International Conference on Hydrogen Safety 2015 in YOKOHAMA

HAZID for CO2-Free Hydrogen Supply Chain FEED (Front End Engineering Design)

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Kawasaki
Powering your potential

Products

Aerospace(Boeing 787)

Motorcycles

Gas turbine power generation

Transportation
Energy•Environment

Refuse incineration

Rolling stock
(Shinkansen)

Ships(LNG carrier)

Energy plant
(Coal-fired power generation plant)

Products for Hydrogen

Fertilizer Plant
(Hydrogen production)

H-II rocket fuel
hydrogen storage tank

Liquid hydrogen
storage tank

Liquid hydrogen container

High pressure hydrogen gas trailer

Contents

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Concepts of Hydrogen Energy Supply Chain

Australia

Low-cost hydrogen production from brown coal

Surplus Renewable Energy

Gasification, Refining

H_2

Liquefaction & Storage

CO_2

Brown Coal

CO_2 Capture Storage (CCS)

Clean H_2

Hydrogen Production

Liquid Hydrogen Carriers

Transport & Storage

Japan

Liquid Hydrogen Container

Liquid Hydrogen Storage Tanks

Use in processes

Semiconductor, solar cell productions
oil refining and desulfurization

Transportation equipment

Refueling station
Fuel cell vehicles

Distributed power generation

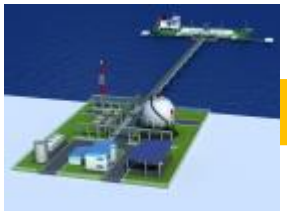
Hydrogen gas turbines and engines, fuel cells etc.

Power plants

Combined cycle power plants

Utilization

Future Scenario towards Hydrogen Society

Technical demonstration(pilot) (Domestic ship scale) 2020	Demonstration chain (Tanker scale) 2025	Commercial 1 chain 2030	20 chains 2040	40 chains 2050
				
		2 ships	40 ships	80 ships
				
		1 plant	20 plants	40 plants
				
		1 plant	20 plants	40 plants

Generation capacity	1GW	20GW	40GW
Rate in Japanese gross generation	0.5%	10%	20%
Reduction of CO_2 emission	3Mt p.a.	60Mt p.a.	120Mt p.a.

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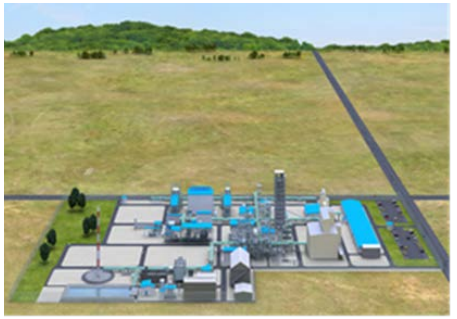
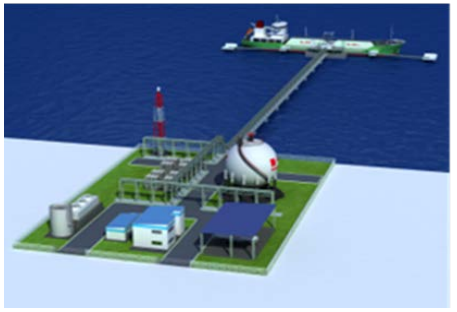
FEED(Front End Engineering Design)

