

MANAGEMENT OF SOLID WASTE USING LOW-TEMPERATURE MAGNETIC PYROLISER

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology Degree in Chemical Engineering

by

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SCHOOL OF BIO & CHEMICAL
ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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OCTOBER 2023



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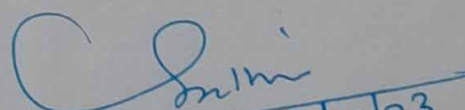
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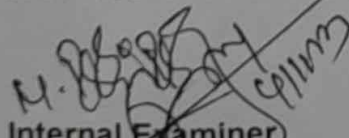
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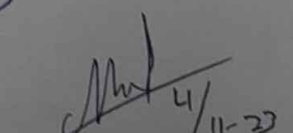
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Submitted for Viva voce Examination held on 4-11-23



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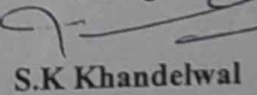
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This is to certify that this Project Report entitled "Management of solid waste using low temperature Magnetic Pyrolizer" is a bonafide work of Mr. BAHAR ALI (Reg No. 40690003) in partial fulfilment of the requirements for the award of "Bachelor of Technology in Chemical Engineering" who can carry out the project under my supervision from July 2023 to November 2023. After the completion of the project, a journal publication of the work carried out shall be done.

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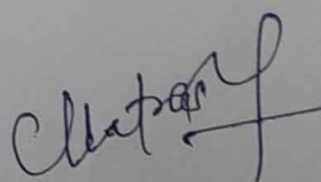
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I CHHATRASHAL CHAUHAN (Reg. No.40690004) hereby declare that the Project Report entitled **Management of Solid Waste using low-temperature magnetic pyroliser** done by me under the guidance of Dr. M. KARTHIKEYAN, M.Tech, Ph.D, Assistant Professor, Department of Chemical Engineering, Sathyabama institute of science and technology at BHABHA ATOMIC RESEARCH CENTRE FACILITY, KALPAKKAM is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in **Chemical Engineering**.

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ACKNOWLEDGEMENT

We express our heartfelt gratitude to the Board of Management of SATHYABAMA for their invaluable support and encouragement in the successful completion of this project.

We extend our appreciation to Dr. S. SATHISH, M.E., Ph.D., Head of the Department of Chemical Engineering, for his timely guidance and support provided during the progressive reviews.

We would like to convey our profound gratitude to our Project Guide Dr. M. KARTHIKEYAN, M.Tech, Ph.D, Assistant Professor, Department of Chemical Engineering at Sathyabama University, and all the official who is helping and guiding us at Bhabha Atomic Research Centre Facility, Kalpakkam, for their invaluable guidance, suggestions, and unwavering encouragement, which played a pivotal role in the successful completion of our project.

We wish to extend our gratitude to all the teaching and non-teaching staff members of the Department of Chemical Engineering who provided valuable assistance in various ways, contributing to the successful completion of our project.

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ABSTRACT

The equipment is designed for management of 100 kg per day of radioactive solid waste received from various units at Kalpakkam. The swatch machine consists of various sub-systems viz. feeding hopper with double door charging mechanism, furnace, two stage spray scrubbers, re-heater, de-humidifier, HEPA filter, exhaust blower, stack, ash removal conveyor and a local control panel.

The feeding hopper provides path for the waste to the furnace and double door charging mechanism aids in maintain negative pressure also prevents the escape of flue-gases into the operating environment during feeding. The furnace consists of six electrical heaters for initial heating and air to the furnace is supplied through eight permanent magnets. These magnets converts the oxygen molecules in the air to its free radical form and aid in destruction of the mixed waste at lower temperature i.e. at about 200-250°C. The flue-gases generated during the decomposition process are passed through two stage spray scrubbers. After first stage scrubbing, the flue-gases are re-heated using electrical heater at about 550-600°C for incinerating carcinogenic gases, if any. These gases are again treated in a second spray scrubber. Water is used as scrub medium in both the stages. The scrubber solution is stored in a dedicated tank of about 200 litres capacity. After second stage scrubbing, moisture in the gases is removed in a demister and particulate activity is removed in HEPA filters and exhausted through blower via stack. Two stages of ash removal conveyors are incorporated in the system for taking out ash collected after decomposition process. A screw conveyor is provided for removal of ash and it is collected in a specially designed container.

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CHAPTER 1

1.1 INTRODUCTION

Radioactive Waste Management Facility has been designed for the receipt & storage, treatment and discharge of radioactive liquid effluents; segregation, collection, treatment and disposal of radioactive solid wastes; decontamination of contaminated protective wear & equipment; generated at various nuclear facilities like nuclear power station, reprocessing plants, test reactors and various laboratories. It has also been designed for receipt and management of institutions and industries.

Solid Waste Management processes with an aim to reduce the volume viz.

- a) Combustible waste in a high temperature excess air Incinerator,
- b) Compressible waste in a Compactor and
- c) Polythene waste in Melt Densification Systems.

Whereas, mixed wastes are being disposed directly in NSDF without processing. Also, the volume reduction achieved in compaction is less and after compaction the product contains radioactivity in migratable form. For the management of mixed waste, it is proposed to develop a system (wherein which these deficiencies could be addressed) named SWATCH Machine in which waste is decomposed at low temperature.

This development is targeted at developing a new Waste Management Technique which can give significant volume reduction of radioactive solid waste, safe destruction of plastic waste and effective containment of the radioactivity in conditioned form.

The system has been designed with enough safety precaution such that if any malfunctioning occurs due to abnormal operation and accidents, operators do not get exposures and also spread of activity is contained in the furnace.

CHAPTER 2

2.1 LITERATURE SURVEY

2.1.1 WASTE SORTING

Enhancing the efficiency of any management method under consideration is contingent upon the initial sorting of waste at its source. When it comes to volume reduction, a significant advantage lies in the ability to pinpoint the origin of waste. This simplifies the handling process, particularly because specific laboratories tend to generate typical waste types and radionuclide contaminants. This holds particularly true for wastes containing tritium, ^{239}Pu , or ^{90}Sr , as they are challenging to detect and require maximum information from the source. For larger items that may contain highly irradiated sections, subsequent processes are streamlined if the source specifies which sections are hazardous. The waste materials are then gathered by the relevant department at the pre-removal storage site and subsequently categorized at the pre-treatment storage site. This classification allows for the identification of batches that need to be directed to various reduction facilities.

Significant importance on the following suggestion for new facilities are placed: Even in the absence of waste-treatment facilities, it is crucial to commence the classification and storage of generated waste into categories immediately. Opting for bulk storage without taking specific precautions would inevitably lead to formidable challenges during the eventual waste collection for treatment, rendering the utilization of reduction methods unfeasible.

2.1.2 DECONTAMINATION

While this primarily focuses on matters outside the realm of decontamination, we find it necessary to mention it due to its relevance to the issues at hand, particularly concerning materials like metal that are amenable to mechanical treatment methods. For instance, a decontamination facility can effectively address numerous challenges associated with mildly contaminated scrap, presenting a highly viable solution. Even if decontamination isn't feasible, it's important to consider that disassembly tasks become significantly more manageable when prior decontamination has been carried out or when radioactive activity has naturally decayed. It's often advisable to develop decontamination and treatment station plans in tandem since they are frequently intertwined.

2.2 MECHANICAL METHODS OF VOLUME REDUCTION

The goal of mechanical methods involves modifying the composition of solid waste using either compaction or fragmentation, with the aim of reducing the total space occupied by the material. Compaction directly decreases empty spaces, while fragmentation indirectly achieves this by breaking down larger pieces into smaller fragments suitable for effective packaging or further reduction through compaction. In essence, compaction and fragmentation can work together to achieve waste reduction. However, the choice between these methods is generally determined by the physical characteristics of the waste, including hardness, shape, size, and rigidity.

2.2.1 COMPACTING

Low-level wastes in nuclear facilities usually make up a substantial portion, approximately 70-80%, of materials that are easily compressible due to their texture and volume. This category often encompasses materials like paper, fragments of plastic or rubber, rags, glassware, and small metallic items.

The remaining waste materials pose challenges for compaction. This category includes large items resulting from dismantling operations, demolition debris (such as concrete, cut-up scrap metal, contaminated soil, etc.) with a volumetric activity slightly above the disposal limit for public services. However, compaction methods are unsuitable for items that are extremely dense and hard, resulting in minimal or no reduction in volume. It's also impractical for items susceptible to press damage, such as very long metal components that might become jammed between the ram and the press's bottom; in such cases, cutting them into sections may be a viable solution. Furthermore, materials containing pyrophoric or explosive substances and any waste materials with liquid content are not suitable for compaction.

Given these restrictions, a thorough assessment of wastes is crucial before considering them for compaction. Regrettably, this entails an extra handling step - sorting - which carries the potential for operator exposure risks. The cost of this process is a notable factor and a drawback of the reduction method when viewed from an economic perspective.

Compacting techniques

Air present within the wastes is expelled during the compaction process, which raises the concern of potential atmospheric contamination. To address this issue, appropriate precautions must be taken in accordance with the potential hazards involved. In the most critical scenarios, particularly when dealing with alpha emitters or toxic materials like beryllium, it is necessary to house the compaction facility within a well-ventilated enclosure. In less severe cases, a ventilation hood can automatically remove aerosols generated by the waste materials. If the activity levels are sufficiently low, a press can be installed outdoors with a simple roof structure. The selection between a horizontal or vertical ram for the press is determined by considerations like input and extraction configurations and the available space.

The pressure applied varies from 30 to 150 kg/cm², depending on the desired reduction factor. The ram's size is determined by the waste materials' dimensions, the quantities to be processed, and the packaging requirements, including the type of final container. These two factors collectively establish the press's capacity, which can range from a few tons to several hundred tons.

Systematic experiments have shown that the maximum volume reduction is yielded by the following pressures:

polyethylene : 80 kg/cm² filter elements : 70 kg/cm²
cotton and rubber : 50 kg/cm² metallic wastes : 110
kg/cm² average sample : 65 kg/cm²

Excessive compaction pressures do not appear to be essential. Generally, a pressure range of 30-45 kg/cm² is sufficient and does not result in undue contamination dispersion due to drum breakage (unless punctured by metallic waste). Moreover, in the majority of instances, this pressure range yields a volume reduction very close to the maximum achievable..

If waste materials are compacted along with the collection containers, it is, of course, vital to consider the durability of those containers. While higher reduction values can be achieved with increased pressures, this necessitates the use of specialized, albeit pricier presses, and higher-quality storage containers, which will be used for the compression process.

Waste bins can be loaded into the press, creating a disposable envelope. If these bins are constructed from metal, they effectively inhibit substantial expansion after the compaction process.

Wastes can be directly introduced into the compaction mold, provided there is an input system in place to prevent contamination, and durable bins that can be reused. It's also worth considering systems where the more radioactive wastes are positioned in the centre to enhance biological shielding.

The selection of the mold shape is influenced by the geometric characteristics of the final packaging. A package in the form of a parallelepiped is better suited for trench storage, whereas a cylindrical package is more appropriate for later bituminization or cementing. When compressing waste inside the storage container, it's crucial to control the force applied by the ram to avoid damaging the container's walls or base. In this context, waste can be loaded in successive layers with retaining strips in between to prevent expansion when the pressure is released.



Fig: 2.1: Drum before & after compaction, VRF ~ 6



Fig: 2.2: HEPA filter before & after compaction, VRF ~ 10

2.3 THERMAL METHOD OF VOLUME REDUCTION - INCINERATION

A substantial portion of the low-activity wastes produced in a nuclear facility is combustible. The resulting ash quantity is relatively minor, resulting in a volume reduction factor of approximately 50 - 80 and a weight reduction factor of 50.

2.3.1 INCINERABLE WASTES

Cellulose: Naturally occurring polymeric compounds like wood, paper and cotton etc.

Composition of waste (typical):

Moisture - 30%

Cellulose- 60%

Non-combustible- 10%

Sulphur, Nitrogen- Negligible

It's also essential to take into account important characteristics such as the physical state, chemical state, and calorific value.

The physical state has an impact on the combustion rate. Materials that are overly compact may result in incomplete combustion, while finely powdered materials can lead to spontaneous combustion.

The chemical state is a critical factor in influencing the extent of corrosion. Certain materials, particularly plastics, can generate highly corrosive gases that can damage the gas extraction and filtration system. The calorific value has a direct impact on the temperature inside the furnace. Many wastes have a specific calorific value or moisture content, both of which affect the combustion rate and the frequency of charging the furnace. Maintaining the correct temperature is essential to ensure thorough combustion and reduce the emission of unburned particles.

2.3.2 WASTE SORTING BEFORE INCINERATION

Sorting wastes before incineration is crucial, even more so than in the case of compaction. It is imperative to exclude any explosive substances, as well as materials that can generate toxic vapors (like phosgene) or corrosive vapors (such as organic chlorides and fluorides).

An additional benefit of sorting is that it allows for a reasonably uniform feed to the burner. This, in turn, leads to improved combustion control and helps prevent the build up of unburnt materials in the off-gases. This aspect is highly significant as it enables more stable operation of the facility and diminishes the risk of accidents resulting from excessive carbon black formation.

The sorting of radioactive wastes will be carried out within a glove box or a leak-proof enclosure. The latter method is more efficient, although it requires operators to wear pressurized suits. It also enables the performance of any necessary preparatory mechanical operations, such as cutting and shredding. Combustible wastes are placed in bags made of non-halogenous materials, like polyethylene or paper.

The installation for sorting radioactive waste must be positioned at a safe distance from the incinerator's charging point. This precaution is taken to minimize the risk of fire propagation in case of an explosion or excess pressure within the charging lock.

2.3.3 INCINERABLE LIQUIDS

Liquid wastes can be disposed of in an incinerator if they possess some calorific value, such as mineral oils or solvents. These liquids are incinerated in conjunction with solid wastes. However, for injection through nozzles, it may be necessary to adjust their viscosity by preheating or by dilution with a solvent (e.g., white spirit). These liquids might contain suspended mineral particles, which should be filtered out. In the case of soluble oils, the aqueous phase must be eliminated through the prior destruction of emulsions.

2.4 INCINERATION

Now, let's explore the different operations necessary for the incineration of these waste types.

2.4.1 CHARGING

The feeding into the furnace is through a securely sealed and well-ventilated system. The ventilation will be adjusted according to the relative pressure levels in both the external area

and the combustion chamber.

The lower door is made of refractory material or designed as a double-walled structure with water circulation for cooling. This design prevents the waste in the lock from overheating. It's important to note that a feeding system involving successive batches presents fewer challenges than a continuous feed (e.g., using a screw). However, the continuous feeding method offers the advantage of ensuring a more uniform operation, especially in systems with limited capacity.

2.4.2 COMBUSTION

The choice of combustion method is contingent on both the waste thickness on the grate and the direction of air flow. Two fundamental principles can be employed:

In this approach, air passes through the grate, facilitating combustion. This method involves preheated air entering at the top of the furnace, traversing through the waste, and exiting with the off-gases at the bottom of the ash pit. When employing a downward air flow and a substantial layer of waste, it tends to increase the unburnt portion but facilitates the combustion of distillation by products.

Both methods have their merits. For instance, upward air flow results in a smaller unburnt fraction but can lead to the entrainment of ash. Nonetheless, the airflow rate must be adequate in either case to guarantee complete combustion.

The furnace chamber can be constructed using firebrick with an external insulation lining made of mild sheet steel, similar to conventional designs used for incinerating industrial waste. Additional insulation is achieved by including an asbestos lining in direct contact with the metal wall. These systems are typically based on standard models used for the incineration of regular waste. Firebrick generally exhibits good resistance to corrosion from the primary combustion products. Reducing contamination can be accomplished by using high-quality bricks, and it's advisable to glaze them before putting the installation into operation.

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2.4.3 COMBUSTION CONTROL

The heat required to initiate and control combustion is provided by burners that use propane, coal gas, or oil. The selection of the fuel depends on the available supply options. It's worth noting that while oil combustion produces less water, it can often lead to the generation of sulfur dioxide, which, in the presence of water, can result in the formation of sulfuric acid and an increased risk of corrosion. In specific situations, electric heating may be employed, particularly in furnaces with low capacity or when high temperatures are required.

