Current Status of MHI CO_2 Capture Plant Technology and Commercial Experiences

2014 CO_2 Conference Week;
The 12th Annual (2014) EOR Carbon Management Workshop, TX
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MITSUBISHI HEAVY INDUSTRIES, LTD.
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Contents

1. Introduction of KM CDR® Process

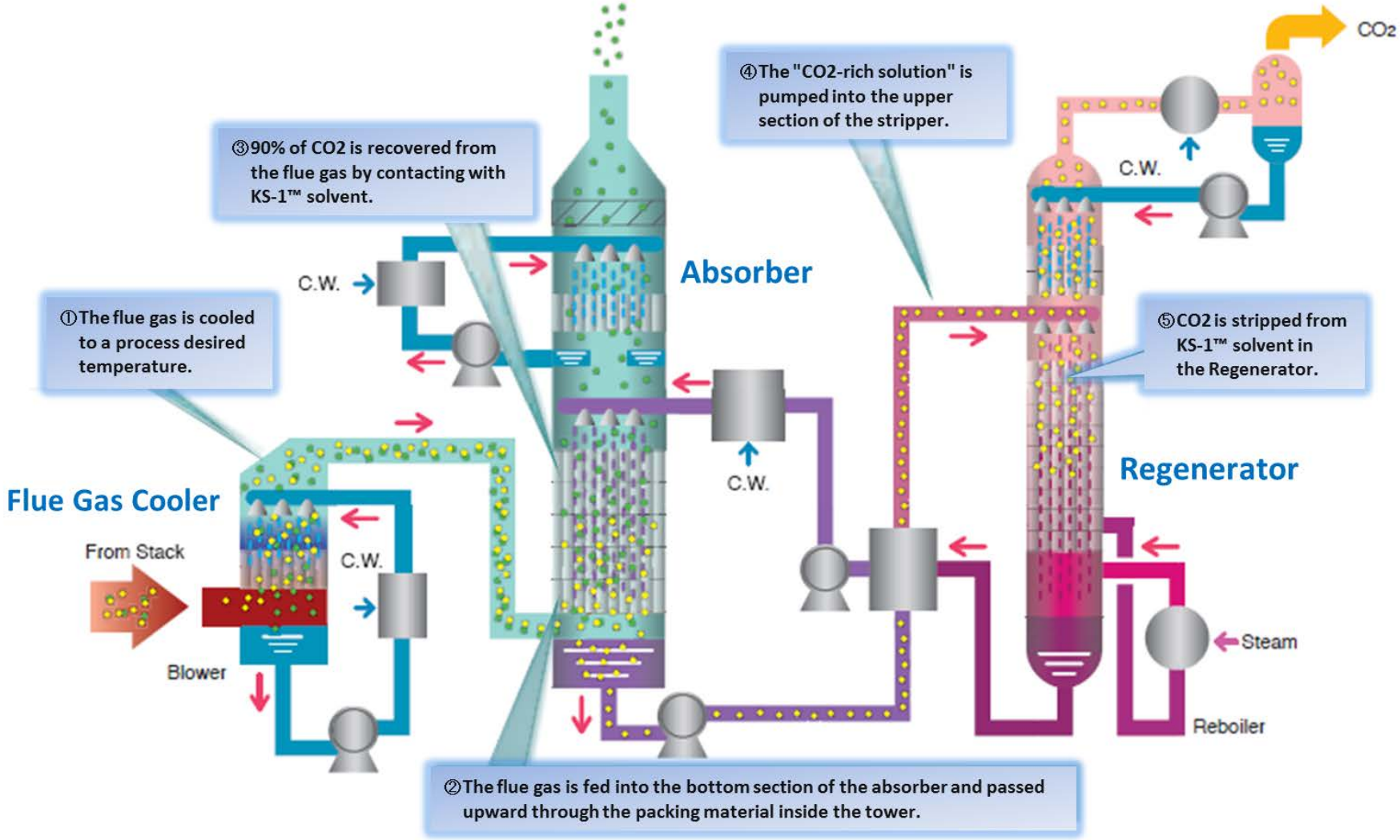
MHI CO_2 Capture Process: KM CDR® Process

- **Proprietary Technology by MHI & Kansai Electric Power Company (KEPCO)**

- **Hindered Amine Solvent "KS-1™" & Proprietary equipment**

- **Advantages**
  - **KS-1™ solvent**
    - **- High CO2 Loading**
    - **- Negligible Corrosion**
    - **- Negligible Solvent Degradation**
  - **Process**
    - **- Low Utility & Solvent Consumption**
    - **- Easy operation & Maintenance**

