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Clean Coal
Technology

Novel Post Combustion CO2 Capture (PCC) Process

- MU Static Spiral Perforated Wings (MU-SSPW) Mixing Element -

December 11 , 2015

Mu Company Ltd. & K-Coal Co., Ltd.

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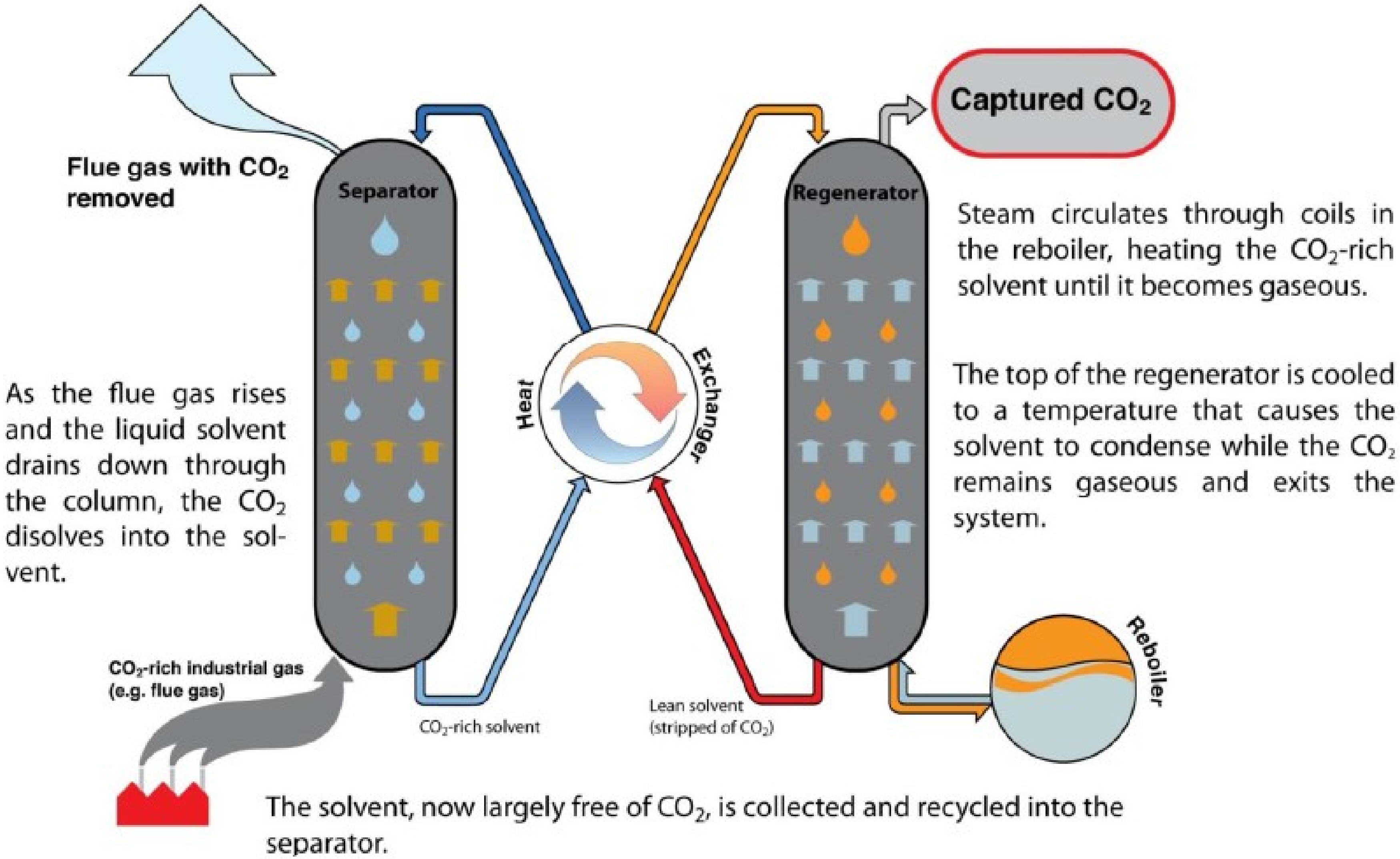
Post Combustion CO2 Capture (PCC)Process



Proposal on R&D

Japanese Technology Venture “Mu Company Ltd.” developed Mu Static Spiral Perforated Wings (MU-SSPW) Mixing Element and had its patent in Japan, USA, EU and China.

The absorbent of CO2 and CO2 capture system in Post Combustion CO2 Capture (PCC) process have been developed by many companies and institute but the reactor of CO2 capture such as absorber & stripper has not been well developed yet.

Mu-SSPW Mixing Element has a big potential to improve energy efficiency of CO2 capture system and also to reduce the size of CO2 absorber and stripper.

Mu Company Ltd. and K-Coal Co., Ltd. plan to conduct CO2 capture test by utilizing MU-SSPW Mixing Element as CO2 absorber and stripper in cooperation with the developer PCC process.

We propose to commercialize Mu-SSPW Mixing Element for CO2 capture new system by utilizing new PCC Process pilot plant and or existing PCC pilot plant in the World.

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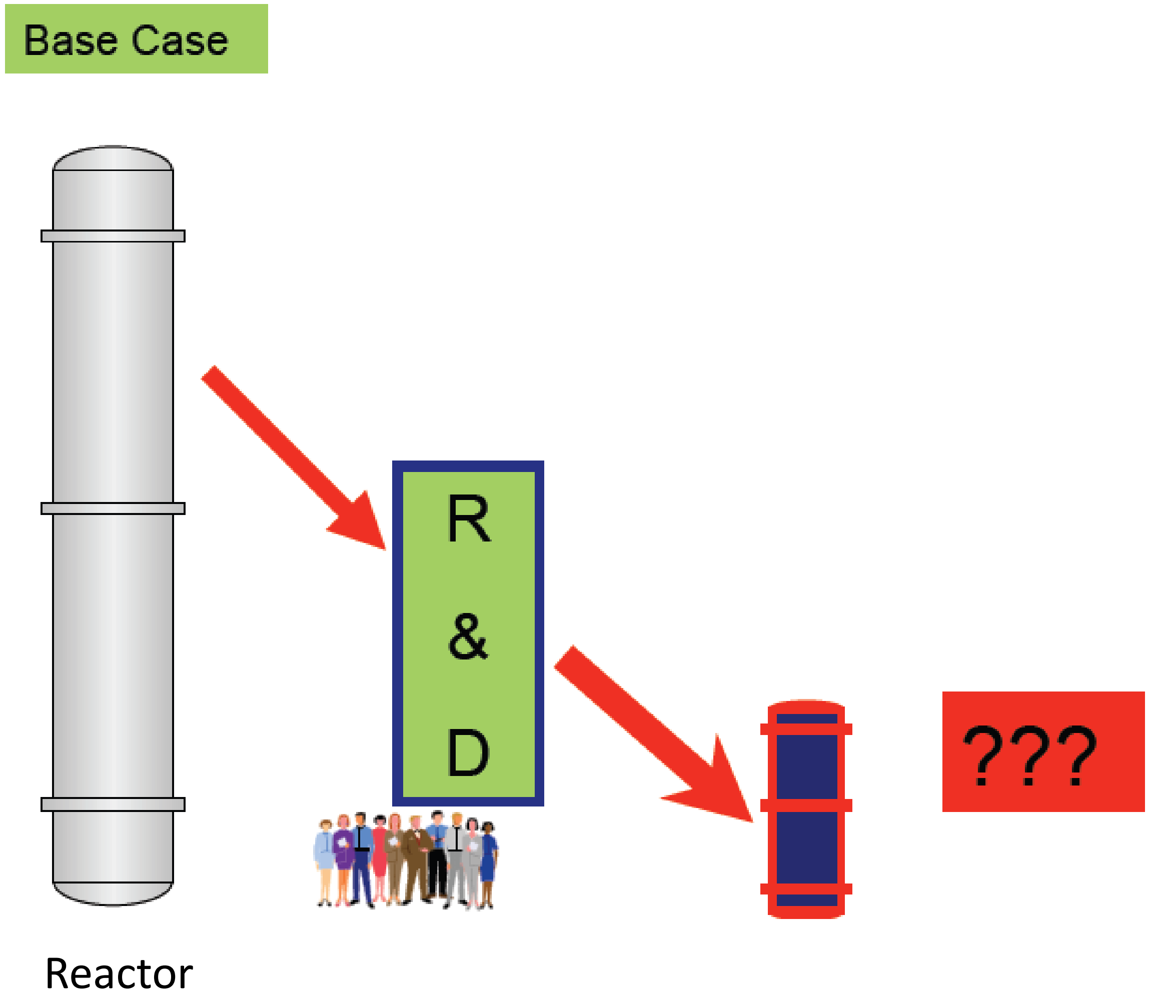
Concept of R&D Project