Purpose of FEED:
To calculate the precise cost of facilities and operating cost

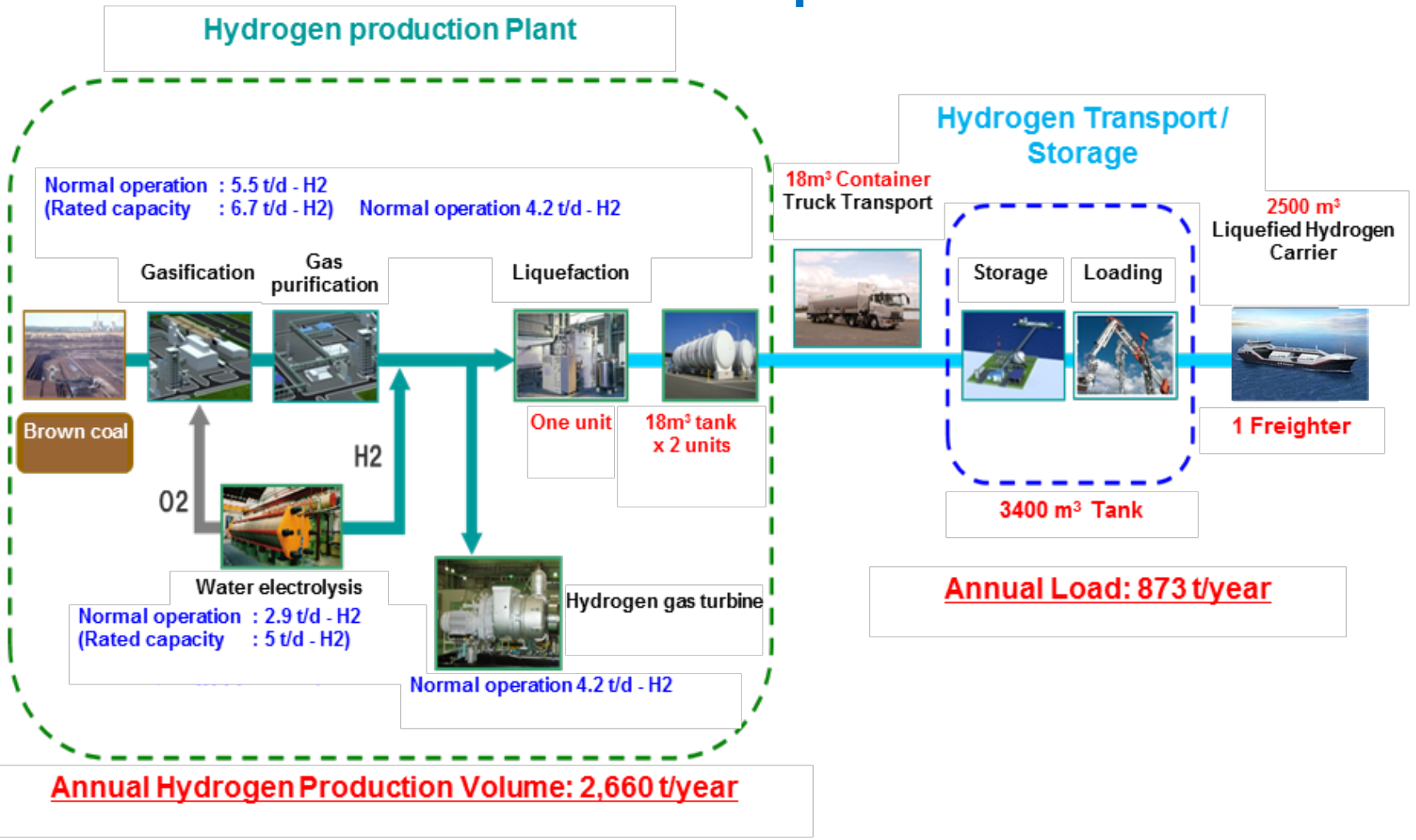
1) Determination of hydrogen producing process and plant capacity
2) Determination of postulated condition for operation
3) Determination of designing conditions(weather condition, degree of leeway, backup perception)
4) Implementation of basic design
5) Drawing of basic design documents
6) **Safety review / evaluation (HAZID)**
7) Drawing of installation specification documents
8) Calculation of vender equipment cost, installation work cost, approval / license cost, owner expenditures including insurance cost
9) Calculation of total plant cost
10) Calculation of operating cost





FEED(Front End Engineering Design)

Result of FEED: Pilot scale plant Mass Balance



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HAZID (Hazard Identification)

Purpose, Outline of HAZID

Global Standard

Risk Management

ISO(International Standard Organization for Standardization)
IEC(International Electrotechnical Commission)

PSM(Process Safety Management)

OSHA(Occupational Safety and Health Administration)

JIS(Japanese Industrial Standards) apply

Hazard Identification and Meeting

Some selected engineers from each design team

Clarify the hazards / review of countermeasurement

Updated Safety Design

Process Safety pf Plant

Process Safety of Plant is fundamentally based on PHA (Process Hazard Analysis)

