CMR INSTITUTE OF TECHNOLOGY

USN | 1 | C | R | 1 | | | | | | |

CMRIT

Internal Assesment Test – 2

Sub: Carbon Capture and Storage (Professional Elective)				Code: 15EE743
Date: 15/10/2019	Duration: 90 mins	Max Marks: 50	Sem: 7	Sections: A&B

Answer **ANY FIVE** full questions. Explain your notations explicitly and clearly.
Sketch figures wherever necessary. Good luck!

		Marks	OBE	
			CO	RBT
Q1.	Explain the carbon capture process in cement production.	[10]	CO4	L2
Q2.	Explain in detail the absorption technology RD&D status.	[10]	CO5	L2
Q3.	Explain adsorption process applications.	[10]	CO5	L1
Q4.	Describe the membrane applications in post combustion CO_2 separation.	[10]	CO5	L1
Q5.	Describe the membrane configuration and module construction.	[10]	CO5	L2
Q6.	Describe the membrane application in natural gas processing.	[10]	CO5	L1

CMR INSTITUTE OF TECHNOLOGY

USN | 1 | C | R | 1 | | | | | | |

CMRIT

Internal Assesment Test – 2

Sub: Carbon Capture and Storage (Professional Elective)				Code: 15EE743
Date: 15/10/2019	Duration: 90 mins	Max Marks: 50	Sem: 7	Sections: A&B

Answer **ANY FIVE** full questions. Explain your notations explicitly and clearly.
Sketch figures wherever necessary. Good luck!

		Marks	OBE	
			CO	RBT
Q1.	Explain the carbon capture process in cement production.	[10]	CO2	L2
Q2.	Explain in detail the absorption technology RD&D status.	[10]	CO1	L2
Q3.	Explain adsorption process applications.	[10]	CO3	L2
Q4.	Describe the membrane applications in post combustion CO_2 separation.	[10]	CO4	L1
Q5.	Describe the membrane configuration and module construction.	[10]	CO1	L2
Q6.	Describe the membrane application in natural gas processing.	[10]	CO4	L2

CMR INSTITUTE OF TECHNOLOGY

USN | 1 | C | R | 1 | | | | | | |

CMRIT

Internal Assesment Test – 2

Sub: Carbon Capture and Storage (Professional Elective)				Code: 15EE743
Date: 15/10/2019	Duration: 90 mins	Max Marks: 50	Sem: 7	Sections: A&B

Answer **ANY FIVE** full questions. Explain your notations explicitly and clearly.
Sketch figures wherever necessary. Good luck!

		Marks	OBE	
			CO	RBT
Q1.	Explain the carbon capture process in cement production.	[10]	CO2	L2
Q2.	Explain in detail the absorption technology RD&D status.	[10]	CO1	L2
Q3.	Explain adsorption process applications.	[10]	CO3	L2
Q4.	Describe the membrane applications in post combustion CO_2 separation.	[10]	CO4	L1
Q5.	Describe the membrane configuration and module construction.	[10]	CO1	L2
Q6.	Describe the membrane application in natural gas processing.	[10]	CO4	L2

ASSIGNMENT-2

Name : Janani . R . Kumar

Subject : Carbon Capture And Storage (15EE743) [Prof. Kashif Ahmed]

