CONCEPTUAL DESIGN OF AN INTEGRATED LLW TREATMENT FACILITY AT A LARGE UTILITY

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ABSTRACT

Ontario Hydro's Waste Volume Reduction Facility (WVRF) has been providing centralized processing for the solid low level radioactive waste (LLW) generated at Ontario Hydro nuclear stations since 1977. The existing incineration and low force mechanical compaction processing equipment is now insufficient. Following intensive review of the possible options it was concluded that a major rebuilding of the WVRF would be required to meet the overall waste management requirements for the next 20 years.

In 1991, Ontario Hydro completed a conceptual design of the new upgraded WVRF. The terms of reference for the design has been to achieve a state-of-the-art integrated waste management facility, which can handle all types and quantities (e.g. 9000 m^3/year) of LLW, including organic liquid LLW, generated presently and in the future at Ontario Hydro. This design includes capability for gradual retrieval, processing and conditioning of the existing stored waste to meet long term waste form requirements. If approved by the corporation, the new facility is to include a replacement incineration system, a high force compaction system and a spectrum of auxiliary processes for waste pretreatment, including a state-of-the-art material handling system.

INTRODUCTION

Ontario Hydro currently has a nuclear generation program consisting of 20 generating units of approximately 14,000 MW(e) of CANDU Pressurized Heavy Water reactors located at three sites, Pickering Generating Stations A and B, Bruce Generating Stations A and B and Darlington Generating Station. Over the next 20 years it is projected that the nuclear program will generate an average of about 7000 m^3 of solid LLW annually, with peaks due to major maintenance activities of up to about 9000 m^3 annually. All of Ontario Hydro's solid LLW is transported to the Bruce Nuclear Power Development (BNPD) Radioactive Waste Operations Site (RWOS) for centralized processing and storage (1). As disposal of LLW is not yet practiced in Canada, the RWOS provides long term engineered storage structures for the waste until a suitable disposal facility becomes operational.

The existing BNPD-RWOS Waste Volume Reduction Facility (WVRF) employs the volume reduction processes of incineration and low force mechanical compaction. This facility, which has been in operation since 1977, now requires major up-dating. The existing processing equipment is approaching the end of its useful life, has insufficient volume reduction capability, cannot be used on all categories of waste and along with its supporting facilities does not have adequate capacity to treat the current and future projected waste volumes.

Expansion and maturing of Ontario Hydro's nuclear generation program over the last decade has necessitated re-examination of the cradle-to-grave waste management scheme. This included re-definition of the waste processing requirements. Following an extensive review of the possible options it was concluded that a basic rebuilding of the centralized waste processing facility, to achieve maximum waste volume reduction using the combination of modern incineration and high force compaction processes, would best meet the overall waste management requirements for the next 20 years (2,3). Rebuilding of the WVRF is a part of Ontario Hydro's overall waste management scheme which also includes programs to minimize the radioactive waste generation at the sources (3).

The new facility is proposed to include a replacement higher capacity, state-of-the-art incineration system, a technologically advanced high force compaction system, a spectrum of auxiliary processes for waste pretreatment, and provisions for final waste conditioning and packaging.

The terms of reference for the design has been to achieve a state-of-the-art integrated waste management facility, capable of treatment and conditioning of all types and quantities of solid LLW and organic liquid waste, generated presently and in the future at Ontario Hydro. This also includes capacity and capability for gradual retrieval and processing of the existing waste, accumulated and stored since the beginning of the Ontario Hydro nuclear program, and provisions for future addition of conditioning equipment to meet the waste form acceptance criteria for final disposal. The system concept is based on minimizing environmental emissions and minimizing manual labor, while operating to higher radiological and conventional safety standards. Improvements in the facility overall building layout and ancillary services are expected to result in better operational efficiency and occupational safety.

This paper describes development of the conceptual design of the new facility.

