Challenging Intensification of Petro-industrial Distillation Processes by a New Internal Heat Integration Method

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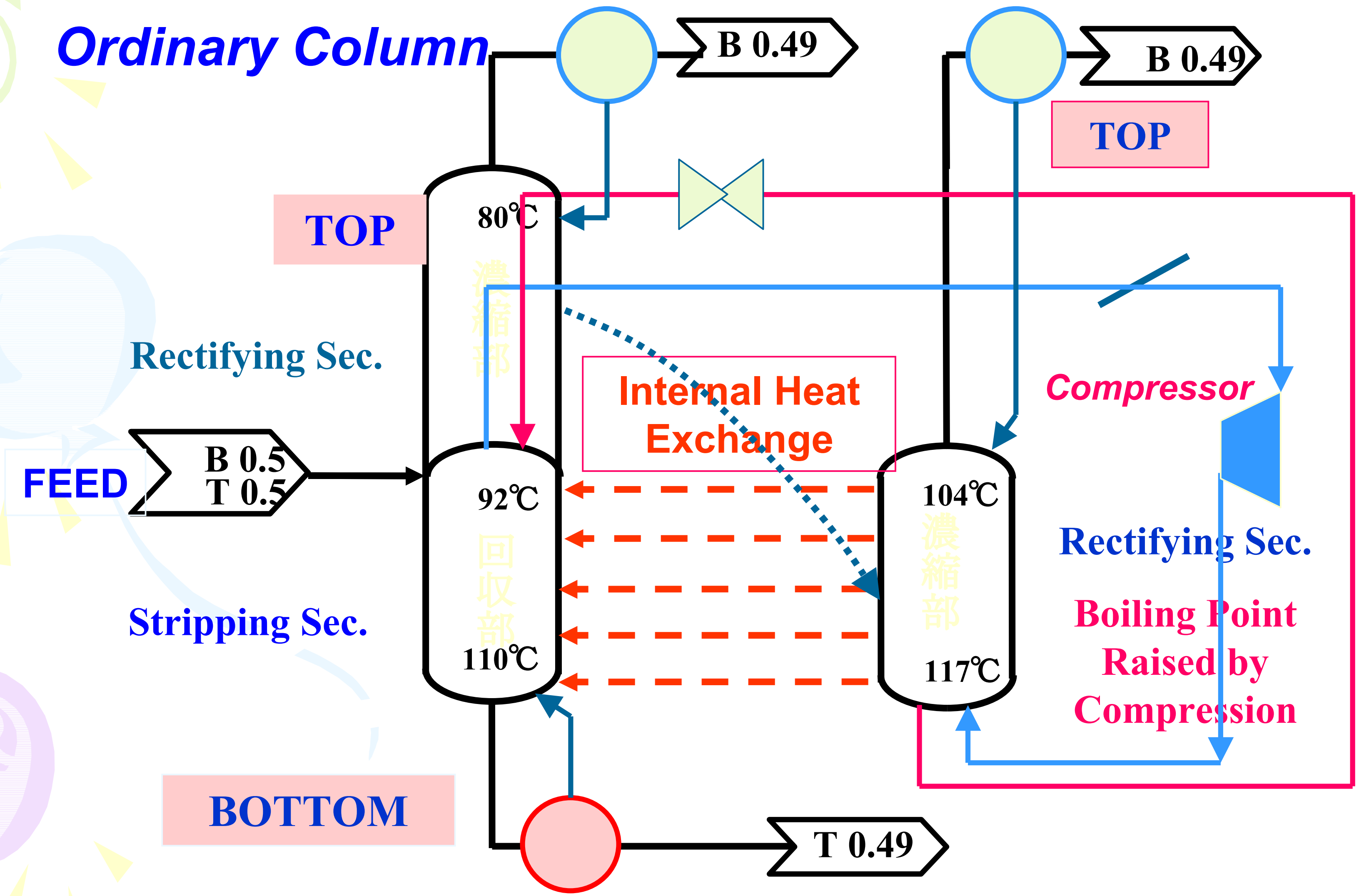
Basic Idea of "Internally Heat Integrated Distillation Column"

(HIDiC System)

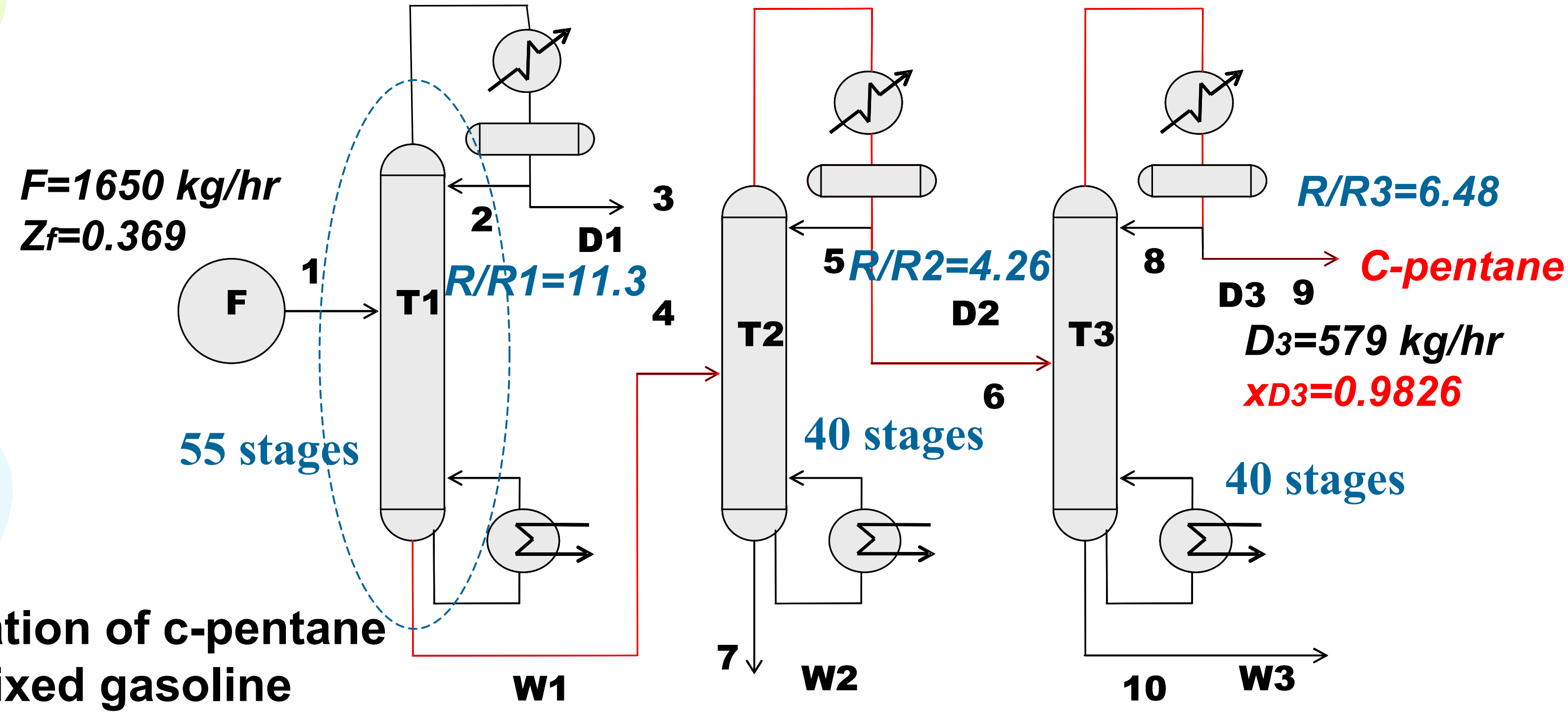


2002-2007 NEDO Project
Title: R&D of Heat Integrated Distillation Technology for Prevention Against Global Warming

Project Team

National Institute of Advanced Industrial Science and Technology
Maruzen Petrochemical Co., Ltd
Kimura Chemical Plants Co., Ltd
Kansai Chemical Engineering Co., Ltd

Existing C5-splitter



Purification of c-pentane from mixed gasoline

Table 1 Feed Composition

Component	Wt%	Component	Wt%
n-butane	0.04	2-methylpentane	13.57
i-pentane	1.80	3-methylpentane	4.71
n-pentane	14.89	n-hexane	11.43
2,2-dimethylbutane	0.22	Methyl-cyclopentane	13.24
Cyclopentane	36.9	Benzene	0.43
2,3-dimethylbutane	1.49	Cyclohexane	1.28

