SUpport to SAfety ANalysis of Hydrogen and Fuel Cell Technologies

Model Validation Database part no. 1

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(randomly ordered by list of partner Institutions)

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1 Validation Database

1.1 Introduction

According to the task 5.1 of project SUSANA, validation database should be built. The subtask will review the experiments available and suitable for inclusion into Model Validation Database and intended benchmarking.

The experiments will be arranged by phenomena and distributed inside a further subdivision with the aim of the creation of a detailed database. The database will include a general description of the experiment, the references to original sources and digitalized experimental records. At the very beginning of the project, website of validation database has been created. Currently, more than 30 experiments are available on the website. Details of the experiment format will be introduced in Chapter 2 and Appendix I. Experiments available in the database are shown in Chapter 3 and Appendix II.

Meantime, in order to make sure that all the experiments on website are in high quality, proper evaluation method of the experiments is introduced to the validation database. On Chapter 4 the quality assurance are introduced in detail.

2 Website of Validation Database

Building the website for database is the fundamental part of the validation database, both experiment updating and quality assurance relay on the website. On September 2013 the design of the website begun and on November basic items of the website were established. The validation Database is located at the web support-cfd.eu.

2.1 Physical Phenomena in Database

On website, in order to assist users of the database finding the proper experiments quickly, all the experiments are classified into 5 main physical categories: Release & Distribution, Ignition & Fire, Deflagration, Deflagration to Detonation transition (DDT) and Detonation. Detailed descriptions of the physical categories are given in following table 2.1.

Table 2.1 Physical Categories in Database

Physical Categories	Description
Release & Distribution	Investigation of the flow motion and distribution of hydrogen (Helium) gas after injected from high pressure vessel with supersonic or sub-sonic speed. Meantime, distribution of hydrogen gas from liquid hydrogen source is included in this category.
Ignition & Fire	Self-ignition or ignition of released hydrogen gas.
Deflagration	Subsonic speed flame in confined vessel or open environment.
DDT	Flame acceleration of the flame from subsonic flame to supersonic flame.
Detonation	Directly initiated supersonic flame in confined vessel or open atmosphere.

Figure 2.1 shown below is the interface of Database, 5 main physical categories are listed in the lower part of the web. For convenience, the user can choose the physical category in the upper part of the website and let the experiments belonging to the corresponding category display in the lower part. Additionally, users can also use the button 'CSV' or 'PDF' to download the experiment.

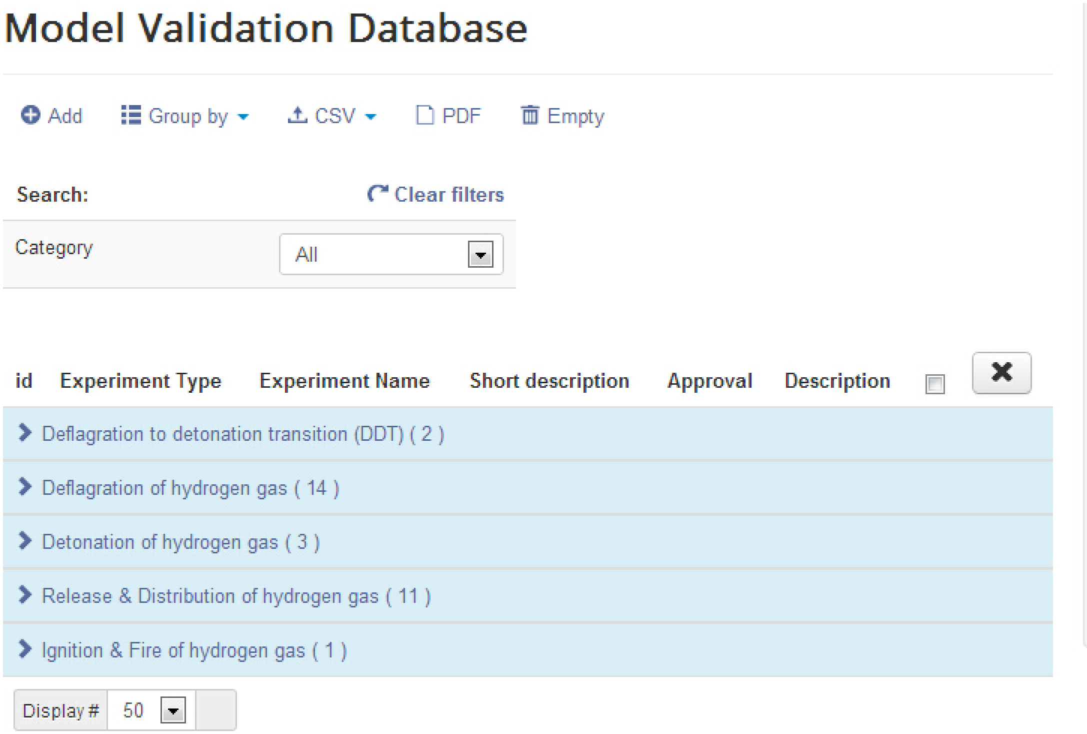


Figure 2.1 Interface of Database

Inside each category, experiments will be displayed in the order of input. On the list of the experiments, important information such as the name of experiment, short description of experiment, the approval of the experiment and the data provided by the experiment are provided. Through the information provided on the list, users of the database can get basic knowledge of each experiment and make their decision.

Category: Deflagration of hydr

id	Experiment Type	Experiment Name	Short description	Approval	Description
Deflagration of hydrogen gas (14)					
5	Deflagration		The experiment was performed in the HYKA A2 experimental facility. A homogeneous mixture of hydrogen (10 vol.%), steam (25 vol.%) and air was established in the vessel. The initial pressure was 1.49 bar, and the average initial temperature was about 90.0 °C. The mixture was ignited at the bottom of the vessel and the ensuing axial and radial flame propagation were observed. Pressure and temperature were measured at different axial and radial locations.	yes	The pressure data and temperature data from the transducers.
6	Deflagration	HYCOM-HYC 14	Combustion experiments have been carried out in large scale multi-compartment geometry	yes	All pressure recordings in digital form

2.2 Topics of Experiments

In the website, in order to provide the information of each experiment systematically and completely, all the information about the experiment are given in 10 topics. The 10 topics include variety aspects of the experiment and let the users have a detailed understanding of the experiments. The 10 topics include:

- **Summary** — Short description of the experiment, including the draft drawing, simple description and keywords.
- **Author** — Who did the experiment and who are responsible to the experiment.
- **Experimental Setup** — Detailed description of the experimental facility, boundary setting and location of instrumentations.
- **Objective of Experiment** — Which physical phenomena are investigated in this experiment.

- Application Calculation — Which kinds of numerical model can be validated by this experiment.
- Experimental Procedure — Detailed description of experimental phenomena, including the figures or movies.
- Experiment Data — Results of the experiment, including some explanations for the experiment data.
- Performed Simulation — Some validation cases by using the experiment.
- Reference — Publications related to the experiments.
- Comments — Some suggestion from the user, the interface for the communication between the users and publishers of the experiment.

In each topic of the experiment several sub-topics are shown to the users, therefore all information can be provided systematically and clearly to the users. In the following parts, descriptions of the sub-topics of each topic are shown in detail (more detailed illustrations are provided in Appendix I).

2.2.1 Summary:

The topic summary is the short description of the experiment. Users can get basic information of the experiment in this topic. Subtopics and their descriptions are shown in the Table 2.2.

Table 2.2 Sub-topics in Summary

Category	The physical phenomena category of the experiment.
Experiment Type	The main physical phenomena studied by the experiment.
Experiment Name	The name or ID of the experiment.
Keywords	The keywords of the experiment
Draft drawing or simple description for the facility	The simplified drawing or written description for the experiment facility.
Short Description	Few words about the experiment background, purpose and preparation.

2.2.2 Author:

The topic is the full information of the experiment participants and the contact information of the experiment publisher. Such topic is necessary for the maintenance and quality assurance of the experiment. Details of the sub-topics are shown in Table 2.3.

Table 2.3 Sub-topics in Author

The main participants	The experts who made the experiment. If necessary, the links to personal website of those experts can be provided by SUSANA web.
The experiment time	Start and end dates of the experiment.
The relevant agencies	The agencies (universities, research institutes and companies) attended in the experiment. If necessary, the links to the official websites of those agencies can be provided.
The place of the experiment	The location (the country, state, institute) of the experiment.
The data provider	The person provided the experiment to SUSANA website.

2.2.3 Experimental setup:

This sub-topic is the detailed description for the experiment facility and instrumentation. This is the key part for the construction of computational domain. Sub-topics are shown in Table 2.4.

