SIXTH FRAMEWORK PROGRAMME
Sustainable Energy Systems

NETWORK OF EXCELLENCE

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Safety of Hydrogen as an Energy Carrier

Updated IEF documents

Deliverable 96 (WP 2)

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SUMMARY

Integration of Experimental Facilities (IEF) is one of the integrating activities within the network HySafe. The objective of this activity is to enable the network to jointly perform high level experimental research needed for investigation of relevant phenomena, for testing devices and concepts as well as for validation of numerical models.

The IEF documents developed in the funding period of HySafe include compilations of the descriptions of experimental facilities (D09) and instrumentation (D35), a classification of the facilities (D45), the on-line presentation of facilities on the HySafe website, and the working document on best practice (D70).

The present deliverable D96 includes an update of the IEF documents D09, D35, and D45. With regard to the previous version of these documents it is enhanced to a total of 109 HySafe facilities operated by 15 partners.

This documents has to be continuously enhanced and extended in order to account for progress in knowledge and technical possibilities. It will be transformed into internal documents and serve as a starting point for future reference in the activities of the HySafe follow-up organisation.

Updated IEF documents

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 objective of this activity is to enable the network to jointly perform high level experimental research by

- supporting partners' development of excellence
- broadening the fields of experience
- enhancing the communication and knowledge base

Research facilities are needed for investigation of relevant phenomena, for testing devices and concepts as well as for validation of numerical models. IEF provides basic support for jointly performed experimental work within HySafe. Hence, IEF represents a long lasting effort for reaching sustainable integration of the partners' experimental research capacities.

The main task of IEF during the first 18 months period of the network was 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 D05 has been used. This compilation was the first step to a better knowledge of each other.

In order to identify the best expertise of the partners, the work in the second period of HySafe focused on the categorisation of the experimental facilities and on the compilation of instrumentation. A website presentation of the facilities was set-up. In order to ensure a common quality standard, a series of workshops was started covering topics related to measurement techniques and experimental work.

In the third period liquid hydrogen applications was identified as major gap in knowledge among the partners. ET EnergieTechnologie joined the work package as active supporter to fill this gap. The well received series of semi-annual IEF workshops was continued. A Wiki page was set up in order to provide a communication platform. A working document including the joint experimental knowledge of all partners with regard to experiments and instrumentation was set up as well.

Activities in the present fourth period continue the successful integration work by including the new partners ET and KI in the set of IEF documents. The series of IEF workshops continues as well. The present deliverable gives an update of the IEF documents providing a detailed insight into the experimental capabilities of the HySafe consortium.

2 Description of experimental facilities

In the first period of the HySafe project a compilation of the experimental facilities (D09) was provided to serve as a starting point for further activities. The present updated set contains the enhanced descriptions of 109 facilities taking into account information on particular features and measurement capabilities in order to identify specific expertise as well as aspects concerning possible integration activities. Table 1 gives on the next pages an overview of the 109 HySafe facilities demonstrating the great variety and the wide range of the experimental possibilities of the partners.

