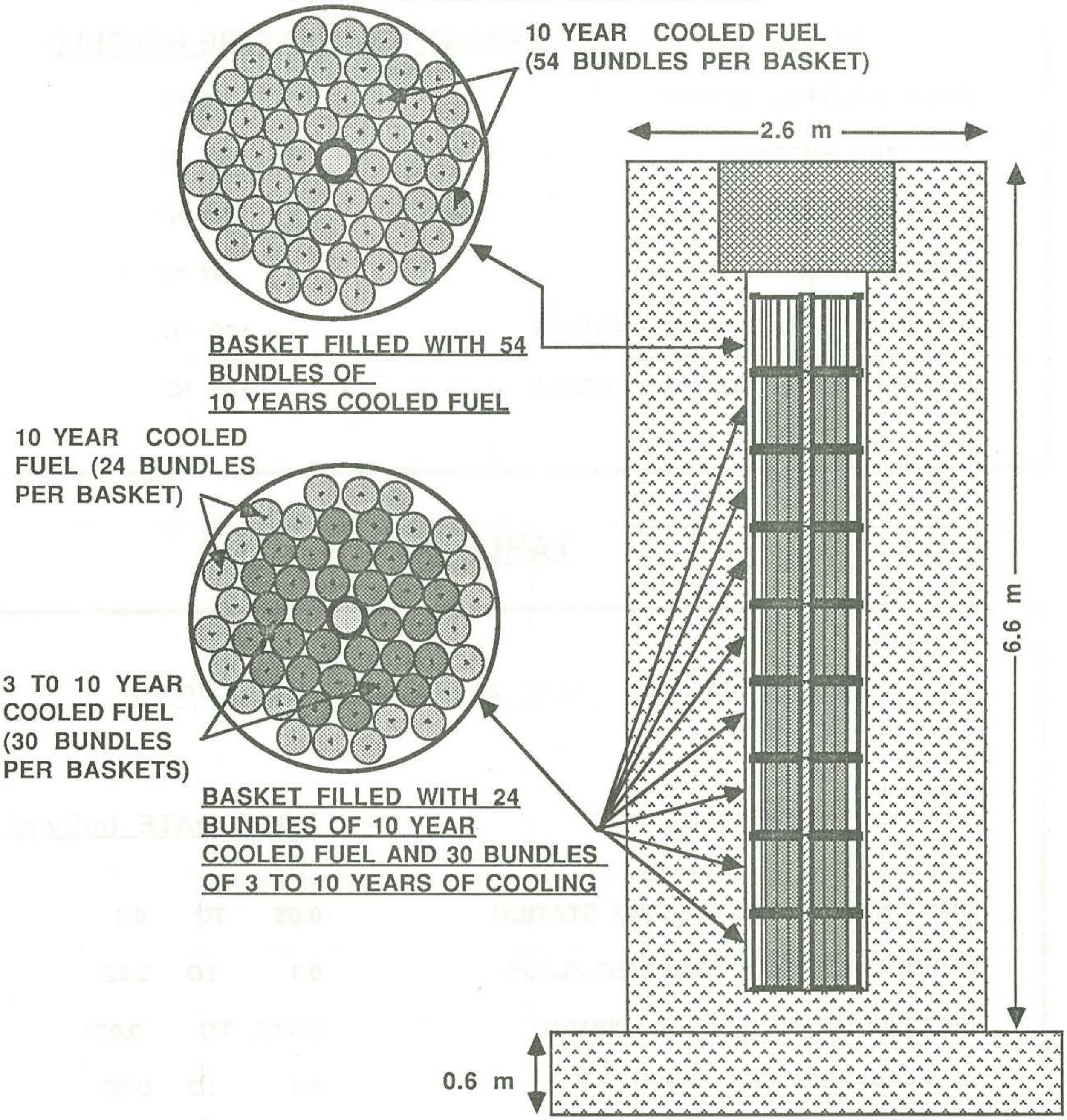

FIGURE I

DETAILED FUEL ARRANGEMENT INSIDE BASKET AND CANISTERS

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