MU Static Spiral Perforated Wings (MU-SSPW) Mixing Element for CO_2 absorber & stripper

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We can solve the problem of upsizing and fouling of the tower using

MU-STATIC SPIRAL PERFORATED WINGS (MU-SSPW)

MU-SSPW is the internals of towers with static spiral perforated wings.

We have been solving the problems mentioned above for 30 years.

Please realize the ability of MU-SSPW.

MU-SSPW is the innovative internals having completely different concept from TRAY and PACKING.

MU-SSPW is most suitable to adopt for the large-scale tower of CCS in particular.

MU-SSPW has the following excellent features.

Supporting documents:

Attachment-1 The features of MU-SSPW
(REVOLUTION OF INTERNALS BY MU - SSPW)

Attachment-2 Merit by adopting MU-SSPW in CCS

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瀧は　怒濤は
なぜ白く観えるのか

WATERFALLS,
SURGING WATERS,
WHY DO THEY LOOK WHITE?

- ガス吸収
  Gas Absorption
- 曝気
  Aeration
- 放散
  Stripping

- ミューミキサー
  MU Mixer
- ミュースクラバー
  MU Scrubber
- ミューリアクター
  MU Reactor

エレメントの構造：

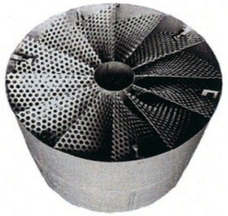
パイプ内に右捻り及び左捻りの螺旋状の多孔板を内設したミューミキシングエレメントが交互に配置されています。

基本的な働き：

原水と空気は、複数のミューミキシングエレメントを通過する間に左右両方向の回転及び分割、合流、反転、剪断応力作用を連続的に繰り返しながら、高効率で原水と空気とが接触・攪拌・混合して放散されます。

放散塔内で：

各ミューミキシングエレメントの径方向及び軸方向上で、下方向に滝のように流下する原水と、その中を上昇する微細な気泡とが、怒濤のように激しく接触・攪拌・混合されます。その結果、高効率で原水は処理されます。



- ミューミキシングエレメント
  MU Mixing Element

STRUCTURE：

Right-twisted blades element and left-twisted blades element are vertically set in alternative in the column.

PRINCIPAL FUNCTION：

Raw water (wastewater) and gas (air) are fed into the column; water from the top and gas blown in from the bottom. While passing through several mixing elements, both air and raw water get efficiently in contact each other, stirred, mixed and stripped.

APPLYING TO STRIPPING：

While raw water falls down like a waterfall in the column, fine water bubbles being rich of air climb up in the falling water from the bottom, to contact, stir and mix like surging waves in the ocean for efficient reaction on axial and radial directions, to accomplish wastewater treatment at high rate.

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(12) **United States Patent**
Kojima

(10) **Patent No.: US 7,510,172 B2**
(45) **Date of Patent: Mar. 31, 2009**

(54) **MIXING ELEMENT AND STATIC FLUID MIXER USING SAME**

(75) Inventor: **Hisao Kojima**, Kanagawa (JP)

(73) Assignee: **Anemos Company Ltd.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 568 days.

(21) Appl. No.: **11/276,340**

(22) Filed: **Feb. 24, 2006**

(65) **Prior Publication Data**

US 2007/0205523 A1 Sep. 6, 2007

Related U.S. Application Data

(63) Continuation-in-part of application No. PCT/JP2004/001631, filed on Feb. 16, 2004.

(51) **Int. Cl.**
B01F 3/04 (2006.01)

(52) **U.S. Cl.** **261/79.2**; 261/113; 96/296; 96/326; 366/339; 366/340

(58) **Field of Classification Search** 261/79.1, 261/79.2, 94, 113; 96/296, 314, 320, 324, 96/326; 366/338, 339, 340, 341

See application file for complete search history.

(56) **References Cited**

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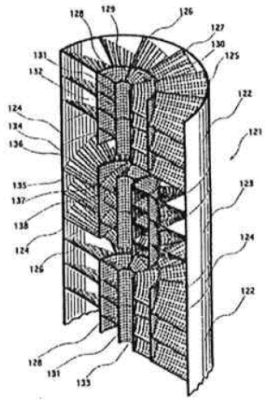
Primary Examiner—Scott Bushey
(74) *Attorney, Agent, or Firm*—Sonnenschein Nath & Rosenthal LLP

(57) **ABSTRACT**

A mixing element, which is produced at low cost, has high mixture agitation effectiveness, and is easily made large, and a static fluid mixer using the mixing element are provided. Further, a gas-liquid treatment apparatus with high treatment ability is provided. A mixing element **1** includes: a cylindrical passage tube **2** trough which fluid flows; a plurality of spiral rightward rotation type first blades **3** formed of a perforated object, which are provided in the passage tube **2**; a first inner cylindrical tube **5** shaped like a cylinder and disposed inside the blades **3**; a plurality of spiral rightward rotation type blades **6** provided in the inner cylindrical tube **5**; and an opening **9** formed in the axial center portion of the blades **6**. A static fluid mixer is formed by using at least one mixing element **1** mentioned above.

24 Claims, 27 Drawing Sheets



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MU-SSPW Mixing Element Supply List

Costomer	Equipment	Purpose
1	Scrubber	Gas cooling & recovery of Si , removal of SiO_2 & HCl
2	Scrubber	Removal of SiO_2 & HCl in waste gas from incinerator
		Removal of SiHC3, $SiCl_4$ with hydrolysis
3	Scrubber	Removal of SiO_2, Cl_2, F, $SiCl_4$
4	Scrubber	Removal of Triethylamine, NH_3, H_2S
5	Scrubber	Condensation and recovery of $TiCl_4$
6	Scrubber	Removal of organic fume and organic acid
7	Scrubber	Recovery of ethanol and removal of medical fume
8	Reactor	Production of Cl_2 aqueous solution and chlorinate organic compound
9	Scrubber	Removal of chemical dye fume
10	Scrubber	Removal by adsorption of SOx and H_2S in waste gas
11	Reactor	Removal of VOC in calcium system waste water
12	Scrubber	Removal and recovery of methylene chloride
13	Mixer	Mixing of cement and binding agent
14	Mixer	Mixing of reduced iron pellet
15	Scrubber	Recovery of uranium compounders (A.D.U.) fume
16	Scrubber	Removal of UF_6 gas in case of emergency
17	Scrubber	Removal of high concentrated HCl gas
18	Reactor	Removal of COD compounds in waste water
19	Aerator	Removal of BOD compounds in waste water