DESCRIPTION OF WASTES

The solid LLW that is collected at the generating stations is segregated and sorted by waste category at the source, and mostly packaged in clear, .06m^3 polyethylene bags with color coded ties. Large waste objects are wrapped in polyethylene sheet and/or packaged in custom made crates. Bagged waste is transported to the WVRF in Type A 1m^3 containers or in drums (e.g. nonprocessible waste). An analysis of the composition and activity level for the different categories of waste is presented in Table I.

With the enhanced processing capabilities offered by supercompaction, the number of waste categories will be

TABLE I

Current Radioactive Waste Categories and Characteristics

Waste Category	Material	Volume %	Activity Distribution (% of bags)
Dry Incinerable	Paper	40.0	-87% < 10μ Sv/h
	Plastic	39.0	
	Rubber	5.0	- 11% between 10-100μ Sv/h
	Cotton	9.0	
	Wood	3.5	- 2% between 100-600μ Sv/h
	Other	3.5	
Compactable	Paper	28.0	- 84% < 10μ Sv/h
	Plastic	35.0	
	Wood	1.6	- 10% between 10-100μ Sv/h
	Sand	2.9	
	Metal Chips	2.9	- 5% between 100-1000μ Sv/h
	Rubber (PVC)	10.8	
	Glass	1.1	- 1% between 1000-2000μ Sv/h
	Metal Parts	11.5	
	Rags	6.1	
Non-Processible (Routine)	Metal	33.0	- mostly < 250μ Sv/h
	Non-combustible Absorbent	25.0	
	Paper	16.0	
	Plastic	8.0	
	Concrete	6.0	
	Wood	5.0	
	Cotton	3.0	
	Rubber	3.0	
	Glass	1.0	
Non-Processible (Non-Routine)	Metal	100.0	N/A

reduced for the new facility. Table II illustrates the design capacity of the new facility by waste category.

The enhanced processing capability will also permit wastes currently in storage to be retrieved and reprocessed to either achieve higher volume reduction factors and/or to facilitate waste immobilization and repackaging to suit waste disposal criteria. Figure 1 illustrates the different types of routine waste and processing materials receipts, and the types of wastes presently in storage.

LLW TREATMENT

Existing Facility

The existing WVRF occupies a building floor space of approximately 1600 m^2 and processes up to 7000 m^3/year of radioactive waste and also approximately 9000 m^3/year of non-radioactive waste. All wastes are received through one central unloading dock where they are separated into active and non-active waste streams and transferred to either the radwaste processing area for incineration or low force compaction (baling), or to the non-radioactive waste incinerator. Operating experience has indicated the need for not only higher capacity major waste processing systems but also a larger facility to house supporting waste management activities.

New Facility Siting and Layout Options

It was established that the new facility would be located on the existing radwaste operations site, to facilitate licensing. The specific location of the building was determined by developing and comparing three alternative building construction schemes:

a. separate stand alone building, not interconnected to the existing WVRF;

b. a major renovation type addition to the existing facility, accomplished by *exterior wall removals* and integration of all new and existing building systems; and

c. a stand alone building interconnected to the existing WVRF via a single enclosed personnel and material transfer corridor.

Assessment of the options resulted in selection of alternative (c).

Addition of new facilities and processing equipment can be carefully integrated with those existing to minimize operational disruptions during construction, to acquire an efficiently operating integrated facility, and to minimize

TABLE II

Design Capacity of New Facility by Waste Category

Existing Waste Category	Annual Quantity (m^3/Year)	New Waste Category	Annual Quantity (m^3/Year)
Incinerable (dry)	7,000	Incinerable (dry)	7,000
Incinerable (liquid)	150	Incinerable (liquid)	150
Compactable	1,000		
Non-Processible (routine)	1,000	Compactable	2,200
Non-Processible (non-routine)	200		
		Non-Processible	Negligible
TOTALS	9,350		9,350

