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MHI Proprietary CO_2 Recovery Process for Increasing Methanol Production

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Outline

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4. References for methanol production expansion

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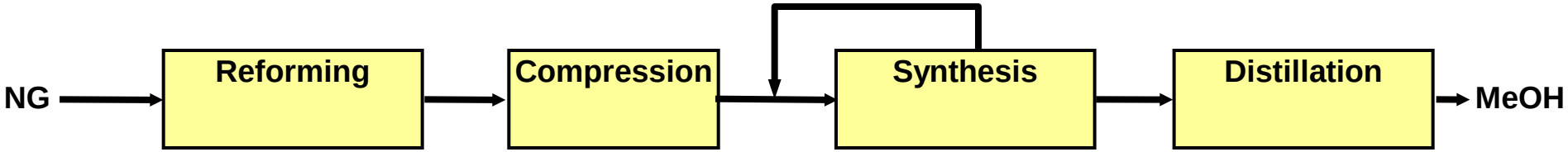
1. Introduction

Typical Process Scheme of Methanol synthesis



- Reforming
  - $CH_4 + H_2O \rightarrow CO + 3H_2$
  - $CO_2 + H_2 \rightarrow CO + H_2O$
- Methanol Synthesis
  - $CO + 2H_2 \rightarrow CH_3OH$
  - $CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$

$[H_2]$ / (3[CO2] + 2 [CO]) = 1.0 (Stoichiometric)
= 1.5 (without CO2 injection)

By CO_2 injection, this value approaches to 1.0

➡ NG Unit Consumption can be reduced

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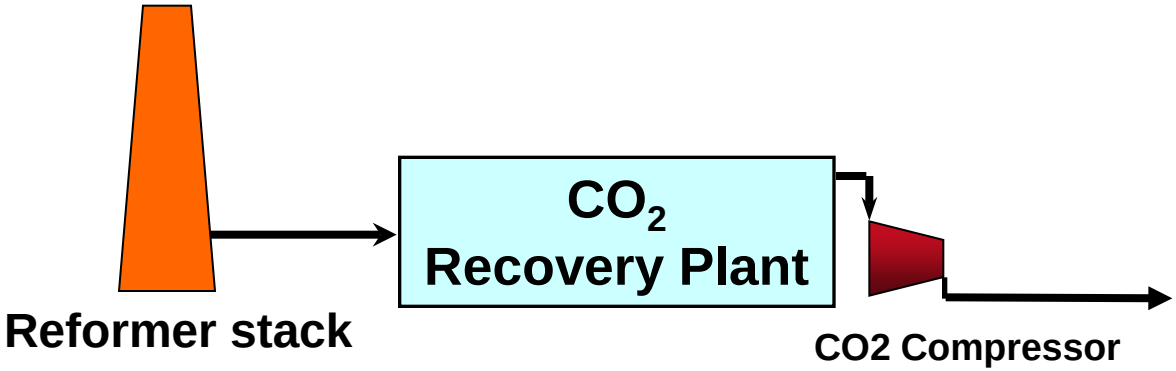
1. Introduction

CO_2 Sources

- ◆CO2 removal from NH_3 Plant
- ◆CO_2 Network Piping
- ◆CO_2 from Reformer Flue Gas

MHI Proprietary CO_2 Recovery Process



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2. CO2 Recovery Technology From Flue Gas

- MHI's proprietary flue gas CO_2 recovery technology is named the KM CDR Process™ ("KEPCO MHI Carbon Dioxide Recovery Process")
- MHI proprietary amine solvent "KS-1™" with accompanying proprietary equipment achieves reduction of utilities and solvent consumption which leads to lower OPEX
- This technology is commercially applied since 1999 (10 plants under operation, 1 under construction)
- World's largest operating flue gas CO2 recovery plant

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2.1 Reference Commercial Plants

- Ten (10) MHI CDR plants are in operation
- Mainly in fertilizer plants
- Easy to operate and high availability

1999
200 t/d
Malaysia

2005
330 t/d
Japan

2006
450 t/d
India

2006
450 t/d
India

2009
450 t/d
India

2009
400 t/d
UAE

2009
450 t/d
Bahrain

2010
240 t/d
Vietnam

2011
340 t/d
Pakistan

2012
450 t/d India

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2.2 Process Performance

2.2.1 History of KS-1™ Solvent development

◆ **Evaluation of MEA**

- MEA is commonly used solvent
- High corrosion, solvent degradation is concerned
- High energy consumption is also issue