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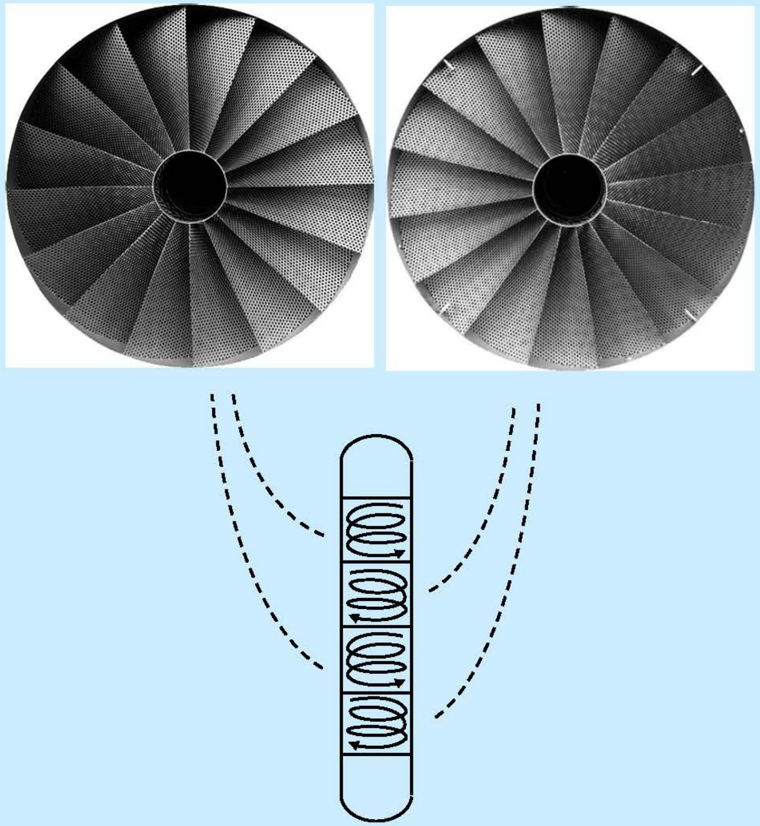
INSTALLATION OF MU-STATIC SPIRAL PERFORATED WINGS (MU-SSPW)

SPIRAL FLOW WITH COUNTER-CLOCKWISE

SPIRAL FLOW WITH CLOCKWISE



Mu Scrubber Scale Up

- Track Record of Mu Scrubber

  1) Dust Remover : φ1.8 m x 5.6 m H
     Gas Flow 90,000Nm3/h

  2) Desulfurization ($Ca(OH)_2$/$Ma(OH)_2$) : φ0.5 m x 5m
     Gas Flow 3,000Nm3/h

- Maximum Size (Transportable) :

  φ3 m x 10m H : Gas Flow 250,000Nm3/h (Vg=9.82m/s)

  150MW Class Coal Power Plant

- Maximum Size (Knockdown) :

  φ12 m x 12m H : Gas Flow 4,000,000Nm3/h (Vg=9.83m/s)

  1,000 MW Class Coal Power Plant

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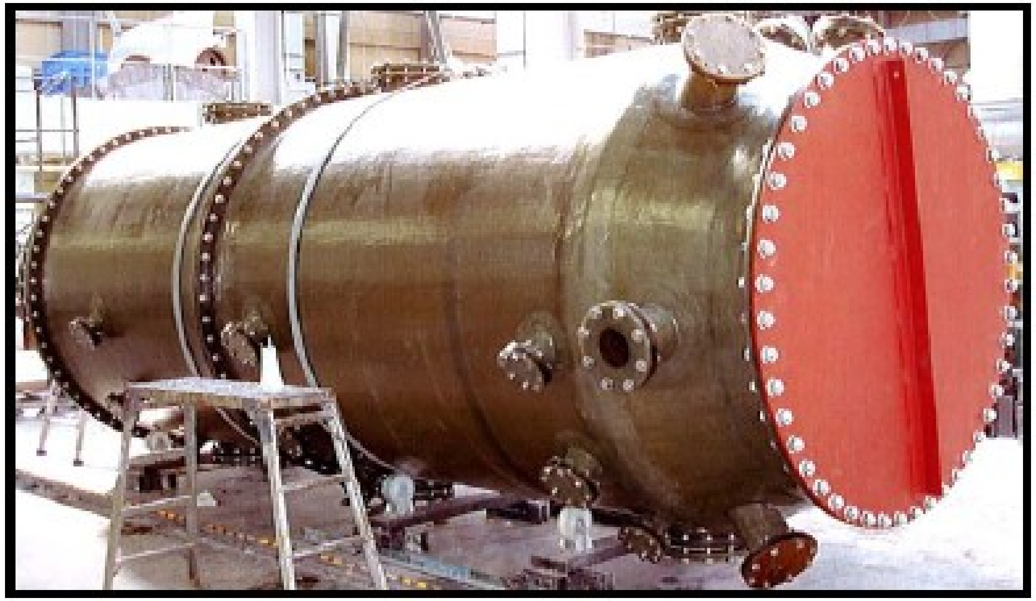
MU-SSPW Mixing Element

MU－SSPW
Diameter : 1,800mm



Φ1,800 × 5,500mmH
Gas Volume(wet) : 10,000 ～ 40,000 m^3N/h
Dust Content : In put 0.15 ～ 0.20 → Output 0.003 ～ 0.004g/m^3N

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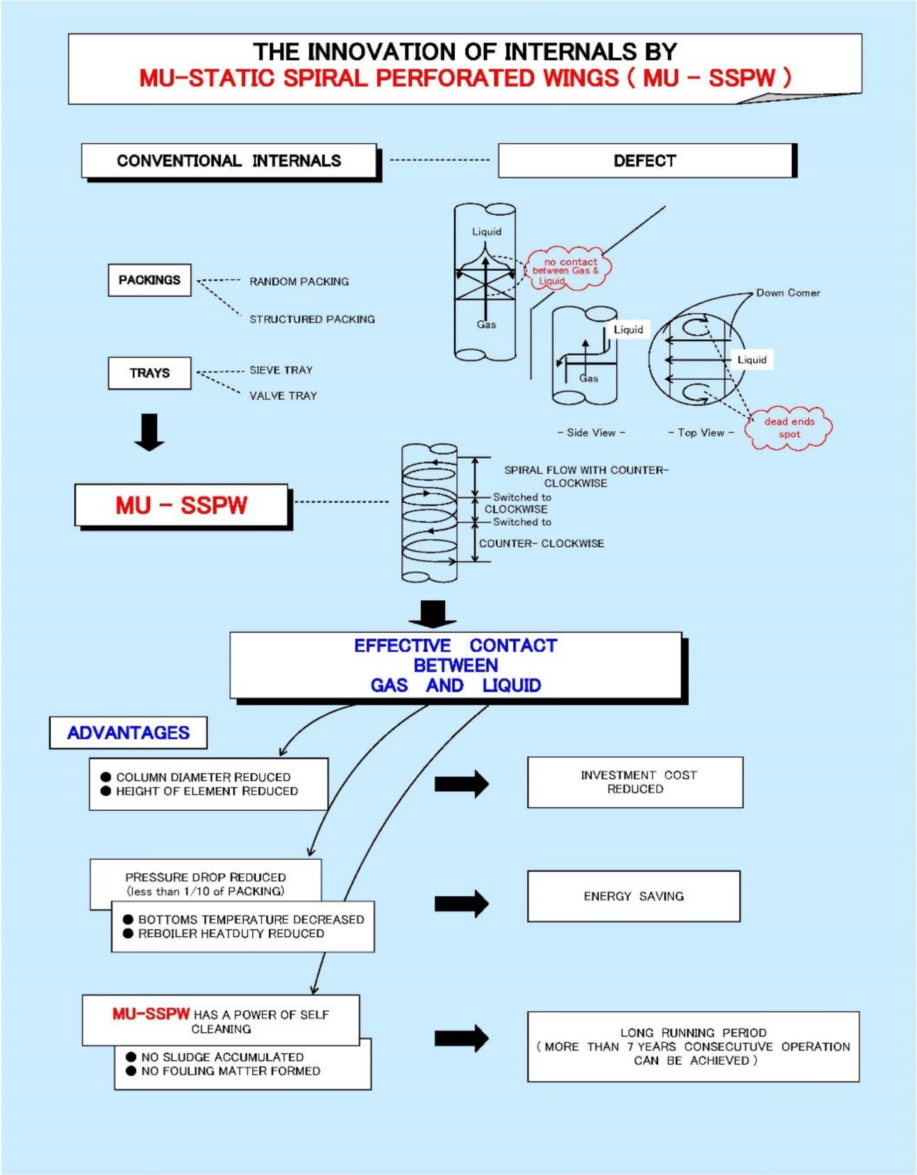
THE INNOVATION OF INTERNALS BY
MU-STATIC SPIRAL PERFORATED WINGS (MU – SSPW)
CONVENTIONAL INTERNALS
DEFECT
PACKINGS
RANDOM PACKING
STRUCTURED PACKING
TRAYS
SIEVE TRAY
VALVE TRAY
Liquid
no contact between Gas & Liquid
Gas
Liquid
Gas
Down Comer
Liquid
dead ends spot
– Side View –
– Top View –
MU – SSPW
SPIRAL FLOW WITH COUNTER-CLOCKWISE
Switched to CLOCKWISE
Switched to
COUNTER- CLOCKWISE
EFFECTIVE CONTACT BETWEEN GAS AND LIQUID
ADVANTAGES
● COLUMN DIAMETER REDUCED
● HEIGHT OF ELEMENT REDUCED
INVESTMENT COST REDUCED
PRESSURE DROP REDUCED (less than 1/10 of PACKING)
● BOTTOMS TEMPERATURE DECREASED
● REBOILER HEATDUTY REDUCED
ENERGY SAVING
MU-SSPW HAS A POWER OF SELF CLEANING
● NO SLUDGE ACCUMULATED
● NO FOULING MATTER FORMED
LONG RUNNING PERIOD
(MORE THAN 7 YEARS CONSECUTUVE OPERATION CAN BE ACHIEVED)