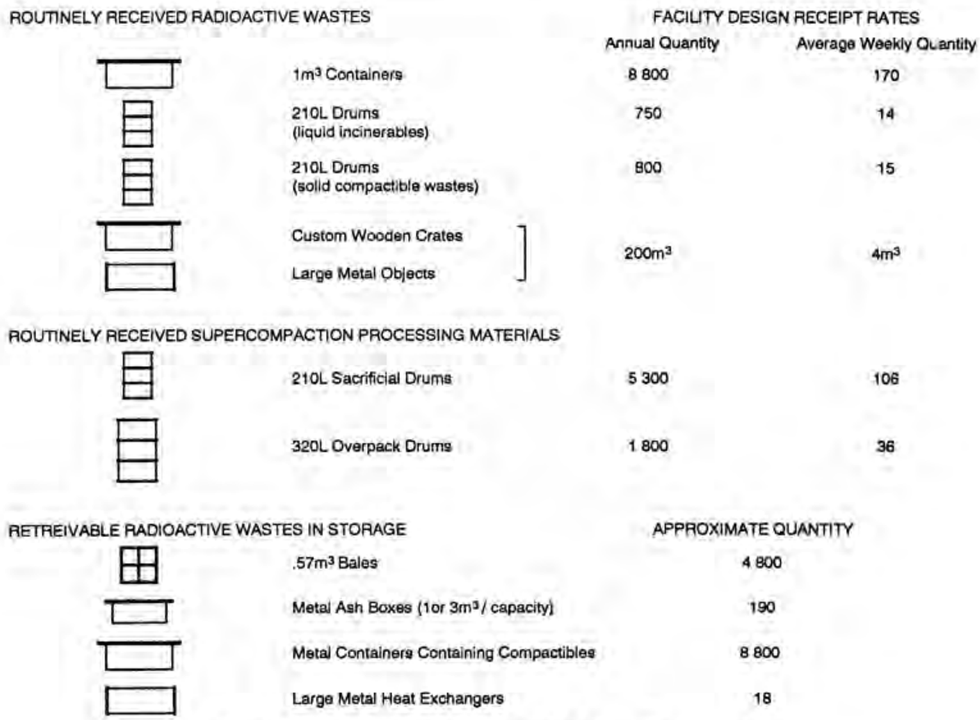

Fig. 1. WVRF extension-materials handling receipts.

potentially costly changes to the front and back ends of the Ontario Hydro waste cycle (i.e., waste collection and transportation practices, and waste storage practices).

Individual floor plan layout options were then developed and compared to establish an optimum building layout from a materials handling and personnel movement perspective (refer to Fig. 2).

The basic design principles taken in consideration were as follows:

- active and inactive waste streams must be totally segregated as early as practical, to eliminate cross contamination;
- maintain continuity of radiological building zoning to simplify the movement of materials and personnel;
- simplify and automate the materials handling system as much as practical to minimize personnel interaction with wastes;
- ensure consistency with current transportation and storage practices.

New Facility Description

The building addition covers an area of approximately 2900 m^2 and is subdivided into the three main functional areas of radwaste receiving; incineration; and supercompaction. The later two are radiologically zoned for the processing of radioactive waste. A majority of the floor area in the existing facility will be reclassified as a non-radioactive work area (with the exception of the existing radwaste incineration area) and will be exclusively used to handle and treat non-radioactive wastes. Separation of radioactive and non-radioactive waste will be accomplished prior to their receipt in the facility (e.g. two receiving docks). To permit the flow of radioactive wastes and personnel between the two buildings, an interconnecting corridor is provided with the capacity to handle two way forklift traffic. All building systems in the new extension (e.g. active ventilation) will be independent of those existing.