To the bottom of the first column

C5-splitter

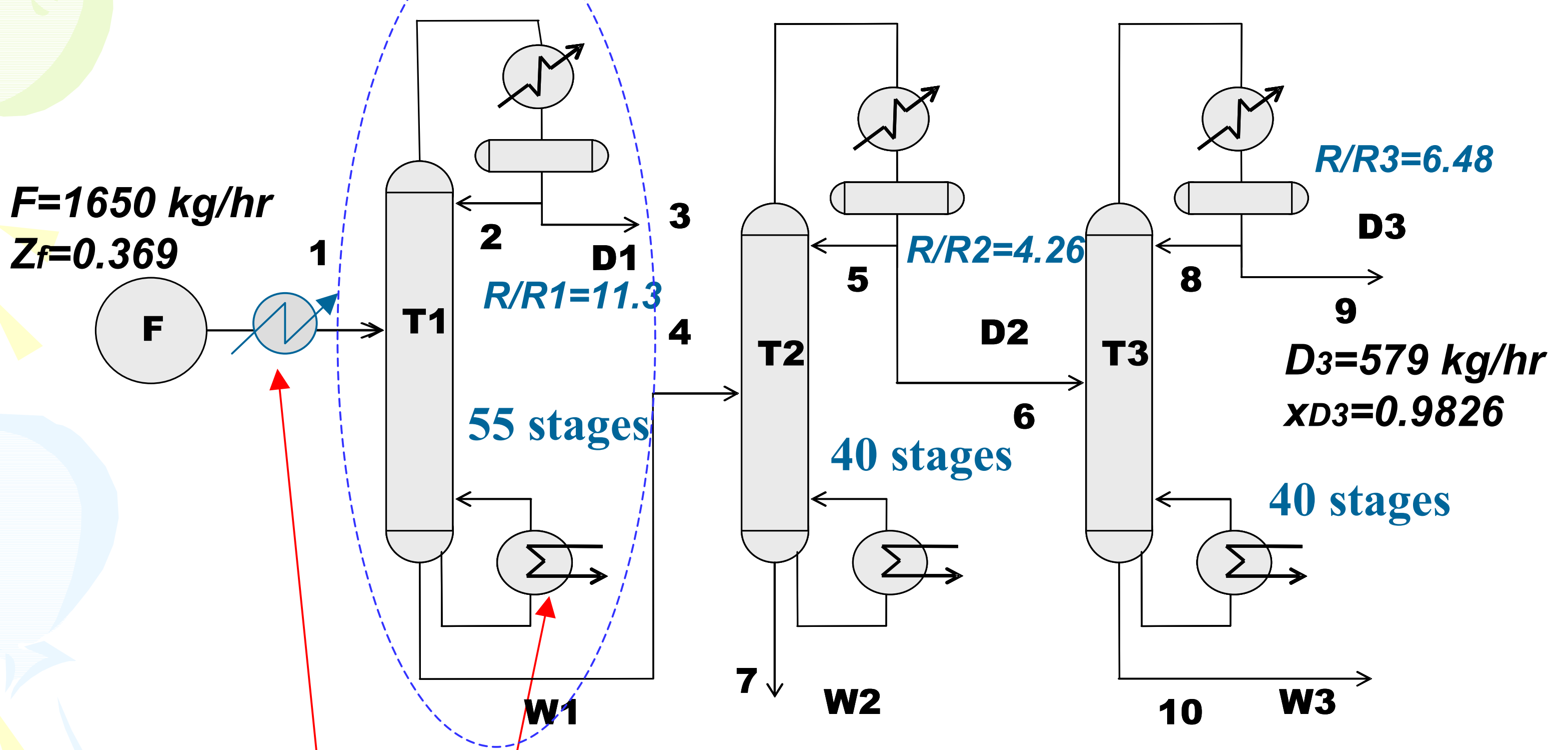
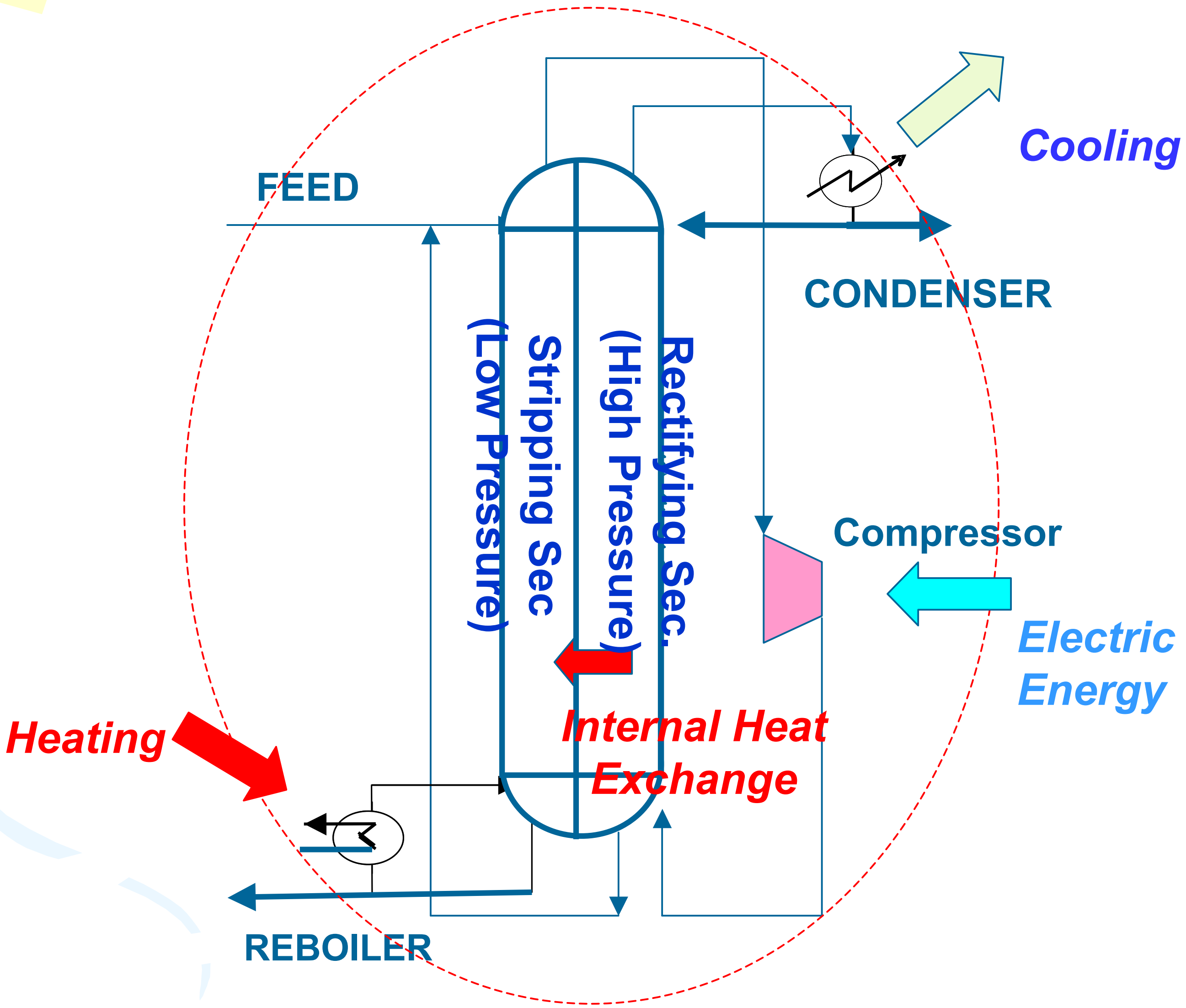


Table 2 Heat duties required for the three columns of the existing C5 splitter
(Simulation results computed using the mass balance of the operation data)