During the startup phase, the burners are used to raise the furnace to its operational temperature. Once this temperature is attained, the burners assume an auxiliary role, primarily because of the heat generated by the combustion of the waste materials. While loading the furnace, temperature fluctuations may occur, but it should be carefully controlled, ensuring it doesn't exceed 1100°C or drop below 700°C. Typically, an average temperature of 900°C is targeted to minimize the quantity of unburnt material and soot in the off-gases and to maintain conditions that won't harm the installation. Excessive temperatures could lead to rapid deterioration.

To reduce the presence of unburnt material carried by the gases, it is recommended to install an afterburner at the outlet of the primary combustion chamber. The temperature within the afterburner is maintained at around 1100°C, which is higher than the temperature in the combustion chamber. Additionally, it's crucial to maximize the contact area between the hot walls and the gas to improve combustion efficiency.

2.4.4 ASH COLLECTION

Sufficient ash collection points should be established to facilitate the cleaning of the entire installation. The ash pits should be constructed from refractory material resistant to corrosion. Ashes can be collected either directly in drums connected to the ash pit outlet or mechanical raking methods.

The ash removal process can also involve flushing the ashes out with water through a dedicated channel that drains the different collection points. While this method helps prevent contamination, it generates a certain volume of liquid effluents, which will need to be treated separately.

2.4.5 GAS CLEANING

At the exit of the combustion chambers, the gases, which remain at a temperature of approximately 1100°C, still carry a significant level of radioactivity, with most of it being attached to the solid particles suspended in the gases. These particles need to be eliminated through a clean-up system before the gases can be safely released into the atmosphere.

The gases are initially cooled and subsequently decontaminated as they pass through various filtration systems.

(a) Cooling

Three methods of cooling can be considered: The cooling process is achieved through adiabatic cooling using a counter-current spray of cold water, dilution of the gases with external air, and circulation of the gases through a tubular air-cooled heat exchanger.

The first of these methods provides efficient cooling and additionally absorbs the free acidity of the off-gases. However, it's necessary to treat the water later to remove contaminants.

The other two dry methods may not be as efficient. Dilution requires an expansion in the capacity of the filtration equipment, and circulating gases through heat exchangers can lead to condensation and corrosion.

(b) Gas cleaning by wet method

After cooling, the gases can be cleaned either in a venturi scrubber; In a washing cyclone; In a washing column packed with ceramic spheres or Raschig rings.

The cleaning devices necessitate an additional installation for filtering and neutralizing the wash water before it can be recycled. This setup typically includes a coarse prefilter, followed by a sand or diatom filter. It also features an exchanger to lower the temperature of the purified water to below 50°C and a pH control system to maintain the pH at around 7.5.

In the event that further thorough removal of dust from the gases is required through absolute-type filtration, the water droplets suspended in the gases must initially be captured at the exit of the wet separators. After this step, the gases are heated above their dew point.

The final stage can be carried out using either an electrostatic filter or a set of conventional absolute filters, with pre-filters if necessary.

(c) Gas cleaning by dry method

The dry method offers the advantage of maintaining the gas temperature above the dew point, thus preventing corrosion resulting from acid condensation. Achieving this requires meticulous insulation of the entire dust removal unit. Additionally, the dry method eliminates the need to manage liquid effluents as in the wet method, and it generally results in less severe corrosion. The disadvantage of the dry method is its potential fire hazard. Dry methods can lead to the accumulation of tar and carbon black in the cleaning system. To mitigate the risk of combustion from these deposits, efforts should be made to minimize their formation. This can be achieved through effective afterburning of the off-gases and continuous removal of deposits. The gases then proceed to the initial stage of filtration, passing through bag filters made of corrosion-resistant materials like silicone-treated glass-fiber. These filters are cleaned either by mechanical shaking or pneumatic pressure, causing the soot to fall into a hopper. Alternatively, electrostatic filters, which are known for their efficiency but come at a higher cost, can also be used as long as the trapped particles are continuously removed.

In the final stage of the cleaning process, similar to wet treatment, absolute filters are employed, and these are protected by pre-filters. Generally, both pre-filters and absolute filters are engineered to function at temperatures exceeding 150°C.

In cases where the wastes contain hazardous volatile substances, such as iodine, mercury, sulfur, or ruthenium, a scrubber or washing tower will be necessary to neutralize the gases.

High-temperature filter

Incinerator gases are typically cleared after cooling for two main reasons. Firstly, it's challenging to create high-temperature filters that can withstand the extreme heat of the gases. Secondly, there's a risk of filter damage due to the combustion of unburnt products if filtering is attempted at high temperatures. As discussed earlier, low-temperature filtration comes with its own set of drawbacks, including the need for cooling, increased corrosion, and filter clogging by unburnt products, which requires frequent or continuous cleaning.

A noteworthy development in the field of hot-gas filtration involves ongoing research on reusable filters. One such filter consists of metal-foil cylinders onto which asbestos fibers, serving as the filter medium, are applied through a spraying process. The filter's operation principle is based on unburnt products from the incinerator, particularly carbon black, completing their combustion on the filter as they are produced. This approach significantly inhibits clogging, allowing the filter to be utilized for several hundred hours before requiring regeneration. In cases where filtration efficiency is deemed inadequate, especially considering the hazardous nature of the treated

wastes, absolute filters can be integrated. An industrial installation employing this innovative filter design is presently under construction in France.

2.4.6 CONTROL AND SAFETY SYSTEMS

The controls for the various electro-mechanical or pneumatic components of the incinerator, such as the fan, pumps, and burners, will be located on a panel in close proximity to the installation. This control panel will also include dials for the various instruments used to measure parameters like combustion-chamber temperatures and pressures, gas temperature at different points in the cleaning circuit, differential pressures to monitor filter clogging, and the pH of the washing water.

Furthermore, the control panel will be equipped with both auditory and visual alarms designed to promptly notify operators of any operational irregularities, including issues related to temperature and pressure in the combustion chamber or the extinguishing of a burner flame. To perform any additional checks, it will be essential to plan for the installation of isokinetic sampling probes at appropriate locations during the construction phase.

To prevent the release of radioactive gases into the working area due to excessive pressures in the combustion chambers, it is recommended to install a relief stack with a calibrated safety valve in the furnace. Non-return valves should also be installed in the air inlets. To enhance safety measures, consider supplementing the essential devices with propane-leak detectors and fire detectors. When utilizing dry cleaning methods, particularly in the cleaning process, anti-spark devices should be positioned upstream of the bag filters. Additionally, ensure the provision of a water or inert-gas extinguisher system for fire safety.



Fig: 2.3: Incinerator

2.5 MELT DENSIFICATION UNIT (MDU)



Fig: 2.4: Melt densification Unit

A new process has been developed indigenously at BARCF for the treatment of polythene waste in which the waste is melted in a furnace at about 180° C temperature. In this process the Volume Reduction Factors (VRF) are higher than that obtained in compaction and the matrix formed has good leaching resistance.

A new method of conditioning radioactive polythene waste uses melting and densification in a closed furnace at 180°C and volume reduction factor is achieved 20 – 30. Fumes are adequately treated to remove all possible radioactivity, before its release to the atmosphere. Furnace temperature is maintained below 200°C. Vacuum is maintained in the furnace. Stack Monitoring is available during operation. HEPA filter bank Efficiency $\geq$ 99.5% for 0.5 μ m particles & above.



Fig: 2.5: Polythene waste before and after MDU operation

2.5.1 DESCRIPTION OF THE SYSTEM

Melt Densification Unit consists of S.S electric oven with steel platform, Teflon Coated S.S. Charging Chute with Slide Valves, S.S. Slat Type Conveyor, Scissors Type Hydraulic Lift with Motorized Trolley, Control Panel etc. The details of these sub-systems are as follows:

2.5.1.1 ELECTRICALLY HEATED FURNACE

The size of the S.S electric oven/enclosure is 1400 mm diameter and 1200 mm height located on a structural steel platform. The enclosure has three viewing windows of size 200 mm x 150 mm. The enclosure has a charging chute with pneumatically operated two slide gates which

will ensure vacuum in the oven while feeding the waste in to the drum. At the bottom of the enclosure a circular opening is provided for entry & exit of standard M.S drum.

The electric oven has three equal heating zones each rated 5 KW, (total oven heating load 15 KW) along the height of the oven. Each zone was electrically connected so that these zones can be operated independently and/or collectively. The oven is constructed using the refractory bricks for insulation and Kanthal heating elements of 16 gauge with a surface loading of 1.3 watts/cm². The elements are placed in the refractory slots from inside the oven and leads were taken out through back holes in the refractory bricks. The outer casing of oven is 2 mm thick S.S sheet. The oven is operated using single phase supply for each heating zone. The maximum temperature the oven can develop is about 200 degree centigrade. Two parallel temperature control units and three temperature measurement points are provided to safeguard against temperature control failure and prevent fire hazard due to uncontrolled temperature rise. The thermocouples used are of copper constantan type PID controllers.

A tapered charging chute/hoper with double door pneumatic slide valve arrangement using S.S coated with Teflon (50 micron) is provided on the top of the oven. The slide valves operate by compressed air. The pneumatic cylinders are double acting type and operates at 6 Kg/cm² with 4 way 24 V solenoid valves for direction control from rotary selector switches located at Control Panel.

2.5.1.2 FEED CONVEYOR

A motorized S.S. slat type conveyor belt with 325 mm wide is used for feeding the waste packages into the hoper. The feed of the conveyor is controllable step-lessly using a VFD motor. Figure gives the details of the conveyor assembly. The technical specifications of the system are:

1. Slat Width - 325 mm
2. Chain - Heavy duty 4" pitch, steel bushed roller chain.
3. Drive Shaft - 40mm diameter cold rolled steel.
4. Drive Location - Floor Mount
5. Tail Shaft - 2" diameter cold rolled steel.
6. Take-Up - Screw type, mounted at tail end of conveyor for adjustment of chain tension.
7. Motor - Suitable HP 415V AC / 50 TEFC motor, Brake Motor (VFD)
8. Reducer - Heavy duty worm gear reducer.
9. Speed - 1500 mm per minute to 10000 mm per minute, variable speed.
10. Capacity - 10 Kg. per foot maximum

2.5.1.3 HYDRAULIC LIFT AND MOTORIZED TROLLEY

The trolley to carry the drum is mounted on rail track for a length of about 6 meter. The rails have three limit switches at home position, loading position and at the bottom of the oven. The scissors type lift table is operated by hydraulic power cylinders for a height of about 1500 meter. Figure details about the hydraulic power pack and scissors lift. Guide is provided on the trolley for resting the drum and precise entry into the furnace. The trolley is provided with silicone rubber which can withstand temperature about 300°C as heat insulator and to act as a seal between trolley table and oven opening. Motorized Trolley with rails is shown in figure. The technical specifications of the system are:

1. Capacity - 0.5 MT dead load on trolley platform
2. Speed of the trolley - 5 m / minute
3. Working temperature - Ambient
4. Motor - 415 V & 50 Hz. +/-5%, brake motor.

2.5.1.4 CONTROL PANEL

A Programmable Logic Controller (PLC) based control panel is provided for the control & monitoring of furnace, motorized trolley, hydraulic lift, feed conveyor, double door mechanism, blower and alkaline scrubber solution pump. It has provision for personnel computer connectivity for editing the automation of the equipment. All operations of MDU are provided in auto and manual modes of operation. The temperature indicating controllers with set point adjustable and process variable indication is provided on the panel. Panel is provided with push buttons for manual operation and emergency stop in mishap. Indicator lamps are located on Control Panel with legend plates. Display is provided on the control panel for:

- The drum is position
- The pneumatic slide valves OPEN / CLOSE position
- The trolley position indication
- Electric supply indication for three Zones of Heating coils
- Visible indication in temperature high alarm
- Audible sound when the process completed

2.5.1.5 OFF – GAS SYSTEM

The unit is provided with a dedicated off-gas system for the treatment of the toxic gases generated, if any. The off-gas system consists of alkaline scrubber, de-mister, HEPA filter and a blower. The treated gases are discharged to the environment through a stack. The unit is maintained under vacuum so that no gases will leak into the working environment.

2.5.1.6 SAFETY FEATURES AND INTERLOCKS

The following safety interlocks are incorporated in the design stage of the unit:

Interlocks:

If drum is not in position on the trolley at drum loading position, the subsequent operation wouldn't occur (object sensor should get cut-off). The Hydraulic Lift cannot be operated, till the trolley is exactly positioned under the furnace (limit switch should get activated). Feed conveyor cannot be operated, if the drum is full OR a waste packet is on the top sliding door of the charging chute (object sensor should get cut-off). If the blower is not in ON position, the sub-systems cannot be operated. If the vacuum is not maintained in furnace, the sub-systems cannot be operated. If the scrubber pump is not working, the sub-systems cannot be operated. Compressed air (6 Kg/cm²) is not available; the conveyor cannot be operated.

Safety Features:

An EMERGENCY STOP button is provided on the control panel for immediate stopping of the operations. Thermocouples are installed at three locations of the furnace to provide continuous temperature monitoring. PID controllers are provided for the temperature control of the heating elements. The pneumatically operated double door charging arrangement provides the desired isolation of the furnace from the environment during the process of charging of the waste packages into the furnace. It is ensured by inter lock that only one of the door can be opened at any time. Stack monitors are provided in the stack for the detection of any activity release. Area gamma monitors are provided in the working area. The operating area has PVC flooring, for easy decontamination.

CHAPTER 3

3.1 AIM

Treatment of solid waste with an aim to reduce its volume employing the techniques viz.

- a) Incineration - Combustible waste in a high temperature excess air Incinerator,
- b) Compaction - Compressible waste in an advanced Compactor and
- c) Melting - Polythene waste in Melt Densification Systems.

Whereas, mixed wastes are viz. mops are being disposed directly in NSDF without processing. Also, the volume reduction achieved in Compaction is low and the product contains radioactivity in migratable form.

- 1. With an aim to manage mixed wastes, it was proposed to develop a pilot-scale system in which waste is destructed at low temperature with the assistance of magnetic field. Presently radioactive mixed solid waste is being disposed directly in NSDF.
- 2. With an aim to enhance the treatable fraction of radioactive solid waste, achieve higher Volume Reduction Factors a novel process technique which decomposes mixed waste at low temperature with the aid of magnetic field was proposed to be developed.

3.2 SCOPE

This facility is a special furnace for Magnetization pyrolysis of all the radioactive organic waste and it's different from the conventional burning because it doesn't need fuel.

The source of energy is only used in ignition and exhaust smoke abatement.

- 1. Installing, Commissioning and Developing the system.
- 2. Carrying out experiments and wanted to achieve the Volume Reduction Factor as high as possible.
- 3. Condition the ash in cement matrix.
- 4. A pilot-scale system of capacity 100 kg per day was developed. It consists of several sub-systems viz. feeding hopper with double door charging mechanism, furnace, two stage spray scrubbers, re-heater, de-humidifier, HEPA filter, exhaust blower, ash removal conveyor and a local control panel.

CHAPTER 4

4.1 EXPERIMENTAL STUDIES METHODS

4.1.1 PILOT SCALE EXPERIMENTAL SETUP

The equipment capacity is 100 kg per day. The system consist various sub-systems viz. feeding hopper with double door charging mechanism, furnace, two stage spray scrubbers, re-heater, de-humidifier, HEPA filter, exhaust blower, stack, ash removal conveyor and a local control panel.

