SIXTH FRAMEWORK PROGRAMME
NETWORK OF EXCELLENCE

HYSAFE

Safety of Hydrogen as an Energy Carrier

Contract no.: 502630

Compilation of descriptions of experimental facilities
Deliverable 9 (WP 2)

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SUMMARY

The main goal of the activity Integration of Experimental Facilities (IEF) is the creation of a set of specialised research facilities for jointly define, rank and perform test series related to the thematic structure of the network.

Preparing the progression into a set of complementary specialised research facilities the partners have provided unified detailed descriptions of the facilities available. This compilation of 78 facility descriptions is intended to serve as a starting point for the integrating process that will include

- identifying the best expertise of the partners,
- identifying gaps and the need of further partners,
- enabling the promotion of improvement of the experimental possibilities,
- implementing common quality standards.

The facility descriptions will be published in a modified version on the HySafe-Website as well.

D9 – Compilation of descriptions of experimental facilities

CONTENTS

1 Introduction

Integration of Experimental Facilities (IEF) is one of the integrating activities within the network HySafe aiming at the integration of experience and knowledge on hydrogen safety in Europe as well as at the integration and harmonisation of the fragmented research base. The creation of a set of specialised research facilities is the main goal of IEF in order to enable the network for jointly define, rank and perform test series. Research facilities are needed for investigation of relevant phenomena, for testing devices and concepts as well as for validation of numerical models.

The main task of WP2 during the first 18 months of the network is to prepare the basis for future integration of the experimental possibilities of the partners. As a first step, the partners have prepared detailed descriptions of the facilities available for carrying out specific tests and experiments related to the thematic structure of the network. The unified format as described in Deliverable D5 has been used. This compilation is intended to be the first step to a better knowledge of each other and will also assist WP7 work.

2 Unified format for the facility descriptions

In order to provide an overview of the experimental possibilities of the partners, a unified format for the descriptions of the experimental facilities has been developed as documented in deliverable D5. The document is divided into the sections

- Overview,
- Technical details,
- Experiments – Equipment,
- Information for the preparation of integration.

Table 1 gives on the next pages an overview of the 78 facilities to be integrated in HySafe, demonstrating the great variety and the wide range of the experimental possibilities of the HySafe partners. The application fields correspond to the HySafe matrix

- H1 - Production,
- H2 - Transport and distribution, refuelling stations,
- H3 – Storing H2,
- H4 - Vehicles powered with H2 ,
- H5 - Tunnels, public parking and private garage,
- H6 - Utilisation, portable and stationary H2 based applications,

and

- V1 - Hydrogen release, mixing, and distribution,
- V2 - Fires, ignition and explosions,
- V3 - Mitigation techniques,
- V4 - Safety assessment and risk analysis,
- V5 - Standardisation and legal requirements.

Table 1: Experimental facilities of the HySafe partners

		Name	***Type***	***Scale***	***Experiments***	***Appl.Field***
BAM	BAM-1	Fire Testing Rig	open propane gas fire	full scale	test of the behaviour of pressurized or protective containers under fire load	H2-H5/ V1-V3
BAM	BAM-2	Open Air Test Site Horstwalde	open air test site	large scale	fire, drop, impact and other tests for flammable, pressurized or otherwise	H2-H6/ V1-V3
BAM	BAM-3	Hydraulic Cycling Equipment	-	full scale	investigation of pressure receptacles under pulsating pressure load	H2-H4/ V4-V5
BAM	BAM-4	Facility for testing and calibration of gas sensors	test gas mixture system and test chamber	laboratory scale	testing and calibration of gas sensors	H4-H6/ V1,V2,V4
BAM	BAM-5	Tribometers for oscill. (PT1) or sliding friction (CT2, CT3)	PT1, CT2, CT3	lab scale	friction and wear at elevated press. or at cryog. temperatures / in cryog. Liquids	H4/ V3-V4
CEA	CEA-1	MISTRA	cylindrical steel vessel	1/10th of PWR cont.	H2(He) release and distribution in confined geometry	H5/ V1
CEA	CEA-2	GAMEL (under construction, available in 2005)	cubic polycarbonate vessel	small scale	detailed studies of H2 (simulated by He) rel. and distr. in a 3D conf. geometry	H2-H5/ V1
Fh-ICT	ICT-1	Heatable high pressure vessel	vessel	small scale	decomposition and ignition induced by temperature increase and external ign.	V2
Fh-ICT	ICT-2	Device for flame jet ignition	cylindrical vessel with vent opening	large scale	flame jet ignition	V2
Fh-ICT	ICT-3	High pressure vessel with windows	1 litre high pressure vessel with windows	small scale	explosions with init. press. up to 3 MPa and time resolved spectroscopic meas.	V2
Fh-ICT	ICT-4	Test stand	closed test stand with blow-out option	full scale	multipurpose tests with energetic materials	V2
Fh-ICT	ICT-5	Testing area	open-air	full scale	explosions, tank testing, H2 release, ...	H3-H5/ V1, V2
Fh-ICT	ICT-6	Fast Online Spectroscopy	NIR to UV-VIS spectrometers	all scales	all kind of exp. where spectral radiation and temperatures must be acquired	-
Fh-ICT	ICT-7	Hydrogen Measurement System	fast 12-channel H2 concentration measurement	all scales	all kind of exp. where H2 concentrations must be observed with high time res.	-
Fh-ICT	ICT-8	3-axis Positioning System	programmable positioning system	all scales	all kind of experiments where position dependent data must be acquired	-
Fh-ICT	ICT-9	Gas Mixing Unit	remote controlled 4 gas mixing unit	all scales	all kind of exp. where well defined (H2) concentr. or mass flows are needed	-
FZJ	FZJ-1	REKO-1	flow reactor	small scale	H2 recombination under forced flow conditions	H5, V3

Table 1 (contd.): Experimental facilities of the HySafe partners

		Name	***Type***	***Scale***	***Experiments***	***Appl.Field***
FZJ	FZJ-2	REKO-2	pressure vessel	medium scale	H2 recombination	H5, V3
FZJ	FZJ-3	REKO-3	flow reactor	medium scale	H2 recombination under forced flow conditions	H5, V3
FZJ	FZJ-4	REKO-4 (under construction)	pressure vessel	medium scale	H2 recombination under natural flow conditions	H5, V3
FZK	FZK-1	A1 Vessel	cylindrical vessel	full/large scale	turbulent combustion and detonations, integrity of mechanical structures	H2-H5/ V1-V3
FZK	FZK-2	A3 Vessel	cylindrical vessel	full/large scale	turbulent combustion and detonations, vented explosions, H2 distribution	H2-H5/ V1-V3
FZK	FZK-3	A6 Vessel	cylindrical vessel	full/large scale	turbulent combustion and detonations, integrity of mechanical structures	H2-H5/ V1-V3
FZK	FZK-4	12 m detonation tube (DT)	cylindrical tube	medium scale	turbulent combustion, DDT and steady state detonations, chemical kinetic	H2-H5/ V1-V3
FZK	FZK-5	Flow Test Chamber (TC)	rectangular chamber	full/large scale	vented combustion and detonations; H2 distribution, testing of ventilation syst.	H2-H5/ V1-V3
FZK	FZK-6	Partially Vented Explosion Tube (PET)	cylindrical tube with variable opening	medium scale	vented explosions, turb. flame propag., flame acceleration and DDT	H2-H5/ V1-V3
GexCon	GC-1	168 m³ open geometry with internal obstructions	explosion vessel	large scale	explosions in open, congested geometries	V2,V3
GexCon	GC-2	1:3.2 scale offshore module	explosion vessel	large scale	vented explosions in realistic geometries	V1, V2, V3
GexCon	GC-3	Connected vessels	explosion vessel	small scale	explosions in vented vessel	V2,V3
GexCon	GC-4	6m channel	explosion vessel	large scale	vented explosions in idealised geometries	V1, V2, V3
GexCon	GC-5	50m³ tube	explosion vessel	large scale	dispersion/explosions in closed/vented vessel (tunnels)	H2, H5/ V1, V2, V3
GexCon	GC-6	1.2 m³ closed vessel	explosion vessel	small scale	explosions in closed vessel	V1, V2, V3
GexCon	GC-7	216 litre dispersion vessel	dispersion/explosion vessel	small scale	gas dispersion/homogeneity	V1
GexCon	GC-8	20 litre spray vessel	explosion vessel	small scale	explosions in closed vessel	V2, V3

Table 1 (contd.): Experimental facilities of the HySafe partners

		Name	***Type***	***Scale***	***Experiments***	***Appl.Field***
GexCon	GC-9	1.4 m channel	explosion vessel	small scale	vented explosions in idealised geometries	V2, V3
GexCon	GC-10	3D corner	explosion vessel	small/large scale	vented explosions in complex idealised geometries	V2, V3
HSE/HSL	HSL-1	Ventilated dispersion and explosion facility	modular vented enclosure with integrated ventilation	full scale	dispersion/ignition/explosion from high pressure releases into ventilation flow	H1-H6/ V1, V2
HSE/HSL	HSL-2	Gas dispersion facility	gas dispersion area	full scale	dispersion of flashiong liquid or gas (LPG, H2)	H1-H6/ V1, V2
HSE/HSL	HSL-3	Jet fire facility	LPG vapour jet fire facility	full scale	PFP material and components testing, Jet-Fire Resistance Test (JFRT)	H1-H6/ V1, V2
HSE/HSL	HSL-4	Hydrogen jet release facility	gas supply and pipe work to enable pressurised releases	full scale	ignited and unignited jet releases	H1-H6/ V1, V2
HSE/HSL	HSL-5	366m gallery/tunnel	concrete test enclosure/tunnel	full/large scale	combustion and ventilation controlled overpressures fragmentation	H4, H5/ V1, V2
HSE/HSL	HSL-6	Frictional ignition apparatus	ignition test facility with vented explosion vessel enclosure	full scale	frictional rubbing events in flammable atmospheres, spark and hot surface	H1-H6/ V1, V2
HSE/HSL	HSL-7	Impact test track	impact test facility	full scale	dynamic impact on components/tanks etc.	H1-H6/ V1, V2
INASMET	INA-1	SSRT equipment	autoclave+ tensile testing	lab scale	effect of hydrogen on the behaviour of materials - hydrogen embrittlement	H1-H6/ V3, V4, V5
INASMET	INA-2	NACE TM 01-77 testing equipment	corrosion cells + load applying rings	lab scale	effect of hydrogen on the behaviour of materials - hydrogen embrittlement	H1-H6/ V3, V4, V5
INASMET	INA-3	Fatigue testing equipment	Servohydraulic universal tensile testing machine	lab scale	effect of hydrogen on the behaviour of materials in fatigue – corrosion	H1-H6/ V3, V4, V5
INASMET	INA-4	LECO TCH 600	-	lab scale	chemical analysis of hydrogen in metals	H1-H6/ V3, V4, V5
INASMET	INA-5	SHS reactor	-	lab scale	metallic hydride production by SHS	H3
INERIS	INE-1	The “Basket”	large scale test area	large scale	rupturing of confinements and investigation of fracturing and missiles	H1-H6/ V2-V3
INERIS	INE-2	ISO-1 m³ chamber, Dust-gas explosion room (DG1m3)	vented or closed vessel	large scale	Kst and Kg meas., turbulence/mixing, flame propagation, safety device tests	H1-H3/ V1-V3
INERIS	INE-3	10 m³ chamber, Dust-gas explosion room (DG10m3)	vented vessel	large scale	turbulence/mixing, flame propagation, safety device tests	H1-H3/ V1-V3

Table 1 (contd.): Experimental facilities of the HySafe partners

		Name	***Type***	***Scale***	***Experiments***	***Appl.Field***
INERIS	INE-4	INERIS-100 m³ chamber, Dust-gas explosion room	vented vessel	large scale	turbulence/mixing, flame propagation, safety device tests	H1-H3, H5/ V1-V3
INERIS	INE-5	Flame Acceleration Pad (FAP)	pipes	large scale	flame propagation in tubes and pipes, vents and flame arrester testing	H1-H6/ V1-V3
INERIS	INE-6	Flexible Ignition Facilities (FIF)	small vessel with various igniters	small scale	characteristics of “practical” ignition sources, fundamentals of flame initiation	H1-H6/ V3-V4
INERIS	INE-7	High pressure-high tempera-ture-2 m³ sphere (HPT2m3)	closed vessel	large scale	flammable limits, auto-ignition delay, explos. param. (high press. and temp.)	H1-H4/ V1-V3
INERIS	INE-8	High press.-high temp. 500ml expl. chamber (HPT500ml)	closed vessel	small scale	max. press. meas. at very high press. and temperatures, ignition behaviour	H1-H4, H6/ V2-V3
INERIS	INE-9	Open Fire Area (OFA)	large scale test area	large scale	ignition and fire of gaseous jets and liquid pools	H1-H6/ V1-V3
INERIS	INE-10	Unconfined Cloud Area (UCA)	large scale test area	large scale	flammable gases and liquids releases from high press. tanks, unconfined expl.	H1-H6/ V1-V3
JRC	JRC-1	AMC Gas Reaction Controller	volumetric absorption measurement apparatus	lab scale	hydrogen storage material testing	H2, V5
JRC	JRC-2	Gravimetric analyser	gravimetric absorption measurement apparatus	lab scale	hydrogen storage material testing	H2, V5
JRC	JRC-3	SenTeF	environmental chamber for explosive/toxic gases	lab scale	sensors performance testing	H2, H4, H5/ V3, V5
JRC	JRC-4	SYSAF bunker	N2-inertised room with pressure vessels	small/full scale	high-pressure cycling and permeation measurements on compressed H2/CH4	H2-V4, H3-V4, H3-V5
TNO	TNO-1	1 litre vessel	closed bomb	lab scale	measure explosion limits and ignition temperatures and energies	H1-H6/ V2, V4, V5
TNO	TNO-2	20 litre vessel	closed bomb	lab scale	measure explosion limits and ignition temperatures and energies	H1-H6/ V2, V4, V5
TNO	TNO-3	500 litre vessel	closed bomb	lab/pilot scale	measure explosion limits and ignition temperatures and energies	H1-H6/ V2- V5
TNO	TNO-4	1 m³ vessels	vessel (closed bomb)	small scale	closed bomb experiments with high initial press. and linked vessels	H1-H6/ V2- V5
TNO	TNO-5	5 m³ vessel	vessel (closed bomb)	medium scale	test of equipment and protective systems for use in explosive atmosph.	H1-H6/ V2- V5
TNO	TNO-6	GEC	cubic shaped vessel	large scale	test constructions that can reduce or protect against explosion overpressures	H1-H6/ V1- V5

Table 1 (contd.): Experimental facilities of the HySafe partners

		Name	***Type***	***Scale***	***Experiments***	***Appl.Field***
TNO	TNO-7	IBBC Bunker	reinforced concrete bunker	large scale	vented gas explosions	H1-H6/ V1- V5
TNO	TNO-8	FAST	open air gas explosion facility	large scale	gas explosions in open air; flame propagation and blast wave experiments	H1-H6/ V1- V5
TNO	TNO-9	GEFEF	flow reactor	small scale	integrated studies on explosion control and process optimisation	H1, H4/ V4, V5
TNO	TNO-10	Small scale blast simulator	long tube	small scale	interaction of shockwaves with structures	H1-H6/ V2, V4, V5
TNO	TNO-11	Large scale blast simulator	long tube	medium scale	blast wave response in atmosphere	H1-H6/ V2, V4, V5
TNO	TNO-12	Laboratory for ballistic research (LBO)	internal firing ranges and a massive target bunker	medium scale	kinetic energy projectiles can be fired at targets	H1-H6/ V2, V4, V5
TNO	TNO-13	Test Facility 3 (TF3)	H2/O2 igniter test facility	full scale	testing small rocket motors, igniters, combustors etc. requiring H2 or O2	H2, H3, H6/ V2, V3
TNO	TNO-14	Large indoor rocket test stand	rocket test facility	full scale	testing large rocket motors etc. and activities like cobustion research etc.	H2, H3/ V2, V3
UNIPI	UP-1	CVE	vented room	large scale	vented explosions	V1, V3, V5
WUT	WUT-1	WUT Detonation Tube	square cross-section tube	lab scale	H2 fast deflagrations, detonations, DDT, explosion initiation, mitigation of	H1-H4/ V2,V3

3 Conclusions and further steps

Deliverable D9 finishes formally the tasks of the IEF activity for the first 18 months of the project. Next steps will be

- identifying the best expertise of the partners
- identifying gaps and the need of further partners
- enabling the promotion of improvement of the experimental possibilities
- implementing common quality standards.

Especially the results from the MPA activity as well as input from the vertical and horizontal JPA activities will be taken into account.

Furthermore, the facility descriptions will be published in the HySafe-Website in a modified version taking mainly into account the technical points.

Annex - Descriptions of experimental facilities

Partner: *BAM*

Facilities:
- *Fire Testing Rig*
- *Open Air Test Site Horstwalde*
- *Hydraulic Cycling Equipment*
- *Facility for testing and calibration of gas sensors*
- *Tribometers for oscillating (PT1) or sliding friction (CT2, CT3)*

Overview

Name	***Fire testing rig for tanks and other pressure vessels or other equipment for dangerous goods***
Type	*open propane gas fire*
Scale	*full scale*
Experiments	*test of the behaviour of pressurized or protective containers under fire load*
Application field	*H2-H5, V1-V3*

Technical details

Dimensions	*size of test object (max.): 8 m x 3 m x 3 m (LxWxH);* *mass of test object (max.): 100 t*
Temperatures	*1100 °C*
Fire Intensity	*adjustable from 50 to 110 kW/m² energy input, depending on test object size*
Fuel	*LPG*
Special features	*The flame configuration can be adapted to the test object in such a way that it is completely engulfed in flames. A wide variety of fire situation options can be simulated by means of fire intensity controls*

Experiments – Equipment

Experiments	*behaviour of pressure vessels and other appropriate objects in a hydrocarbon fire*
Instrumentation	*fire intensity and size can be adapted to the test object*
Schedule	*by agreement*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

Depends of the experiment

What kind of movable equipment is available and could be shared?

This test rig is not transportable at all; there is, however, a smaller movable rig especially for gas cylinders.

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Wood instead of propane fire

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Overview

Name	***Open Air Test Site Horstwalde***
Type	o*pen air test site*
Scale	*large scale*
Experiments	*fire, drop, impact and other tests for flammable, pressurized or otherwise dangerous goods or vessels containing them*
Application field	*H2-H6, V1-V3*

Technical details

Dimensions	*The whole test site is a territory which extends over ca. 12 km^2, with various test installations at different places. The most prominent feature is an explosion test site of 400 m diameter (photo) which is equipped with an observation shelter and other basic infrastructure. The site is capable of fire and explosion tests up to an equivalent (NEQ) of 150 kg TNT.*
Special features	*It is difficult to find a place which is remote enough for large scale experiments and has at the same time the infrastructure necessary for scientific work.*

Experiments – Equipment

Experiments	*The site is appropriate for almost any kind of experiment which fits into the given space. Among the tests performed regularly by BAM are fire tests with packages of explosives and other dangerous goods as required by transport law. A spectacular test done once involved firing a railway car filled with propane until it burst.*
Instrumentation	*Basic infrastructure is provided. Experimentators are required to bring their specific scientific instrumentation with them.*
Schedule	*on agreement*
Further particulars	*The test site is close to the village of Horstwalde which is about 50 km south of Berlin.*

Information for the preparation of integration

- **Exchange of instruments and personnel**

How many persons are needed to prepare/conduct experiments?

Depends of the experiment

What kind of movable equipment is available and could be shared?

Basic fixed infrastructure is provided and can be used.

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  The facility will not be modified since it is already very flexible

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Overview

Name	***Hydraulic Cycling Equipment***
Type	-
Scale	*full scale*
Experiments	*investigation of pressure receptacles under pulsating pressure load*
Application field	*H2-H4, V4-V5*

Technical details

Dimensions	*test receptacles up to 4000 mm length and 800 m diameter*
Temperatures	*-60 … +90 °C*
Pressure	*between atmospheric and 1200 bar, up to 30 pressure cycles per minute, stroke volume up to 6 l*
Media	*test objects are filled with a water-glycole mixture*
Special features	*unique in Europe*

Experiments – Equipment

Experiments	*Pressure receptacles are subjected to cyclic pressure load as required by the user of the regulation. Life time assessment or fatigue strength can be observed. Both metallic and composite receptacles can be tested.*
Level of detail	*pressure deviation ±10 bar at a test pressure of 1200 bar*
Instrumentation	*pressure, temperature, volume change*
Schedule	*by agreement*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  For test preparation and start depending on the experiment; test can run automatically part of the time.