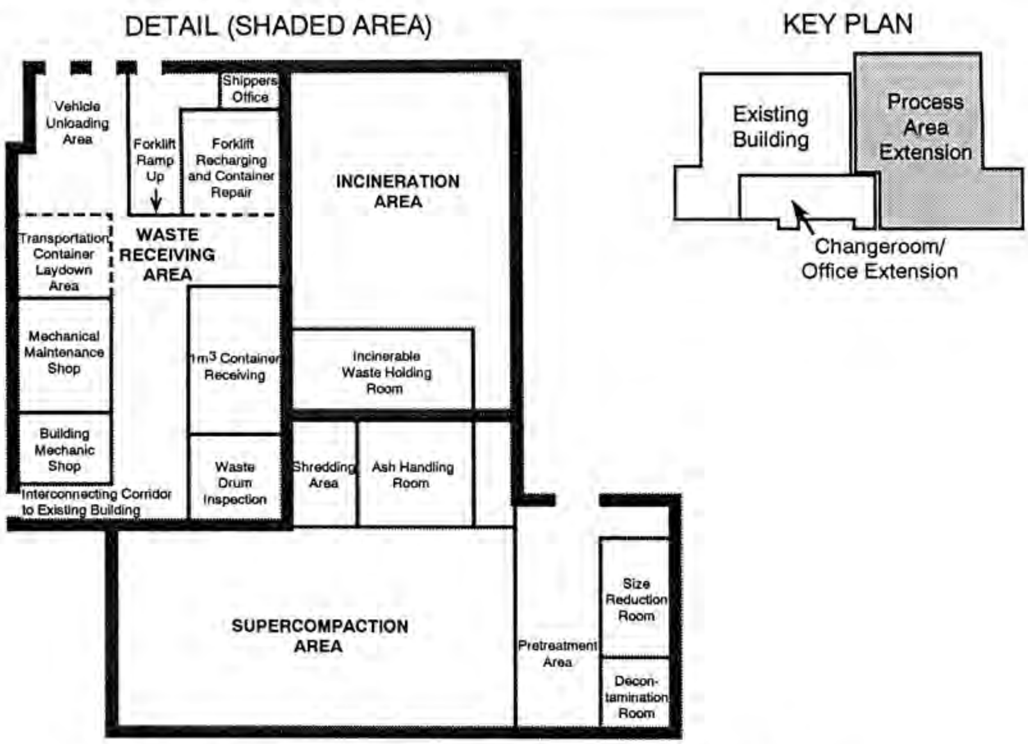

Fig. 2. Waste volume reduction facility - extension building.

The radioactive waste receiving area will function as a receiving point for all LLW, an inspection station to verify waste suitability for processing, and a segregation station for directing wastes into appropriate processing streams. The receiving area is comprised of two truck unloading stations; a transportation container laydown area; a container emptying and waste inspection table; a drum receiving and inspection room; and several equipment maintenance rooms.

The LLW incineration area houses all incineration system equipment, inclusive of the solid and liquid waste feed systems. All rooms are provided with forklift accessible doors and are sized to accommodate maintenance replacements. The incineration area also houses a waste feed holding system, which is sized to accommodate three days of average incinerator throughput.

The supercompaction area contains the supercompactor system and its containment, a precompactor, drum and overpack laydown areas, a three day capacity waste holding area, and a local control station. Waste pretreatment equipment such as a shredder, cutting and sizing equipment, and decontamination equipment are housed is separate rooms within this area. All processed waste is forklifted from this area directly to nearby storage buildings.

The operation of the facility is controlled from an elevated control room which overlooks the supercompaction and incineration areas and the waste inspection table. Additions to the office and administration area will upgrade personnel amenities and improve personnel radiological monitoring. The building will be equipped with all required service systems such as active liquid drainage, controlled active ventilation, compressed air, breathing air, central vacuum system, fire suppression systems, sewage, etc.

MATERIALS HANDLING

The materials handling system in the existing facility was designed with a high reliance on manual labor for activities such as the unloading of transportation containers, the receipt inspection of waste, the loading of processing equipment feed systems, and the internal movement of bagged waste. In addition, the lack of space and equipment capacity results is an increased worker interaction with wastes beyond that originally designed. Human factors engineering studies have concluded that more than half of waste handling tasks exceed currently recommended safe musculoskeletal risk limits.

The philosophy behind the design of the new materials handling system is based on correcting human factors deficiencies, while minimizing worker radiological exposure and the spread of contamination through use of a higher degree of system mechanization. The main design objectives of the new materials handling system are as follows:

- Minimize worker interaction with waste (preferably to one visual inspection).
- Eliminate manual lifting of bagged waste.
- Simplify the flow of materials between different radiological zones.
- Provide the capability to receive peak waste delivery rates and, through buffer storage capacity, eliminate double handling of waste.
- To unload transportation shipments and reload vehicles with empty waste containers in less than 90 minutes.
- To incorporate routine radiological safety operating procedures into the mechanized sequence of operations.

