






THE HYDROGEN DETECTION TECHNIQUE FOR SG PROTECTION SYSTEM

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Content

-  1 Background
-  2 Engineering Implementation
-  3 Calibration Test
-  4 Time Response Characteristics
-  5 Conclusion

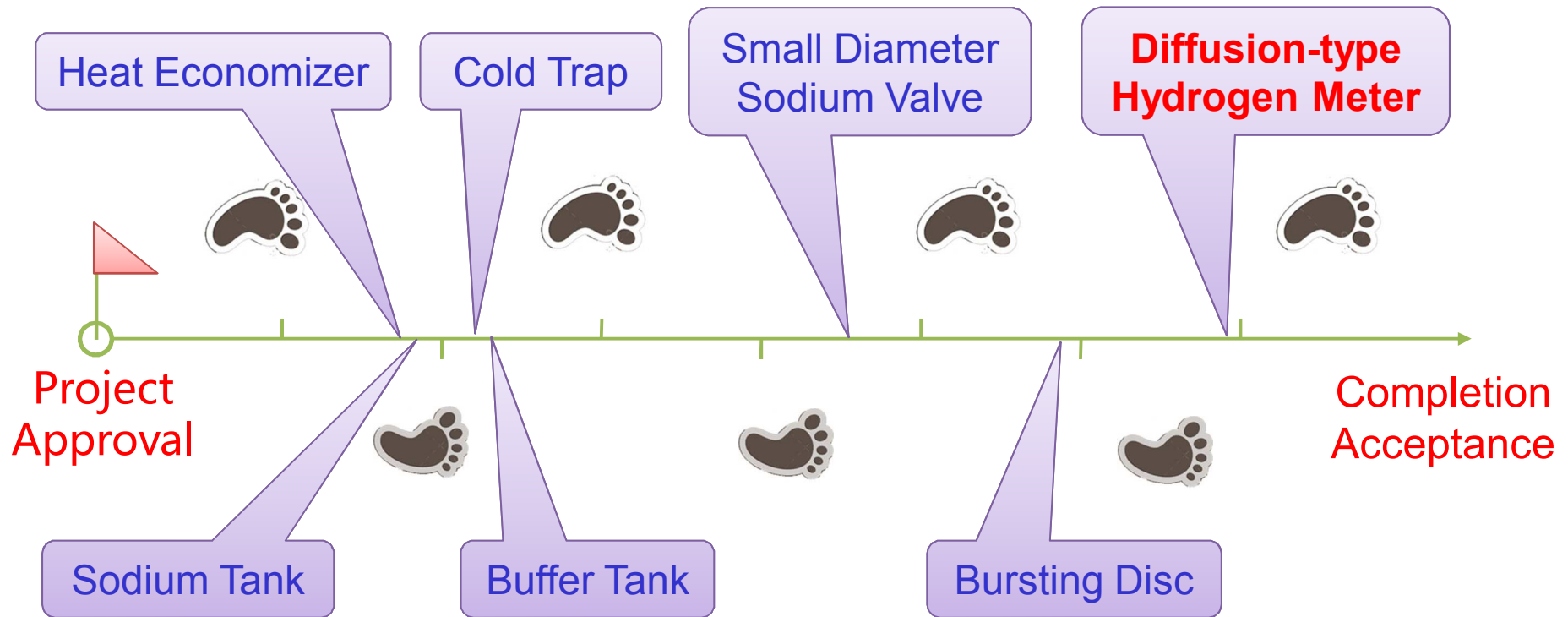
»» Background

- ✓ In Dec 1995, CEFR Project was Formally Established
- ✓ In 1997, Primary Design Completion
- ✓ In May 2000, First Concrete Date
- ✓ In Aug 2002, Main Power House Capping
- ✓ In Dec 2008, Installation Completion
- ✓ In Sep 2009, A Stage Commissioning Completion
- ✓ In Jul 2010, First Criticality
- ✓ In Dec 2010, B Stage Commissioning Completion
- ✓ In Jul 2011, Grid-Connection Power Generation
- ✓ In Nov 2012, Completion Acceptance