  What kind of movable equipment is available and could be shared?

  none

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Overview

Name	***Facility for testing and calibration of gas sensors***
Type	*test gas mixture system and test chamber*
Scale	*laboratory scale*
Experiments	*testing and calibration of gas sensors*
Application field	*H4-H6, V1,V2,V4*

Technical details

Dimensions	*Facility: approx. 2.0 x 1.0 x 0.8 meters* *Test chamber approx. 2.5 litres volume* *These test chambers are equipped with five (or up to ten) sensors of different types and provide for measurement of gas temperature between –40 °C +180 °C. Two test chambers have been developed, optimised for a small and a larger volume, respectively, and accurately defined gas flow.*
Temperatures	*- 40 to +180 °C*
Pressure	*Test chamber 0.8 to 1.3 bar*
Media	*hydrogen, air, water vapour and up to 3 other gases (e.g.CO_2, SO_2, NH_3, propane…) and up to 2 other vapours (e.g. ethanol, isooctane)*
Special features	*Reliable and accredited method by using certified gas mixtures and calibrated electrical measuring devices. A sophisticated gas handling and control systems allows simulating real ambient conditions (complex gas mixtures, humidity, altitudes,) designed in view of testing and calibrating sensors.*
Further particulars	*Gas sensors are calibrated and tested using a test system where test gas mixtures of defined composition are generated dynamically from appropriate parent gases in cylinders. These test gas mixtures are transferred into test chambers containing the sensors under investigation. The gas blending system provides for continuous variation of mixture composition, including humidification, at a high dynamic range). Gas blending is performed using mass-flow controllers (MFC), which control four different gas streams. The blending process and the resulting composition are regulated by varying the gas flow through the MFC's. The system is able to generate gas mixtures containing up to four components, an inert carrier gas (synthetic air or nitrogen) and humidity. A personal computer controls all parts of the system via an IEEE-bus net.*

Experiments – Equipment

Experiments

Assessment of hydrogen sensors performance with respect to:

- *sensitivity to target gas*
- *influence of temperature, humidity and altitude*
- *cross sensitivity to other gases/vapours*
- *aging and reproducibility*

Level of detail -

Instrumentation *Gas sensors are tested and calibrated using test gas mixtures of defined composition and humidity generated dynamically from appropriate parent gases or by permeation. The gas mixtures generated are analysed using a chilled mirror hygrometer, a gas chromatograph and a quadrupole mass-spectrometer to check the accuracy of the pre-determined mixture composition and its humidity.*

Gas system	
Flow control	thermic mass flow controller
Number of gas components	maximum 4
Gas dilution	1:1 to 1:1000
Total gas flow	maximum 1l/min
Humidity	-80 to +80°C (t_d) 0,1 to 100% r.h.
Data acquisition	
Measurand	Impedance, capacity, resistance, phase angle, dielectric loss
Frequency range	100 Hz to 40 MHz
Number of sensors	5 internal, 5 external
Sensor chamber thermostat to:	-40 to +180°C, ±0,3 K

Schedule *The facility is in operation, the time needed for preparation of experiments will be about 1 to 3 day, the time needed for conduction of experiments will depend on the test. The sensors output data will be collected and visualised in real time and recorded on general laboratory software platforms (LabView, Excel)*

Tools *general laboratory software, LabView, Excel*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  To prepare/conduct experiments 2 persons are needed

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  The system has been designed in view of the follow major upgrades:

  - *sensor response time*
  - *sensitivity, aging, reproducibility*
  - *reaction to sudden changes of environment (temperature, humidity, gases)*
  - *calibration of gas sensors*

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  BAM is highly interested in co-operating with both manufacturers and users, to help developing a unified procedure for testing the hydrogen sensors performance in a controlled environment. BAM can provide assistance to companies developing safety sensors in meeting the performance requirements demanded by users.

  Which additional equipment could enhance your results?

  The equipment is integrated in multipurpose laboratory of BAM.

Overview

Name	***Tribometers for oscillating (PT1) or sliding friction (CT2, CT3)***
Type	*PT1, CT2, CT3*
Scale	*lab scale*
Experiments	*friction and wear at elevated pressures or at cryogenic temperatures and in cryogenic liquids, including hydrogen*
Application field	*H4, V3-V4*

Technical details

Dimensions	*samples up to ca. 10 cm diameter*
Temperatures	*ambient (PT1); between ambient and 4 K (CT2, CT3)*
Pressure	10^{-6} … ambient (CT2, CT3), … 20 bar (PT1)
Media	*liquid or gaseous helium, hydrogen, or nitrogen; gaseous methane (PT1)*
Special features	*frequency: 0,1 to 20 Hz, stroke : 0,1 500 mic; normal forces between 1 and 20 N (PT1)* *up to 3000 rotations per minute with a relative velocity of up to 6 m/s; normal forces between 5 N and 500 kN (CT2, 3)*

Experiments – Equipment

Experiments	*Selected pairs of material are investigated for their behaviour under oscillating (PT1) or sliding (CT2, CT3) friction by moving one partner against the other (pin on disk). Tests of the performance and lifetime of axial bearings*
Instrumentation	*force, displacement, pressure, temperature, sample investigation after test*
Schedule	*by agreement*

Information for the preparation of integration

- **Exchange of instruments and personnel**

How many persons are needed to prepare/conduct experiments?

Depends on the experiment, normally 1 (PT1) or 2 (CT2, CT3)

What kind of movable equipment is available and could be shared?

none

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  PT1: pressures up to 100 bar

  CT2, CT3: The cryostat can be used for any experiment which fits in

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Partner: *CEA*

Facilities: *- MISTRA*
- GAMEL

Overview

Name	***MISTRA***
Type	*cylindrical steel vessel*
Scale	*originally designed as 1/10th in linear scale of Pressurized Water Reactor containment*
Experiments	*studies of H2 (simulated by He) release and distribution in a confined geometry*
Application field	*H5 (tunnels, parking, garage)* *V1 (hydrogen release, mixing and distribution)*

Technical details

Dimensions	*7m high, 4m diameter, 100m³*
Temperatures	*Inner walls (water circuit) may be set at temperatures up to 140°C (controlled within 1°C). The injected helium gas (to represent hydrogen) may be heated (up to 200°C) to increase buoyancy effects.*
Pressure	*Design pressure = 6 bars*
Media	*Air and helium.*
Special features	*Large scale, with 3D spatial instrumentation (thermocouples, gas sampling points, LDV at several locations) to study helium release in jet or plume regimes in confined or semi-confined (with opening of the facility) geometry. Data suitable for CFD code validation. As of end of 2004, compartments will be installed inside the facility to study H2 distribution in a complex geometry.*
Further particulars	*The facility is mainly used in the framework of containment thermal-hydraulics and hydrogen risk for Pressurized Water Reactors. As such, it also contains a steam injection line, condensate collectors and a spray system.*

Experiments - Equipment

Experiments	*Helium distribution tests (axisymmetric configuration, performed in 1999-2000). New tests (3D configuration) scheduled in 2004.*	
Level of detail	*Gas concentration measurements, velocity measurements using LDV, vane wheels or hot wire anemometry. Spatial resolution about 0.5m in horizontal and vertical directions.*	
Instrumentation	*Gas temperature*	*Thermocouples*
	Pressure	
	Gas composition	*Simultaneous sampling and analysis by mass spectrometry*

	Velocity	*LDV (on different radii), PIV, hot wire anemometry, vane wheels*
Schedule	*Tests are generally conducted within one day. Post-processing of results within one week.*	
Tools	*Post-processing of results using MATLAB*	
	CFD analyses have been performed using the CAST3M code of CEA (Boussinesq model, Low Mach number model, k-ε model or mixing length)	
Further particulars	-	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  3

  What kind of movable equipment is available and could be shared?

  LDV bench, mass spectrometry. Sharing of equipment is possible but needs to be approved internally by CEA.

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  A more powerful PIV system with a larger frame would allow to have a more complete picture of the velocity field in the containment. (the current PIV system is limited to a small frame of about 20cm length).

  Non-intrusive optical techniques to measure concentrations could be investigated and compared to measurements using sampling and mass spectrography.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Good control of initial and boundary conditions for study of H2 release and distribution in confined geometry. Compartments will add geometric complexity. The instrumentation yields data suitable for CFD code validation.

  Which additional equipment could enhance the results of your experiments?

  Better velocity measurements using a more powerful PIV system. Alternative measurement systems for concentration measurements to improve transient analysis (faster sampling and analysis).

Overview

Name	***GAMEL** (under construction, available in 2005)*
Type	*cubic polycarbonate vessel*
Scale	*small scale*
Experiments	*detailed studies of H2 (simulated by He) release and distribution in a 3D confined geometry*
Application field	*H2-H5, V1*

Technical details

Dimensions	*1 m³ vessel (0.91x0.91x1.22)*
Temperatures	test at *normal temperature*
Pressure	*test at normal pressure*
Media	*air, helium, nitrogen, and others gas*
Special features	*idealised geometry and transparent for optical diagnostics*
Further particulars	-

Experiments - Equipment

Experiments	*This small vessel is designed for detailed analytical studies of flow distribution and various gas mixtures. This facility will be available in the first semester of 2005.*	
Level of detail	*Gas concentration measurements (mass spectrometry or gas chromatography)*	
	Velocity, turbulence characterisation by LDA (Laser Doppler Anemometry), PIV (Particle Image Velocimetry) and hot wire anemometry. We want to use PLIF (Planar Laser-Induced Fluorescence) simultaneously to PIV diagnostic for concentration field and develop some new non-intrusive optical techniques like UV absorption spectrometry.	
Instrumentation	*gas temperature*	*thermocouples*
	pressure	*piezoelectric*
	gas composition	*mass spectrometer (and PLIF, UV spectroscopy)*
	velocity	*LDV, PIV, hot wire anemometry*

Schedule	*tests are generally conducted within one day and post-processing of result within one week*
Tools	*Post-processing of results using MATLAB*
	CFD analysis have been performed with using the CAST3M code of the CEA (Boussinesq model, Low Mach number model, k-ε model or mixing length)
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2

  What kind of movable equipment is available and could be shared?

  LDV bench, mass spectrometry. Sharing of equipment is possible but needs to be approved internally by CEA.

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  A more powerful PIV system with a larger frame would allow to have a more complete picture of the velocity field in the containment. (the current PIV system is limited to a small frame of about 20cm length).

  Non-intrusive optical techniques to measure concentrations could be investigated and compared to measurements using sampling and mass spectrography.

- **To prepare promotion and specialisation**

  Which features/possibilities would you like to promote?

  Non-intrusive optical diagnostic

  Which additional equipment could enhance the results of your experiments?

  -

Partner: *Fh-ICT*

Fraunhofer Institut Chemische Technologie

Facilities:
- *Heatable high pressure vessel*
- *Device for flame jet ignition*
- *High pressure vessel with windows*
- *Test stand*
- *Testing area*
- *Fast Online Spectroscopy*
- *Hydrogen Measurement System*
- *3-axis Positioning System*
- *Gas Mixing Unit*

Overview

Name	***Heatable high pressure vessel***
Type	*vessel*
Scale	*small scale*
Experiments	*studies on decomposition and ignition induced by temperature increase and external ignition*
Application field	*V2*

Technical details

Dimensions	*20.6 cm³ vessel, spherical volume* *38.6 cm³ vessel in a tube like modification*
Temperatures	*heatable from 20 °C up to 500 °C*
Pressure	*static pressures up to 100 MPa, short pressure peaks up to 600 MPa*
Media	*hydrogen, air, nitrogen, non corrosive gases, solids*
Special features	*isothermal and non-isothermal experiments are enabled in a wide pressure and temperature range (up to 100 MPa and 500 °C)* *the system is able to withstand pressure peaks and therefore even explosion like reactions*
Description	*The system consists of 2 stainless steel chamber parts which are closed by an hydraulic system. The system is therefore statically leak tight up to 100 MPa and withstands short pressure peaks up to 600 MPa. It is heated by heating coils. Operation temperature range is from 20 °C up to 500 °C. Data acquisition and appropriate sensors enable measurements of long time duration (hours) and simultaneously deliver information of short time pressure changes (up to 40 MHz acquisition rate) caused e.g. by self-ignition.*

Experiments - Equipment

Experiments	*The test system enables measurements of the profiles and absolute values of pressure increase depending on temperature (isothermal and non-isothermal) in a wide pressure and temperature range (up to 100 MPa and 500 °C !). The system withstands pressure peaks and therefore even explosion like reactions. Ignition of pressurized gas mixtures in the high pressure and temperature regime have been investigated. Decomposition studies have been conducted.*
Level of detail	-

Instrumentation	*thermocouples* *pressure sensors*
Schedule	*heating experiments with different heating rates are possible, these experiments have a duration (depending on the heating rate) of 1 day* *the number of ignition experiments in the high pressure regime during one day depend on the selected temperature profile*
Tools	*high speed data acquisition*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2

  What kind of movable equipment is available and could be shared?

  none

Overview

Name	***Device for flame jet ignition***
Type	*cylindrical vessel with vent opening*
Scale	*large scale*
Experiments	*studies on flame jet ignition*
Application field	*V2*

Technical details

Dimensions	*9.35m^3 vessel; total length 4.8m; outer dia: 1.6m; length of cylindrical part: 4.35m; wall thickness: 5mm; max static overpressure: 2bars; front side openings: ½, ¼, 1/8 of total front area*
Temperatures	-
Pressure	*static overpressure max. 2 bars*
Media	-
Special features	-

Experiments - Equipment

Experiments	*Vessel could be used for flame jet ignition of hydrogen-air mixtures located adjacent to the vessel opening; flame jet is generated by ignition of a hydrogen-air-mixture within the vessel at its rear side and then emerging from the vessel opening.*
Level of detail	-
Instrumentation	*pressure; gas composition; flame speed*
Schedule	-
Tools	-

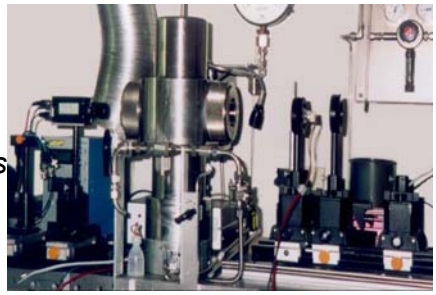
Information for the preparation of integration

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  See above; additionally, the interaction of the flame jet with an obstacle located within the cloud outside of the vessel is possible: the obstacle is a 3 dimensional array of pipework, consisting of single cruciform plastic parts: Outer dim. of obstacle: 4x4x2 m^3; volume blockage: 10%.

Overview



Name	***High pressure vessel with windows***
Type	*1 litre high pressure vessel with windows*
Scale	*small scale*
Experiments	*Hydrogen-Air-explosions with initial pressures up to 3 MPa and time resolved spectroscopic measurements in the UV (OH-bands) and the NIR (water bands) and pressure measurement*
Application field	*V2*

Technical details

Dimensions	*1 litre*
Temperatures	*-*
Pressure	*up to 3 MPa*
Media	*e.g. Hydrogen-Air (others possible)*
Description	*- piezoelectric pressure transducer* *- high-speed-camera up to 40.000 frames/s* *- Spectroscopy: - UV: Diode-Array, 300-330nm, 0.1nm, scan 10ms* *- NIR: AOTF-spectrometer 1-2.6ym, scan 1ms*

Experiments

Experiments	*Quantitative measurement of molecular band radiation in correlation to pressure and time, pressures, flame front velocities, laminar burning velocities depending on pressure*

Overview

Name	***Test stand***
Type	*closed test stand with blow-out option*
Scale	*full scale*
Experiments	*multipurpose tests with energetic materials*
Application field	*V2*

Technical details

Dimensions	*4 separated test stands (3x4m)*
Temperatures	-
Pressure	-
Media	-
Description	*test stands for energetic materials* *protected control-room nearby* *universal testing-equipment setup possibilities*

Overview

Name	***Testing area***
Type	*open-air*
Scale	*full scale*
Experiments	*studies on explosions, tank testing, hydrogen-release…..*
Application field	*V1, V2, H3, H4, H5*

Technical details

Dimensions	*18 m diameter*
Temperatures	-
Pressure	-
Media	-
Description	*protected testing-area* *protected control-room nearby* *universal testing-equipment setup possibilities*

Overview

Name	***Fast Online Spectroscopy***
Type	*NIR to UV-VIS spectrometers*
Scale	*all scales*
Experiments	*all kind of experiments where spectral radiation and temperatures must be acquired*
Application field	-

Technical details

Description *several types of spectrometers are available:*

Filter wheel spectrometer
spectral range: 1.6…14µm
resolution ~1% FS
speed 50, max 100 spectra per second

Lattice spectrometer (OMA)
spectral range UV-VIS
lattices 30/150/300nm
speed up to 1000 spectra per second

Lattice Spectrometer (Zeiss diode array)
spectral range 0.95…1,7µm
resolution 18nm
speed up to 100 spectra per second

Fourier spectrometer
spectral range 2.5…16µm
resolution 0.5cm^{-1}
speed up to 1 spectrum per second

AOTF spectrometer
spectral range 1.25…2.6µm without restrictions flexible selectable
resolution flexible selectable
speed 1000 spectra per second @ 200 points resolution

2-colour sandwich pyrometer
spectral range NIR
speed 100000 temperature measurements per second

Hot gas sensor
spectral range NIR
speed 500 measurements per second
data emission temperature, water- and soot density

Multi colour spectrometer
spectral range visible light
speed 200 spectra per second

Overview

Name	***Hydrogen Measurement System***
Type	*fast 12-channel H2 concentration measurement system*
Scale	*all scales*
Experiments	*all kind of experiments where hydrogen concentrations must be observed with high time resolution*
Application field	-

Technical details

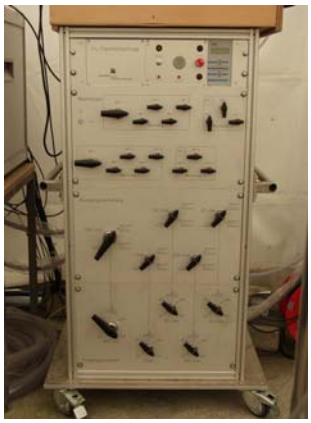
Dimensions	-
Temperatures	*ambient temperature range*
Pressure	-
Media	*hydrogen in air*
Description	*continuous gas probe sampling system with 12 heat conducting sensors* *time resolution < 2s* *0,1-0,5 l/min gas sampling flow* *0-10 Vol.-% (+/-0.05 Vol.-%) hydrogen in air measurement range*

Overview

Name	***3-axis Positioning System***
Type	*programmable positioning system*
Scale	*all scales*
Experiments	*all kind of experiments where position dependent data must be acquired*
Application field	-

Technical details

Dimensions	*2m x 2m x 2m working range*
Temperatures	*ambient temperature range*
Pressure	-
Media	-
Description	*programmable 3-axis positioning system based on tooth strap stepping motor axes with control unit* *5 kg moved mass (max.)* *0.1 mm positioning precision* *remote control possible*



Overview

Name	***Gas Mixing Unit***
Type	*remote controlled 4 gas mixing unit*
Scale	*all scales*
Experiments	*all kind of experiments where well defined (hydrogen-) concentrations or mass flows are needed*
Application field	-

Technical details

Dimensions	-
Temperatures	-
Pressure	*0 – 44 bar output*
Media	*hydrogen, nitrogen, air, oxygen (others possible)*
Description	*5 mass flow controllers* *0.05 - 1250 ln/min flow range* *4 mixing stages* *remote controlled* *programmable*

Partner: *FZJ*

Facilities:
– REKO-1
– REKO-2
– REKO-3
– REKO-4

Overview

Name	***REKO-1***
Type	*flow reactor*
Scale	*small scale*
Experiments	*studies on catalyst elements for H2 recombination under forced flow conditions*
Application field	*H5, V3*

Technical details

Dimensions	*2.5 cm pipe diameter*
Temperatures	*up to 150 °C inlet gas temperature*
Pressure	*ambient pressure*
Media	*hydrogen, air, nitrogen, water steam*
Special features	*glass section enabling optical measurement of substrate temperatures*

Experiments – Equipment

Experiments	*Catalyst elements to be used for hydrogen recombination are tested under steady-state conditions. Testing parameters are gas composition (hydrogen, nitrogen, air, water steam), gas temperature, flow conditions.*	
Level of detail	-	
Instrumentation	*gas temperature*	*thermocouples*
	catalyst temperature	*pyrometers*
	gas composition	*hydrogen analyser*
		oxygen analyser
		water steam analyser
	flow	*mass flow controllers*
Schedule	*one day needed for preparation, conduction, interpretation of experiments*	
Tools	*DeltaV Process Control, MS Excel*	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1 person

  What kind of movable equipment is available and could be shared?

  pyrometers

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Sensors testing, influence of different gas components

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***REKO-2***
Type	*pressure vessel*
Scale	*medium scale*
Experiments	*studies on catalyst elements for H2 recombination*
Application field	*H5, V3*

Technical details

Dimensions	*1m height, 156 litres volume*
Temperatures	*up to 150 °C initial gas temperature*
Pressure	*10 bars*
Media	*hydrogen, air, nitrogen, water steam*
Special features	*vessel evacuation in order to create inert N2 atmosphere*

Experiments – Equipment

Experiments	*Startup behaviour and depletion efficiency of catalyst elements to be used for hydrogen recombination are tested. Testing parameters are gas composition (hydrogen, nitrogen, air, water steam), gas temperature. The facility was especially designed for tests in inert N2 atmosphere.*	
Level of detail	-	
Instrumentation	*gas temperature* *catalyst temperature* *pressure* *gas composition* *injection flow*	*thermocouples* *thermocouples* *pressure transducer* *hydrogen analyser* *mass flow controllers*
Schedule	*one day needed for preparation* *one day needed for conduction and interpretation of experiments*	
Tools	*DeltaV Process Control, MS Excel*	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2 persons for preparation, 1 person for conduction

  What kind of movable equipment is available and could be shared?

  none

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Sensors testing, influence of different gas components

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***REKO-3***
Type	*flow reactor*
Scale	*medium scale*
Experiments	*studies on catalyst elements for H2 recombination under forced flow conditions*
Application field	*H5, V3*

Technical details

Dimensions	*46 x 5 cm² flow channel*
Temperatures	*up to 150 °C inlet gas temperature*
Pressure	*ambient pressure*
Media	*hydrogen, air, nitrogen, water steam*
Special features	-

Experiments – Equipment

Experiments	*Catalyst elements to be used for hydrogen recombination are tested under steady-state conditions. Testing parameters are gas composition (hydrogen, nitrogen, air, water steam), gas temperature, flow conditions.*	
Level of detail	-	
Instrumentation	*gas temperature*	*thermocouples*
	catalyst temperature	*thermocouples inserted inside the plates*
	gas composition	*mass spectrometer*
	flow	*mass flow controllers*
Schedule	*one day needed for preparation,* *one day needed for conduction and interpretation of experiments*	
Tools	*DeltaV Process Control, MS Excel*	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1 person

  What kind of movable equipment is available and could be shared?

  none

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Sensors testing, influence of different gas components

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***REKO-4 (under construction)***
Type	*pressure vessel*
Scale	*medium/large scale*
Experiments	*studies on catalyst elements for H2 recombination under natural flow conditions*
Application field	*H5, V3*

Technical details

Dimensions	*3.5 m height, 2.0 m diameter*
Temperatures	*250 °C gas temperature*
Pressure	*70 bars*
Media	*hydrogen, air, nitrogen, water steam*
Special features	-

Experiments – Equipment

Experiments	*Startup behaviour and depletion efficiency of catalyst elements to be used for hydrogen recombination are tested under natural flow conditions. Testing parameters are gas composition (hydrogen, nitrogen, air, water steam), gas temperature.*
Level of detail	-
Instrumentation	*gas temperature* *catalyst temperature* *gas composition*
Schedule	-
Tools	*DeltaV Process Control, MS Excel*

Information for the preparation of integration

- **Exchange of instruments and personnel**

How many persons are needed to prepare/conduct experiments?