Some of the features of the Materials Handling System design concept are as follows.

Most wastes are received through the vehicle unloading area and transferred to either the drum inspection room or the $1m^3$ Container Receiving Area. Large waste items and wastes retrieved from storage are received through the Pretreatment Area, (refer to Fig. 2) for size reduction, shredding and/or decontamination and transfer to sacrificial supercompaction drums.

An automated emptying of $1m^3$ Containers is achieved via a system which remotely removes the container lid, vents it's airborne contents and lifts and tilts the container contents onto a low friction receiving table, where an operator inspects each bag and directs it into either the incinerable, compactable, or non-processible waste streams (refer to Fig. 3).

The incinerable and compactable waste streams each have buffer storage in the form of rubber belt conveyors, which are located between the receiving table and the process systems' waste charging equipment.

Drummed waste that is received in the Drum Inspection Room is bar coded and transferred via roller conveyer to the appropriate area within the supercompaction system.

All waste destined for storage is packaged inside 320 L drums, which are decontaminated, if required, weighed, radiation field scanned and bar coded prior to exiting the facility.

INCINERATION SYSTEM

Experience Ontario Hydro has gained over the years with incineration led to the specifications for the new incinerator (4). A basic operational requirement is that the design be based on proven operational experience. The new incinerator building extension is sized to allow ample access space for normal operations and maintenance activities. After the new system is in-service the existing incinerator will be decommissioned and dismantled. Some of the basic design requirements and features of the incineration system are as follows.

The specified design capacity for the new system is an annual throughput of 7000 m^3 while allowing for peak waste loads and routine outages. This translates to an instantaneous processing rate of 150 kg/hr for solid waste (28000 kJ/kg) in combination with 30 kg/hr organic liquid waste (40000 kJ/kg), based on continuous operation 24 hours per day and 5 days per week. The design processing rate makes allowance for adequate maintenance time so that performance will not deteriorate with age. A minimum gross volume reduction factor of approximately 75:1 shall be achieved, taking into account secondary wastes.

The combustion system is to provide a minimum destruction and removal efficiency (DRE) of 99.99%. Specified final combustion conditions are a minimum operating temperature of 1000°C (ensured by an auxiliary fuel burner), design temperature 1200°C, gas residence time minimum of 2 seconds with the oxygen content in the flue gas greater than 6%.

Fully automated, computer controlled operation is a basic requirement, along with complete instrumentation to enable process control and combustion efficiency monitoring.

A major process consideration is selection of an offgas treatment system that will satisfy the environmental regulatory requirements and which is compatible with Ontario Hydro waste characteristics. The tritium content of Ontario Hydro's wastes (4-70 GBq/m^3) necessitated special attention. After assessment of potential technologies it was concluded that the tritium occupational hazard from concentrating effects in a wet scrubbing loop made wet treatment options undesirable. Two basic offgas treatment schemes, dry and semi-dry, have been evaluated to be appropriate and are being considered further. Both potential offgas treatment schemes would use a pulse-jet baghouse filter followed by High Efficiency Particulate Air, HEPA filters (minimum 99.97% removal) for particulate removal. The dry treatment scheme (Fig. 4) would consist of flue gas cooling, from the afterburner temperature to 120-150°C, in a heat recovery boiler providing energy recovery in the form of hot water, followed by direct lime plus recycled secondary waste residue (excess lime plus neutralized acid gas salts) injection and flue gas contacting, followed by the particulate filtration. The semi-dry treatment scheme (Fig. 5) would consist of flue gas cooling, from the afterburner temperature to 180-200°C, by direct water spray injection quenching and caustic solution injection in a spray dryer (acid gas neutralization/removal), followed by the particulate filtration. A final offgas treatment stage of a deep bed charcoal filter is being considered for trace organics removal. Further evaluation of the offgas treatment options is continuing leading to the final specification of the most appropriate system.

