Development of CO_2 Capture System with MCFC

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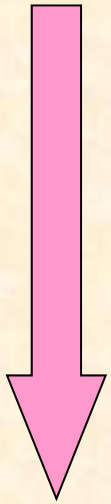
【Purpose of development】

To reduce CO_2 emissions from thermal power stations

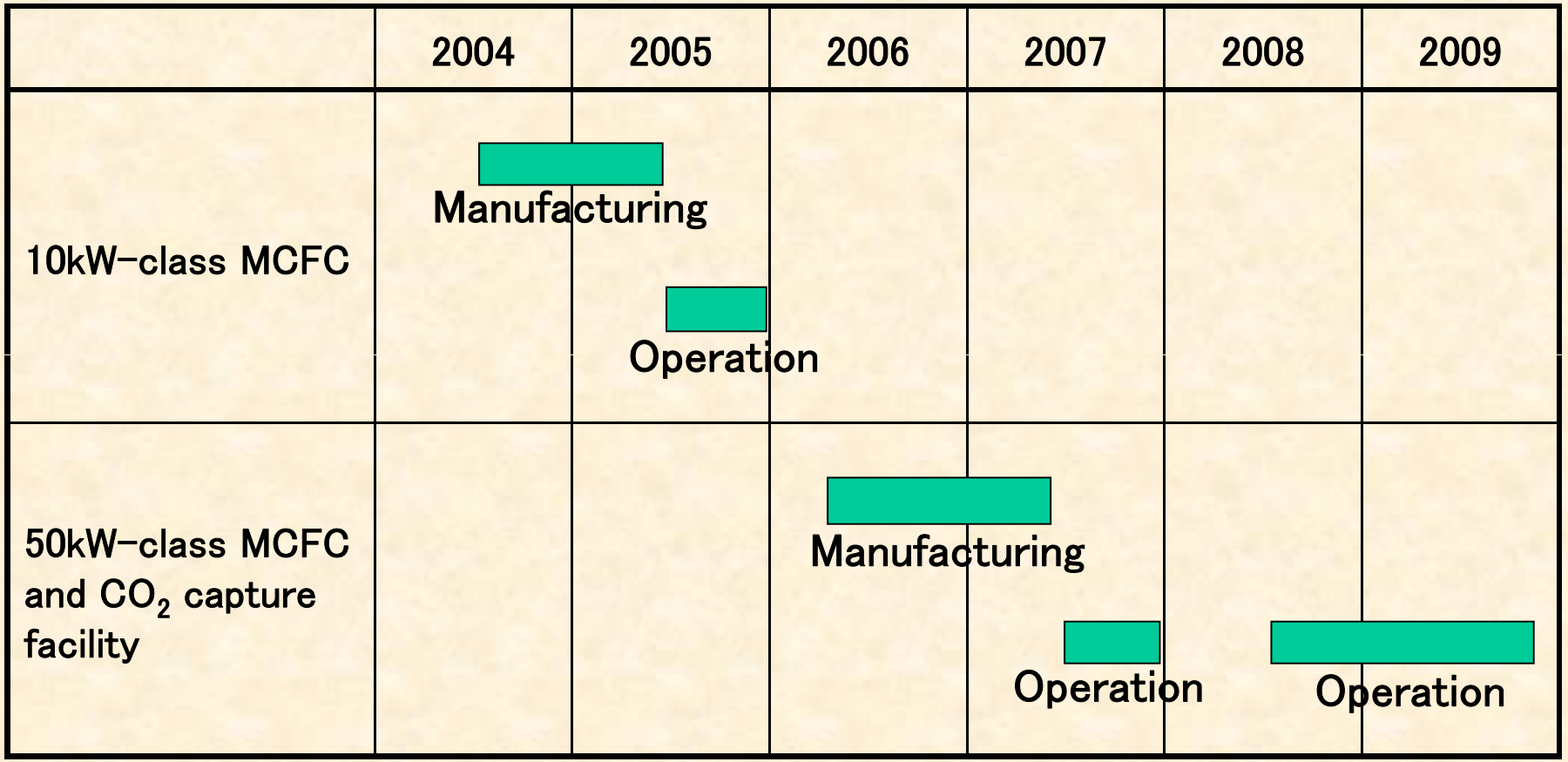


CO_2 supplied to cathode inlet is highly concentrated to anode outlet by MCFC generation