-

What kind of movable equipment is available and could be shared?

-

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Partner: *FZK*

Facilities:
- *A1 Vessel*
- *A3 Vessel*
- *A6 Vessel*
- *12 m detonation tube (DT)*
- *Flow Test Chamber (TC)*
- *Partially Vented Explosion Tube (PET)*

Overview

Name	***A1 Vessel***
Type	*cylindrical vessel*
Scale	*full or large scale*
Experiments	*studies on turbulent combustion and detonations, vented explosions, hydrogen distribution, integrity of mechanical structures under high pressure load*
Application field	*H2-H5, V1-V3*

Technical details

Dimensions	*98 m³ vessel, internal diameter 3.3 m, length 12 m*
Temperatures	*ambient*
Pressure	*up to 100 bar of static pressure*
Media	*hydrogen, air, nitrogen, oxygen.*
Special features	*full or large scale; licensed high static pressure 100 bar; multiple entries possible*
Further particulars	*several vents up to 800 mm in diameter; several windows for visual observations; internal volume can be divided on several joined rooms with different volume; regular grid with obstacles can be used inside the volume; A1 vessel can be connected with other large vessel (e.g. A3 vessel)*

Experiments – Equipment

Experiments

- *experiments on turbulent combustion in uniform and nonuniform gas mixtures at different initial pressure;*
- *effect of obstacles and multi-compartment (room connections with different volumes) on flame acceleration and DDT;*
- *effect of venting and pre-compression in connecting rooms on flame propagation regime;*
- *jet initiation of detonation;*
- *experiments on hydrogen distribution in closed volume*

Level of detail	*integral*	
Instrumentation	*gas temperature*	*thermocouples*
	pressure	*piezoelectric, piezoresistive gauges*
	gas composition	*mass spectrometer, gas flow control*
	hydrogen distribution	*sonic hydrogen sensors*
	velocity	*photodiodes, ion probes*
	deformations	*strain gauges*
Schedule	*preparatory work of experimental set-up to specific test series requires one month;* *1 – 2 days are needed for preparation and conduction of one experiment in the series;* *1 day is needed for processing of raw experimental data*	
Tools	*standard software required for data acquisition system to convert analogous signals to digital form (ASCII or binary format)*	
Further particulars	-	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  3-4 persons are needed to prepare/conduct experiments

  What kind of movable equipment is available and could be shared?

  Data acquisition system processed by accompanying service team (1-2 persons)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Experiments on integrity of mechanical structures under detonation pressure load could be done using A1 vessel as secure shell against missiles.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Large and full scale experiments on turbulent combustion and detonation, experiments under elevated pressures and extremely high pressure load, hydrogen distribution in closed volume.

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***A3 Vessel***
Type	*cylindrical vessel*
Scale	*full or large scale*
Experiments	*studies on turbulent combustion and detonations, vented explosions, hydrogen distribution*
Application field	*H2-H5, V1-V3*

Technical details

Dimensions	*33 m³ vessel, internal diameter 2.5 m, height 8 m*
Temperatures	*ambient*
Pressure	*up to 60 bar of static pressure*
Media	*hydrogen, air, nitrogen, oxygen*
Special features	*large scale; licensed high static pressure 60 bar, multiple entries possible*
Further particulars	*vessel has several vents of different sizes;* *internal volume can be divided on several joined rooms with different volume;* *regular grid with obstacles can be used inside the volume;* *A3 vessel can be connected with other large vessel (e.g. A1 vessel)*

Experiments – Equipment

Experiments	*- experiments on turbulent combustion in uniform and nonuniform gas mixtures at different initial pressure;* *- effect of obstacles and multi-compartment (room connections with different volumes) on flame acceleration and DDT;* *- effect of venting and pre-compression in connecting rooms on flame propagation regime;* *- experiments on hydrogen distribution in closed volume*	
Level of detail	*integral*	
Instrumentation	*gas temperature* *pressure* *gas composition*	*thermocouples* *piezoelectric, piezoresistive* *mass spectrometer, gas flow control*

	hydrogen distribution *velocity*	*sonic hydrogen sensors* *photodiodes, ion probes*
Schedule	*preparatory work of experimental set-up to specific test series requires one month;* *1 – 2 days are needed for preparation and conduction of one experiment in the series;* *1 day is needed for processing of raw experimental data*	
Tools	*standard software required for data acquisition system to convert analogous signals to digital form (ASCII or binary format)*	
Further particulars	-	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  3-4 persons are needed to prepare/conduct experiments

  What kind of movable equipment is available and could be shared?

  Data acquisition system processed by accompanying service team (1-2 persons)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Experiments on hydrogen distribution and hydrogen stratification effect on flame propagation.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Large or full scale experiments on turbulent combustion and detonation, experiments under elevated pressures and extremely high pressure load, hydrogen distribution in closed volume.

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***A6 Vessel***
Type	*cylindrical vessel*
Scale	*large scale*
Experiments	*studies on turbulent combustion and detonations, vented explosions, hydrogen distribution, integrity of mechanical structures under high pressure load*
Application field	*H2-H5, V1-V3*

Technical details

Dimensions	*21 .5 m³ vessel, internal diameter 3.3 m, height 3.1 m*
Temperatures	*ambient*
Pressure	*up to 40 bar of static pressure*
Media	*hydrogen, air, nitrogen, oxygen*
Special features	*large scale; licensed high static pressure 40 bar, multiple entries possible*
Further particulars	*vessel has two vents of 800 mm in diameter;* *gas filling system;* *data acquisition system;* *spark/glow plug for mixture ignition*

Experiments – Equipment

Experiments	*- experiments on turbulent combustion in uniform and nonuniform gas mixtures at different initial pressure;* *- effect of venting and pre-compression in connecting rooms on flame propagation regime;* *- experiments on hydrogen distribution in closed volume;* *- integrity of mechanical structures under detonation pressure load*	
Level of detail	*integral*	
Instrumentation	*gas temperature* *pressure*	*thermocouples* *piezoelectric, piezoresistive gauges*

	gas composition	*mass spectrometer, gas flow control*
	velocity	*photodiodes, ion probes*
	deformations	*strain gauges*
Schedule	*preparatory work of experimental set-up to specific test series requires one month;* *1 day is needed for preparation and conduction of one experiment in the series;* *1 day is needed for processing of raw experimental data*	
Tools	*standard software required for data acquisition system to convert analogous signals to digital form (ASCII or binary format)*	
Further particulars	-	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2-3 persons are needed to prepare/conduct experiments

  What kind of movable equipment is available and could be shared?

  Data acquisition system processed by accompanying service team (1-2 persons)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Experiments on integrity of mechanical structures under detonation pressure load could be done using A6 vessel as protection against missiles.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Large scale experiments on turbulent combustion and detonation, experiments under elevated pressures and extremely high pressure load, hydrogen distribution in closed volume.

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	**12 m detonation tube (DT)**
Type	*cylindrical tube*
Scale	*medium scale*
Experiments	*studies on turbulent combustion, DDT and steady state detonations, heat transfer, ignition, flame propagation regimes, chemical kinetic.*
Application field	*H2-H5, V1-V3*

Technical details

Dimensions	*internal diameter 350 mm, length 12 m*
Temperatures	*ambient*
Pressure	*up to 100 bar of static pressure*
Media	*hydrogen, air, nitrogen, oxygen*
Special features	*medium scale*
Further particulars	*tube could be filled with regular ring shape obstacles grid spaced by tube diameter, blockage ratio BR = 0.3, 0.45, 0.6, 0.75, 0.9;* *tube is equipped with gas filling system and data acquisition system, spark/glow plug for ignition*

Experiments – Equipment

Experiments	*- experiments on turbulent combustion in uniform and nonuniform gas mixtures at different initial pressure;* *- experiments on flame acceleration, DDT and flammability limits; hydrogen distribution in closed volume*	
Level of detail	*microscopic to integral*	
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity*	*thermocouples* *piezoelectric, piezoresistive gauges* *mass spectrometer, gas flow control* *photodiodes, ion probes*

Schedule	*preparatory work of experimental set-up to specific test series requires one week;* 3 *– 4 hours are needed for preparation and conduction of one experiment in the series;* *1 day is needed for processing of raw experimental data*
Tools	*standard software required for data acquisition system to convert analogous signals to digital form (ASCII or binary format)*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2-3 persons are needed to prepare/conduct experiments

  What kind of movable equipment is available and could be shared?

  Data acquisition system processed by accompanying service team (1-2 persons)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Experiments on chemical kinetic and heat transfer.

- **To prepare promotion and specialisation**

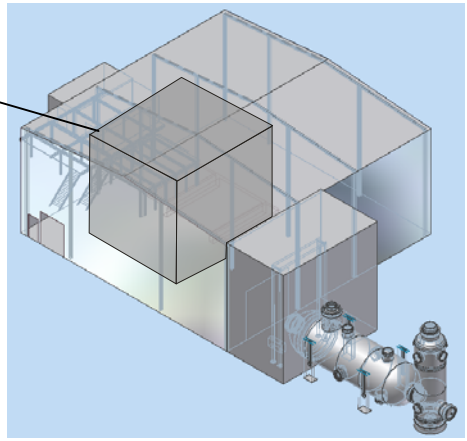
  What features/possibilities would you like to promote?

  Medium scale experiments on turbulent combustion and detonation, experiments under elevated and reduced pressures, experiment on ignition and flame propagation limits.

  Which additional equipment could enhance the results of your experiments?

  -

Overview



Name	**Flow Test Chamber (TC)**
Type	*rectangular chamber*
Scale	*full or large scale*
Experiments	*studies on vented combustion and detonations (up to 16g of hydrogen); hydrogen distribution, testing of ventilation system; testing of automotive hydrogen engines*
Application field	*H2-H5, V1-V3*

Technical details

Dimensions	*160 m³ chamber, dimensions 8.53x5.5x3.3 m*
Temperatures	*ambient*
Pressure	*ambient*
Media	*hydrogen, air*
Special features	*full/large scale*
Further particulars	*chamber is equipped with ventilation system with variable exchange rate;* *possibility of hydrogen inlet with controlled flow rate;* *hydrogen engines can be tested inside of test chamber*

Experiments – Equipment

Experiments	*- experiments on vented combustion and detonations;* *- experiments on hydrogen distribution in closed volume* *- experiments on shock wave load under combustion and detonation*	
Level of detail	*integral (macroscopic)*	
Instrumentation	*gas temperature* *pressure* *gas composition* *hydrogen distribution* *velocity*	*thermocouples* *piezoelectric, piezoresistive gauges* *mass spectrometer, gas flow control* *sonic hydrogen sensors* *photodiodes, ion probes, visual observations with high speed CCD camera*

	deformations	*strain gauges, displacement sensors (laser, mechanical and visual)*
Schedule	*preparatory work of experimental set-up to specific test series requires one month;* *1 – 2 days are needed for preparation and conduction of one experiment in the series;* *1 day is needed for processing of raw experimental data*	
Tools	*standard software required for data acquisition system to convert analogous signals to digital form (ASCII or binary format)*	
Further particulars	-	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  3-4 persons are needed to prepare/conduct experiments

  What kind of movable equipment is available and could be shared?

  Data acquisition system processed by accompanying service team (1-2 persons)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Experiments on vented combustion and detonation could be done using test chamber as protection against shock wave and thermal load.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Large and full scale experiments on hydrogen distribution in big closed volume, vented combustion and detonation (up to 16 g of hydrogen)

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***Partially Vented Explosion Tube PET***
Type	*cylindrical tube with variable opening*
Scale	*medium scale*
Experiments	*studies on vented explosions, turbulent flame propagation, flame acceleration and DDT; jet initiation of detonation*
Application field	*H2-H5, V1-V3*

Technical details

Dimensions	55 *dm^3 vessel, internal diameter 0.1 m, length 7 m*
Temperatures	*ambient*
Pressure	*ambient*
Media	*hydrogen, air, nitrogen, oxygen*
Special features	*medium scale; controlled venting degree*
Further particulars	*tube could be filled with regular ring shape obstacles grid spaced by tube diameter, blockage ratio BR = 0.3, 0.6;* *variable transverse venting ratio (opening rate) from 0 to 40%* *tube is equipped with gas filling system and data acquisition system, spark/glow plug for ignition;* *PEV has possibility to make combustible surrounding atmosphere with thin polyethylene film around of the tube.*

Experiments – Equipment

Experiments	*- experiments on vented combustion in uniform and nonuniform gas mixtures;* *- experiments on flame acceleration and DDT under transverse venting conditions.*	
Level of detail	*integral*	
Instrumentation	*gas temperature* *pressure* *gas composition*	*thermocouples* *piezoelectric, piezoresistive gauges* *mass spectrometer, gas flow control*

	velocity	*photodiodes, ion probes, visual observation with high speed CCD camera.*
Schedule	*preparatory work of experimental set-up to specific test series requires one week;* 3 *– 4 hours are needed for preparation and conduction of one experiment in the series;* *1 day is needed for processing of raw experimental data*	
Tools	*standard software required for data acquisition system to convert analogous signals to digital form (ASCII or binary format)*	
Further particulars	-	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2-3 persons are needed to prepare/conduct experiments.

  What kind of movable equipment is available and could be shared?

  Experimental facility and data acquisition system processed by accompanying service team (2-3 persons)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Experiments on transient regimes of DDT at various degree of venting: from fully confined to unconfined gas mixture.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Small scale experiments on turbulent combustion and DDT under transverse venting conditions.

  Which additional equipment could enhance the results of your experiments?

  -

Partner: *GexCon*

Facilities:
- *168 m³ open geometry with internal obstructions*
- *1:3.2 scale offshore module*
- *Connected vessels*
- *6m channel*
- *50m³ tube*
- *1.2 m³ closed vessel*
- *216 litre dispersion vessel*
- *20 litre spray vessel*
- *1.4 m channel*
- *3D corner*

Overview

Name	***GexCon 168 m³ open geometry with internal obstructions***
Type	*explosion vessel*
Scale	*large scale (168 m³)*
Experiments	*studies on explosions in open, congested geometries*
Application field	*V2, V3*

Technical details

Dimensions	168 *m³ vessel, 12 m long, 4 m wide and 3.5 m high*
Temperatures	*normal outdoor temperatures*
Pressure	*tests at normal pressure.*
Media	*gas explosions hydrogen/air*
Special	*variable geometry congestion. Obstructed volume 9x3x3 m (81 m³). Will be suitable for explosion tests using homogeneous hydrogen gas clouds with limited gas concentration or for non-homogeneous (leak-generated) gas mixtures. Potential for detonations but ability to handle them is somewhat uncertain. Explosion mitigation experiments and simulation validation for complex, congested but open geometries*
Description	*A simple frame system is covered with light plastic sheeting prior to gas filling. This sheet is clamped in place and is released just prior to ignition.*

Experiments - Equipment

Experiments	*Test configuration is set up in terms of internal geometry and congestion. The vessel is equipped with measuring devices and instrumentation for explosion pressure and flame speed measurement etc. After covering the frame with plastic foil, gas is introduced into the vessel either by a high-pressure release or by mixing using a recirculation system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored.*
Level of detail	-

Instrumentation	*Gas concentration (O_2)*
	Explosion pressure (piezoelectric/piezoresistive)
	Dynamic pressure component
	External blast pressures
	Flame velocity
	Video (normal and high speed)
Schedule	*Preparation:1-3 weeks depending on experimental content*
	Conduction: depending on experimental content,(typical 2-3 tests/day)
	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  3-4 persons are needed to prepare/conduct experiments

  equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

Overview

Name	***GexCon 1:3.2 scale offshore module***
Type	*explosion vessel*
Scale	*large scale (50 m^3)*

Experiments	*studies on vented explosions in realistic geometries*
Application field	*V1, V2, V3*

Technical details

Dimensions	50 *m³ vessel, 8 m long, 2.5x2.5 m cross section*
Temperatures	*normal outdoor temperatures*
Pressure	*tests at normal pressure. Explosion pressures up to 3 barg*
Media	*gas explosions hydrogen/air, hybrid gas/oil mist explosions*
Special	*realistic and variable geometry. Vented explosions, variable vent area. Transparent front wall to allow optical access.*
Description:	*Will be suitable for explosion tests using homogeneous hydrogen gas clouds with limited gas concentration or for non-homogeneous (leak-generated) gas mixtures due to maximum pressure limitations. Explosion mitigation experiments and simulation validation for realistic geometries*

Experiments - Equipment

Experiments	*Test configuration is set up in terms of internal geometry and vent openings. The module is equipped with measuring devices and instrumentation for explosion pressure measurement etc. After covering the vent openings with plastic foil, gas is introduced into the vessel either by a high-pressure release or by mixing using a recirculation system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored.*
Level of detail	-
Instrumentation	*Gas concentration (O_2)* *Explosion pressure (piezoelectric/piezoresistive)* *Dynamic pressure component*

	External blast pressures
	Flame velocity
	Video (normal and high speed)
Schedule	*Preparation:1-3 weeks depending on experimental content*
	Conduction: depending on experimental content,(typical 2-3 tests/day)
	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  2-3 persons are needed to prepare/conduct experiments

  equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

  Hydrogen dispersion experiments could be performed in this facility by applying additional instrumentation for hydrogen concentration measurements in real time

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

  Turbulence measurements

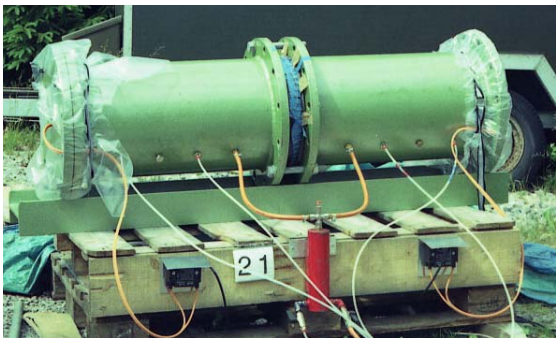
  Structural response

- **Website presentation**

  Additional material to be presented on the HySafe Website

  Videos of release of hydrogen and transformer oil (used in a safety study for transformers) can be provided to web-site.