Background

Equipment Domestication Rate of CEFR is Reaching 70%

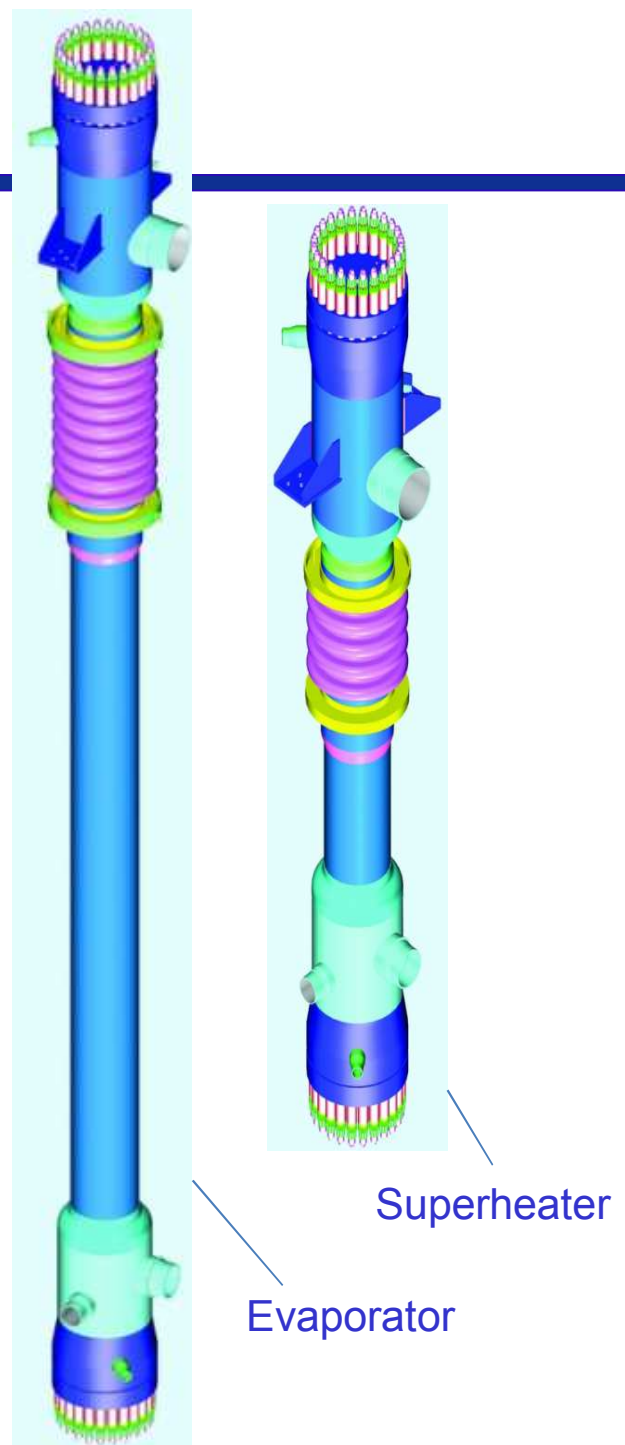
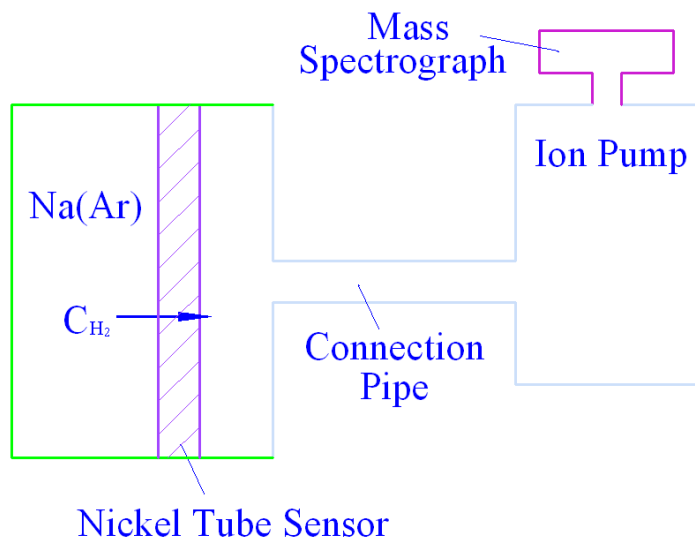


