2. Task 2 Study of Safety Measures

2.1 Research and Development Goals

The following items are planned for WE-NET, Task-2 (safety measures) program during the second phase of 1999 – 2003.

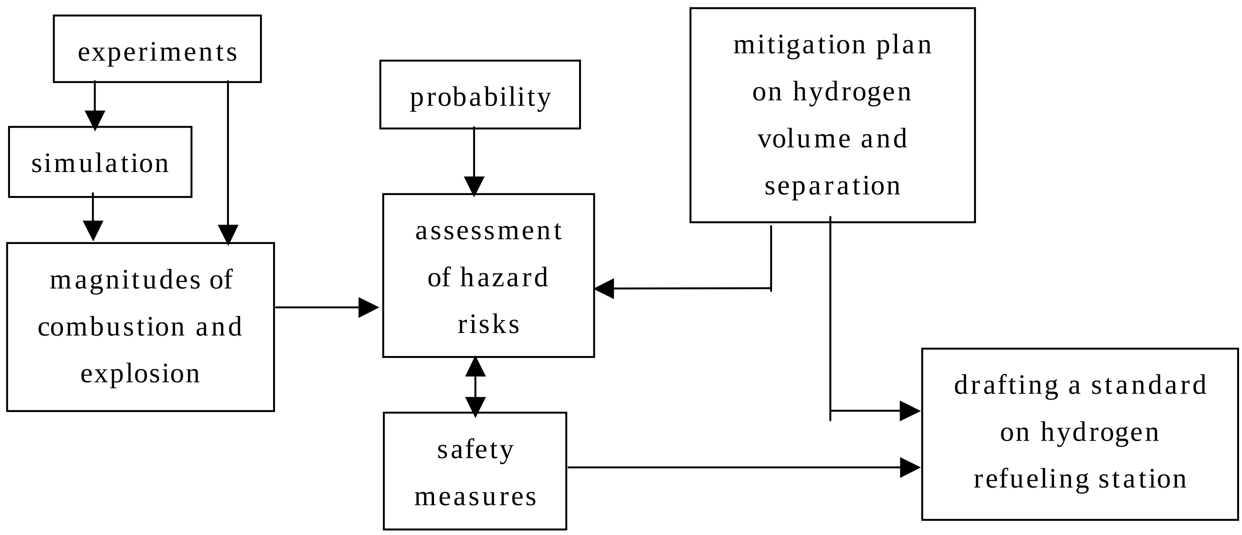
(1) to gather and arrange data concerning possible hazard consequences, the causes and the probabilities at hydrogen facilities

(2) to carry out experiments on leakage, ignition, diffusion and deflagration of hydrogen

(3) to simulate the phenomena and to evaluate the magnitudes of possible hazards

(4) to assess the hazard risks on presumed hydrogen refueling stations on the basis of the above data

(5) to draft a standard of hydrogen refueling stations with necessary safety measures, mitigating the regulations on hydrogen storage volume and separation distance restricting the sites of the stations



2.2 Results in Fiscal Year 2001

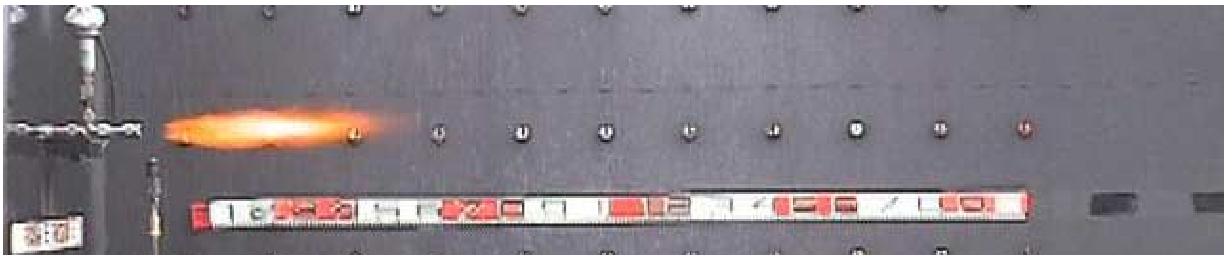
Hydrogen deflagration experiments with tube or semi-open equipment have been carried out in the fiscal year 2001. Experiments spouting high pressure hydrogen through a pinhole and examining ignition and flame characteristics have also begun. The activities are as the followings.