USN : 1CR16EE031

BRANCH : EEE

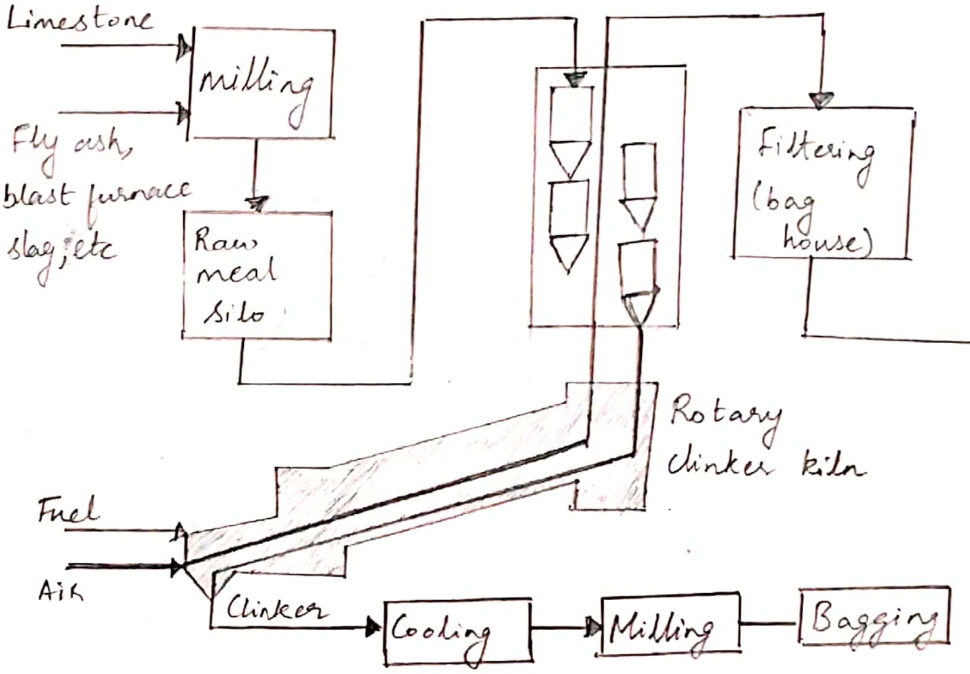
Class : 7th Sem, 'A' section

Date of Submission : 17/10/2019

Due date : 17/10/2019

Q1. Explain the Carbon Capture process in cement production.

Ans.



Block Diagram

The first stage of cement production process is the sintering of a controlled mixture of raw materials in a kiln, typically a horizontal rotary kiln at temperature of ~1450°c.

Calcium Carbonate ($CaCO_3$) is the primary raw material and may be in the form of crushed limestones, shells or chalk.

A variety of secondary raw materials are used as the source of silica and other minerals including sand, shell, clay, blast, furnace slag and coal ash. The main reaction taking place in the cement kiln is the conversion or calcining of calcium carbonate to calcium oxide, a highly endothermic reaction requiring of energy per ton of cement produced, depending on plant efficiency.

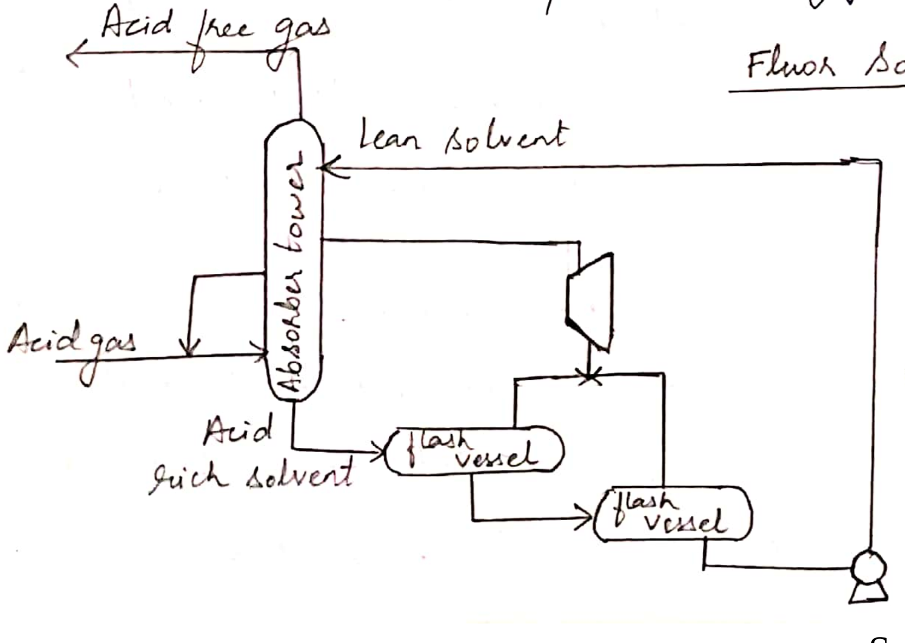
$$CaCO_3 + heat \rightarrow CaO + CO_2$$
$$2CaO + SiO_2 \rightarrow 2CaO.SiO_2 \text{ (Bellite)}$$
$$3CaO + Al_2O_3 \rightarrow 3CaO.Al_2O_3$$
$$4CaO + Al_2O_3 + Fe_2O_3 \rightarrow 4CaO.Al_2O_3.Fe_2O_3$$
$$CaO + 2CaO.SiO_2 \rightarrow 3CaO.SiO_2 \text{ (Alite)}$$

Post Combustion Capture from Cement Plant:

Capture of CO_2 from calcining can be achieved by using different technologies. It is same as carbon capture from power plants. Compared to "conventional" post combustion applications, the higher CO_2 enables their technologies.

Q2. Explain in detail the absorption technology RD&D status.

Ans.



Fluor Solvent Process Scheme for CO_2 Capture from natural gas.

- Physical Adsorption
  ↳ Fluor Solvent Process.