Table 2.4 Sub-topics in experimental setup

Components	The main components of the experimental facilities. Some experimental facilities may have several components, number and size of the components should be given in this part.
Boundary geometry	Geometrical information for special boundary such as the fan, the release source and ignition point. - The type of the boundary (source, velocity, pressure) - The size of such special boundary (can be given in the latter facility drawing) - The location of the special boundary (can be given in the latter facility drawing)
Instrumentations	The instrumentations used in this experiment, detailed information should cover: - The types of the instrumentations - The numbers of the instrumentations - The position of the instrumentations (can be given in the latter facility drawing)
The mutable variables in the facility	Sometimes, geometry may also be a mutable factor in experiment, including - The destructible boundary and parameter of the boundary - The mutable geometry in the facility (such as the size of the

	obstacles is mutable when the influences of the different geometry is studied by the experiment)
Drawing or detailed written description of facility	The detailed description of the experiment facility. All information mentioned above should be included in the drawing.

2.2.4 Objective of the experiment:

In this topic, the purposes of the experiment are given. Sub-topics are shown in Table 2.5.

Table 2.5 Sub-topics in objective of the experiment

Experimental goals	What detailed physical phenomena are planned to be studied by the experiment originally.
Phenomena	What physical phenomena can be studied from the experiment results

2.2.5 Applicable calculations:

This topic shows the users what numerical or physical models can be validated by the experiment. Such topic can improve the validation efficiency and help the users making their own judgment about if the experiment is proper for their code. Subtopics are shown in Table 2.6.

Table 2.6 Sub-topics in applicable calculations

Fluid governing equations	The transportation equations used to describe the gas dynamics.
Chemical models	The models used to simulation the chemical reaction.
Boundaries	Numerical method used to simulate the boundary.

2.2.6 Experimental procedure:

This topic shows the experimental process, including preparation and detailed experimental phenomena. This topic contains the key parameters of the experiment, setting of initial conditions and boundary conditions rely on this topic. Sub-topics are shown in Table 2.7.

Table 2.7 Sub-topics in experimental procedure

Initial condition	The initial state inside the experiment facility, including - Gas species and their ratio - Initial pressure - Initial temperature - Initial velocity

	- Turbulence parameters
Boundary condition	Some experiments have special boundary conditions such as the source of the gas, velocity inlet or outlet and pressure boundary.
Descriptions	Some written description for the experiment, including - Preparation of the experiment - Experiment procedure - Experiment phenomena - Theoretical analysis - Conclusions

2.2.7 Experiment data:

Final experiment results are given in this topic. Sub-topics are shown in Table 2.8.

Table 2.8 Sub-topics in experiment data

Availability	If the data can be accessed by the public.
Description	Some information about the experiment data, including - Measurement procedures - Measured quantities - Measure errors - The format of the data file - Description for each data file
Experiment data	The final result, experiment data collected under different conditions can be shown in different sub-topics.
Figure	Time dependent figure of the quantities measured by the instrumentations. Figures should be classified by the instrumentation types or physical quantities, and each figure should be marked by the position.
Video	Videos can express the experiment phenomena objectively. - Overview of the experiment facility - Preparation of the experiment - Detailed experiment phenomena

2.2.8 Performed simulation:

In this topic, some code validation examples based on the experiment are shown. For each example, the sub-topics should be as shown in Table 2.9.

Table 2.9 Sub-topics in each example

Author	The people or agencies attended in the validation.
Validation code	The code validated or verified by the experiment.

Mathematical treatments	The mathematical methods used to make the data processing.
Setting of domain	The setting of the computational domain in this calcualtion, including - Grid structure and resolution - Construction of the geometry - Initial condition - Establishment of the boundary conditions - Properties of the physical boundary - Figures of the domain
Validation Models	The numerical models validated or verified by the experiment data.
Validation results	The validation results, including: - Figures - Conclusion

2.2.9 References:

In this topic, papers related to this experiment are given. Sub-topics are shown in Table 2.10.

Table 2.10 Sub-topics in references

References about the experiment from the participants	The reports and papers published by the experiment participants, including: - Reports or papers about the experiment - Analysis for the experiment - Validation made by the experiment participants
References about the experiment from the third party	The reports and papers published by third party related to the experiment, including: - Reports or papers about the repeatability of the experiment - Analysis for the experiment - Validation made by the third party

2.2.10 Comments:

Inside the topic some comments from the users are listed, the comments can be displayed by time. Additionally, if the questions in the comment part are answered by the publisher or administrator the answers will be displayed after the question.

3 Experiments in Validation Database

Currently, around 40 experiments have been uploaded to the validation database. Following Table 3.1 shows short discerptions of all the experiments available in the database (to save pages, the experimets who share the same experiment facility are mentiones as one in the Table, but in the website the experiments are uploaded sperately). More detialed illustrations of each experiment are provided in the Appendix II.

Table 3.1 Experiments in Validation Database

Category		
Release & Distribution	Low Temperature Jet	High pressure low temperature hydrogen gas released from different diameters nozzle. Distribution of the hydrogen and the velocity are measured in experiment.
	Gamelan	Helium released from the nozzle which was installed inside the 1 m^3 vented box. Volume fraction of Helium is measured at different positions inside the box.
	SBEP_21	Helium was released continuously from the nozzle set inside the garage side vented facility. Volume fractions of the gas are measured at different positions.
	GEXCON	Hydrogen gas was released as a jet inside lab scale facility. Three different obstacle setting accompany with different nozzle diameter are used to investigate the behavior of hydrogen.
	INERIS-6C	Hydrogen was released inside a vented facility with the volume of 70 m^3. Volume fractions of the hydrogen are measured at different position.
	NASA-6	Liquid hydrogen are disposed in open environment with constant wind flow, volume fractions of hydrogen are measured by sensors located at downwind position.
	SBEP_1	A subsonic release of hydrogen in a closed vessel with the volume of 20 m^3. Volume fractions of the gas are measured at 6 sensors inside this vessel.

	He_GARAGE	Helium was released in a vented garage which has a 1:1 car model inside. Volume fractions of the Helium are measured at different positions.
	H2_HALLWAY	Helium was released in vented tunnel model. Volume fractions of the gas are measured at different positions.
Ignition	PRD	High pressure hydrogen gas was released through the pressure relief devices. Relation between the gas pressure and self ignition is investigated.
	Ignition_Jet	Ignition was made in front of the low temperature hydrogen jet. The burning behaviors resulted by the release pressure and temperature are investigated.
Deflagration	HYCOM-HYC01	10% Hydrogen-Air mixture in RUT facility was ignited at the end of round tunnel. Pressure data was collected in the experiment.
	HYCOM-HYC14	11.5% Hydrogen-Air mixture in RUT facility was ignited at the corner of canyon. Pressure data was collected in the experiment.
	HYCOM-MC03	In the 12.2 m long 174mm diameter tube, repeated obstacles with block ratio 0.6 are installed. 10% Hydrogen-Air mixture was filled in this tube and ignited at one end of the tube.
	HYCOM-MC12	In the 12.2 m long 174mm diameter tube, repeated obstacles with block ratio 0.6 are installed. 13% Hydrogen-Air mixture was filled in this tube and ignited at one end of the tube.

	HYCOM-MC43	One 12.2 long 174mm diameter tube was separated by membrane in the middle. Two parts are filled with different Hydrogen-Air mixtures and installed with repeated obstacles with different block ratio. Ignition was made at one end of the tube and then the flame propagation was investigated.
	HYCOM-HC20	10% Hydrogen-Air mixture was fill in the facility combined by two tubes with different diameters. In the two tubes repeated obstacles with different block ratios were installed. Ignition was made at the end of large diameter tube, and the propagation of flame was investigated.
	Deflagration_sphere_vessel	Large sphere structure vessel was filled with 29.5% Hydrogen-Air mixture, ignition was given at the center of the vessel and the pressure data was collected through the sensors installed at on the wall.
	HyInDoor_WP3	Vented 1 m^3 box was filled with 18% Hydrogen-Air mixture initially. Then the ignition was given at the center of the wall opposite to the vent. Pressures along the vented fire were measured.
	Open Deflagration	20m diameter hemisphere balloon was filled with 29.5% Hydrogen-Air mixture, ignition was given at the center of the balloon and the pressures were measured.

	Vent_Deflagration	In a large vented vessel, 10% Hydrogen-Air mixture was filled inside. Then the ignitions were given at different location and the relation between flame behavior and ignition points was investigated.
DDT	FZK-R 049809	15% Hydrogen-Air was filled in the 12m long 350mm diameter tube. In order to boot the mixing effect, 0.3 block ratio repeated obstacles were installed in the tube. Lighting sensors and pressure sensors are installed in the tube to collect experiment data.
	DDT_RUT	In RUT facility, different Hydrogen-Steam-Air mixtures were ignited to investigate the flame acceleration and DDT. Pressure data were collected by sensors located in the facility.
	DDT_MINIRUT	Different Hydrogen-Air mixtures in the small scale 'RUT' facility were ignited to investigate the DDT behavior. Pressure data was collected in the experiment.
Detonation	KI_RUT_hyd05	RUT facility was filled with 20% Hydrogen-Air mixture, initiation of the detonation wave was accomplished by the 100g TNT located at the corner of canyon. Pressure data was collected by the pressure sensors.
	KI_RUT_hyd09	RUT facility was filled with 25.5% Hydrogen-Air mixture, initiation of the detonation wave was accomplished by the 100g TNT located at the end of round tunnel. Pressure data was collected by the pressure

		sensors.