Overview



Name	***GexCon connected vessels***
Type	*explosion vessel*
Scale	*small scale (100 litre)*
Experiments	*studies on explosions in vented vessel*
Application field	*V2, V3*

Technical details

Dimensions	*100 litre vessel, 2 m long, ~0.3 m in diameter*
Temperatures	*normal temperatures*
Pressure	*tests at normal pressure.*
Media	*gas explosions hydrogen/air*
Special	*variable internal configurations used to test explosion propagation ability through small orifices and pressure piling effects. Will be suitable for explosion tests using homogeneous hydrogen gas clouds.*
Description:	*Internal orifice plate is inserted between flanges to investigate pressure piling effects and flame travel through small openings.*

Experiments - Equipment

Experiments	*Test configuration is set up in terms of orifice configuration. The vessel is equipped with measuring devices and instrumentation for explosion pressure etc. After covering the vent with plastic foil, gas is introduced into the vessel by mixing using a flushing/recirculation system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored.*
Level of detail	-
Instrumentation	*Gas concentration (O_2)*
	Explosion pressure (piezoelectric/piezoresistive)
Schedule	*Preparation: 1 week depending on experimental content*
	Conduction: depending on experimental content,(typical 5-6 tests/day)

	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  1 person is needed to prepare/conduct experiments

  equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

Overview

Name	***GexCon 6m channel***
Type	*explosion vessel*
Scale	*large scale (9 m^3)*
Experiments	*studies on vented explosions in idealised geometries*
Application field	*V1, V2, V3*

Technical details

Dimensions	*9 m³ vessel, 6 m long,1.25x1.25 m cross section*
Temperatures	*normal outdoor temperatures*
Pressure	*tests at normal pressure. Explosion pressures up to 5 barg (>5 if steel roof)*
Media	*gas explosions hydrogen/air, hybrid gas/oil mist explosions*
Special	*idealised and variable geometry. Vented explosions, variable vent area. Transparent roof to allow optical access.*
Description:	*Will be suitable for explosion tests using homogeneous hydrogen gas clouds with limited gas concentration or for non-homogeneous (leak-generated) gas mixtures due to maximum pressure limitations. Explosion mitigation experiments and simulation validation for idealised geometries. Obstruction baffles of various heights can be inserted at 1m intervals on both sides of the vessel. 3 baffle sizes are available.*

Experiments - Equipment

Experiments	*Test configuration is set up in terms of internal geometry and vent opening. The vessel is equipped with measuring devices and instrumentation for explosion pressure measurement etc. After covering the vent opening with plastic foil, gas is introduced into the vessel either by a high-pressure release or by mixing using a recirculation system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored.*
Level of detail	-

Instrumentation	*Gas concentration (O_2)*
	Explosion pressure (piezoelectric/piezoresistive)
	Dynamic pressure component
	External blast pressures
	Flame velocity
	Video (normal and high speed)
Schedule	*Preparation: 1-3 weeks depending on experimental content*
	Conduction: depending on experimental content,(typical 2-3 tests/day)
	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  2-3 persons are needed to prepare/conduct experiments

  equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

  Hydrogen dispersion experiments could be performed in this facility by applying additional instrumentation for hydrogen concentration measurements in real time

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

  Turbulence measurements

  Structural response and explosion loading

Overview

Name	***GexCon 50 m³ tube***
Type	*explosion vessel*
Scale	*large scale (50 m³)*

Experiments	*studies on dispersion/explosions in closed/vented vessel (tunnels)*
Application field	*V1, V2, V3, H5, H2*

Technical details

Dimensions	*50 m³ vessel, 10 m long, 2.5 m in diameter*
Temperatures	*normal outdoor temperatures*
Pressure	*tests at normal pressure. High pressures/detonations possible*
Media	*gas explosions hydrogen/air*
Special	*variable internal congestion. Will be suitable for explosion tests using homogeneous hydrogen gas clouds. Potential for detonations. Explosion mitigation experiments and simulation validation for idealised geometry.*
Description:	*Internal circumferential rings are inserted to investigate turbulence-generation. Vented explosion normally performed.*

Experiments - Equipment

Experiments	*Test configuration is set up in terms of internal geometry. The vessel is equipped with measuring devices and instrumentation for explosion pressure and flame speed measurement etc. After covering the vent with plastic foil, gas is introduced into the vessel by mixing using a recirculation system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored.*
Level of detail	-
Instrumentation	*Gas concentration (O_2)* *Explosion pressure (piezoelectric/piezoresistive)* *Dynamic pressure component* *External blast pressures*

	Flame velocity
	Video (normal and high speed)
Schedule	*Preparation:4-5 weeks depending on experimental content*
	Conduction: depending on experimental content,(typical 2-3 tests/day)
	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  3-4 persons are needed to prepare/conduct experiments

  equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

Overview

Name	***GexCon 1.2 m^3 closed vessel***
Type	*explosion vessel*
Scale	*small scale (1.2 m^3)*
Experiments	*studies on explosions in closed vessel*
Application field	*V1, V2, V3*

Technical details

Dimensions	*1.2 m^3 cylindrical vessel*
Temperatures	*normal temperatures*
Pressure	*tests at normal pressure.*
Media	*gas explosions hydrogen/air*
Special	*Will be suitable for explosion tests using homogeneous hydrogen gas clouds to test combustion characteristics and mitigation techniques.*
Description:	*A closed cylindrical vessel with L/D ~2. Several inlets allow for variable ignition location and instrumentation layouts.*

Experiments - Equipment

Experiments	*The vessel is equipped with measuring devices and instrumentation for explosion pressure etc. Gas is introduced into the vessel by mixing using a recirculation system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored. Effect of sprays and/or other mitigation materials can be investigated.*
Level of detail	-
Instrumentation	*Gas concentration (O_2)*
	Explosion pressure (piezoelectric/piezoresistive)
Schedule	*Preparation:1 week depending on experimental content*
	Conduction: depending on experimental content,(typical 2-3 tests/day)
	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  1 person is needed to prepare/conduct experiments

  equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

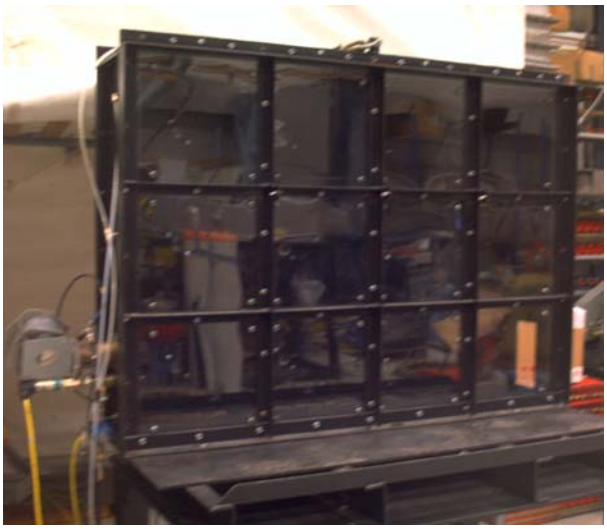
  -

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

Overview

Name	***GexCon 216 litre dispersion vessel***
Type	*gas dispersion/explosion vessel*
Scale	*small scale (216 litre)*
Experiments	*studies on gas dispersion/homogeneity*
Application field	*V1*



Technical details

Dimensions	*216 litre rectangular vessel, 1.2x0.9x0.2 m, possibility to mount partition walls*
Temperatures	*normal temperatures*
Pressure	*tests at normal pressure.*
Media	*gas dispersion of hydrogen*
Special	*Will be suitable for gas release & dispersion tests using hydrogen gas. Explosions for non-ideal (poorly mixed) clouds may be possible despite pressure tolerance limitations of vessel.*
Description:	*A semi-closed rectangular vessel designed for gas release and dispersion tests within idealised geometries. Internal layout can be varied by use of movable baffle plates. Real-time gas concentration measurements are performed to monitor gas dispersion processes for hydrogen. Gas mixtures are also allowed.*

Experiments - Equipment

Experiments	*The vessel is equipped with measuring devices and instrumentation for gas release monitoring and gas concentration measurements etc. Gas is introduced into the vessel via a high-pressure release. The effect of release type and characteristics and vessel geometry can be investigated.*
Level of detail	-
Instrumentation	*Gas release pressure / flowrate*
	Gas concentration (H_2/O_2)
Schedule	*Preparation:1 week depending on experimental content*

	Conduction: depending on experimental content,(typical 8-10 tests/day)
	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  1 person is needed to prepare/conduct experiments

  equipment that is available and could be shared is limited

- **To prepare filling possible gaps**

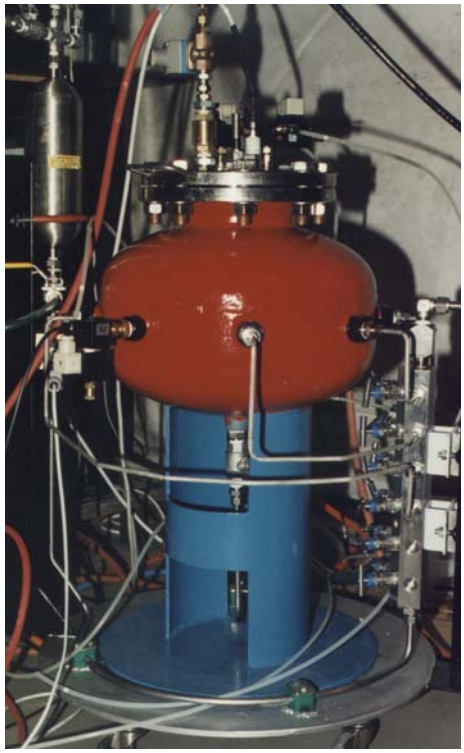
- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  A greater number of more accurate gas composition/concentration sensors for H_2 would improve the results obtainable.



Overview

Name	***GexCon 20-litre spray vessel***
Type	*explosion vessel*
Scale	*small scale (20 litre)*
Experiments	*studies on explosions in closed vessel*
Application field	*V2, V3*

Technical details

Dimensions	*20 litre vessel, ~ semi-spherical*
Temperatures	*normal temperatures*
Pressure	*tests at normal pressure*
Media	*gas explosions hydrogen/air*
Special	*Will be suitable for explosion tests using homogeneous hydrogen gas clouds to test combustion characteristics and mitigation techniques using sprays.*
Description	*approximately spherical vessel with 8-10 spray inlets for water and/or other liquids. Central ignition and pressure measurement allows determination of burning velocity characteristics etc.*

Experiments - Equipment

Experiments	*The vessel is equipped with measuring devices and instrumentation for explosion pressure etc. Gas is introduced into the vessel by mixing using a flushing system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored. Effect of sprays and mitigation liquids can be investigated.*
Level of detail	-
Instrumentation	*Gas concentration (O_2)*
	Explosion pressure (piezoelectric/piezoresistive)
Schedule	*Preparation:1 week depending on experimental content*
	Conduction: depending on experimental content,(typical 5-6 tests/day)

	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  1 person is needed to prepare/conduct experiments

  equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

- **To prepare promotion and specialisation**

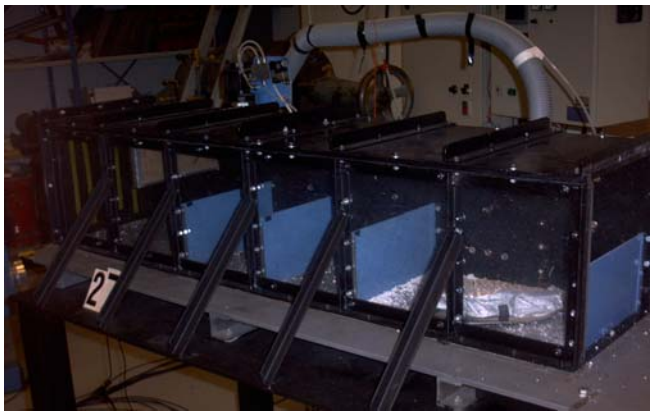
  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

Overview



Name	***GexCon 1.4m channel***
Type	*explosion vessel*
Scale	*small scale (130 litre)*
Experiments	*studies on vented explosions in idealised geometries*
Application field	*V2, V3*

Technical details

Dimensions	*130 litre vessel, 1.44 m long,0.3x0.3 m cross section*
Temperatures	*normal temperatures*
Pressure	*tests at normal pressure. Explosion pressures up to ~3 barg*
Media	*gas explosions hydrogen/air or gas mixtures*
Special	idealised *and variable geometry. Vented explosions, variable vent area. Transparent front wall to allow optical access.*
Description:	*Obstruction baffles of various heights can be inserted at 0.24m intervals of the vessel. 3 baffle sizes are available (5, 10 & 15 cm).Vessel will only be suitable for explosion tests using homogeneous hydrogen gas clouds with limited gas concentration or for non-homogeneous (leak-generated) gas mixtures for the more complex obstacle configurations due to maximum pressure limitations. Ideal mixtures will be possible for the simpler geometries. Explosion mitigation experiments and simulation validation tests for idealised geometries are among the possibilities for this test vessel.*

Experiments - Equipment

Experiments	*Test configuration is set up in terms of internal geometry and vent opening. The vessel is equipped with measuring devices and instrumentation for explosion pressure measurement etc. After covering the vent opening with plastic foil, gas is introduced into the vessel either by a high-pressure release or by mixing using a recirculation system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored.*

Level of detail	-
Instrumentation	*Gas concentration (O_2)*
	Explosion pressure (piezoelectric/piezoresistive)
	Dynamic pressure component
	External blast pressures
	Flame velocity
	Video (normal and high speed)
Schedule	*Preparation: 2-3 days depending on experimental content*
	Conduction: depending on experimental content, (typical 5-6 tests/day)
	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  1 person is needed to prepare/conduct experiments

  equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

  Hydrogen dispersion experiments could be performed in this facility by applying additional instrumentation for hydrogen concentration measurements in real time

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

  Turbulence measurements

  Structural response and explosion loading

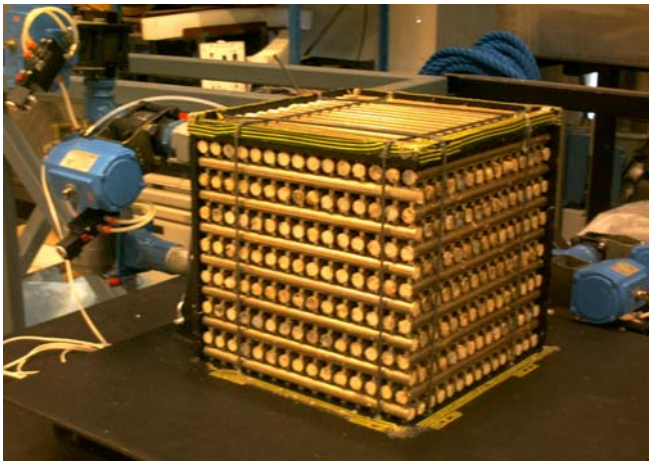
- **Website presentation**

  Additional material to be presented on the HySafe Website

  We can make available a couple of photos from tests

Overview

Name	***GexCon 3D corner***
Type	*explosion vessel*
Scale	small/*large scale (50 litre / 27 m^3)*
Experiments	*studies on vented explosions in complex idealised geometries*
Application field	*V2,V3*



Technical details

Dimensions	*50 litre vessel* (0.37x0.37x0.37 m) or 27 *m³ vessel, 3x3x3 m* *Pipe arrays of different diameter and pitch giving volume blockage from 0.1 to 0.5*
Temperatures	*normal temperatures*
Pressure	*tests at normal pressure*
Media	*gas explosions hydrogen/air*
Special	idealised *and variable geometry. Vented explosions in idealised geometry*
Description:	*Will be suitable for explosion tests using homogeneous hydrogen gas clouds. Obstruction "pipe sets" of various types (number and size) can be inserted. Area and volume blockage ratio can thus be varied.*

Experiments - Equipment

Experiments	*Test configuration is set up in terms of internal geometry. The vessel is equipped with measuring devices and instrumentation for explosion pressure measurement etc. After covering the rig with plastic foil, gas is introduced into the vessel by mixing using a recirculation system (to obtain homogenous mixtures). The gas cloud is then ignited and the ensuing explosion monitored.*
Level of detail	-
Instrumentation	*Gas concentration (O_2)* *Explosion pressure (piezoelectric/piezoresistive)* *External blast pressures*

	Video (normal and high speed)
Schedule	*Preparation: 1-3 weeks depending on scale and experimental content*
	Conduction: depending on scale (typical 5-6 tests/day small scale, 2-3 tests/day large scale)
	Interpretation of experiments/reporting: 2-3 weeks depending on content
Tools	*NI-LabView, MS-Excel, MS-Word*

Information for the preparation of integration

- **To prepare exchange of instruments and personnel**

  1 person is needed to prepare/conduct small scale experiments. 2-3 persons are needed to prepare/conduct large scale experiments. equipment that is available and could be shared is primarily limited to instrumentation and data logging equipment

- **To prepare filling possible gaps**

- **To prepare promotion and specialisation**

  Which additional equipment could enhance the results of your experiments?

  Gas composition/concentration (H_2)

Partner: *HSE/HSL*

Health & Safety Laboratory

An Agency of the Health & Safety Executive

Facilities:
- *Ventilated dispersion and explosion facility*
- *Gas dispersion facility*
- *Jet fire facility*
- *Hydrogen jet release facility*
- *366m gallery/tunnel*
- *Frictional ignition apparatus*
- *Impact test track*

Overview

Name	***Ventilated dispersion and explosion facility***
Type	*Modular Vented enclosure with integrated ventilation system*
Scale	*Full scale tests of gas releases into a controlled ventilation flow*
Experiments	*e.g. studies on vented explosions, tank testing, ...*
Application field	*H1-H6, V1-V2*

Technical details

Dimensions	*Enclosure with internal dimensions of 2.5m x 2.5m x15m. Modular construction to vary length up to 15 m.*
Temperatures	*Ambient temperature – outdoor facility*
Pressure	*Vented structure with up to 2 bar overpressure maximum operating pressure 150 bar*
Media	*Hydrogen or other gases*
Special features	*Ventilation system capable of 2500 m^3s^{-1}* *Different ventilation configurations multiple entries possible*

Experiments – Equipment

Experiments	*Characterisation of hydrogen release, ignited and un-ignited into a controlled ventilation flow. Study effects of leak size, ventilation, congestion, vent area ect on dispersion and overpressure*	
Level of detail	*High using large thermocouple and transducer arrays.*	
Instrumentation	*gas temperature* *pressure* *gas concentration* *flame size* *logging*	*thermocouples* *pressure transducers* *oxygen concentration cells* *thermal imaging camera* *up to 100 kHz*
Schedule	*time needed for:* *preparation (2 weeks),* *conduction (2 tests per day),* *interpretation of experiments(2 weeks)*	
Tools	*Microlink, FAMOS software, Excel Software*	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  3

  What kind of movable equipment is available and could be shared?

  None

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  High pressure and liquid releases into ventilated flows.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Adaptation of apparatus for different types of release.

  Which additional equipment could enhance the results of your experiments?

  Effects of ventilation on different types of release.

Overview

Name	***Gas dispersion facility***
Type	*Flat area suitable for characterising gas dispersion*
Scale	*Full scale tests, with flashing liquid releases up to 5 kgs^{-1} or gaseous releases*
Experiments	*Study of dispersion of flashing liquid or gas – mainly used with LPG, but could be used with H_2*
Application field	*H1-H6, V1-V2*

Technical details

Dimensions	*> 100m wide x 200 m long*
Temperatures	*Ambient temperature*
Pressure	*Local storage pressure*
Media	*Hydrogen (LH2 and CGH2), LPG*
Special features	*Fully instrumented release and dispersion facility*

Experiments – Equipment

Experiments	*Characterisation of clouds of dispersing gas* *Characterisation of source terms* *Ignition of released gas*	
Level of detail	-	
Instrumentation	*gas temperature* *pressure* *gas concentration* *flame size* *weather conditions* *logging*	*thermocouples* *pressure transducers* *oxygen concentration cells* *thermal imaging camera* *3 x weather stations* *up to 100 kHz*
Schedule	*time needed for:* *preparation (2-3 weeks),* *conduction (3-4 weeks),* *interpretation of experiments(2 weeks)*	

Tools *Excel Software, data logging equipment*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  4

  What kind of movable equipment is available and could be shared?

  None

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Releases of cryogenically stored fluids

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Dispersion of releases of liquefied hydrogen and pressurised releases.

  Which additional equipment could enhance the results of your experiments?

  Direct hydrogen concentration measurements with H_2 analysers.

Overview

Name	***Jet fire facility***
Type	*LPG vapour jet fire facility*
Scale	*Full scale tests on samples and panels for up to 2 hour duration.*
Experiments	*Commercial testing of PFP material and components. Testing to Jet-Fire Resistance Test (JFRT) standards*
Application field	*H1-H6, V1-V2*

Technical details

Dimensions	*0.55 kg s^{-1} vapour, 10 kg s^{-1} liquid, LPG jet fire; 14 tonne LPG storage supply; 1000 l min^{-1} water deluge facility*
Temperatures	*Ambient temperature, Flame temperature ~1100 °C*
Pressure	*Local storage pressure , ~ 8 bar LPG*
Media	*LPG,*
Special features	*Commercial JFRT facility*

Experiments – Equipment

Experiments	*Characterisation of behaviour of PFP material and components* *Investigation of BLEVE behaviour of LPG storage cylinders (2 tonne)*
Level of detail	-
Instrumentation	*gas temperature thermocouples* *pressure pressure transducers* *fuel flow rate mass flow meters* *flame thermal imaging camera and video camera* *weather conditions weather stations*
Schedule	*time needed for:* *preparation (2 days),* *conduction (2 days per test),* *interpretation of experiments(1 day)*
Tools	*Excel Software, data logging equipment,*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  3 - 4

  What kind of movable equipment is available and could be shared?