System layout

The layout of the system has been designed in such a way that the space requirement is minimum and ease of operation & maintenance. The layout & elevation drawings of the system are given in the following figures:

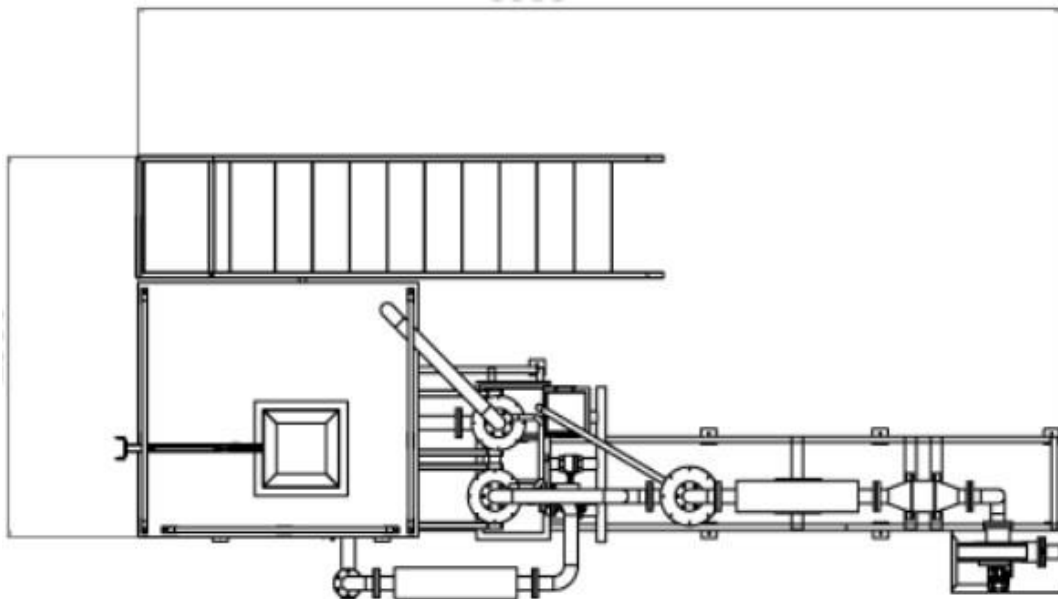


Fig: 4.1: Layout diagram of the system

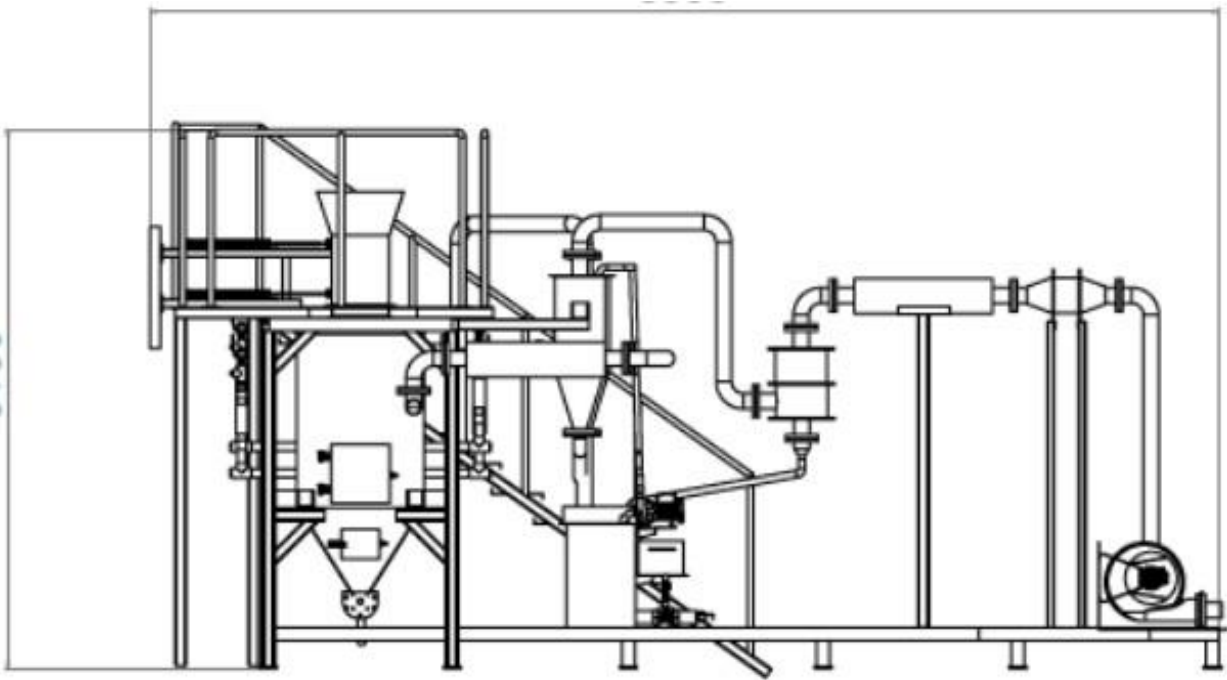


Fig: 4.2: Elevation diagram of the system

4.1.2 ACTUAL PILOT SCALE SETUP



Fig: 4.3: Experimental setup



Fig: 4.4: Experimental setup



Fig: 4.5: Experimental setup

4.1.3 SYSTEM DESCRIPTION

The swatch system shall contain the following major parts:

- a. Feeding hopper: This will provide path for the waste to the furnace with double door charging mechanism. The doors are operated and will arrest escape of flue-gases into the operating environment.
- b. Furnace: It consists of permanent magnets for ionization of the oxygen molecules to form free radicals. These free radicals will aid in destruction of the mixed waste at lower temperature.
- c. Scrubbers: The flue-gases generated during the decomposition process are passed through two stage venturi wet scrubbers. Water is used as scrub medium in both the stages. The scrub solution is stored in a dedicated tank of about 100 liters capacity, divided into two parts.
- d. Re-heater: The flue-gases after first stage scrubbing are re-heated using electrical heater for treating left out carcinogenic gases.
- e. De-humidifier: The flue-gases after second stage scrubbing are de-humidified and passed to the HEPA filter.
- f. Exhaust system: It will remove the flue-gases formed in the furnace during decomposition process and maintains vacuum.

- g. Ash removal conveyor: Two stages of ash removal conveyors are incorporated in the system for taking out ash collected after decomposition process.
- h. Control panel: All the sub-systems listed above are operated using a local control panel.

The following developmental works are carried out to adopt the system for treatment of radioactive solid waste:

- a. Pneumatically operated double door feeding system to integrate with the furnace to load radioactive solid waste into the furnace.
- b. DE-mister/ De-humidifier for eliminating the moisture in flue gases (after scrubbing).
- c. HEPA filter to in the off-gas treatment which decontaminates particulate radioactivity in the flue gases.
- d. Exhaust blower on the downstream of HEPA, to maintain the complete system under vacuum and to discharge treated off-gases into the environment via stack.
- e. The scrubber tank is sealed to avoid airborne activity generation in the operating area.
- f. Provision to supply air required for the destruction operation.

4.1.4 DESIGN SAFETY FEATURES OF THE SYSTEM

- a. Double door charging mechanism for feeding mixed waste in to the waste destruction chamber.
- b. The chamber is maintained under minimum of 10 mm of vacuum during operation with the help of an exhaust blower.
- c. The temperature of the chamber is monitored using thermocouples.
- d. Un-burnt particulates if any will be combusted in after heater.
- e. The off-gases are treated in a dedicated wet off-gas decontamination system and passed through HEPA filters before releasing to atmosphere.

Table 4.1: Specifications of the system

i.	Model	Swatch - 100
ii.	Capacity of the machine	100 kg/day
iii.	Type of system	Magnetic Thermal Waste Destruction System
iv.	Material for treatment	Mixed Solid Waste Dry & Wet viz. Plastic waste, Paper Waste, Cartons Waste, mops, Polyethylene bags & sheets etc.
v.	Material Characteristics	Organic waste
vi.	Temperature	350 - 400 Deg. Celsius
vii.	Material of Construction	Mild Steel (M.S.)
viii.	Type of feeding & no's	Top Feeding System with a hopper - one point
ix.	Furnace with permanent magnets	Decomposition of mixed waste at low temperature
x.	Scrubber type & no. of stages	Venturi type - two stages with a storage tank
xi.	Re-heater	Electrical type - One number
xii.	De-humidifier	One number
xiii.	Exhaust system	500 CMH and 250mm static head Blower HEPA filter casing with one no. of 610mm x 610mm x 300mm HEPA filter
xiv.	Ash Removal	Using screw conveyor
xv.	Safety Features	Vacuum in the chamber during waste destruction operation, Off-gas treatment, temperature monitoring etc.
xvi.	Insulation	Insulation to maintain skin temperature less than 50 Deg. Celsius

4.1.5 SWATCH MACHINE DESIGN SPECIFICATIONS

The equipment is designed for management of 100 kg per day of radioactive solid waste received from various units at Kalpakkam. The moisture content of the waste has to be less than 40%, if not time taken for destruction will be higher.

Design Specifications / Basis

1. Designed capacity - 100 kg per day or 0.5 cu.m/day with maximum of 40% moisture.
2. Maximum surface dose rate of the mixed waste processed ≤ 0.2 mGy/h (20mR/h).
3. Designed to maintain negative pressure greater than 10 mm of WC in the furnace.
4. The flue gases (produced during decomposition) are treated in dual stage spray scrubbers.
5. Secondary auxiliary heater is provided in the flue-gas line for the incineration of toxic gases, if any.
6. The flue-gases are discharged through stack meeting CPCB norms on flue gases release for industrial Incinerators.
7. Particulate activity in the flue-gases is decontaminated by HEPA filter. The efficiency of the filter is $> 99.95\%$ and pressure drop maintained across the filter is 100 mm of WC.
8. Radioactivity in the flue-gases is monitored through stack monitor and discharges are maintained within the authorized limits.
9. The specific activity of the scrubber water (secondary waste) is maintained below 37 Bq/ml (10^{-3} mCi/l, i.e. up to Category-II), and is transferred to LETP for further management.
10. The ash produced is conditioned in cement matrix prior to disposal in NSDF.

4.1.6 OTHER SAFETY FEATURES

1. The system has double door charging mechanism for feeding mixed waste into the waste destruction chamber/furnace.
2. The chamber is maintained under minimum of 10 mm of vacuum during operation, with the help of an exhaust blower.
3. The temperature of the chamber is monitored using thermocouples.

4. Un-burnt particulates, if any are incinerated in an after heater.
5. The flue-gases are treated in a dedicated wet flue-gas decontamination system and passed through HEPA filters before releasing to atmosphere via stack.
6. Class -III power supply is provided for safe shutdown of the system, in case of failure of Class-IV power.
7. Area Gamma Monitor, stack monitor is provided for radiological safety.

4.2 METHODOLOGY

The mixed waste is fed into the furnace through hopper with the help of double door charging mechanism, maintains negative pressure and also prevents the escape of flue-gases to the operating area during feeding. The furnace consist six electrical heaters (1.6 kW each) for initial heating and air to the furnace is supplied through eight permanent magnets. These magnets convert the oxygen molecules in the air to its free radical form which aids in destructing the mixed waste at lower temperature i.e. 200-250°C. The flue-gases generated during the decomposition process are passed through two stages of spray scrubbers. After first stage scrubbing, the flue-gases are re-heated using electrical heater to about 550-600°C for incinerating dioxins & furans, if formed. These gases are again treated in a second spray scrubber. Water is used as scrub medium in both the stages. The scrub solution is collected in a dedicated tank of about 200 litres capacity and recycled. After second stage scrubbing, moisture in the gases is removed in a demister, heated again through auxiliary heater. The pre-heated gases are passed through HEPA filter wherein particulate activity is removed and exhausted through blower via stack. A screw conveyor is provided for removal of ash and is collected in a specially designed container. The operations are carried out from a local control panel. The system has been designed with enough safety precaution such that if any malfunctioning occurs due to abnormal operation and accidents, person should not get excessive exposures and also spread of activity is contained in the furnace.

4.2.1 WASTE ACCEPTANCE CRITERION

The following is waste acceptance criterion for treatment of mixed organic solid waste in the Swatch machine:

1. Solid waste packed in double polythene bags and placed inside standard MS drums of 200 litre capacity with a lid properly secured is to be received and stored.
2. The moisture content of the mixed organic solid waste should be less than 40% w/w.
3. The surface dose rate on the waste package should be less than 0.2 mSv/h (20 mR/h).
4. Transferable contamination on the external surface of waste packages should not exceed 4 Bq/sq.cm.
5. Waste should not contain leachable material.
6. Waste should not contain any self-igniting or pyrophoric materials and free liquid.
7. The waste should not contain inorganic materials such as glass, ceramic, metals etc.
8. The waste should not contain any explosive materials.

Prerequisites

Class - IV power supply, compressed air supply (6 kg/cm²), ventilation system in the operation area and Working of AGM / CAM should be available.

Precautions

Ensure that both the sliding doors and maintenance ports of the furnace are closed. Heater, scrubber pump, exhaust blower is in working condition and negative pressure in the enclosure is maintained.

4.2.1 PROCEDURE FOR EXPERIMENT

Check list (Ensure the following before Starting the experiment)

Table 4.2: Check List

1.	All valves in the air lines are open	Yes / No
2.	Both the feed doors are closed	Yes / No
3.	Air Compressor is working and reservoir pressure is ~ 6 kg/sq.cm	Yes / No
4.	Sludge water collected due to moisture content in garbage from the quencher is removed	Yes / No
5.	Availability of waste packets	Yes / No
6.	Stack monitor is ON	Yes / No
7.	CAM is ON	Yes / No
8.	Working of all HP instruments/ AGM	Yes / No
9.	Exhaust blower is ON	Yes / No
10.	Availability of compressed air	Yes / No
11.	Sufficient negative pressure in the furnace	Yes / No
12.	Ash collection tray is placed below the conveyor	Yes / No
13.	Sufficient water level is maintained in scrubber tank	Yes / No

The procedure for the destruction of mixed waste is as follows:

Follow the checklist

1. Switch ON the Class -IV power supply to the control panel.
2. Switch ON the ON/OFF button of the control panel.
3. Switch ON the MCBs of the respective sub-systems such as heaters, scrubber pump & exhaust blower etc.
4. Switch ON control circuit.
5. Switch ON the exhaust blower.
6. Adjust the temperature of the all primary heating elements to 200°C, auxiliary heater-01 to 550°C and auxiliary heater-02 at 100°C.
7. Switch ON the scrubber pump and ensure its operation through the running status of motor.
8. Switch ON the continuous air monitor for alpha & beta-gamma after mounting fresh filter papers.
9. Note down the furnace negative pressure readings every hour and should be greater than 10 mm of WC.
10. Press OPEN button of the first door present in double door charging mechanism.
11. Feed mixed waste into the hopper in the double door charging mechanism.
12. Press CLOSE button of the first door present in double door charging mechanism.
13. Press OPEN button of the second door present in double door charging mechanism.
14. Press CLOSE button of the second door present in double door charging mechanism.
15. Note temperature readings of the thermocouples.
16. In case any emergency, press the EMERGENCY STOP button provided on the control panel.
17. The following procedure is to be adopted for ash removal & its conditioning:
 - a. Place specially designed ash collection container at the bottom of the screw conveyor
 - b. Open the flange connected to the screw conveyor
 - c. Operate screw conveyor to collect the ash produced
 - d. Transfer the ash from the container to the standard MS drum (containing water)
 - e. Analyze radioactivity content by sampling
 - f. Transport the ash drum to cement fixation area for its conditioning

- g. Transport the conditioned drum to SWMF for its disposal in NSDF

18. The following procedure is to be adopted for secondary liquid waste management:

- a. Analyze radioactivity content by sampling
- b. Using scrubber pump empty the secondary liquid waste in the storage tank (every 15 days) to SS drum
- c. If ash dirt (muck) is observed at the bottom of the tank, remove it by diluting with fresh water and transfer to SS drums (as above)
- d. Transport the SS drums to liquid effluent treatment plant for further management (by filling form L-I).

PROCEDURES IN CASE OF

A) Failure of Limit Switches

If limit switches fails, opening and closing of feeding system cannot be operated and operations can't be carried out further, go for initiation fault rectification.

B) Exhaust System Failure

Exhaust blower is used for the removal of the flue-gases and to maintain the downstream equipment under vacuum. In case of failure of exhaust blower, Ensure that the double doors of the feeder are closed. (due to stack effect, the flue-gases will exhaust),Evacuate people from the operating area.

C) Class-IV Power Failure

In case of failure of Class - IV power supply, Class - III (DG) will resume for exhausting the flue-gasses for safe shutdown. In case of failure of Class - IV power supply, Ensure the furnace doors and air supply valve to the furnace & charging doors are closed. Switch ON exhaust blower, once the temperature in the furnace reaches ambient temperature switch OFF exhaust blower and supply to Control Panel.

D) HEPA filter failure

In case of failure of HEPA Filter, gaseous effluents will get discharged to the environment and activity if present will be detected by stack monitors. The following procedure has to be followed in case of failure of HEPA Filter ensure closure of the pneumatically operated doors of enclosure switch OFF power supply to the heaters in the furnace and stop Feeding to the furnace.