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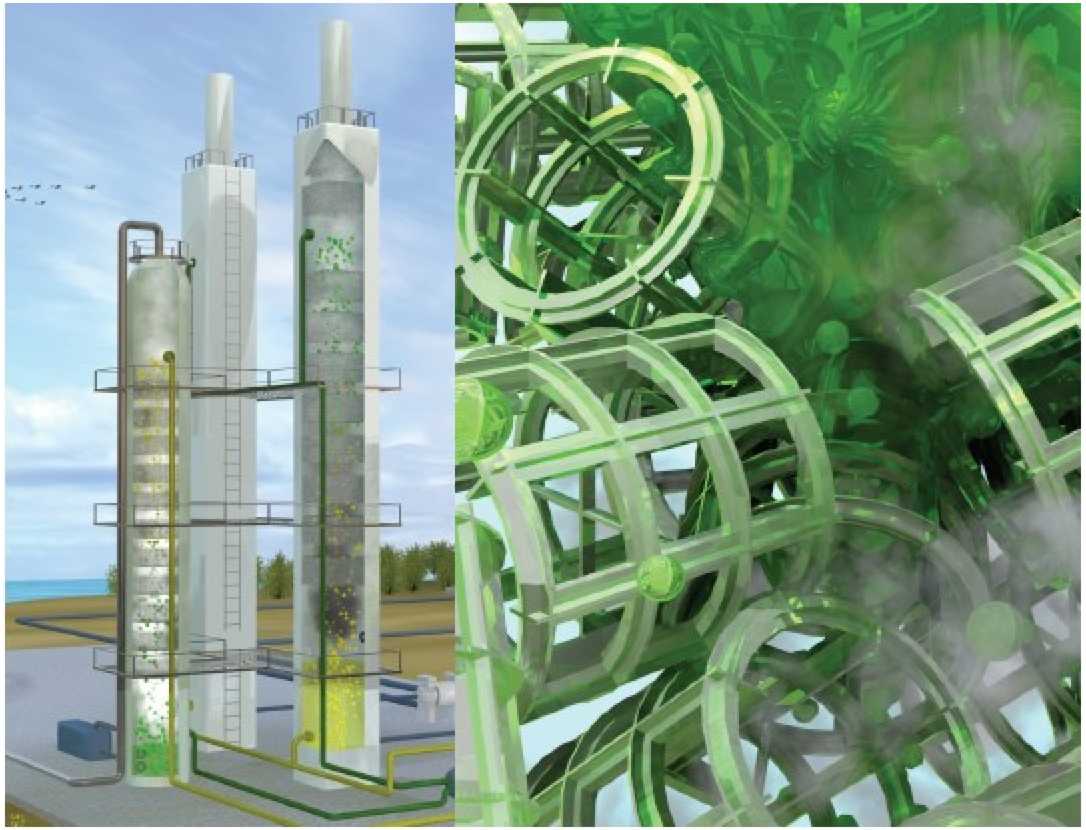
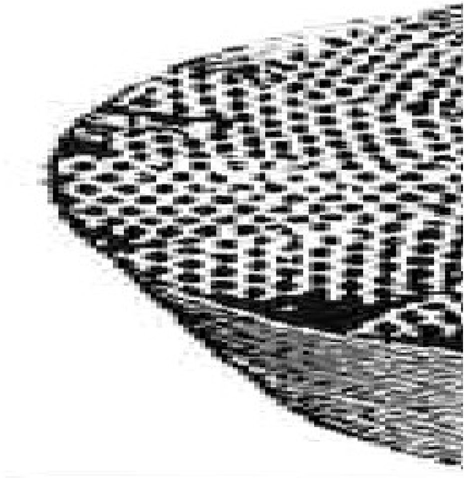
Application of MU-SSPW Mixing Element for CO2 Absorber & Stripper



Towers Packing



Advantages of Using Mu Static Mixer for CO_2 Capture

1) Over 10% energy saving is achievable due to improved e fficiency of absorption and degassing.
2) Contamination of solvent is prevented due to effective r emoval of dust and SO_3 fume, thus maintenance free. A lso filtration system for mist in the solvent recycle line c an be simplified.
3) Absorber/flash column are made compact due to excell ent performance at high gas velocity inside the towers.
4) Improved efficiency of amine mist collection, etc., are p ossible.

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Comparative Table of Packed Tower and Mu for CO_2 Degasser (at RICH solvent: 15t/hr and CO_2: 480Kg/hr)

	Packed Tower	Mu
Gas/liquid contact Status	Countercurrent	Countercurrent
Gas velocity (m/sec)	1	3
Tower diameter (m)	1	0.6
Height of packing (m)	9	5
Steam consumption (Kg/h)	463	408 (12% reduction)
Frequency of maintenance	Every year	Once every 5 years

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Advantages To Apply Mu Static Mixer

Saving of Maintenance Fee

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Energy Saving

10% energy saving is achieved by three excellent advantages.

- Separating efficiency is increased by Mu's dynamic vapor-liquid contact.

