OBG PRESENTS:

Design Challenges for Modifications to a Low Level Radioactive Waste Incinerator

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Low Level Radioactive Wastes

Nuclear power generation

LLRW waste disposal

**Maintenance activities**

- Tyvex
- Lubricants
- Lab wastes
- Plastics
- Trash
- Waste oil
Understanding The Waste

The solid waste is typically comprised of plastics, rubber, cotton, wood and small portion of non-combustibles.

Historically, the average solid waste composition is as follows:

- Paper: 50%
- Plastic: 29%
- Rubber: 5%
- Cotton: 9%
- Wood: 3%
- Non-combustibles: 4%
Waste Oils

Primarily a mixture of contaminated hydraulic and lubricating oils with the following characteristics

<table>
<thead>
<tr>
<th>Average density</th>
<th>Average heating value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9 kg/l</td>
<td>40,000 kJ/kg</td>
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</tbody>
</table>

Composition
Mainly oil and a small amount of organics and suspended particulate

Maximum feed capacity
45 L/hr
Radioactivity

The historical radionuclide composition is as follows:

<table>
<thead>
<tr>
<th></th>
<th>Average contact dose rate</th>
<th>Average gross gamma activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22 μSv/h (2.2 mR/h)</td>
<td>13 MBq (350 μCi)/m³</td>
</tr>
<tr>
<td><strong>Tritium activity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-70 Gbq (108-1900 mCi)/m³</td>
<td></td>
<td></td>
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<tr>
<td><strong>Carbon-14 activity</strong></td>
<td></td>
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<tr>
<td>37-120 kBq (1-3.25 μCi)/m³</td>
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</table>
# Existing Incinerator

*Controlled-air design, 1000-1200 kg per day*

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
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<tbody>
<tr>
<td>Ram feeder</td>
<td></td>
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<tr>
<td>Single hearth with dual ash plows</td>
<td></td>
</tr>
<tr>
<td>Starved air primary</td>
<td>UFA &amp; OFA</td>
</tr>
<tr>
<td>Dry ash removal</td>
<td></td>
</tr>
<tr>
<td>Excess air secondary</td>
<td></td>
</tr>
<tr>
<td>Evaporative spray cooler</td>
<td></td>
</tr>
<tr>
<td>Lime / carbon injection</td>
<td></td>
</tr>
<tr>
<td>Baghouse</td>
<td></td>
</tr>
<tr>
<td>ID Fan</td>
<td></td>
</tr>
<tr>
<td>CEMS</td>
<td></td>
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</tbody>
</table>
Incidents

External duct fires (2)

- UFA header piping
- Low point, accumulation, ignition
- Manual control of UFA and OFA air
RA 330 alloy, perforated

- Failure
- Loss of distribution and control
- Collection point for grease, lubricants
- Interference with ash plow operation and uptime reliability
- Plenum, 1 per side
- Located in front 1/3 of hearth only
- Low velocity
- Not integrated with waste bed
Design Changes

Through a collaborative effort with the end user, the following design changes were planned...

- Elimination the UFA piping assembly
- Replacement of the OFA assembly with an improved design
- Return the control of the OFA system to automatic control by PLC
- Redesign and install a new primary chamber burner system comprised of two burners, opposed and staggered
- Provide a portable \( \text{O}_2 \) measurement system for tuning
- Modifications to the refractory lining system as required.
MEB was performed to check the theoretical performance of the incinerator.

The characteristics of each waste compound were determined and a single representative compound established.

This representative compound was entered into a proprietary MEB program as a waste feed.

The MEB could then be used to predict system conditions under various waste feed and combustion air scenarios, and OBG used the results of the MEBs to verify burner sizing as determine the size of new combustion air and OFA blowers.
### MEB Example

#### Source: O'Brien & Gere Engineers, Inc.

**O'BRIEN & GERE**

**MASS & ENERGY BALANCE**

- **Plant Name**: NA
- **Location**: NA
- **Description**: 226.2 lb/hr Solid Waste Feed Condition
- **CONC NO.**: 1
- **THERMAL EFFECTIVENESS**: 0.6
- **ENC**: 50
- **DETRITE REMOVAL**: AUXILIARY FUEL TYPE:
- **FRESH AIR TEMPERATURE**: 80°F
- **BURNER SET-POINT TEMP. (°F)**: 1,000
- **REFERENCE TEMP. (°F)**: 60°F (999999)
- **EMISSIVITY**: 0.9
- **Ambient Temperature**: 70°F
- **Wind Velocity (Min)**: 5