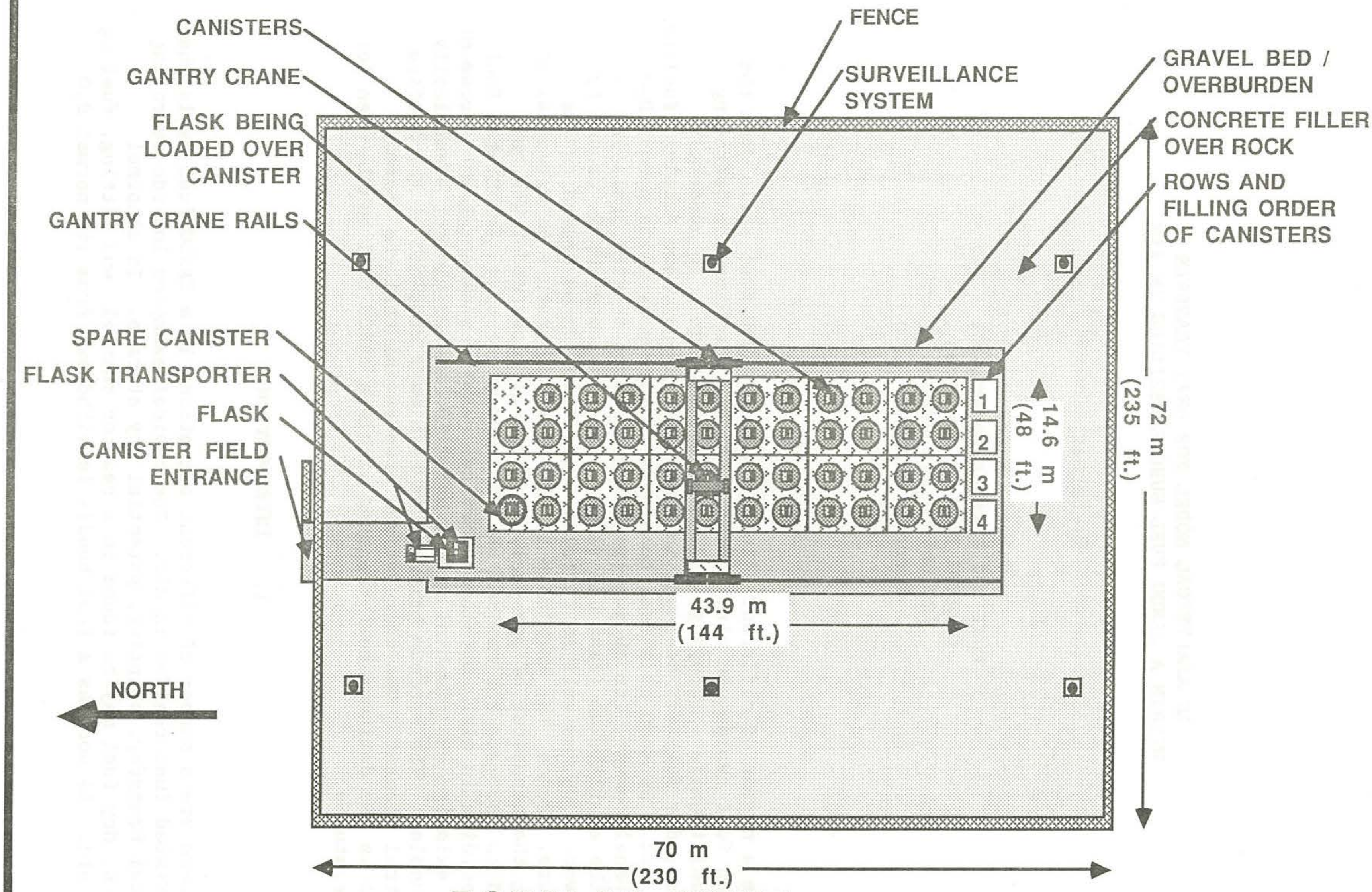

FIGURE II **DOUGLAS POINT STORAGE FIELD FOR 47 CANISTERS**

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