Process Design based on PHA

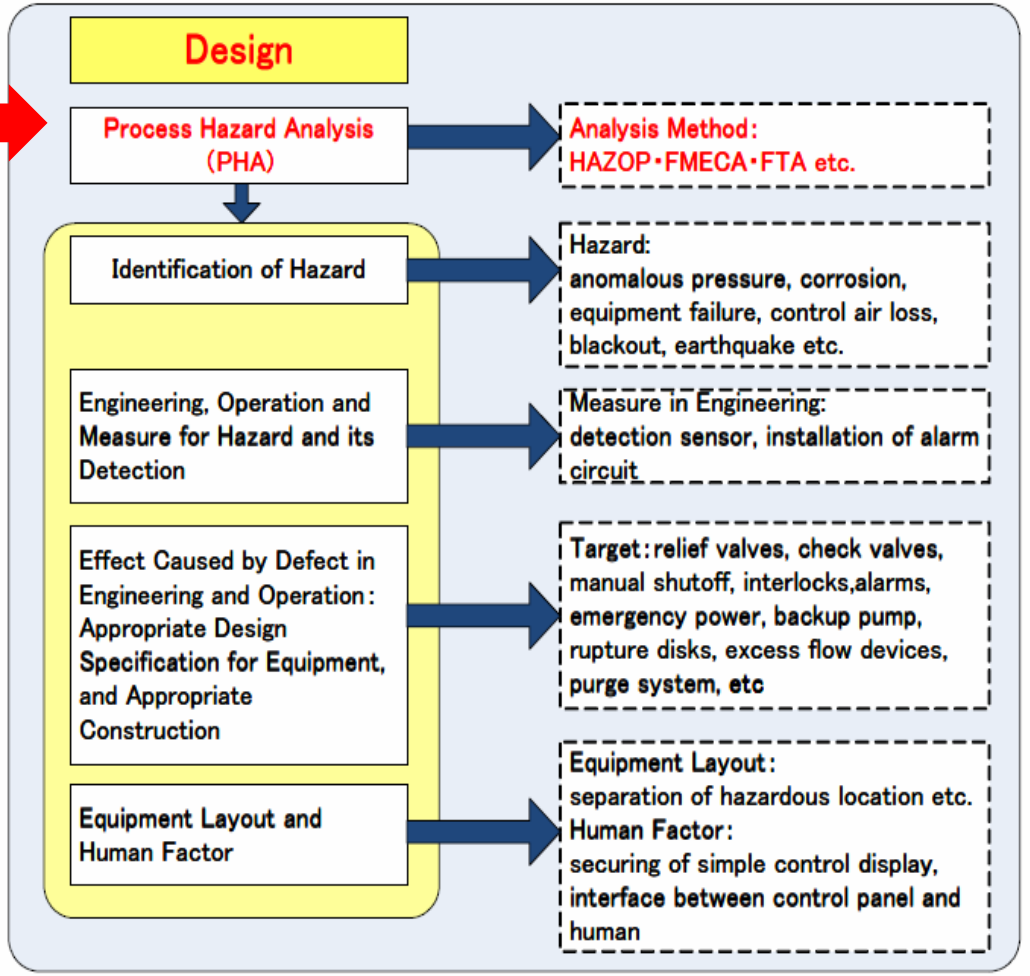
Procurement based on Process Design

Construction based on Process Design

Test and Adjustment based on PHA

Operation and Maintenance based on PHA

Safety of plant



PPHA(Preliminary Process Hazard Analysis)

Purpose of PPHA and Method

The eventual outcome is an estimation of the likely impact of the event on the system's total environment

More specific information on equipment and facilities

types of equipment, dangerous disturbances (major releases, typical control, emergency control systems)

Prepared format for documentation

PLANT NAME									Sheet No.
	Immediate Causes	Inadequate Normal Control	Process Deviation	Failure to Control (on Alarm)	Harzardous Disturbance	Inadequate Emergency Control	Dangerous Disturbance	Failure to Recover Situation	Significant Event
		IPL2: Basic process control system(BPCS)		IPL3: Critical alarm and human intervention		IPL4: Safety instrumented function (SIF, Interlocks)		IPL5, IPL6: Physical protection (Relief devices, Dikes)	
UNIT/SECTION									Date :
Node No.		EQUIPMENT/LINE No.							P & ID No.
		From	Through	Through	Through	Through	To		
Name									

Assist: Tree, Event Tree, Equipment knowledge bases, etc.