Background

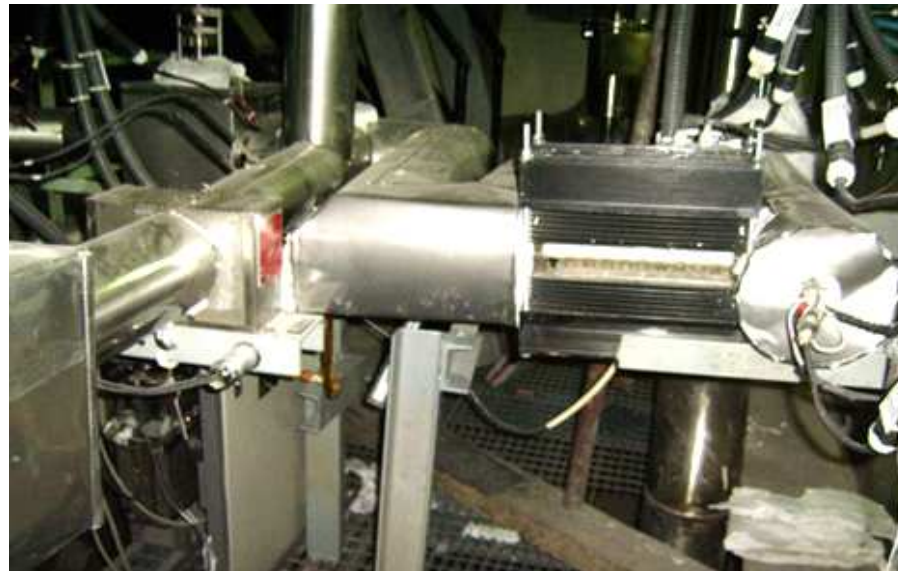
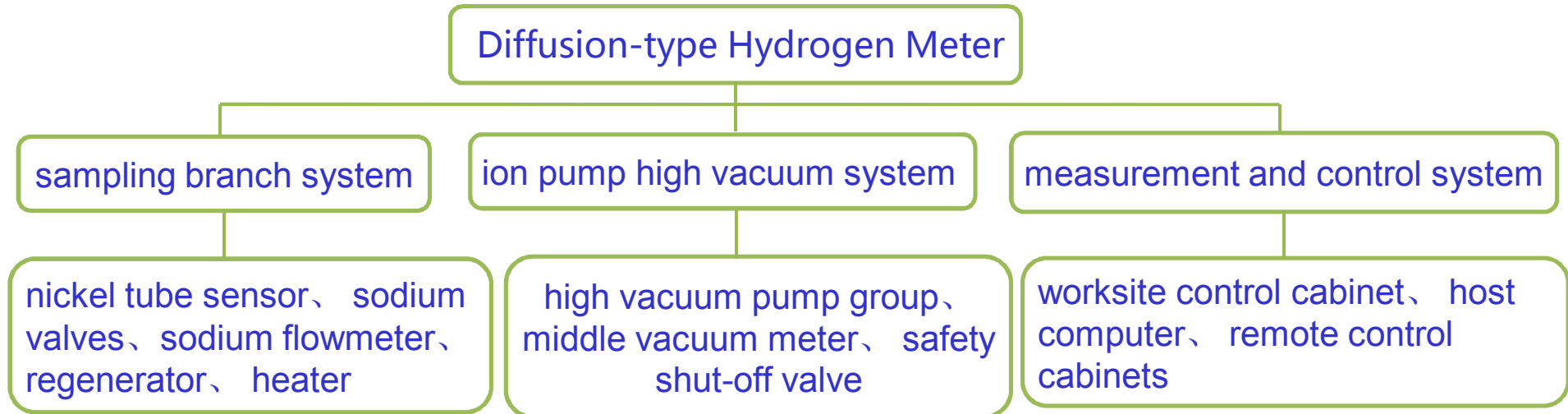
Sodium-Water
Reaction:



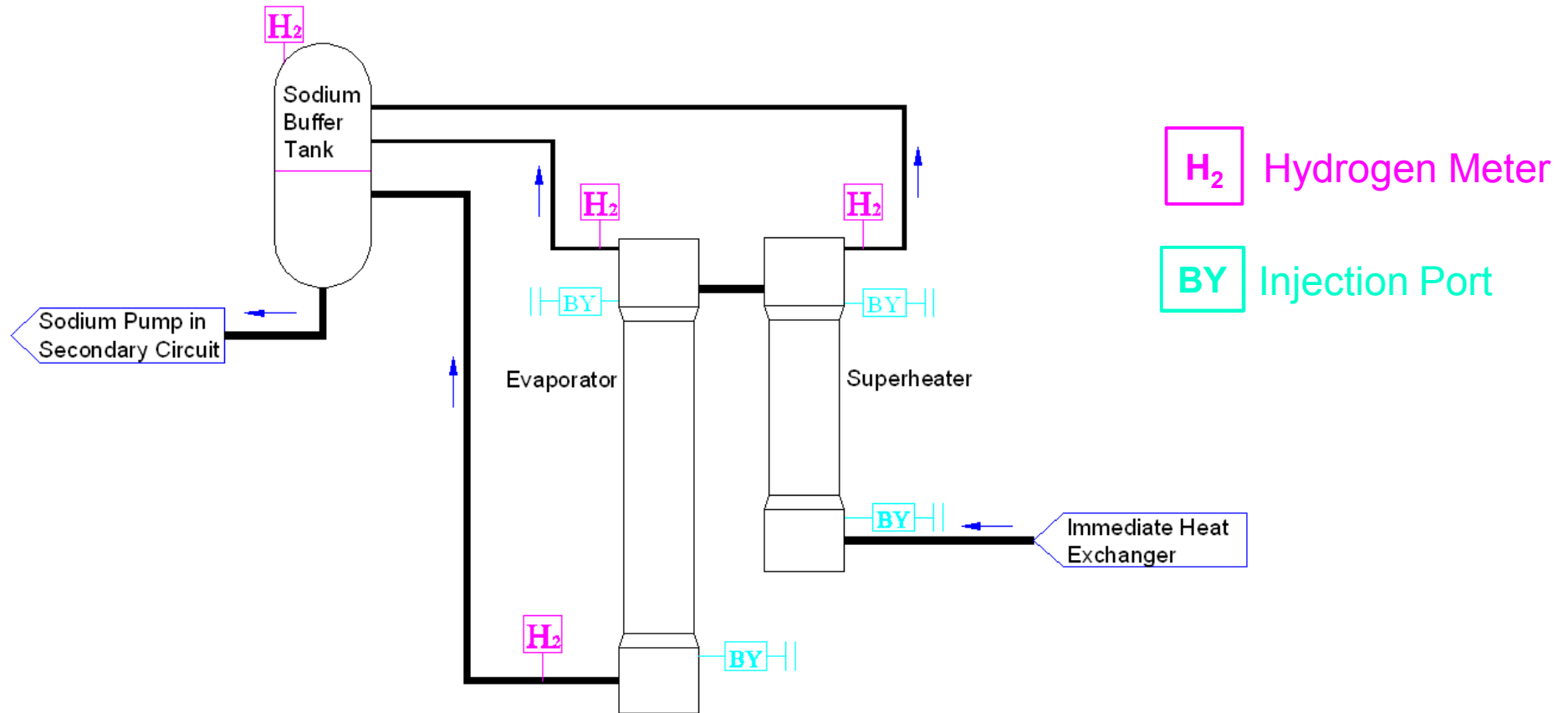
Detection
Principle:



Engineering Implementation



Engineering Implementation



Schematic Diagram for Single Loop Hydrogen Meter Layout

Engineering Implementation

Sequence Number and Installation Position of Hydrogen Meter

Sequence number	Number of hydrogen meter	Installation position of hydrogen meter	Type of hydrogen meter
1	No.1 hydrogen meter	Evaporator port in I loop	Large hydrogen meter (sodium)
2	No.2 hydrogen meter	Evaporator port in II loop	Large hydrogen meter (sodium)
3	No.3 hydrogen meter	Overflow pipe of evaporator in I loop	Small hydrogen meter (sodium)
4	No.4 hydrogen meter	Overflow pipe of evaporator in II loop	Small hydrogen meter (sodium)
5	No.5 hydrogen meter	Overflow pipe of superheater in I loop	Small hydrogen meter (sodium)
6	No.6 hydrogen meter	Overflow pipe of superheater in II loop	Small hydrogen meter (sodium)
7	No.7 hydrogen meter	Top of buffer tank in I loop	Small hydrogen meter (argon)
8	No.8 hydrogen meter	Top of buffer tank in II loop	Small hydrogen meter (argon)

»» Calibration Test

Description of Calibration Test

- ✓ Sweep injection hydrogen pipe with argon and keep argon flow
- ✓ Open ball valve in inlet of injection hydrogen capillary to inject hydrogen
- ✓ Stop injection hydrogen until accumulative flow reaching
- ✓ Sweep injection hydrogen pipe with high-purity argon to make rudimental hydrogen in pipe enter into SG
- ✓ Record output of hydrogen meter as soon as ball valve is open, until 60min later

 Bottom of Superheater(twice)

 Top of Evaporator(once)

 Bottom of Evaporator(once)

(Sodium Temperature at 300~310°C, Speed of Sodium Pump at 950r/min)