◆ **KS-1™ Solvent**

- MHI R&D tested 200 solvents in pilot plant
- MHI developed proprietary KS-1™ solvent
- Process also optimized

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2.2 Process Performance

- **Advantages of KS-1™ Solvent**
  - **Low corrosive, corrosion inhibitor not required**

(Unit : mils (1/1000 inch) per year)

	Test 1	Test 2
MEA	93.0	76.4
MEA + inhibitor	9.5	8.3
KS-1™	3.1	3.6

Test condition : 130° C, in the presence of O_2

Corrosion test result

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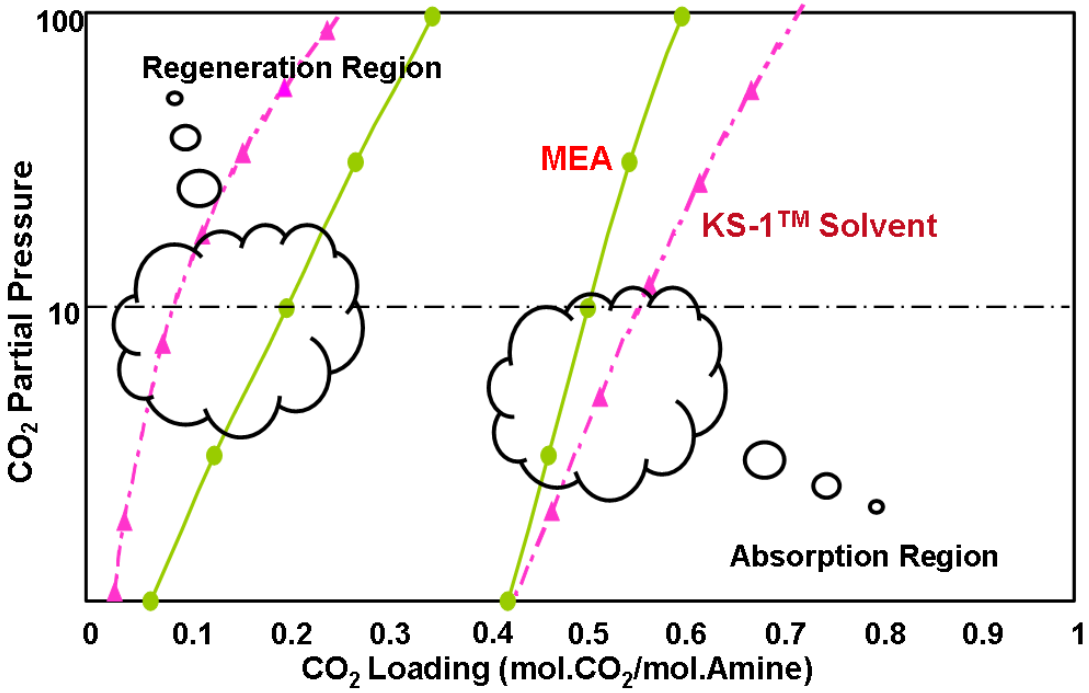
2.2.2 Utility Consumption

- KS-1™ offers lower regeneration energy requirement
- MHI patented CDR process can reduce steam consumption by 30% compared to the conventional MEA process