2.2.1 Safety Check of Hydrogen Refueling Stations

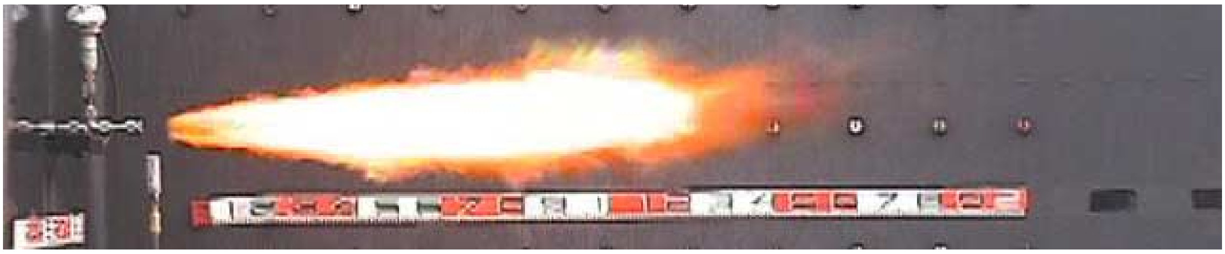
The working group of Task-2 has confirmed the taken safety measures for the hydrogen refueling stations which Task-7 designed and constructed in Osaka and Takamatsu. The check list and the advices will be used to improve the safety of the stations and will be utilized in making a technical guide of the stations.

2.2.2 Spouting Test of High Pressure Hydrogen

We have installed the experiment equipment for spouting test of high pressure hydrogen and have carried out the experiments. While the ideal gas is said to come out at the weight flow rate proportional to the source pressure, much more hydrogen has actually come out especially at a higher pressure than the proportional rate. It has been also proved that hydrogen effluence is hard to ignite without any igniter and that both the length and width of hydrogen flame are proportional to the diameter of a nozzle and also proportional to about 0.5 power of the source pressure. Radiation heat flux and temperatures have been measured. Examples of hydrogen flame are shown in Figure 2.2.2-1.



(1 MPa)



(10 MPa)

(14 MPa)

Figure 2.2.2-1 Flames from pressurized Hydrogen (visualized with a mist of NaCl aq.)
(diameter of nozzle ：1 mmφ, length of flame ：~1.7 m)

2.2.3 Hydrogen Deflagration Experiments with Tube Type Equipment

We could not obtain a high signal / noise (S/N) ratio in ion current measurement to estimate the flame propagation velocity in hydrogen deflagration experiments carried out with a tube type equipment last year. We could improve the S/N ratio drastically by adding a tiny amount of methane to hydrogen and by adopting new ion current probes that were made for ourselves in FY 2001. A series of tube experiments has been completed with obtaining useful data concerning hydrogen deflagration.

2.2.4 Hydrogen Deflagration Experiments with Semi-open Type Equipment

We observed the maximum overpressures of 1.5 kPa from 30% hydrogen and 3.1 kPa from 57% hydrogen at the range of 11 m from the gas mixture, under the condition of no obstacle and an electric spark ignition with a semi-open deflagration equipment of 5.2 m^3 gas volume. They were much higher than the maximum overpressure of 0.18 kPa from 9.5% town gas deflagration, the experiment result by JAERI, while they did not exceed the safety limit of 9.8 kPa recommended in WE-NET safe design guideline. However, greater overpressure and flame propagation velocity and partial deflagration to detonation transition have appeared when a dense obstacle exists inside of hydrogen air mixture. Figure 2.2.4-1 shows the pictures of the deflagration and the overpressure results are in Table 2.2.4-1.