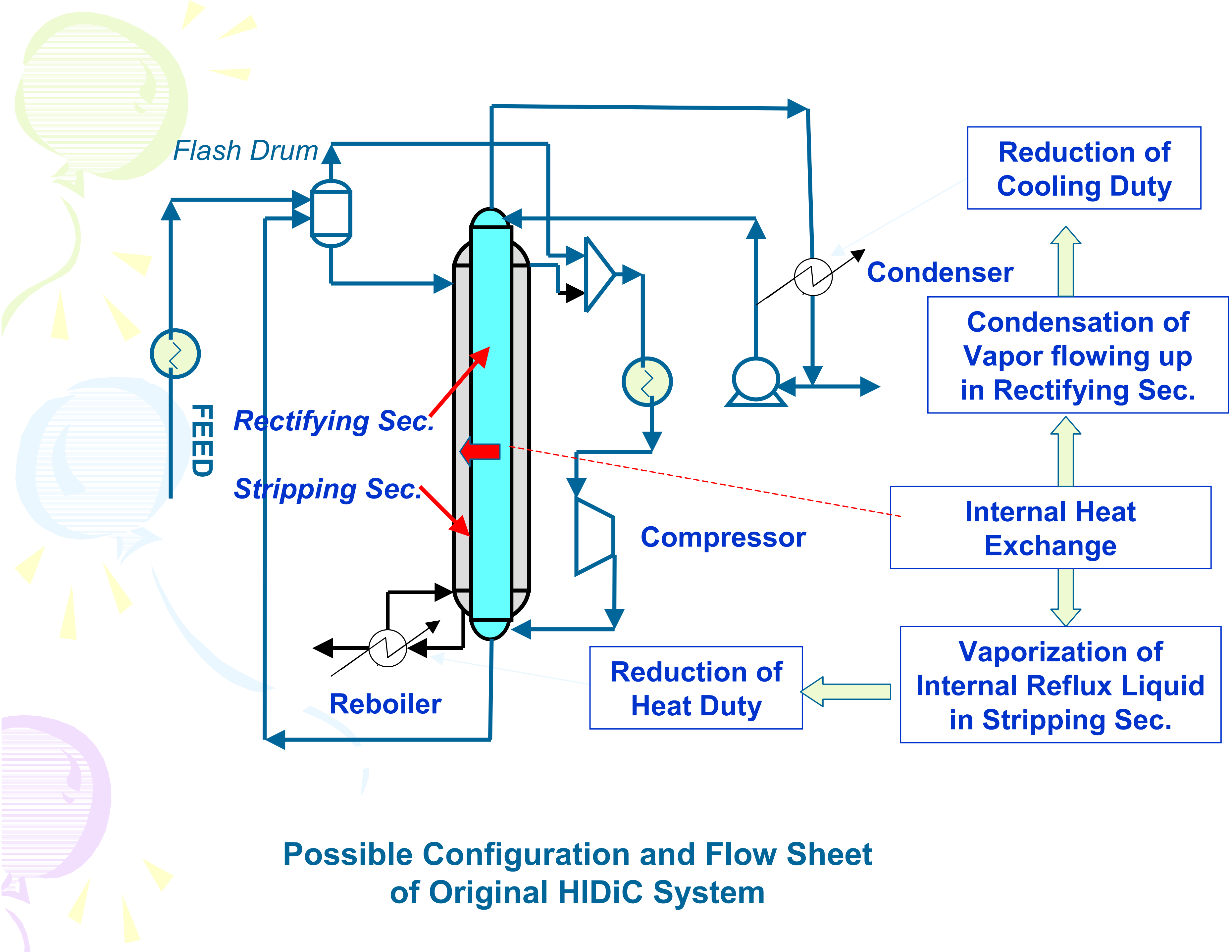
	Column #1	Column #2	Column #3	Total Heat Duty
OH Condenser	-0.3588 Gcal/hr	-0.3315 Gcal/hr	-0.3971 Gcal/hr	-1.0874 Gcal/hr
BTM Reboiler	0.3892 Gcal/hr	0.3311 Gcal/hr	0.3976 Gcal/hr	1.1179 Gcal/hr
Preheater	0.0039 Gcal/hr			

1 Gcal/hr = 10^9 cal/hr = 4.184 GJ/h

How to reduce



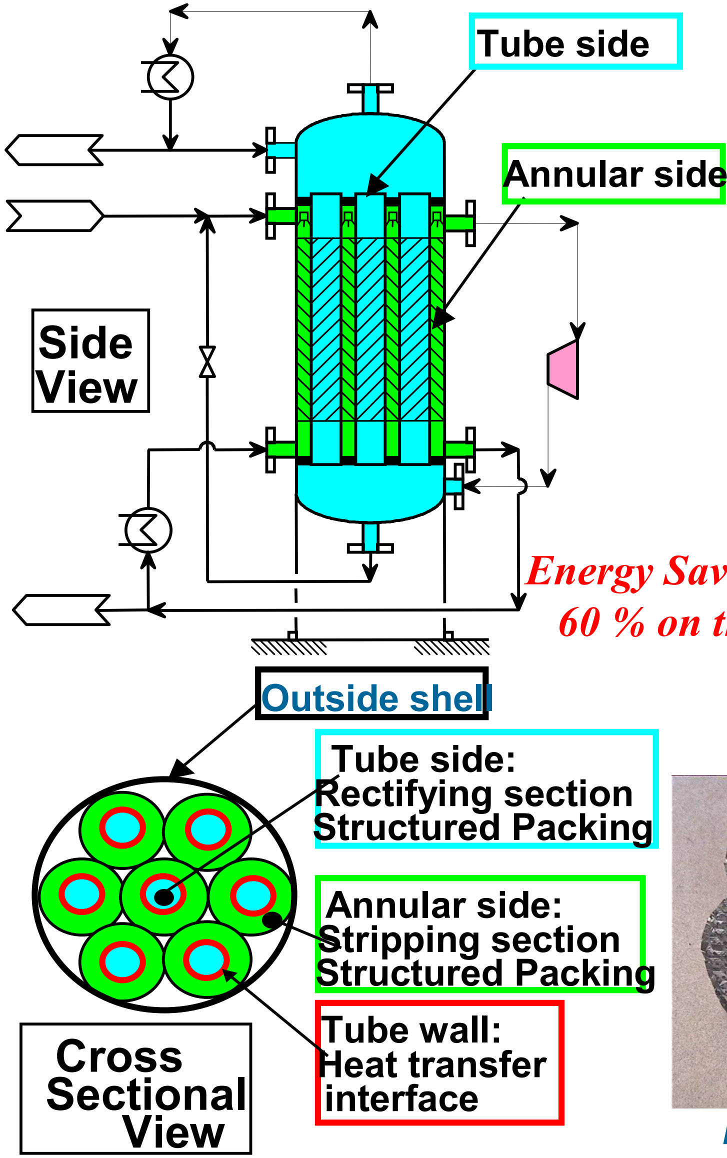
Standard configuration of the original HIDiC system invented by Mah et al. (AIChE J, 23(5), 651 (1977))



Possible Configuration and Flow Sheet of Original HIDiC System

Commercial-scale Pilot Plant of HIDiC Serving for an Existing C-5 Splitter

Double-tube Packed HIDiC Column



Energy Saving Rate = 60 % on the average

MCPack

2007 NEDO Project
Title: Development of Compressor-free Heat Integrated Distillation System By Cascade Utilization of Vapor Pressure (Feasibility Study)

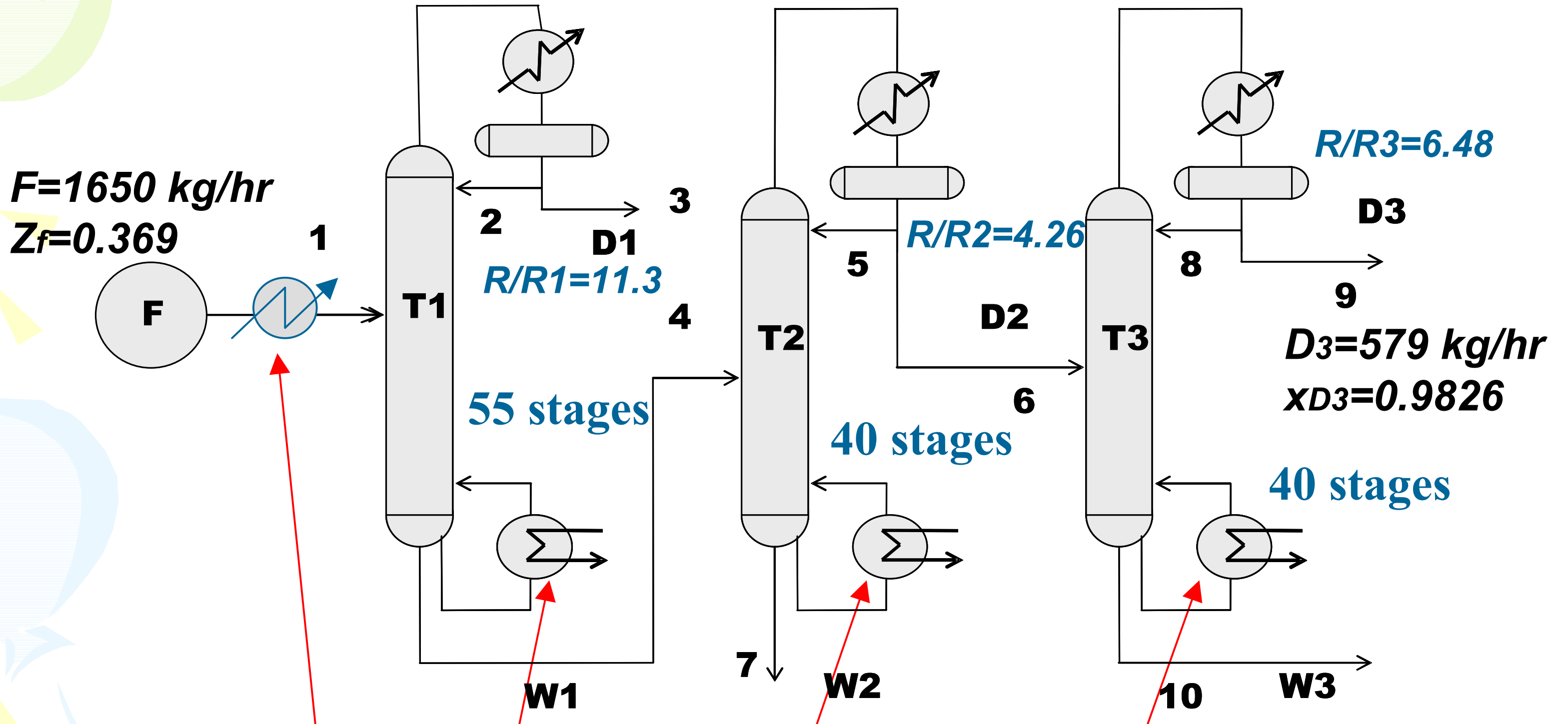
Kansai Chemical Engineering Co., Ltd
Objective： Pervasion of HIDiC technology in chemical industry for prevention against global warming