	Conventional packing	Mu
Differential pressure (kPa/m)	0.2	0.04 or lower

Effective Heat Recovery → Installation of internal reboiler at lower stage of column

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Reduction of Investment Cost

High Efficiency (High technical advantages)

Smaller diameter of column

	Conventional packing	Mu	
Column diameter	**4m**	**1.8m**	Mu can be smaller by more than 50%.
Vapor velocity	**1m/sec**	**5m/sec**	

Lower height of column

No fouling

- **No spare equipment required**
- **Maintenance fee reduced.**

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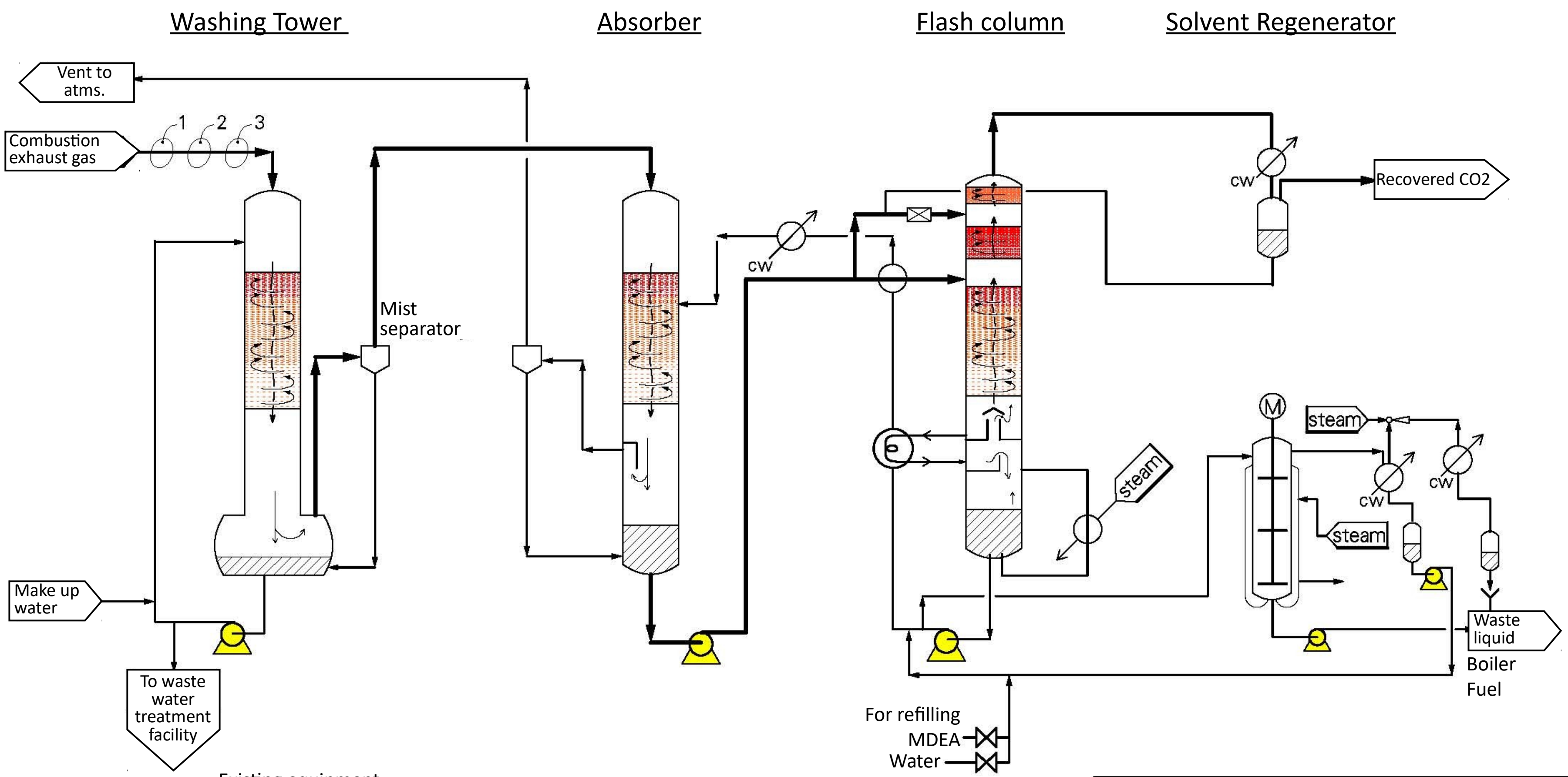
Mu System Flow Chart of CO2 Recovery From Exhaust Gas （Proposal 1）



Existing equipment

1. Denitrificator
2. Dust remover
3. Desulfurizer

	Mu System Flow Chart of CO2 Recovery From Exhaust Gas
	Proposal 1
'12. 6. 4	Mu Co. Ltd.

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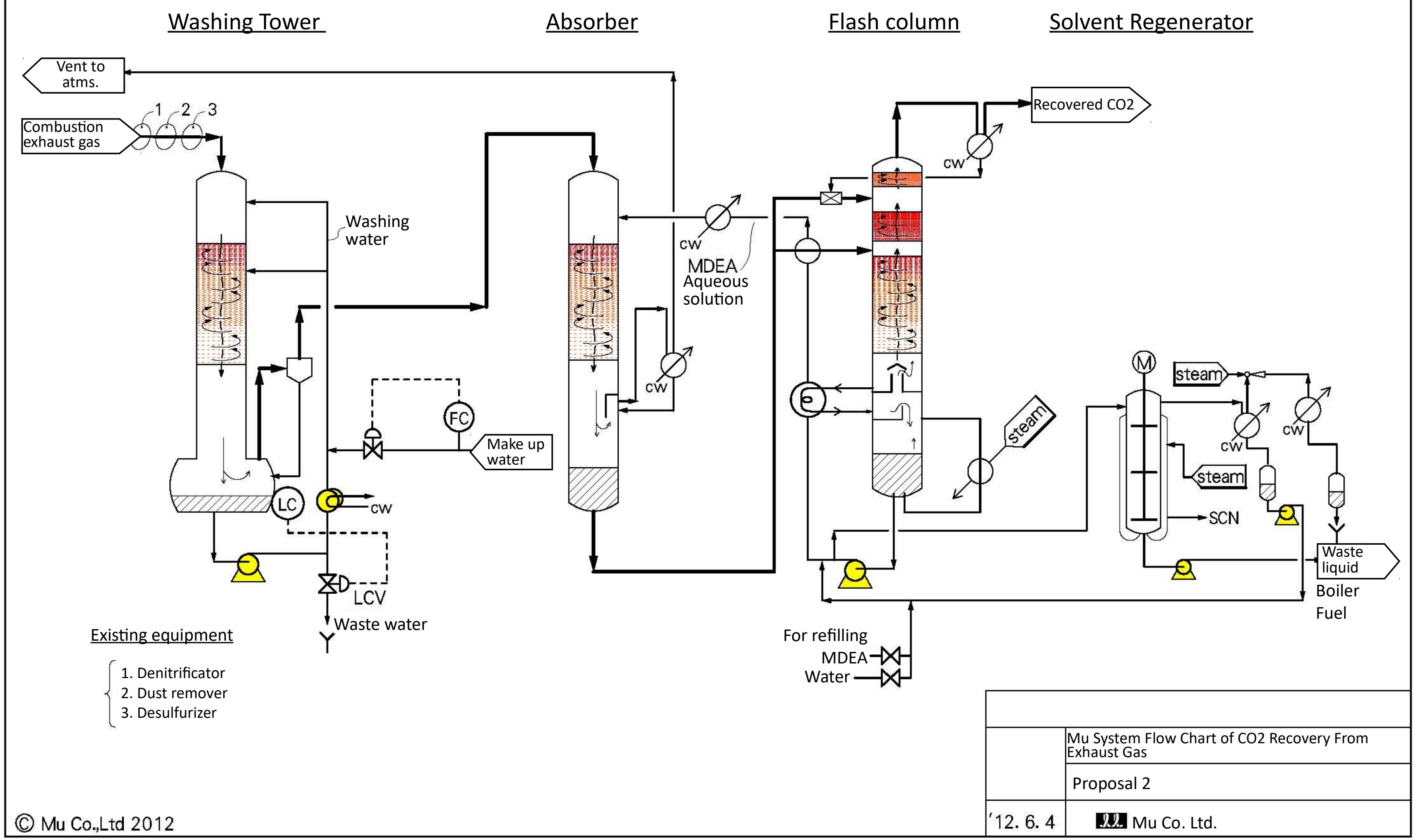
Mu System Flow Chart of CO2 Recovery From Exhaust Gas (Proposal 2)
Combined Scheme of Absorber and Flash Column