Advanced CO2 Capture Process – MHI's Own Technology



MHI CO2 Capture Reference Plants

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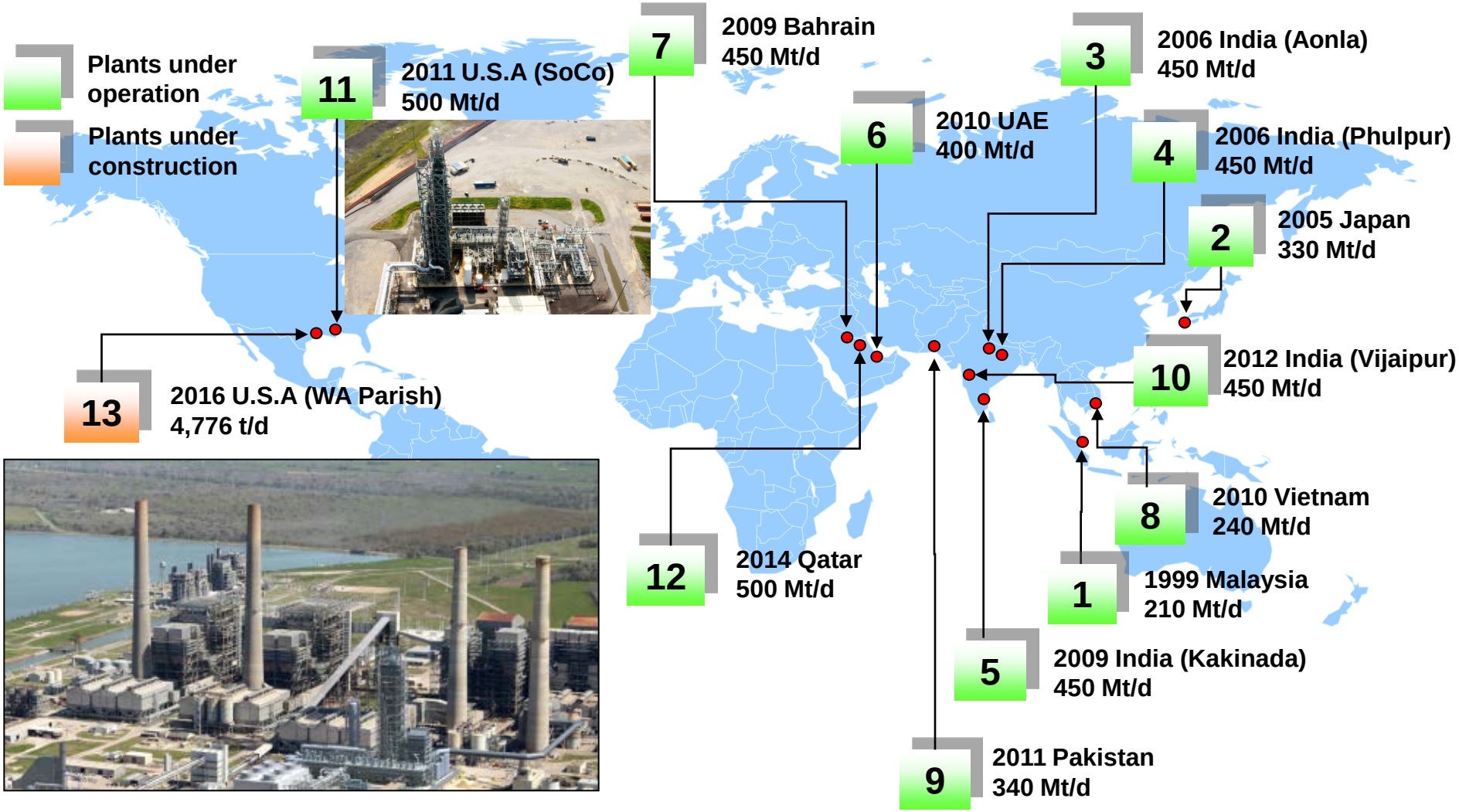
MHI is a World leading LARGE-SCALE post combustion CO_2 capture technology licensor, with 11 commercial PCC plants in operation



Commercial Experiences

1999
210 t/d Malaysia

2005
330 t/d Japan

2006
450 t/d India

2006
450 t/d India

2009
450 t/d India

2009
450 t/d Bahrain

2010
400 t/d UAE

2010
240 t/d Vietnam

2011
340 t/d Pakistan

2012
450 t/d India

2014
500 t/d Qatar

2016
4,776 t/d U.S.A.