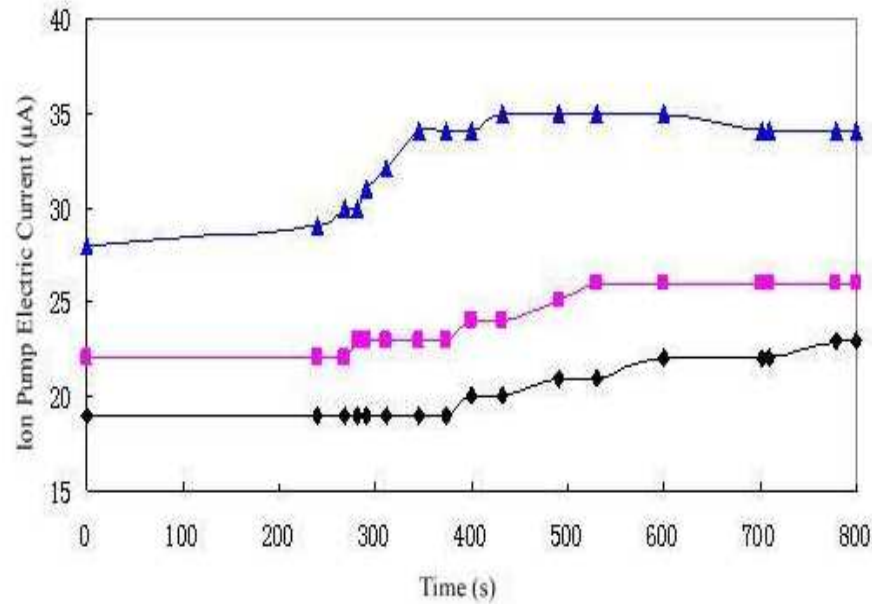
» Calibration Test

Response of Hydrogen Meters in I Loop During Injection Hydrogen Test

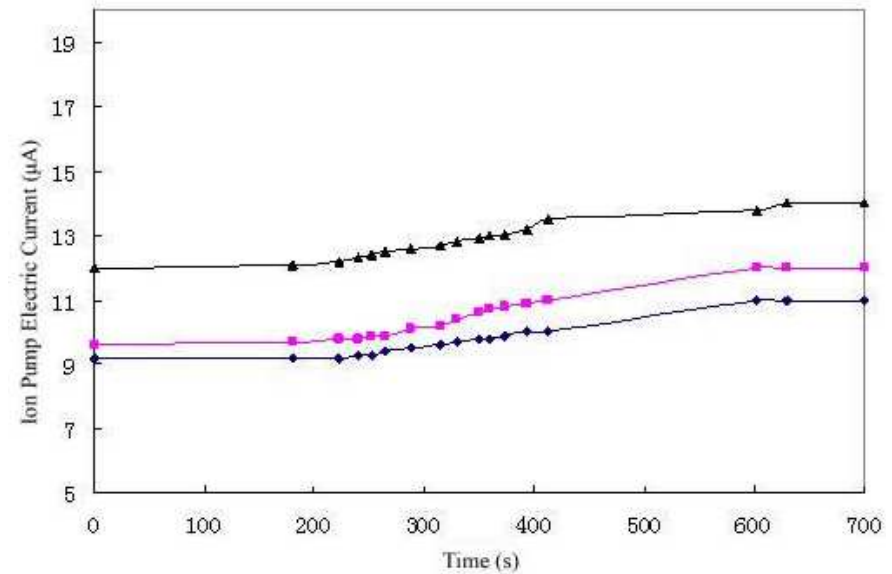
Sequence number of injection hydrogen test		1		2		3		4
Test stage		before	after	before	after	before	after	after
Injection time / (s)		---	420	---	420	---	480	450
Injection volume / (l)		---	3	---	3	---	3	3
Accumulative volume / (l)		---	3	---	3	---	6	9
Hydrogen concentration in sodium / ($\mu\text{g/g}$)		0.0375	0.0475	0.045	0.052	0.052	0.055	0.085
Ion pump electric current / (μA)	No.1 hydrogen meter	19	23	22	26	26	28	35
	No.5 hydrogen meter	9.2	11	9.6	12	11	12	14
	No.7 hydrogen meter	64	98	40	79	73	92	190

Calibration Test

Response Curve of Hydrogen Meter



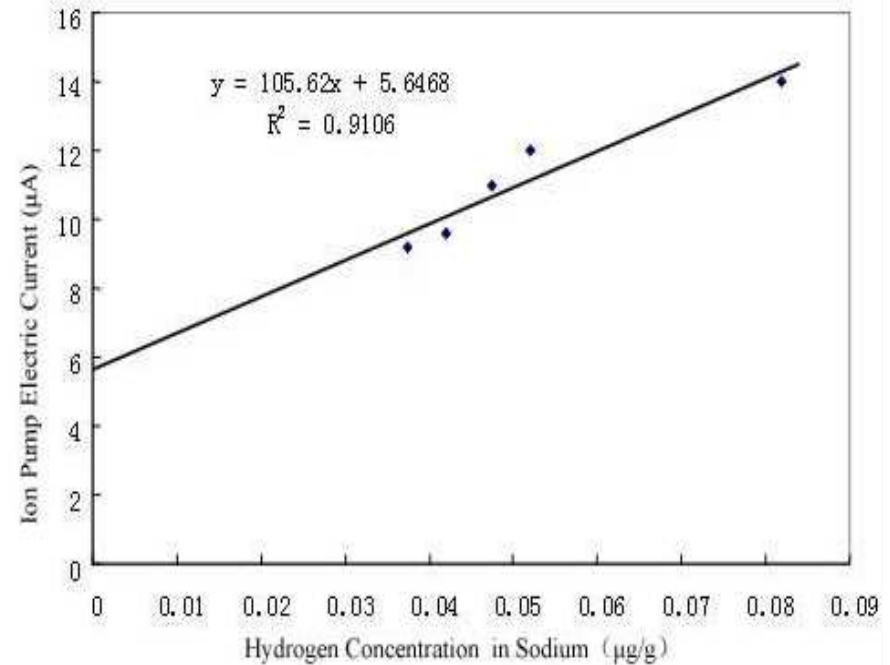
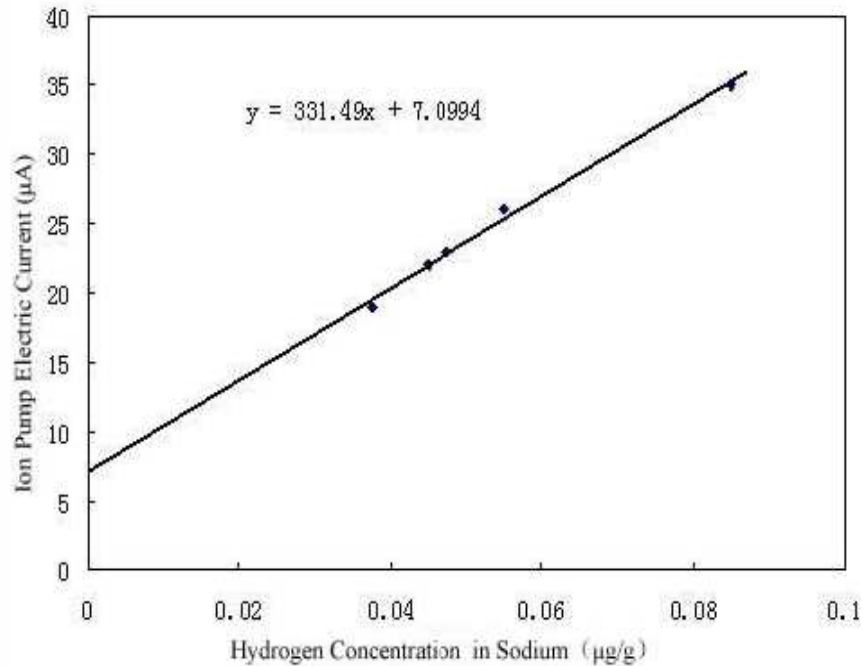
Response Process of No.1 Hydrogen Meter