In the selection of experiments, scaling of the experiment is also very important issue should be considered. To satisfy the users with different requirements, experiments with different scaling should be provided. Current database keeps a good balancing in scaling, enough experiments are provided for each scaling. Table 3.2 shows the scaling of the experiments in database.

Table 3.2 Scaling of experiments

Laboratory Scale Experiments (<1 cubic meter)	Medium Scale Experiments (~10 cubic meter)	Industrial Scale Experiments (>100 cubic meter)
Gamelan, PRD, HYCOM-MC03, HYCOM-MC12, HYCOM-MC43, HYCOM-HC20, DDT_MINIRUT	Low Temperature Jet, GEXCON, SBEP_1, Ignition_Jet, Deflagration_shpere_vessel, HyInDoor_WP3, FZK-R 049809	SBEP_21, INERIS-6C, NASA-6, He_GARAGE, H2_HALLWAY, Open Deflagration, Vent_Deflagration, HYCOM-HYC01, HYCOM-HYC14, DDT_RUT, KI_RUT_hyd05, KI_RUT_hyd09

4 Quality assurance

Both quantity and quality are important to a successful database. Big number of experiments can satisfy the requirements from different users and provide more confidence to the code. Meantime, quality of the experiments is also important, validation through high quality experiments can provide more confidence to the code.

To reach a high quality, each experiment in SUSANA validation database should pass through the so called publisher-reviewer cycle. Figure 4.1 shows the publisher-reviewer cycle. It is clear that main components of this cycle are publishers, reviewers and administrators. Publishers are the people who are responsible for uploading experiment to database. Reviewers are invited experts or experienced CFD developers/users of SUSANA project participants who can evaluate the quality of experiment. Administrators are ones who take in charge of the maintenance and management of the website.

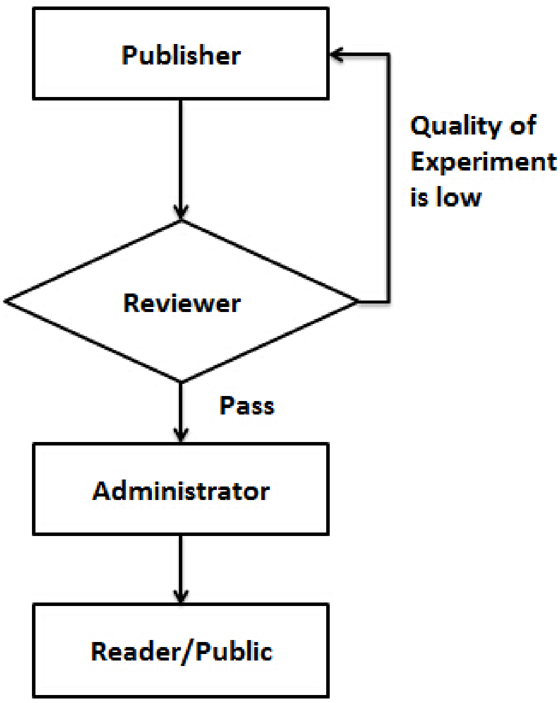


Figure 4.1 Quality assurance

In the cycle, firstly the experiments should be uploaded to the website by the publishers. At this moment, the experiments been uploaded are marked as no in the approval part, which means that the experiments are only available to the publishers, reviewers and administrators but not to the reader/public. Then, at least two reviewers will be notified by the auto-email or publishers to evaluate the quality of the experiment. In the evaluation phase the reviewers will evaluate if the experiment can be used for validation (by judging if enough information about the geometry, initial condition and boundary condition are provided) and the quality of the experiment (through the description of the experimental procedure, movie, experiment results and the capability of the experiment agency). After the evaluation, high quality experiment will be marked as yes in the approval part and open to the readers/public trough the operation of administrators, but low quality experiment will be sent back to the publishers for further optimization. So, with the help of publisher-reviewer cycle, all the experiments shown to the readers/public are guaranteed in its quality. Currently, 8 publishers and 11 reviewers are working for the validation database. Details of the publishers are shown in Table 4.1.

Table 4.1 Publishers and reviewers in each parnter

Partner	Publishers	Reviewers
KIT	2	2
UU	2	2
NCSRD	2	2
JRC		1
HSL		1
EE	1	1
AREVA	1	2

In addition, after the experiment is open to the readers/public, evaluation of the experiment and the improvement of the quality are still possible. The comment part and the author part of each experiment provide a perfect feedback interface between the publisher and readers. Firstly, readers can contact the publishers through the contact information provided at the author part to ask question and give comments. In this way, errors can be found quickly and improvement can be made immediately. If no responds from the publishers due to some technique reasons (such as the departure of the publishers or problems of the email), reader can use the comment to leave message to the administrators and the administrators can contact the publisher who is responsible to the experiment or the other publishers who also have enough knowledge to the experiment to fix the problem.

The last but not the least, the setting of the database make it is possible to increase the quality of each experiment. Compared to the common quality assurance through 'fixing' problems, increasing the quality of the experiment is more positive quality assurance. In the performed simulation part, some validation works based on the experiment are shown. Those validation examples can show the compatibility of the numerical simulation to the real experiment, good compatibility not only shows that the numerical model can reproduce the real world but also shows that the experiment itself fits the theory. As more and more validation examples are included in the performance simulations, quality of the experiment will increase and more users will use the experiment to make code validation, such feedback mechanism can improve the quality of experiment in a long period of time.

5 Future work

As one main output of SUSANA project, validation database should become a systematic and complete base for the validation of hydrogen code. Current database still has a big distance to the planning in quantity, quality and variety.

Firstly, more experiments should be uploaded to the validation database. At the end of the project, more than 100 high quality experiments are expected in the validation database. In order to reach the quantity expected, more publishers are necessary. Currently, the publishers are all from the partners of SUSANA, so the source of experiment might be limited. In order to upload more experiments, other experimental agencies can be invited as publishers.

Meantime, in the experiment updating, all the publishers should pay more attention to the scaling and variety of the experiments. As the development of fuel cell hydrogen energy has the potential to replace other style of energy in common life, possible accidents may happen in any scaling and under any circumstance. In order to assistant the development of CFD codes which are aim to make safety analysis of hydrogen in daily life, validation data base should pay attention to the scaling and variety of the experiments in each category. In the scaling, all experiments can be classified into laboratory scaling, medium scaling and industrial scaling, experiments in all three scaling should reach balance. In variety part, for different physical categories the definition of variety should be different: for release & distribution, variety at least means the different sources of hydrogen should be considered, such as supersonic release, subsonic release and liquid hydrogen; for ignition & fire, variety means the style of ignition and the status of burning mixture, such as the self-ignition, passive-ignition, ignition of premixed gas and ignition of non-premixed gas; for the other three styles of combustions, variety can be different confinements, obstacles and the status of burning gas, such as closed vessel, vented vessel, open environment, with obstacles, without obstacles, premixed gas and non-premixed gas.

In the quality assurance part, future work should be focused on increasing the reviewers of database and introduce more code validation examples to the performed simulations. As more and more experiments are expected in the validation database, more reviewers should be invited to the database to evaluate the quality of experiments. Currently, only one or two reviewers are selected in each project participants, more reviewers are expected in each participants (each project participant has lots of experiences in CFD and considerable ratio of workers there has enough knowledge in numerical simulation). In addition, if possible, some agencies which have interest in code validation can also be invited to use the experiments in database and experts in the agencies can be invited as reviewers. As mentioned in Chapter 4, introduction of performed simulations to experiment is positive quality assurance, so more validation cases based on the validation database should be introduced in future. Firstly, benchmarking working in task 5.2 can provide high quality validation cases to the performed simulations. Then, each project participants may also have code development and education works, the code developers and students are encouraged to make simulations based on other experiments in the database. If possible, the database can be open to some experiences code development group and research institutes in next step, and then get calculation results from them. Getting simulations from third parts indeed is a reciprocal method, the third parties can advertise their code or working ability through our website and we can get validation cases to increase the quality of experiments.

In all, in the coming period of the project SUSANA, sub-tack 5.1 should mainly focus on increase the quantity of the database, including increasing the quantity of the experiments, increasing the quantity of reviewers and increasing the quantity of validation cases.

Appendix I

In Chapter 2, topics and sub-topics of each experiment in database are shown. However, limited by the pages the detailed illustration of the topics cannot be provided in the Chapter. Therefore, detailed descriptions are shown in Appendix I.

Summary:

The topic summary is the short description of the experiment. Users can get basic information of the experiment in this topic.