CO_2 can be captured efficiently

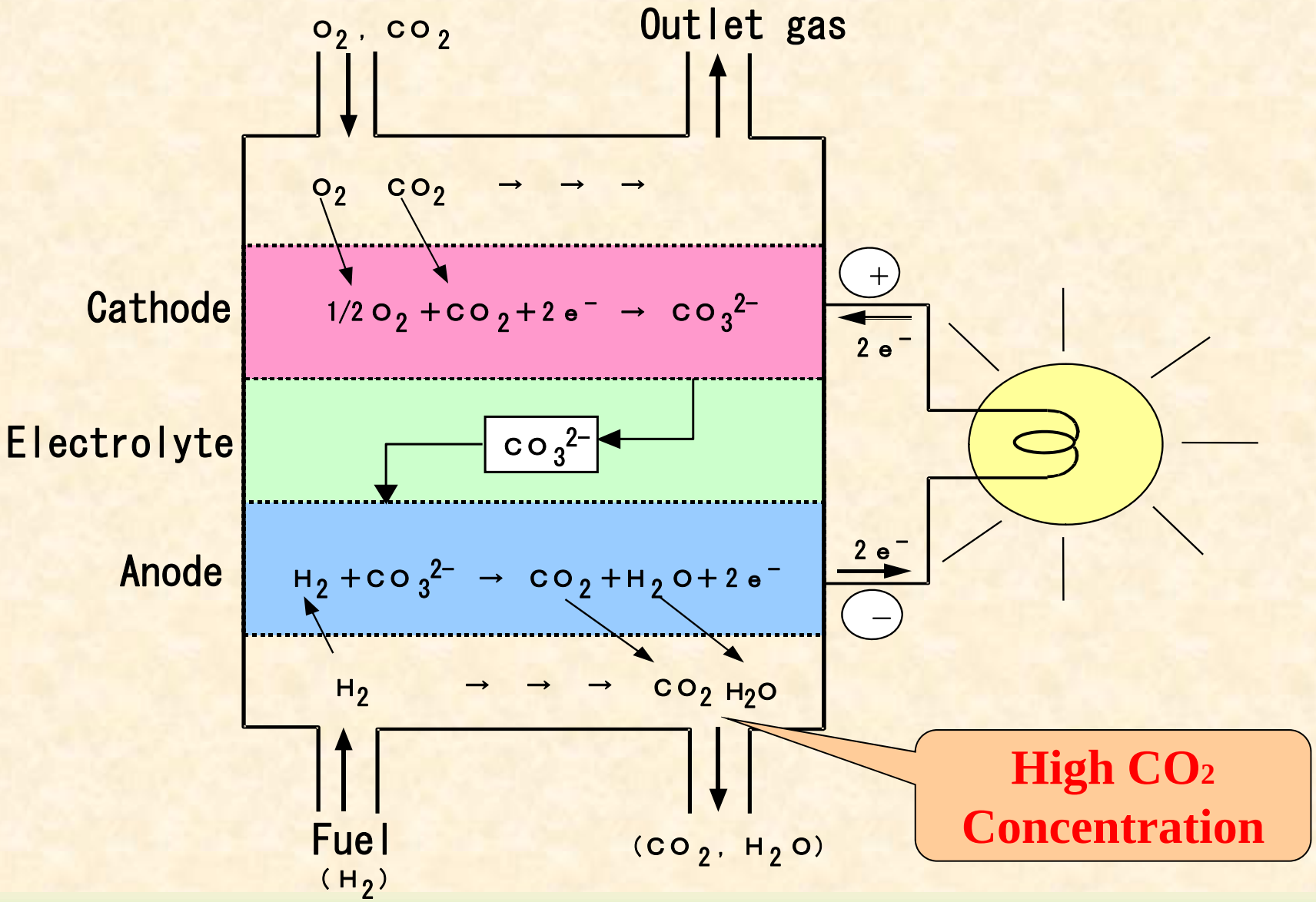
CO_2 Capture System using MCFC

【Development schedule】

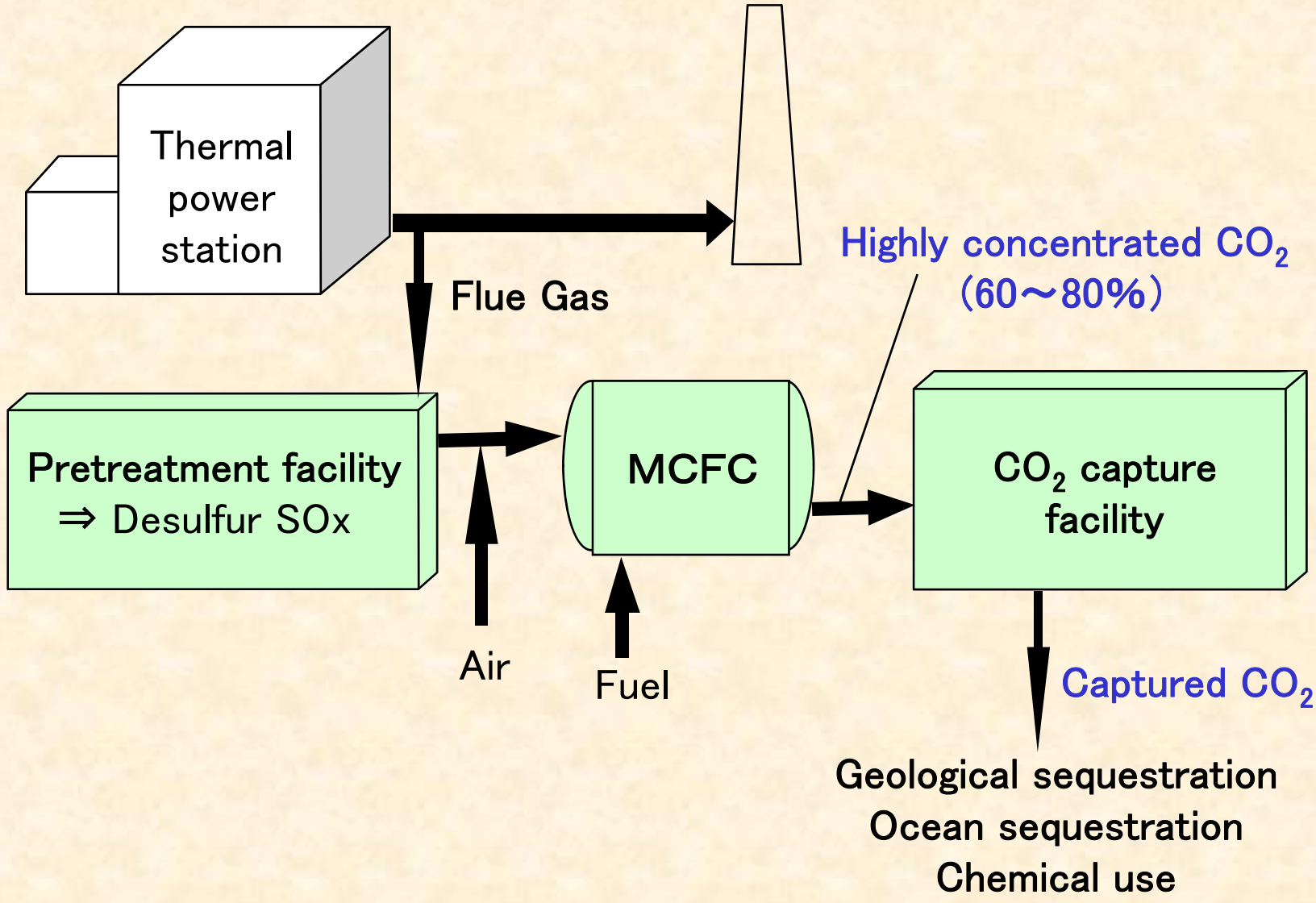


This development was sponsored by The Ministry of Economy, Trade and Industry, Japan from 2004 to 2007.