  None – fixed facility

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Investigation of behaviour of hydrogen storage tanks under jet-fire attack.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Standard jet-fire resistance testing of samples and components. Could be used for H2 equipment.

  Which additional equipment could enhance the results of your experiments?

  Longer duration tests with more LPG storage.

Overview

Name	***Hydrogen jet release facility***
Type	*Gas supply and pipe work to enable pressurised releases*
Scale	*Full scale tests, with releases up to 150 bar, 12mm release orifice ,*
Experiments	*Study of ignited and unignited jet releases of hydrogen*
Application field	*H1-H6, V1-V2*

Technical details

Dimensions	*Release orifice up to 12 mm diameter, pressure up to 150 bar*
Temperatures	*Ambient temperature*
Pressure	*150 bar*
Media	*Hydrogen*
Special features	*Large scale release of ignited or unignited hydrogen at medium pressure*

Experiments – Equipment

Experiments	*Characterisation of hydrogen jet releases – gas concentration. Characterisation of hydrogen jet flames – size, visibility, temperature, etc.*
Level of detail	-
Instrumentation	*gas temperature thermocouples* *pressure pressure transducers* *gas concentration oxygen concentration cells* *flame size thermal imaging camera* *logging up to 100 kHz*
Schedule	*time needed for:* *preparation (3 weeks),* *conduction (4 weeks),* *interpretation of experiments(2 weeks)*
Tools	*Microlink, FAMOS software, Excel Software*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  5

  What kind of movable equipment is available and could be shared?

  None

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Confined jet releases, releases with obstructions.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Dispersion tests, obstructed releases (ignited and unignited) and experience of measuring over-pressures of ignition.

  Which additional equipment could enhance the results of your experiments?

  Direct hydrogen concentration measurements with H_2 analysers.

Overview

Name	***366m gallery/tunnel***
Type	*Concrete test enclosure/tunnel*
Scale	*Full/large scale*
Experiments	*Combustion and ventilation controlled overpressures Fragmentation.*
Application field	V1, V2 and H4, H5

Technical details

Dimensions	*Cross section = 5.6 m^2 (2.55 m to crown, 2.75 m maximum width)* *Length: 366 m*
Temperatures	*Up to 750ºC in limited (20 m long) area. Up to 90ºC overall.*
Pressure	*Atmospheric*
Media	*Air*
Special features	*Ventilation flow up to 5 $m.s^{-1}$ throughout.* *Access for instrumentation every 3 m (25 mm diameter).* *Larger access ports every 25 m (0.3 m x 0.2 m)*

Experiments – Equipment

Experiments	*Fire effects on components at full-scale / reduced scales (previously used to validate codes for Channel Tunnel using 1/3 scale models)* *Small explosion tests.* *Effect of ventilation/wind on combustion / consequences*
Level of detail	-
Instrumentation	*Thermocouples (>100 have been used in single experiments)* *Heat flux (Gardon Gauges)* *Mass change (load cells)* *Air flows (hot wire / rotary vane / vortex shedding anemometry)* *Smoke detection* *Video/still image cameras*
Schedule	*Typical work at this scale would involve:* *Preparation for test programme: 10 days* *Testing: 1 to 4 tests per day* *Preliminary analysis of results (e.g. elimination of broken*

	instruments): up to 4 tests per day. *Full Analysis of results: 1 to 2 days per test.* *As facility is adaptable to a range of work, exact schedule would vary depending on specific details.*
Tools	*Microcal Origin, SPSS Sigmaplot, Microsoft Excel*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  -

  What kind of movable equipment is available and could be shared?

  Fixed facility available to other partners

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Hydrogen ventilation, fire and explosion in tunnels and mitigation

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  Full/large scale tunnel facility with extensive scope for instrumentation

Overview

Name	***Frictional ignition apparatus***
Type	*Ignition test facility with vented explosion vessel enclosure*
Scale	*Full scale test apparatus operating at up to 20m/s, 5kN loads in a 0.3m^3 vented explosion vessel*
Experiments	*Studies into frictional rubbing events in flammable atmospheres. Research into spark and hot surface ignition events.*
Application field	*H1-H6, V1-V2*

Technical details

Dimensions	*Apparatus laboratory based on 4m long lathe bed. Explosion vessel is 0.3m^3 volume. Driven disc 30 cm diameter maximum and 25mm cross section sacrificial slider.*
Temperatures	*Test carried out at ambient but scope for heating or cooling. Temperature measurement used to detect ignition. 50fps high resolution thermal imaging camera also used to measure surface temperatures.*
Pressure	*Vented system*
Media	*Explosive atmosphere mainly flammable gases, but vapours dusts and Hybrid mixtures. Friction materials include metals and ceramics.*
Special features	*Driven by 30kW variable speed induction motor. Frictional rubbing speeds up to 20m/s and loads up to 5kN. High speed video (40,000 fps) also available.*

Experiments – Equipment

Experiments	*Characterisation of ignition behaviour of hydrogen under different conditions. Factors include materials, operating conditions including state of H2.*	
Level of detail	-	
Instrumentation	*gas temperature*	*thermocouples*
	pressure	*pressure transducers*
	fuel concentration	*mass flow meters*
	flame	*thermal imaging camera and video camera*

Schedule	*time needed for:* *preparation (2 days),* *conduction (2 hours per test),* *interpretation of experiments(0.5 day)*
Tools	*Excel Software, Sigmaplot and data logging equipment*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1 - 2

  What kind of movable equipment is available and could be shared?

  None – fixed facility

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Investigation of ignition of H2 by friction to establish optimum materials ect.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Unique apparatus with direct application for H2 equipment. Information essential as required by EU ATEX Directives

  Which additional equipment could enhance the results of your experiments?

  Adaptation of apparatus to investigate hydrogen as LH2.

Overview

Name	***Impact test track***
Type	*Impact test facility*
Scale	*Full scale tests*
Experiments	*Dynamic impact tests on components/ tanks etc.*
Application field	*H1-H6, V1-V2*

Technical details

Dimensions	*Twin gauge impact track wit maximum impact speed of 23 m/s and truck masses of 23 tonnes .*
Temperatures	*Ambient temperature*
Pressure	-
Media	*Tests completed with large diesel tanks.*
Special features	*Site suitable destructive testing leading to fire and explosion*

Experiments – Equipment

Experiments	*Testing of storage vessels*
Level of detail	-
Instrumentation	*Force, strain, displacement and others as required, acquired at a maximum logging rate of 10 MSamples per second. High speed video also available.*
Schedule	*time needed for:* *preparation (3 weeks),* *conduction (2 days per test),* *interpretation of experiments(2 weeks)*
Tools	*Microlink, FAMOS software, Excel Software*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  5

  What kind of movable equipment is available and could be shared?

  None

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  Impact testing of storage vessels and assessment of resulting release/fireball.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Partner: *INASMET*

Facilities:
- *SSRT equipment*
- *NACE TM 01-77 testing equipment*
- *Fatigue testing equipment*
- *LECO TCH 600*
- *SHS reactor*

Overview

Name	***SSRT equipment***
Type	*autoclave+ tensile testing*
Scale	*lab scale*
Experiments	*studies on the effect of hydrogen on the behaviour of materials - hydrogen embrittlement*
Application field	*H1-H6, V3, V4, V5*

Technical details

Dimensions	*four equivalent SSRT machines with 2 lit Hastelloy C-276 autoclaves*
Temperatures	*up to 250°C*
Pressure	*up to 150 bar*
Media	*an testing (corrosive) media, liquid or gas*
Special features	*It consist of a universal materials testing equipment*
Further particulars	-

Experiments – Equipment

Experiments	*The sensitivity of materials to the Hydrogen Induced Cracking (HIC) is studied by means of a combined test in which a mechanical test is performed while hydrogen is produced on the specimen surface.* *The Slow Strain Rate Technique (SSRT) is used for the study of stress corrosion cracking. A tensile test is performed at very low strain rate with the specimen in contact with a corrosive environment and coupled to a potentiostat that applies a cathodic potential to the specimen. Hydrogen is electrochemically produced on the specimen surface during the test.*
Level of detail	-
Instrumentation	*load cell, displacement (LVDT), thermocouples, pressure*

Schedule	*tests on evaluating the sensitivity of materials to SCC/HIC last from some hours up to one month.*
Tools	*The tested specimen should be studied by optical and scanning electron microscopy in order to identify different fracture mode features.*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Overview

Name	***NACE TM 01-77 testing equipment***
Type	*corrosion cells + load applying rings*
Scale	*lab scale*
Experiments	*studies on the effect of hydrogen on the behaviour of materials - hydrogen embrittlement*
Application field	*H1-H6,V3, V4, V5*

Technical details

Dimensions	*Five desktop Rings for different load ranges*
Temperatures	*ambient*
Pressure	*atmospheric*
Media	*corrosive media with gas bubling (H_2S, others,..)*
Special features	*It consist of a universal materials testing equipment specially designed for testing materials for oil applications (sea water+ H_2S)*
Further particulars	-

Experiments – Equipment

Experiments	*The sensitivity of materials to the Hydrogen Induced Cracking (HIC) is studied by means of a combined test in which a mechanical test is performed while hydrogen is produced on the specimen surface.* *In some cases the hydrogen is produced chemically. That is the case of test performed according to NACE TM 01-77 standard in which a tensile load is applied to the specimen immersed in a aqueous solution saturated with H_2S, this acid produced the hydrogen that diffuses into the material.*
Level of detail	-
Instrumentation	*displacement, load, time*

Schedule	*tests on evaluating the sensitivity of materials to SCC/HIC last up to one month*
Tools	*The tested specimen should be studied by optical and scanning electron microscopy in order to identify different fracture mode features*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1.

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Overview

Name	***Fatigue testing equipment***
Type	*Servohydraulic universal tensile testing machine*
Scale	*lab scale*
Experiments	*studies on the effect of hydrogen on the behaviour of materials in fatigue – corrosion, hydrogen embrittlement*
Application field	*H1-H6, V3, V4, V5*

Technical details

Dimensions	-
Temperatures	-
Pressure	-
Media	-
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*The sensitivity of materials to the Hydrogen Induced Cracking (HIC) is studied by means of a combined test in which a mechanical test is performed while hydrogen is produced on the specimen surface. In this case the mechanical test used is a fatigue test and the production of hydrogen is generally electrochemical. For this purpose dynamic mechanical testing equipment is used.*
Level of detail	-
Instrumentation	-

Schedule	-
Tools	-
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  -

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Overview

Name	***LECO TCH 600***
Type	-
Scale	*lab scale*
Experiments	*chemical analysis of hydrogen in metals*
Application field	*H1-H6, V3, V4,V5*

Technical details

Dimensions	-
Temperatures	-
Pressure	-
Media	-
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*The presence of gases as nitrogen, oxygen and hydrogen in materials is limited to low values in metals. The analysis of these gases is performed by automatic equipments as the LECO TCH 600.*
Level of detail	-
Instrumentation	*temperature, pressure, flow (all incorporated to the equipment but not externally accessible).*
Schedule	*minutes*
Tools	-
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Overview

Name	***SHS reactor***
Type	-
Scale	*lab scale*
Experiments	*Metallic hydride production by SHS*
Application field	*H3*

Technical details

Dimensions	-
Temperatures	-
Pressure	-
Media	*different gases (hydrogen, air, nitrogen, steam, ...)*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*Metallic Hydride as hydrogen storage materials are produced by the Self-Propagating High-Temperature Synthesis (SHS) method.*
Level of detail	-
Instrumentation	*temperature, pressure, flow*
Schedule	*hours*
Tools	-
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -

Partner: *INERIS*

Facilities:
- *The "Basket"*
- *ISO-1m³ chamber, Dust-gas explosion room (DG1m3)*
- *10 m³ chamber, Dust-gas explosion room (DG10m3)*
- *INERIS-100 m³ chamber, Dust-gas explosion room (DG100m3)*
- *Flame Acceleration Pad (FAP)*
- *Flexible Ignition Facilities (FIF)*
- *High pressure-high temperature-2 m3 sphere (HPT2m3)*
- *Burton 1000 b chamber,*
  High pressure-high temperature 500 ml explosion chamber (HPT500ml)
- *Open Fire Area (OFA)*
- *Unconfined Cloud Area (UCA)*

Overview

Name	***The "Basket"***
Type	*large scale test area*
Scale	*large scale*
Experiments	*rupturing of confinements and investigation of fracturing and missiles*
Application field	*H1-H6, V2-V3*

Technical details

Dimensions	*4 meters large, 4 m long, 4 meters high*
Temperatures	*ambient*
Pressure	*ambient*
Media	*flammable liquid and gases*
Special features	*for typical volumes of a few tens of litres bursting with a maximum TNT equivalent of 1 kg* *mesh resistance to impact = 60 000 Joules*
Further particulars	-

Experiments – Equipment

Experiments	*investigation of the bursting of metallic confinements by using high speed video* *effects of the dynamics of the pressure rise* *effects of an external heating*
Level of detail	-

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
pressure	*piezoresistive device*	*0 to 1000 bar*	*±0.1% range*
gas analysis	*Oxygen controllers*	*0 to 100%*	*±0.2% abs (gas)*
video	*normal and high speed motion*	*25 to 8000 fps*	*± 60 μs*

Schedule *2 technicians for 4 days typically*

Tools -

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  2 technicians

  What kind of movable equipment is available and could be shared ?

  All standard measurement techniques

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  Provide a faster video system to tracks the cracks !

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

  It is possible to investigate the dynamics of fracturing , missile effects and mitigation techniques (shields)

  Which additional equipment could enhance your results?

  Work out a practicable mean to measure more precisely the deformations.

Overview

Name	***ISO-1 m³ chamber Dust-gas explosion room (DG1m3)***
Type	*vented or closed vessel*
Scale	*large scale*
Experiments	*Kst and Kg measurements (Pmax)* *turbulence/mixing diagnostic with aerodynamical probes* *flame propagation diagnostic with pressure/temperature/ionisation gages* *safety device tests like flame arresters, vents, suppressors*
Application field	*H1-H3, V1-V3*

Technical details

Dimensions	*1,37 m long and 0,95 m in diameter*
Temperatures	*ambient*
Pressure	*20 bar overpressure max*
Media	*flammable gases and dusts*
Special features	*fitted for Kst/Kg tests in accordance with European standard* *Even gaseous mixtures are produced by pneumatic injection (±0.2%vol.)*
Further particulars	*a-variable ignition sources (coils, sparks, jets,…) and position* *b-variable vent area (from 0 to 400 mm)* *c-possibility of coupling with pipes up to 400 mm in diameter*

Experiments – Equipment

Experiments	*Apart from classical explosion violence measurements, this vessel is used to investigate flame propagation rates (flame trajectories and velocities, turbulence, flame temperatures…) in various configurations (closed, open, with a duct, connected to another vessel..). It has been recently used to investigate in details the relationships between internal and external explosions, the flame dynamics when coupled to a duct*

and the incidence of particles on the turbulence field. Flame arresters, vents, suppressors are frequently tested with this vessel

Level of detail *detailed information may be obtained but internal visualisation is difficult*

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
pressure	*piezoresistive device*	*0 to 100 bar*	*±0.1% range*
gas analysis	*Oxygen controllers*	*0 to 100%*	*±0.2% abs (gas)*
video	*high speed motion*	*125 to 8000 fps*	*± 60 μs*
flame trajectory	*in-house ionisation gages*	*0 to 2000 m/s*	*±1%*
turbulence	*in-house probes*	*0.2 to 100 m/s*	*±5% range*

Schedule *standard explosion violence of one product : 3 days for 2 technicians*

preparing a fully equipped test for combustion diagnostic in the isolated vessel : 2 days for 2 technicians

preparing a fully equipped test for combustion diagnostic in a vessel duct configuration: 7 days for 2 technicians

Tools *standard*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  2 technicians

  What kind of movable equipment is available and could be shared ?

  All standard measurement techniques (more difficult for ionisation gages and turbulence measurement)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  In-house techniques have been internally developed at lab scale to heat up very rapidly the atmosphere inside a vessel without heating the envelope (principle of a rapid compression machine). They need to be scaled up and adapted to perform explosion mitigation at higher temperature (flame arresters, venting…).

- **To prepare promotion and specialisation**

What features/possibilities would you like to promote ?

This versatile equipment with the afore mentioned battery of equipments proved very useful for the investigation of flame dynamics especially in view of flame transmission from or towards a pipe.

Which additional equipment could enhance your results?

Data reduction need to be refined to enable a better correlation between flame dynamics and pressure effects. In this view, software modelling is required but also better techniques to detect the flame.

Overview

Name	***10 m³ chamber Dust-gas explosion room (DG10 m3)***
Type	*vented vessel*
Scale	*large scale*
Experiments	*turbulence/mixing diagnostic with in-house aerodynamical probes* *flame propagation diagnostic with pressure/temperature/ionisation gages* *safety device tests like vents, suppressors*
Application field	*H1-H3, V1-V3*

Technical details

Dimensions	*5.83 m long and 1.6 m in diameter*
Temperatures	*ambient*
Pressure	*7 bar overpressure max*
Media	*flammable gases and dusts*
Special features	*4 flanges (800 and 1600 mm in diameter)* *Even gaseous mixtures are produced by pneumatic injection (±0.2%vol.) by multiple ports*
Further particulars	*a-variable ignition sources (coils, sparks, jets,…) and position* *b-variable vent area (from 200 to 1600 mm)* *c-possibility of coupling with pipes up to 800 mm in diameter*

Experiments – Equipment

Experiments	*This vessel is used to investigate flame propagation rates (flame trajectories and velocities, turbulence, flame temperatures…) in various configurations (open, with a duct, connected to another vessel..). It has been recently used to investigate in details the relationships between internal and external explosions, the flame dynamics when coupled to a duct and the incidence of particles on the turbulence field. Flame vents, suppressors, barriers are regularly tested with this vessel.*

Level of detail *detailed information may be obtained either by probes or via internal visualisation*

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
pressure	*piezoresistive device*	*0 to 1000 bar*	*±0.1% range*
gas analysis	*Oxygen controllers*	*0 to 100%*	*±0.2% abs (gas)*
video	*normal and high speed motion*	*25 to 8000 fps*	*± 60 μs*
flame trajectory	*in-house ionisation gages*	*0 to 2000 m/s*	*±1%*
turbulence	*in-house probes*	*0.2 to 100 m/s*	*±5% range*

Schedule *preparing a fully equipped test for combustion diagnostic in the isolated vessel : 3 days for 2 technicians (1 test = ½ day with 2 techn.)*

preparing a fully equipped test for combustion diagnostic in a vessel duct configuration: 10 days for 3 technicians (1 test = 1 day with 2 techn.)

Tools *cranes to move the flanges or the vessel*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  2 to 3 technicians

  What kind of movable equipment is available and could be shared ?

  All standard measurement techniques (more difficult for ionisation gages and turbulence measurement)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

  This versatile equipment with the afore mentioned battery of equipments proved very useful for the investigation of flame dynamics especially in view of flame transmission from or towards a pipe.

  Which additional equipment could enhance your results?

Data reduction need to be refined to enable a better correlation between flame dynamics and pressure effects. In this view, software modelling is required but also better techniques to detect the flame.

Overview

Name	***INERIS-100 m^3 chamber Dust-gas explosion room (DG100m3)***
Type	*vented vessel*
Scale	*large scale*
Experiments	*turbulence/mixing diagnostic with in-house aerodynamical probes and tomographic techniques* *flame propagation diagnostic with pressure/temperature/ionisation gages* *safety device tests like vents, suppressors*
Application field	*H1-H3, H5, V1-V3*

Technical details

Dimensions	*10 m long and 3.5 m in diameter (square section)*
Temperatures	*ambient*
Pressure	*2 bar overpressure max*
Media	*flammable gases and dusts*
Special features	*vent area from 1 to 10 m²* *Even or stratified gaseous/dusts mixtures are produced by pneumatic injection (±0.2%vol.) by multiple ports.*
Further particulars	*a-variable ignition sources (coils, sparks, jets,…) and position* *b-variable vent area (from 1 to 10 m^2)* *c-possibility of coupling with pipes up to 800 mm in diameter*

Experiments – Equipment

Experiments	*This vessel is used to investigate flame propagation rates (flame trajectories and velocities, turbulence, flame temperatures…) in various configurations (open, with a duct, connected to another vessel..). It has been recently used to investigate in details the relationships between internal and external explosions and the incidence of particles on the turbulence field. Flame vents, suppressors, barriers are tested with this vessel but also the resistance of structural components to blast.*

It is also used to investigate the stratification of gases and diffusion

Level of detail *detailed information may be obtained either by probes or via internal visualisation and laser tomography (Ar ion laser + rotating miror)*

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
pressure	*piezoresistive device*	*0 to 1000 bar*	*±0.1% range*
gas analysis	*Oxygen controllers and tomography*	*0 to 100%*	*±0.2% abs (gas)*
video	*normal and high speed motion*	*25 to 8000 fps*	*± 60 μs*
flame trajectory	*in-house ionisation gages*	*0 to 2000 m/s*	*±1%*
turbulence	*in-house probes*	*0.2 to 100 m/s*	*±5% range*

Schedule *preparing a fully equipped test for combustion diagnostic in the isolated vessel : 5 days for 3 technicians*

preparing a fully equipped test for combustion diagnostic in a vessel duct configuration: 20 days for 3 technicians

preparing a fully equipped test for diffusion of gases in the isolated vessel : 10 days for 2 technicians

Tools *cranes to move the flanges or the vessel*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  2 to 3 technicians

  What kind of movable equipment is available and could be shared ?