*Experiment Type	The main physical phenomena studied by the experiment. For example: Deflagration Words appeared in this sub-topic should be from the terminology list of SUSANA, the terminology list will be built later. Experiment type dominates the final classification of the experiment in the SUSANA website, and can bring lots of convenience when distributing this article to the reviewers. Such item is decided by the publisher, so it is better to provide this information in the article submitting.
*Experiment Name	For naming the experiment.
*Keywords	The keywords of the experiment The keywords are used for the search function in the website. For each article, 4-5 keywords should be given. For example: the wrinkled fire, premixed mixture, closed environment and etc. Those key words should also be from the terminology list of SUSANA. The keywords are decided by the publisher, it is better to provide those words in the submitting phase.
Draft drawing or simple description for the facility	The simplified drawing or written description for the experiment facility. For the users, establishing the computational domain is very important task. The draft drawing of the experiment facility can help them judging if their code can deal with the geometry in this experiment. Information in this topic just provides a more comprehensive view of the experiment. Indeed, this topic can be kept in blank

	in article submitting phase.
*Short description	Few words about the experiment background, purpose and preparation. The short description provide the basic information of the experiment, users can make preliminary assessment on if the experiment is proper for the Validation (if their code has the capability to make the simulation). Normally, report of the experiment has some brief description for the experiment. If no description is available, the publishers can make it by themselves.

When clicking inside one experiment data, the summary of the experiment should be given firstly. Summary of one experiment contains the basic information, users can decide if it is necessary to read the details after reading it. For some experiment data which have already been included by other websites, only the summary and links to the experiment data are given. In the user's interface, the summary can be given as above table.

Author:

The topic is the full information of the experiment participants. For validation, the experiments made by experienced experts are more reliable and can bring more confidences to the code.

The main participants	The experts who made the experiment. If necessary, the links to personal website of those experts can be provided by SUSANA web. Experiment made by experienced and famous scientist is more reliable. If the users are not quite familiar with the scientists, the links provided by the SUSANA website can help the users making their own judgment. Normally, the names of the experts attended in the experiment are mentioned in the experiment report. However, It is quite possible that the information about the participants is missed due to some reasons. So, such item can be kept in blank in the submitting phase.
The experiment time	Start and end dates of the experiment. As the improvement of the technology, the accuracy and types of the experimental instrumentations have been improved a lot. So, exact dates of the experiment can express the quantity of the experiment data partially.

	Similarly to the name of scientists, date of the experiment can be missed in the submitting phase.
The relevant agencies	The agencies (universities, research institutes and companies) attended in the experiment. If necessary, the links to the official websites of those agencies can be provided. Similarly, experiments made by professional agencies are more reliable. The name and links of the relevant provided in the sub-topic can help the users making their own evaluation for the data quality. Similarly, the topic about the experiment related agencies can be kept in blank in the submitting phase.
The place of the experiment	The location (the country, state, institute) of the experiment. Some agencies may have several experimental institutes, and the quality of the experiment facilities might be different. Providing where the experiment was made can partially prove the quality of the experiment data. Location of the experiment even has less importance than the information of scientists, date and agencies, so this topic can be kept in blank in the submitting phase as well.
*The data provider	The person provided the experiment to SUSANA website. Under the consideration of the data revise and answering the questions from the users, providing the name of publishers is quite necessary. The name of the provider is very important for the maintenance of the article, it is better to provide the information in the submitting phase. For convenience, such information can be added by the system automatically.

Experimental setup:

The topic is the detailed description for the experiment facility and instrumentation. Such information is quite important for the establishment of computational domain in simulation.

Components	The main components of the experimental facilities. Some experimental facilities may have several components (like A1 and A3 in KIT), number of the components should be given in this part.

	For the simulation with multi-block method, information and number of the facility components can be a reference for the construction of computational domain. Some experimental facilities only have simple geometry, so the component information is not necessary for every article. Such sub-topic can be kept in blank in the submitting phase.
**Boundary geometry	Geometrical information for special boundary such as the fan, the release source and ignition point. - The type of the boundary (source, velocity, pressure) - The size of such special boundary (can be given in the latter facility drawing) - The location of the special boundary (can be given in the latter facility drawing) Establishment of the boundaries can dominate the final result of numerical simulation. No one will doubt the necessity of boundary setting message. Description of the boundary is quite necessary for the construction of computational domain, so such message must be given in the submitting phase. During the review, such topic is a key subject.
**Instrumentations	The instrumentations used in this experiment, detailed information should cover: - The types of the instrumentations - The numbers of the instrumentations - The position of the instrumentations (can be given in the latter facility drawing) Instrumentations are the data collectors in the experiment, and the validation is done between the data collected by instrumentations and simulation results. Exact information of instrumentations is important factor for the success of validation. Sometimes, the information about the types of the instrumentation might be unavailable, but the position of the instrumentation must be provided in the article. Otherwise, the Validation cannot be done. Such topic is also a key subject in the review phase.
The mutable variables in the facility	Sometimes, geometry may also be a mutable factor in experiment, including - The destructible boundary and parameter of the boundary - The mutable geometry in the facility (such as the size of the obstacles is mutable when the influences of the different

	geometry is studied by the experiment) The mutable factors in the facility are important for the construction of computational domain. If there are no mutable factors in the facility, such information can be missed in the submitting. If some boundaries are mutable in the experiment, the related information must be provided. This sub-topic is checked by the reviewer.
**Drawing or detailed written description of facility	The detailed description of the experiment facility. All information mentioned above should be included in the drawing. Computational domain should be constructed under the guidance of drawings. Especially for the boundary conditions and the instrumentations, the drawing can show the users their exact sizes and positions. For some simple experiment, detailed description of the facility should be made instead if the drawing is not available. Such topic is very important for the construction of the computational domain. The article without the description of the facility should be rejected.

Information of experiment facility is quite important for the construction of computational domain. In the users interface, such topic can be given as following format:

Components	Component1: description, size
	Component2: description, size
Boundary Geometry	Flow in 01: description, location, size
	Flow out 01: description, location, size
	…
Instrumentations	Type 01: quantities measured, number, locations, …
	Type 02: quantities measured, number, locations, …
	Type 03: quantities measured, number, locations, …
	…
The mutable variables in the	Mutable viable 01: positions, the mutable factors
	Mutable viable 02: positions, the mutable factors

facility	…
Drawing	The detailed figure is provided here. The instrumentations and special boundaries should be marked on the figure.

Objective of the experiment:

In this topic, the purposes of the experiment are given.

Experimental goals	What detailed physical phenomena are planned to be studied by the experiment originally? The original plan of the experiment is the basic information of the experiment data, it is better to provide it to the users. Comparing to the experimental phenomena, the original plan of the experiment may not be important. Such sub-topic can be kept in blank in the submitting phase.
*Phenomena	What physical phenomena can be studied from the experiment results? Those phenomena can be more than or different from the original plan. The phenomena can be studied by the experiment also show what kinds of models can be validated or verified by the experiment. The physical phenomena can be studied by the experiment is one part of the experimental conclusion, so it is better to provide the information in the submitting phase. If no such message is provided by the experiment at all, the topic can be kept in blank in the first submitting. However, the information should be added latterly by the publishers or reviewers.

Applicable calculations:

This topic shows the users what numerical or physical models can be validated or verified by the experiment. Such topic can improve the validation efficiency and help the users making their own judgment about if the experiment is proper for their code.

Fluid governing equations	The transportation equations used to describe the gas dynamics. Such information can be quite useful, but not quite necessary. If no such information is available, it can be kept blank in the submitting phase.

Chemical models	The models used to simulation the chemical reaction. In the cases that no chemical reaction appeared in the experiment or no such information provided by the references, the sub-topic can be blank in the submitting phase.
Boundaries	Numerical method used to simulate the boundary. If no such information is available or the numerical treatments are unnecessary, the sub-topic can be kept blank in the submitting phase.

Experimental procedure:

This topic shows the experimental process, including preparation and detailed experimental phenomena.

**Initial condition	The initial state inside the experiment facility, including - Gas species and their ratio - Initial pressure - Initial temperature - Initial velocity - Turbulence parameters All of initial conditions can be given in a template table. For the solution of PDE, proper initial conditions are quite necessary. Without the initial data, validation is impossible. Information as the component of the gas mixture, pressure, temperature and velocity are the basic information for the solution of transportation equation, the turbulence parameters such as turbulence energy, turbulence dissipation and etc. might be optional for some simulation. In the submitting phase, information about the initial state must be given. The reviewers should pay much attention on this part to ensure the initial condition is complete to make the simulation.
**Boundary condition	Some experiments have special boundary conditions such as the source of the gas, velocity inlet or outlet and pressure boundary. Parameters of the boundary should be complete, and the parameters of one boundary can be given by a template table as well. Boundary condition is another necessary factor for the solution of PDE. In the topic of experimental setup information as the

	type, size and position of these boundaries are provided, and here are the detailed physical parameters of the boundaries. The physical qualities of the boundaries are similar to the initial boundary, but some special boundary may have special requests. Boundary information is another sub-topic must be provided in the submitting phase. For the reviewers, checking the boundary conditions is also a very important task they should focus on.
*Descriptions	Some written description for the experiment, including - Preparation of the experiment - Experiment procedure - Experiment phenomena - Theoretical analysis - Conclusions The description of the experiment phenomena can help the users selecting proper physical models in the Validation. In addition, comparison between the simulation results and experiment phenomena is a rough validation, it can show if the model can express the real world as well. This sub-topic is usually contained in the collusion part of the experiment. If no written descriptions are available, this sub-topic can be kept in blank in the submitting phase.