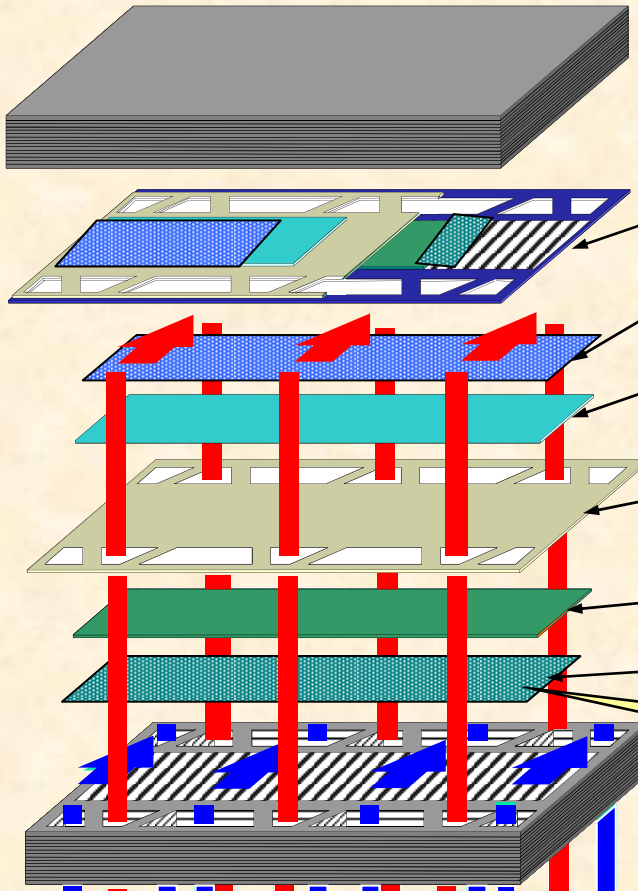
【Chemical reaction of MCFC】



【Schematic system diagram】



【Problem of this system】



Separator（Stainless steel）

Anode current collector（Ni）

Anode electrode（Ni）

Electrolyte（Li_2CO_3／Na_2CO_3）

Electrolyte matrix（$LiAlO_2$）

Cathode electrode（NiO）

Cathode current collector（Stainless steel）

Corroded with SOx in coal-fired flue gas

Anode outlet gas（H_2O, CO_2）

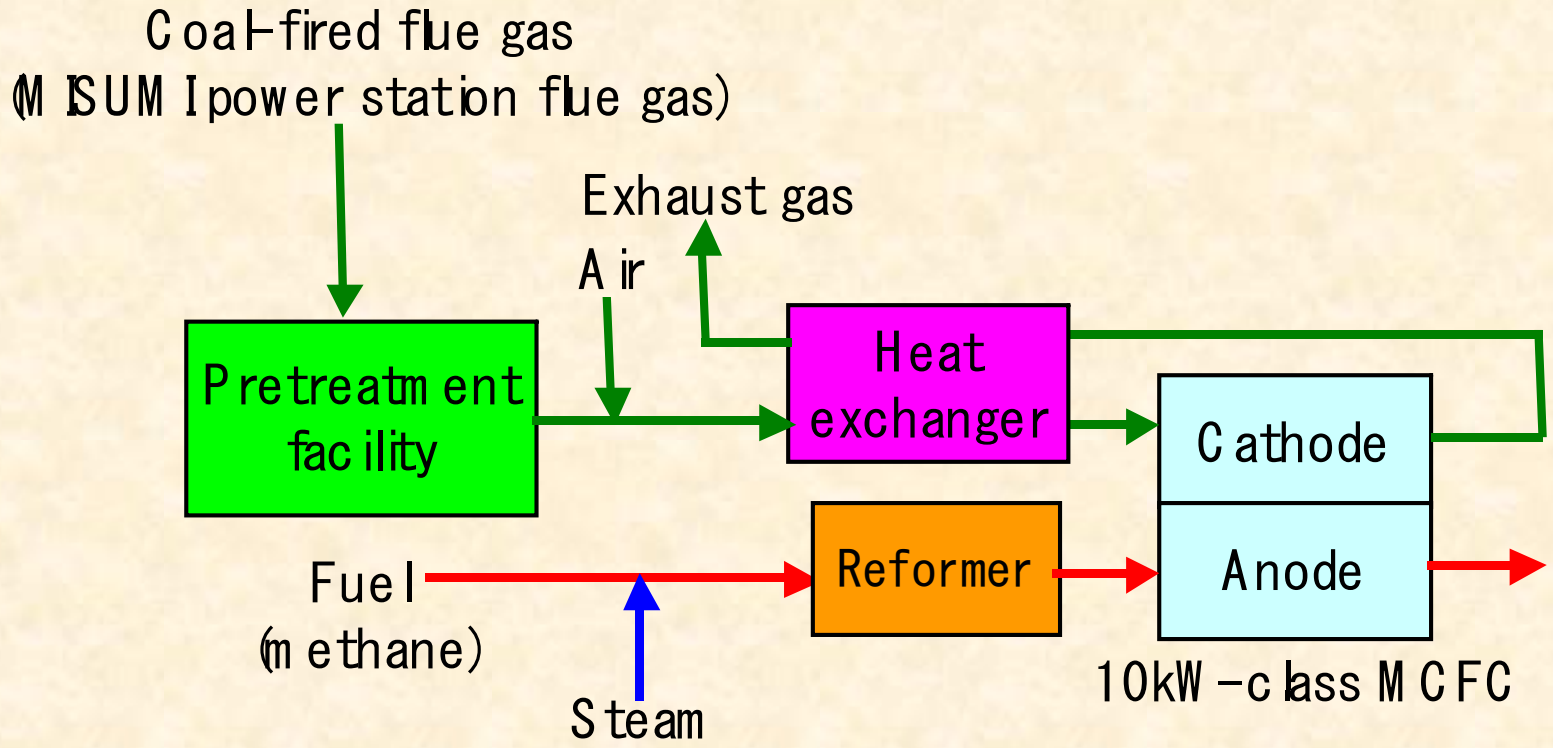
Fuel（H_2）

Cathode outlet gas（O_2,CO_2,N_2）

Coal-fired flue gas ＋ Air（O_2,CO_2,N_2）

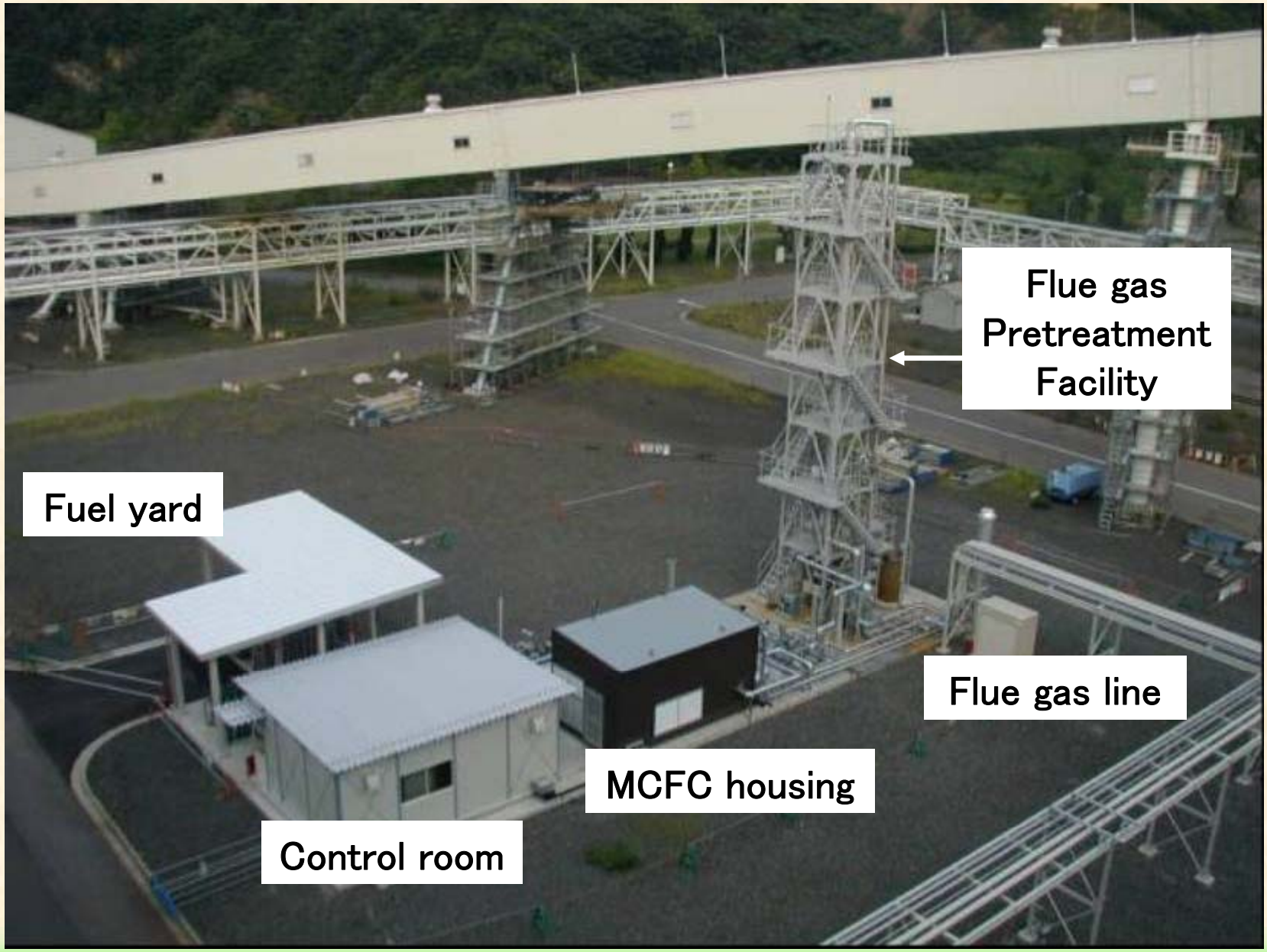
【Schematic diagram of 10kW-class test facility 】

① To evaluate the performance of flue gas pretreatment facility
② To select proper material for cathode current collector




【Test facility】
(at Misumi coal-fired power station)

【10kW-class test facility】(at MISUMI power station)



【Composition of Misumi power station flue gas】

	Concentration
N_2	80.0 %
CO_2	14.5 %
O_2	5.5 %
SO_2	20 ～ 70 ppm (less than environmental standards)
NOx	40 ～ 50 ppm (less than environmental standards)

Further desulfulization is necessary to prevent corrosion at cathode current collector.

【Specification of flue gas pretreatment facility】

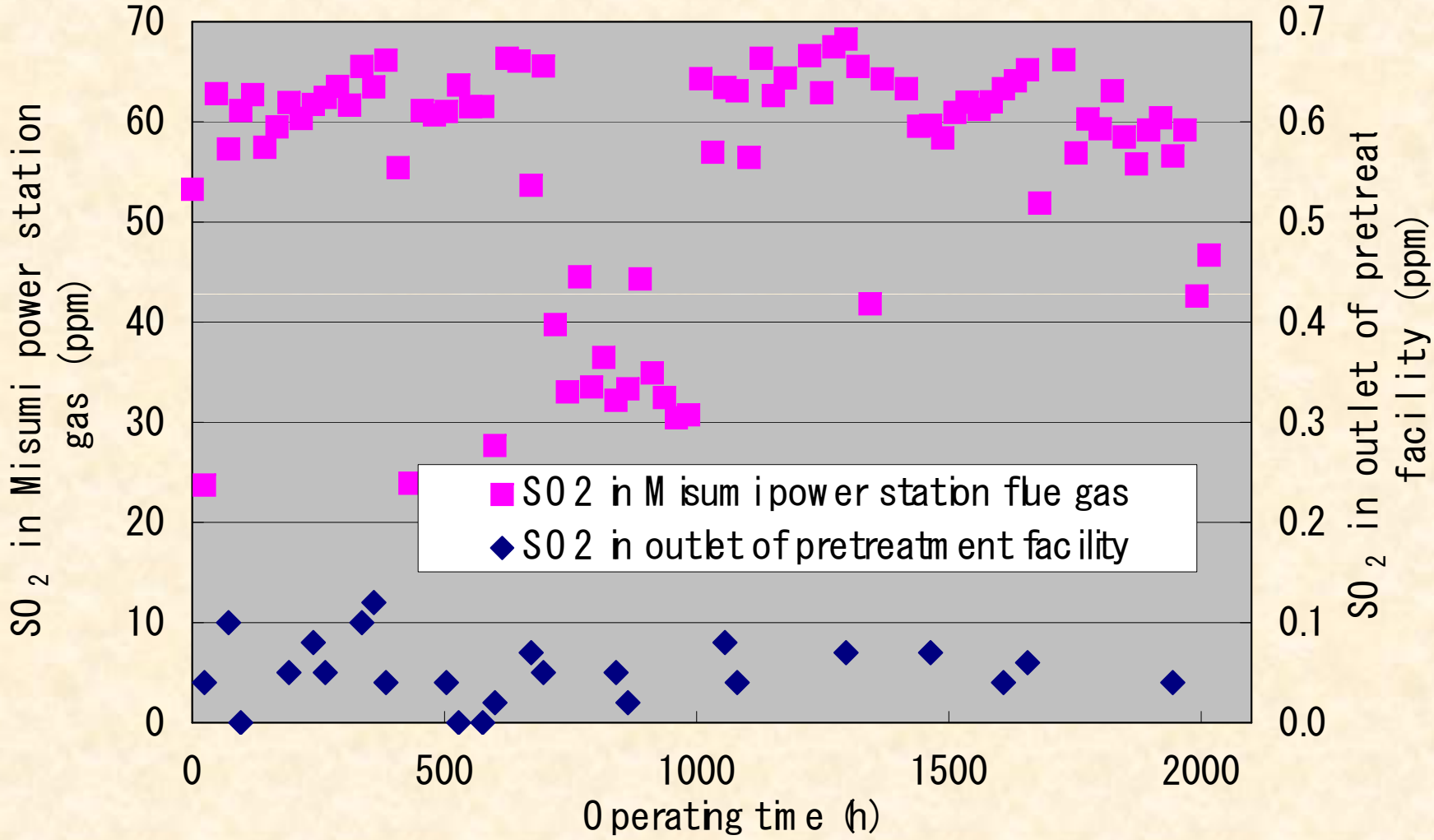
	Specification
Type	Wet limestone-gypsum process (Spray type)
Amount of treated gas	580Nm^3/h
Inlet SO_2 concentration	60 ppm
Target SO_2 concentration	Less than 1 ppm
Spray stages	6 stages （ordinary 3 – 4 stages）
Ratio of liquid to gas	25 L/m^3 （ordinary 8 – 15）
Gas flow velocity	1.01 – 1.07 m/s （ordinary 2 – 5）

【Flue gas pretreatment facility】

【Specification of MCFC stack】

	Specification	
Manufacturer	IHI Corporation	
Rated output	10kW-class (10 cells)	
Cell reaction area	1m^2-class	
Operating pressure	Atmospheric pressure	
Fuel gas	Methane	
Cathode gas	Coal-fired flue gas ＋ Air	
Materials of cathode current collector	Upper 5 cells	SUS316L
	Lower 5 cells	SUS310S

【SO_2 concentration trends】



【Impurity concentrations in outlet gas of flue gas pretreatment facility】

	Unit	Concentration
SO_2	ppm	＜0.1 (less than 1ppm)
F	mg/Nm^3	＜0.2 (less than determination limit)
Cl	mg/Nm^3	＜0.2 (less than determination limit)
NOx	ppm	40 ～ 50 (No denitration)