CO2 Solubility KS-1™

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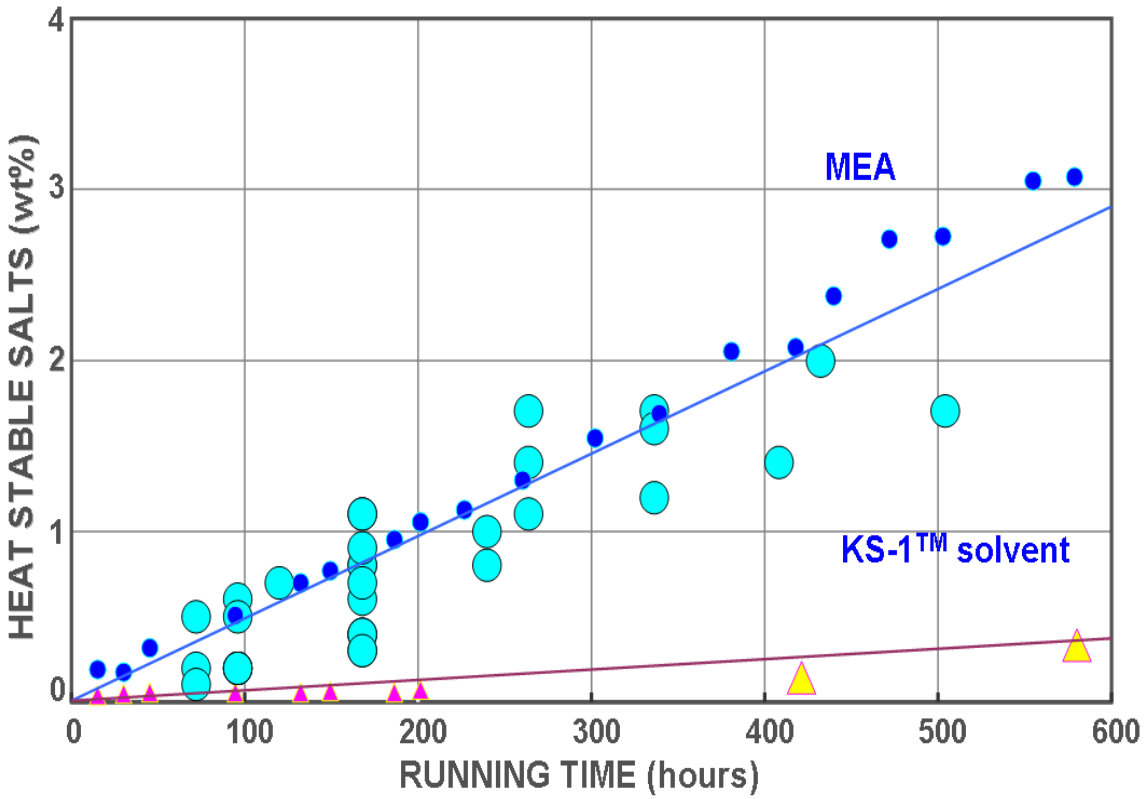
2.2 Process Performance

- **Low Degradation late**



Heat Stable Salts (HSS)

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2.2.3 Operational Reliability

- KM CDR Process™ based plants are highly available and reliable
- KS-1™ is very stable solvent
- It reduces frequency of reclaiming operation
- Reference plants experiences employed to improve the process and reliability

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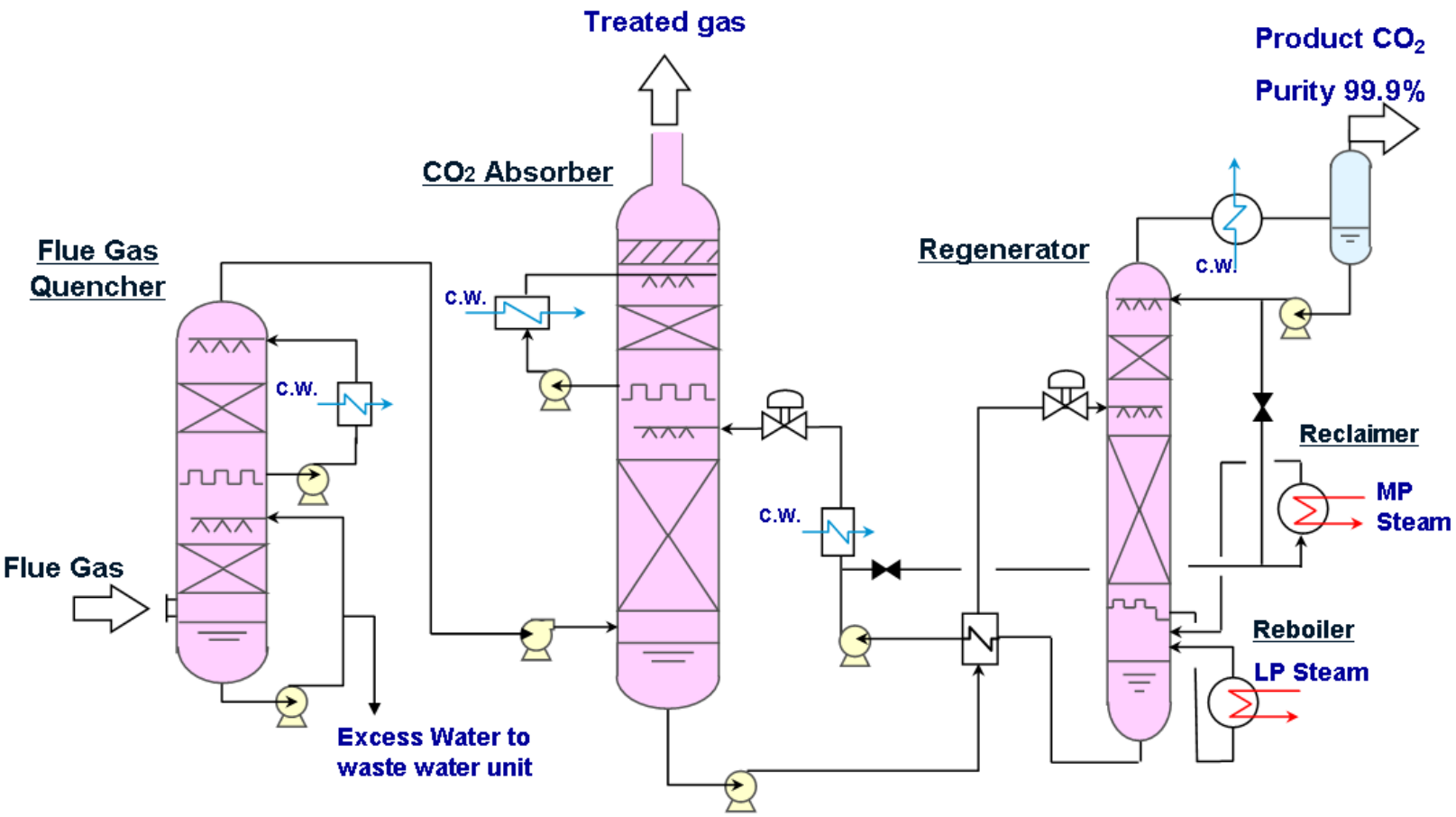
2.2.4 MHI Post Combustion CDR Process