What is Amine Emission ?

- **Amine is contained in treated gas from Absorber and is one of VOC source.**

- **MHI discovered the first in the World in 2010 that SO_3 accelerates amine emission drastically.**

  Reference: Electric Power Research Institute (EPRI). 2011. "Amines for Post-Combustion Capture"

- **This is common phenomena among all amine CO_2 capture processes.**

MHI Amine Emission Reduction Technology

- Deep understanding of Amine emission phenomena through abundant R&D activities.
- Already incorporated operation data and lesson learned from Commercial Plants into current Parish Unit 8 project design.
- Proprietary Emission Reduction System (MHI Patent), including Proprietary Demister.

Amine Emission

- SO_3 in flue gas from power plant significantly increases amine emission from CO2 absorber outlet.
- This will cause increase solvent consumption and VOC significantly
- MHI proprietary amine emission reduction system drastically reduce amine emission – VOC figures and solvent consumption
- Applied for multiple patents and some were already granted

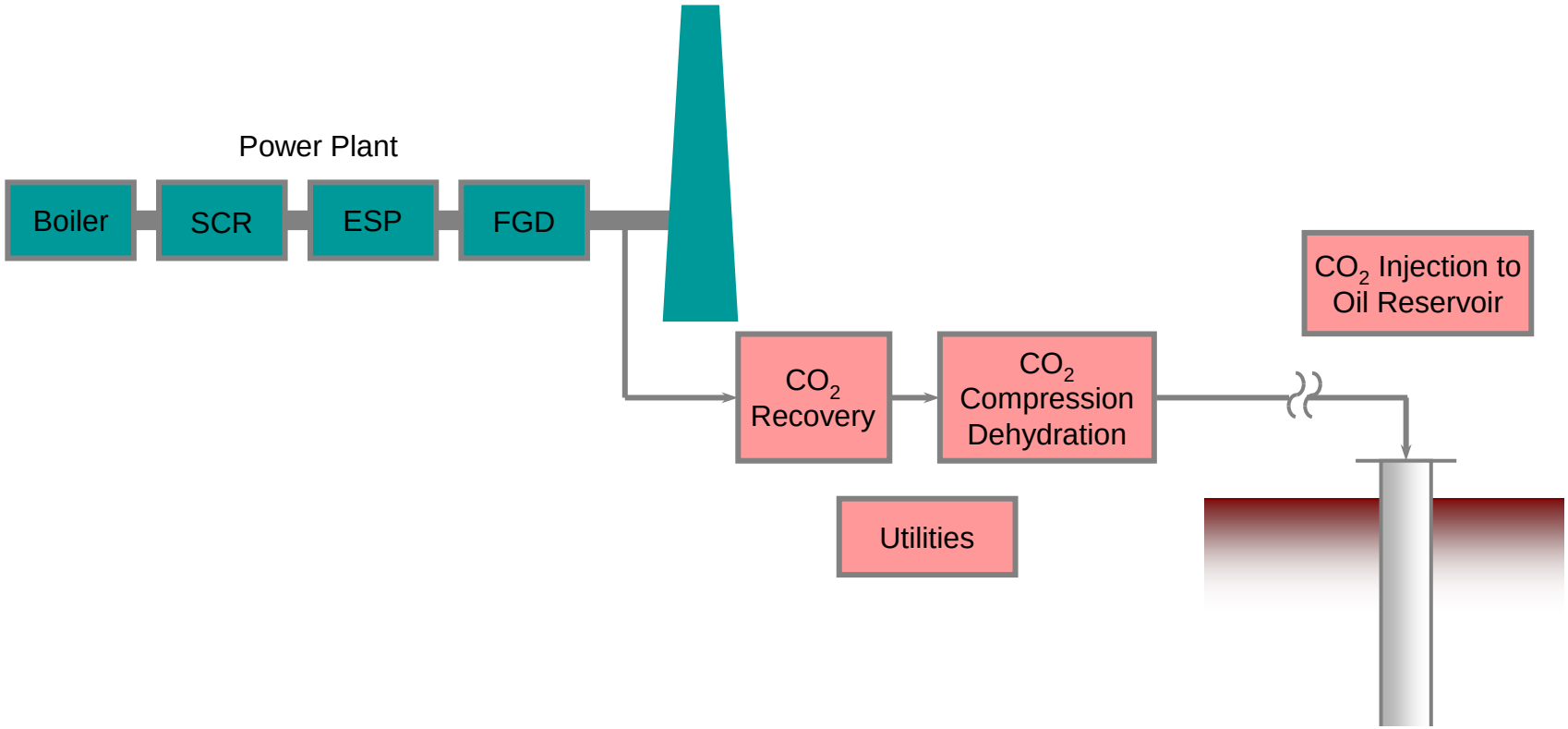
Item	Before Modification	After Modification
SO_3 concentration at Quencher inlet [ppm]	2.1-2.7	2.3-3.6
Amine (KS-1) emission [ppm]	12 - 35	0.7 - 3
Solvent consumption	Base	1/4