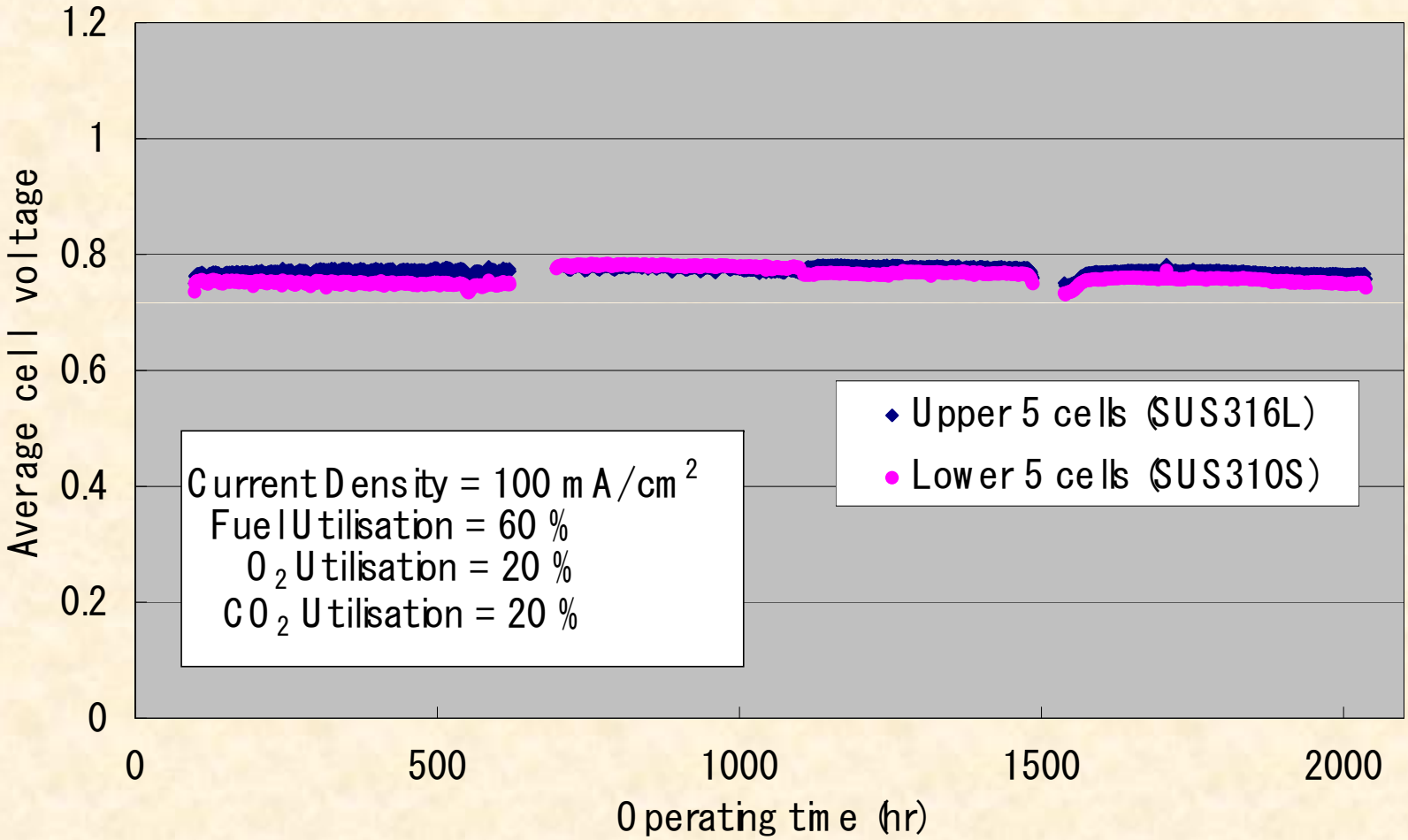
【Properties of stainless steels used for cathode current corrector】

		SUS316L (Upper 5 cells)	SUS310S (lower 5 cells)
Composition (%)	Cr	16～18	24～26
	Ni	12～15	19～22
	Mo	2～3	0
Specific resistance（μΩ･cm）		74	78

・SUS316L is used conventionally, and its electric resistance is lower than SUS310S.

・SUS310S is more durable but more expensive than SUS316L..

【Cell voltage trends】



【Results of analysis of dismantled stack】

Maximum corrosion depth of each cathode current collector

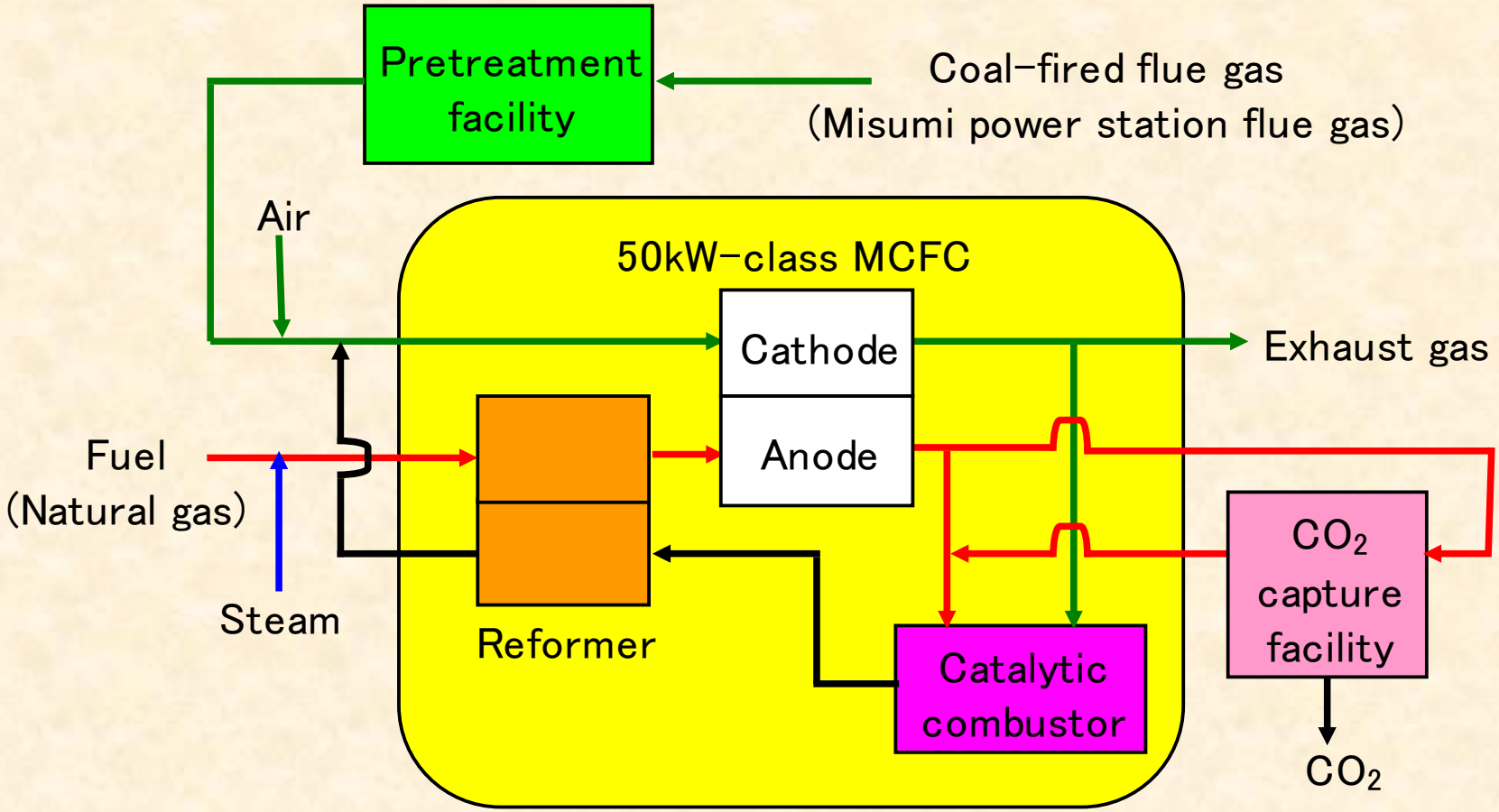
Material	Maximum corrosion depth
SUS316L	13 μm
SUS310S	11 μm

・Each corrosion depth is as little as that caused by ordinary operations without coal-fired flue gas being supplied.

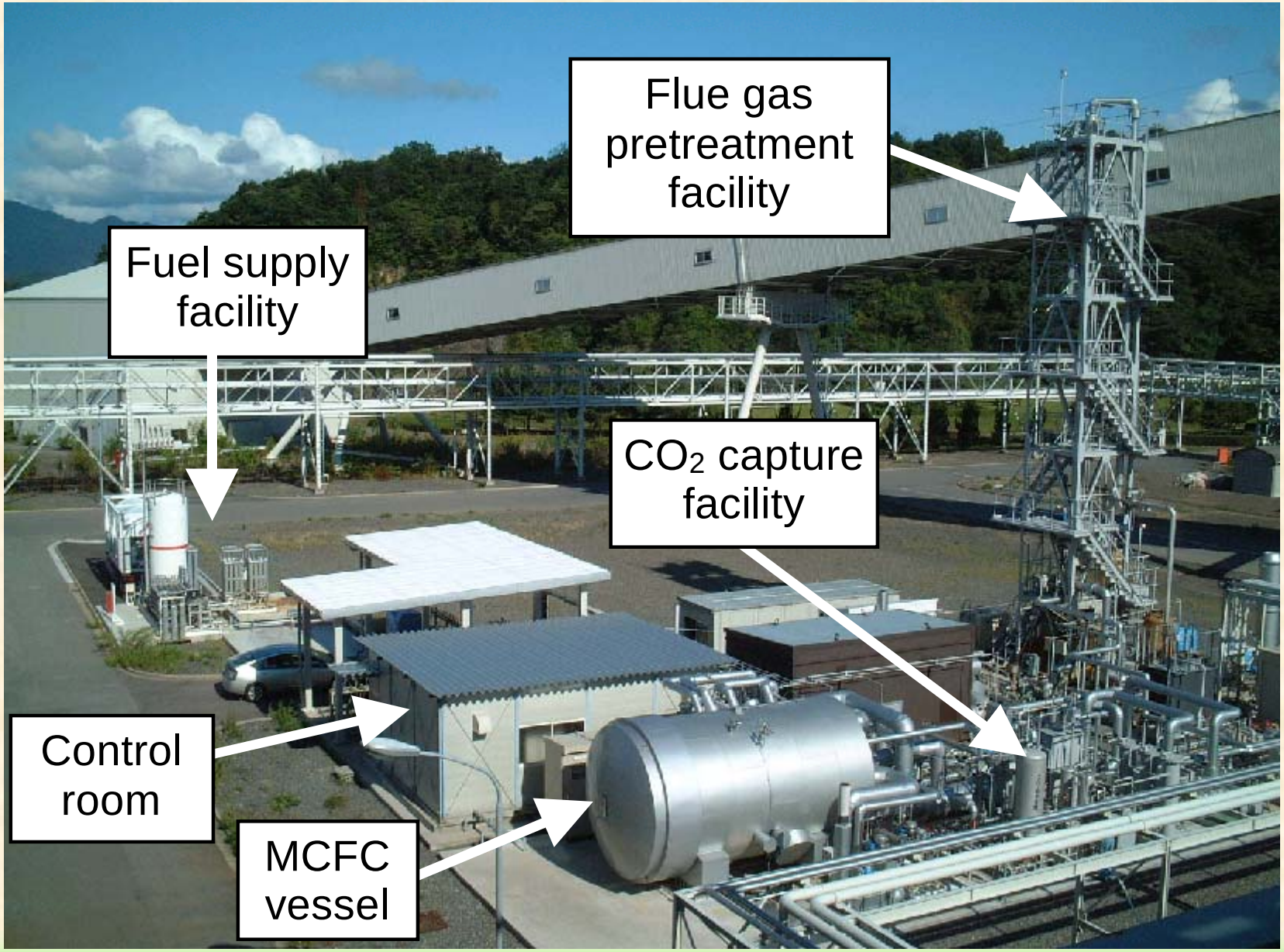
・Conventional material (SUS316L) is usable for cathode current collector with sufficient desulfurization.