  All standard measurement techniques (more difficult for ionisation gages, turbulence measurement and tomographic technique)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  We may investigate internal or external mixing field and flame dynamics by using tomography. However at such scale a much more powerful light source is required. It is partially available but the optics has to be designed.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

This versatile equipment with the afore mentioned battery of equipments proved very useful for the investigation of flame dynamics especially in view of large scale flame development and instabilities.

Which additional equipment could enhance your results?

Cloud dynamics with powerful tomography. Data reduction need to be refined to enable a better correlation between flame dynamics and pressure effects. In this view, software modelling is required but also better techniques to detect the flame.

Overview

Name	***Flame Acceleration Pad (FAP)***
Type	*pipes*
Scale	*large scale*
Experiments	*flame propagation in tubes and pipes fundamental studies* *vents and flame arrester testing* *coupling with vessels is possible*
Application field	*H1-H6, V1-V3*

Technical details

Dimensions	*100, 250, 450, 700 and 800 mm diameter steel tubes; up to 30 m long for each diameter*
Temperatures	*ambient*
Pressure	*20 bar max.*
Media	*flammables gases and dusts*
Special features	*up to 24 ports for pressure measurements and flame detection along the pipes*
Further particulars	*a-varied internal ignition devices (sparks, coil, hot spot)* *b-special mass-flowmeter device to fill the duct very homogeneously*

Experiments – Equipment

Experiments	*investigation of flame dynamics and self acceleration. DDT analysis* *study of the efficiency of flame arresters by varying the flame velocity at the barrier* *flame dynamics in a system duct-vessel*
Level of detail	*flame trajectory and pressures, dynamics of the mitigation technique if any*

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
pressure	*piezoresistive device*	*0 to 200 bar*	*±0.1% range*
gas analysis	*Oxygen controllers*	*0 to 100%*	*±0.2% abs (gas)*
flame trajectory	*in-house ionisation gages*	*0 to 2000 m/s*	*±1%*

Schedule *preparing a fully equipped test for combustion diagnostic in the isolated duct : 5 days for 2 technicians*

preparing a fully equipped test for combustion diagnostic in a vessel duct configuration: 10 days for 3 technicians

Tools *cranes*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  2 to 3 technicians

  What kind of movable equipment is available and could be shared ?

  All standard measurement techniques (more difficult for ionisation gages and turbulence measurement)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

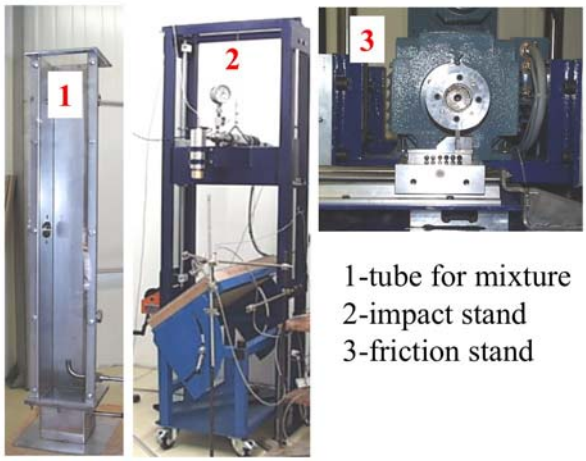
  This versatile equipment with the afore mentioned battery of equipments proved very useful for the investigation of flame dynamics especially in view of flame transmission from or towards a pipe. New injection techniques should be thought about to be able to master non homogeneous mixtures.

  Which additional equipment could enhance your results?

  Data reduction need to be refined to enable a better correlation between flame dynamics and pressure effects. In this view, software modelling is required but also better techniques to detect the flame.

Overview

Name	***Flexible Ignition Facilities (FIF)***
Type	*small vessel with various igniters*
Scale	*small scale*
Experiments	*investigation of the characteristics of "practical" ignition sources* *analysis of the fundamentals of flame initiation*
Application field	*H1-H6, V3-V4*



1-tube for mixture
2-impact stand
3-friction stand

Technical details

Dimensions	*chamber = tube 80 cm high, 10 cm wide, square, transparent, for gases and two phase mixtures*
Temperatures	*ambient*
Pressure	*ambient*
Media	*flammable gases and dusts*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*Investigation of the characteristics of "practical" ignition sources like electrostatic discharges up to several Joules, electrical sparks, impacts and friction sources, hot spot, laser heating,….* *analysis of the fundamentals of flame initiation (point ignition, continuous and transient surface ignition,…).*
Level of detail	*extremely detailed information may be obtained including temperature and microcalorimetric techniques to measure the energy release by a given ignition source in the atmosphere.*

Instrumentation

nature	***principle***	***range***	***error***
IR thermography	*IR video/ 2 colour pyro.*	*200 to 2000 °C*	*±30 °C*
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
energy	*in-house microcalorimetry*	*0 to 1000 J*	*±1% range*
pressure	*piezoresistive device*	*0 to 1 bar*	*±0.1% range*
gas analysis	*Oxygen controllers*	*0 to 100%*	*±0.2% abs (gas)*
video	*normal and high speed motion*	*25 to 8000 fps*	*± 60 μs*
flame trajectory	*in-house ionisation gages*	*0 to 2000 m/s*	*±1%*
data acquisition	*LECROY 1 GHz*		

Schedule *minimum ignition curve: 5 days for 1 technician*

Tools -

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  1 technicians

  What kind of movable equipment is available and could be shared ?

  Measuring techniques can be shared but training is required

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  A very high voltage supply equipment for electrostatics; UV detection and measurements.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

  The high versatility of the laboratory and the possibility to mimic real ignition source and measure/analyse their characteristics.

  Which additional equipment could enhance your results?

  Prepare a very low energy electrical spark device and means to measure very low energies (below 0,3 mJ)

Overview

Name	***High pressure-high temperature-2 m^3 sphere (HPT2m3)***
Type	*closed vessel*
Scale	*large scale*
Experiments	*determination of flammable limits, auto-ignition delay and explosion parameters (dP/dt, Pmax, flame velocities) of gases and vapours under high pressure and high temperature.*
Application field	*H1-H4, V1-V3*

Technical details

Dimensions	*1,55 m diameter, steel sphere 65 mm thick*
Temperatures	*ambient to 200°C regulated*
Pressure	*0 - 30 bar in charge. 200 bar overpressure*
Media	*flammables gases and vapours*
Special features	*3 flanges 350mm diameter for gases and liquids inlet and outlet, pressure measurements, gases analysis, unique mixing device*
Further particulars	*varied internal ignition devices (sparks, coil, hot spot)*

Experiments – Equipment

Experiments	*closed volume explosion experiments in "ideal" spherical situation; level of accuracy equivalent to lab scale for flame diagnostic specially adapted to produce exotic mixtures*
Level of detail	*detailed information may be obtained either by probes or via internal visualisation*

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
pressure	*piezoresistive device*	*0 to 1000 bar*	*±0.1% range*
gas analysis	*Oxygen controllers*	*0 to 100%*	*±0.1% abs*
video	*normal and high speed motion*	*25 to 8000 fps*	*± 60 μs*
flame trajectory	*in-house ionisation gages*	*0 to 2000 m/s*	*±1%*

Schedule *preparation : 2 technicians for 5 days typically*

test : 2 technicians for 1 to 2 day(s)

Tools *standard*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  2 technicians

  What kind of movable equipment is available and could be shared ?

  All standard measurement techniques (more difficult for ionisation gages and turbulence measurement)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  Prepare an additional system to inject mists under pressure.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

  This equipment with the afore mentioned battery of equipments proved very useful for the investigation of fundamental parameters of the propagation.

  Which additional equipment could enhance your results?

  -

Overview

Name	***Burton 1000 b chamber***
	High pressure-high temperature 500 ml explosion chamber (HPT500ml)
Type	*closed vessel*
Scale	*small scale*
Experiments	*maximum pressure measurements at very high pressures and temperatures with various mixtures*
	ignition behaviour (sparks, self-ignition,…)
Application field	*H1-H4, H6, V2-V3*

Technical details

Dimensions	*½ litre*
Temperatures	*up to 300 °C*
Pressure	*up to 1000 bar max explosion pressure*
Media	*flammable gases and liquids*
Special features	*mixing device*
Further particulars	-

Experiments – Equipment

Experiments	*explosion violence measurements and ignition test in abnormal conditions*
Level of detail	*detailed information may be obtained but internal visualisation is difficult*

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
pressure	*piezoresistive device*	*0 to 1000 bar*	*±0.1% range*
gas analysis	*Oxygen controllers and tomography*	*0 to 100%*	*±0.2% abs (gas)*
flame trajectory	*in-house ionisation gages*	*0 to 2000 m/s*	*±1%*

Schedule *explosion violence of one product and one set of conditions: 3 days for 1 technicians*

Tools *special*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  1 technicians

  What kind of movable equipment is available and could be shared ?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  -

- **To prepare promotion and specialisation**

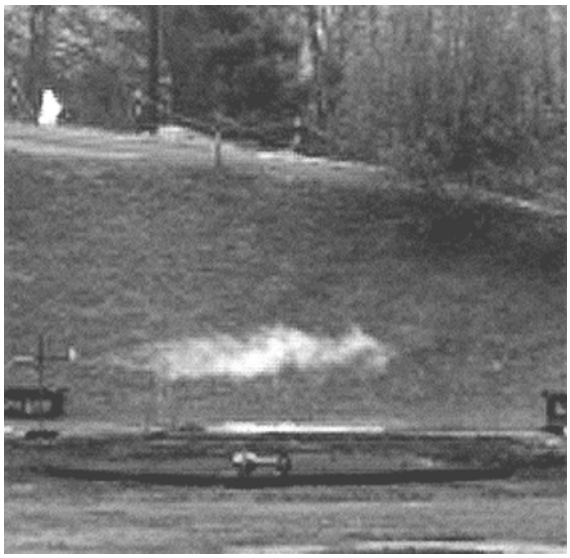
  What features/possibilities would you like to promote ?

  The possibility to perform tests in very unusual situations

  Which additional equipment could enhance your results?

  Prepare a very low energy electrical spark device. A fast data acquisition system.

Overview



Name	***Open Fire Area (OFA)***
Type	*large scale test area*
Scale	*large scale*
Experiments	*ignition and fire of gaseous jets and liquid pools*
Application field	*H1-H6, V1-V3*

Technical details

Dimensions	*20 meters large, 50 m long*
Temperatures	*ambient*
Pressure	*ambient*
Media	*flammable liquid and gases*
Special features	*experimental pool (5 m^2, 0.4 m deep) for liquid fires* *possibility to produce large jets of more than 200 bar through a hole of more than 20 mm* *investigation of the fire of large static cloud (more than 200 m^3)*
Further particulars	*high pressure stand (up to 1000 bar)*

Experiments – Equipment

Experiments	*investigation of liquid fires* *investigation of jet fires under high pressure or of large static clouds*
Level of detail	-

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
irradiance	*thermopiles*	*up to 50 000 kW/m²*	*±5% range*
turbulence measurement	*In-house probes*	*0.2 to 100 m/s*	*±5% range*
video	*normal and high speed*	*25 to 8000 fps*	*±60 μs*
IR thermography	*IR video/ 2 colour pyro.*		

Schedule *assembling a jet experiment : 2 technicians for 2 days typically (one hour for a test)*

assembling a static cloud experiment : 3 technicians for 4 days (a few hours for a test)

Tools -

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  2 to 3 technicians

  What kind of movable equipment is available and could be shared ?

  All standard measurement techniques

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  Develop a high speed irradiance measurement tool for highly transient phenomena.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

  The capacity to perform tests with large clouds and high pressures.

  Which additional equipment could enhance your results?

  Provide a larger very high pressure tank of larger volume for quasi stationary test and a HP compressor with a larger flowrate.

Overview

Name	***Unconfined Cloud Area (UCA)***
Type	*large scale test area*
Scale	*large scale*
Experiments	*fundamental studies on flammable gases and liquids releases from high pressure tanks* *unconfined explosions investigations*
Application field	*H1-H6, V1-V3*

Technical details

Dimensions	*30 meters large, 75 m long*
Temperatures	*ambient*
Pressure	*ambient*
Media	*flammable liquid and gases*
Special features	*experimental tank (5 m^3, 40 bar) equipped with control and measurement settings (temperature, pressure, flowrate) and nozzles up to 150 mm)* *possibility to discharge smaller tanks (tens of litres) through nozzles up to 20 mm and pressures up to 700 bars* *experimental system to investigate the formation of very large clouds (including cryogenic spills up to a few kg/s) up to more than 200 m long and 100 m high*
Further particulars	*high pressure stand (up to 1000 bar)* *special data acquisition system 10 Hz, 220 channels with master/slaves computers*

Experiments – Equipment

Experiments	*investigation of the dispersion plume and mist formation (droplet sizes) for high pressure gases (temperature, concentrations, aerodynamic and density fields)*

investigation of the dispersion plume and mist formation (droplet sizes) medium pressure liquid releases and cryogenics (temperature, concentrations, aerodynamic and density fields)

investigation of the development of unconfined explosions in quiescent and turbulent situations (simultaneous measurement of turbulence, pressure flame position and combustion rate)

Level of detail -

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
pressure	*piezoresistive devices*	*0 to 1000 bar*	*±0.1% range*
velocimetry and anemometry	*PDA laser*	*1 to 400 m/s* *2 to 600 μm*	*±1% range*
turbulence measurement	*in-house probes*	*0.2 to 100 m/s*	*±5% range*
video	*normal and high speed motion*	*25 to 8000 fps*	*± 60 μs*

Schedule *assembling a jet experiment : 2 technicians for 5 days typically (a few hours for a test)*

preparing a large unconfined explosion : 3 technicians for 5 days

preparing the equipment for liquid spills : 3 technicians for 40 days (1 to 2 days per test)

Tools *cranes for heavy equipments and to erect the mast for the 220 gauges measuring system*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments ?

  2 to 3 technicians

  What kind of movable equipment is available and could be shared ?

  All standard measurement techniques (more difficult for ionisation gages and turbulence measurement) including the special device for cryogenic spills

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modification and or by applying additional instrumentation ?

  We may investigate gas dynamics by using tomography and other optical techniques. However at such scale a powerful light source is required and large optics (system also useful for the explosion chambers)

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

  These versatile equipments with the afore mentioned battery of equipments proved very useful for the investigation of cloud and flame dynamics especially for large momentum releases and cryogenic spills.

  Which additional equipment could enhance your results?

  Provide a larger very high pressure tank of larger volume for quasi stationary test and a HP compressor with a larger flow rate. Cloud dynamics with powerful tomography and other optical technique like interferometry.

Partner: *JRC*

Facilities:
- *AMC Gas Reaction Controller*
- *Gravimetric analyser*
- *SenTeF*
- *SYSAF bunker*

Overview

Name	***AMC Gas Reaction Controller*** *(Currently installed and undergoing commissioning)*
Type	*Volumetric sorption measurement apparatus*
Scale	*Laboratory scale*
Experiments	*Hydrogen storage material testing*
Application field	*H2 (Transport and distribution, refuelling stations)* *V5 (Standardisation and legal requirements)*

Technical details

Dimensions	*Overall unit: 0.86 × 0.76 × 0.69 m* *Sample chamber: 2 cm^3*
Temperatures	*-60 to + 60°C (with a cryostat) and Room temperature to 500°C*
Pressure	*0.01 to 200 bar*
Media	*Hydrogen, nitrogen and other inert gases*
Special features	*High-pressure testing of equilibrium pressure-composition isotherms over a wide temperature range. The system is fully automated and can perform repeated sorption cycles, at a range of temperatures, without user intervention.*
Further particulars	*Kinetic absorption and desorption measurements can be made using two gas flow meters.*

Experiments - Equipment

Experiments	*Assessment of potential hydrogen storage materials with respect to:* *1) Storage capacity (e.g. maximum wt%) – all materials* *2) PCT behaviour - intermetallic hydrides* 3) *Absorption/desorption rates – all materials* 4) *Cycling Stability – intermetallic and complex hydrides*
Level of detail	-
Instrumentation	*Overview:* *Reaction chambers - volume available for the sample ~2 cm^3* *Temperature control and measurement system – furnace, cryofurnace, thermocouples*

	Pressure measurement system - four HPO series pressure transducers
	Mass flow meters with maximum flow range for absorption =1000 sccm and for desorption = 500 sccm
	Control volume vessels
	Solenoid valves and control relays
	Mechanical vacuum pump
	Automation system
	Data logging/acquisition system and custom software program compatible with Labview®
Schedule	*The time needed for preparation of experiments is about 1 day.*
	The time needed for the conduction of experiments depends on what materials and which properties are to be studied. A typical PC isotherm for an intermetallic hydride will take less than 24 hours, whereas a long term cycling stability test could take months, depending on the number of cycles to be performed.
	The time needed for interpretation of experiments also depends on the properties being measured. The simple determination of a sample's plateau pressure would take less than 1 hour, but further analysis and fitting could take considerably longer.
Tools	*General laboratory software*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  To prepare/conduct experiments only 1 person is needed

  What kind of movable equipment is available and could be shared?

  The facility will be integrated in a multi-purpose laboratory at JRC-Petten and it is not scheduled to be moved after installation. Access to external users will be open in the frame of research training (e.g. PhD Thesis) and/or collaboration agreements with JRC.

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or applying additional instrumentation?

  With additional temperature control equipment, e.g. powerful cryostat, measurements could be made at lower temperatures.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  JRC is highly interested in participating with these testing facilities in validation exercises for the harmonisation of data, the identification of best practices and standardisation of test methods and procedures related to hydrogen storage capacity measurements of metal hydrides and porous materials.

Overview

Name	***Hiden Isochema Intelligent Gravimetric Analyser*** *(Installation scheduled October 2004)*
Type	*Gravimetric sorption measurement apparatus*
Scale	*Laboratory scale*
Experiments	*Hydrogen storage material testing*
Application field	*H2 (Transport and distribution, refuelling stations)* *V5. (Standardisation and legal requirements)*

Technical details

Dimensions	*Overall unit: 1.8 × 0.5 × 1.8 m*
Temperatures	*-150°C to +500°C*
Pressure	*vacuum to 20 bar*
Media	*Hydrogen, nitrogen and other inert gases*
Special features	*The accurate determination of isothermal hydriding kinetics over a wide temperature range. This allows, for example, the derivation of the hydrogen diffusion coefficient in the case of intermetallic hydrides. Pressure-Composition isotherms can also be determined accurately. The system is fully automated and can perform repeated sorption cycles, at a range of temperatures, without user intervention. The system is fitted with a unit to transfer sensitive samples directly from a glove box to the sample chamber.*

Experiments - Equipment

Experiments	*Assessment of potential hydrogen storage materials with respect to:* *1) Storage capacity (eg, maximum wt%) – all materials* *2) PCT behaviour - intermetallic hydrides* 3) *Ab / ad-sorption/desorption rates – all materials* 4) *Cycling Stability – intermetallic and complex hydrides*
Level of detail	-
Instrumentation	*Overview* *Four Stream Thermal Gravimetric Analysis / Mass Spectrometer system - dynamic pressure control, multi-stream inlet for carrier and reactive mixtures, with an integrated dynamic sampling mass*

	spectrometer for evolved gas analysis.UHV stainless steel vessel; balance capacity up to 5g; pressure regulation via high resolution sensors. Data logging/acquisition system and custom software program compatible with Labview® .
Schedule	*the time needed for preparation of experiments is about 1 day;* *the time needed for the conduction of experiments depends on what materials and which properties are to be studied. The determination of the sorption kinetics of an intermetallic hydride at one temperature could take less than 24 hours, whereas a long term cycling stability test could take months, depending on the number of cycles to be performed. The time taken for experiments will also be dependent on the temperature/s at which the measurements are to be made.* *the time needed for interpretation of experiments also depends on the properties being measured. The simple determination of a sample's plateau pressure would take less than 1 hour, but further analysis and fitting could take considerably longer.*
Tools	*General laboratory software*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  To prepare/conduct experiments only 1 person is needed

  What kind of movable equipment is available and could be shared?

  The facility will be integrated in a multi-purpose laboratory at JRC-Petten and it is not scheduled to be moved after installation. Access to external users will be open in the frame of research training (e.g. PhD Thesis) and/or collaboration agreements with JRC.

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or y applying additional instrumentation?

  JRC is considering upgrading its laboratories with a further instrument with the capability of performing temperature programmed desorption from liquid nitrogen temperatures. This could be used to quickly scan the hydrogen sorption properties of materials, as well as investigating more fundamental properties.