CHAPTER 5

5.1 RESULTS AND DISCUSSIONS (BEFORE MODIFICATION)

The equipment capacity is 100 kg per day. The system consist various sub-systems viz. feeding hopper with double door charging mechanism, furnace, two stage spray scrubbers, re-heater, de-humidifier, HEPA filter, exhaust blower, stack, ash removal conveyor and a local control panel.

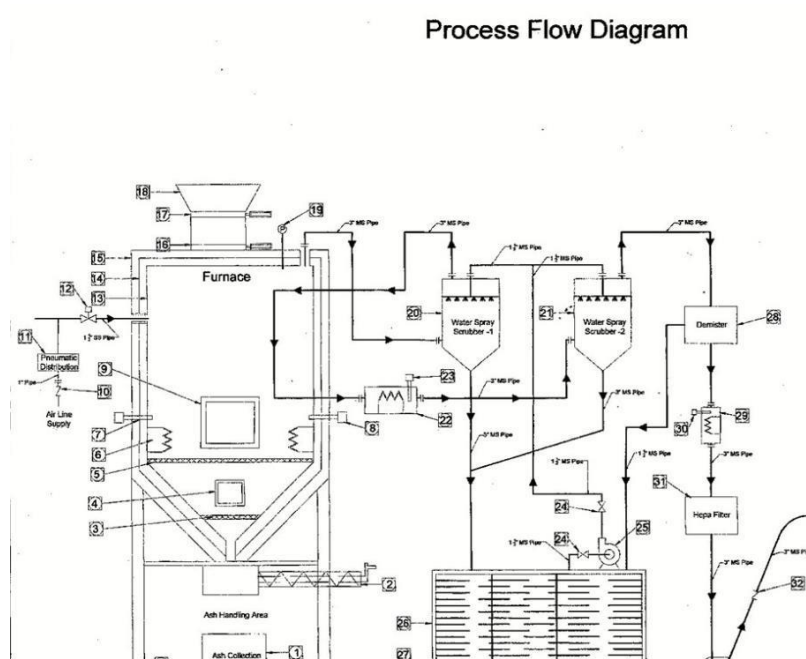


Fig: 5.1: Initial process flow diagram

5.1.1 EXPERIMENTAL OUTCOME

Inactive Trials: Inactive trials were carried out (Initial process flow diagram adopted here for trials). The following table provides details on the trials:

Table 5.1: Details on processing of waste - Initial trials

Trial Number	Weight of Cellulosic Waste (kg)	Weight of Plastic Waste (kg)	Weight of Total Waste (kg)
1	08	00	08
2	10	00	10
3	10	00	10
4	09	00	09
5	08	01 (10%)	09
6	06	03 (30%)	09

Table 5.2: –Sample data on Initial trial number-05

Time	Furnace Negative Pressure (mm Wc)	Furnace Temperature		AH-01 Temp.	AH-02 Temp.	DP across HEPA Filter (mm Wc)
		IG-01	IG-02			
10:00	15	34	35	37	36	7
10:30	12	111	95	375	184	7
11:00	11	151	141	676	394	7
11:30	10	160	149	750	409	7
12:00	13	162	149	558	389	9
12:30	13	304	250	573	388	9
13:00	10	220	245	581	391	9
13:30	10	238	239	577	366	9
14:00	10	236	220	601	385	9
14:30	10	310	306	664	411	9
15:00	10	306	300	750	394	9
15:30	10	260	255	750	410	9
16:00	10	251	249	750	400	9

Table 5.3: Optimal process parameters - Initial trials

Trial Number	Furnace Negative Pressure (mm Wc)	Furnace Temperature		AH-01 Temp.	AH-02 Temp.	DP across HEPA Filter (mm Wc)
		IG-01	IG-02			
1	15	248	239	750	410	10
2	13	245	247	741	396	10
3	14	245	250	730	390	10
4	14	238	241	750	409	9
5	15	249	243	750	408	10
6	14	242	245	743	398	9

It can be inferred from the Table that

- a) Vacuum observed in the range of 13-15mm WC,
- b) Furnace Temperature is observed in the range of 240-250°C,
- c) Auxiliary Heater (AH) - 01 temperature is observed in the range of 730-750°C,
- d) Auxiliary Heater (AH) - 02 temperature is observed in the range of 390-410°C and
- e) DP across HEPA Filter is nearly 10 mm Wc.

It was observed that the waste fed was destructed in all the trial operations. The visual inspection of furnace showed complete destruction of the material.

During these initial trials, it was observed that Soot is being carried away by the flue gases. It is scrubbed & collected in the scrubber tank. Based on the literature the carbon soot can be destructed at about 700°C with excess air and it was confirmed with laboratory experiment.

5.2 MODIFICATION

Passing the off-gases directly to the primary auxiliary heater with an additional air supply (instead of first stage scrubber).

5.3 FINDING

In both the heaters (primary auxiliary heater and secondary auxiliary heater) thermocouple shows the heating coil temperature instead of off-gas temperature, so the thermocouple location is changed in such a way that now it shows off-gas temperature.

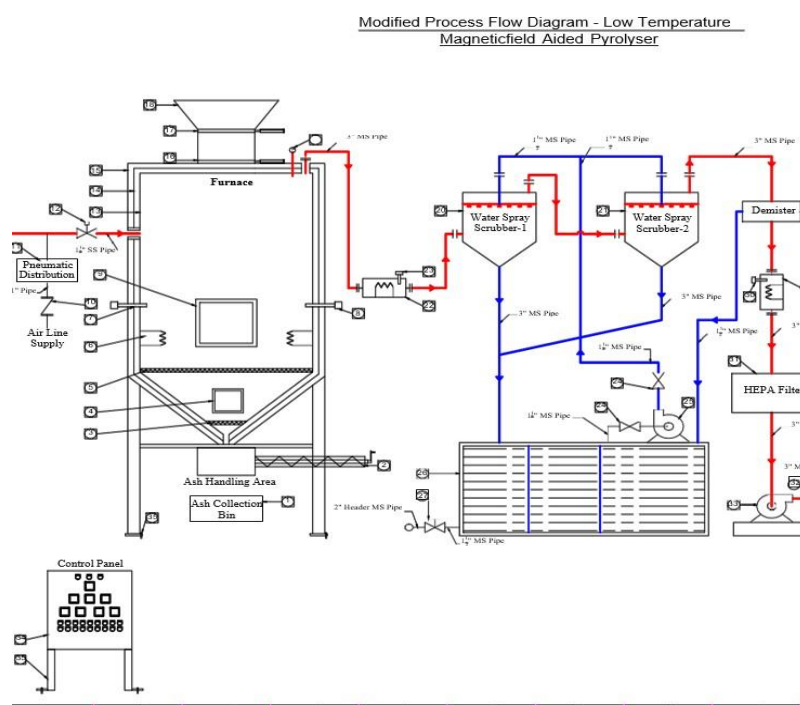


Fig: 5.2: Modified process flow diagram

5.4 RESULTS AND DISCUSSIONS (AFTER MODIFICATION)

Thereafter, five inactive trials were carried out for the destruction of 74 kg of mixed waste with varying composition of plastic (25%-40%) & cellulose. The VRF obtained based on initial inactive trials is in the range of 30-35.

5.4.1 EXPERIMENTAL OUTCOME

The following were the observation during the trials (Modified process flow diagram adopted here for trials).

Table 5.4: Data on process parameters after modifications

Time	Furnace Negative Pressure (mm Wc)	Furnace Temperature		AH- 01 Tem p.	AH- 02 Tem p.	Scrubber Pump Pressure (kg/sq.cm)	DP across HEPA Filter (mm Wc)
		IG-01	IG-02				
10:30	11	29	28	27	28	1.3	35
11:00	11	151	146	47	36	1.2	35
11:30	10	180	201	161	62	1.3	12
12:00	10	248	241	238	79	1.3	14
12:30	10	258	234	275	119	1.2	15
13:00	10	235	221	280	116	1.3	11
13:30	10	150	151	285	118	1.3	10
14:00	10	260	251	351	114	1.3	10
14:30	10	220	190	320	116	1.3	10
15:00	10	171	153	308	116	1.3	10
16:00	10	112	104	257	113	1.3	10
16:40	10	68	65	223	109	1.3	10

Table 5.5: Optimised process parameters after modifications

Trial Number	Furnace Negative Pressure (mm Wc)	Furnace Temperature		AH-01 Temp.	AH-02 Temp.	Scrubber Pump Pressure (kg/sq.cm)	DP across HEPA Filter (mm Wc)
		IG-01	IG-02				
1	14	249	248	651	101	1.3	10
2	14	242	245	647	98	1.2	10
3	13	245	247	644	97	1.3	10
4	14	248	241	649	100	1.3	10
5	13	250	243	648	100	1.2	10

The above table shows that the

- Vacuum is observed in the range of 13-14mm WC,
- Furnace Temperature is observed in the range of 242-250°C,
- Auxiliary Heater (AH) - 01 temperature is observed in the range of 644-651°C,
- Auxiliary Heater (AH) - 02 temperature is observed in the range of 97-101°C,
- DP across HEPA Filter is about 10 mm WC.

The following are the observations during these trials:

- The six heaters in the furnace functioned as per the design intent, the material was completely destructed and ash could be collected in the container.
- A negative pressure greater than 10 mm WC in the furnace was maintained.
- The bottom door of the double door charging mechanism was maintained and working smoothly.
- The secondary auxiliary heater could reach the set temperature of 100°C after replacement the thermocouple location.

5.5 SOOT CONTENT IN SCRUBBER TANK BEFORE AND AFTER MODIFICATION



Fig: 5.3: Soot content in scrubber tank (Initial)

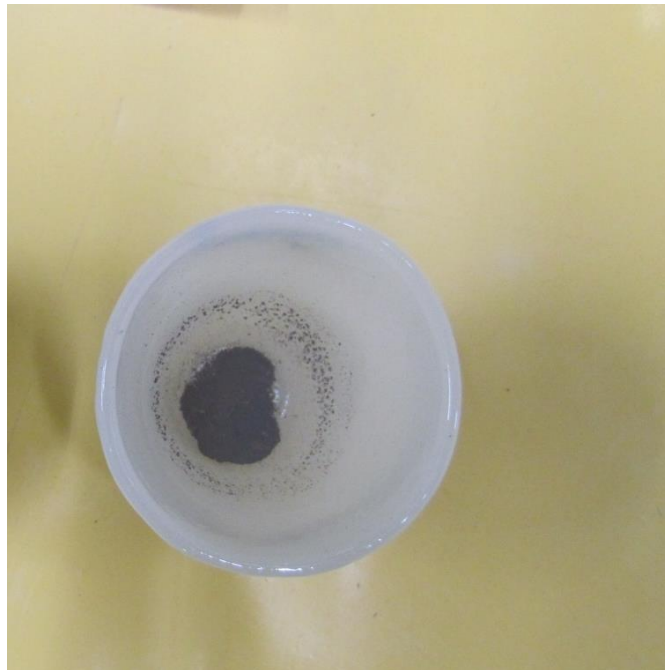


Fig: 5.4: Soot content in scrubber tank (after modification)

5.6 COMPARISON

(a) COMPACTION: The compactable waste drums (Plastic waste such as shoe cover, gloves) are processed in a Compactor. Volume Reduction Factor (VRF) is 5 – 10. Drums, Pre, HEPA filters can be compacted. Negative pressure 10mm of W.C.

Advantages:

- (i) Simple process
- (ii) No secondary waste generation
- (iii) Small amount of spring back action

Disadvantages: Low VRF

Limitation: Not suitable for treating Cellulosic waste and Polythene waste because of low Volume Reduction Factor (VRF).

(b) INCINERATION: Destruction of cellulose material converted into CO₂, water vapour and fire is called as incineration. The combustible wastes are processed in an incinerator VRF is in the range of 50 to 80. Cellulose: Naturally occurring polymeric compounds like wood, paper and cotton etc.

Advantages:

- (i) High Volume Reduction
- (ii) Immobilisable Residue

Disadvantages:

- (i) Off Gas cleaning system required
- (ii) Production of Carcinogens

Limitation: Not suitable for treating Plastic waste such as shoe cover, gloves waste and Polythene waste because of Off Gas Cleaning system will chock very frequently and secondary waste will generate, Production of Carcinogens.

(c) MELT DENSIFICATION UNIT (MDU)

A new method of conditioning polythene waste (change the phase of the material) uses melting and densification in a closed furnace at 180°C. Volume reduction factor 10 – 20.

Advantages:

- (i) Volume reduction factor is more.
- (ii) Minimize the disposal area.
- (iii) No need for the conditioning.
- (iv) Minimize leaching.

Disadvantages:

- (i) Toxic gases may be formed.
- (ii) Secondary waste is generated.
- (iii) More time is required.

Limitation: Not suitable for treating Plastic waste such as shoe cover, gloves waste and Cellulosic waste (at 180°C no treatment for cellulosic waste, at this temperature plastic waste will be embedded only and toxic gases may be formed).

(d) LOW TEMPERATURE MAGNETIC PYROLISER

A new Waste Management Technique which can give significant volume reduction and safe destruction of mixed radioactive solid waste (plastic waste, cellulosic waste and polythene waste) and effective containment of the radioactivity in conditioned form.

Advantages:

- (i) NO SEGREGATION - Mixed Solid Waste (MSW) containing mixer of both dry and wet waste generated from households are suitable.
- (ii) DECOMPOSITION AT SOURCE - De-Centralized and Scientific method of Disposal which avoids Costly logistics to transport the waste to landfills.
- (iii) THD METHOD - Operates in low temperature Thermal Heat Destruction (THD) method.
- (iv) SMALL FOOTPRINT - A small floor space depending on the system size is sufficient to accommodate SWATCH system anywhere close to source of waste generated.
- (v) QUICK & FAST - Decomposition of waste takes place at a faster rate in 8 hours period for single batch load.
- (vi) USER FRIENDLY simple operation and easy to load, MSW garbage bags can be loaded 2-3 times a day as such collected from households.
- (vii) MOISTURE CONTENT of the MSW recommended less than 40% for optimum

decomposition. No liquids in food waste are acceptable which will harm the speed of decomposition process.

(viii) NO POLLUTION, NO FLAMES, NO DIOXINS - Does not produce any flames, thus generating dioxins and other poisonous gases are eliminated, even when plastics and PVC are processed.

(ix) SIGNIFICANT VOLUME REDUCTION FACTOR -Based on initial trials VRF is achieved in the range of 30 - 35.

(x) OPERATIONAL STANDARDS are compatible to the norms and standards set by the Central and State Pollution Control Boards (CPCB).

(xi) ECO FRIENDLY - A total ECO FRIENDLY and 100% Environment compliance product

Disadvantages:

(i) Soot formation

(ii) Waste conditioning is required before final disposal

(iii) Off gas treatment is required

Limitation: Cannot decompose such inorganic substances such as glasses, metal, sand, soil, ceramics etc.

CHAPTER 6

6.1 CONCLUSIONS

The following conclusions could be drawn based on the installation, commissioning and experimental studies on the Magnetic Field assisted Low-temperature Pyrolysis system:

1. The mixed solid waste could be destructed effectively at low temperature with the aid of magnetic field.
2. Successfully, VRF in the range of 30-35 was obtained, which is greater than the some of the conventional processes being adopted.
3. The ash produced in the flue gases could be minimised with the help of modified process flow sheet.
4. The ash content in scrubber tank was reduced by 60-70%.
5. The product (ash) formed from the process is conditioned in cement, a better matrix for disposal.

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File name: Project_SOHIT_Corrected.docx (3.4M)

Word count: 11485

Character count: 61866

MANAGEMENT OF SOLID WASTE USING LOW-TEMPERATURE MAGNETIC PYROLISER

² Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology Degree in Chemical Engineering

by

CHHATRASHAL CHAUHAN (40690004)

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This is to certify that this Project Report is the bonafide work of **CHHATRASHAL CHAUHAN (Reg. No. 40690004)** and **BAHAR ALI (Reg. No. 40690003)** who carried out the project entitled "**Management of Solid Waste using low temperature Magnetic Pyroliser**" under our supervision from July 2023 to October 2023.