【Flow diagram of 50kW-class system】

To evaluate the performance of total system including CO_2 capture facility



【50kW-class system view】(at Misumi power station)



【Specification of MCFC stack】

	Specification
Manufacturer	IHI Corporation
Rated output	50kW-class (50 cells)
Cell reaction aria	1m^2-class
Operating pressure	0.08 MPa(G)
Fuel	Natural gas
Cathode gas	Coal-fired flue gas + Air

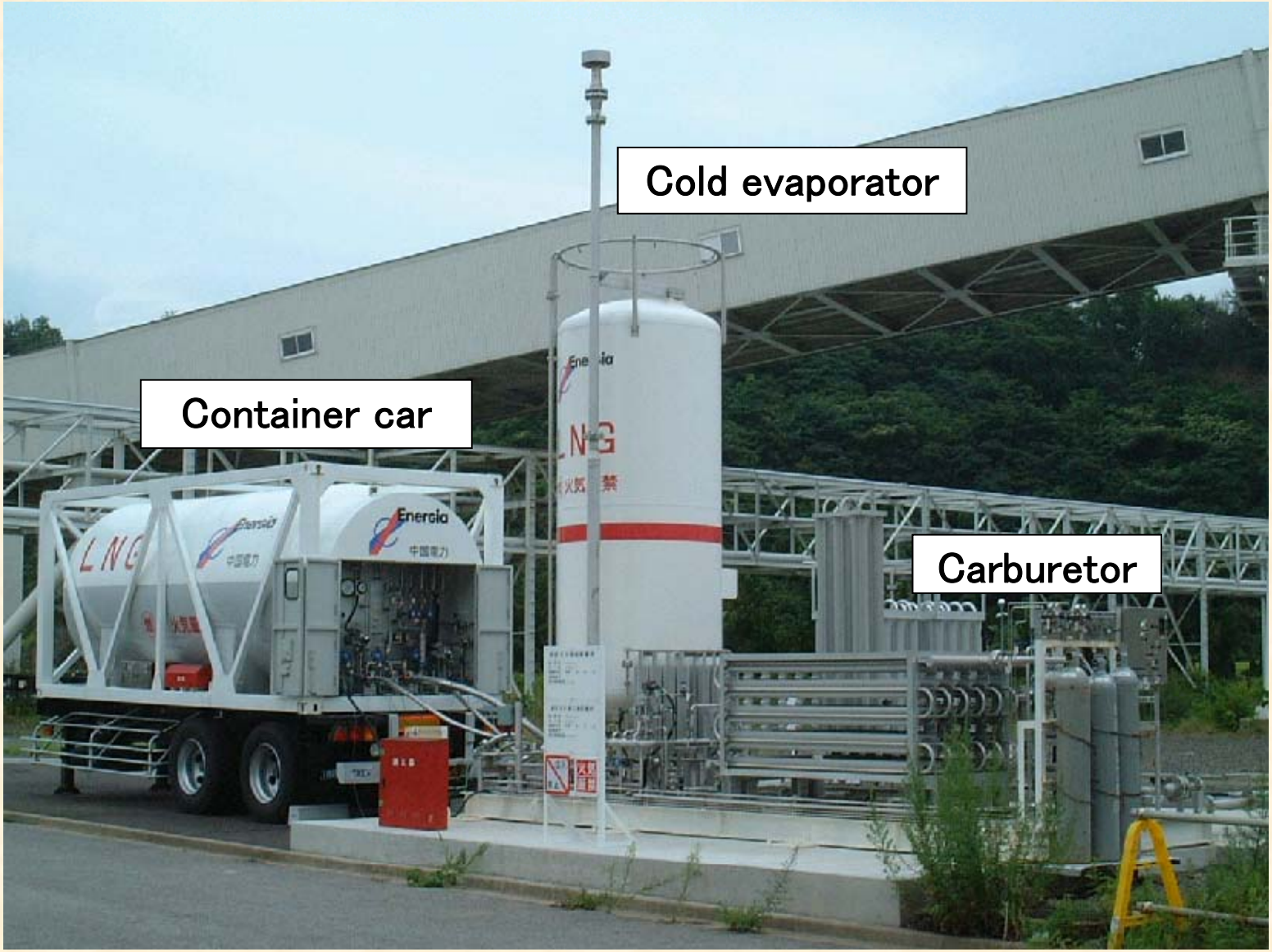
【MCFC vessel】

【Specification of CO_2 capture facility】

	Specification
Type	PSA (Pressure Swing Adsorption) process
Inlet gas	Anode outlet gas
Rated amount of inlet gas	24 Nm^3/hr (dry base)
Number of adsorption tanks	3 tanks
Adsorption pressure	90 kPa
Desorption pressure	50 Torr
Rated amount of captured CO_2	30kg/hr

【CO_2 capture facility】

【Fuel supply facility（LNG bulk system）】



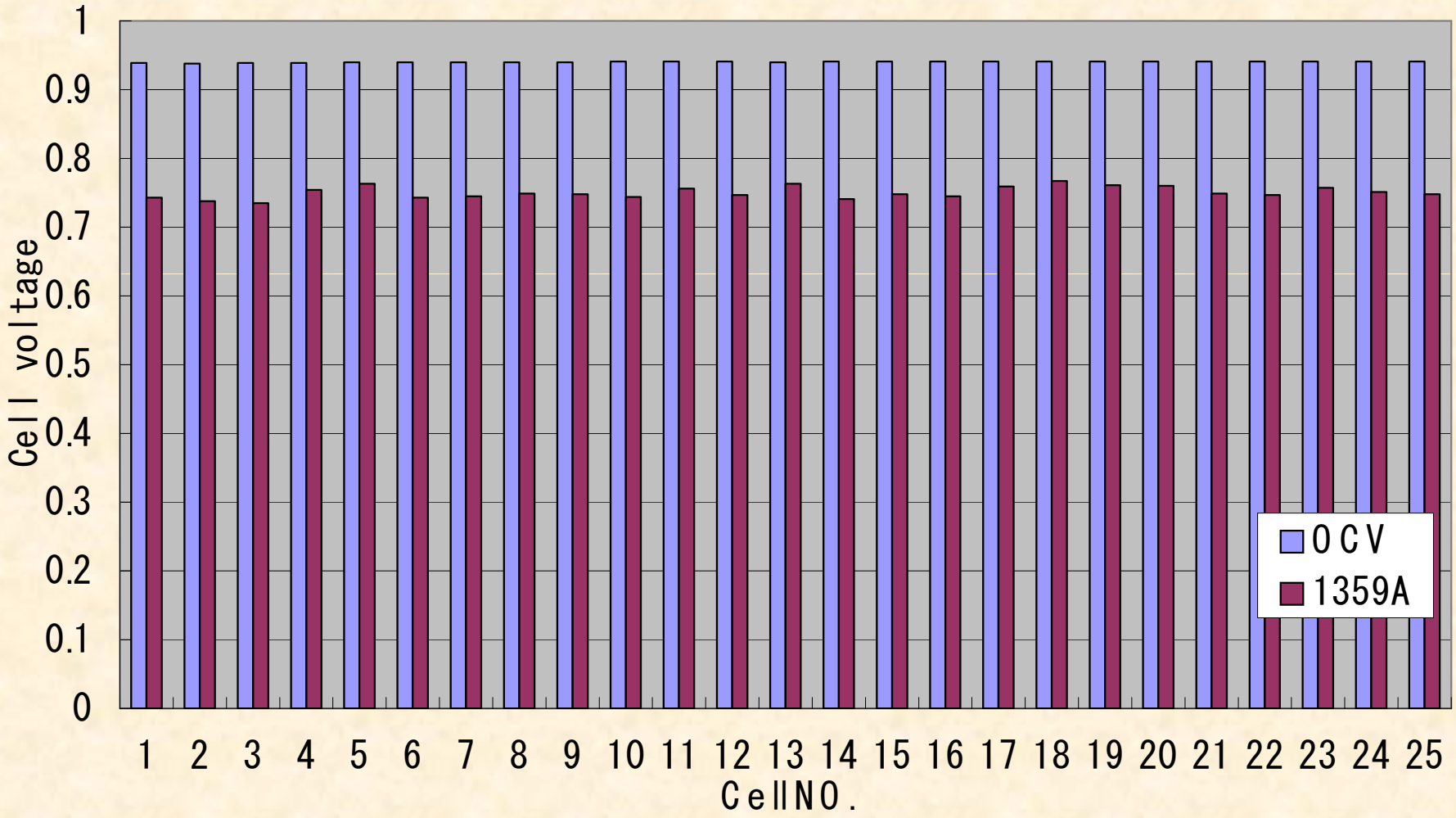
【Specification of fuel supply facility (LNG bulk system)】

