Vitrification and

Vitrous Materials

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Vitrification

- Turning a substance into glass

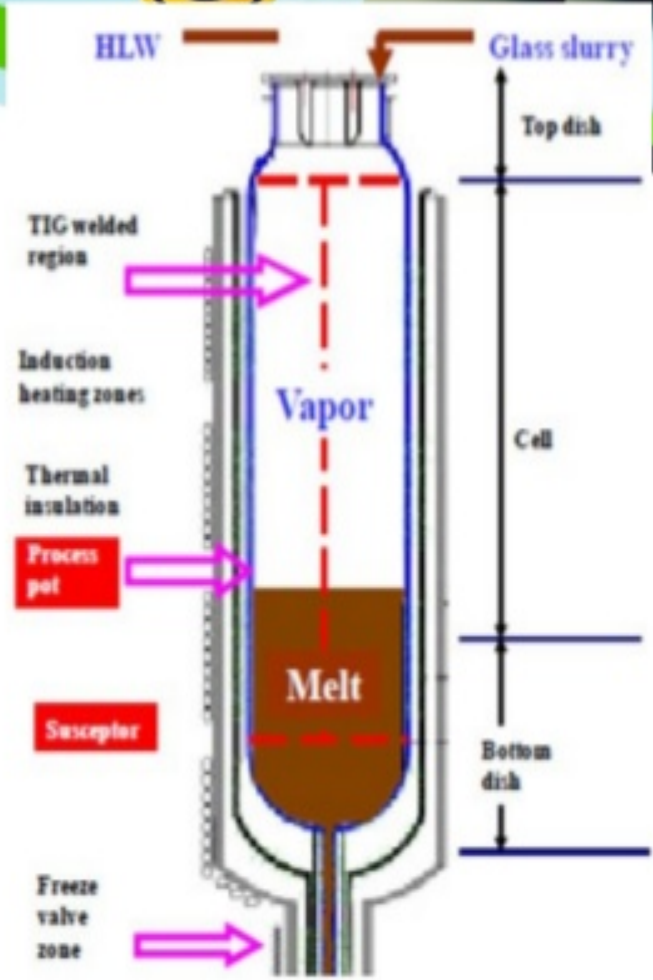
- Immobilization of waste by conversion into a glass.

- The embedding of Nuclear or Hazardous materials in a glassy matrix .

- Accepted Internationally for the conditioning of HLW.

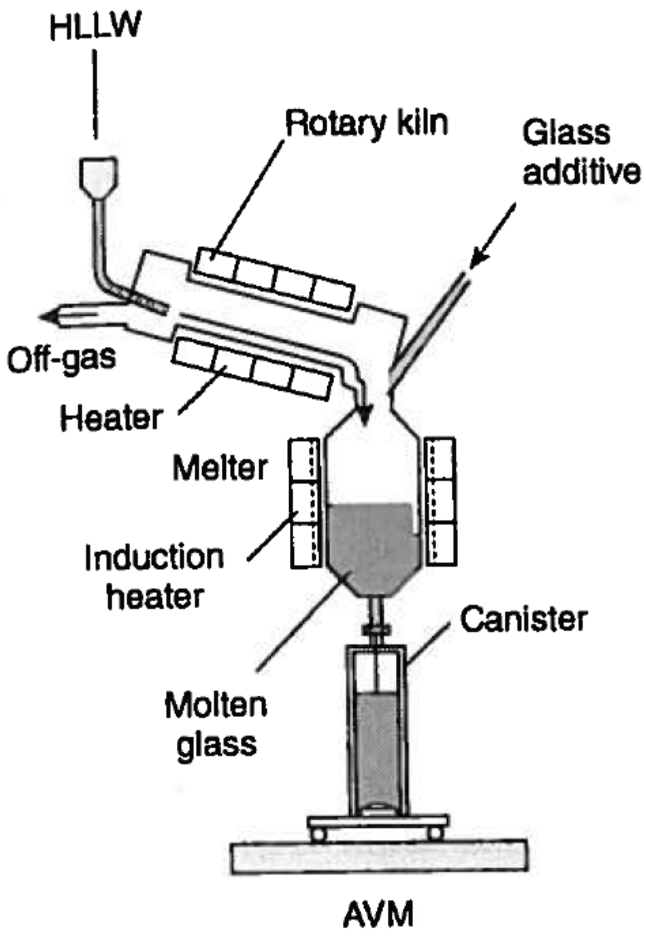
Vitrification

- Radioactive waste to glass
- Low solubility
- Immobilization of waste for thousands of years.
- Widely used for storage purpose.