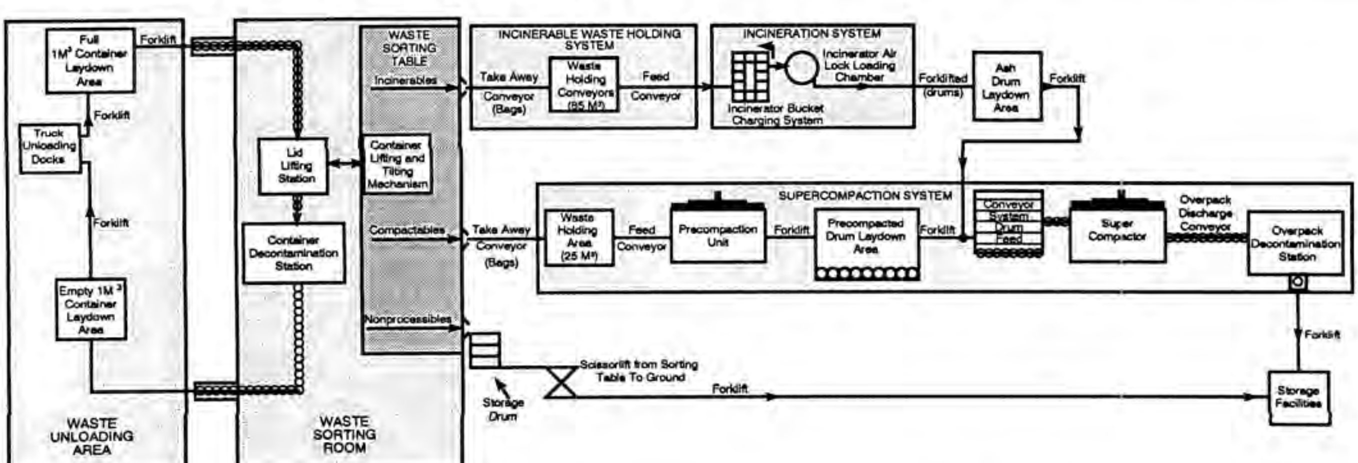

Fig. 3. Simplified flow schematic for wastes received in 1 m^3 containers.

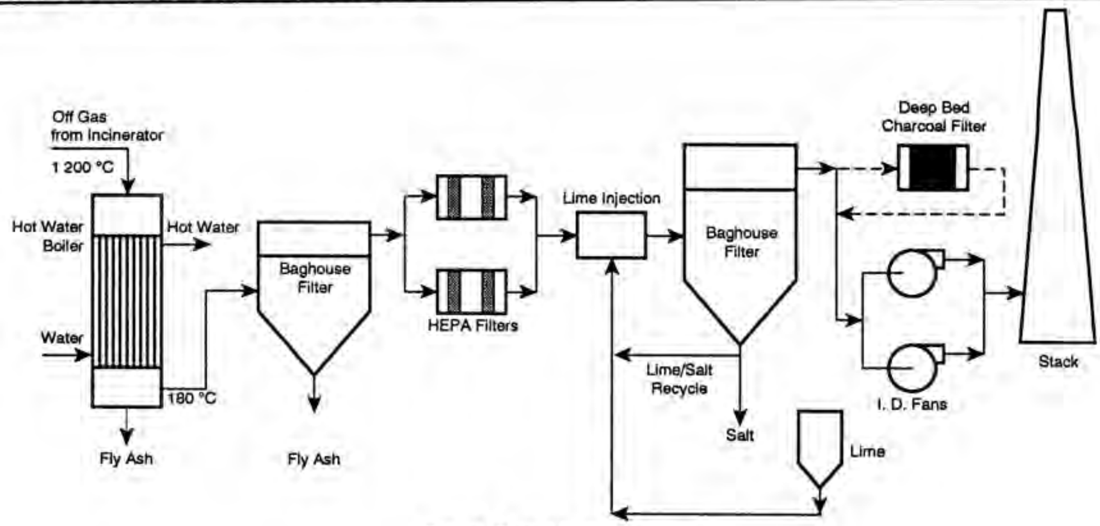

Fig. 4. Dry offgas system.