	Specification
Natural gas supply amount	12 Nm^3/h
Natural gas supply pressure	0.3 MPa
LNG stockpile in container car	5.6 t
LNG stockpile in cold evaporator	1.2 t

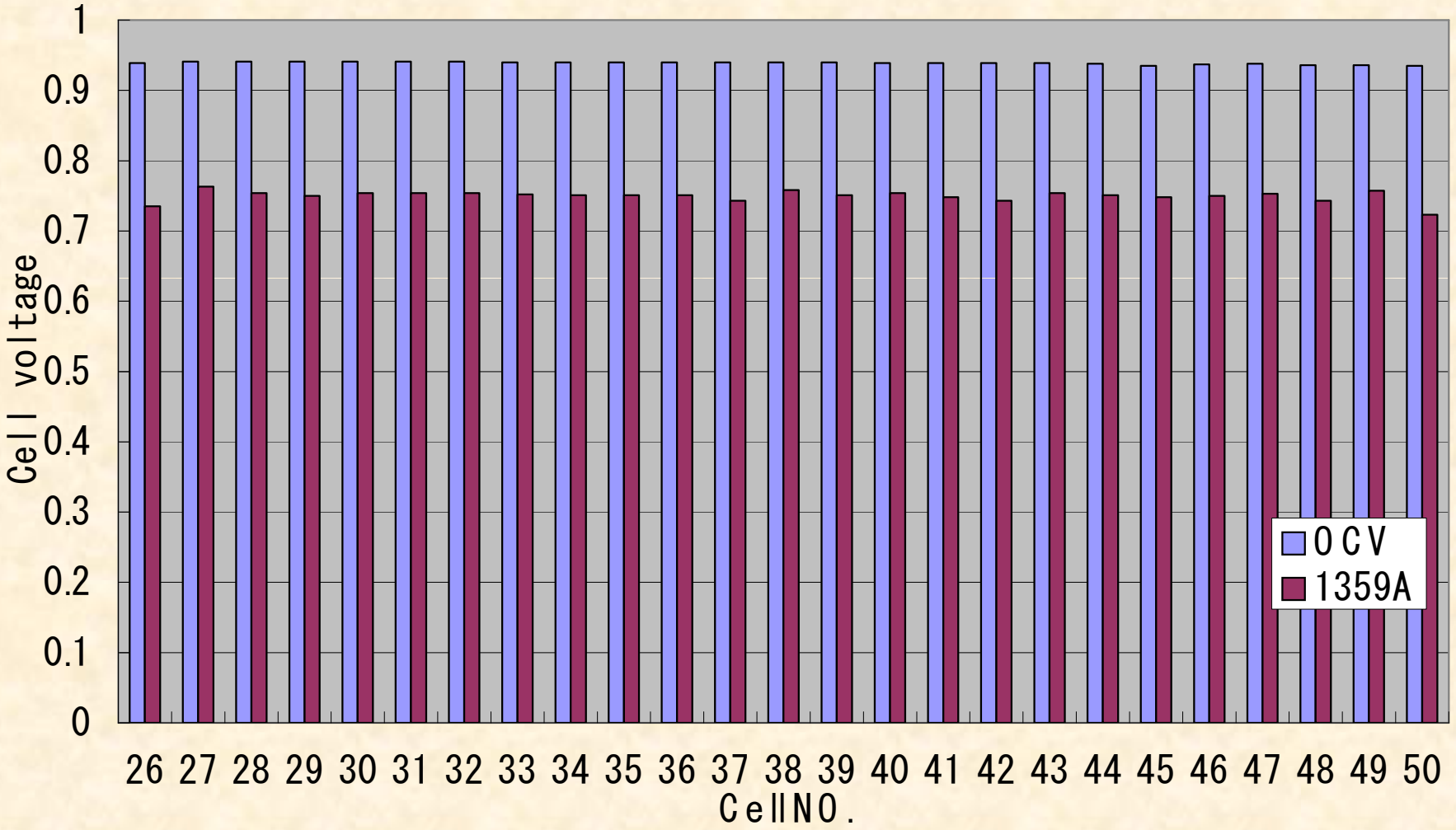
【Performance at maximum output (Not capturing CO_2)】

	Results
Output	51.0 kW (DC)
Operating pressure	72 kPa(G)
Load current	1359A
Average cell voltage	0.750 V
Maximum cell voltage	0.767 V
Minimum cell voltage	0.723 V
Fuel utilization	60.0 %
CO_2 utilization	24.2 %
O_2 utilization	19.8 %