（1） Possibility of great saving-rate of energy consumption
（2） Applicability to various nonideal distillation processes
（3） Possibility of trayed columns for HIDiC structure

How to Design Multi-component Distillation Plants in New HIDiC Style

System Design of Two or more Columns Plant

C5-splitter



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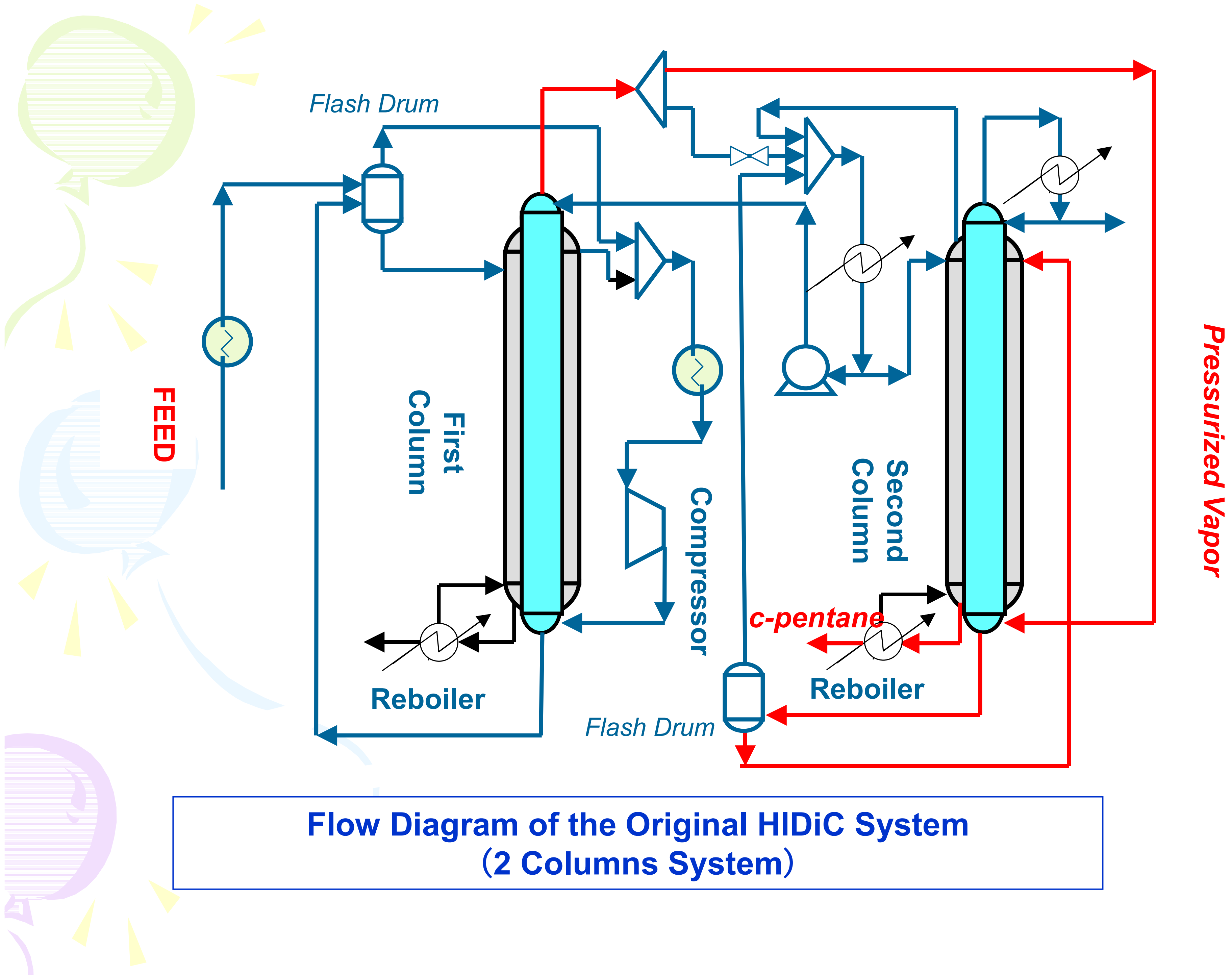
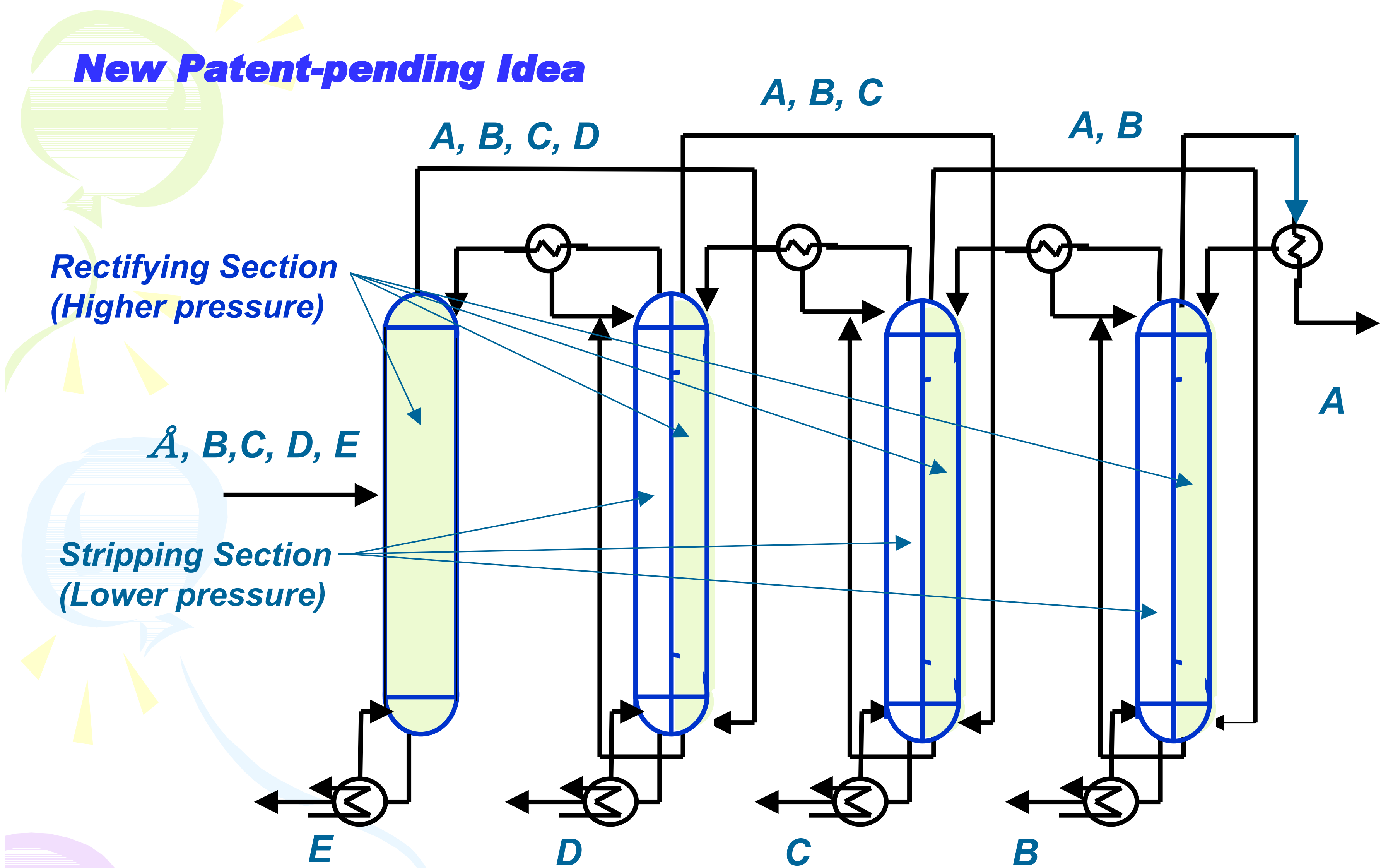