HAZID WORK and Meeting

Analysis work procedure

1) 1 or 2 persons are in charge of HAZID meeting selected 8 WG
2) Charged persons took the lead of analysis work in the group meeting and produced necessary documents and finished preparation for the plenary HAZID Meeting before 1 week at the latest
3) Those who charged from all WG joined the plenary HAZID Meeting, which was hosted by Hydrogen Project Department and held weekly essentially
4) Plenary HAZID meeting was held 2 or 3 times per each sub plant in sequence for plant design review from safety point of view
5) As for Integrated Drying and Gasification Plant, an Australian vendor company was in charge, and plenary HAZID Meeting was scheduled last and Gasification WG studied and explained instead of the company
6) All of the HAZID results are ready to be reviewed by the outside professional company to judge the conformity with the international safety standards

HAZID WORK and Meeting

Work Procedure【Prosess1】

Preparation of relevant data / information

1) PFD(Process Flow Diagram):
   Heat balance of process flow(temperature, pressure, etc.) at inlet/outlet/inner of equipment

2) P&ID(Piping & Instruments Diagram)

3) Processing details and reaction formula of process equipment

4) Operation procedure

5) Accident information on other similar plant

HAZID WORK and Meeting

Work Procedure【Prosess2】

Partition into the study nodes

1) Partition the plant into the study nodes based chiefly on functional schematics

2) Allot the node number (alphanumeric)

HAZID WORK and Meeting

Work Procedure【Prosess3】

Identification of major hazard (Latent dangerous conditions causing serious accidents)

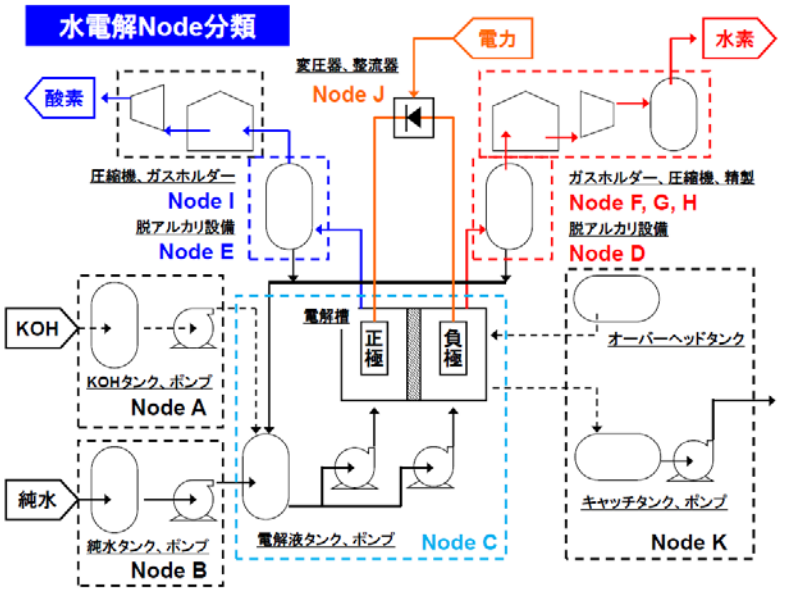
1) Define clearly the heat balance of study node at inlet, inside, outlet
2) Simulate and analyze the process behavior under control of operation in steady state in accordance with P&ID
3) Examine possible occurrence of abnormality in process, which may proceed **to significant event like as fracture of equipment, explosion, fire and discharge of toxic material**, and **to check and review the validity of existing safety measures for studying need of additional or revising action**
4) Find immediate cause for each possible abnormality
5) If generation of hazard scenario is left something to be desired according to above mentioned manner, it may help to use **HAZOP guide words**
6) Summarize these information and analysis and fill in **“Equipment knowledge base”**

HAZID WORK and Meeting

Equipment knowledge base (Example: Electrolysis Plant)

PLANT NAME	Water Electrolysis Plant	SHEET NO. F-2
Node No.	Node F: H2 Compressor Unit	P&ID No. 01D3232001
EQUIPMENT NAME	C-3201A/B: H2 Compressor	