【Cell voltage comparison（NO.1 – NO.25 cell）】

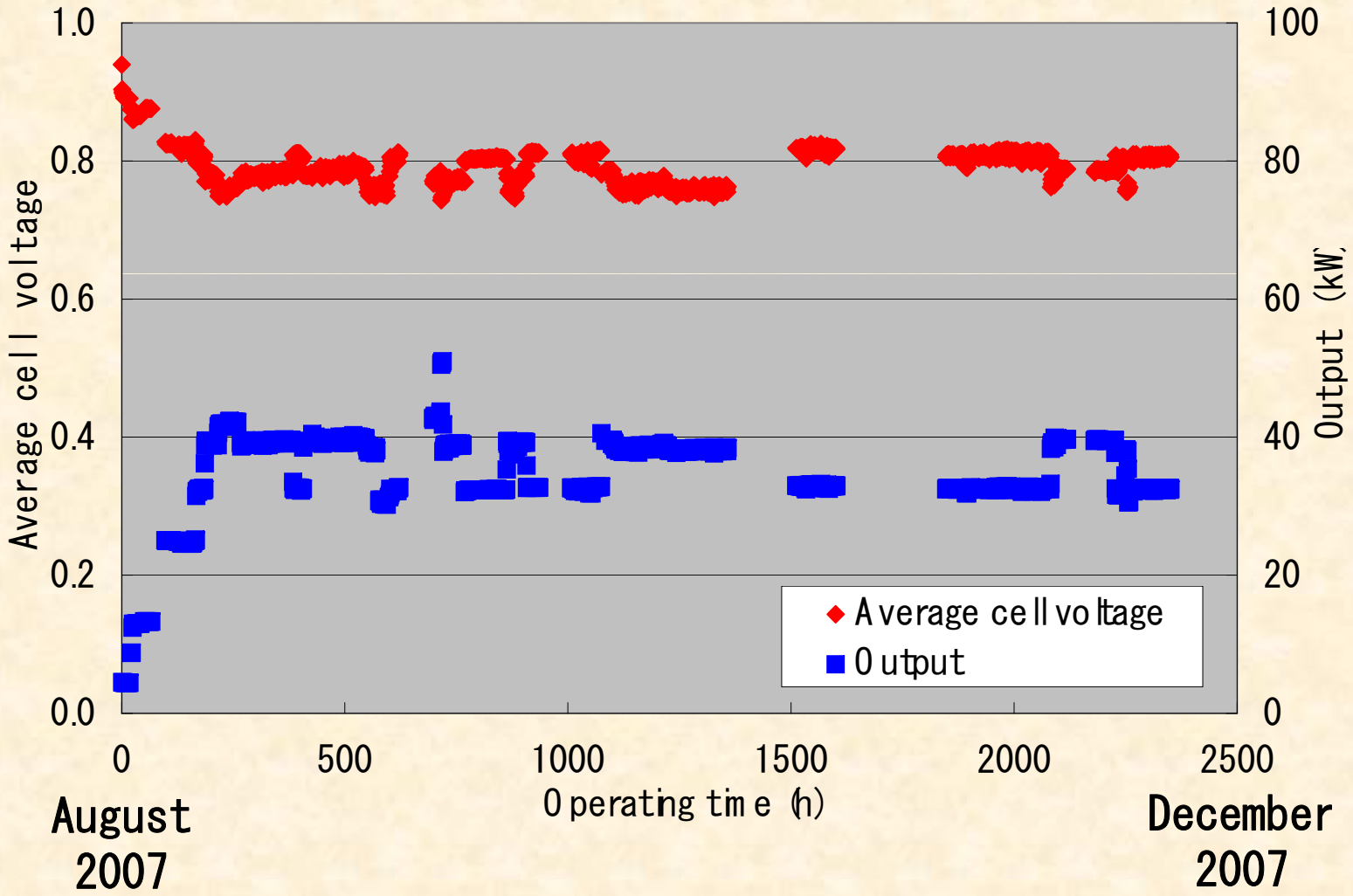


【Cell voltage comparison（NO.26 – NO.50 cell）】



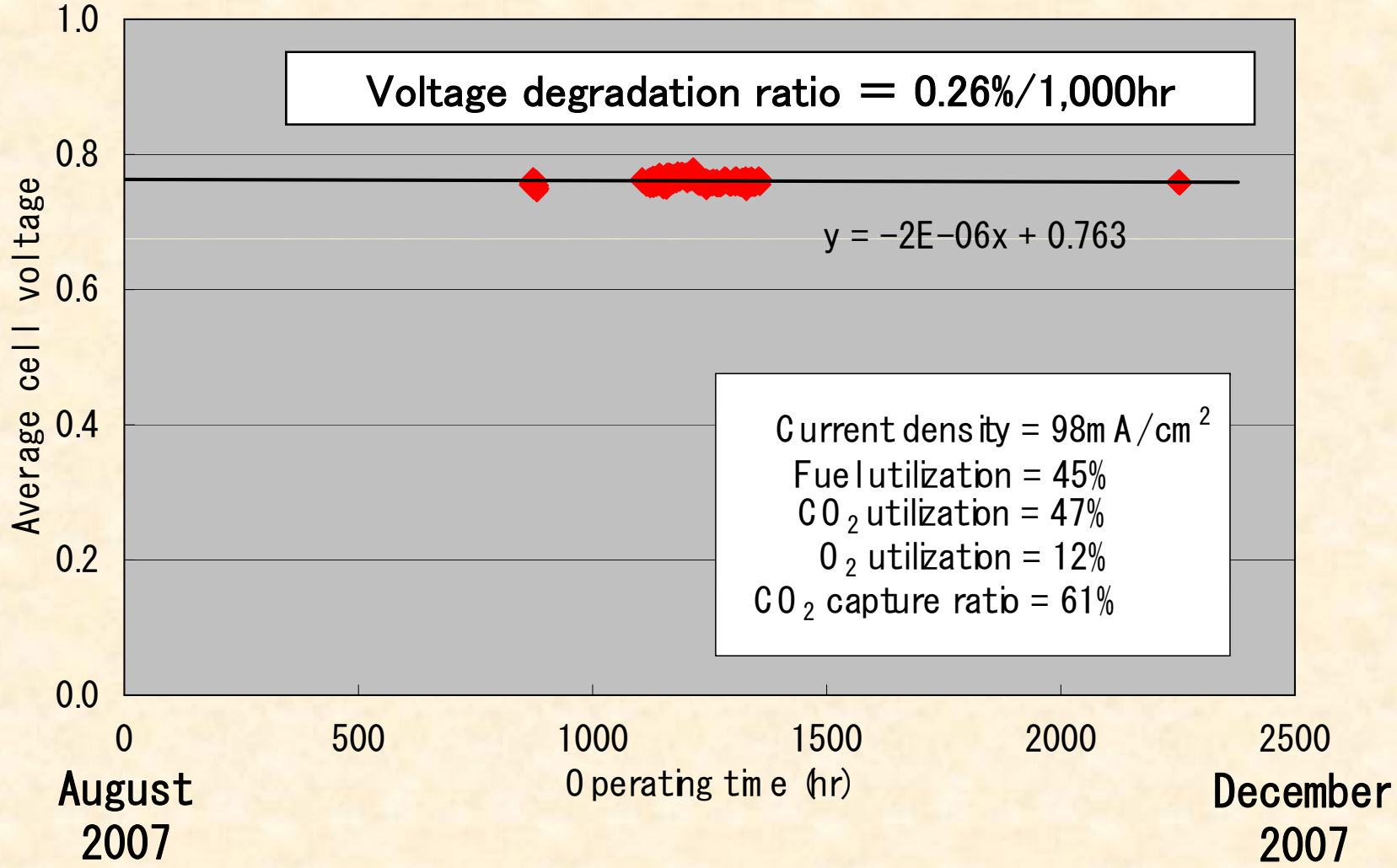
【Cell voltage and power output trends in 2007 】

Under various operating conditions to evaluate system performance

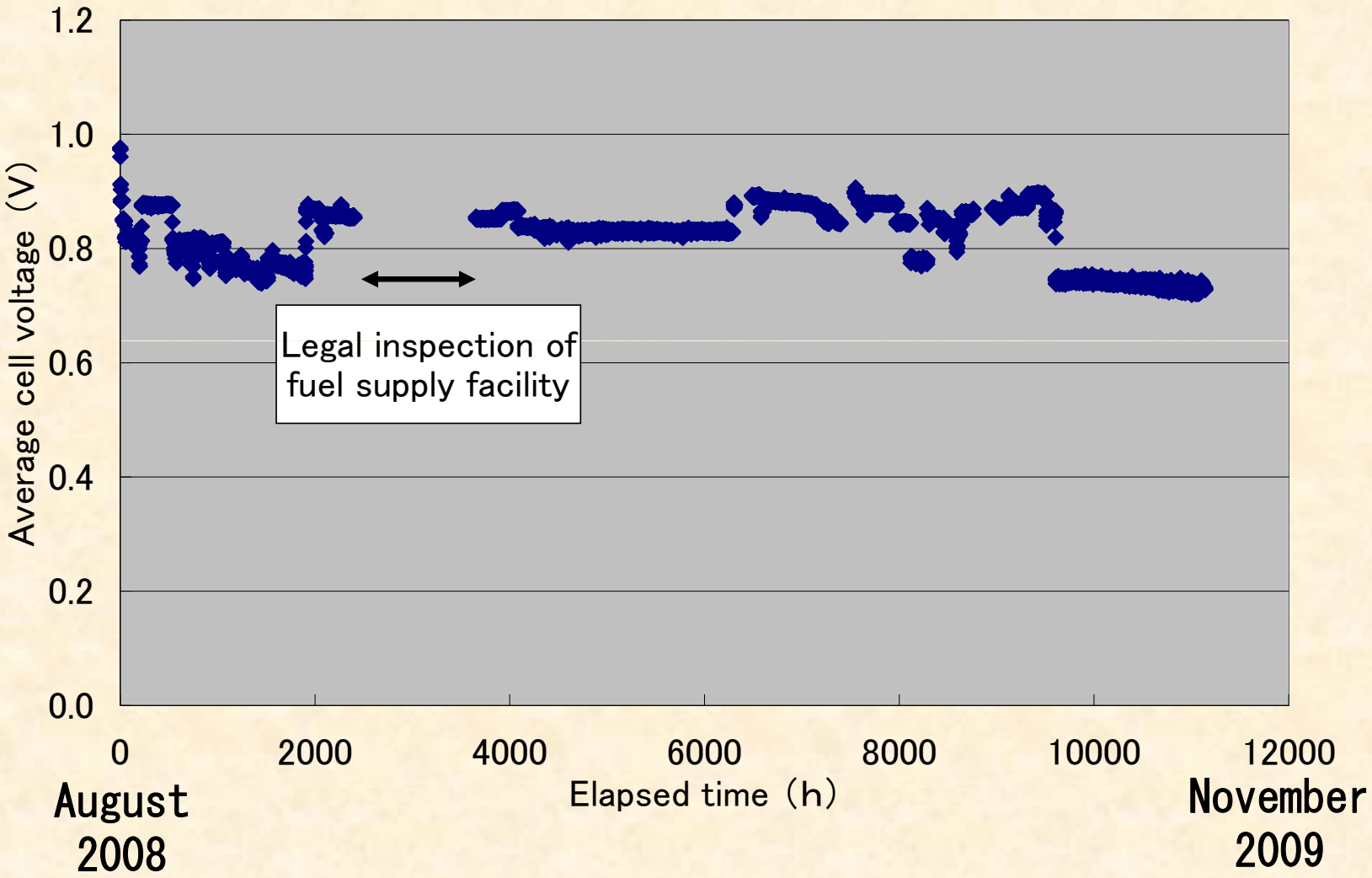


【Cell voltage trend in 2007】

Extracted data under same operating conditions to calculate voltage degradation ratio



【Cell voltage trend since 2008】



We will continue the operation until December 2009.

【Parameters to evaluate system performance】

To evaluate system performance without depending on system scale

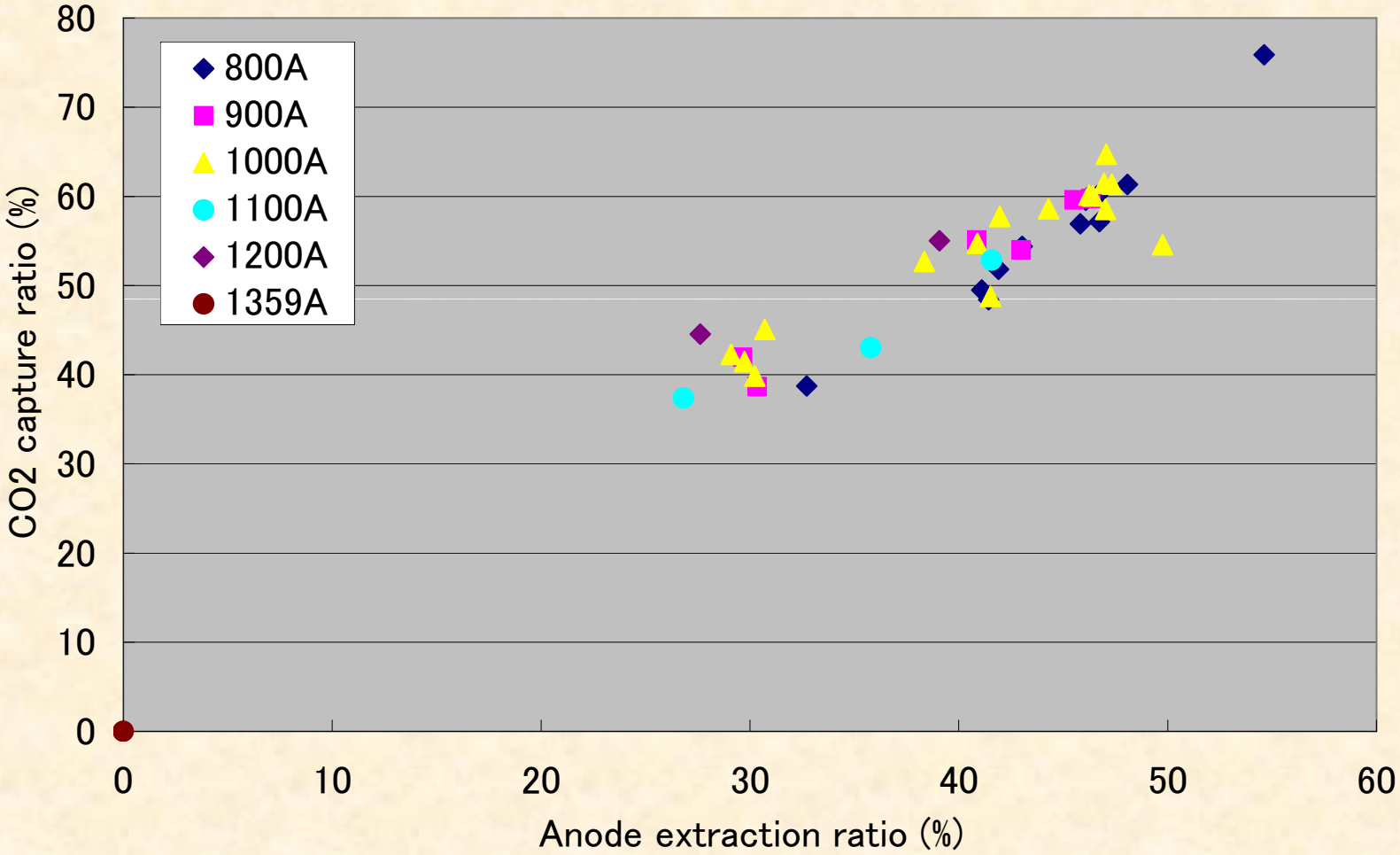
CO_2 capture ratio =

$$\frac{\text{Amount of captured } CO_2}{\text{Amount of } CO_2 \text{ in fuel gas supplied to anode inlet + Amount of } CO_2 \text{ in flue gas supplied to cathode inlet}}$$