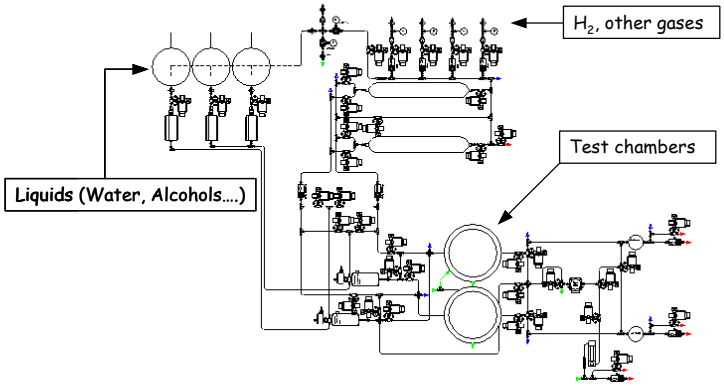
- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  JRC is highly interested in participating with these testing facilities in validation exercises for the harmonisation of data, the identification of best practices and standardisation of test methods and procedures related to hydrogen storage capacity measurements of metal hydrides and porous materials.

Overview

Name	***SenTeF** (To be commissioned by end 2004)*
Type	*Environmental chamber for explosive/toxic gases*
Scale	*Laboratory scale*
Experiments	*Sensors performance testing*



Application field
H2 (Transport and distribution, refuelling stations)
H4 (Vehicles powered with H2)
H5 (Tunnels, parking and garage)
V3 (Development and validation of hydrogen mitigation techniques)
V5 (Standardisation, and legal requirements)

Technical details

Dimensions	*Facility: approx. 2.5 x 1 x 1.5 meters* *Test Chamber: approx. 2.5 litres volume*
Temperatures	*- 50 to +130 °C*
Pressure	*Test chamber: 0.5 to 1.3 bar* *Gas buffers: 5 bar*
Media	*hydrogen/air/water vapour + another gas (e.g. CO) by end 2004* *+ up to 4 other gases (e.g. CO_2, H_2S, SO_2, NH_3) by mid 2005* *+ up to 2 other vapours (e.g. Ethanol, Isooctane) by mid 2005*
Special features	*a sophisticated gas handling and environmental control system allows simulating real ambient conditions (complex gas mixtures, altitudes). Designed in view of testing sensors response time and resistance to thermal shocks (upgrades 2005) and vibrations (upgrade possible).*
Further particulars:	*The system core is a 316 SS test chamber internally coated with Halar polymer for improved resistance against contamination, double walled for circulation of the heating/refrigerating fluid; the chamber is isolated from the laboratory environment by a further containment, streamed with Argon. Test gases and vapours (water, alcohols, alcanes) are released at concentrations down to ppm levels through gas and liquid mass flow controllers and evaporators. The gas composition is stabilised in buffers and can be determined with a 3-columns gas chromatograph equipped with multiple detectors. Humidity is measured with a chilled mirror hygrometer.*

Experiments - Equipment

Experiments

Assessment of hydrogen sensors performance with respect to:

- *Sensitivity to target gas*
- *Influence of temperature, humidity and altitude (reduced pressure)*
- *Cross sensitivity to other gases/vapours*

Instrumentation

TEST PARAMETER	INSTRUMENT TYPE	N. OF ITEMS	OPERATING PRINCIPLE	RANGE	ACCURACY
Atmosphere composition	Mass flow controllers	9	Thermal	Varying between 1.2-60 ml/min to 60-3000 ml/min	0.1 to 0.5 % full scale
	Liquid mass flow controllers	1	Thermal	0-10 g/h	0.2% full scale
	Controlled evaporator mixer (by mid 2005)	1	Heat exchange	10 g/h liquid, 1 l_n/min gas	0.2% full scale
	3-columns gas chromatograph	1	TCD (PDD by mid 2005)	H_2 : from 2 ppm, (100 ppb with PDD) to 100%	5% at 2 ppm
				CO: 2 ppm (with PDD) to 100%	5% at 2 ppm
			TCD	CO_2: 5 ppm to 100%	5% at 5 ppm
				H_2S: 10 ppm to 100%	5% at 10 ppm
				SO_2: 10 ppm to 100%	5% at 10 ppm
				NH_3: 200 ppm to 100%	20% at 200 ppm
			FID	Alcohols/alcanes: 1 ppm to 100%	1% at 10 ppm
Temperature	Circulating bath	1	Heat exchange	- 50 to 150°C	± 0.01°C
	PT100	5-6	Resistance	-200 to 500°C	± 0.1°C
Humidity	Liquid flow meter	1	Thermal	0-5 g/h	0.2% full scale
				0-100 g/h	0.2% full scale
	Controlled evaporator mixers	1	Heat exchange	10 g/h liquid, 1 l_n/min gas	0.2% full scale
				100 g/h liquid, 10 l_n/min gas	0.2% full scale
	Hygrometer	1	Chill mirror	Dew/frost point: –50 to 100°C	±0.2°C
Pressure (Gas buffers)	Transducer	2	Strain gage	0-10 bar abs	0.15% full scale
Pressure Test chamber)	Transducer	1	Strain gage	0-1.6 bar abs	0.1 % full scale

Schedule

the facility is scheduled to be in operation by the end of 2004
the time needed for preparation of experiments will be about 1 day
the time needed for conduction of experiments will depend on the test
The sensors output data will be collected and visualised in real time, and recorded on general laboratory software platforms (Labview®, Excel®).

Tools

general labs software

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  To prepare/conduct experiments 2 persons are needed

  What kind of movable equipment is available and could be shared?

  The facility will be integrated in a multi-purpose laboratory at JRC Petten, and is not scheduled to be moved after installation. Access to external users will be open in the frame of research training (e.g. Ph.D. Thesis) and/or collaboration agreements with JRC.

- **To prepare filling possible gaps**

What kind of experiments/tests could be performed in this facility after minor modifications and/or y applying additional instrumentation?

The system has been designed in view of two major upgrades:

- *Installation of a multiple test chamber with actuated sample holders (foreseen in 2005), to enable the system to carry out the following tests:*
  - *sensors response time*
  - *reaction to sudden changes of environment (temperature, pressure, humidity)*
  - *resistance to thermal shocks/cycling*
  - *accelerated lifetime testing*
- *Installation of a vibrating table, to be used in combination with the existing 2.5 litres chamber for testing sensors performance under simulated on-vehicle use conditions.*

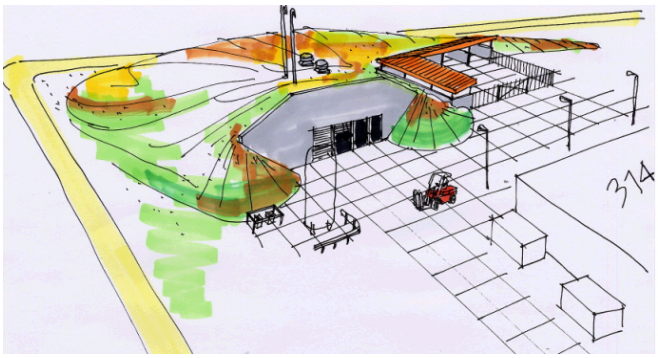
- **To prepare promotion and specialisation**

What features/possibilities would you like to promote?

JRC can provide assistance to companies developing hydrogen safety sensors in meeting the performance requirements demanded by users

JRC is highly interested in co-operating with both manufacturers and users, to help developing a unified procedure for testing the hydrogen sensors performance in a controlled environment.

Overview



Name	***SYSAF high-pressure facility (SYSAF bunker)*** <u>*To be commissioned mid 2005*</u>
Type	*N_2-inertised room with pressure vessels*
Scale	*Small to full scale*
Experiments	*High-pressure cycling and permeation measurements on compressed H_2 / CH_4 storage systems for vehicles*
Application field	*H2-V4 (testing of distribution components)* *H3-V4 (testing of CGH_2 vehicle systems)* *H3-V5 (inputs to pre-normative research)*

Technical details

Dimensions	*Half-buried strongly reinforced concrete bunker with annexed gas storage area. 225 m^3 room (10 x 7.5 x 3 m^3) inertised using gaseous N_2 including:* - *The pressure vessels containing the parts to be tested,* - *A high-pressure compressor,* - *Controlling equipment and instrumentation.*
Temperatures	*ambient up to approx. 100°C*
Pressure	*Vacuum (permeation tests) to 350 bar – Upgrade to ca. 800 bar foreseen*
Media	*Methane (pure CH4), gaseous hydrogen. Helium, Argon as blanket gases*
Special features	*Full-scale testing of CGH2 / natural gas vehicle tanks using the real gases.* *Testing of other components of the gaseous hydrogen distribution chain shall be possible. The facility is remotely controlled. The gases are used in a closed-loop circuit between the facility and the storage area. The gas consumption and the amount vented in the atmosphere are minimised.*
Further particulars	*(a) Permeation measurements can be performed statically (at constant high pressure) or dynamically (during pressure-cycling)* *(b) Permeation tests carried out using gas chromatography* *(c) Possibility of temperature measurements on the part being tested*

Experiments - Equipment

Experiments	*Vehicle storage components (mainly tanks) are pressure-cycled for a pre-defined number of cycles. During the cycling test or after the test the permeation rate is measured using gas chromatography. A typical cycle will consist of 3 minutes filling time and ca. 20 minutes emptying to the low pressure. The results will be validated using existing standards and possibly used as input to pre-normative research.*
Instrumentation	*Measurement performances of the facility will be given at a later stage.* *Overview of instrumentation:* *Gas chromatograph with Pulse Discharge Detector,* *Thermocouples,* *High-pressure 3-stage piston compressor,* *Compressor cooling unit,* *H_2 /CH_4 on the exhaust line of the inert blanket gas (for early detection of dangerously high permeation/leakage rates),* *H_2, CH_4 and O_2 concentration sensors in facility room for safety purposes (doubled installation),* *Automation system including two independent PLC's and Labview® software for data acquisition,* *Closed circuit cameras and other safety-related devices.*
Schedule	*The time needed for preparation of experiments is about 5 days.* *The time needed for conduction of experiments depends essentially on the number of cycles. For instance, a 1500-cycle test will last about 25 days.* *A static permeation test will last a few hours.* *For all tests, data is collected in real time*
Tools	*general labs software*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  To prepare/conduct experiments at least 3 persons are needed (two of whom accredited as operators)

  What kind of movable equipment is available and could be shared?

  The facility will be integrated in a multi-purpose laboratory at JRC Petten, and is not scheduled to be moved after installation. Access to external users will be open in the frame of research training (e.g. Ph.D. Thesis) and/or collaboration agreements with JRC.

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or y applying additional instrumentation?

  Other components than vehicle tanks can be tested after some (minor) modifications in the mechanical set up.
  An upgrade of the facility is foreseen in 2006 in order to increase the maximum static pressure from ca. 350 to ca. 800 bar.

Tests involving hydrogen / natural gas mixtures should be possible after some modifications.

- **To prepare promotion and specialisation**

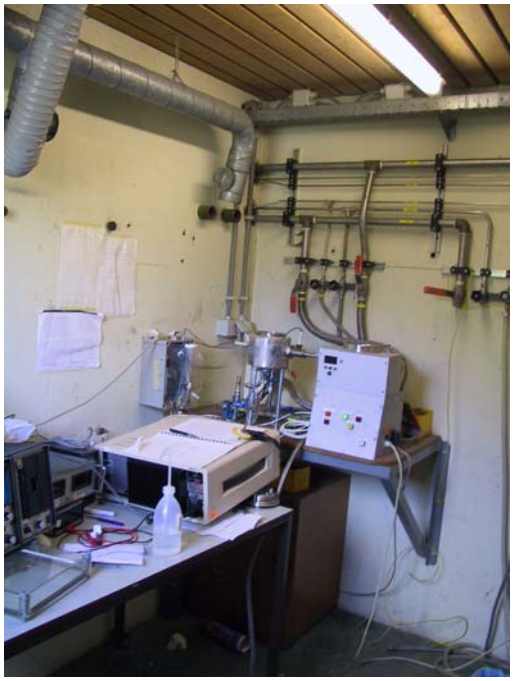
  What features/possibilities would you like to promote?

  JRC is highly interested in co-operating with both manufacturers and users, to help developing procedures for testing hydrogen storage systems for vehicles and contributing to standardisation.

Partner: *TNO*

Facilities:
– 1 litre vessel
– 20 litre vessel
– 500 litre vessel
– 1 m³ vessels
– 5 m³ vessel
– Gas explosion chamber
– IBBC Bunker
– FAST
– GEFEF
– Small scale blast simulator
– Large scale blast simulator
– Laboratory for ballistic research (LBO)
– Test Facility 3 (TF3)
– Large indoor rocket test stand

Overview



Name	***1 litre vessel***
Type	*closed bomb*
Scale	*lab scale*
Experiments	*Closed bomb experiments, to measure explosion limits and ignition temperatures and energies*
Application field	*H1-H6 / V2, V4, V5*

Technical details

Dimensions	*1 litre*
Temperatures	*hot water bath for the wall*
Pressure	-
Media	*various flammable gasses and inerts*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*Closed bomb experiments, to measure explosion limits and ignition temperatures and energies*
Level of detail	-
Instrumentation	*gas temperature* *pressure* *gas composition*
Schedule	-
Tools	-
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  Equipment easy to move

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***20 litre vessel***
Type	*closed bomb*
Scale	*lab scale*
Experiments	*Closed bomb experiments, to measure explosion limits and ignition temperatures and energies*
Application field	*H1-H6 / V2, V4, V5*

Technical details

Dimensions	*20 liter*
Temperatures	*hot water bath for wall*
Pressure	*maximum static overpressure of 40 bar*
Media	*various flammable gasses and inerts*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*Closed bomb experiments, to measure explosion limits and ignition temperatures and energies*
Level of detail	-
Instrumentation	*gas temperature* *pressure* *gas composition*
Schedule	-
Tools	*Kuhner data-acquisition software*

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  Equipment easy to move

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  gas, dust or hybrid mixtures can be applied

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***500 litre vessel***
Type	*closed bomb*
Scale	*lab/pilot scale*
Experiments	*Closed bomb experiments, to measure explosion limits and ignition temperatures and energies*
Application field	*H1-H6 / V2-V5*

Technical details

Dimensions	*500 liter*
Temperatures	*atmospheric temperature*
Pressure	-
Media	*various flammable gases and inerts*
Special features	*Flanges enable to install instruments and bursting disks or vent covers etc.*
Further particulars	-

Experiments – Equipment

Experiments	*Closed bomb experiments, to measure explosion limits and ignition temperatures and energies*
Level of detail	-
Instrumentation	*gas temperature* *pressure* *gas composition*
Schedule	-
Tools	-
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  Equipment easy to move

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  gas, dust or hybrid mixtures can be applied

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***1 m³ vessel*** *(P_{max} = 20 bar and 100 bar)*
Type	*vessel (closed bomb)*
Scale	*small scale*
Experiments	*closed bomb experiments with* *- higher operating / initial pressure* *- other substances; for ex. pure oxygen* *- linked vessel systems (2 times 1m³)*
Application field	*H1-H6 / V2-V5*

Technical details

Dimensions	*cylindrical vessels of 0,97 m I.D. and a length of 1,05 m*
Temperatures	*atmospheric temperature*
Pressure	*maximum static overpressure of 20 and 100 bar*
Media	*gases and dust*
Special features	*Flanges enable to install instruments and bursting disks or vent covers etc.*
Further particulars	-

Experiments – Equipment

Experiments	*The 1-m³ explosion vessels are cylindrical vessels capable to withstand a maximum static overpressure of 20 and 100 bar. This makes it possible to do experiments with higher operating pressures or explosions with pure oxygen instead of air. The front of the vessel is closed by a door, the rear by a blind flange. If necessary the blind flange can be replaced by other flanges to enable the testing of bursting disks, vent covers etc. With the two 1 m³ vessels also linked vessel experiments can be performed. The vessel is operated at room temperature.* *As with the 5-m3 vessel, the 1-m3 explosion vessel can also be used to determine the efficiency of equipment and protective systems intended for use in potentially explosive atmospheres. These include*

	explosion suppression devices, explosion detectors, and pressure resistant devices.
Level of detail	-
Instrumentation	*gas temperature* *pressure* *gas composition*
Schedule	-
Tools	*The signals from the pressure gauges and thermocouples are transmitted to the SCADAS II Signal Conditioning and Data Acquisition System.*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  gas, dust or hybrid mixtures can be applied

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***5 m³ vessel** (gas/dust)* *P_{max} 15 bar*
Type	*vessel (closed bomb)*
Scale	*medium scale*
Experiments	*test of equipment and protective systems intended for use in potentially explosive atmospheres*
Application field	*H1-H6 / V2-V5*

Technical details

Dimensions	*cylindrical 5 m³ vessel*
Temperatures	*room temperature*
Pressure	*maximum static overpressure of 15 bar*
Media	*gas and dust*
Special features	*Flanges enable to install instruments and bursting disks or vent covers etc.*
Further particulars	-

Experiments – Equipment

Experiments	*The 5-m³ explosion vessel is used to determine the efficiency of equipment and protective systems intended for use in potentially explosive atmospheres. These include explosion suppression devices, explosion detectors, and pressure resistant devices.* *The 5-m³ explosion vessel is a cylindrical vessel, capable to withstand a maximum static overpressure of 15 bar. Flanges enable to install instruments and bursting disks or vent covers etc.. The vessel is operated at room temperature.*
Level of detail	-
Instrumentation	*gas temperature* *pressure* *gas composition*

Schedule	-
Tools	-
Further particulars	*if appropriate*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  gas, dust or hybrid mixtures can be applied

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***Gas Explosion Chamber (GEC)***
Type	*cubic shaped vessel*
Scale	*large scale*
Experiments	*test constructions that can reduce or protect against explosion overpressures; venting devices and explosion resistant constructions can be tested*
Application field	*H1-H6, V1-V5*

Technical details

Dimensions	*cubic shaped vessel of 36 m³* *venting areas from about 2 to 5 m²*
Temperatures	*atmospheric temperatures*
Pressure	*maximum explosion overpressure of 1 bar*
Media	*gas*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*The GEC is fitted with a gas supply and can be used to test constructions that can reduce or protect against explosion overpressures. Venting devices can be tested with venting areas from about 2 to 5 m^2. Explosion resistant constructions can be tested with a maximum explosion overpressure of 1 bar.*
Level of detail	-
Instrumentation	*gas temperature* *pressure* *gas composition*
Schedule	-

Tools	*The signals from the pressure gauges, blast pencils and thermocouples are transmitted to the SCADAS II Signal Conditioning and Data Acquisition System.*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***IBBC Bunker***
Type	*reinforced concrete bunker*
Scale	*large scale*
Experiments	v*ented gas explosions*
Application field	*H1-H6 / V1-V5*

Technical details

Dimensions	*"kitchen" (20 m^3) and "living room" (40 m^3)*
Temperatures	*room temperature*
Pressure	*P_{max} 0.35 bar*
Media	*gas*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*The IBBC bunker was built to experiment with vented gas explosions in domestic applications. This reinforced concrete bunker has two chambers, which have the size and shape of a realistic kitchen (20 m^3) and living room (40 m^3). In the bunker, numerous venting experiments have been conducted. Openings in the walls of the bunker can be fitted with vent panels or brick walls in order to test their strength and venting efficiency.*
Level of detail	-
Instrumentation	*gas temperature* *pressure* *gas composition*
Schedule	-
Tools	*AutoReaGas™ is a CFD software package that consists of two CFD codes: a gas explosion simulator and a blast simulator. Both codes are*

integrated in an interactive and user-friendly environment. The gas explosion simulator is capable of simulating the turbulent premixed combustion process in gas explosions. This process is the origin of blast effects. Given the blast source characteristics, the blast simulator is capable of computing the propagation of the blast wave in the vicinity of the explosion and the interaction with objects.

The gas dynamics of a gas explosion is simulated by the numerical solution of a full set of conservation equations, that constitutes a model for the gas dynamics, the turbulence and the fuel distribution. The propagation and interaction of blast with structures is simulated by numerical solution of conservation equations which constitute a model for inviscid gas dynamics. A Flux-Corrected Transport scheme is used to capture and preserve shocks.