Before modification

After modification

2. Application of KM CDR® Process to CO_2 EOR

Application of KM CDR® Process to CO_2 EOR (1/2)

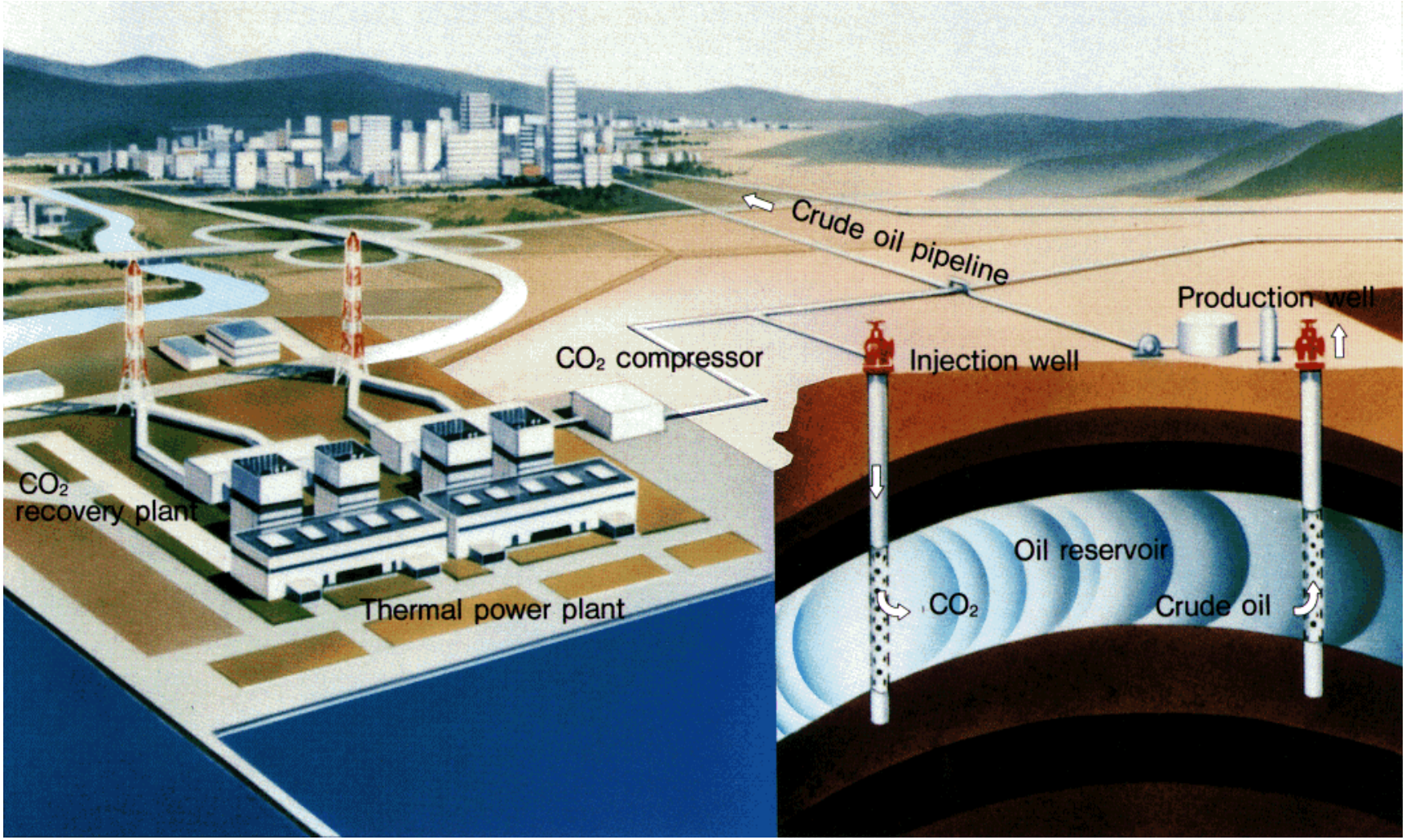


- **CO_2 Purity**

  CO_2: App 99.95%

  Impurity: Others are mostly nitrogen and trace O_2

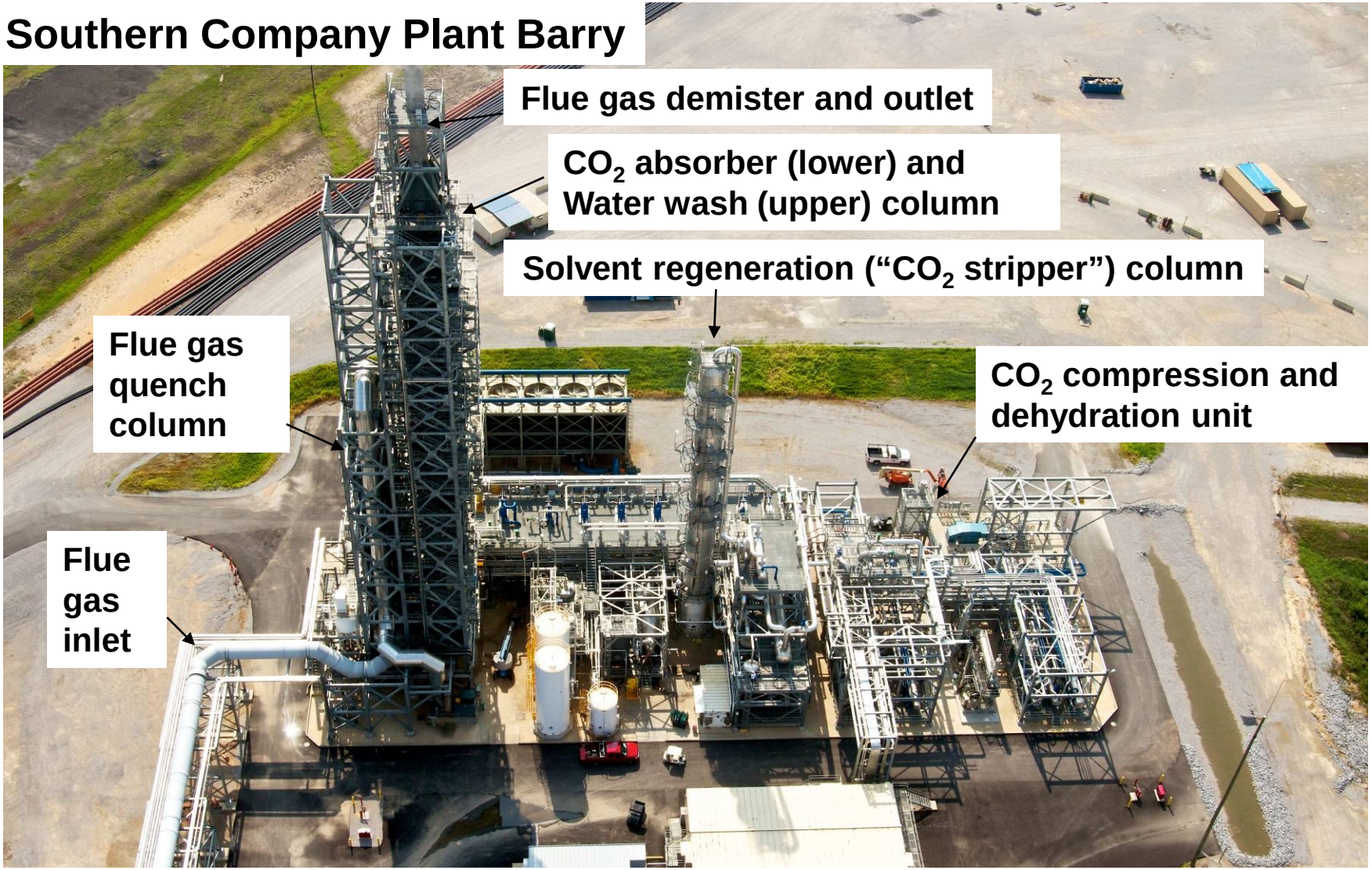
Application of KM CDR® Process to CO_2 EOR (2/2)



3. Latest MHI CO_2 Capture Project

500 Metric TPD Demonstration Plant

Southern Company Plant Barry



World's First Integrated CCS plant from Coal-fired Power Plant to CO_2 injection

500 Metric TPD Integrated CCS Demo PJ (1/2)

<Project Overview>

- CO_2 Capture and Compression
  - SCS/MHI collaboration with partners
  - KM-CDR® capture technology
- Transportation and Sequestration
  - DOE SECARB Phase III "Anthropogenic Test"
  - 12 mile CO_2 pipeline to Citronelle Dome
- World's First CCS Project integrated with Amine-based Post Combustion Process and CO_2 Injection