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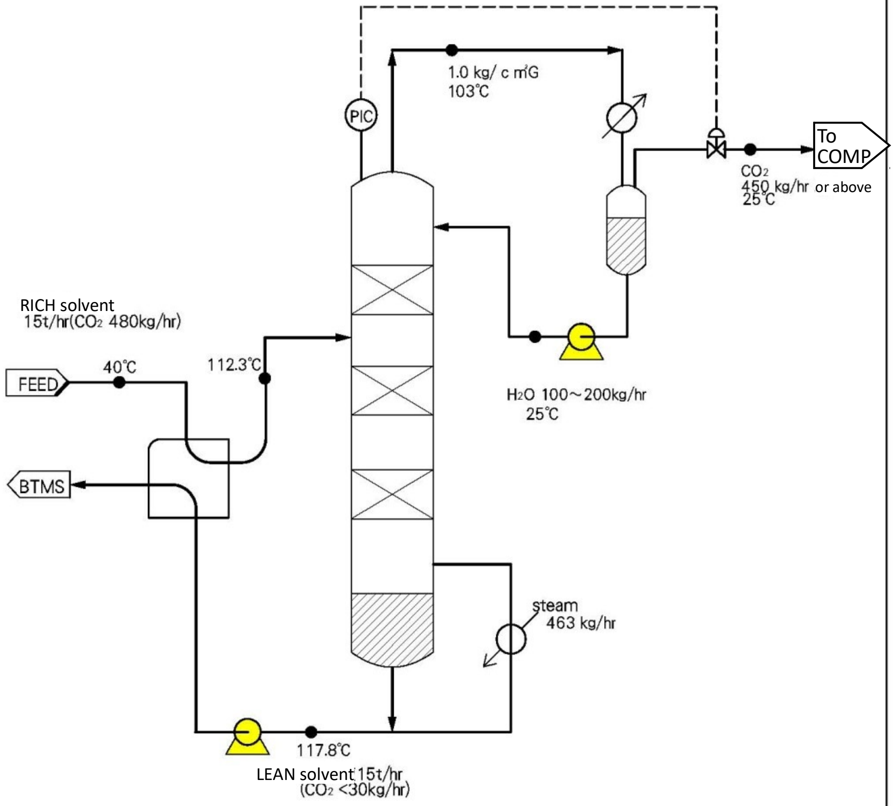
1. Current Operational Status of Flash Column



	Exhaust Gas Degassing Treatment Equipment
	1. Current Operational Status Of Flash Column
'12. 5.23	Mu Co. Ltd.

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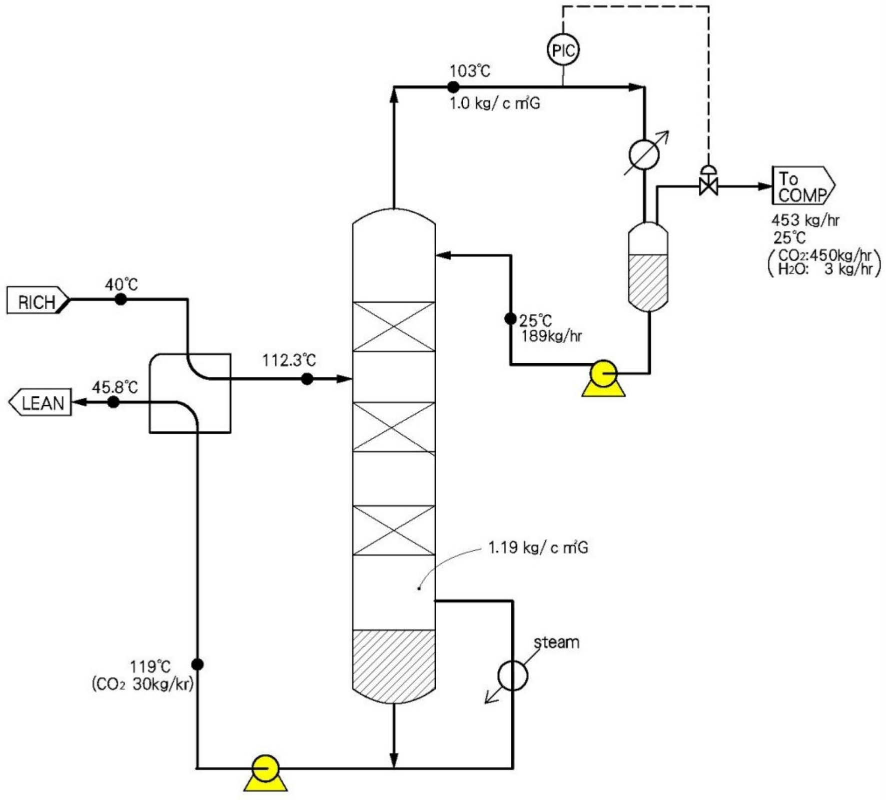
2. Simulation Modeling of Current Flash Column



	Exhaust Gas Degassing Treatment Equipment
	2. Simulation Modeling of Current Flash Column
'12. 5. 23	Mu Co. Ltd.

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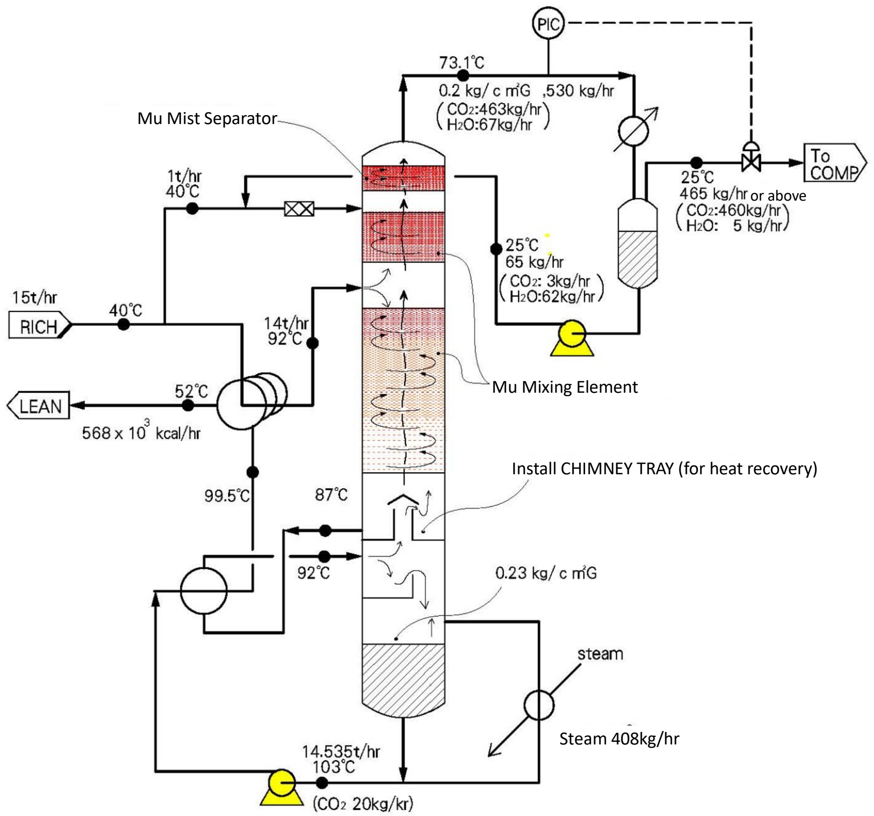
3. Proposed "Mu System" for Flash Column



	Exhaust Gas Degassing Treatment Equipment
	3. Proposed "Mu System" for Flash Column
'12. 5.23	Mu Co. Ltd.