Although absorption process for CO_2 capture have over half a century of industrial applications, it remains an area of significant ongoing RD & D effort, applied both to the continuous improvement of existing process and also to the development of novel systems aiming for a step-change improvement in cost effectiveness of absorption as a capture technology.

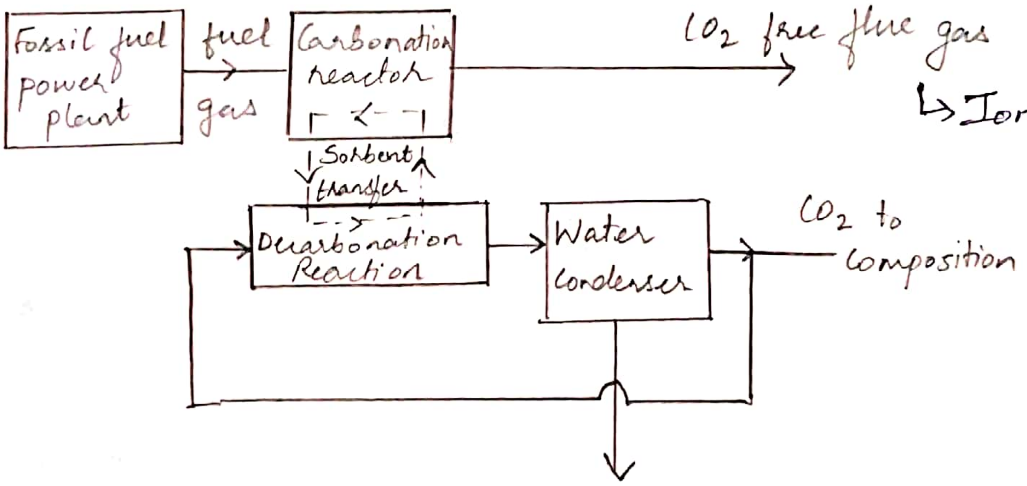
Improved amine based systems:

↳ Implemented technologies are

1. Reducing energy requirements by increasing heat integration with the host plant.
2. Improving process for solvent regeneration.

- Chemical Adsorption
  - ↳ Dry sorbent based process RD & D
  - ↳ Ionic liquid Solvent

Dry Sorbent based process R & D.



The dry sorbent process is illustrated in the above diagram. The sorbent is conveyed respectively to and from the decarbonation reactor by steam heated and water cooled screw conveyors. This process is less costly and less energy intensive than conventional amine based systems.

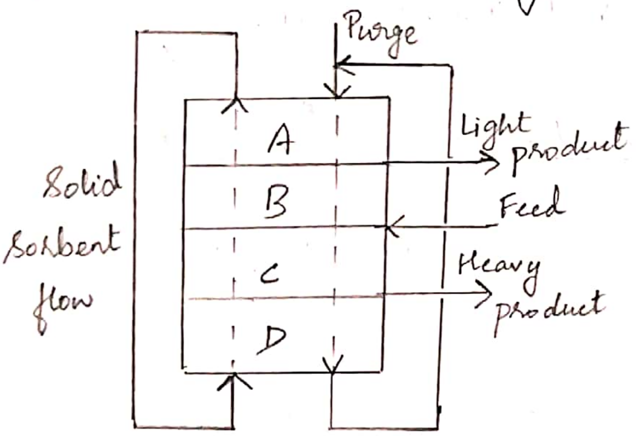
Ionic Liquid Solvent

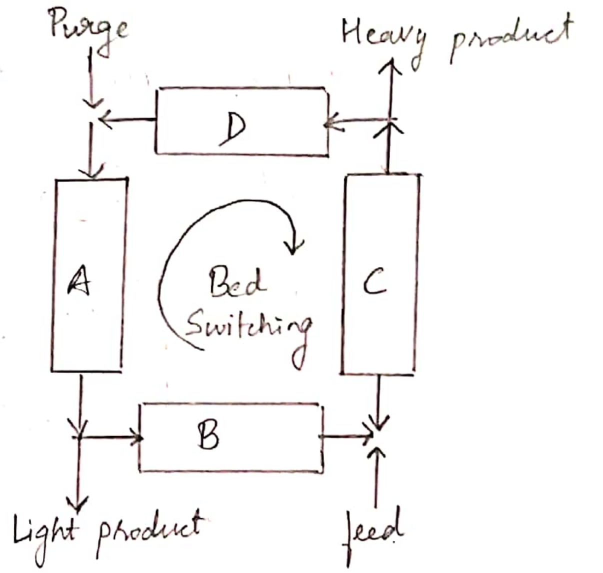
Ionic liquids (IL's) typically comprise a large organic cation & a smaller inorganic anion & it is asymmetry between the cation and anion that reduces strength of binding force and low melting point.