<Operation Status>

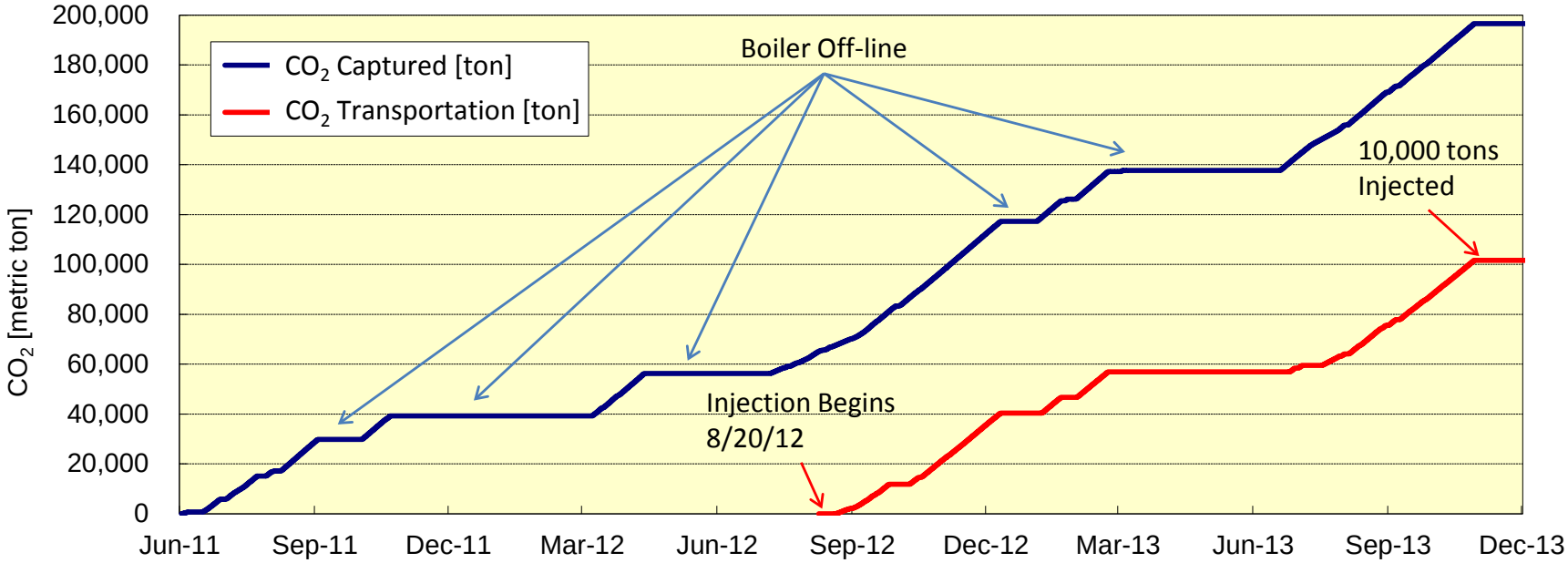
- Gas In for CO_2 Capture Plant: June, 2011
- CO_2 injection started on August 20th, 2012
- 100,000 metric tons of CO_2 injection was achieved as of October 29th, 2013

Items		Results
Total Operation Time *	hrs	12,400
Total Amount of Captured CO_2 *	metric tons	230,100
Total Amount of Injected CO_2 *	metric tons	115,500

*As of August 31th, 2014

Reference: Denbury, "SECARB - Plant Barry to Citronelle", Knowledge Sharing Conference – Mobile, May 17, 2012

Operation History



500 Metric TPD Integrated CCS Demo PJ (2/2)

- **Operation Reliability > 98%**

Reliability calculation basis

$$\boldsymbol{Reliability = \frac{Operation\ hours}{Operation\ hours\ + Unexpected\ S/D\ period}}$$

Remarks

**1) Operation hours does not contain commissioning period*

**2) Unexpected S/D is defined as a period of outage by operation malfunction. Plant outage for test implementation purpose and test originated purpose is excluded*