Vitrification

- Liquids may come from reprocessing, power plant, and Pu warheads
- Liquid waste is usually calcined to dry it and then glass-forming “frit” is added.
- A variety of methods are used. A two-stage calcining and vitrification method is shown.
- Neutron absorbers may be added to prevent criticality for high-loadings of U/Pu



Vitrification process

- Nuclear waste vitrification, a process in which the waste forms are melted together with stable glass compositions, has several advantages, namely: a large number of radioactive elements can easily be incorporated into the glass, producing highly durable and mechanically strong small-volume waste products.
- Silicate glasses, in particular borosilicate (high silica) compositions (like those used in Pyrex and other commercial glasses), have very good chemical stability and are normally used at present.

Vitrous Waste Forms

1. Borosilicate glasses
2. Phosphate Glass
3. Aluminosilicate Glass
4. High Silica Glass
5. Lead iron phosphate Glass

Typical Range of Waste Glass Compositions

Oxide wt %	Pyrex *	Borosilicate *	Alumino silicate *	Glass ceramics *	WSEP P_2O_5*	Pbo-Fe_2O_3-P_2O_5**
SiO_2	81	25-50	33-40	32-60	0-6	0-0.25
B_2O_3	13	9-22	-------	1-11	------	-------
P_2O_5	-------	0-2	--------	------	30-55	25-42
Alkali Oxide	4	8-19	18-22	0-13	5-25	1-2
Alkaline Earth Oxide	-------	0-6	13-16	2-33	------	--------
Fe_2O_3,NiO, Cr_2O_3.MnO	-------	1-20	--------	------	0-30	6-13
Al_2O_3	2	0-10	26-30	10-24	0-35	1-2
TiO_2	-------	0-3	0-3	------		--------
ZnO	-------	0-22	-------	0-13		--------
PbO	-------	0-50	-------		0-30	36-53
Fission Products	-------	30	5	20	30	0-0.25
Actinides	10	1	7	10	[illegible]	

Performance criteria of waste forms

- Must maintain mechanical integrity.
- Must be radiation resistance.
- Must be chemically flexible.
- Must be capable of high waste loading.
- Must an acceptable thermal conductivity.
- Must have low leach rate.

Borosilicate Glasses

Borosilicate = alkali aluminosilcate + B_2O_3

1. The Excellent Leach Resistance Properties

2 Compositional flexibility

3 Low thermal expansion.

4 Overall Ease of process ability

Borosilicate glasses are alkali aluminosilicate type glasses which are fluxed with Boron. The lower alumina contents and the presence of Boron lower the melt viscosity and hence the processing temperature(about 1150^{o}C)relative to other glass matrix. The Boron increases the solubility of many waste constituents in the silica bases glass while maintaining their thermal and mechanical stability. Boron decreases the chemical durability only slightly relative to the high durable but difficult to fabricate aluminosilicate glasses

Phosphate Glasses

Advantages

- Can accept very high %Al, Mo.
- Less corrosion(solubility) than borosilicate glass.
- One stage process (i.e. no calcination).
- Low melting point(1000°C for Na- Al-P).

Disadvantages

- Na-Al-P corrosive melt.
- Devitrifies at relatively low temperatures.
- High solubility after devitrified.
- Na-Al-P showed very high leachability rate.