CO2 Recovery Process Flow

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2.2.4 MHI Post Combustion CDR Process

- Main three sections,
  - The Flue Gas Quencher - To cool flue gas
  - The Absorber - Absorption and Washing
  - The Regenerator - Steam stripping of CO_2
- Water circulation in washing section
- Heat integration between Lean and Rich Solvent
- LP Steam used for stripping
- Stripped CO_2 with purity of 99.9% (Expected)

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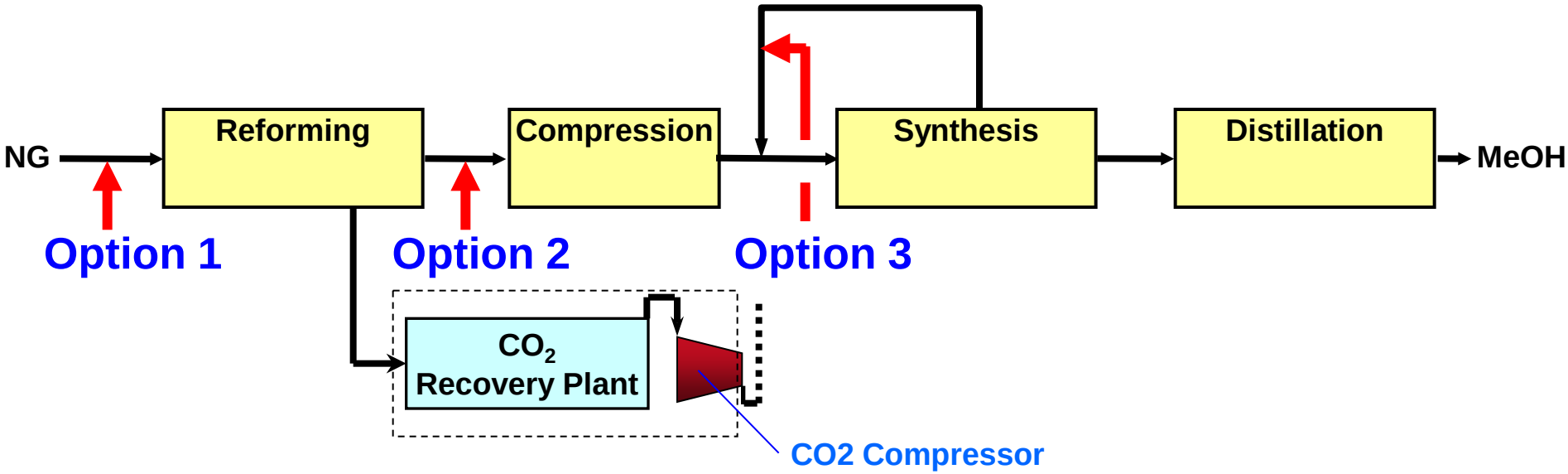
3. CO_2 Injection Point Enhancing Methanol Production



Option-1: Reformer Inlet
Option-2: Syn gas Compressor Inlet
Option-3: SynGas loop line