Anode extraction ratio =

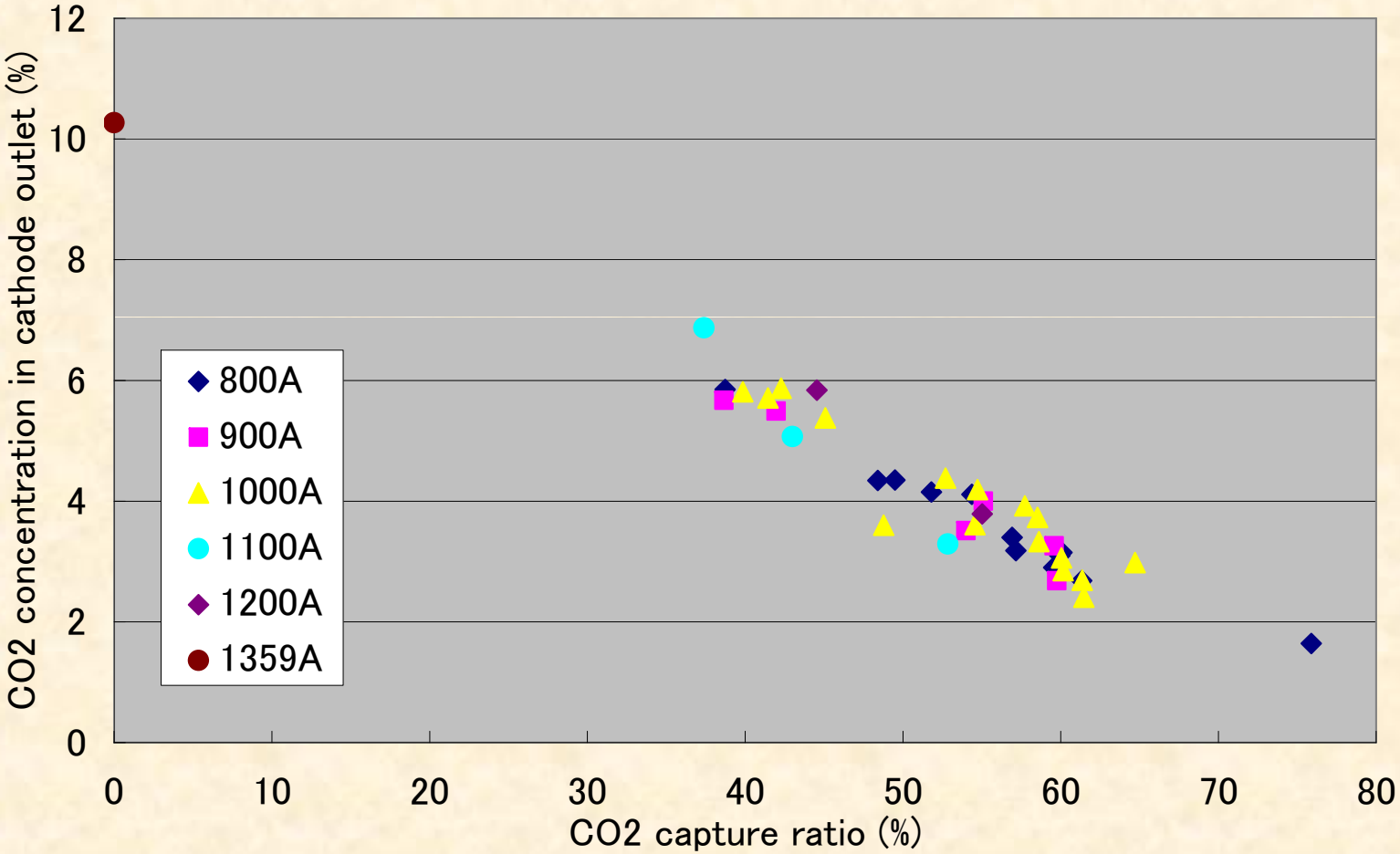
$$\frac{\text{Amount of extracted gas from anode outlet}}{\text{Total amount of anode outlet gas.}}$$

【Relation between anode extraction ratio and CO_2 capture ratio】



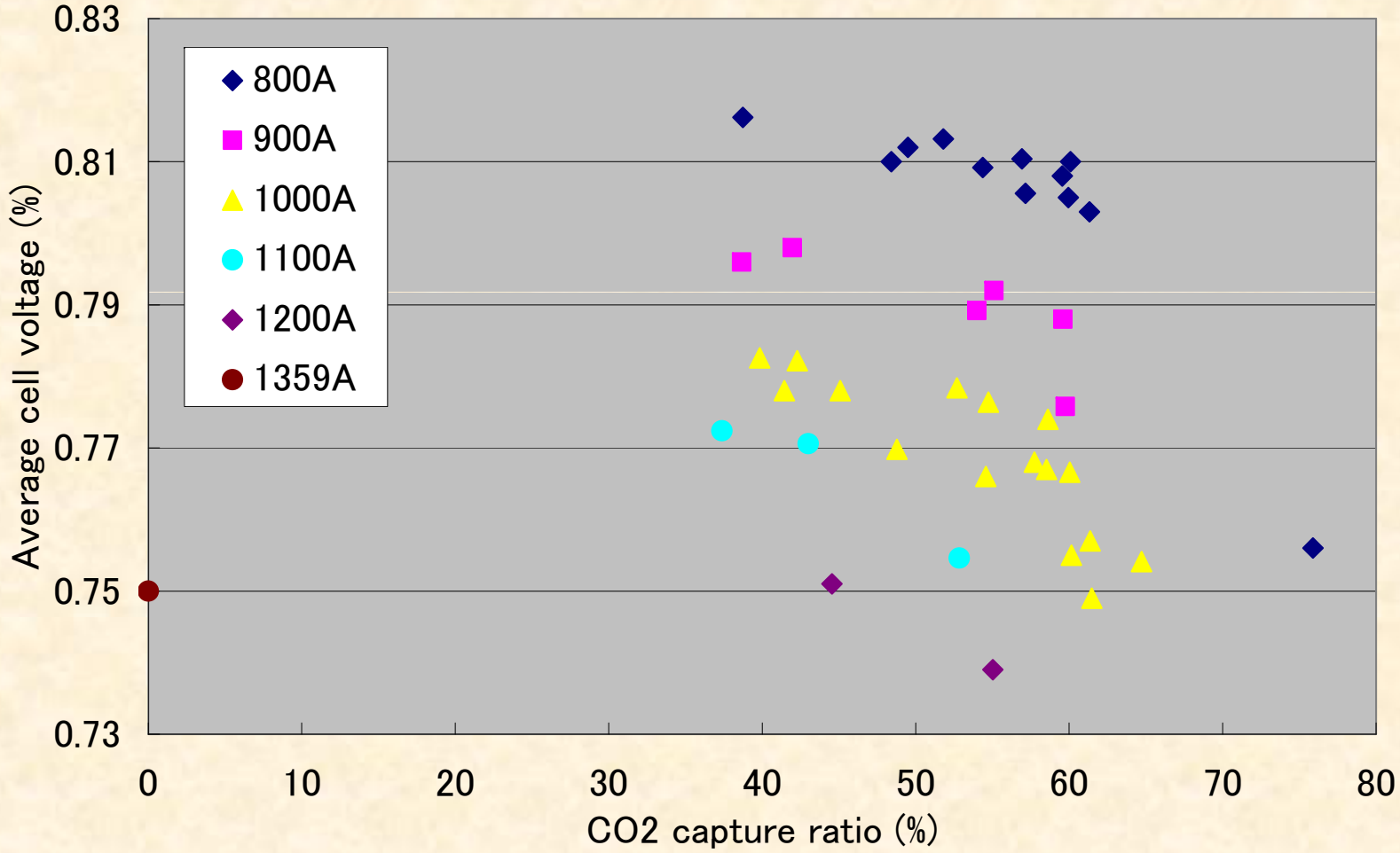
Amount of CO_2 supplied to CO_2 capture facility increases with increasing anode extraction ratio

【Relation between CO_2 capture ratio and CO_2 concentration in cathode outlet】



Amount of CO_2 returned from catalytic combustor to cathode inlet decrease with increasing CO_2 capture ratio

【 Relation between CO_2 capture ratio and cell voltage】



CO_2 concentration in cathode side decreases with increasing CO_2 capture ratio

【Conclusions】

・SOx in coal-fired flue gas can be desulfured sufficiently with wet limestone-gypsum process.

・Sufficient desulfurization allows us to use conventional materials for cathode current collector.

・CO_2 capture ratio highly depends on anode extraction ratio.

・Cell voltage and CO_2 capture ratio have a trade-off relation.

・Operation of this system, capturing CO_2 from coal-fired flue gas, can be continued for tens of thousands hours because of slight degradation of cell voltage.