System Evaluation of
Borosilicate and Phosphate Waste Glasses

Type of glasses		
Product Reliability	Borosilicate	Phosphate
Chemical durability	Good	Good
Thermal Stability	Good	Poor
Mechanical Stability	Good	Poor
Process Reliability		
Melt Temperature	1150^{o}C	850^{o}C-1050^{o}C
Waste Solubility	Good(28-35%)	Low(5-15%)
Volatility	Good	Good

System Approach of Nuclear Waste Glass Development

Product Reliability	
1	Chemical Durability
2	Thermal Stability
3	Mechanical Stability
Process Reliability	
1	Melt Temperature
2	Melt Corrosivity
3	Waste Solubility
4	Volatility

Methods of Vitrification

- **Single stage Method**

  Concentration, drying, calcinations and vitrification in the same step.

- **two-stage Method**

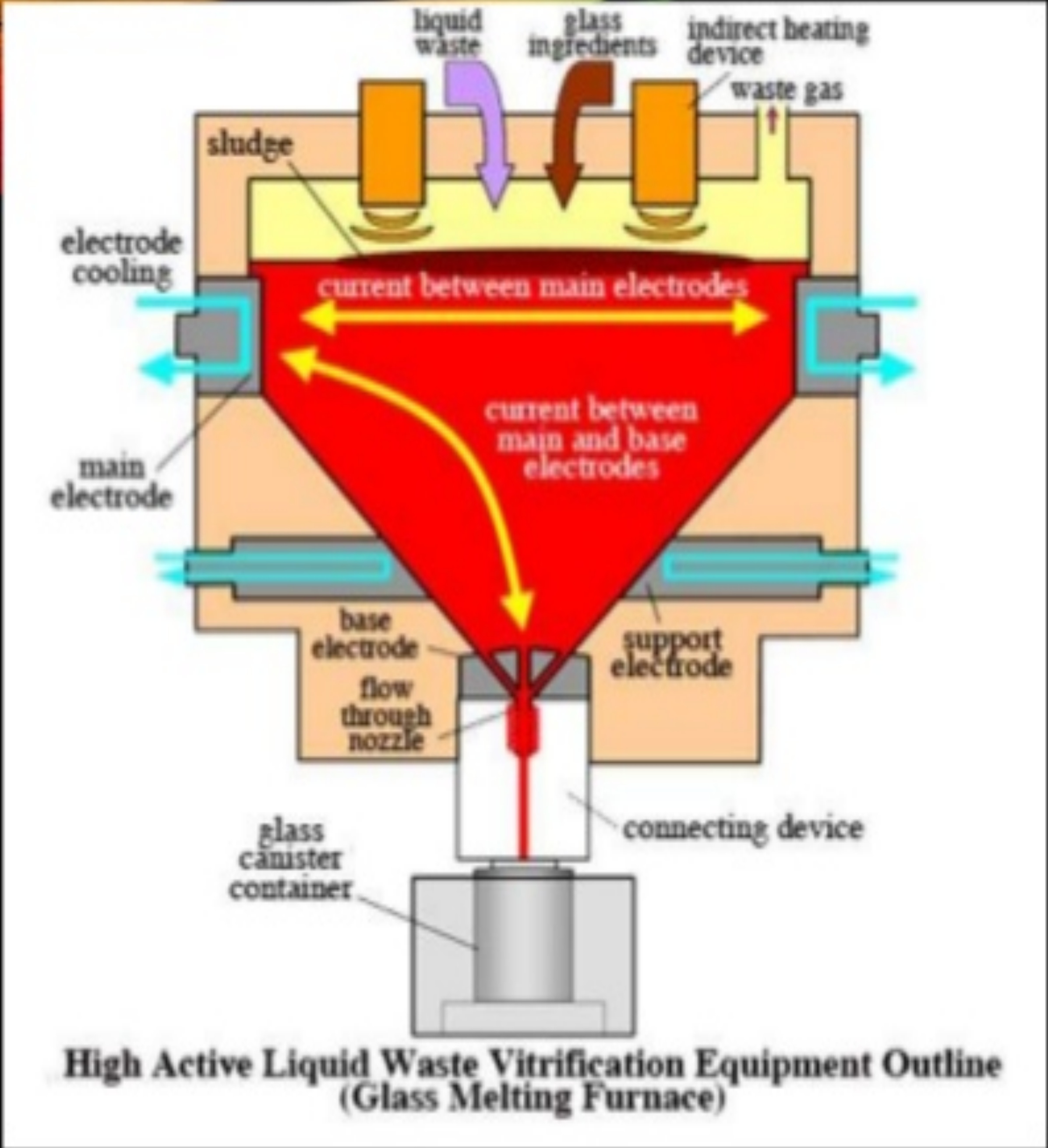
➢ Concentration, drying & calcination in one step.