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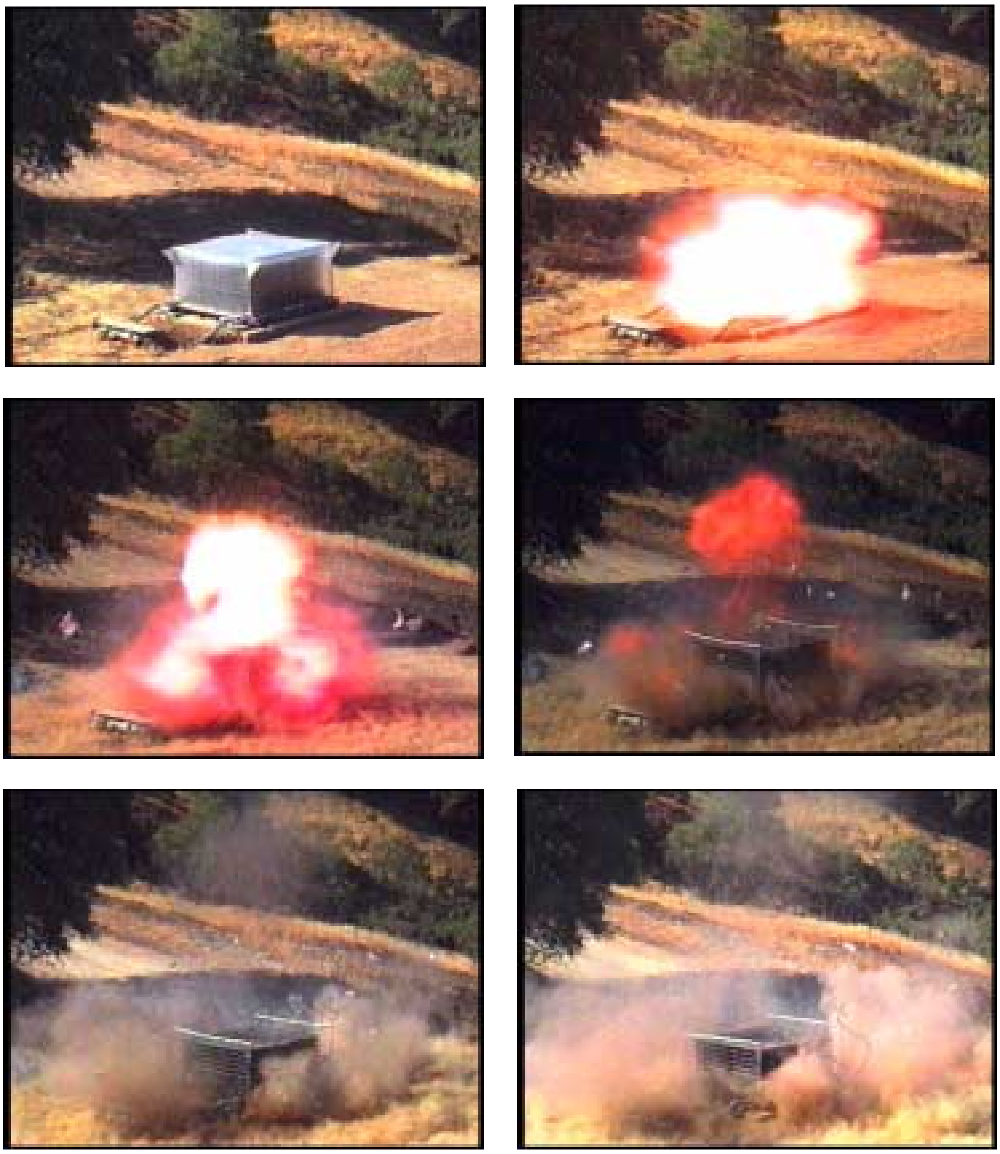

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Figure 2.2.4-1 Hydrogen Deflagration with semi-open Equipment (test 2-01)

Table2.2.4- 1 Overpressures and Impulses of Hydrogen Deflagration with Semi-open Space Facility

Test No.	Maximum Overpressure (kPa) range from gas mixture (m)					Impulse (Pa-s) (range) 11m	Remarks
	Top of Obstacle	Bottom End of Tent	10m	20m	40m		
1	66.0	41.5	9.09	4.32	1.62	16	H2 Conc. 20%
1-01	60.9	53.2	9.82	4.07	1.63	29	H2 Conc. 60%
2-01	3,270	764	23	7.3	2.7	42	H2 Conc.30%
3-01	—	2.14	0.44	0.20	0.11	10	H2 Conc. 20% No Obstacle
4-01	—	8.21	1.54	0.85	0.38	26	H2 Conc. 30% No Obstacle
5-01	—	11.4	3.13	1.62	0.79	32	H2 Conc. 57% No Obstacle
6-01	—	1,290	22.7	7.87	2.74	45	H2 Conc. 30% No Obstacle C4 Ignition
(ref. *) Town Gas	—	0.40	0.18	0.09	0.03	～4	T.G. Conc. 9.5% No Obstacle

Gas Mixture Volume : 5.2m^3

(ref. *) from experiment result of JARI program

2.2.5 Improvement of Simulation Codes

We have a prospect of clear way to fix parameters for analyzing hydrogen deflagration and have analyzed and modeled this year's experiment result on a computer preliminarily. We have also examined a simulation model to evaluate the influence of presumed accidents, considering the condition for combining CHAMPAGNE code, a simulator for hydrogen diffusion, and AutoReaGas code, a simulator for hydrogen deflagration. We could grasp the subjects to be solved for the simulation. A simulation model for the spillage and evaporation of liquid hydrogen has been improved in the precision using the spillage experiment data of liquid hydrogen carried out in FY 2000.

2.3 Subjects in the Future

As the results in FY 2001, we could obtain the data about the effect of hydrogen concentration,