In the user's interface, the above information should be given as following (the numbering and classification of components and boundary conditions should be the same as the topic of experiment setup):

Initial condition	Component 01: Temperature- Pressure- Velocity- Gas components- Turbulent parameter-
	Component 01: Temperature- Pressure- Velocity-

	Gas components- Turbulent parameter-
	…
Boundary conditions	Flow in 01: Temperature- Pressure- Velocity- Gas components- Turbulent parameter-
	Flow out 01: Temperature- Pressure- Velocity- Gas components- Turbulent parameter-
	…
Description	…

Experiment data:

Final experiment results are given in this topic.

*Availability	If the data can be accessed by the public. Show if the data is available to the common readers.
*Description	Some information about the experiment data, including - Measurement procedures - Measured quantities - Measure errors - The format of the data file - Description for each data file Basically, description of the experiment data illustrates the contents of the data file. For the cases that several data files are

	provided, the correspondence between the data files and experiments conditions are given by the description. In addition, the description of the experiment data can show the reliability of the data. The data with less uncertainty can bring more confidence to the code in Validation. It is better to have such information. Such message is strongly recommend. However, since the information is not critical for the numerical simulation, such sub-topic can be kept blank in the submitting phase.
**Experiment data	The final result, experiment data collected under different conditions can be shown in different sub-topics. The most important part in the validation, on one will doubt its importance. Such part must be given in the submitting of the article. There is no doubt that the experimental data is the core of the article, this topic must be given in the submitting phase.
Figure	Time dependent figure of the quantities measured by the instrumentations. Figures should be classified by the instrumentation types or physical quantities, and each figure should be marked by the position. The time dependent figures can also express the experiment phenomena, the figures can be useful supplement for the above description. The Figures can be provided by some literature or made by the publishers. If the written description can be provided in the submitting, it is strongly recommend providing some figures as well. If there is no written description, figures are provided if there are some existing ones.
Video	Videos can express the experiment phenomena objectively. - Overview of the experiment facility - Preparation of the experiment - Detailed experiment phenomena Similarly, the video of the experiment phenomena can also be useful supplement for the written description. Where the videos about the experiment are available, publishers can submit them to the website.

In the user's interface, the experiment data should be given as following format:

Availability	…
Description	…
Data	File_001 download Figures_001 download Movies_001 download File_002 download Figures_002 download Movies_002 download ….. download all

The PDF file containing the information expect performed simulation will be given along with the experiment data file.

Performed simulation:

In this topic, some code validation examples are shown. For each example, the sub-topics should be as following:

Author	The people or agencies attended in the validation. Under the consideration of the user's privacy, this topic can be blank.
*Validation code	The code validated or verified by the experiment. If the validation code is very famous and the result is good enough, the reliability of the experiment data can be proved. The administrator has the right to decide which validation results can be given as example, the chosen ones should be as complete as possible. The validation code can be very critical factor for the selection of validation example.
Mathematical treatments	The mathematical methods used to make the data processing. For some experiments which provides large amount of data, the information in this sub-topics can be great help for the users who are not good at mathematics. Not all the experiment data requires further mathematical treatments, so the topic can be kept blank in the submitting phase.
*Setting of domain	The setting of the computational domain in this validation,

	including - Grid structure and resolution - Construction of the geometry - Initial condition - Establishment of the boundary conditions - Properties of the physical boundary - Figures of the domain All these information can be provided in a table. As example, the methodology used in the numerical simulation is very important. For the other users such information can help saving large amount of working efforts. The purpose of providing examples is to guide the user making their validation more efficient. Therefore, the results provided as example should have the information about the domain setting, or the results are not proper and should be rejected.
*Validation Models	The numerical models validated or verified by the experiment data. The example should be as complete as possible and the validation models are critical information for the users, so the sub-topic should not be empty.
*Validation results	The validation results, including: - Figures - Conclusion Comparison with the experiment data is the best proof for the quality of the experiment data. The results also show the other users the validation criteria. The validation example should have the validation result and conclusion, or the administrator can reject it.

In the user's interface, each simulation example is given by a individual table. As shown in following:

Performed simulation 01:

Author	...
*Validation code	...
Mathematical treatments	...
*Setting of domain	...
*Validation Models	...

*Validation results	…
	download

Performed simulation 02:

Author	…
*Validation code	…
Mathematical treatments	…
*Setting of domain	…
*Validation Models	…
*Validation results	…
	download

…

References:

*References about the experiment from the participants	The reports and papers published by the experiment participants, including: - Reports or papers about the experiment - Analysis for the experiment - Validation made by the experiment participants For the users who need more detailed illustration of the experiment, the references are important. At least the source of the data should be provided.
References about the experiment from the third party	The reports and papers published by third party related to the experiment, including: - Reports or papers about the repeatability of the experiment - Analysis for the experiment - Validation made by the third party The Validation works or repeat experiments made by the third party are good evaluation for the experiment data. It is quit recommended to have this sub-topic in the article. If no such information is available the topic can be kept blank. Latter, if some validation works are done based on the experiment, information can be added by the administrators.

Comments:

Inside the topic some comments from the users are listed, the comments can be displayed by time.

Remark:

**): The mark means the topics must be contained in the article, without the topics the validation is impossible.

*): The mark means the information contained in the topics can assist the validation, it is better to have such topics.

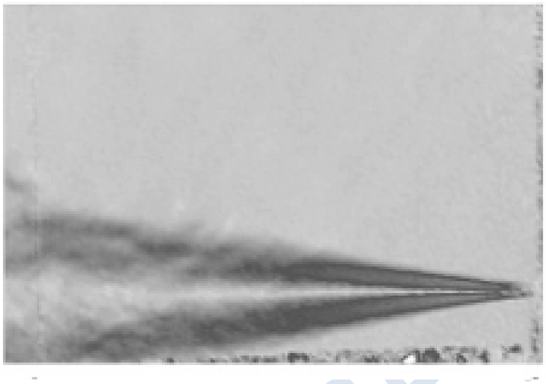
Black words: the name of the topic and what should be included in the topic.

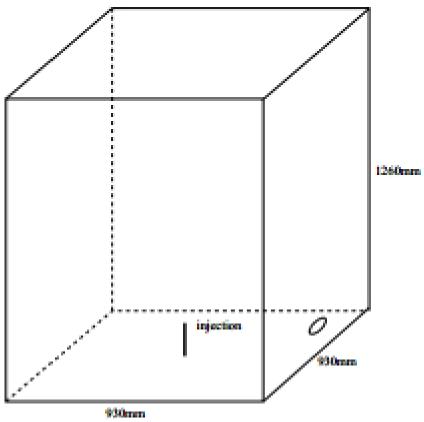
Red words: the reason why such information should be given on the website and provided to the readers (users).

Blue words: the necessity of the topic and if the topic can be remained blank in the submitting phase.

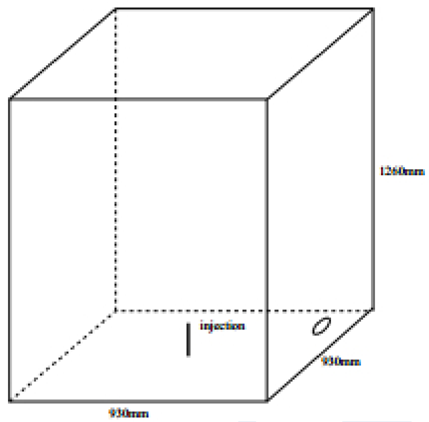
Appendix II

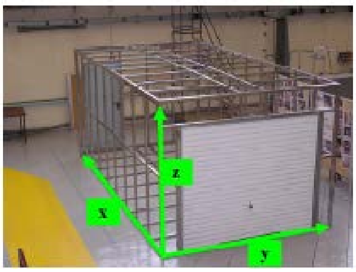
In this appendix, summary of all the experiments on the website are given.

Experiment Name	Low Temperature Jet
Experiment Type	Release
Keywords	Release, Low Temperature, High Pressure,
Draft drawing or simple description for the facility	
Short description	Horizontal hydrogen jets released at different temperatures and different pressure.

Experiment Name	Gamelan_300NL
Experiment Type	Dispersion
Keywords	Dispersion, Venting, Helium
Draft drawing or simple description for the facility	
Short description	Validation experiments were carried out at CEA in the enclosure with sizes *HxWxL*=1.26x0.93x0.93 m with one vent located on a wall. Vents were located at a wall opposite to that where sensors are located. The release of helium was directed vertically upward from a pipe with internal diameter 20 mm

	located 21 cm above the centre of the floor.