Flow Diagram of the Original HIDiC System (2 Columns System)

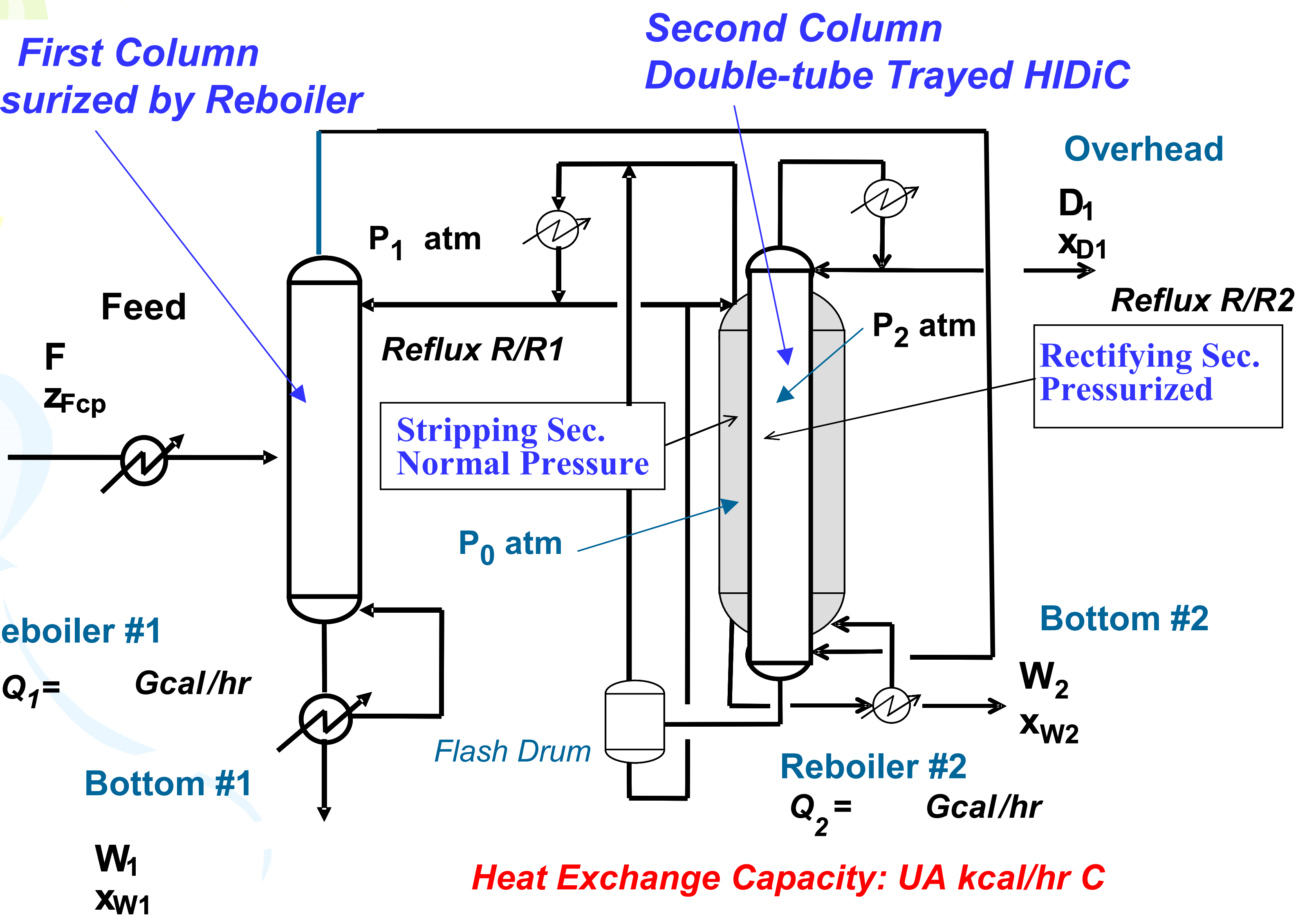
For pervasion of the heat integrated distillation technology (HIDiC Technology) in chemical industry for prevention against global warming

How to do
Heat pumping without using a compressor
Rectification of nonideal or dirty solution

Invention of "Compressor-free HIDiC System"



Conceptional Flow Diagram of
Compressor-free Heat Integrated Distillation System
By cascade utilization of Vapor Pressure
for Multi-component Systems



New HIDiC System Consisting of Two Columns for Three-component Separation

Feed Composition

Vaporized by the first column

Component	Wt%	Component	Wt%
n-butane	0.04	2-methylpentane	13.57
i-pentane	1.80	3-methylpentane	4.71
n-pentane	14.89	n-hexane	11.43
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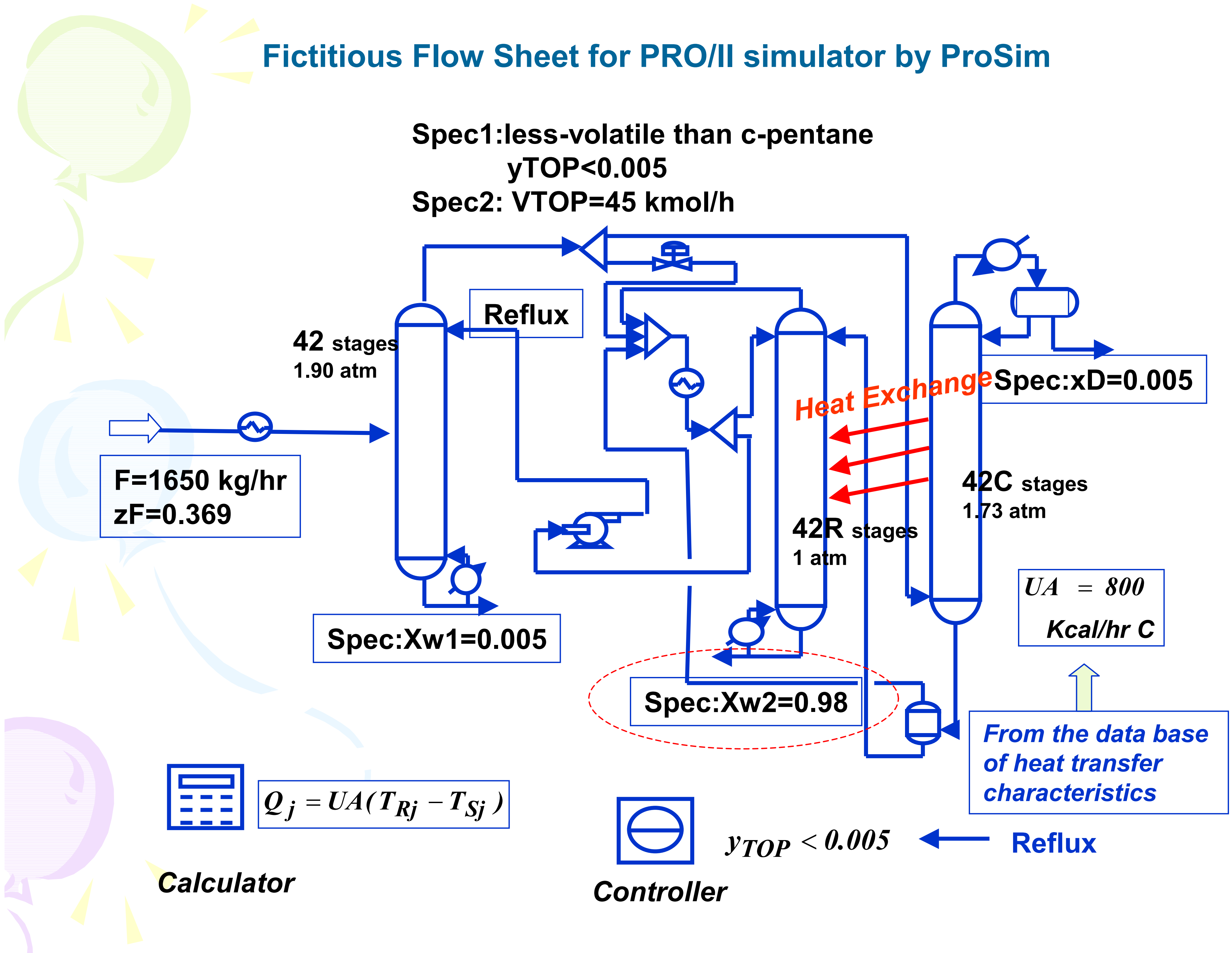
Fictitious Flow Sheet for PRO/II simulator by ProSim
Spec1:less-volatile than c-pentane
yTOP<0.005
Spec2: VTOP=45 kmol/h
Reflux
42 stages
1.90 atm
F=1650 kg/hr
zF=0.369
Spec:Xw1=0.005
Heat Exchange
Spec:xD=0.005
42C stages
1.73 atm
42R stages
1 atm
Spec:Xw2=0.98
UA = 800
Kcal/hr C
From the data base of heat transfer characteristics
$Q_j = UA(T_{Rj} - T_{Sj})$
Calculator
$y_{TOP} < 0.005$
Reflux
Controller