#### Thermal Losses

- **Duty**: Incinerator Only
- **Auxiliary Fuel**

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Primary Combustion Boiler</th>
<th>Auxiliary Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb/hr</td>
<td>Btu/hr</td>
<td>SCCM</td>
</tr>
<tr>
<td>151,000</td>
<td>1,059,000</td>
<td>390</td>
</tr>
</tbody>
</table>

#### Streams

- **Stream 1: Waste Incineration**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**

- **Stream 2: Non-Applicable**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**

- **Stream 3: Non-Applicable**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**

- **Stream 4: Primary Air**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**

- **Combined Streams 1-4**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**

- **Steam 5: Post-Combustion Stream**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
  - **Temperature (°F)**
  - **Units**
MEB Constraints

Exhaust flow from primary must not exceed design flow for existing SCC and APC system

Existing APC comprised of spray cooler, lime / carbon injection

Limited by under-sized ID fan

Meet or improve waste volume reduction

Design allowed for range of 25% of stoichiometric to 200% excess air (total)
OFA Design

- Distribution along the length of the hearth
- Both side walls
- Improved velocities
- Individualized flow control and metering orifices
- Delivered at waste bed
- Starved or excess air modes
- Dedicated blower
<table>
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<th>Burner Design</th>
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<tbody>
<tr>
<td>Split thermal load into two burners, staggered and opposed</td>
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<tr>
<td>Angled to hearth for waste impingement</td>
</tr>
<tr>
<td>Dedicated fuel trains, TSSA &amp; NFPA compliant</td>
</tr>
<tr>
<td>Dedicated blower</td>
</tr>
<tr>
<td>Burners operated as one via common control signal</td>
</tr>
<tr>
<td><em>Limited PLC modifications allowed</em></td>
</tr>
<tr>
<td>Refractory modified to suit new installation</td>
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Project Implementation

- Nuclear power facility design standards
- Multi-layered design reviews
- Rigorous quality and safety controls
- Human factors
- Software categorization issues (minimal changes)
- Aggressive construction and commissioning schedule
  - Procurement parallel with design
- Extraordinary degree of coordination between design and contractor entities
A separate technical peer review was performed at the 100% design stage by the Design Review Board (DRB). The DRB was comprised of subject matter experts in each aspect of mechanical, electrical and I&C engineering.

Each EC package was submitted for review at the 50%, 90% and 100% design completion stages.

Each EC package was subjected to two stage gates within the review process. Constructability, Operations and Maintenance (COMs) teams reviewed the 50% and 90% design packages.

Engineering Change (EC) packages developed for Demolition, Civil Mechanical, Refractory, Electrical, Instrumentation and Controls (I&C), PLC, Propane and Software Modifications.
New blowers, burners, fuel train and OFA system all had to be accomplished with the bare minimum of code changes to the existing PLC program and no changes to the Human Machine Interface (HMI).

Early on in the project, it was necessary to identify PLC changes that were absolutely necessary so that a rigorous internal review process could be completed in time for commissioning.

A list of control functions of each component was developed and ranked in order of safety and criticality to meet the design requirements of the project. Only those changes required for safe operations were prioritized as critical.

While dozens of changes were originally considered, it was decided that the less critical features will be implemented in a future project when the PLC system is replaced in its entirety.

In the interim, these control changes were all hard-wired. In addition, re-use of existing PLC code, digital and analog inputs and output signals, were maximized.
Commissioning

Development of Work Order Execution Plan

- Started with a Commissioning Plan
- Developed procedures, limits and instructions for each individual step in the commissioning process
- Sign-off from relevant parties for each step
- Changes required work stoppage, editing and sign-off before work could proceed
Tuning

- A number of loops and variables were tuned during trial burns of all waste types
- Burner PID loops
- Primary and secondary air loops
- Feed-forward secondary air timer
- All variables were balanced to achieve maximum waste reduction while minimizing CO emissions and maintaining draft control
- ID fan undersized for application made these challenging
Summary

- Modification of primary burner and air distribution and control
- Resume automatic control of incinerator variables
- Complex and fast-track design in parallel with construction
- Multiple nuclear facility quality and design reviews
- Volume reduction a significant improvement over prior operations
- Additional overall system improvements required
Thank you!

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