➢ Vitrification in the second step.

  – AVM (Atelier de vitrification Marcoule)

Single Stage Process

- Glass forming additives may be mixed with concentrated liquid wastes.
- Glass additives are fed into the melter.
- Water evaporation occurs,followed by calcination and glass melting.



CERAMIC MELTER

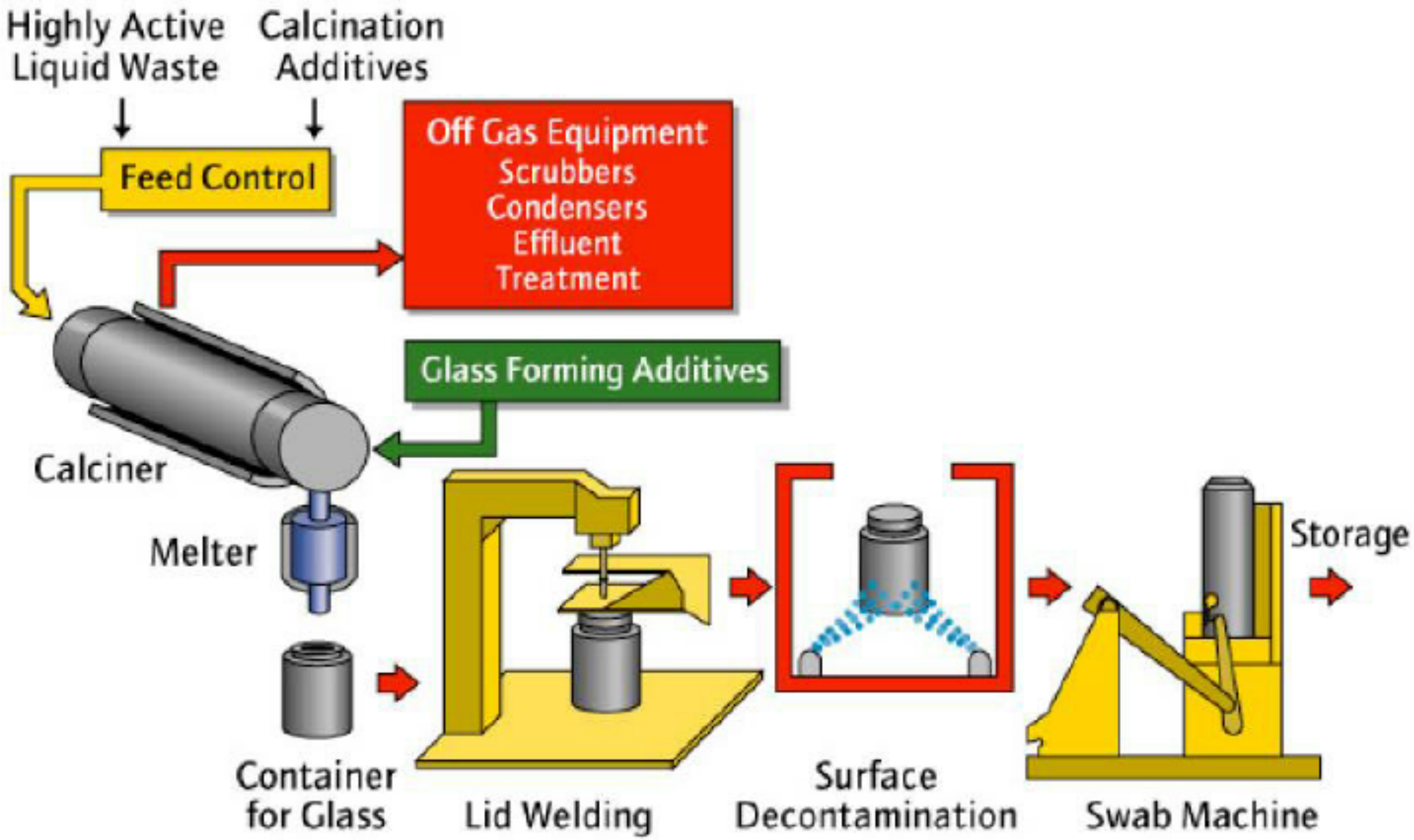
Heated by induction

Some have a life span of about 5 years, some melters only last six months[2]