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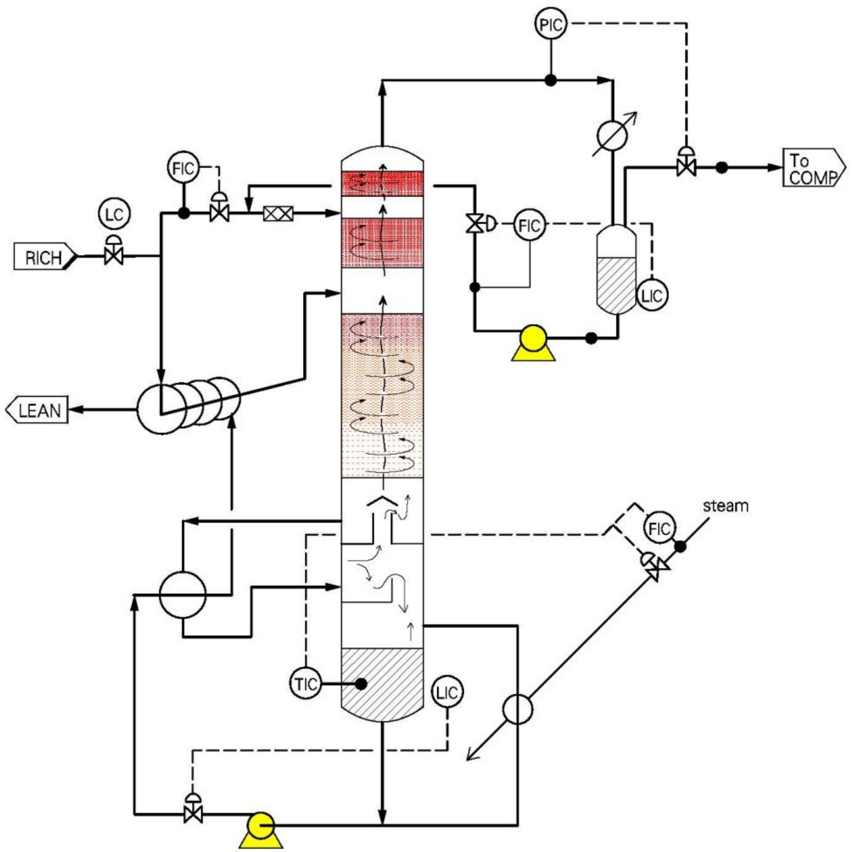
4. Proposed Control System for Flash Column



	Exhaust Gas Degassing Treatment Equipment
	4. Proposed Control System for Flash Column
'12. 5.23	Mu Co. Ltd.

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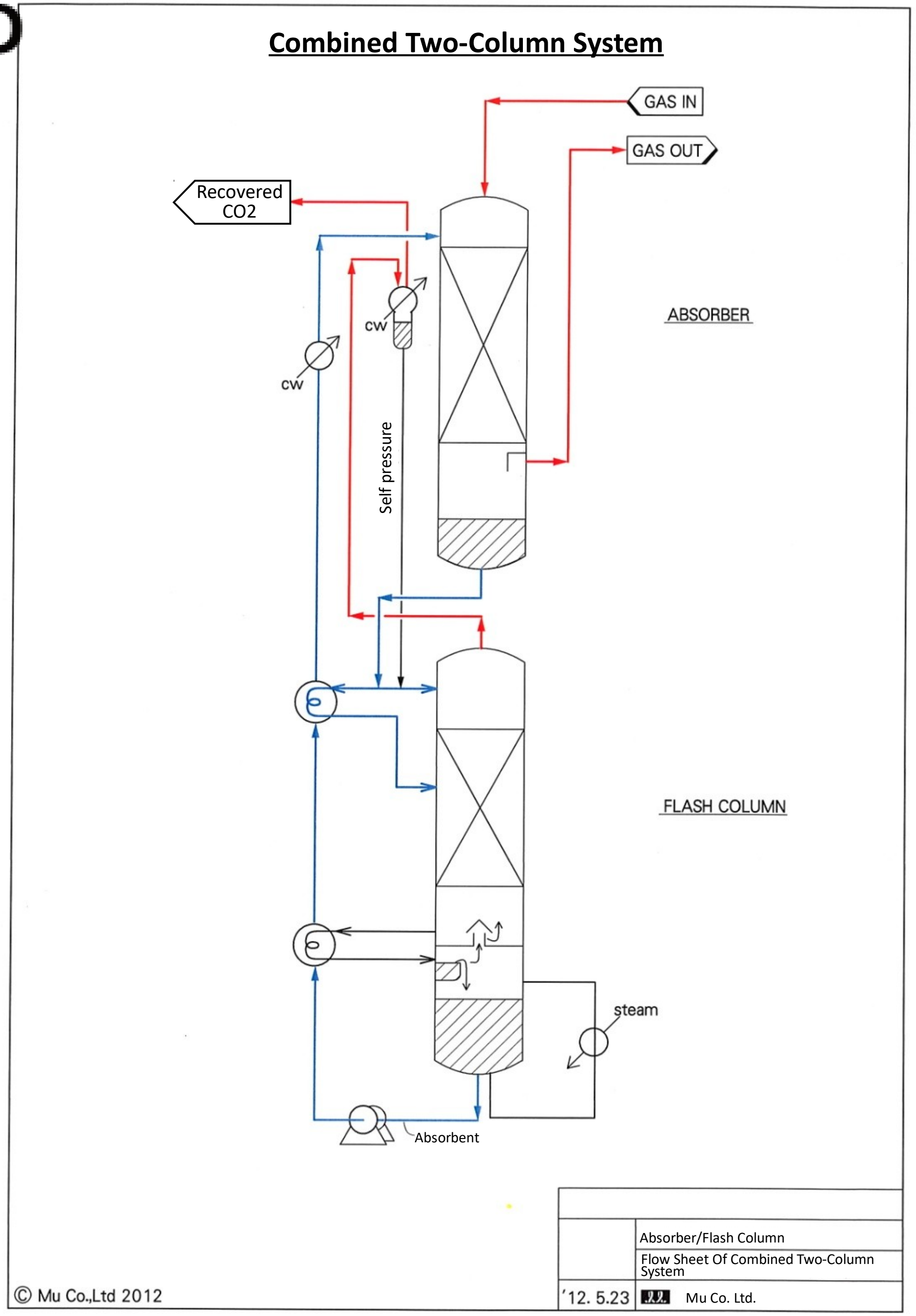

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Low Pressure Drop by Mu Static Mixer

COMPARISON BTWN MU AND SULZAR PACKING

(AT COUNTER FLOW)

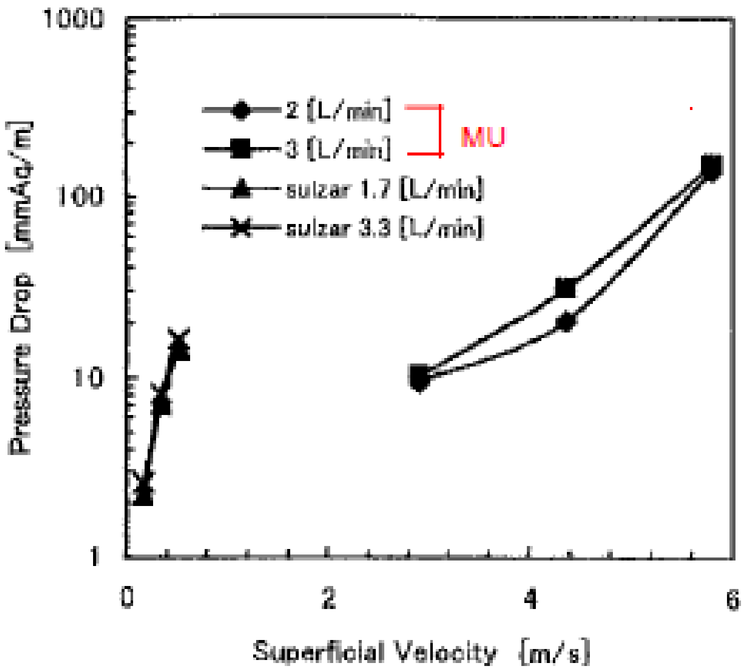

Fig.2 Relation between superficial velocity and pressure drop.