Response Process of No.5 Hydrogen Meter

Calibration Test

Calibration Curve



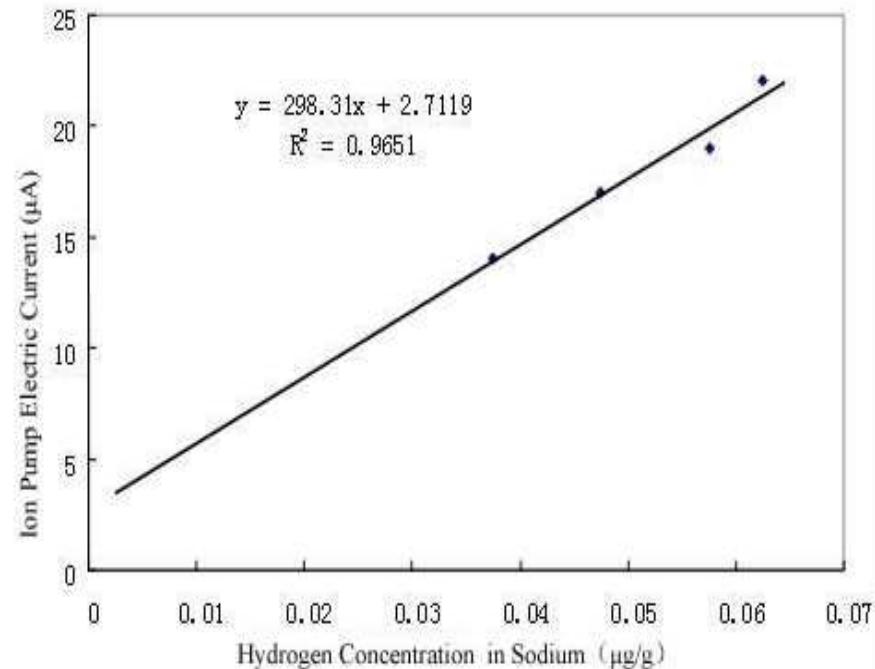
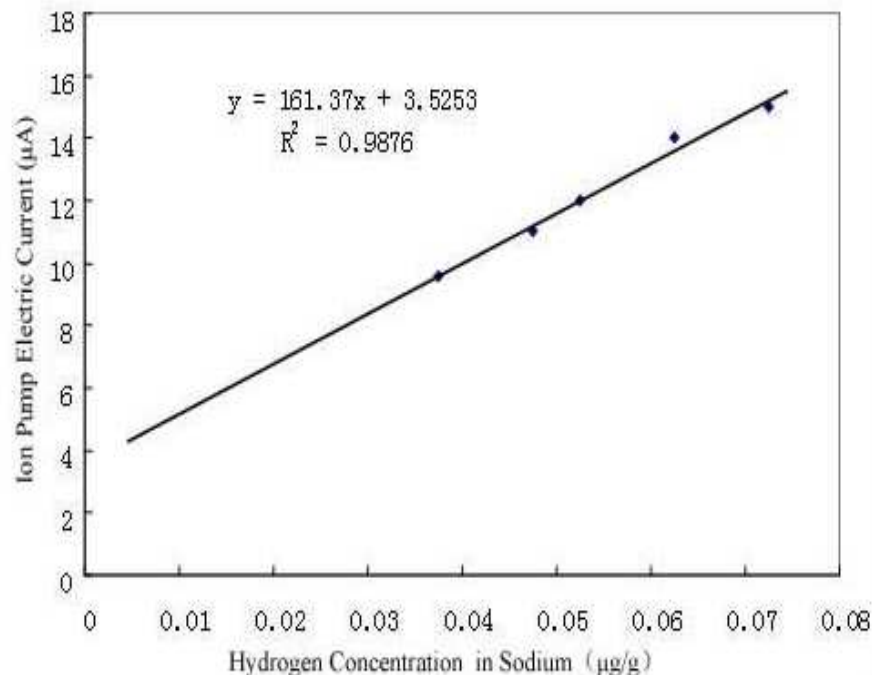
Calibration Curve of No.1 Hydrogen Meter Calibration Curve of No.5 Hydrogen Meter