Heat Duties of the Existing C5－splitter

	Column #1	Column #2	Column #3	Total Heat Duty
OH Condenser	-0.3588 Gcal/hr	-0.3315 Gcal/hr	-0.3971 Gcal/hr	-1.0874 Gcal/hr
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Preheater	0.0039 Gcal/hr			

$$Es = (1 - Q_{total} / Q_{base}) \times 100 = (1 - 0.5474 / 1.1179) \times 100 = \underline{51.03\%}$$

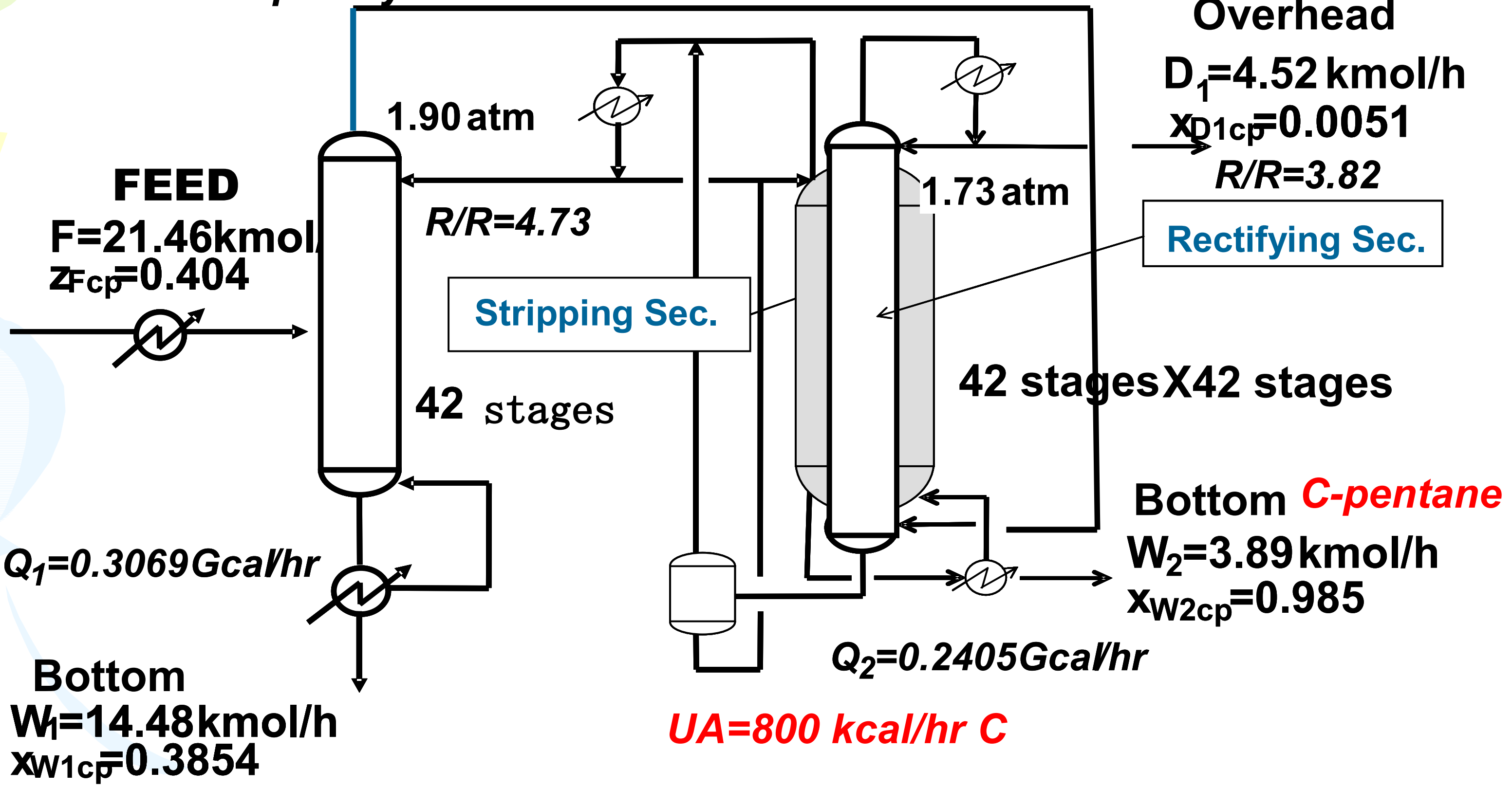
Ordinary Two Column C5-splitter and New HIDiC

	Column #1	Column #2
Two columns system of C5-splitter (no internal heat integration)	0.6920 Gcal/hr	0,2317 Gcal/hr
New HIDiC (Present study)	0.3069 Gcal/hr	0.2405 Gcal/hr

$$Es' = (1 - Q_{total} / Q_{base}') \times 100 = (1 - 0.5464 / 0.9237) \times 100 = \underline{40.7\%}$$

Simulation Result

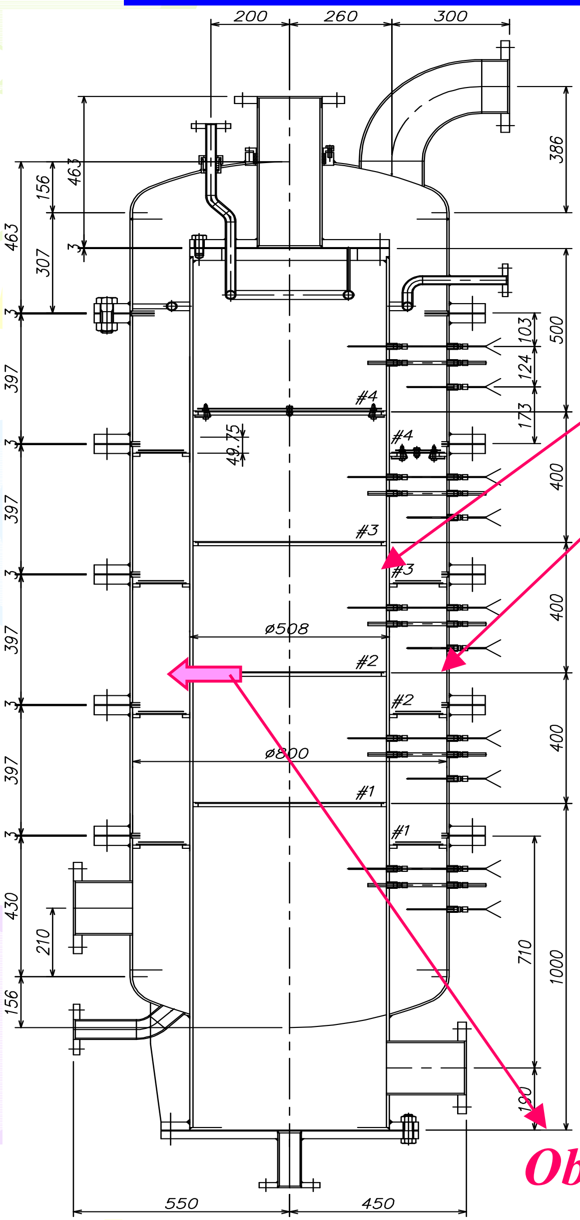
Vapor components less-volatile than c-pentane
spec.: y<0.005