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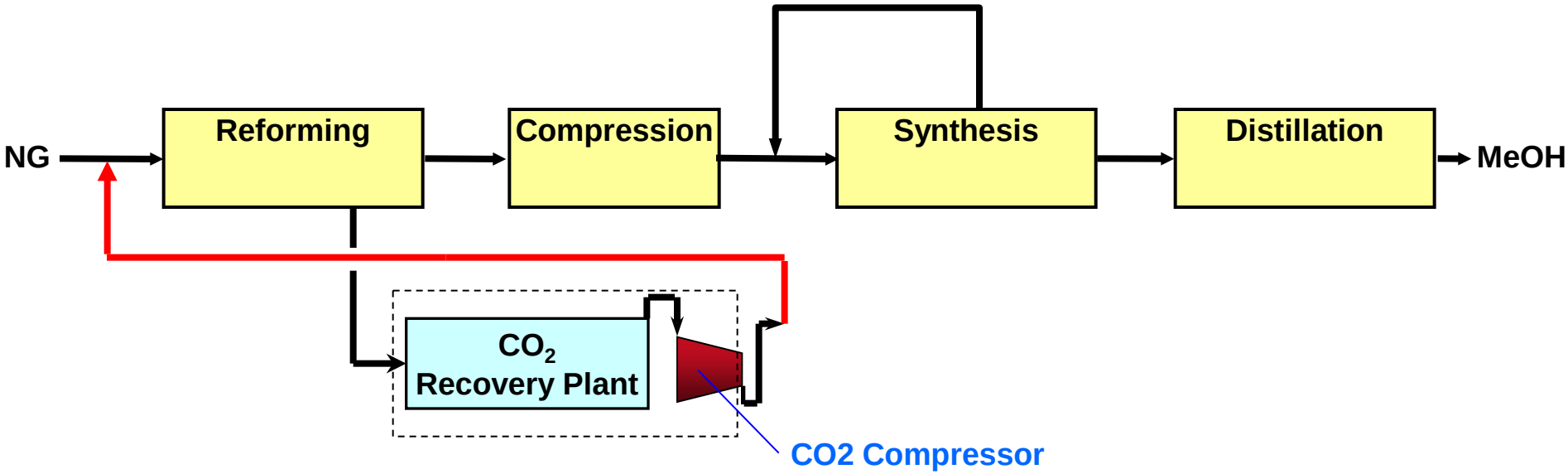
3. CO_2 Injection Point Enhancing Methanol Production

Option-1: CO_2 Injection at Reformer Inlet



- Part of CO_2 shifted to CO by reverse reaction
- Methanol synthesis from CO increase
- Higher synthesis yield
- Capacity of Reformer and downstream system need to be debottlenecked

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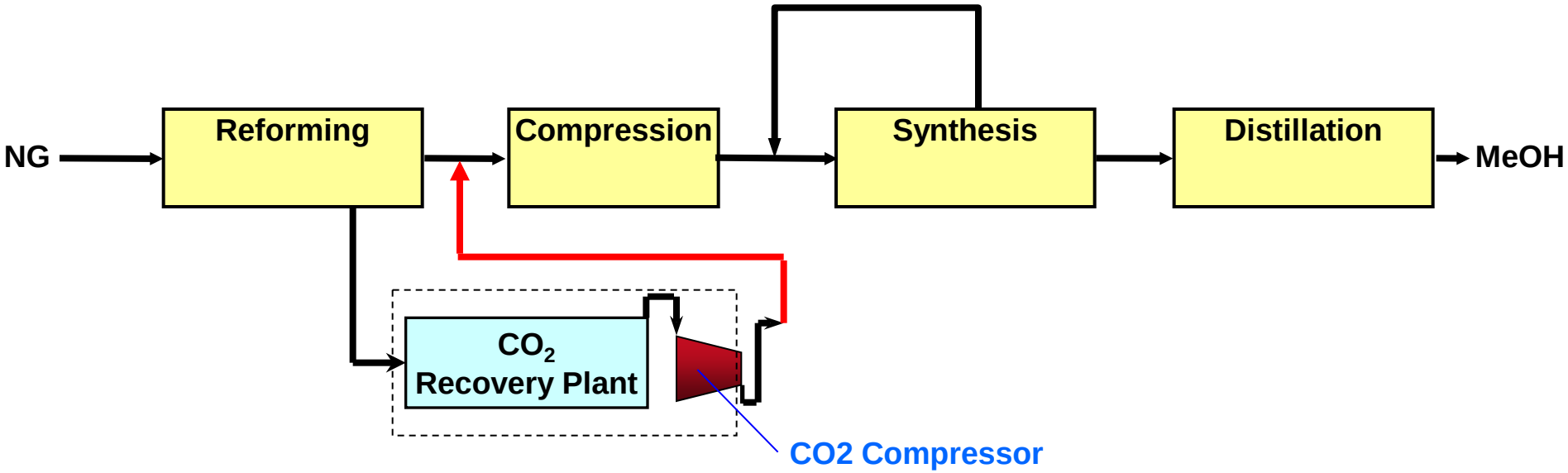
3. CO_2 Injection Point Enhancing Methanol Production