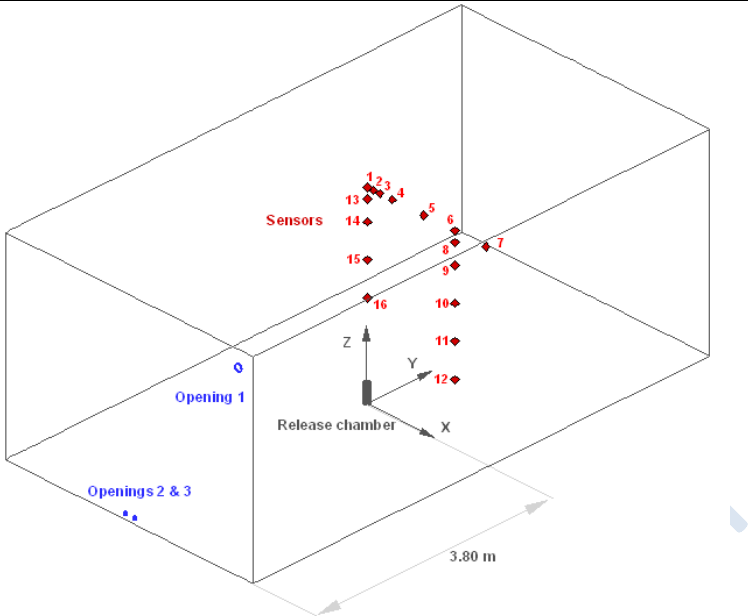
Experiment Name	Gamelan_180NL
Experiment Type	Dispersion
Keywords	Dispersion, Venting, Helium
Draft drawing or simple description for the facility	
Short description	Validation experiments were carried out at CEA in the enclosure with sizes *HxWxL*=1.26x0.93x0.93 m with one vent located on a wall. Vents were located at a wall opposite to that where sensors are located. The release of helium was directed vertically upward from a pipe with internal diameter 5 mm located 21 cm above the centre of the floor.

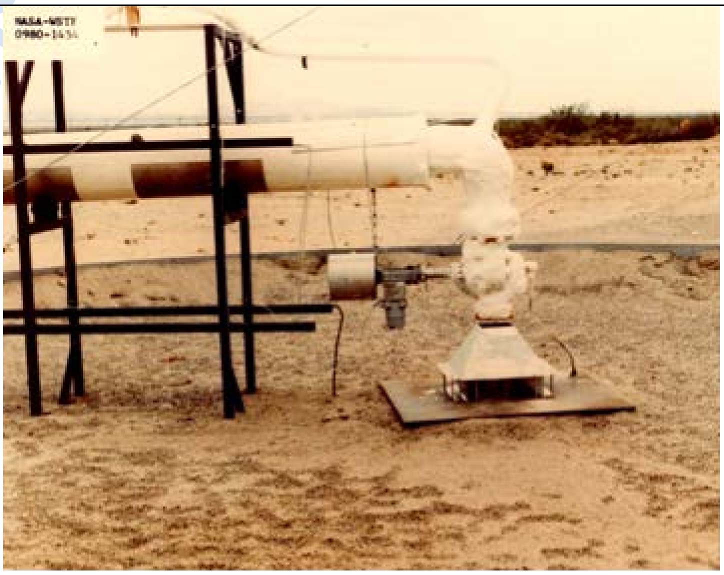
Experiment Name	SPEB_V21
Experiment Type	Dispersion
Keywords	Dispersion, large-scaled experiment, Helium
Draft drawing or simple description for the facility	 
Short description	The GARAGE facility is representative of a realistic single vehicle private garage. The GARAGE facility is situated indoors to attenuate the variations in meteorological conditions. The internal volume of GARAGE is 40.92 m^3. Continuous injection of

	helium is installed in this big volume GARAGE.

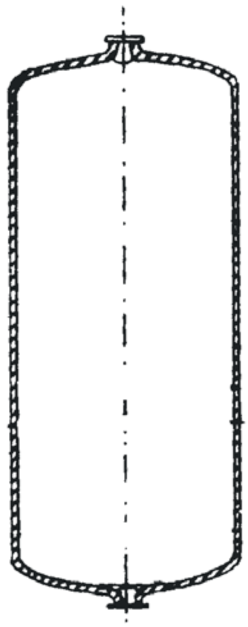
Experiment Name	GEXCON
Experiment Type	Dispersion
Keywords	Jet, Dispersion, Obstacles, Venting
Draft drawing or simple description for the facility	
Short description	The experimental rig consists of a 1.20 m x 0.20 m x 0.90 m vessel, divided into compartments by use of 4 baffle plates with dimensions 0.30 m x 0.20 m. There is one vent opening at the wall opposite the release location centrally located. Different installations of the plates and nozzle diameters are used in the test.

Experiment Name	INERIS-6
Experiment Type	Dispersion
Keywords	Dispersion, Small Inflow, Large Volume, Venting

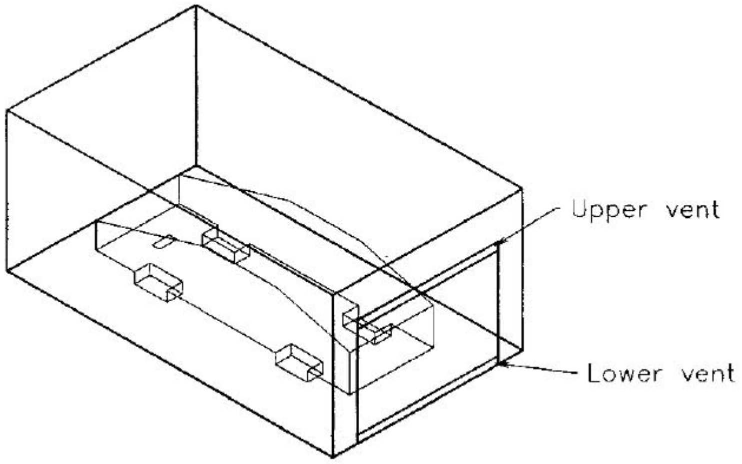
Draft drawing or simple description for the facility	
Short description	The experiment INERIS-TEST-6C, performed within the InsHyde project by INERIS, consisting of a 1 g/s vertical hydrogen release for 240 s from an orifice of 20mm diameter into a rectangular room (garage) of dimensions 3.78 X 7.2 X 2.88m in width, length and height respectively. Two small openings at the bottom of the front side of the room assured constant pressure conditions.

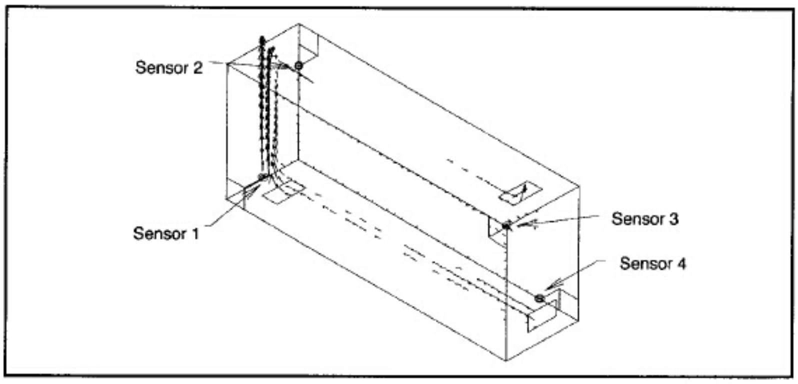
Experiment Name	NASA-6C
Experiment Type	Dispersion
Keywords	Liquid Hydrogen, Dispersion, Wind, Open Atmosphere
Draft drawing or simple description for the facility	

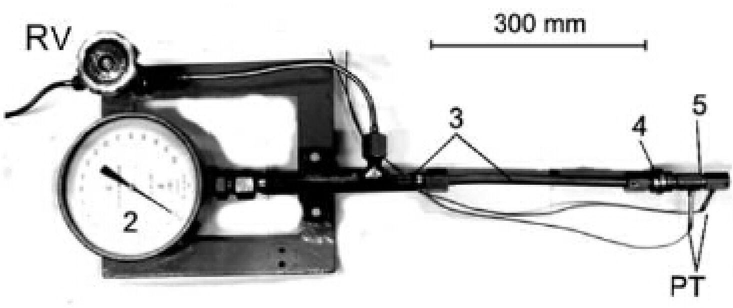
Short description	The experiments consisted of ground spills of up to 5.7 m3 of liquid hydrogen (402 kg), with spill durations of approximately 35 seconds. Instrumented towers located downwind of the spill site gathered data on the temperature, hydrogen concentration and turbulence levels.

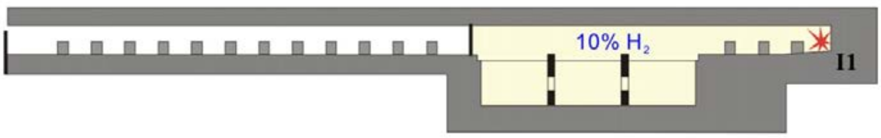
Experiment Name	SBEP_1_WP8
Experiment Type	Dispersion
Keywords	Dispersion, Subsonic Release, Closed Vessel
Draft drawing or simple description for the facility	
Short description	A subsonic release of hydrogen in a closed vessel with height 5.5 m, diameter 2.2 m and volume 20 m^3. Then the concentrations of hydrogen are detected by 6 sensors installed at the central line of the vessel.