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Submitted for Viva voce Examination held on _____

Internal Examiner

External Examiner

DECLARATION

I **CHHATRASHAL CHAUHAN (Reg. No.40690004)** hereby declare that the Project Report entitled **Management of Solid Waste using low-temperature magnetic pyroliser** done by us under the guidance of **Dr.Kartikeyan Ph.D.**, Assistant Professor, Department of Chemical Engineering, Sathyabama University is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in **Chemical Engineering**.

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DECLARATION

I **BAHAR ALI (Reg. No.4069003)** hereby declare that the Project Report entitled **Management of solid waste using low temperature magnetic pyroliser** done by us under the guidance of **Dr.Kartikeyan, Ph.D**, Assistant Professor, Department of Chemical Engineering, Sathyabama University, is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in **Chemical Engineering**.

2

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ACKNOWLEDGEMENT

We express our heartfelt gratitude to the Board of Management of SATHYABAMA for their invaluable support and encouragement in the successful completion of this project.

We extend our appreciation to Dr. S. SATHISH, M.E., Ph.D., Head of the Department of Chemical Engineering, for his timely guidance and support provided during the progressive reviews.

We would like to convey our profound gratitude to our Project Guides, Dr. Kartikeyan, Ph.D., Assistant Professor, Department of Chemical Engineering at Sathyabama University, and D. Anjireddy, SO(F) at Bhabha Atomic Research Centre, Kalpakkam, for their invaluable guidance, suggestions, and unwavering encouragement, which played a pivotal role in the successful completion of our project.

We wish to extend our gratitude to all the teaching and non-teaching staff members of the Department of Chemical Engineering who provided valuable assistance in various ways, contributing to the successful completion of our project.

CHHATRASHAL CHAUHAN

BAHAR ALI

ABSTRACT

The equipment is designed for management of 100 kg per day of radioactive solid waste received from various units at Kalpakkam. The swatch machine consists various sub-systems viz. feeding hopper with double door charging mechanism, furnace, two stage spray scrubbers, re-heater, de-humidifier, HEPA filter, exhaust blower, chimney, ash removal conveyor and a local control panel.

The feeding hopper provides path for the waste to the furnace and double door charging mechanism aids in maintain negative pressure also prevents the escape of flue-gases into the operating environment during feeding. The furnace consists six electrical heaters for initial heating and ait to the furnace is supplied through eight permanent magnets. These magnets converts the oxygen molecules in the air to its free radical form and aid in destruction of the mixed waste at lower temperature i.e. at about 200°C. The flue-gases generated during the decomposition process are passed through two stage spray scrubbers. After first stage scrubbing, the flue-gases are re-heated using electrical heater at about 550°C for incinerating carcinogenic gases, if any. These gases are again treated in a second spray scrubber. Water is used as scrub medium in both the stages. The scrubber solution is stored in a dedicated tank of about 200 litres capacity. After second stage scrubbing, moisture in the gases is removed in a demister and particulate activity is removed in HEPA filters and exhausted through blower via chimney. Two stages of ash removal conveyors are incorporated in the system for taking out ash collected after decomposition process. A screw conveyor is provided for removal of ash and it is collected in a specially designed container. The operations are carried out manually from a local control panel.

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LIST OF ABBREVIATION

CHAPTER 1

1.1 INTRODUCTION

Centralised Waste Management Facility (CWMF) has been designed for the receipt & storage, treatment and discharge of radioactive liquid effluents; segregation, collection, treatment and disposal of radioactive solid wastes; decontamination of contaminated protective wear & equipment; generated at various nuclear facilities like nuclear power station, reprocessing plants, test reactors and various laboratories of IGCAR at Kalpakkam site. It has also been designed for receipt and management of institutions and industries of south India.

Solid Waste Management Facility (SWMF) at CWMF processes with an aim to reduce the volume viz.

- a) Combustible waste in a high temperature excess air Incinerator,
- b) Compressible waste in a Compactor and
- c) Polythene waste in Melt Densification Systems.

Whereas, mixed wastes are being disposed directly in NSDF without processing. Also, the volume reduction achieved in compaction is less and after compaction the product contains radioactivity in migratable form. For the management of mixed waste, it is proposed to procure a system (wherein which these deficiencies could be addressed) named SWATCH Machine in which waste is decomposed at low temperature. A similar system is being used in GSO-IGCAR for destruction of municipal waste.

This procurement is targeted at **developing** a new Waste Management Technique which can give significant volume reduction of radioactive solid waste, safe destruction of plastic waste and effective containment of the radioactivity in conditioned form.

The system has been designed with enough safety precaution such that if any malfunctioning occurs due to abnormal operation and accidents, operators do not get excessive exposures and also spread of activity is contained in the furnace.

- NO SEGREGATION - Mixed Solid Waste (MSW) containing mixer of both dry and wet waste generated from households are suitable
- DECOMPOSITION AT SOURCE - De-Centralized and Scientific method of Disposal which avoids Costly logistics to transport the waste to landfills.
- PATENTED TECHNOLOGY. Swatch system is patented in India for Technology,

Design and Process.

- **THD METHOD** - Operates in low temperature Thermal Heat Destruction (THD) method.
- **SMALL FOOTPRINT** - A small floor space depending on the system size is sufficient to accommodate SWATCH system anywhere close to source of waste generated.
- **QUICK & FAST** - Decomposition of waste takes place at a faster rate in 8 hours period for single batch load.
- **USER FRIENDLY** simple operation and easy to load, MSW garbage bags can be loaded 2-3 times a day as such collected from households
- **MOISTURE CONTENT** of the MSW recommended less than 40% for optimum decomposition. No liquids in food waste are acceptable which will harm the speed of decomposition process
- **NO POLLUTION, NO FLAMES, NO DIOXINS** - Does not produce any flames, thus generating dioxins and other poisonous gases are eliminated, even when plastics and PVC are processed
- **MASSIVE VOLUME REDUCTION** - Reduces the output by 98-99% from the amount of the input waste loaded.
- **BY PRODUCT** - Small volume of normal Ash of about just 1-2% of the input waste which can be taken to landfills
- **CAN'T DECOMPOSE** such inorganic substances such as glasses, metal, sand, soil, ceramics etc.,
- **OPERATIONAL STANDARDS** are compatible to the norms and standards set by the Central and State Pollution Control Boards (CPCB)
- **ECO FRIENDLY** - A total ECO FRIENDLY and 100% Environment compliance product

CHAPTER 2

2.1 LITERATURE SURVEY

2.1.1 WASTE SORTING

Enhancing the efficiency of any management method under consideration is contingent upon the initial sorting of waste at its source. When it comes to volume reduction, a significant advantage lies in the ability to pinpoint the origin of waste. This simplifies the handling process, particularly because specific laboratories tend to generate typical waste types and radionuclide contaminants. This holds particularly true for wastes containing tritium, ^{239}Pu , or ^{90}Sr , as they are challenging to detect and require maximum information from the source. For larger items that may contain highly irradiated sections, subsequent processes are streamlined if the source specifies which sections are hazardous. The waste materials are then gathered by the relevant department at the pre-removal storage site and subsequently categorized at the pre-treatment storage site. This classification allows for the identification of batches that need to be directed to various reduction facilities.

We place significant importance on the following suggestion for new facilities: Even in the absence of waste-treatment facilities, it is crucial to commence the classification and storage of generated waste into categories immediately. Opting for bulk storage without taking specific precautions would inevitably lead to formidable challenges during the eventual waste collection for treatment, rendering the utilization of reduction methods unfeasible.

2.1.2 DECONTAMINATION

While this manual primarily focuses on matters outside the realm of decontamination, we find it necessary to mention it due to its relevance to the issues at hand, particularly concerning materials like metal that are amenable to mechanical treatment methods. For instance, a decontamination facility can effectively address numerous challenges associated with mildly contaminated scrap, presenting a highly viable solution. Even if decontamination isn't feasible, it's important to consider that disassembly tasks become significantly more manageable when prior decontamination has been carried out or when radioactive activity has naturally decayed. It's often advisable to develop decontamination and treatment station plans in tandem since they are frequently intertwined.

2.2 MECHANICAL METHODS OF VOLUME REDUCTION

The goal of mechanical methods involves modifying the composition of solid waste using either compaction or fragmentation, with the aim of reducing the total space occupied by the material. Compaction directly decreases empty spaces, while fragmentation indirectly achieves this by breaking down larger pieces into smaller fragments suitable for effective packaging or further reduction through compaction. In essence, compaction and fragmentation can work together to achieve waste reduction. However, the choice between these methods is generally determined by the physical characteristics of the waste, including hardness, shape, size, and rigidity.

2.2.1 COMPACTING

Low-level wastes in nuclear facilities usually make up a substantial portion, approximately 70-80%, of materials that are easily compressible due to their texture and volume. This category often encompasses materials like paper, fragments of plastic or rubber, rags, glassware, and small metallic items.

The remaining waste materials pose challenges for compaction. This category includes large items resulting from dismantling operations, demolition debris (such as concrete, cut-up scrap metal, contaminated soil, etc.) with a volumetric activity slightly above the disposal limit for public services. However, compaction methods are unsuitable for items that are extremely dense and hard, resulting in minimal or no reduction in volume. It's also impractical for items susceptible to press damage, such as very long metal components that might become jammed between the ram and the press's bottom; in such cases, cutting them into sections may be a viable solution. Furthermore, materials containing pyrophoric or explosive substances and any waste materials with liquid content are not suitable for compaction.

Given these restrictions, a thorough assessment of wastes is crucial before considering them for compaction. Regrettably, this entails an extra handling step - sorting - which carries the potential for operator exposure risks. The cost of this process is a notable factor and a drawback of the reduction method when viewed from an economic perspective.

Compacting techniques

Air present within the wastes is expelled during the compaction process, which raises the

concern of potential atmospheric contamination. To address this issue, appropriate precautions must be taken in accordance with the potential hazards involved. In the most critical scenarios, particularly when dealing with alpha emitters or toxic materials like beryllium, it is necessary to house the compaction facility within a well-ventilated enclosure. In less severe cases, a ventilation hood can automatically remove aerosols generated by the waste materials. If the activity levels are sufficiently low, a press can be installed outdoors with a simple roof structure.

The selection between a horizontal or vertical ram for the press is determined by considerations like input and extraction configurations and the available space.

The pressure applied varies from 30 to 150 kg/cm², depending on the desired reduction factor. The ram's size is determined by the waste materials' dimensions, the quantities to be processed, and the packaging requirements, including the type of final container. These two factors collectively establish the press's capacity, which can range from a few tons to several hundred tons.

Systematic experiments have shown that the maximum volume reduction is yielded by the following pressures:

polyethylene : 80 kg/cm² filter elements : 70 kg/cm²
 cotton and rubber : 50 kg/cm² metallic wastes : 110
 kg/cm² average sample : 65 kg/cm²

Excessive compaction pressures do not appear to be essential. Generally, a pressure range of 30-45 kg/cm² is sufficient and does not result in undue contamination dispersion due to drum breakage (unless punctured by metallic waste). Moreover, in the majority of instances, this pressure range yields a volume reduction very close to the maximum achievable..

For guidance, the following table gives the results which can be expected for different types of waste with the presses currently used:

Wastes Origin	Reduction factor	kg/cm ²
Easy to compress	Laboratory wastes	30 2 to 5
		50 5 to 15
Difficult to compress	Dismantling operations	50 1.5 to 3

If waste materials are compacted along with the collection containers, it is, of course, vital to consider the durability of those containers. While higher reduction values can be achieved with increased pressures, this necessitates the use of specialized, albeit pricier presses, and higher-quality storage containers, which will be used for the compression process.

Waste bins can be loaded into the press, creating a disposable envelope. If these bins are constructed from metal, they effectively inhibit substantial expansion after the compaction process.

Wastes can be directly introduced into the compaction mold, provided there is an input system in place to prevent contamination, and durable bins that can be reused. It's also worth considering systems where the more radioactive wastes are positioned in the center to enhance biological shielding.

The selection of the mold shape is influenced by the geometric characteristics of the final packaging. A package in the form of a parallelepiped is better suited for trench storage, whereas a cylindrical package is more appropriate for later bituminization or cementing. When compressing waste inside the storage container, it's crucial to control the force applied by the ram to avoid damaging the container's walls or base. In this context, waste can be loaded in successive layers with retaining strips in between to prevent expansion when the pressure is released.



Fig: 2.1 : Drum before & after compaction, VRF ~ 6

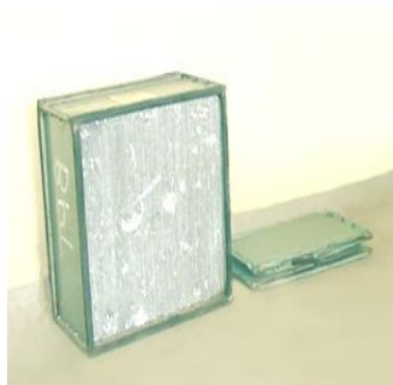


Fig: 2.2 : HEPA filter before & after compaction, VRF ~ 10

2.3 INCINERATION

A substantial portion of the low-activity wastes produced in a nuclear facility is combustible. The resulting ash quantity is relatively minor, resulting in a volume reduction factor of approximately 100 and a weight reduction factor of 13-25.

2.3.1 INCINERABLE WASTES

For the purposes of incineration, wastes can be divided into three types:

1. cellulose materials, such as paper, cardboard and wood;
2. plastics and rubber;
3. animal carcasses.

It's also essential to take into account important characteristics such as the physical state, chemical state, and calorific value.

The physical state has an impact on the combustion rate. Materials that are overly compact may result in incomplete combustion, while finely powdered materials can lead to spontaneous combustion.

The chemical state is a critical factor in influencing the extent of corrosion. Certain materials, particularly plastics, can generate highly corrosive gases that can damage the gas extraction and filtration system. The calorific value has a direct impact on the temperature inside the furnace. Many wastes have a specific calorific value or moisture content, both of which affect the combustion rate and the frequency of charging the furnace. Maintaining the correct temperature is essential to ensure thorough combustion and reduce the emission of unburned particles.

The following table gives the minimum calorific value for various typical substances contained in wastes (disregarding moisture content):

Rubber	9800 - 10 000 kcal/kg	Polyethylene	8500 - 9000	PVC	6000 - 6500	Paper, cardboard	
4000 - 6000	Wood	³⁵⁰⁰					

2.3.2 WASTE SORTING BEFORE INCINERATION

Sorting wastes before incineration is crucial, even more so than in the case of compaction. It is imperative to exclude any explosive substances, as well as materials that can generate toxic vapors (like phosgene) or corrosive vapors (such as organic chlorides and fluorides). An additional benefit of sorting is that it allows for a reasonably uniform feed to the burner. This, in turn, leads to improved combustion control and helps prevent the buildup of unburnt materials in the off-gases. This aspect is highly significant as it enables more stable operation of the facility and diminishes the risk of accidents resulting from excessive carbon black formation.

The sorting of radioactive wastes will be carried out manually within a glove box or a leak-proof enclosure. The latter method is more efficient, although it requires operators to wear pressurized suits. It also enables the performance of any necessary preparatory mechanical operations, such as cutting and shredding. Combustible wastes are placed in bags made of non-halogenous materials, like polyethylene or paper.

The installation for sorting radioactive waste must be positioned at a safe distance from the incinerator's charging point. This precaution is taken to minimize the risk of fire propagation in case of an explosion or excess pressure within the charging lock.

2.3.3 INCINERABLE LIQUIDS

Liquid wastes can be disposed of in an incinerator if they possess some calorific value, such as mineral oils or solvents. These liquids are incinerated in conjunction with solid wastes. However, for injection through nozzles, it may be necessary to adjust their viscosity by preheating or by dilution with a solvent (e.g., white spirit). These liquids might contain suspended mineral particles, which should be filtered out. In the case of soluble oils, the aqueous phase must be eliminated through the prior destruction of emulsions.

2.4 INCINERATION TECHNIQUES

Now, let's explore the different operations necessary for the incineration of these waste types.

2.4.1. CHARGING

The feed into the furnace should be conducted through a securely sealed and well-

ventilated lock. The ventilation will be adjusted according to the relative pressure levels in both the external area and the combustion chamber.