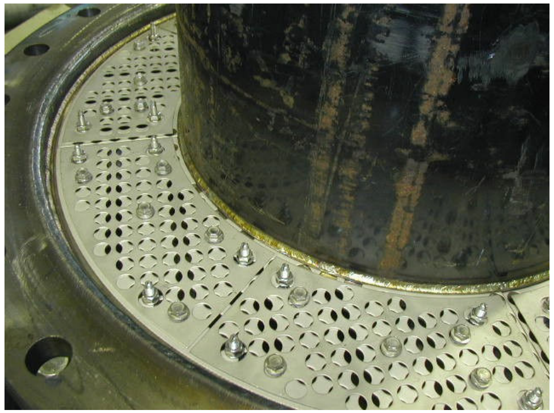
Column #1:Reboiler Q1 = 0.3069 Gcal/hr,
Column #2（HIDiC）:Reboiler Q2 = 0.2405 Gcal/hr
Total Consumption： Q(total) = 0.5474 Gcal/hr
Energy-saving Rate：
Es = (1 – Q(total)/Q(base))x100= 51.03 %

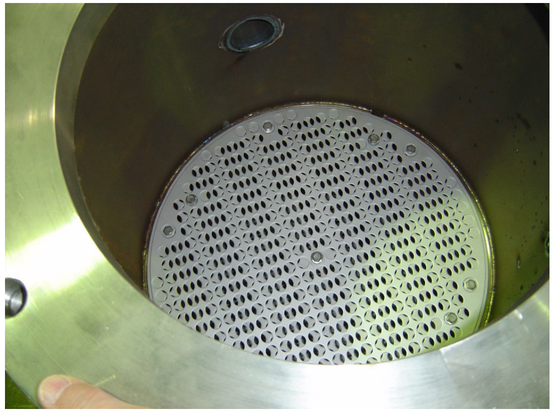
Ordinary Two Columns Plant
With Two Reboilers
Total Consumption:
Q’=0.6920+0.2317=0.9237 Gcal/hr
Es = (1 – Q(total)/Q’)x100= 40.7 %

Double-tube structured New HIDiC Trayed Column (Experimental Apparatus)



Double-tube-type column
Inner column : 508 mm OD
Outer column : 800 mm ID
Column height: 2640 mm
Heat transfer area : 3.97 m^2