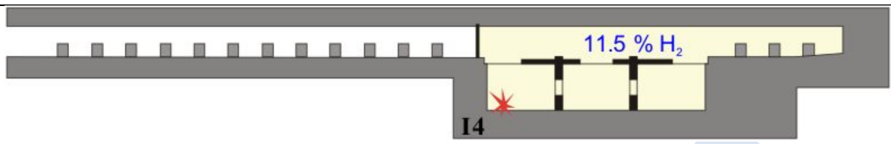
Experiment Name	SWAIN_GARAGE
Experiment Type	Dispersion
Keywords	Dispersion, Helium, Complicated Geometry, Venting

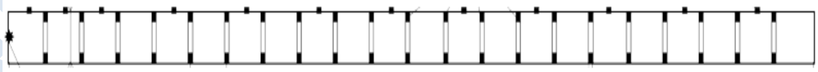
Draft drawing or simple description for the facility	
Short description	The experimental facility represents a full-scale single car garage with dimensions 6.4 X 3.7 X 2.8 m and two vents on the door. Vent openings with varying height were examined. A full-scale plywood model vehicle was placed inside the garage. The helium flow rate was 7200 l/h and the release lasted 2 h.

Experiment Name	SWAIN_HALLWAY
Experiment Type	Dispersion
Keywords	Dispersion, Confined Volume, Venting
Draft drawing or simple description for the facility	
Short description	In the vented hallway experiment, the hydrogen leaks from the floor at the left end of a hallway with the dimension of 2.9 m × 0.74 m ×1.22 m. At the right end of the hallway, there are a roof vent and a lower door vent for the gas ventilation. The hydrogen leak is at 2 SCFM (Standard Cubic Feet per Minute) and for a period of 20 minutes.

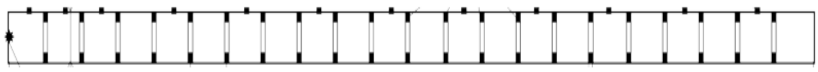
Experiment Name	PRD
Experiment Type	Ignition
Keywords	Auto Ignition, High Pressure Release,
Draft drawing or simple description for the facility	
Short description	In order to investigate the spontaneous of hydrogen, the pressurized tube with a T shaped pressure relief devices were used. In the experiment, the tube was filled with different pressure to investigate the relation between the pressure and ignition.

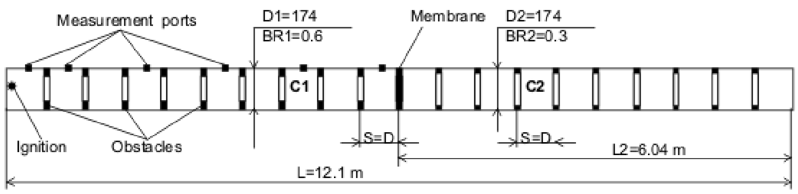
Experiment Name	HYCOM-HYC01
Experiment Type	Deflagration
Keywords	Deflagration, Large-scale Complex Geometry, Obstacles, Flame Acceleration
Draft drawing or simple description for the facility	
Short description	Combustion experiments have been carried out in large scale multi-compartment geometry consisted of curved channel and canyon. Four repeatable obstacles with blockage ratio BR=0.3 installed in the channel and two obstacles in bottom part of canyon. Uniform hydrogen/air mixture with concentration of 10% H_2 was tested.

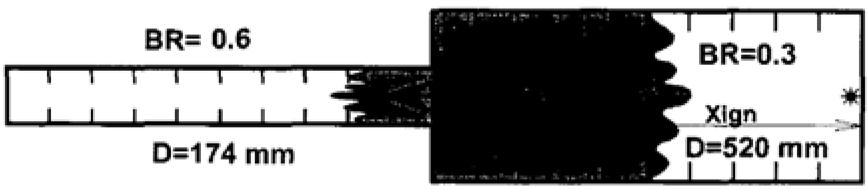
Experiment Name	HYCOM-HYC14
Experiment Type	Deflagration
Keywords	Deflagration, Large-scale Complex Geometry, Obstacles, Flame Acceleration
Draft drawing or simple description for the facility	
Short description	Combustion experiments have been carried out in large scale multi-compartment geometry consisted of curved channel and canyon. Four repeatable obstacles with blockage ratio BR=0.3 installed in the channel. Canyon has been divided in four separate rooms connected with orifices. Uniform hydrogen/air mixture with concentration of 11.5% H_2 was tested.

Experiment Name	HYCOM-MC03
Experiment Type	Deflagration
Keywords	Deflagration, Obstacles, Quenching, Closed Tube
Draft drawing or simple description for the facility	
Short description	Combustion experiments have been carried out in obstructed tube of 174 mm in diameter and 12.2 m in length (DRIVER facility). Repeatable obstacles with blockage ratio BR=0.6 at distances equal to diameter. Hydrogen/air mixture with concentration of 10% H_2 was tested.

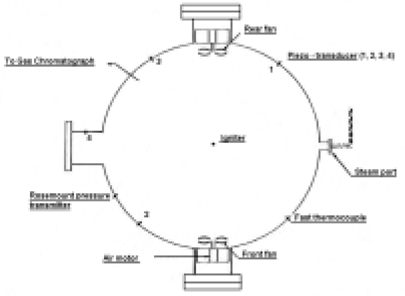
Experiment Name	HYCOM-MC12
Experiment Type	Deflagration
Keywords	Deflagration, Obstacles, Flame Acceleration, Closed Tube

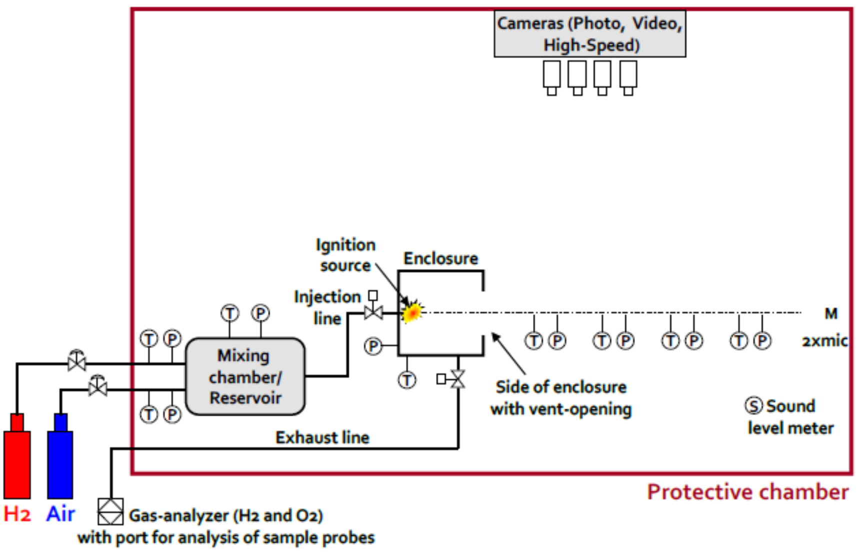
Draft drawing or simple description for the facility	
Short description	Combustion experiments have been carried out in obstructed tube of 174 mm in diameter and 12.2 m in length (DRIVER facility). Repeatable obstacles with blockage ratio BR=0.6 at distances equal to diameter. Hydrogen/air mixture with concentration of 13% H_2 was tested.

Experiment Name	HYCOM-MC43
Experiment Type	Deflagration
Keywords	Deflagration, Obstacles, None Uniform Hydrogen, Flame Acceleration
Draft drawing or simple description for the facility	
Short description	Combustion experiments have been carried out in obstructed tube of 174 mm in diameter and 12.1 m in length. Repeatable obstacles at distances equal to diameter. The experimental tube was divided in two equal parts by thin polyethylene membrane with different blockage ratios and hydrogen concentrations.

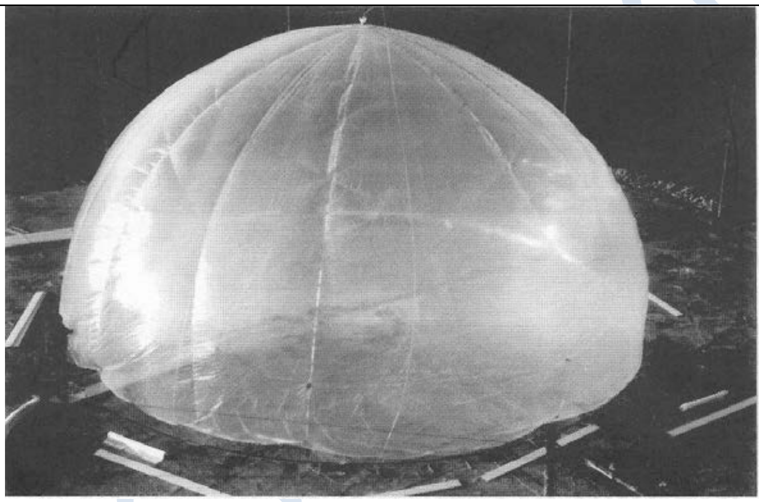
Experiment Name	HYCOM-HC20
Experiment Type	Deflagration
Keywords	Deflagration, Non-uniform Obstructed Tube,
Draft drawing or simple description for the facility	

Short description	Combustion experiments have been carried out in non-uniform obstructed tube of 12.4 m long combined of two parts with diameter of 174 and 520 mm in diameter. Combustion of uniform test mixture with 10% of H2 in air was investigated.