(nickel tube sensor temperature at 450°C)

(nickel tube sensor temperature at 450°C)

Calibration Test

Calibration Curve



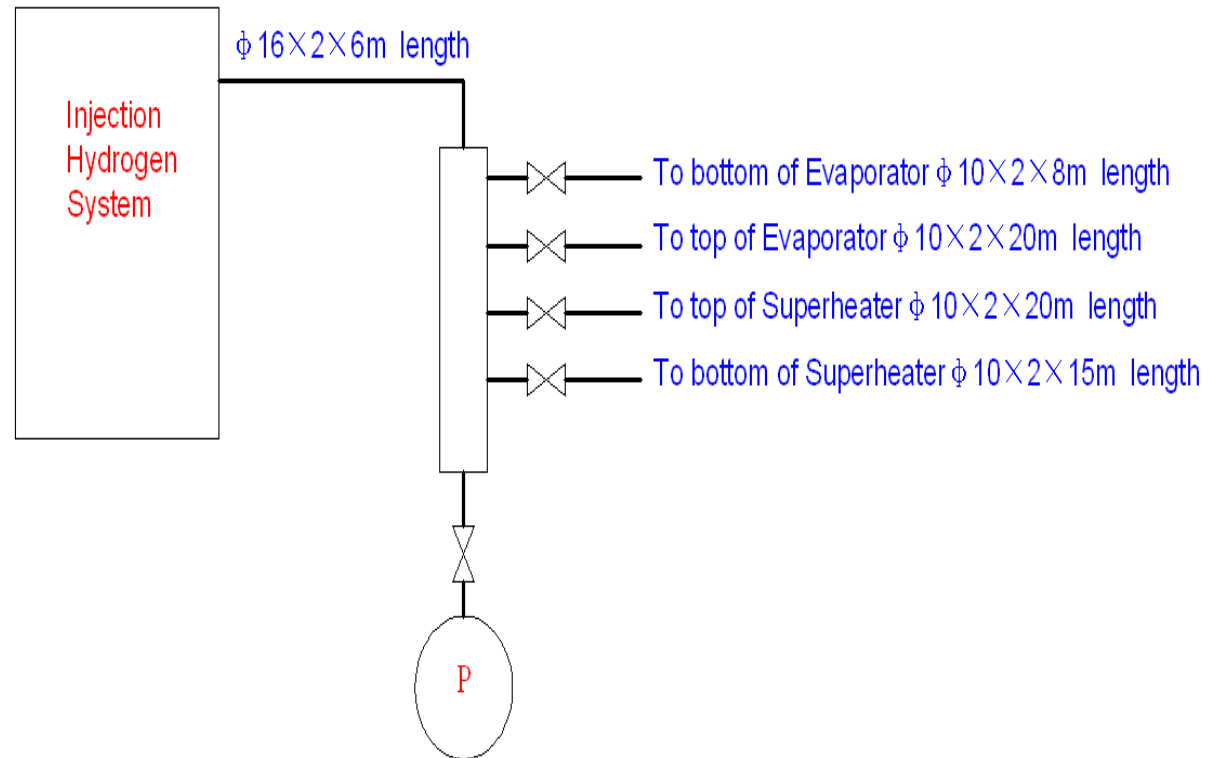
Calibration Curve of No.2 Hydrogen Meter
(nickel tube sensor temperature at 450°C)

Calibration Curve of No.6 Hydrogen Meter
(nickel tube sensor temperature at 450°C)

Time Response Characteristics

Effect of Injection Hydrogen Test:

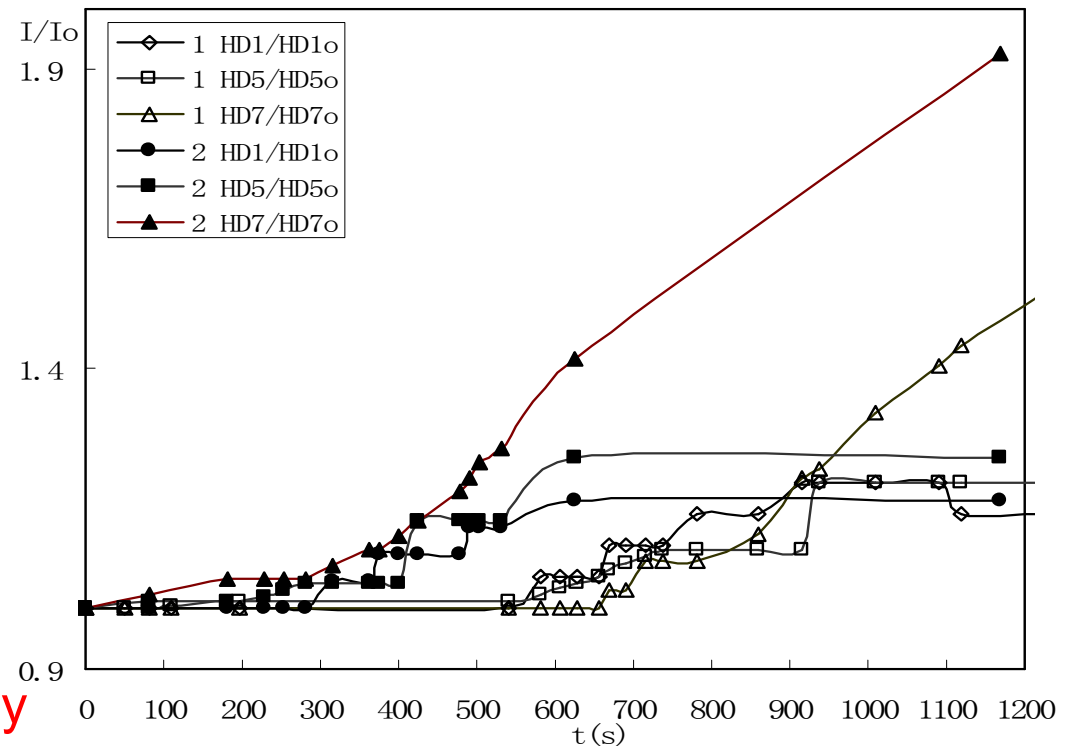
- ✓ Calibrate relation between hydrogen concentration and response of hydrogen meter
- ✓ Investigate hydrogen propagation in SG and even the whole secondary circuit
- ✓ Judge size and approximate position of leaking according to response of each hydrogen meter



Time Response Characteristics

Time response characteristics of hydrogen meter when speed of sodium pump is high

- ★ Injection Point: bottom of superheater
- ★ Injection Time: twice
- ★ Difference: Adopt different argon flow in two tests
- ★ Different argon flow results in different delay time that hydrogen resort in pipeline, which is main reason for delay of response of hydrogen meter



Time Response Characteristics

Time response characteristics of hydrogen meter when speed of sodium pump is low

- ★ It is obviously different that flow behavior of sodium in secondary circuit when speed of sodium pump is low compared with design condition
- ★ Injection Point: bottom of superheater
- ★ Injection Time: twice
- ★ No.2 Hydrogen Meter(bottom of evaporator): no response for long time, Reason: accumulate in top of evaporator or superheater
- ★ No.4 Hydrogen Meter(top of evaporator): work abnormally
- ★ No.6 Hydrogen Meter(top of superheater): huge response(electric current of ion pump increases from $14\mu\text{A}$ to $130\mu\text{A}$) , Reason: hydrogen bubble lifts along superheater into overflow pipe
- ★ No.8 Hydrogen Meter(meter in argon): no obvious response, Reason: hydrogen bubble can't enter into buffer tank through overflow pipe or outlet pipe of evaporator

»» Conclusion

★ Sensitivity

As shown from calibration curve of hydrogen meter, output of hydrogen meter exists about 2~3 μA response when increment of hydrogen concentration is $0.01\mu\text{g/g}$.

It is totally satisfied that sensitivity of hydrogen meter for $0.1\mu\text{g/g}$ alarm value of SG accident protection system in CEFR.

★ Time Response Characteristic

Spreading Time of Hydrogen in Sodium

Injection point	Response time of No.1 hydrogen meter/(s)	Response time of No.5 hydrogen meter/(s)	Response time of No.7 hydrogen meter/(s)
Bottom of superheater	300	25	30
Top of evaporator	350	410	450
Bottom of evaporator	80	260	20



Thank you