The lower door should be made of refractory material or designed as a double-walled structure with water circulation for cooling. This design prevents the waste in the lock from overheating. It's important to note that a feeding system involving successive batches presents fewer challenges than a continuous feed (e.g., using a screw). However, the continuous feeding method offers the advantage of ensuring a more uniform operation, especially in systems with limited capacity.

2.4.2. COMBUSTION

The choice of combustion method is contingent on both the waste thickness on the grate and the direction of air flow. Two fundamental principles can be employed:

In this approach, air passes through the grate, facilitating combustion.

This method involves preheated air entering at the top of the furnace, traversing through the waste, and exiting with the off-gases at the bottom of the ash pit.

When employing a downward air flow and a substantial layer of waste, it tends to increase the unburnt portion but facilitates the combustion of distillation byproducts.

Both methods have their merits. For instance, upward air flow results in a smaller unburnt fraction but can lead to the entrainment of ash. Nonetheless, the airflow rate must be adequate in either case to guarantee complete combustion.

The furnace chamber can be constructed using firebrick with an external insulation lining made of mild sheet steel, similar to conventional designs used for incinerating industrial waste. Additional insulation is achieved by including an asbestos lining in direct contact with the metal wall. These systems are typically based on standard models used for the incineration of regular waste. Firebrick generally exhibits good resistance to corrosion from the primary combustion products. Reducing contamination can be accomplished by using high-quality bricks, and it's advisable to glaze them before putting the installation into operation.

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bricks, and it's advisable to glaze them before putting the installation into operation.

2.4.3 COMBUSTION CONTROL

The heat required to initiate and control combustion is provided by burners that use propane, coal gas, or oil. The selection of the fuel depends on the available supply options. It's worth noting that while oil combustion produces less water, it can often lead to the generation of sulfur dioxide, which, in the presence of water, can result in the formation of sulfuric acid and an increased risk of corrosion. In specific situations, electric heating may be employed, particularly in furnaces with low capacity or when high temperatures are required.

During the startup phase, the burners are used to raise the furnace to its operational temperature. Once this temperature is attained, the burners assume an auxiliary role, primarily because of the heat generated by the combustion of the waste materials. While loading the furnace, temperature fluctuations may occur, but it should be carefully controlled, ensuring it doesn't exceed 1100°C or drop below 700°C. Typically, an average temperature of 900°C is targeted to minimize the quantity of unburnt material and soot in the off-gases and to maintain conditions that won't harm the installation. Excessive temperatures could lead to rapid deterioration.

To reduce the presence of unburnt material carried by the gases, it is recommended to install an afterburner at the outlet of the primary combustion chamber. The temperature within the afterburner is maintained at around 1100°C, which is higher than the temperature in the combustion chamber. Additionally, it's crucial to maximize the contact area between the hot walls and the gas to improve combustion efficiency.

2.4.4. ASH COLLECTION

Sufficient ash collection points should be established to facilitate the cleaning of the entire installation. The ash pits should be constructed from refractory material resistant to corrosion. Ashes can be collected either directly in drums connected to the ash pit outlet or through manual or mechanical raking methods.

The ash removal process can also involve flushing the ashes out with water through a dedicated channel that drains the different collection points. While this method helps prevent contamination, it generates a certain volume of liquid effluents, which will need to be treated separately.

2.4.5. GAS CLEANING

At the exit of the combustion chambers, the gases, which remain at a temperature of approximately 1100°C, still carry a significant level of radioactivity, with most of it being attached to the solid particles suspended in the gases. These particles need to be eliminated through a clean-up system before the gases can be safely released into the atmosphere.

The gases are initially cooled and subsequently decontaminated as they pass through various filtration systems.

(a) Cooling

Three methods of cooling can be considered:

The cooling process is achieved through adiabatic cooling using a counter-current spray of cold water, dilution of the gases with external air, and circulation of the gases through a tubular air-cooled heat exchanger.

The first of these methods provides efficient cooling and additionally absorbs the free acidity of the off-gases. However, it's necessary to treat the water later to remove contaminants.

The other two dry methods may not be as efficient. Dilution requires an expansion in the capacity of the filtration equipment, and circulating gases through heat exchangers can lead to condensation and corrosion.

(b) Gas cleaning by wet method

After cooling, the gases can be cleaned either;

In a venturi scrubber; In a washing cyclone; In a washing column packed with ceramic spheres or Raschig rings.

The cleaning devices necessitate an additional installation for filtering and neutralizing the wash water before it can be recycled. This setup typically includes a coarse prefilter, followed by a sand or diatom filter. It also features an exchanger to lower the temperature of the purified water to below 50°C and a pH control system to maintain the pH at around 7.5.

In the event that further thorough removal of dust from the gases is required through absolute-type filtration, the water droplets suspended in the gases must initially be captured at the exit of the wet separators. After this step, the gases are heated above their dew point.

The final stage can be carried out using either an electrostatic filter or a set of conventional absolute filters, with pre-filters if necessary.

(c) Gas cleaning by dry method

The dry method offers the advantage of maintaining the gas temperature above the dew point, thus preventing corrosion resulting from acid condensation. Achieving this requires meticulous insulation of the entire dust removal unit. Additionally, the dry method eliminates the need to manage liquid effluents as in the wet method, and it generally results in less severe corrosion.

The disadvantage of the dry method is its potential fire hazard. Dry methods can lead to the accumulation of tar and carbon black in the cleaning system. To mitigate the risk of combustion from these deposits, efforts should be made to minimize their formation. This can be achieved through effective afterburning of the off-gases and continuous removal of deposits. The gases then proceed to the initial stage of filtration, passing through bag filters made of corrosion-resistant materials like silicone-treated glass-fiber. These filters are cleaned either by mechanical shaking or pneumatic pressure, causing the soot to fall into a hopper. Alternatively, electrostatic filters, which are known for their efficiency but come at a higher cost, can also be used as long as the trapped particles are continuously removed.

In the final stage of the cleaning process, similar to wet treatment, absolute filters are employed, and these are protected by pre-filters. Generally, both pre-filters and absolute filters are engineered to function at temperatures exceeding 150°C.

In cases where the wastes contain hazardous volatile substances, such as iodine, mercury, sulfur, or ruthenium, a scrubber or washing tower will be necessary to neutralize the gases.

High-temperature filter

Incinerator gases are typically cleared after cooling for two main reasons. Firstly, it's challenging to create high-temperature filters that can withstand the extreme heat of the gases. Secondly, there's a risk of filter damage due to the combustion of unburnt products if filtering is attempted at high temperatures. As discussed earlier, low-temperature filtration comes with its own set of drawbacks, including the need for cooling, increased corrosion, and filter clogging by unburnt products, which requires frequent or continuous cleaning.

A noteworthy development in the field of hot-gas filtration involves ongoing research on reusable filters. One such filter consists of metal-foil cylinders onto which asbestos fibers,

serving as the filter medium, are applied through a spraying process. The filter's operation principle is based on unburnt products from the incinerator, particularly carbon black, completing their combustion on the filter as they are produced. This approach significantly inhibits clogging, allowing the filter to be utilized for several hundred hours before requiring regeneration. In cases where filtration efficiency is deemed inadequate, especially considering the hazardous nature of the treated wastes, absolute filters can be integrated. An industrial installation employing this innovative filter design is presently under construction in France.

2.4.6. CONTROL AND SAFETY SYSTEMS

The controls for the various electro-mechanical or pneumatic components of the incinerator, such as the fan, pumps, and burners, will be located on a panel in close proximity to the installation. This control panel will also include dials for the various instruments used to measure parameters like combustion-chamber temperatures and pressures, gas temperature at different points in the cleaning circuit, differential pressures to monitor filter clogging, and the pH of the washing water.

Furthermore, the control panel will be equipped with both auditory and visual alarms designed to promptly notify operators of any operational irregularities, including issues related to temperature and pressure in the combustion chamber or the extinguishing of a burner flame.

To perform any additional checks, it will be essential to plan for the installation of isokinetic sampling probes at appropriate locations during the construction phase.

To prevent the release of radioactive gases into the working area due to excessive pressures in the combustion chambers, it is recommended to install a relief chimney with a calibrated safety valve in the furnace. Non-return valves should also be installed in the air inlets. To enhance safety measures, consider supplementing the essential devices with propane-leak detectors and fire detectors. When utilizing dry cleaning methods, particularly in the cleaning process, anti-spark devices should be positioned upstream of the bag filters. Additionally, ensure the provision of a water or inert-gas extinguisher system for fire safety.



Fig: 2.3 : Incinerator

2.5 MELT DENSIFICATION UNIT (MDU)



Fig: 2.4 : Melt densification Unit

A new process has been developed indigenously at CWMF for the treatment of polythene

waste in which the waste is melted in a furnace at about 180° C temperature. In this process the Volume Reduction Factors (VRF) are higher than that obtained in compaction by baling and the matrix formed has good leaching resistance.

A new method of conditioning radioactive polythene waste

- Uses melting and densification in a closed furnace at 180°C
- Volume reduction factor 20 - 30
- Fumes are adequately treated to remove all possible radioactivity, before its release to the atmosphere Furnace temperature should not exceed 200°C.
- Vacuum should be maintained in the furnace.
- Stack Monitoring should be available during operation.
- HEPA filter bank Efficiency $\geq 99.5\%$ for $0.5\mu\text{m}$ particles & above

The manual describes the Melt Densification Unit (MDU) specifications and the operation procedure to be followed (SOP). It also describes the action to be taken in case of design basis events envisaged and accident scenarios with Emergency Operating Procedures (EOP).



Fig: 2.5 : Polythene waste before and after MDU operation

2.5.1 DESCRIPTION OF THE SYSTEM

Melt Densification Unit at CWMF, Kalpakkam consists of S.S electric oven with steel platform, Teflon Coated S.S. Charging Chute with Slide Valves, S.S. Slat Type Conveyor, Scissors Type

Hydraulic Lift with Motorized Trolley, Control Panel etc. Fig.1 shows the layout of the unit installed and commissioned. The details of these sub-systems are as follows:

2.5.1.1 ELECTRICALLY HEATED FURNACE

The size of the S.S electric oven/enclosure is 1400 mm diameter and 1200 mm height located on a structural steel platform. The enclosure has three viewing windows of size 200 mm x 150 mm. The enclosure has a charging chute with pneumatically operated two slide gates which will ensure vacuum in the oven while feeding the waste in to the drum. At the bottom of the enclosure a circular opening is provided for entry & exit of standard M.S drum. Figure gives the details of the top view and sectional elevation of the furnace.

The electric oven has three equal heating zones each rated 5 KW, (total oven heating load 15 KW) along the height of the oven. Each zone was electrically connected so that these zones can be operated independently and/or collectively. The oven is constructed using the refractory bricks for insulation and Kanthal heating elements of 16 gauge with a surface loading of 1.3 watts/cm². The elements are placed in the refractory slots from inside the oven and leads were taken out through back holes in the refractory bricks. The outer casing of oven is 2 mm thick S.S sheet. The oven is operated using single phase supply for each heating zone. The maximum temperature the oven can develop is about 200 degree centigrade. Two parallel temperature control units and three temperature measurement points are provided to safeguard against temperature control failure and prevent fire hazard due to uncontrolled temperature rise. The thermocouples used are of copper constantan type PID controllers.

A tapered charging chute/hoper with double door pneumatic slide valve arrangement using S.S coated with Teflon (50 micron) is provided on the top of the oven. The slide valves operate by compressed air. The pneumatic cylinders are double acting type and operates at 6 Kg/cm² with 4 way 24 V solenoid valves for direction control from rotary selector switches located at Control Panel.

2.5.1.2 FEED CONVEYOR

A motorized S.S. slat type conveyor belt with 325 mm wide is used for feeding the waste packages into the hoper. The feed of the conveyor is controllable step-lessly using a VFD motor. Figure gives the details of the conveyor assembly. The technical specifications of the system are:

- Slat Width - 325 mm
- Chain - Heavy duty 4" pitch, steel bushed roller chain.
- Drive Shaft – 40mm diameter cold rolled steel.

- Drive Location - Floor Mount
- Tail Shaft - 2" diameter cold rolled steel.
- Take-Up - Screw type, mounted at tail end of conveyor for adjustment of chain tension.
- Motor – Suitable HP 415V AC / 50 TEFC motor, Brake Motor (VFD)
- Reducer - Heavy duty worm gear reducer.
- Speed – 1500 mm per minute to 10000 mm per minute, variable speed.
- Capacity – 10 Kg. per foot maximum

2.5.1.3 HYDRAULIC LIFT AND MOTORIZED TROLLEY

The trolley to carry the drum is mounted on rail track for a length of about 6 meter. The rails have three limit switches at home position, loading position and at the bottom of the oven. The scissors type lift table is operated by hydraulic power cylinders for a height of about 1500 meter. Fig. 4 details about the hydraulic power pack and scissors lift. Guide is provided on the trolley for resting the drum and precise entry into the furnace. The trolley is provided with silicone rubber which can withstand temperature about 300°C as heat insulator and to act as a seal between trolley table and oven opening. Motorized Trolley with rails is shown in Fig.5. The technical specifications of the system are:

- Capacity - 0.5 MT dead load on trolley platform
- Speed of the trolley - 5 m / minute
- Working temperature - Ambient
- Motor - 415 V & 50 Hz. +/-5%, brake motor.

2.5.1.4 CONTROL PANEL

A Programmable Logic Controller (PLC) based control panel is provided for the control & monitoring of furnace, motorized trolley, hydraulic lift, feed conveyor, double door mechanism, blower and alkaline scrubber solution pump. It has provision for personnel computer connectivity for editing the automation of the equipment. All operations of MDU are provided in auto and manual modes of operation. The temperature indicating controllers with set point adjustable and process variable indication is provided on the panel. Panel is provided with push buttons for manual operation and emergency stop in mishap. Indicator lamps are located on Control Panel with legend plates. Display is provided on the control panel for:

- The drum is position
- The pneumatic slide valves OPEN / CLOSE position
- The trolley position indication

- Electric supply indication for three Zones of Heating coils
- Visible indication in temperature high alarm
- Audible sound when the process completed

The Process and Instrumentation diagram is shown in Fig - 6.

Control panel is provided with HRC fuses, OLR, single phasing preventer, phase loss detector, main and auxiliary contactors and the connectors for all the electric motors. Noise filtered power is provided control circuits. Control power is 24 V DC and operating voltage is 415 V / 230 V AC, 50 Hz.

Supply to each equipment is provided with MCB.

2.5.1.5 OFF – GAS SYSTEM

The unit is provided with a dedicated off-gas system for the treatment of the toxic gases generated, if any. The off-gas system consists of alkaline scrubber, de-mister, HEPA filter and a blower. The treated gases are discharged to the environment through a 25 m high chimney. The unit is maintained under vacuum so that no gases will leak into the working environment.

2.5.1.6 SAFETY FEATURES AND INTERLOCKS

The following safety interlocks are incorporated in the design stage of the unit:

Interlocks:

- If drum is not in position on the trolley at drum loading position, the subsequent operation wouldn't occur (object sensor should get cut-off).
- The Hydraulic Lift can not be operated, till the trolley is exactly positioned under the furnace (limit switch should get activated)
- Feed conveyor can not be operated, if the drum is full OR a waste packet is on the top sliding door of the charging chute (object sensor should get cut-off).
- If the blower is not in ON position, the sub-systems can not be operated.
- If the vacuum is not maintained in furnace, the sub-systems can not be operated.
- If the scrubber pump is not working, the sub-systems can not be operated.
- Compressed air (6 Kg/cm²) is not available; the conveyor can not be operated.

Safety Features:

- An EMERGENCY STOP button is provided on the control panel for immediate stopping of the operations.
- Thermocouples are installed at three locations of the furnace to provide continuous temperature monitoring.
- PID controllers are provided for the temperature control of the heating elements.
- The pneumatically operated double door charging arrangement provides the desired isolation of the furnace from the environment during the process of charging of the waste packages into the furnace. It is ensured by inter lock that only one of the door can be opened at any time.
- Stack monitors are provided in the chimney for the detection of any activity release.
- Area gamma monitors are provided in the working area.
- The operating area has PVC flooring, for easy decontamination.

CHAPTER 3

3.1 AIM

Solid Waste Management Facility (SWMF) at CWMF processes solid waste with an aim to reduce its volume employing the techniques viz.