DESIGN INTENT	UNDESIRED EVENTS AND THEIR CAUSES
The role of H2 compressor unit is 1. To compress H2 gas to 2.3MPaG.	*Abnormal H2 gas discharged* ***pressure*** 〈Cause〉 ・post-process failure ・Compressor malfunction ・Instrument failure ・32-PV-1201 failure 〈Consequences〉 ・If the pressure becomes high, safety valve is operated. ・If the pressure becomes low , the amount of H2 gas to be used in the next step is insufficient or H2 gas flow back from the next step *Abnormal cooling water flow rate* 〈Cause〉 ・Instrument failure ・Cooling water system down ・Manual valve misoperation 〈Consequences〉 ・The compressor is failed due to overheating. *Abnormal H2 gas discharged temperature* 〈Cause〉 ・Instrument failure ・Cooling water system down ・Burning in the cylinder 〈Consequences〉 ・If the temperature is high impure H2 gas is supplied to the Liquefaction plant ・Compressor or other equipment are broken.
TYPE OF UNIT ・Reciprocating	
ANCILLARY EQUIPMENT ・Bypass valve (32-PV-1201A/B) ・Pressure indicator (32-PT-1201) ・Temperature indicator/Flow rate indicator/ Safety valve	
NORMAL CONTROL ・Discharged pressure is controlled by returning a part of the compressed gas through the bypass valve. ・Discharged temperature is controlled by cooling water. [Alarm] ・H2 gas discharged pressure (32-PT-1201)/H,L ・Cooling water flow rate (32-FICA-****) /L ・H2 gas discharged temperature (32-TICA-****)/H	
EMERGENCY CONTROL ・If H2 gas discharged temperature become HH, ・If H2 gas discharged pressure become HH,	

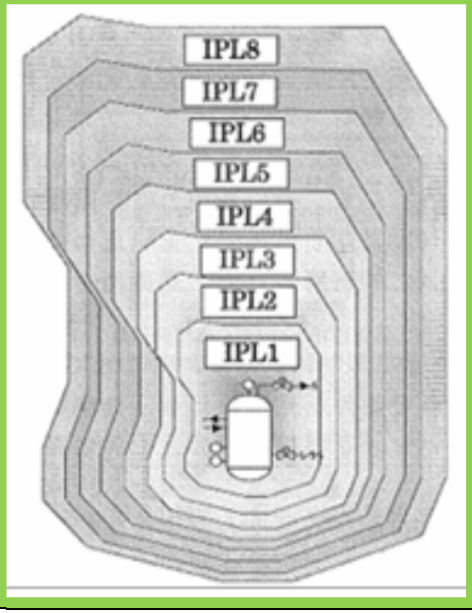


HAZID WORK and Meeting

Work Procedure【Prosess4】

IPL (Independent protection layer) model in plant

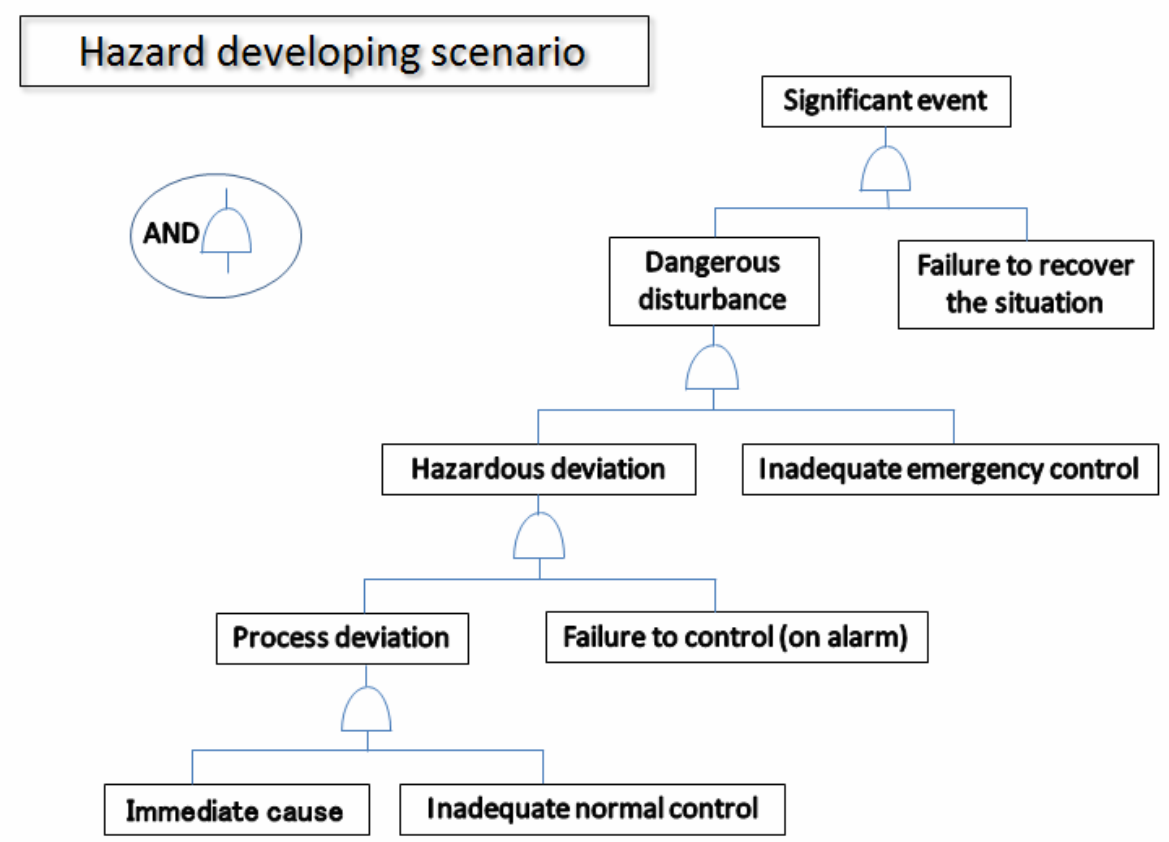
(1) Abnormality prevention	(IPL1,2)
(2) Abnormarity detection	(IPL3)
(3) Hazard prevention	(IPL4,5)
(4) Damage confinement	(IPL6,7,8)