CO_2 Capture Plant for CO_2-EOR

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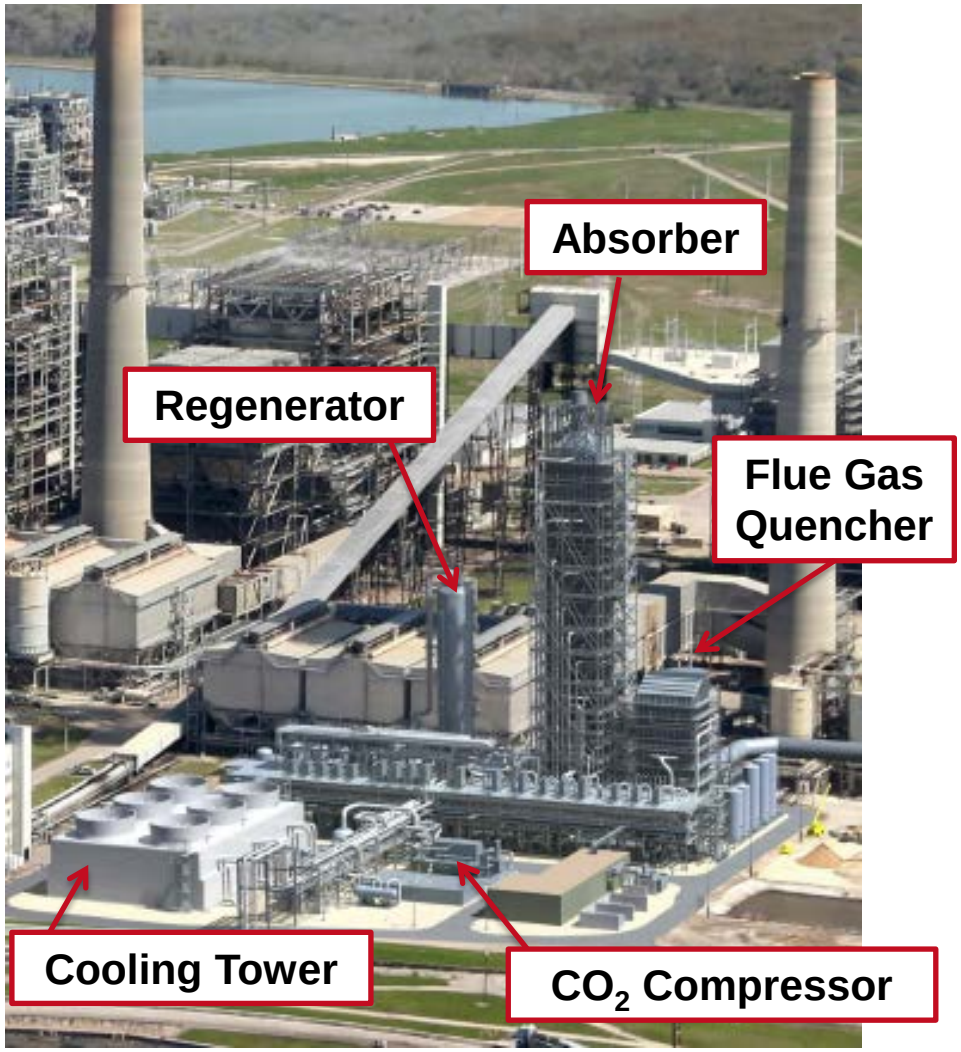
The worlds largest CO_2 capture plant from an existing coal-fired power plant

- Project owner: NRG Energy Inc. and JX Nippon Oil & Gas Exploration Corporation
- Location : NRG WA Parish Power Plant near Houston, TX.
- Flue gas source: 240MWe slipstream from an existing 650MW coal-fired boiler
- CO_2 concentration: 11.5%
- CO_2 capture capacity : 4,776 TPD
- CO_2 recovery ratio: 90%
- CO_2 Use: Enhanced Oil Recovery (EOR)
- Transport: 12 inch diameter pipeline, Approximately 81 miles
- Injection Site: West Ranch oil field in Jackson County, TX
- Operation Start : 4th Quarter, 2016



4. Summary

Summary

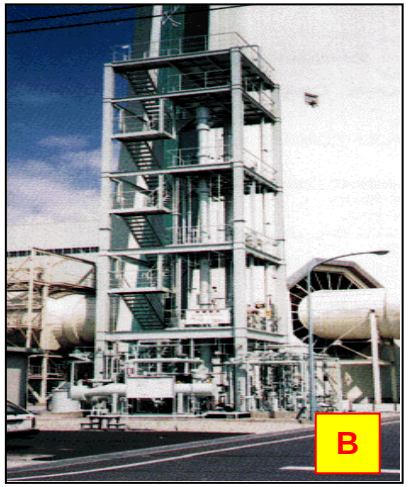
- MHI can provide cost competitive and reliable CO2 capture plant from flue gas based on our abundant commercial experiences
- Southern Company's Plant Barry 500 TPD CCS plant has successfully completed its 2nd year of operation
- MHI has started to construct the world largest CO_2 capture and compression plant near Houston, Texas for NRG Energy Inc. and JX Nippon Oil & Gas Exploration Corporation
- CO_2 capture from flue gas can contribute to global warming issue and useful for CO_2 EOR