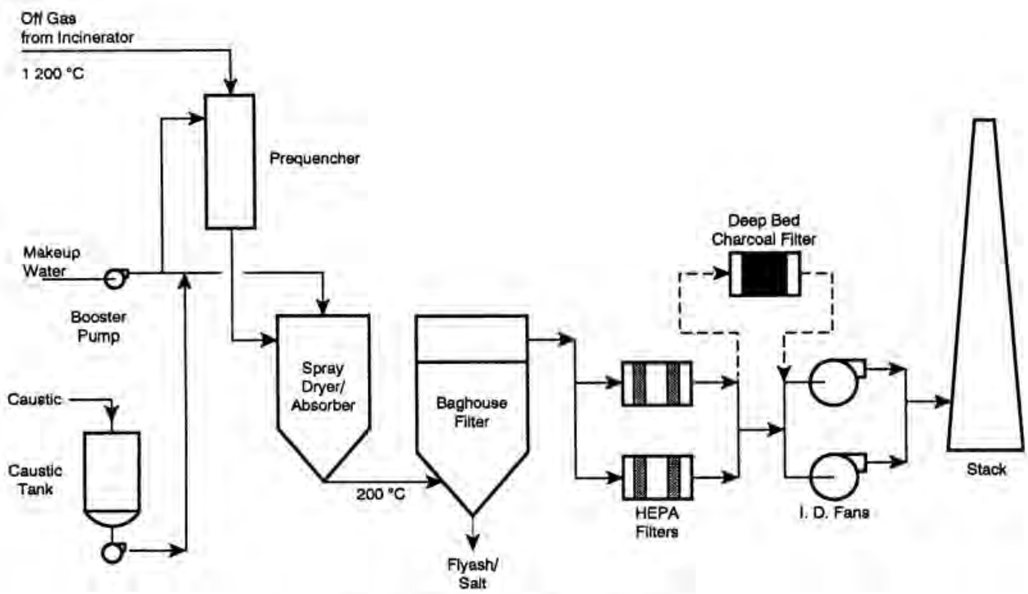

Fig. 5. Semi-dry offgas system.

The current reference design basis for the handling of incinerator bottom ash, fly ash and secondary acid gas scrubbing residue waste solids is to directly package in 210 L drums which could be further processed by the supercompaction system. Supercompaction is expected to enhance the overall incineration volume reduction factor by about 3-4 times and provide a more stable (less dispersable) final waste form, which if necessary can be further conditioned to meet eventual disposal criteria. Research investigations are on-going to verify and optimize supercompaction with preconditioning as the most appropriate ash management technique.

SUPERCOMPACTION SYSTEM

Supercompaction was selected to be included in the upgraded WVRF based on the assessed capability to provide maximum volume reduction of virtually all the non-incinerable solid LLW (2). The supercompaction building extension is sized to allow ample access space for normal operations, including all material handling functions, and maintenance activities. Some of the basic design features of the supercompaction system are as follows.

The current reference specification is a 2000 ton High Force Mechanical Compaction System receiving 210 L sacrificial drums and using 320 L overpack drums. Design capacity is based on a normal annual throughput of 2200 m^3, operating 60 eight hour shifts, with capability to process up to 9200 m^3 annually, operating 170 eight hour shifts, should the need arise to handle the incinerable waste fraction as a standby process. The design processing rate is based on allowing for maintenance outage time. A minimum gross volume reduction factor of approximately 7:1 shall be achieved on the normal waste load.

The supercompaction facility includes provision of ancillary equipment to be used on an as required basis for waste that is not directly supercompactable and for retrieved existing stored wastes because of large size or other characteristics. Such waste pretreatment would include low force precompaction, size reduction (shredding, plasma arc cutting, band saw), and decontamination. Currently stored waste bales would be shredded prior to supercompaction and some currently stored non-processible waste would require cutting prior to supercompaction.