COMPARISON BTWN COUNTER FLOW AND PARALLEL FLOW BY MU

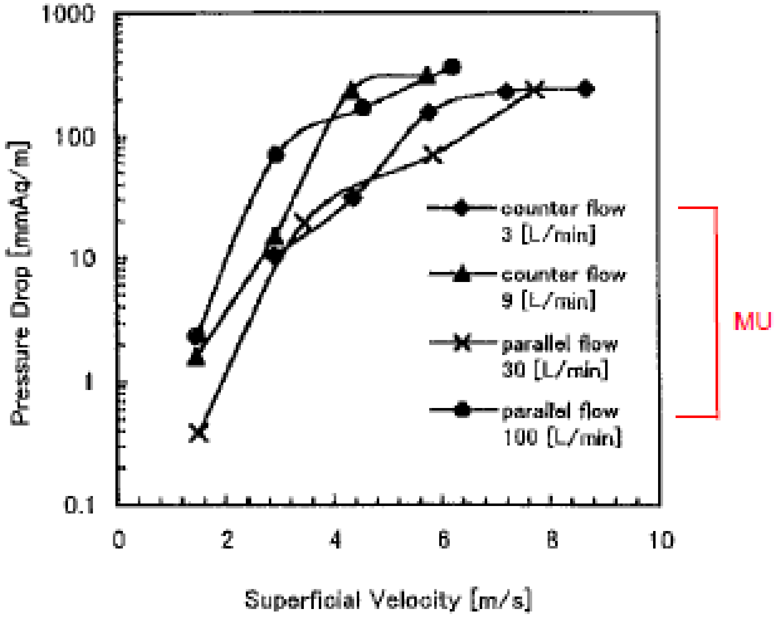

Fig.3 Relation between superficial velocity and pressure drop.

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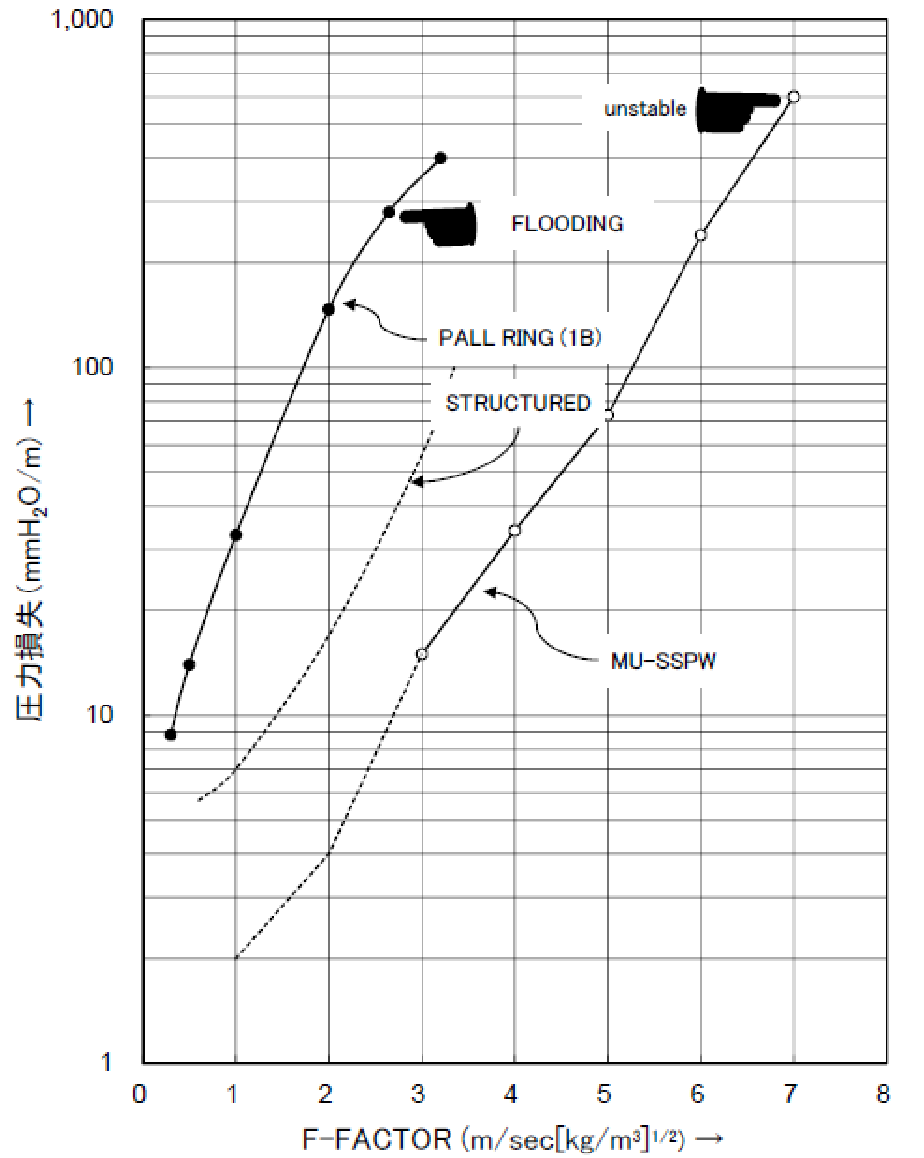
Comparison of Pressure Drop MU-SSPW vs. Pall Ring (Alternate Current)



$$F - FACTOR = U_G \sqrt{\rho_G}$$

U_G : Superficial Velocity $(m/\sec)$

ρ_G : Air Density (kg/m^3)

Measurement Condition

- Pressure : Atmosphere
- Fluid : Water & Air
- Water Flow Rate : 31m3/m2/hr

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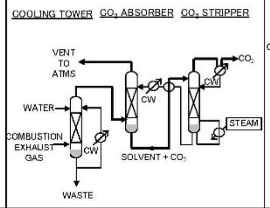
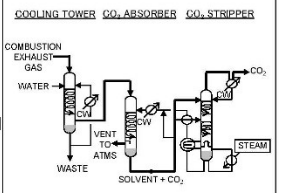
MERIT BY ADOPTING MU-SSPW IN CCS
(RECOVERED CO_2 300t/d BASIS)

INTERNALS	CURRENT PROCESS	USING MU-SSPW		MERIT
CCS SYSTEM				
COLUMN INTERNALS	CONVENTIONAL PACKING	MU-SSPW		
COLUMN				
COOLING TOWER				
① FLUID CONTACT STATUS	COUNTER CURRENT	PARALLEL CURRENT		
② DIAMETER	5.4 (m)	2.0 (m)	63% ↓	
③ HEIGHT OF PACKNG	4 (m)	3 (m)	38% ↓	
④ GAS VELOCITY	1 (m/sec)	7 (m/sec)		
CO_2 ABSORBER				
① FLUID CONTACT STATUS	COUNTER CURRENT	PARALLEL CURRENT		
② DIAMETER	5.4 (m)	3.0 (m)	45% ↓	LOWER INVESTMENT COST
③ HEIGHT OF PACKING	8 (m)	5 (m)	38% ↓	
④ GAS VELOCITY	1 (m/sec)	3 (m/sec)		
CO_2 STRIPPER				
① FLUID CONTACT STATUS	COUNTER CURRENT	COUNTER CURRENT		
② DIAMETER	1.6 (m)	1.0 (m)	38% ↓	
③ HEIGHT OF PACKING	6 (m)	4 (m)	33% ↓	
④ GAS VELOCITY	1 (m/sec)	2 (m/sec)		
STEAM CONSUMPTION	100 (%)	88 (%)	12% ↓	ENERGY SAVING
FREQUENCY OF MAINTENANCE	EVERY YEAR	ONCE EVERY 7 YEARS		NO FOULING & NO PLUGGING ↓ LOWER MAINTENANCE COST

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Thank you!