Q3. Explain adsorption process applications.

Ans. **Temperature swing adsorption processes**

The use of CaO as a regenerable sorbent for CO_2 is an example of a temperature swing process that was first proposed in 19th century.





Simulated moving bed using cascaded fixed beds.

In the temperature range 600-800°C the carbonation reaction proceeds rapidly and high sorbent capacity can be achieved, while the familiar calcining reaction, releasing CO_2, is favored at >900°C. A pilot-scale post combustion seperation plant has been demonstrated, using interconnected fluidized bed carbonation and calcining reactors.

Electric Swing adsorption: One disadvantage of desorption by temperature swing is the relatively long time needed to heat the sorbent bed during the desorption step and then cool the bed for the next adsorption step.

Pressure Swing adsorption processes

The pressure swing adsorption concept was developed by the ESSO Research and Engineering Company & published in a 1960 patent that disclosed a dual-bed, 2-step cycle known as the Skarstrom cycle.

Feedair is pretreated by compression, drying and filtering and then flows into one of two parallel adsorption beds (A). Here nitrogen is adsorbed and oxygen passes through the bed & is recovered as the first product stream.

Q4. Describe the membrane applications in post combustion CO_2 separation.

Ans. The key characteristics that need to be combined in a commercial membrane are:

→ Sufficient permeate flux rate to achieve desired operating throughput.

→ Low space requirements and capital cost, including membrane material cost.

→ Low sorption capacity for non-selected gases.

→ Chemical resistance to contaminants.

→ Thermal stability at required operating temperature.

→ Inexpensive fabrication methods for a variety of module configurations.

High-temperature molten carbonate membranes

A dual ion conduction membrane using a molten carbonate electrolyte is under development for high-temperature and pressure CO_2 separation form flue gas streams close to the point of combustion, or to remove CO_2 from a syngas stream after the production of hydrogen in the WGS reaction.

Facilitated transport membranes

An example of a facilitated transport mechanism that has been developed at the laboratory scale to demonstrate CO_2 separation from flue gas involves the incorporation of amine carries into a cross-linked polyvinyl alcohol (PVA) polymer membrane. The membrane showed good CO_2 permeability and CO_2 & N_2 selectivity at operating temperature upto 170°C.

Carbon molecular sieve membranes

CMS membranes hold promise for flue gas CO_2 separation applications because of their high thermal and chemical stability in non-oxidizing environments, essential characteristics for this application.

Q5. Describe the membrane configuration and module construction.

Ans. The key challenges here are:

1. Reducing the thickness of the membrane selective layer to increase flux and reduce cost.

2. The large-scale production of defect-free membranes with desired physical and chemical properties.

3. Automation of membrane and module fabrication processes to cost-effectively package the membrane into reliable modules.

Membrane types:

Membrane preparation methods & suitable module configurations are strongly tied to the required structure of the membrane material. Most non-liquid membranes, whether polymeric, ceramic, or metallic, can be prepared as either symmetric or asymmetric structures.

Membrane Module Configurations:

Symmetric or asymmetric membranes can be prepared either as hollow tubes or fibres or as cas laminar membranes, as wafers and packaged in a variety of different module configurations.

Spiral-wound modules: It consists of a number of membrane envelops wound onto a central perforated collecting tube. Each membrane envelope, or leaf consists of 2 membranes separated by a permeate spacer and sealed on three sides, leaving one side open for permeate removal.

Hollow-fiber modules: There are also extensively used in natural gas treatment because of the very high surface to bulk volume ratio. Modules consists of bundles of fibres enclosed in a pressure vessel, with the permeate passing either out of the fibres or into them.

Ceramic Wafer Stack modules: Advanced membrane materials such as metal oxide ion transport membranes require new module structures to cope with the high operating temperatures and pressures.

Q6. Describe the membrane application in natural gas processing.

Ans. The removal of CO_2 from natural gas or natural gas liquids is important in order to deliver hydrocarbon products to a low CO_2 sales specification and to reduce the potential for corrosion of process equipment, pipelines and product distribution systems.

Polymeric membranes

Polymeric membranes have been in use for CO_2 removal from natural gas since early 1980s and many systems are operating around world, most commonly using spiral-wound or hollow-fibre cellulose acetate-based asymmetric polymer membranes.

Gas-liquid membrane contactors

These make use of macroporous membranes to provide an interface between a gas and a liquid absorbent and are being developed for CO_2 removal from flue gases and for natural gas sweetening.