IPL8	Community emergency response
IPL7	Plant emergency response
IPL6	Post-release physical protection (Dikes)
IPL5	Physical protection (Relief devices)
IPL4	Safety instrumented function (SIF, Interlocks)
IPL3	Critical alarm and human intervention
IPL2	Basic process control system (BPCS)
IPL1	Process design (Inherent safety)

HAZID WORK and Meeting

Work Procedure【Prosess4】



HAZID WORK and Meeting

Work Procedure 【Prosess4】

Sub Node	Immediate Causes	Inadequate Normal Control 〔IPL2〕	Process Deviation	Failure to Control (on Alarm) 〔IPL3〕	Hazardous Disturbance 【HAZARD】	Inadequate Emergency Control 〔IPL4〕	Dangerous Disturbance	Failure to Recover Situation 〔IPL5,6〕	Significant Event
F-1	Forget to remove drainage on V-3201 inlet piping	Failure of 31-PT-1101 (Pressure of hydrogen piping) failure of visual confirmation	Pressure in the upstream pipe rises.	Misoperation of drain valve	Pressure in the upstream pipe rises.	Failure of 31-PT-1101 INT system (Pressure of hydrogen piping)	Change in pressure balance at electrolyzer. Hydrogen and oxygen are mixed.		Deterioration or damage of membrane →Hydrogen and oxygen are mixed. →Ignition and explosion
F-3	32-PV-1201 is fully opened due to a failure	Failure of 31-PT-1101 (Pressure of hydrogen piping) Failure of 32-LT-1201 (Amount of displacement of V-3201) failure of visual confirmation	Pressure rise on the low pressure side	Does not stop the compressor. (Failure of response to malfunction)	V-3201roof is risen	Failure of 31-PT-1101 INT system (Pressure of hydrogen piping) Failure of 32-LT -1201 INT system (Amount of displacement of V-3201)	①Change in pressure balance at electrolyzer ②V-3201 roof is moved to the top.	Failure of safety valve at V-3201	①Deterioration or damage of membranes →Hydrogen and oxygen are mixed. →Ignition and explosion ②Damage of V-3201 and Hydrogen leaks
F-4		Failure of 31-PT-1101 (Pressure of hydrogen piping) Failure of 32-LT-1201 (Amount of displacement of V-3201) failure of visual confirmation	Pressure drop on the high pressure side		Pressure drop on the high pressure side	Failure of 31-PT-1201 INT system (Pressure of hydrogen piping) Failure of 32-FT -**** INT system (Flow rate of hydrogen)	Pressure drop on the high pressure side	Installa-tion of the check valve	
…	…	…	…	…	…	…	…	…	…