Option-2: CO_2 Injection at Syn gas Compressor Inlet



- Lower synthesis yield
- Capacity of SynGas compressor and downstream system need to be debottlenecked
- Modification of reformer is not required

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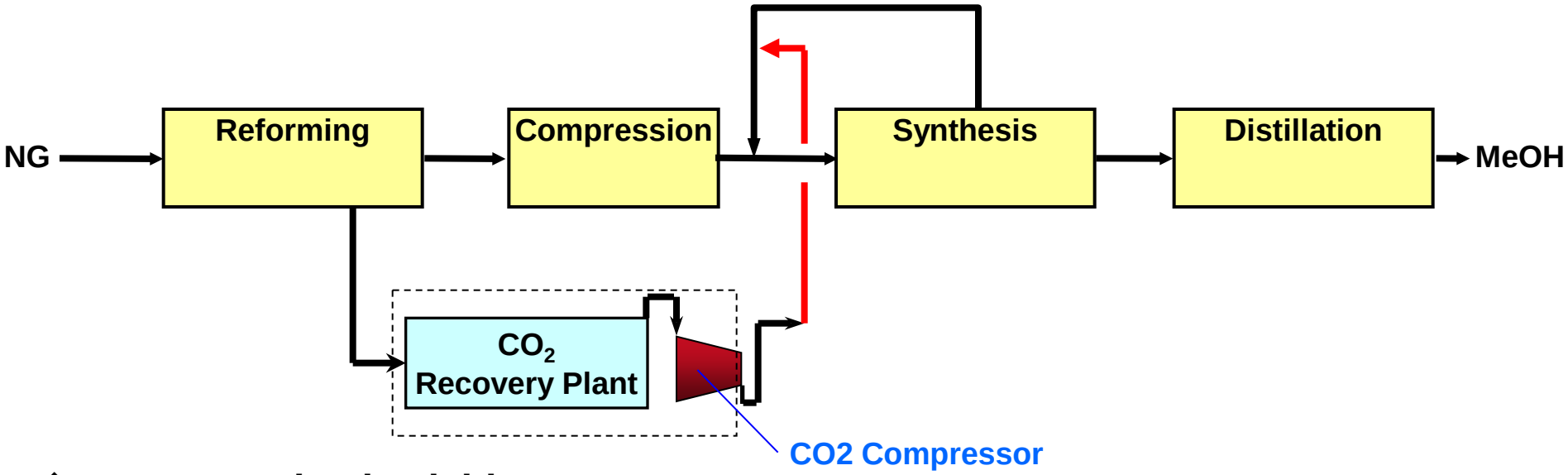
3. CO_2 Injection Point Enhancing Methanol Production

Option-3: CO_2 Injection in SynGas loop line



- Lower synthesis yield
- CO2 compressor required head is much higher than other cases
- Capacity of synthesis loop and all downstream have to be debottlenecked
- Modification of critical equipment such as reformer and Syn gas compressor is not required.

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4. References for Methanol Production Enhancement

- **Location** : Qatar
- **Technology** : KM CDR Process™ by MHI
- **Contractor** : Mitsubishi Heavy Industries Engineering & Services Private Ltd. (MIES)
  (100% Subsidiary Company of MHI established in Singapore)
- **Capacity** : 500 t/d
- **Source** : Flue Gas from Methanol Reformer
- **CO_2 Use** : Methanol Production Enhancement
- **Start-up** : 2014

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5. Conclusion

- MHI has developed KM CDR Process™
- This process is applied to ten (10) commercial plants
- KM CDR Process™ and KS-1™ solvent are tried, tested and guaranteed
- Recovered CO_2 can be utilized to increase the methanol production capacity
- Recently MIES is engaged with 500 t/d capacity CDR plant for Methanol production enhancement

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Thank You

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