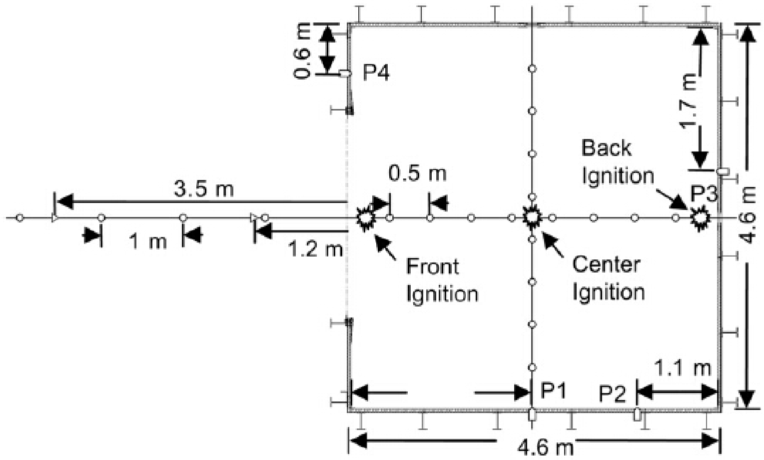
Experiment Name	Kumar1983
Experiment Type	Deflagration
Keywords	Deflagration, Uniform Hydrogen Air Mixture , Closed Environment
Draft drawing or simple description for the facility	
Short description	Deflagration of 29.5% (by vol.) hydrogen-air quiescent mixture in the 6.37 m3 closed spherical vessel (diameter 2.3 m). Central point ignition source. Initial temperature is 373 K, initial pressure 97 kPa.

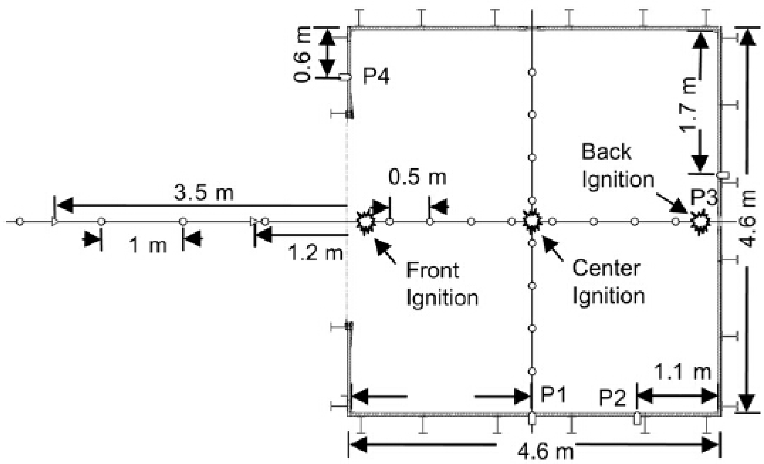
Experiment Name	HIWP3
Experiment Type	Deflagration
Keywords	Deflagration, Ignition, Venting, Small-scale
Draft drawing of the facility	

Short description	Hydrogen combustion experiments were made in 1 m^3 facility. In the experiments, 18%vol hydrogen-air mixture was prepared in the chamber, ignition points were installed on the rear plate and 50cmX50cm venting was made in the front plate of the cubic test facility.

Experiment Name	Open Deflagration
Experiment Type	Deflagration
Keywords	Deflagration, Large-scale, Open environment
Draft drawing or simple description for the facility	
Short description	Deflagration of large-scale (initial radius 10 m) hemispherical stoichiometric hydrogen-air mixture in open atmosphere ignited at the centre of hemisphere.

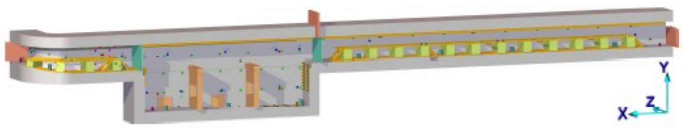
Experiment Name	Vent_Deflagration_center
Experiment Type	Deflagration
Keywords	Deflagration, Venting

Draft drawing or simple description for the facility	
Short description	The experiment facility has the size of 4.6X3X4.6 m. in experiment, 18.2% H2-Air mixture was filled homogenously inside the facility. On one side wall of the facility, a square size ventilation with the area of 5.4 m^2 is given. In the experiment, ignition point is given at the center of the facility, and then 4 pressure sensors and couples of thermal couples are used to record the experiment data.

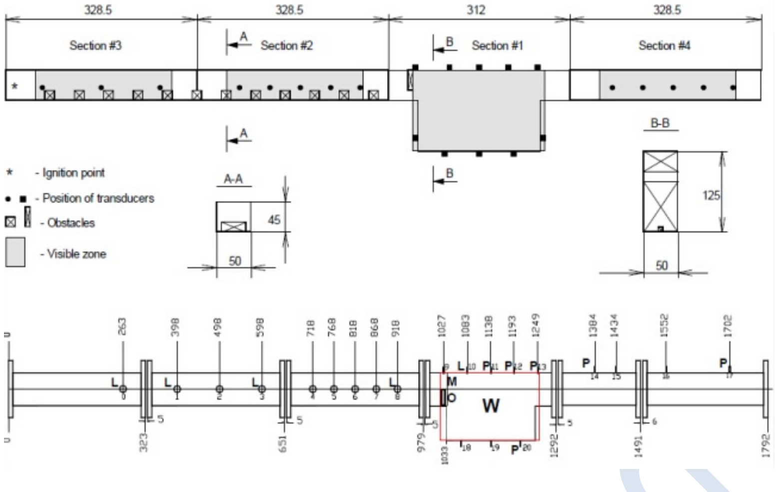
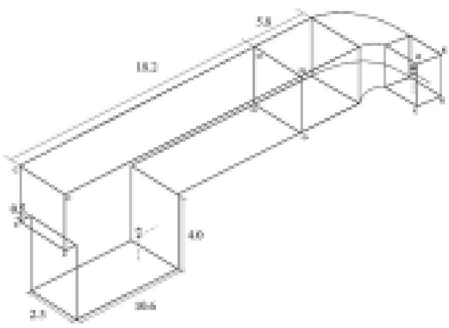
Experiment Name	Vent_Deflagration_back
Experiment Type	Deflagration
Keywords	Deflagration, Venting
Draft drawing or simple description for the facility	
Short description	The experiment facility has the size of 4.6X3X4.6 m. in experiment, 18.2% H2-Air mixture was filled homogenously inside the facility. On one side wall of the facility, a square size ventilation with the area of 5.4 m^2 is given. In the experiment, ignition point is given at the center of back wall, and then 4

	pressure sensors and couples of thermal couples are used to record the experiment data.

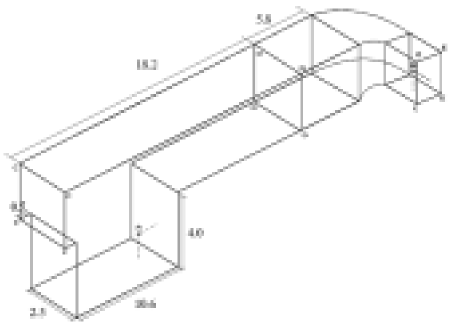
Experiment Name	FZK-R 049809
Experiment Type	DDT
Keywords	DDT, Flame Acceleration, Obstacles, Closed Tube
Draft drawing or simple description for the facility	
Short description	Combustion experiments have been carried out in obstructed tube of 350 mm in diameter and 12 m in length. Repeatable obstacles with blockage ratio BR=0.3 at distances 500mm. Hydrogen/air mixture with concentration of 15% H_2 was tested.

Experiment Name	DDT_RUT
Experiment Type	DDT
Keywords	DDT, Flame Acceleration, Obstacles, Complex Geometry
Draft drawing or simple description for the facility	
Short description	Investigation of flame acceleration and DDT were given in the RUT facility. In the experiments, hydrogen-air-steam mixtures with different concentrations are given to test of the criteria of DDT.

Experiment Name	DDT_MINIRUT
Experiment Type	DDT
Keywords	DDT, Flame Acceleration, Obstacles

Draft drawing or simple description for the facility	
Short description	Investigation of flame acceleration and DDT were given in the scale-down MINIRUT facility. In the experiments, hydrogen-air mixtures with different concentrations are given to make the test.
Experiment Name	KI-RUT-Hyd05
Experiment Type	Detonation
Keywords	Detonation, Large-scale, Complex Geometry
Draft drawing or simple description for the facility	
Short description	Detonation experiments have been carried out in large scale confined complex geometry (263 m^3). Uniform hydrogen/air mixture with concentration of 20.0% H_2 was tested.

Experiment Name	KI-RUT-Hyd09
Experiment Type	Detonation
Keywords	Detonation, Large-scale, Complex Geometry

Draft drawing or simple description for the facility	
Short description	Detonation experiments have been carried out in large scale confined complex geometry (263 m^3). Uniform hydrogen/air mixture with concentration of 25.5% H_2 was tested. Ignition in the channel (B).