Further particulars -

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***FAST (Flame Acceleration STudy)***
Type	*Open air gas explosion facility*
Scale	*large scale*
Experiments	*Flame propagation and blast wave experiments of gas explosions in open air*
Application field	*H1-H6 / V1-V5*

Technical details

Dimensions	*open field of approx. 70 x 70 m^2*
Temperatures	*atmospheric temperature*
Pressure	-
Media	*gas*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*The FAST is a facility that enables a continuous monitoring of the flame propagation process in a gas explosion by pressure and temperature recording. Various models can be incorporated in the facility, such as a tunnel like structure or a geometric 3D grid of pipes.*
Level of detail	-
Instrumentation	*gas temperature* *pressure* *gas composition* *flame velocity* *(High speed) camera*
Schedule	-

Tools	*AutoReaGas is a CFD software package that consists of two CFD codes: a gas explosion simulator and a blast simulator. Both codes are integrated in an interactive and user-friendly environment. The gas explosion simulator is capable of simulating the turbulent premixed combustion process in gas explosions. This process is the origin of blast effects. Given the blast source characteristics, the blast simulator is capable of computing the propagation of the blast wave in the vicinity of the explosion and the interaction with objects.* *The gas dynamics of a gas explosion is simulated by the numerical solution of a full set of conservation equations, that constitutes a model for the gas dynamics, the turbulence and the fuel distribution. The propagation and interaction of blast with structures is simulated by numerical solution of conservation equations which constitute a model for inviscid gas dynamics. A Flux-Corrected Transport scheme is used to capture and preserve shocks.*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  various models can be tested, such as:
  - small scale tunnel model:
  4 segments, each 2 x 0.5 x 0.25 m in dimension
  - 3D geometrical grids

- **To prepare promotion and specialisation**

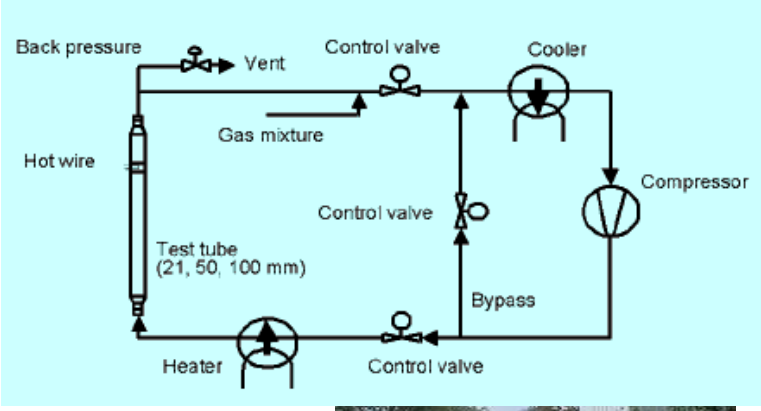
  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview



Name	***GEFEF (Gas Flow Explosion Facility)***
Type	*flow reactor*
Scale	*small scale*
Experiments	*integrated studies on explosion control and process optimisation*
Application field	*H1, H4 / V4, V5*

Technical details

Dimensions	*Basically, the facility consists of a gas circulation system with variable test tubes. The tubes are equipped with an ignition/explosion section.* *The standard operational conditions of the flow explosion facility are:* *- 0.25 - 24 m/s* *- 21, 50 and 100 mm tube diameter*
Temperatures	*25-300 °C*
Pressure	*up to 1.5 MPa*
Media	*various flammable gasses and inerts*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*A unique gas flow explosion pilot plant for integrated studies on explosion control and process optimisation. The conditions in the tube with respect to temperature, pressure and flow rate can be set similar to those in the plant. Explosion limits for example, can thus be determined under actual circumstances encountered in industrial processes.* *The gas flow explosion facility enables research into the effect of the following parameters on the indices that are related to the formation, ignition and deflagration characteristics of flammable gas mixtures in chemical and petrochemical installations:* *- temperature and pressure,* *- flow rate and flow direction,*

	- mixture composition, *- catalytic materials,* *- source of ignition and ignition strength,* *- tube dimensions, and,* *- obstacles within the flow or dead zones.* *The facility can also be used for more complex and fundamental studies as for example the effect of flow instabilities and precompression on deflagration characteristics and deflagration to detonation transition phenomena. Techniques like laser Doppler interferometry are available to characterise turbulence levels.)*
Level of detail	-
Instrumentation	*gas temperature (heat camera)* *pressure* *gas composition* *flame velocity* *Techniques like laser Doppler interferometry are available to characterise turbulence levels*
Schedule	-
Tools	-
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***Small scale blast simulator***
Type	*long tube*
Scale	*small scale*
Experiments	*visualize the interaction of shockwaves with structures*
Application field	*H1-H6 / V2, V4, V5*

Technical details

Dimensions	*overall length 22 m;* *driver section 3-m long, 13.5 x 13.5 cm²* *expanding to 40 x 40 cm²*
Temperatures	*atmospheric temperature*
Pressure	*max. peak overpressure 120 kPa (side-on)* *max. positive phase duration 55 ms*
Media	*air*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	- *the evaluation of civil and military equipment or structures to resist the blast environment of conventional explosions, i.e. caused by High-Explosives or fuel air, and nuclear explosions,* - *the improvement of hardening methods to protect equipment or structures against these effects.*
Level of detail	-
Instrumentation	*transducers, displacement, strain and acceleratiometers;* *optical techniques (Schlieren, differential and holographic interferometry) for flow visualization;* *high speed cameras for studying the failure modes*
Schedule	-

Tools	*For the numerical simulation of three-dimensional blast-object interaction, the computational fluid dynamics code BLAST-3D has been developed. This code solves the Euler equations, which describe inviscid compressible flow. The Flux-Corrected Transport scheme is used for optimum description of shocks and contact discontinuities. The code has the capability to calculate the pressure-, density-, and temperature-distribution around objects and to display velocity vector plots of the flow field. The code is also available as a sub-routine in the code AutoReaGas^{TM} , which is used to simulate vapour cloud explosions and the explosion blast propagation in arbitrary environments.*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  1

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***Large scale Blast simulator***
Type	*long tube*
Scale	*medium scale*
Experiments	*blast wave response in atmosphere*
Application field	*H1-H6 / V2, V4, V5*

Technical details

Dimensions	*overall length 63 m;* *driver section 3-m long, 0.3 m diameter* *expanding to 1-m and 2-m diameter*
Temperatures	*atmospheric temperature*
Pressure	*max. peak overpressure 200 kPa (side-on) at 1-m diameter sect.* *max. peak overpr. 60 kPa (side-on)/120 kPa (face-on) at tube end.* *max positive phase duration 60 ms.*
Media	*air*
Special features	-
Further particulars	-

Experiments – Equipment

Experiments	*studying blast wave/structure interactions* *target load and structural response measurements* *testing of window panes of different type and dimensions to determine explosion resistance capabilities* *determination of the dynamic behaviour of brick walls* *blast hardness trails on blast-resistant walls and doors* *blast hardness trails on scale models and small full scale models (gas masks)* *studying the effectiveness of blast walls in reducing impulse noise from large caliber weapons*
Level of detail	-

Instrumentation	*pressure transducers, strain gauges and accelerometers for target load and structural response measurements* *high-speed camera's for studying failure modes*
Schedule	-
Tools	*For the numerical simulation of three-dimensional blast-object interaction, the computational fluid dynamics code BLAST-3D has been developed. This code solves the Euler equations, which describe inviscid compressible flow. The Flux-Corrected Transport scheme is used for optimum description of shocks and contact discontinuities. The code has the capability to calculate the pressure-, density-, and temperature-distribution around objects and to display velocity vector plots of the flow field. The code is also available as a sub-routine in the code AutoReaGas^{TM} , which is used to simulate vapour cloud explosions and the explosion blast propagation in arbitrary environments.*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  -

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***Laboratory for Ballistic Research (LBO)***
Type	*internal firing ranges and a massive target bunker*
Scale	*medium scale*
Experiments	*In the target bunker and large caliber firing range, kinetic energy projectiles can be fired at targets.*
Application field	*H1-H6 / V2, V4, V5*

Technical details

Dimensions	-
Temperatures	-
Pressure	*The target bunker is designed and proven to withstand detonations of up to 25 kg of high explosives.*
Media	-
Special features	*The maximum attainable velocity is 2500 m/s for a 0.5-kg launch package.*
Further particulars	-

Experiments – Equipment

Experiments	*In the target bunker and large caliber firing range, kinetic energy projectiles up to and including 40 mm can be fired at targets that may contain explosives. Fragmenting ammunition up to 76 mm and weapon systems up to 105 mm can be evaluated.* *The target bunker is designed and proven to withstand detonations of up to 25 kg of high explosives. In addition to standardized guns and accelerators, the laboratory has 29, 50 and 78 mm laboratory powder guns available. The maximum attainable velocity is 2500 m/s for a 0.5-kg launch package. A vacuum target chamber is available for studying material properties under impact conditions.*
Level of detail	-
Instrumentation	*The experimental facilities are extensively instrumented to facilitate data acquisition and analysis.*

Schedule	-
Tools	-
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  -

  What kind of movable equipment is available and could be shared?

  -

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  impact of fragments on fuel tanks or cylinders can be studied

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -

Overview

Name	***Test Facility 3 (TF3)***
Type	*H2/O2 igniter test facility*
Scale	*full scale*
Experiments	*Testing small rocket motors, igniters (including acoustic igniters), combustors and other devices that require hydrogen (or oxygen) such as for developments in hydrogen technology*
Application field	*H2/H3/H6-V2/V3*

Technical details

Dimensions	*The TF3 has a test unit which is 4 by 6 meters and 2.5m tall.*
Temperatures	*The TF3 operates at ambient temperature*
Pressure	*The TF3 can deliver pressures from 0-220 bar with an increase to 300 bar possible*
Media	*hydrogen, oxygen, nitrogen*
Special features	*TF3 can provide high mass flow rates of hydrogen and oxygen in very wide pressure ranges. The hydrogen storage is 240 n-m³, oxygen storage is 240 n-m³.*
Further particulars	*TF3 has a versatile automatic control and data acquisition system that can record events at high frequencies. Standard measurements are measurements of pressure, temperature, and force. Additional measurements (e.g. spectroscopic measurements) are possible. Normal video recording of test runs is standard, high speed cameras are available for special test runs.*

Experiments – Equipment

Experiments	*This facility is in operation for experimental propulsion tests. The performance of the Vinci motor igniter (H2/O2) has been tested using this facility. The TF3 is equipped with a gas supply system which can supply oxygen, hydrogen and nitrogen with feed pressures up to 22 MPa. The maximum obtainable mass flow rates for the Vinci test set up and other relevant characteristics are 100, 20 and 100g/sec respectively.*
Level of detail	-

Instrumentation	*gas temperature*	*thermocouples, thermographic camera*
	pressure	*piezoelectric, piezoresistance*
	gas composition	*mass spectrometer*
	velocity	*optical*
	force/thrust	*piezoelectric*
	gas density	*Schlieren camera*
Schedule	*Between 1-4 weeks for preparation of new experiments and 2 days-1 week for execution of repeat experiments.*	
Tools	*TNO developed SMART software (Signal Modification Analysing and Reduction Tool) for data interpretation . MASTER database for recording/tracking instrumentation calibrations ensuring a high precision level.*	
Further particulars	*National Instruments DAQ PC system with 64 channels. The TF3 is fully computer controlled and is suitable for executing hydrogen experiments with an associated medium-high risk. Instrument calibration can be performed in-house.*	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  Minimum of 2 persons for preparation and execution of experiments.

  What kind of movable equipment is available and could be shared?

  None easily

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  The TF3 has a flexible set-up and is designed for a wide range of experiments with varying set-ups and instrumentation.

- **To prepare promotion and specialisation**

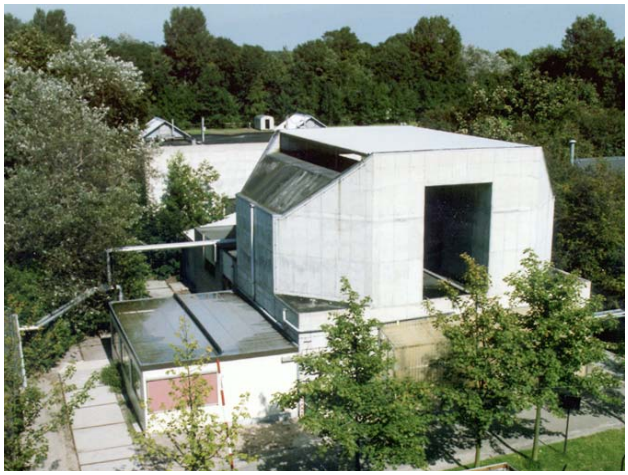
  What features/possibilities would you like to promote?

  A well equipped workshop is present on site for the performance of any required repairs/modifications to the facility. The TF3 has a high H2 massflow with the possibility of conducting experiments involving hydrogen ignition.

  Which additional equipment could enhance the results of your experiments?

  -

Overview



Name	***Large Indoor Rocket Test Stand***
Type	*rocket test facility*
Scale	*full scale*
Experiments	*Used for testing (large) rocket motors, ramjets, ducted rockets and for special activities, like combustion research, simulation of aerodynamic heating, or base pressure measurements on scaled-down rockets, launchers or boosters.*
Application field	*H2/H3-V2/V3*

Technical details

Dimensions	*tunnel section dimensions: 4x3.5x30 m*
Temperatures	*ambient to 2000 K*
Pressure	*0-70 bar*
Media	*hydrogen, oxygen, nitrogen, (dry) air, methane, ethylene, additional gases possible*
Special features	*gas supply details:*

	Flow Rate (kg/s)	*Storage Capacity (kg)*	*Pressure (MPa)*
Hydrogen	*0.05*	*2.5*	*up to 7 MPa*
Oxygen	*1.6*	*100*	*up to 7 MPa*
Nitrogen	*0,06*	*10*	*up to 20 MPa*
Air	*10*	*900*	*up to 7 MPa*
Methane	*0.3*	*16*	*up to 7 MPa*

Further particulars	*It is possible to mix the air and other gases in precisely controlled ratios. At the same time to total mass flow rate and pressure can be precisely controlled. A heater allows heating of air, or mixtures of gases up 2000 K.*

Experiments – Equipment

Experiments	*The indoor test facility is primarily designed for static firing of tactical missile rocket motors to assess the service lifetime of rocket motors.*

Level of detail	-	
Instrumentation	*gas temperature*	*thermocouples, thermographic camera*
	pressure	*piezoelectric, piezoresistance*
	gas composition	*mass spectrometer*
	velocity	*optical*
	force/thrust	*piezoelectric*
	gas density	*Schlieren camera*
Schedule	*The time needed for preparation, conduction, interpretation of experiments is dependant on the type of experiment and the data acquired. Typically 3 days preparation and 2 days interpretation*	
Tools	*TNO developed SMART software (Signal Modification Analysing and Reduction Tool) for data interpretation. MASTER database for recording/tracking instrumentation calibrations ensuring a high precision level.*	
Further particulars	*Withstands explosions of 10 kg TNT equivalent. Sound level reduction up to 40 dB. Active venting system, toxic gases detection possible. Data-acquisition of thrust, pressure and temperature is feasible with: 100 channels up to 100 kHz (HP), 10 channels up to 1 MHz (NI) or 100 channels up to 500 kHz (NI). High speed video recording. Instrument calibration can be performed in-house.*	

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  Minimum of 2 persons for preparation and execution of experiments.

  What kind of movable equipment is available and could be shared?

  None easily

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  With modifications this facility can be used for performing high risk tests on hydrogen systems and parts thereof (valves, regulators…).

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  A well equipped workshop is present on site for the performance of any required repairs/modifications to the facility.

  Which additional equipment could enhance the results of your experiments?

  -

Partner: *UNIPI*

Facilities: *- CVE*

Overview

Name	***CVE***
Type	*Vented room*
Scale	*large scale*
Experiments	*studies on vented explosions*
Application field	*V1 (Hydrogen release, mixing, and distribution),* *V3 (Development and validation of hydrogen mitigation techniques)* *V5 (Standardisation and legal requirements)*

Technical details

Dimensions	*27 m³ vented room*
Temperatures	-
Pressure	*maximum design overpressure 200 mbar*
Media	*hydrogen-air and methane-air mixtures*
Special features	*the size of the camber allow to simulate real ambient behaviours in case of explosion and to extrapolate the minimum safety value for the vent area as a function of expected hydrogen concentration*
Further particulars	*(a) two side of the chamber entirely covered with panes of glass (upper and one lateral sides) in order to view and record the flame's shape propagation* *(b) variable vent area* *(c) variable number and location of the ignition points* *(d) variable number of concentration measurement points*

Experiments - Equipment

Experiments: *hydrogen-air atmospheres vented explosion with uniform or non uniform initial condition; some test variables are (1) vent area; (2) hydrogen concentration; (3) number and location of ignition points (we have eight different ignition points inside the CVE)*

Level of detail: -

Instrumentation

INSTRUMENT TYPE	N. OF ITEMS	MEASURING PRINCIPLE	RANGE	OUTPUT	MAXIMUM ERROR
Flow meter	1	Turbine	6-100 Nm^3/h	0.4-7 Hz	1.5 % of the range
Flow meter	1	variable area	0-19 Nl/sec	4-20 mA	0.8 % of the range
Concentration analyser	6	Thermal conductibility	0-20 %vol.	4-20 mA	3 % of the range
Pressure transducer	3	Piezoelectric	0-5 bar	4-20 mA	0.3 % of the range
Digital camera	2		25 fps		

Schedule	*the time needed for preparation of experiments is about 1 day;* *the time needed for conduction of experiments is about 30 minutes (aerosol immission 10 minutes; gas immission 10 minutes; a few cycle of gas concentration measurements 10 minutes);* *the time needed for interpretation of experiments is about 1 hour (assembly and analysis of digital camera's recordings, interpretation of pressure transducer's data, extrapolation of the correlation between explosion pressure and vent area, and hydrogen concentration data)*
Tools	*general labs software*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  To prepare/conduct experiments only 3-5 persons are needed

  What kind of movable equipment is available and could be shared?

  All measurement devices and instrumentation (pressure transducers, flow meter, concentration analyser and so on)

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or y applying additional instrumentation?

  In order to perform a comparison between flammable gases, besides hydrogen vented explosions in the CVE we could carry out also methane-air vented explosions (modification of the gas concentration analyser's calibration curve needed).

  In addition we could carry out also study/check on the safety of other hydrogen applications: by introducing an element in the CVE (hydrogen sensor, fuel cell, etc.) we can measure hydrogen leakages, pressure waves generated in case of explosion, and so on.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  The exchange of personnel between the partners or the employee of person from other University

  The production of spreading material, in particular explosion behaviour movies.

  Which additional equipment could enhance the results of your experiments?

  With specific concentration measurement devices we could carry out also explosions of hydrogen mixed to methane atmospheres.

Partner: *WUT*

Facilities: *- WUT Detonation Tube*

Overview

Name	***WUT Detonation Tube***
Type	*square cross-section tube*
Scale	*lab scale*
Experiments	*studies on hydrogen fast deflagrations, detonations, DDT, explosion initiation, mitigation of detonations*
Application field	*H1,H2,H3,H4, V2,V3*

Technical details

Dimensions	*Detonation tube consists of a 1 m long booster and 8 m long square cross-section channel with internal dimensions 110×110 mm*
Temperatures	*room initial temperature*
Pressure	*up to 0.1 MPa initial pressure*
Media	*hydrogen, air, nitrogen, oxygen, argon, helium, carbon dioxide*
Special features	*The booster is filled with the oxy-acetylene stoichiometric mixture, which ignited, by a 1 J electric spark rapidly detonates initiating in turn detonation in the acceptor mixture in the main channel. A number of piezo-electric pressure transducers are fitted into the channel to monitor detonation and shock propagation. An X-band radar Doppler unit is also used for continuous monitoring of the detonation velocity. The Doppler unit is located at the end of the channel.*
Further particulars	-

Experiments – Equipment

Experiments	*studies on hydrogen fast deflagrations, detonations, DDT, explosion initiation, mitigation of detonations by diffraction, heat and momentum losses, initiation of detonation*
Level of detail	-

Instrumentation		
	pressure	*piezoelectric*
	velocity	*microwave Doppler anemometer*
	flame luminosity	*photodiodes*
	flame position	*ion probes*
	visualization	*Schlieren instrumentation*

Schedule	*operational any time*
Tools	*in-house high speed data acquisition system with software*
Further particulars	-

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  At least 2 people are needed to prepare/conduct experiments

  What kind of movable equipment is available and could be shared?

  Microwave Doppler anemometer and high speed data acquisition system could be shared

- **To prepare filling possible gaps**

  What kind of experiments/tests could be performed in this facility after minor modifications and/or by applying additional instrumentation?

  High speed visualization of deflagrations and detonations could be performed in this facility after applying high speed digital camera (not available).

  Chemical reaction progress visualization could be performed after applying PLIF instrumentation (not available).

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Experiments conducted on the facility could be used for validation of numerical codes related to gas detonations: in particular the validation of detonation initiation, DDT, propagation in obstructed channels and mitigation, using following results:
  - *Pressure profiles, continuous velocity record, schlieren pictures for unsteady cases of detonation mitigation by inert gas pockets*
  - *pressure profiles, velocity record, schlieren pictures for hydrogen-air and hydrogen-oxygen detonation propagation,*
  - *pressure profiles for experiments with detonation initiation by incident shock wave*

  Which additional equipment could enhance the results of your experiments?

  -

- **Website presentation**

  Additional material to be presented on the HySafe Website

  Pdf files of the articles:

  Dąbkowski A., Kozak A., Teodorczyk A.:The Initiation of Gaseous Detonations in H_2-O_2 Mixtures by Incident Shock Wave

  P.Buraczewski, A.Dąbkowski, A.Kozak, A.Teodorczyk:The Influence of Inert Gas Pockets on Propagation of Gaseous Detonations