HAZID WORK and Meeting

Work Procedure【Prosess4】

PLANT NAME		Water Electrolysis Plant			Sheet No. 3-1
Node No.					Date:
#	DANGEROUS DISTURBANCE	CAUSES	EXISTING SAFETY MEASURES	RECOMMENDATIONS, COMMENTS, ACTIONS	CORRRELATION TO SCENARIO
1	Electrolyte leaks and injury by alkaline	Misoperation and failure of equipment	・Liquid surface and flow rate monitoring, ・Installation of dike, Emergency shower and eyewash, ・Connect to tank outlet and gutter	・Work rules creation ・Wearing protective equipment such as safety glasses, gloves ・Installation of rainwater drain valve and pH meter	A-1 C-1,2,5,6
2	Low pressure hydrogen leaks	Misoperation and failure of gasholder (V-3201)	・Pressure safety valve ・Pressure and amount of displacement monitoring of gas holder (V-3201)	Vacuum safety valve	F-2,3,5
3	High pressure hydrogen leaks	・Failure of equipment ・Damage of piping or eqipment	・Margin of piping Class ・Pressure safety valve ・Temperature monitoring at compressor cylinder outlet	Oxygen concentration measurement in hydrogen	F-7,8
4	Deterioration or damage of membrane	・Pressure change in the electrolyzer ・Flow of the high temperature electrolyte solution ・Impurity deposition on the electrode	・Pressure monitoring ・Temperature monitoring	Purity monitoring of demineralized water	C-1,4,5,6,7 D-1,2,3,4 E-1,2,3,4 F-1,3,5 G-1 I-1,3,5
5	…	…	…	…	…

HAZID WORK and Meeting

Hydrogen Safety Evaluation Test

HAZID WORK and Meeting

HAZID Meeting Practice

nth	Day held	Work group name	Attendant	hour	Man-time	Place
1	2013/9/24	Water electrolysis	16	3.5	56	Akashi103
2	2013/10/1	Water electrolysis, Hydrogen Liquefaction	13	3.5	45.5	Kobe1201
3	2013/10/8	Hydrogen Liquefaction	11	3.5	38.5	Akashi107
4	2013/10/15	Hydrogen Liquefaction	11	4	44	Akashi107
5	2013/10/22	Hydrogen Liquefaction	14	4	56	Akashi107
6	2013/10/29	Truck and loading station	14	4	56	Akashi107
7	2013/11/5	Hydrogen Liquefaction, BOP	11	4	44	Akashi107
8	2013/11/12	BOP, Truck & loading station	12	4	48	Akashi107
9	2013/11/19	BOP	10	4.5	45	Akashi107
10	2013/11/26	BOP	12	4.5	54	Akashi107
11	2013/12/3	Truck & loading station, Gas Refining	11	4	44	Akashi107
12	2013/12/10	Gas Refining	12	4	48	Akashi107
13	2013/12/17	Gas Refining	7	4.5	31.5	Akashi107
14	2013/12/24	Gas Refining	11	3.5	38.5	Akashi107
15	2014/1/7	Gas Refining	8	3.5	28	Akashi107
16	2014/1/14	Hydrogen Gas turbine	10	3.5	35	Akashi107
17	2014/1/21	Hydrogen Gas turbine	11	3.5	38.5	Akashi107
18	2014/2/4	Gasification	9	3	27	Akashi107
19	2014/3/27	Entire Plant	14	3.5	49	Akashi107

HAZID WORK and Meeting

HAZID Documentation

WG Name	Commentary on PID, Node, etc.	HAZID_Work_Sheet	Minute	Other data
Water electrolysis	Done	(Japanese, English)	With drawing No.	PFD, Material balance, arrangement plan
Hydrogen Liquefaction	Done	(Japanese, English)	With drawing No.	PFD, arrangement plan
Truck & loading station	Done	(Japanese, English)	With drawing No.	
BOP	Done	(Japanese, English)	With drawing No.	PFD, arrangement plan
Gas Refining	Done	(Japanese, English)	With drawing No.	PFD, arrangement plan
Hydrogen Gas Turbine	Done	(Japanese, English)	With drawing No.	PFD, arrangement plan, timing chart
Gasification	Vender Scope	Vender Scope	With drawing No.	Process flow

Contents

Conclusion

We explained

1)FEED for the pilot chain for which we are pursuing demonstration as a step of development toward the realization of CO2-Free Hydrogen Supply Chain

2)The procedures and outcomes of the safety assessment (HAZID) performed as a process of safety design

We will advance our project for superior safety measures compatible with international safety standards conforming to each phase of basic design, detailed design, plant construction, operation, and maintenance.

KAWASAKI realize
"CO2 free Hydrogen Supply Chain"

Thank you for your attention

Create new value-for a better environment and a brighter future for generations to come

“Global Kawasaki”

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