- a) Incineration - Combustible waste in a high temperature excess air Incinerator,
- b) Compaction - Compressible waste in an advanced Compactor and
- c) Melting - Polythene waste in Melt Densification Systems. Whereas, mixed wastes are viz. mops are being disposed directly in NSDF without processing.

Also, the volume reduction achieved in Compaction is low and the product contains radioactivity in migratable form.

3.2 SCOPE

4 This facility is a special furnace for Magnetization pyrolysis of all the radioactive organic waste and it's different from the conventional burning because it doesn't need fuel.

The source of energy is only used in ignition and exhaust smoke abatement.

1. With an aim to manage mixed wastes, it was proposed to develop a pilot-scale system in which waste is destructed at low temperature with the assistance of magnetic field. Presently at CWMF, radioactive mixed solid waste is being disposed directly in NSDF without processing.
2. With an aim to enhance the treatable fraction of radioactive solid waste, achieve higher Volume Reduction Factors a novel process technique which decomposes mixed waste at low temperature with the aid of magnetic field was proposed to be developed based on the system being employed for destruction of municipal mixed solid waste.
3. A pilot-scale system of capacity 100 kg per day was developed after incorporating various changes.
4. It consists of several sub-systems viz. feeding hopper with double door charging mechanism, furnace, two stage spray scrubbers, re-heater, de-humidifier, HEPA filter, exhaust blower, ash removal conveyor and a local control panel.

CHAPTER 4

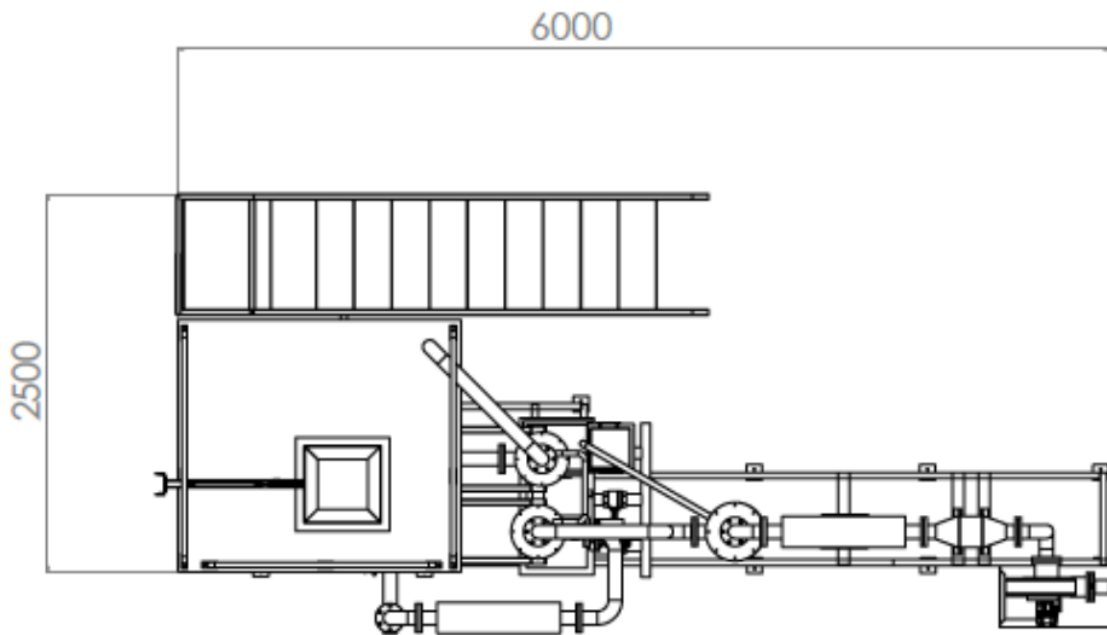
4.1 EXPERIMENTAL STUDIES METHODS & METHODOLOGY

4.1.1 EXPERIMENTAL SET UP

The equipment capacity is 100 kg per day. The system consist various sub-systems viz. feeding hopper with double door charging mechanism, furnace, two stage spray scrubbers, re-heater, de-humidifier, HEPA filter, exhaust blower, chimney, ash removal conveyor and a local control panel.

System layout

The layout of the system has been designed in such a way that the space requirement is minimum and ease of operation & maintenance. The layout & elevation drawings of the system are given in the following figures:



¹²
Fig: 4.1 : Layout diagram of the system

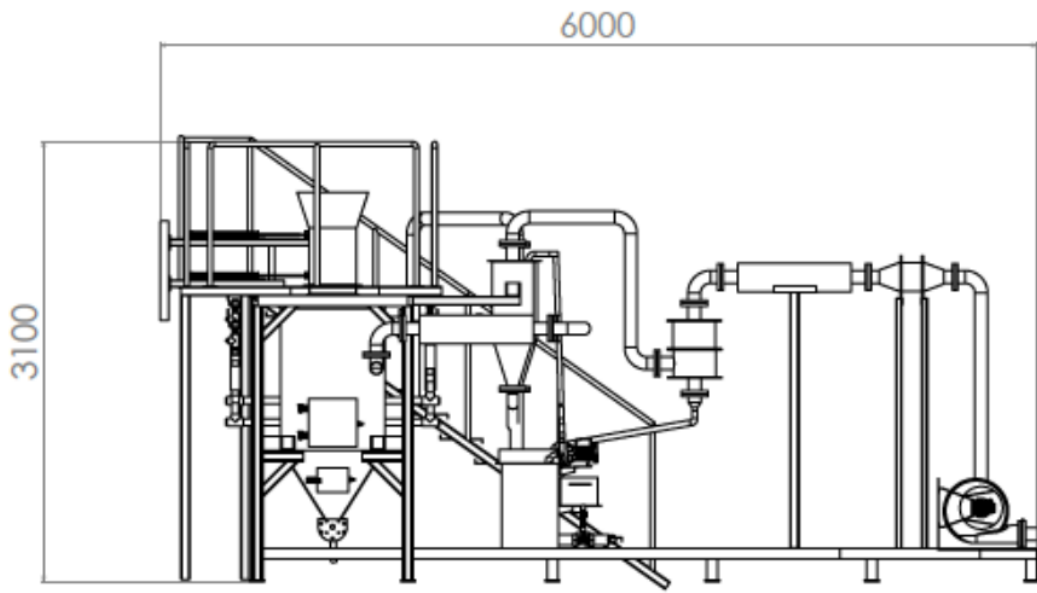


Fig: 4.2 : Elevation diagram of the system

4.1.2 EXPERIMENTAL PROCEDURE

Table 4.1 : Check List

Operators:	1.	
	2.	
Ensure the following before Start of Operation		
1.	All valves in the air lines are open	Yes / No
2.	Both the feed doors are closed	Yes / No
3.	Air Compressor is working and reservoir pressure is ~ 6 kg/sq.cm	Yes / No
4.	Sludge water collected due to moisture content in garbage from the quencher is removed	Yes / No
5.	Availability of waste packets	Yes / No
6.	Stack monitor is ON	Yes / No
7.	CAM is ON	Yes / No
8.	Working of all HP instruments/ AGM	Yes / No
9.	Exhaust blower is ON	Yes / No
10.	Availability of compressed air	Yes / No
11.	Sufficient negative pressure in the furnace	Yes / No
12.	Ash collection tray is placed below the conveyor	Yes / No
13.	Sufficient water level is maintained in scrubber tank	Yes / No

4.1.2.1 STANDARD OPERATING PROCEDURE

Waste Acceptance Criterion

The following waste acceptance criterion is to be implemented for treatment of **mixed organic solid waste** in the Swatch machine:

1. Solid waste packed in double polythene bags and placed inside standard MS drums of 200 l capacity with a lid properly secured is to be received and stored.
2. The moisture content of the **mixed organic solid waste** should be less than 40% w/w.
3. The surface dose rate on the waste package should be less than 0.2 mSv/h (20 mR/h).
4. Transferable contamination on the external surface of waste packages should not exceed 4 Bq/sq.cm.
5. Waste should not contain leachable material.
6. Waste should not contain any self-igniting or pyrophoric materials and free liquid.
7. The waste should not contain inorganic materials such as glass, ceramic, metals etc.
8. The waste should not contain any explosive materials.

Prerequisites

1. Availability of Class – IV power supply
2. Availability of compressed air supply (6 kg/cm²)
3. Availability of ventilation system in the operation area
4. Working of AGM / CAM

Precautions

1. Ensure that both the sliding doors of the furnace are closed
2. Ensure that both the maintenance ports are closed
3. Ensure all the heaters (Primary & Auxiliary) are working
4. Ensure that scrubber pump is working
5. Ensure that exhaust blower is running
6. Ensure negative pressure in the enclosure is maintained

Operating procedure

The operating procedure for the destruction of mixed waste is as follows:

Follow the operation checklist

1. Switch ON the Class –IV power supply to the control panel

2. Switch ON the ON/OFF button of the control panel
3. Switch ON the MCBs of the respective sub-systems such as heaters, scrubber pump & exhaust blower etc.
4. Switch ON control circuit
5. Switch ON the exhaust blower
6. Adjust the temperature of the all primary heating elements to 200°C, auxiliary heater-01 to 550°C and auxiliary heater-02 at 100°C
7. Switch ON the scrubber pump and ensure its operation through the running status of motor.
8. Switch ON the continuous air monitor for alpha & beta-gamma after mounting fresh filter papers.
9. Note down the furnace negative pressure readings every hour and should be greater than 10 mm of WC
10. Press OPEN button of the first door present in double door charging mechanism
11. Feed mixed waste into the hopper in the double door charging mechanism (12.5 kg/h)
12. Press CLOSE button of the first door present in double door charging mechanism
13. Press OPEN button of the second door present in double door charging mechanism
14. Press CLOSE button of the second door present in double door charging mechanism
15. Note temperature readings of the thermocouples
16. In case any emergency, press the EMERGENCY STOP button provided on the control panel.
17. The following procedure is to be adopted for ash removal & its conditioning:
 - a. Place specially designed ash collection container at the bottom of the screw conveyor
 - b. Open the flange connected to the screw conveyor
 - c. Operate screw conveyor to collect the ash produced
 - d. Transfer the ash from the container to the standard MS drum (containing water)
 - e. Analyze radioactivity content by sampling
 - f. Transport the ash drum to cement fixation area for its conditioning
 - g. Transport the conditioned drum to SWMF for its disposal in NSDF
18. The following procedure is to be adopted for secondary liquid waste management:
 - a. Analyze radioactivity content by sampling
 - b. Using scrubber pump empty the secondary liquid waste in the storage tank (every 15 days) to SS drum

- c. If ash dirt (muck) is observed at the bottom of the tank, remove it by diluting with fresh water and transfer to SS drums (as above)
- d. Transport the SS drums to liquid effluent treatment plant for further management (by filling form L-1).

4.1.2.2 EMERGENCY OPERATING PROCEDURES

Failure of Limit Switches

If limit switches fails, opening and closing of feeding system cannot be operated. The operator informs supervisor and operations can't be carried out further.

1. Inform the OIC, Solid Waste Management Operations for initiation fault rectification.

Exhaust System Failure

Exhaust blower is used for the removal of the flue-gases and to maintain the downstream equipment under vacuum. In case of failure of exhaust blower, the procedure to be followed is listed below:

1. Ensure that the double doors of the feeder are closed. (due to stack effect, the flue-gases will exhaust)
2. Evacuate people from the operating area
3. Inform the OIC-SWMF, for initiation fault rectification & also RSO-CWMF.

Class-IV Power Failure

In case of failure of Class - IV power supply, Class - III (DG) will resume for exhausting the flue-gasses for safe shutdown. In case of failure of Class - IV power supply, the procedure to be followed is listed below:

1. Ensure the furnace doors are closed
2. Close air supply valve to the furnace & charging doors
3. Switch ON exhaust blower.
4. Ensure the temperature in the furnace reaches ambient temperature.
5. Switch OFF exhaust blower.
6. Switch OFF the supply to Control Panel.
7. Switch all the lights OFF.
8. Close all the doors, lock them and handover the keys to the CISF on duty at CWMF.

HEPA filter failure

In case of failure of HEPA Filter, gaseous effluents will get discharged to the environment and activity if present will be detected by stack monitors. The following procedure has to be followed in case of failure of HEPA Filter:

1. Ensure closure of the pneumatically operated doors of enclosure.

2. Switch OFF power supply to the heaters in the furnace
3. Stop Feeding to the furnace

4.1.3 METHODOLOGY

The mixed waste is fed into the furnace through hopper with the help of double door charging mechanism, maintains negative pressure and also prevents the escape of flue-gases to the operating area during feeding. The furnace consist six electrical heaters (1.6 kW each) for initial heating and air to the furnace is supplied through eight permanent magnets. These magnets convert the oxygen molecules in the air to its free radical form which aids in destructing the mixed waste at lower temperature i.e. 200-250°C. The flue-gases generated during the decomposition process are passed through two stages of spray scrubbers. After first stage scrubbing, the flue-gases are re-heated using electrical heater to about 550-600°C for incinerating dioxins & furans, if formed. These gases are again treated in a second spray scrubber. Water is used as scrub medium in both the stages. The scrub solution is collected in a dedicated tank of about 200 litres capacity and recycled. After second stage scrubbing, moisture in the gases is removed in a demister, heated again through auxiliary heater. The pre-heated gases are passed through HEPA filter wherein particulate activity is removed and exhausted through blower via chimney. A screw conveyor is provided for removal of ash and is collected in a specially designed container. The operations are carried out manually from a local control panel. The system has been designed with enough safety precaution such that if any malfunctioning occurs due to abnormal operation and accidents, operators do not get excessive exposures and also spread of activity is contained in the furnace.

4.1.4 ACTUAL SETUP



Fig: 4.3 : Experimental setup



Fig: 4.4 : Experimental setup



Fig: 4.5 : Experimental setup

4.1.5 SYSTEM DESCRIPTION

The swatch system shall contain the following major parts:

- a. *Feeding hopper*: This will provide path for the waste to the furnace with double door charging mechanism. The doors are manually operated and will arrest escape of flue-gases into the operating environment.
- b. *Furnace*: It consists of permanent magnets for ionization of the oxygen molecules to form free radicals. These free radicals will aid in destruction of the mixed waste at lower temperature.
- c. *Scrubbers*: The flue-gases generated during the decomposition process are passed through two stage venturi wet scrubbers. Water is used as scrub medium in both the stages. The scrub solution is stored in a dedicated tank of about 100 liters capacity, divided into two parts.
- d. *Re-heater*: The flue-gases after first stage scrubbing are re-heated using electrical heater for treating left out carcinogenic gases.
- e. *De-humidifier*: The flue-gases after second stage scrubbing are de-humidified and passed to the HEPA filter.
- f. *Exhaust system*: It will remove the flue-gases formed in the furnace during decomposition process and maintains vacuum.

- g. *Ash removal conveyor*: Two stages of ash removal conveyors are incorporated in the system for taking out ash collected after decomposition process.
- h. *Control panel*: All the sub-systems listed above are operated manually using a local control panel.

The following developmental works are to be carried out by the firm to adopt the original system for treatment of radioactive solid waste:

- a. Pneumatically operated double door feeding system is to be integrated with the furnace to load radioactive solid waste into the furnace.
- b. DE-mister/ De-humidifier needs to be provided for eliminating the moisture in flue gases (after scrubbing).
- c. HEPA filter has to be incorporated in the off-gas treatment which decontaminates particulate radioactivity in the flue gases.
- d. Exhaust blower on the downstream of HEPA is to be located, to maintain the complete system under vacuum and to discharge treated off-gases into the environment via chimney.
- e. The scrubber tank has to be sealed / closed to avoid airborne activity generation in the operating area.
- f. Provision has to be made available to supply air required for the destruction operation.

4.1.5.1 DESIGN SAFETY FEATURES OF THE SYSTEM

- a. The system will have double door charging mechanism for feeding mixed waste in to the waste destruction chamber.
- b. The chamber is maintained under minimum of 5 mm of vacuum during operation with the help of an exhaust blower.
- c. The temperature of the chamber is monitored using thermocouples.
- d. Un-burnt particulates if any will be combusted in after heater.
- e. The off-gases are treated in a dedicated wet off-gas decontamination system and passed through HEPA filters before releasing to atmosphere.