Two Stage Process

- The waste concentrate is fed into the calciner
- After calcination,the required glass forming additives are fed into the melter along with the calcine.where melting takes place

Vitrification Process (AVM)



Reference

1. Vitrification of High Level Waste in the UK

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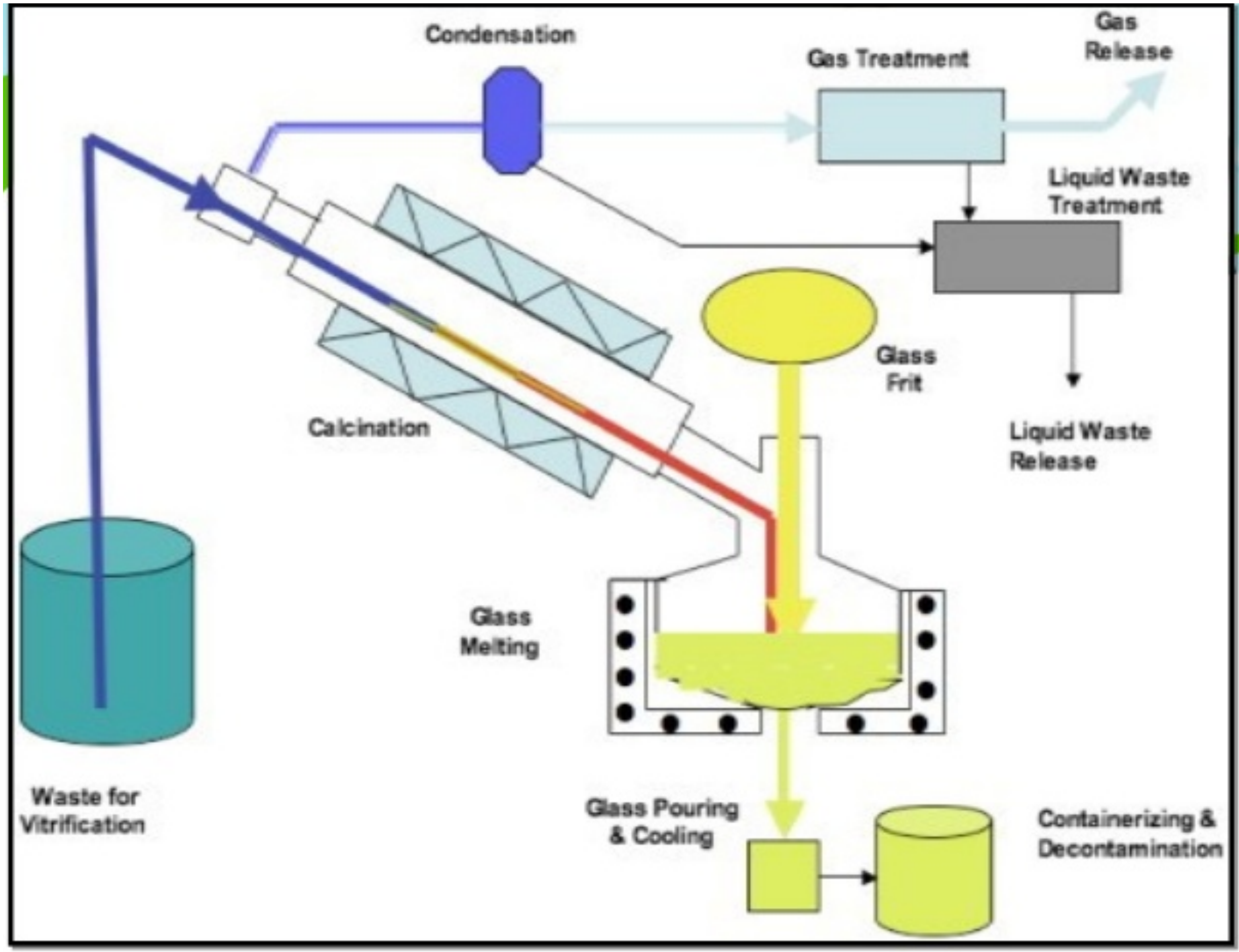