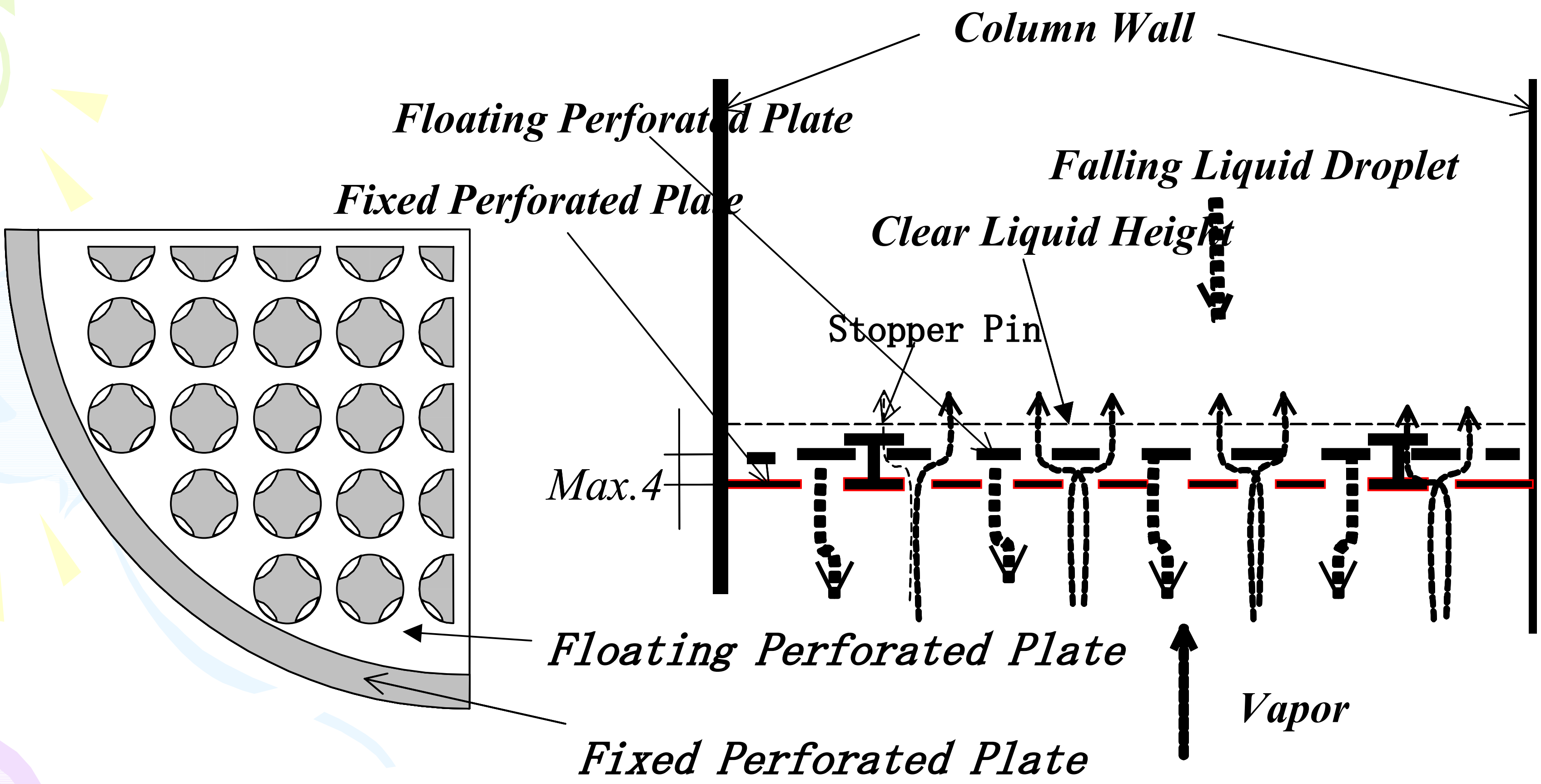


Lift Tray (Outer column) *Lift Tray (Inner column)*

Observation of heat transfer characteristics

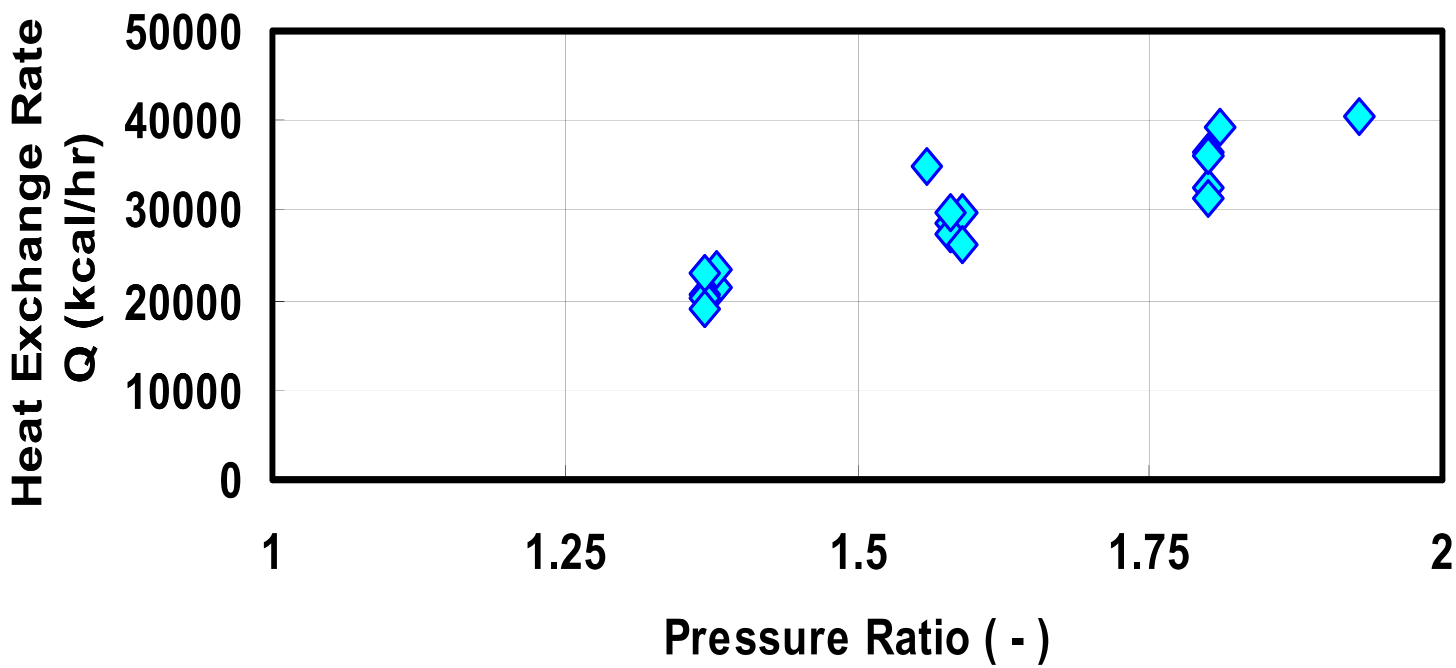
Lift Tray

Suitable for HIDiC trayed columns

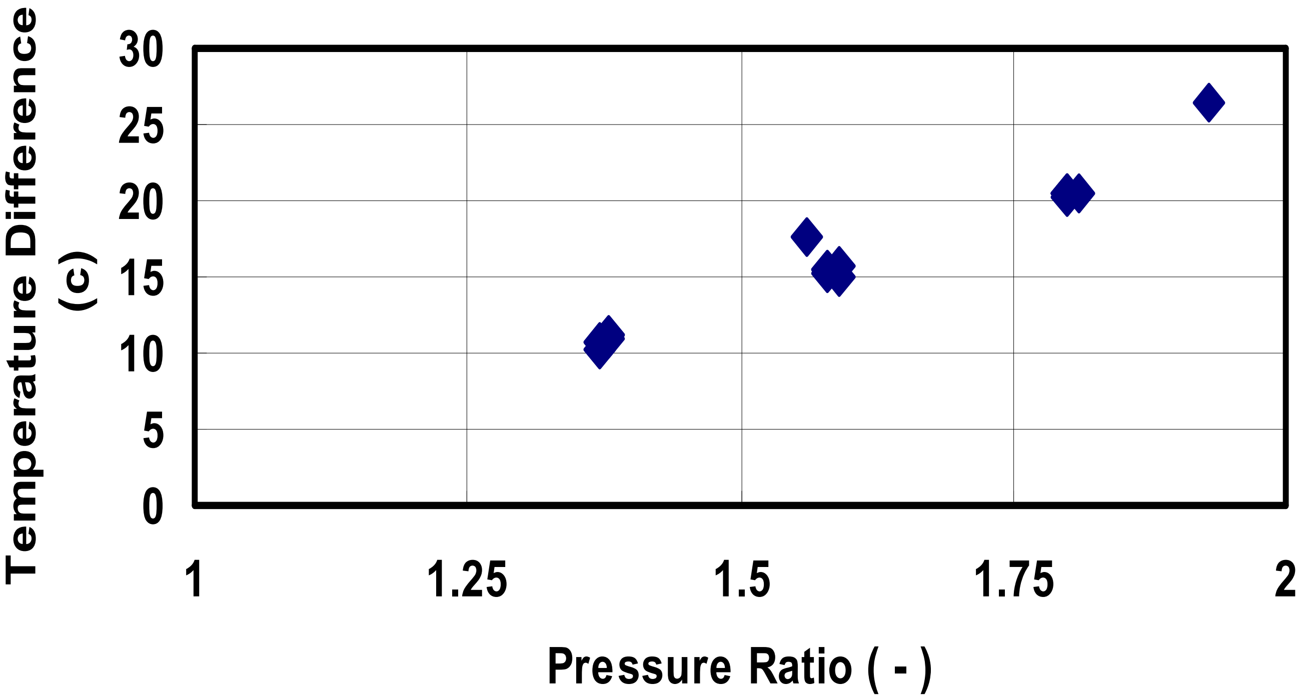


Stable bubbling over a wide F-factor range due to the self-controlling pressure drop depending on Vapor Flow Rate

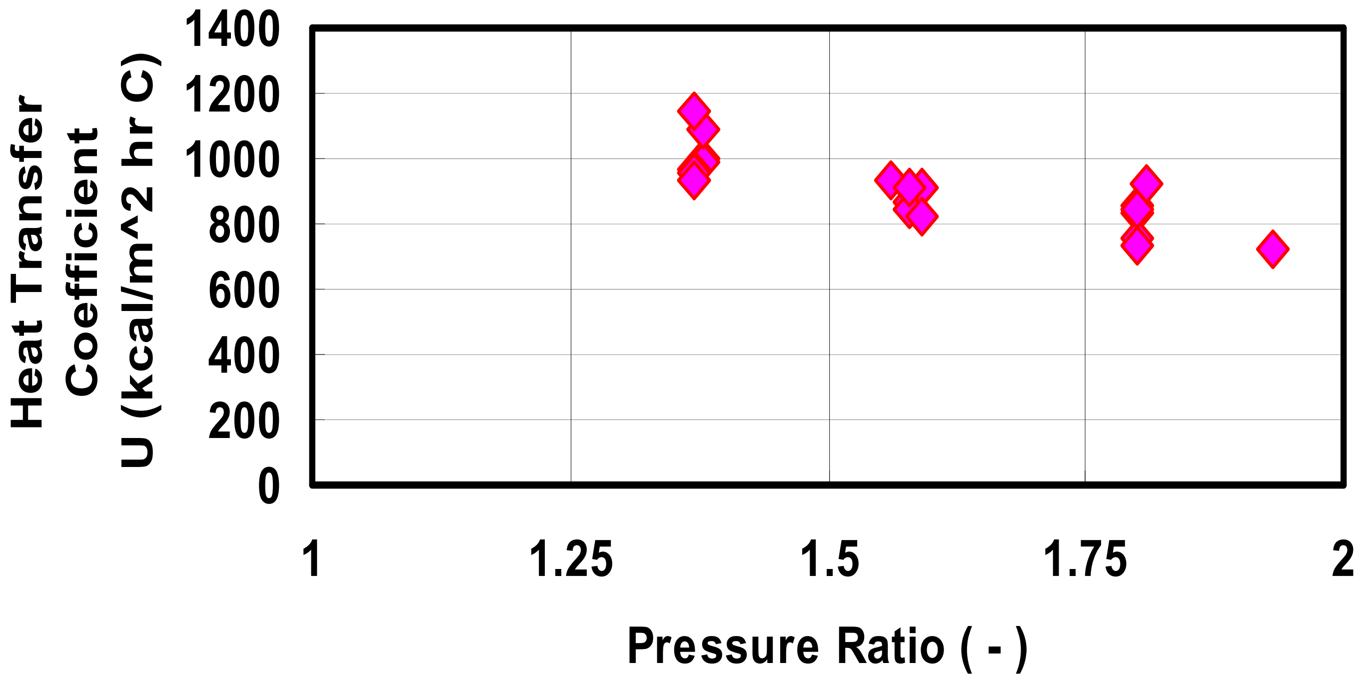
Experimental Data of Heat Transfer Characteristics For Double-tube-structured HIDiC trayed Column



The internal heat exchange rate is proportional to the pressure ratio of the rectifying to the stripping section.



The averaged temperature difference between the rectifying and the stripping section is proportional to the pressure ratio.



The overall heat transfer coefficient has a trend slightly-decreasing
With the pressure ratio increasing.

Concluding Remarks

The new compressor-free HIDiC system consisting of an ordinary column and a HIDiC-structured Column has the following advantages:

(1) The first column having no energy-saving effect has a role to supply a pressurized vapor into the next HIDiC rectifying section for heat pumping.

(2) The overhead condenser of the HIDiC stripping section has a role to reflux to the top of the first column.

(3) The next HIDiC-structured column has a great energy-saving effect.

(4) This system can widely be applied to various distillation processes such as dirty or sticky and corrosive systems as well as clean systems.

8TH WORLD CONGRESS OF CHEMICAL ENGINEERING
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AND THE XXIV INTERAMERICAN CONGRESS OF CHEMICAL ENGINEERING
August 23-27, 2009
Montréal, Quebec, Canada

SYMPOSIUM
Energy-saving Distillation Technology For Prevention Against Global Warming

Scope

This topical conference is dedicated to distillation hardware related work in the field of energy-saving distillation technology. Typically, these methods cover:

① **Heat integrated distillation column or diabatic distillation column techniques**
② **Vapour recompression techniques**
③ **Heat-coupling and dividing wall column techniques**
④ **Reactive distillation**

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