Table 4.2 : Technical specifications

i.	Model	Swatch – 100
ii.	Capacity of the machine	100 kg/day
iii.	Type of system	Magnetic Thermal Waste Destruction System
iv.	Material for treatment	Mixed Solid Waste Dry & Wet viz. Plastic waste, Paper Waste, Cartons Waste, mops, Polyethylene bags & sheets etc.
v.	Material Characteristics	Organic waste
vi.	Temperature	350 - 400 Deg. Celsius
vii.	Material of Construction	Mild Steel (M.S.)
viii.	Type of feeding & no's	Top Feeding System with a hopper – one point
ix.	Furnace with permanent magnets	Decomposition of mixed waste at low temperature
x.	Scrubber type & no. of stages	Venturi type – two stages with a storage tank
xi.	Re-heater	Electrical type - One number
xii.	De-humidifier	One number
xiii.	Exhaust system	500 CMH and 250mm static head Blower HEPA filter casing with one no. of 610mm x 610mm x 300mm HEPA filter
xiv.	Ash Removal	Using screw conveyor
xv.	Safety Features	Vacuum in the chamber during waste destruction operation, Off-gas treatment, temperature monitoring etc.
xvi.	Insulation	Insulation to maintain skin temperature less than 50 Deg. Celsius
xvii.	Functional trials	Functional test to check the capacity and performance by carrying out inactive trials at CWMF, INRPK, BARC, Kalpakkam.

xviii.	Painting of equipment	1 coat of epoxy primer-50 micron thick 2 coats of epoxy paint- 50 micron thick each
xix.	Spares	One set of permanent magnets and Heater

4.1.6 SWATCH MACHINE DESIGN SPECIFICATIONS

The equipment is designed for management of 100 kg per day of radioactive solid waste received from various units at Kalpakkam. The moisture content of the waste has to be less than 40%, if not time taken for destruction will be higher.

Design Specifications / Basis

- Designed capacity - 100 kg per day or 0.5 cu.m/day with maximum of 40% moisture
- Maximum surface dose rate of the mixed waste processed ≤ 0.2 mGy/h (20mR/h)
- Designed to maintain negative pressure greater than 10 mm of WC in the furnace
- The flue gases (produced during decomposition) are treated in dual stage spray scrubbers
- Secondary auxiliary heater is provided in the flue-gas line for the incineration of toxic gases, if any
- The flue-gases are discharged through a 25 m tall chimney meeting CPCB norms on flue gases release for industrial Incinerators
- Particulate activity in the flue-gases is decontaminated by HEPA filter. The efficiency of the filter is $> 99.95\%$ and pressure drop maintained across the filter is 100 mm of WC
- Radioactivity in the flue-gases is monitored through stack monitor and discharges are maintained within the authorized limits
- The specific activity of the scrubber water (secondary waste) is maintained below 37 Bq/ml (10^{-3} mCi/l, i.e. up to Category-II), and is transferred to LETP for further management
- The ash produced is conditioned in cement matrix prior to disposal in NSDF

4.1.6.1 DESIGN SAFETY FEATURES OF THE SYSTEM

1. The system has double door charging mechanism for feeding mixed waste into the waste destruction chamber/furnace.
2. The chamber is maintained under minimum of 10 mm of vacuum during operation, with the help of an exhaust blower.
3. The temperature of the chamber is monitored using thermocouples.
 4. Un-burnt particulates, if any are incinerated in an after heater.
5. The flue-gases are treated in a dedicated wet flue-gas decontamination system and passed through HEPA filters before releasing to atmosphere via chimney.
6. Class -III power supply is provided for safe shutdown of the system, in case of failure of Class-IV power.
7. Area Gamma Monitor, stack monitor is provided for radiological safety

CHAPTER 5

5.1 RESULTS AND DISCUSSIONS

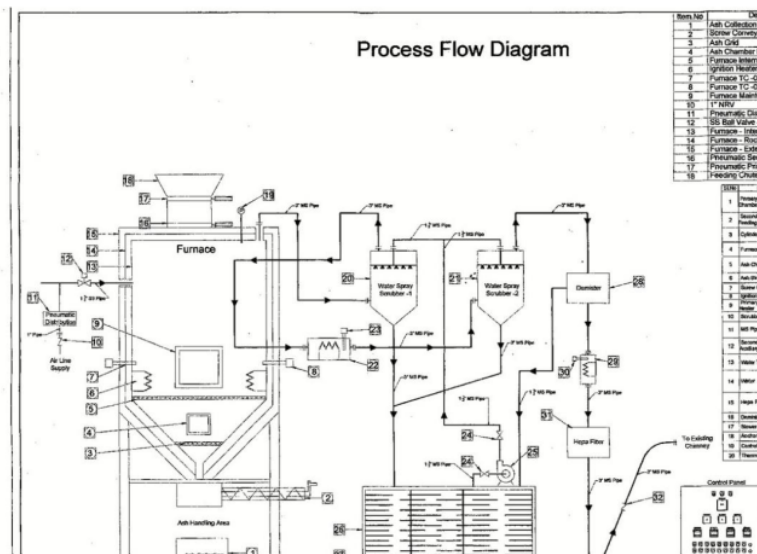


Fig: 5.1 : Initial process flow diagram

5.1.1 EXPERIMENTAL OUTCOME

Inactive Trials: Inactive trials were carried out. The following table provides details on the trials:

Table 5.1 : Details on processing of waste - Initial trials

Trial Number	Weight of Cellulosic Waste (kg)	Weight of Plastic Waste (kg)	Weight of Total Waste (kg)
1	08	00	08
2	10	00	10
3	10	00	10
4	09	00	09
5	08	01 (10%)	09
6	06	03 (30%)	09

Table 5.2 : Variation of process parameters - Initial trials

Time	Furnace Negative Pressure (mm Wc)	Furnace Temperature		AH-01 Temp.	AH-02 Temp.	DP across HEPA Filter (mm Wc)
		IG-01	IG-02			
10:00	15	34	35	37	36	7
10:30	12	111	95	375	184	7
11:00	11	151	141	676	394	7
11:30	10	160	149	750	409	7
12:00	13	162	149	558	389	9
12:30	13	304	250	573	388	9
13:00	10	220	245	581	391	9
13:30	10	238	239	577	366	9
14:00	10	236	220	601	385	9
14:30	10	310	306	664	411	9
15:00	10	306	300	750	394	9
15:30	10	260	255	750	410	9
16:00	10	251	249	750	400	9

Table 5.3 : Variation of process parameters - Initial trials

Trial Number	Furnace Negative Pressure (mm Wc)	Furnace Temperature		AH-01 Temp.	AH-02 Temp.	DP across HEPA Filter (mm Wc)
		IG-01	IG-02			
1	15	248	239	750	410	10
2	13	245	247	741	396	10
3	14	245	250	730	390	10
4	14	238	241	750	409	9
5	15	249	243	750	408	10
6	14	242	245	743	398	9

It can be inferred from the Table-2 that

- a) Vacuum is observed in the range of 13-15mm WC,
- b) Furnace Temperature is observed in the range of 240-250°C,
- c) Auxiliary Heater (AH) - 01 temperature is observed in the range of 730-750°C,
- d) Auxiliary Heater (AH) - 02 temperature is observed in the range of 390-410°C and
- e) DP across HEPA Filter is nearly 10 mm Wc.

It was observed that the waste fed was destructed in all the trial operations. The visual inspection of furnace showed complete destruction of the material and performance is satisfactory. But during these trials, it was observed that soot is being carried away by the flue gases. It is scrubbed & collected in the scrubber tank. Based on the literature the carbon soot can be destructed at about 700°C with excess air and it was confirmed with laboratory experiment. After supplier's concurrence, changes viz. a) Passing the off-gases directly to the primary auxiliary heater with additional air supply (instead of first stage scrubber) and b) HEPA filter;er bank were 1qcarried out.

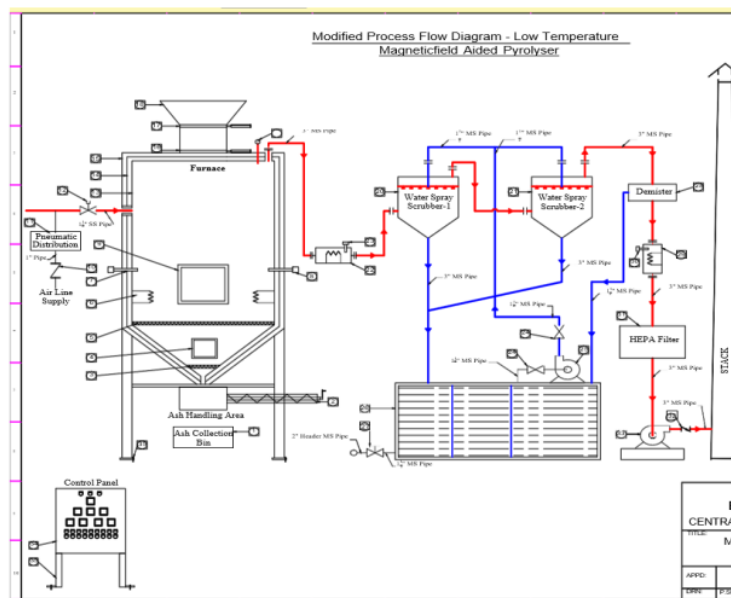


Fig: 5.2 : Modified process flow diagram

Thereafter, five inactive trials were carried out during May-2022 for the destruction of 74 kg of

mixed waste with varying composition of plastic (25%-40%) & cellulose. The VRF obtained based on initial inactive trials is in the range of 30-35. The following were the observation during the trials:

Table 5.4 : Variation of process parameters after modifications

Trial Number	Furnace Negative Pressure (mm Wc)	Furnace Temperature		AH-01 Temp.	AH-02 Temp.	Scrubber Pump Pressure (kg/sq.cm)	DP across HEPA Filter (mm Wc)
		IG-01	IG-02				
1	14	249	248	351	101	1.3	10
2	14	242	245	347	98	1.2	10
3	13	245	247	344	97	1.3	10
4	14	248	241	349	100	1.3	10
5	13	250	243	348	100	1.2	10

The above table shows that the

- Vacuum is observed in the range of 13-14mm WC,
- Furnace Temperature is observed in the range of 242-250°C,
- Auxiliary Heater (AH) - 01 temperature is observed in the range of 344-351°C,
- Auxiliary Heater (AH) - 02 temperature is observed in the range of 97-101°C,
- DP across HEPA Filter is about 10 mm Wc.

The following are the observations during these trials:

- The six heaters in the furnace functioned as per the design intent, the material was completely destructed and ash could be collected in the container.
- A negative pressure greater than 10 mm WC in the furnace was maintained.
- The bottom door of the double door charging mechanism was maintained and working smoothly.
- On one instance, the ash collected consists of little quantity of liquid.
- The secondary auxiliary heater could reach the set temperature of 100°C after replacement.

- The primary auxiliary heater, after its replacement is working and could reach only up to the temperature of 351°C and the desired set point of 700°C was not achieved. This was due to the inadequate capacity of the heating coils provided. Hence, there was no appreciable reduction in soot production and it is being carried to the HEPA.
- Due to the condensation of the off-gases water was accumulated in the exhaust blowers.

It was observed that the waste fed was destructed in all the trial operations. The visual inspection of furnace showed complete destruction of the material and performance is satisfactory. But during these trials, it was observed that soot is being carried away by the flue gases. It is scrubbed & collected in the scrubber tank. Based on the literature the carbon soot can be destructed at about 700°C with excess air and it was confirmed with laboratory experiment. After supplier's concurrence, changes viz. a) Passing the off-gases directly to the primary auxiliary heater with additional air supply (instead of first stage Scrubber) and b) HEPA filter bank were carried out.

Thereafter, five inactive trials were carried out for the destruction of 74 kg of mixed waste with varying composition of plastic (25%-40%) & cellulose. The VRF obtained based on initial inactive trials is in the range of 30-35. The following were the observation during the trials:

Table 5.5 : Variation of process parameters after modifications

Time	Furnace Negative Pressure (mm Wc)	Furnace Temperature		AH-01 Tem p.	AH-02 Tem p.	Scrubber Pump Pressure (kg/sq.cm)	DP across HEPA Filter (mm Wc)
		IG-01	IG-02				
10:30	11	29	28	27	28	1.3	35
11:00	11	151	146	47	36	1.2	35
11:30	10	180	201	161	62	1.3	12
12:00	10	248	241	238	79	1.3	14
12:30	10	258	234	275	119	1.2	15
13:00	10	235	221	280	116	1.3	11
13:30	10	150	151	285	118	1.3	10
14:00	10	260	251	351	114	1.3	10
14:30	10	220	190	320	116	1.3	10

15:00	10	171	153	308	116	1.3	10
16:00	10	112	104	257	113	1.3	10
16:40	10	68	65	223	109	1.3	10

- The six heaters in the furnace functioned as per the design intent, the material was completely destructed and ash could be collected in the container.
- A negative pressure greater than 10 mm WC in the furnace was maintained.
- The bottom door of the double door charging mechanism was maintained and working smoothly.
- The secondary auxiliary heater could reach the set temperature of 100°C after replacement.
- On one instance, the ash collected consists of little quantity of liquid.
- The primary auxiliary heater, after its replacement is working and could reach only up to the temperature of 351°C and the desired set point of 700°C was not achieved. Hence, there was no appreciable reduction in soot production and it is being carried to the HEPA.

Due to the condensation of the off-gases water was accumulated in the exhaust blowers.



Fig: 5.3 : Soot content in scrubber tank (Initial)

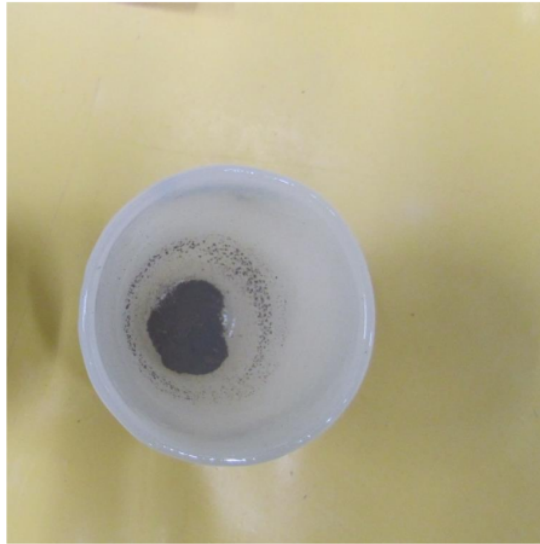


Fig: 5.4 : Soot content in scrubber tank (after modification)

6.1 CONCLUSIONS

The following conclusions could be drawn based on the commissioning of the Magnetic Field assisted Low-temperature Pyrolysis system at CWMF, INRPK, NRB:

- a. The mixed solid waste could be destructed effectively at low temperature with the aid of magnetic field.
- b. The VRF obtained based on initial inactive trials is in the range of 25-30.
- c. Active trials to be performed to obtain Decontamination Factors across various sub-systems, to comply the safety recommendations and verification of process performance with respect to radioactivity.
- d. Carbon soot is being carried to the HEPA even after scrubbing.
- e. On one instance, the ash collected consists of little quantity of liquid. It may be due to increased percentage addition of plastic in the feed.
- f. Due to the condensation of the off-gases water was accumulated in the exhaust blowers. The drain of the blower needs to be connected to a suitable drainage pipe.

CHAPTER 7

7.1 WAY FORWARD

Future Plan of Action:

The following are to be addressed for implementing the system in the plant scale:

- Carbon soot produced to be oxidised in an after burner.
- Improvements need to be done in the spray scrubbers for enhancing the particulate removal.
- Design modifications in the de-mister.
- Measurement of dioxins & furans in the off-gases to ascertain the discharges are within the limits.
- Overall improvements with respect to off-gas treatment.

To carry out active operations, the following process improvements are proposed to be carried out:

- Use of enhanced oxygen concentration in the supply air.
 - Oxidation of the carbon soot in an after burner.
 - Providing suitable arrangement for drainage of condensate from the exhaust blower.
- a) After Burner:** Based on the calculations, it is proposed to provide an after burner of about 61 kW with 30% heating efficiency. It will cater to the heating requirement of the air with soot particulates to about 700°C from 250°C.
- b) Exhaust Blower Condensate Drainage:** It is proposed to provide an arrangement for drainage of condensate from the exhaust blower by installing it at an elevated position.

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