Condensation
Gas Treatment
Gas Release
Liquid Waste Treatment
Glass Frit
Liquid Waste Release
Calcination
Glass Melting
Waste for Vitrification
Glass Pouring & Cooling
Containerizing & Decontamination

Calciner

- Tubular Kiln with a slightly inclined that rotates at about 30rpm.
- Liquid waste is fed into the kiln along with calcinating additives.
- The additives main job is to convert the liquid radioactive waste into a granular solid by evaporating the waste in the fluidized bed of the vessel.

Melter

- The granular solid from the Calciner is fed directly into the Melter.
- A Melter is a melting furnace, usually made of metallic or ceramic materials.
- Heated medium-frequency induction to temperature of about 1150^{o}C.
- Along with the granular waste, fragmented glass is also fed into the melter.
- The glass and radioactive waste mixed at a high temperature will bond together

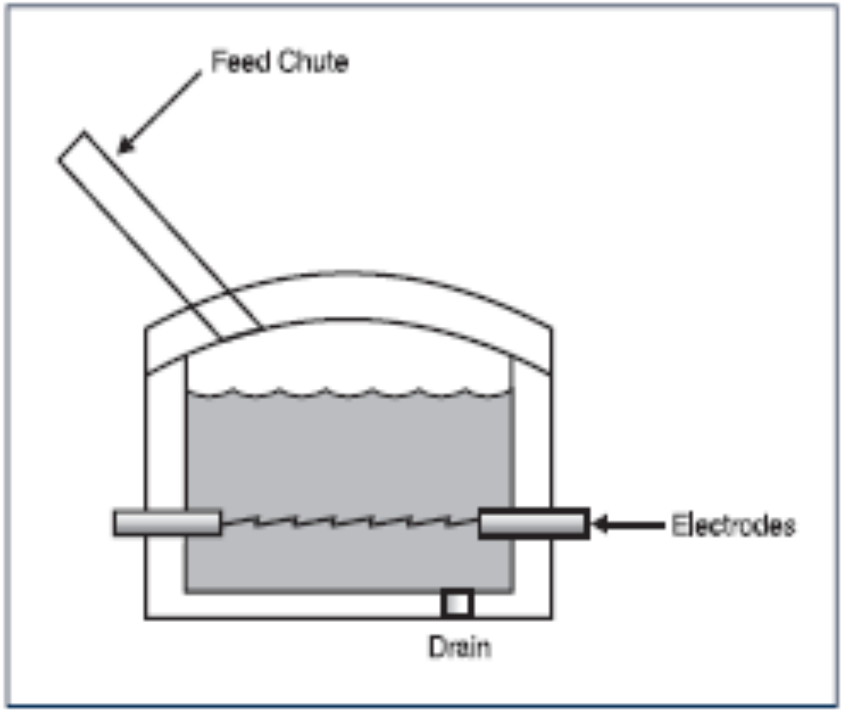
Melting techniques

- - Joule heated melting
- - Induction melting
- - Plasma arc vitrification

Joule heated melter

- A new generation of high throughput Joule heated melters, available from the commercial glass industry, allow for rapid vitrification of large volumes of waste.
- The electrical current which passes through the melt heats it due to the Joule effect.
- Compact melter technology minimizes capital and operating costs, making vitrification cost effective on a life cycle basis, compared to other stabilization technologies which do not support recycle uses.
- The compact, modular Joule heated melter can be transported from waste site to waste site.