Automated, computer controlled operation including optimum filling of overpack drums with supercompacted pellets is a basic requirement. Waste handling and processing is mechanized and automated to minimize occupational injuries and radiation doses.

Direct controlled venting of air displaced from the waste during supercompaction and an atmosphere control enclosure of the supercompactor are basic design requirements to minimize contamination spread and maintain a clean normal access working environment. The tritium content of Ontario Hydro wastes and potential for airborne tritium necessitates special attention to containment.

Controlled capture, containment and collection of liquid released from wet wastes is a design requirement.

Active Liquid Waste Management

Liquid waste from the supercompaction operation (estimated at up to 30 m^3/yr) would be pretreated, in-line, for particulates and oil removal during collection. Centralized collection of the supercompactor effluent with other liquid wastes from the WVRF operations (decontamination, cleanup and floor drainage water; estimated at up to 60 m^3/yr) is proposed. Due to the expected variability of the waste, batch treatment by a flexible combination of filtration and absorption (e.g. activated carbon, ion exchange) is the reference concept. Several options are being considered for final disposition of the liquid, such as, processing in the incineration system of the organic and part of the aqueous fraction, solidification, and transfer, via tanker truck, to the liquid waste treatment system of the nearby nuclear power station.

Final Waste Conditioning

In the absence of a disposal facility and specific waste acceptance criteria, the current reference design for the final waste package is 210 L drum pellets in 320 L steel drum overpacks, which meets current low level waste storage program requirements. Provisions in the facility design concept allow for the addition of *final waste conditioning* to meet eventual disposal criteria. Options considered include the future use of high integrity overpacks and/or encapsulation of the pellets in the overpack with an immobilization agent (e.g. cement). The aim is to achieve the earliest possible implementation of final waste conditioning so as to minimize waste double handling.

PROJECT STATUS

Completion of the conceptual engineering enabled project cost estimation suitable for submission to the Ontario Hydro Board. If approval is granted, then the project would proceed as per the schedule depicted in Fig. 6. Technical specifications for all major processing and materials handling equipment will be issued in the first quarter of 1993, with final equipment deliveries by mid 1995. Installation and commissioning activities will lead to all processing equipment being in-service by May 1996.

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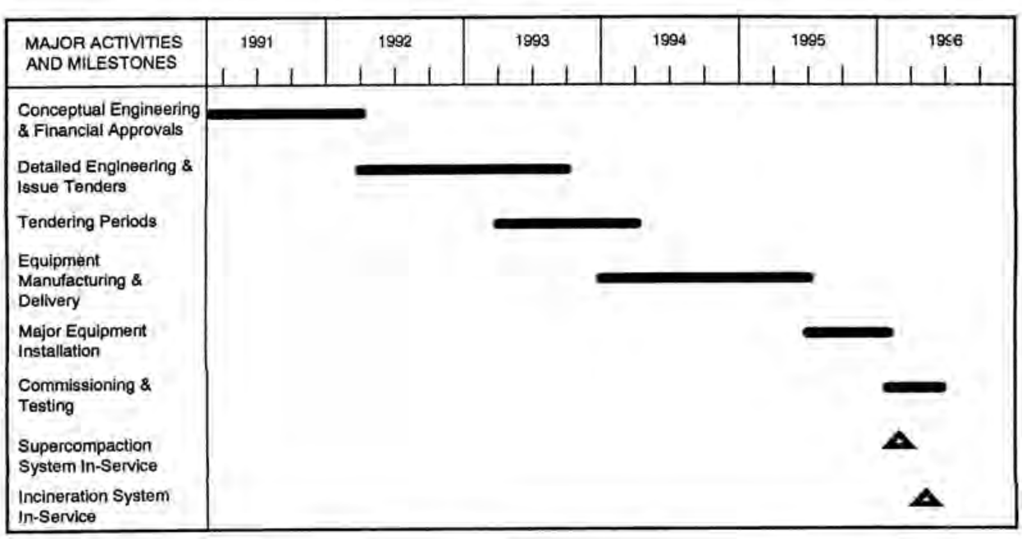

Fig. 6. Project schedule.