Appendix

MHI - R&D Strength & Experience

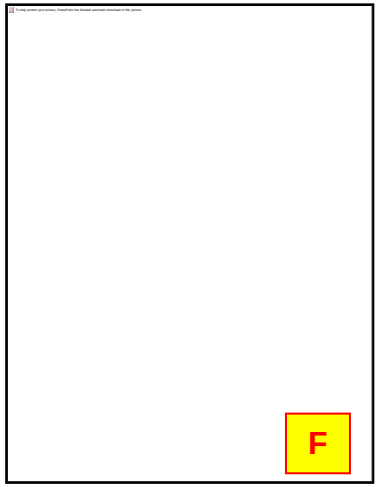
- **Deployment of R&D Facilities for specific CO_2 capture testing. More than 25 years R&D Experience**

(A) R&D laboratories (MHI Technologies and Innovation Headquarters)
(B) 2.0 TPD Nanko Osaka pilot plant from 1991
(C) 1.0 TPD Hiroshima pilot plant
(D) 0.2 TPD mobile test unit
(E) Absorber 1 by 1 scale test plant in Mihara (400 MW equivalent)
(F) 10 TPD Matsushima pilot for testing coal fired flue gas
(G) 500 TPD Barry CCS demonstration plant in Alabama, (25MW equivalent)



2.0TPD Nanko Pilot Plant
(Kansai Electric Power Co.)

1.0TPD Hiroshima Pilot Plant
(MHI' R&D Center)



10TPD Matsushima Pilot Plant
(J-Power)

500TPD Barry Demonstration Plant
(Southern Company)

Summary of Coal-Fired Pilot & Demonstration Plants

- MHI conducted R&D at various stages of the test for coal-fired flue gas.
- 500 TPD demonstration plant integrated with coal-fired power plant and CO_2 injection started in June, 2011.
- The demonstration test results verified the high reliability of the KM-CDR® Process

Location	Capacity	Client/Host	Flue gas source	Purpose	Start up
U.S.A. SoCo Yates power station	0.2 MT/D	Mobile unit (Southern Company)	Coal fired boiler flue gas	R&D	September 2010
Japan MHI R&D Center	1 MT/D	-	Coal fired boiler flue gas	R&D	April 1999
Japan Matsushima power station	10 MT/D	J - Power	Coal fired boiler flue gas	R&D	July 2006
U.S.A. SoCo Barry power station	500 MT/D	Southern Company	Coal fired boiler flue gas	R&D	June 2011

CO_2 Capture & Compression Test Items

Item	Main Results
Initial Baseline Testing	• Verified that actual utility and solvent consumption were lower than the design but within the expectation (CO_2 removal efficiency: 90%, CO_2 capture rate: 500MTPD). • Proven that KM-CDR® Process can follow the operation condition of CO_2 injection • Captured CO_2 quality is within the criteria of the pipeline and CO_2 injection site
Emissions and Waste Stream Monitoring	• Successfully demonstrated amine emission reduction technologies under the various SO_3 concentration condition (2013) • Measured total Volatile Organic Compound (VOC) emissions and verified that the commercial scale CO_2 capture plant using KM-CDR® Process will be acceptable
Process Parametric Test and Performance Optimization	• Verified **operation performance** under several controlled operating parameters changes (2011-2012) • Achieved **0.95 ton-steam/ton-CO_2** by optimizing steam consumption (2011)
Dynamic Response Evaluation Test	• Carried out continuous control testing to optimize the operation condition with self-developed dynamic simulator. The system successfully controlled the operation condition (Oct. 2013)
Long Term Impurities Influence Test	• Achieved **100,000 metric tons of CO_2 injection** without any operational issues • Verified that the **amine emission increased** as a result of **higher SO_3 loading** (Oct. 2011) • Verified that the impurities were removed from the solvent by **reclaiming** operation (2012, 2013)

Basic Process Flow Diagram

- Post-Combustion CO_2 capture process using MHI proprietary KS-1™ solvent
- MHI developed the KM-CDR® process with Kansai Electric Power Co. since 1990