Joule heated melter



Joule–Heated Melter

Induction Melters with high Throughput

- Induction melters with high throughput, also used in the commercial glass industry, are robust and compact enough to handle high throughput vitrification of TRU (transuranic, containing PU) waste
- Induction melters are used in UK and France.

Induction melters

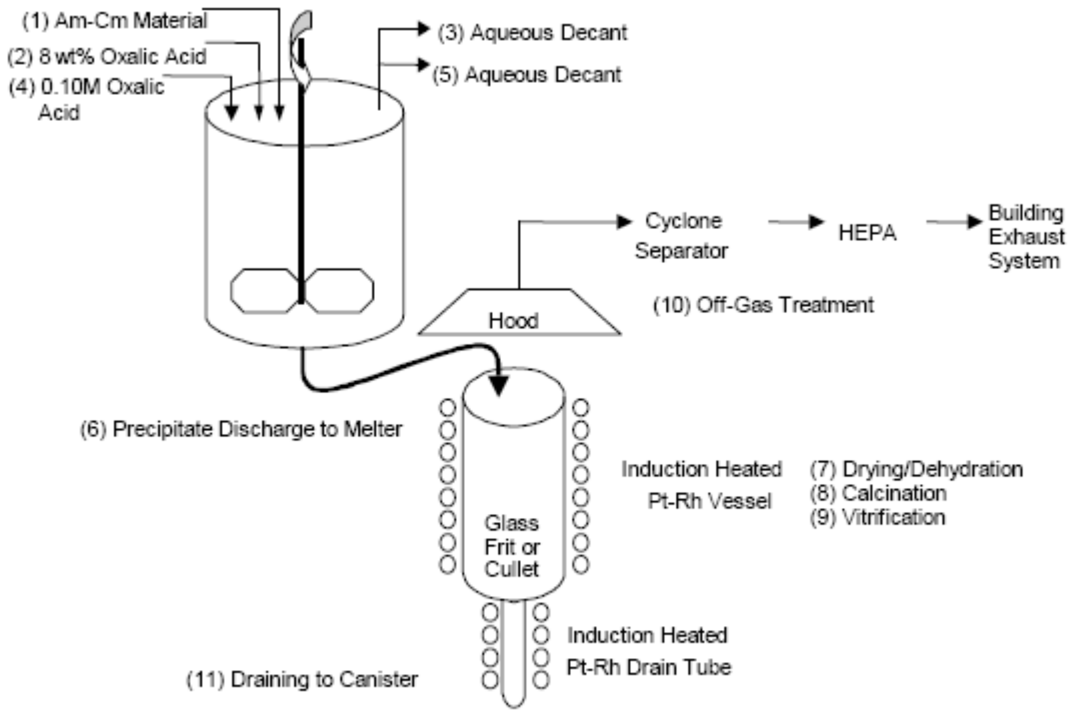


Figure 6. Schematic of the Batch Vitrification Process.

Steps after Melter

- Product is poured into an capsule like container of stainless steel .
- When cooled it solidifies into a glass that is extremely resistant to water .The canisters have lids welded onto them, are washed ,then doubled checked for contaminations on the outside surface via a swabbing machine before being put into storage.
- The process of vitrification allows for immobilization of waste for thousands of years.

summary

- Vitrification has been widely evaluated for the immobilization of high level radioactive waste. The continued application of the system approach for the evaluating glass and processing techniques between 1956 and the present has led to the acceptance of borosilicate waste glass for the immobilization of a wide range of nuclear waste compositions.
- The excellent leach resistance property of the resulting glass waste form is the principal advantage of vitrification. Vitrification has four major advantages over other methods of waste immobilization.
- The primary advantage is the durability of waste glass resulting in exceptionally well performance in leach tests.
- The second major advantage of vitrification is the flexibility of waste glass incorporating a wide variety of containments.
- The third advantage of the vitrification process is its ability to accommodate both organic and inorganic containments of various amounts.
- Lastly vitrification may reduce the volume of waste material.

Thank you
for your
Attention

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