Table 1: Experimental facilities of the HySafe partners

BAM-1	Fire Testing Rig	open propane gas fire	test of the behaviour of pressurized or protective containers under fire load
BAM-2	Open Air Test Site Horstwalde	open air test site	fire, drop, impact and other tests for flammable, pressurized or otherwise
BAM-3	Hydraulic Cycling Equipment	-	investigation of pressure receptacles under pulsating pressure load
BAM-4	Facility for testing and calibration of gas sensors	test gas mixture system and test chamber	testing and calibration of gas sensors
BAM-5	Tribometers for oscill. (PT1) or sliding friction (CT2, CT3)	PT1, CT2, CT3	friction and wear at elevated press. or at cryog. temperatures / in cryog. liquids
BAM-6	Facility for testing and calibration of gas sensors	test gas mixture system and test chamber	testing and calibration of gas sensors
CEA-1	MISTRA	cylindrical steel vessel	H2(He) release and distribution in confined geometry
CEA-2	GAMEL (under construction, available in 2005)	cubic polycarbonate vessel	detailed studies of H2 (simulated by He) rel. and distr. in a 3D conf. geometry
ET-1	Liquid hydrogen vacuum insulation rupture rig	LH2-car tank	behaviour of LH2-car tank under spont. rupture of vacuum insulation
ET-2	Liquid hydrogen tank test equipment	Tank test installation	experimental study of tank and component failures
ET-3	Liquid hydrogen test rig for material tests	Vessel	behaviour of liquid hydrogen structures under mechanical and thermal loads
ET-4	High pressure hydrogen tank and component test equipment	Test chambers (various)	tank and component failures, Extreme temperature tests, Fast fill and drain
ICT-1	High pressure H2 compressor	Remote controlled system based on Maximator DLE 75-	material, component and system tests, burst tests
ICT-2	Heatable high pressure vessel	vessel	decomposition and ignition induced by temperature increase and external ign.
ICT-3	Device for flame jet ignition	cylindrical vessel with vent opening	flame jet ignition
ICT-4	High pressure vessel with windows	1 litre high pressure vessel with windows	explosions with init. press. up to 3 MPa and time resolved spectroscopic meas.
ICT-5	45 m³ closed detonation room		detonation experiments with explosive gases, liquids and solids
ICT-6	splinter protected Test box / area		high pressure, free jet, burning and medium size explosion experiments
ICT-7	Test stand	closed test stand with blow-out option	multipurpose tests with energetic materials
ICT-8	Testing area	open-air	explosions, tank testing, H2 release, ...
ICT-9	6 MPa Autoclave		
FZJ-1	REKO-1	flow reactor	H2 recombination under forced flow conditions
FZJ-2	REKO-2	pressure vessel	H2 recombination
FZJ-3	REKO-3	flow reactor	H2 recombination under forced flow conditions
FZJ-4	REKO-4 (under construction)	pressure vessel	H2 recombination under natural flow conditions
FZK-1	A1 Vessel	cylindrical vessel	turbulent combustion and detonations, integrity of mechanical structures
FZK-2	A3 Vessel	cylindrical vessel	turbulent combustion and detonations, vented explosions, H2 distribution
FZK-3	A6 Vessel	cylindrical vessel	turbulent combustion and detonations, integrity of mechanical structures
FZK-4	12 m detonation tube (DT)	cylindrical tube	turbulent combustion, DDT and steady state detonations, chemical kinetic
FZK-5	Flow Test Chamber (TC)	rectangular chamber	vented combustion and detonations; H2 distribution, testing of ventilation syst.
FZK-6	Partially Vented Explosion Tube (PET)	cylindrical tube with variable opening	vented explosions, turb. flame propag., flame acceleration and DDT
FZK-7	A8 Vessel	cylindrical vessel	turbulent combustion and detonations, vented explosions, H2 distribution
FZK-8	Explosion bomb	spherical vessel	flammability limits, minimum ignition energy, laminar flame velocity, chemical
FZK-9	HyJet	horizontal/vertical hydrogen jet	hydrogen release from pressurized vessel, hydrogen concentrations and
GC-1	168 m³ open geometry with internal obstructions	explosion vessel	explosions in open, congested geometries
GC-2	1:3.2 scale offshore module	explosion vessel	vented explosions in realistic geometries
GC-3	Connected vessels	explosion vessel	explosions in vented vessel

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

GC-4	6m channel	explosion vessel	vented explosions in idealised geometries
GC-5	50m³ tube	explosion vessel	dispersion/explosions in closed/vented vessel (tunnels)
GC-6	1.2 m³ closed vessel	explosion vessel	explosions in closed vessel
GC-7	216 litre dispersion vessel	dispersion/explosion vessel	gas dispersion/homogeneity
GC-8	20 litre spray vessel	explosion vessel	explosions in closed vessel
GC-9	1.4 m channel	explosion vessel	vented explosions in idealised geometries
GC-10	3D corner	explosion vessel	vented explosions in complex idealised geometries
HSL-1	Ventilated dispersion and explosion facility	modular vented enclosure with integrated ventilation	dispersion/ignition/explosion from high pressure releases into ventilation flow
HSL-2	Gas dispersion facility	gas dispersion area	dispersion of flashiong liquid or gas (LPG, H2)
HSL-3	Under water gas release and explosion facility	explosion vessel	Ulage space gas explosions
HSL-4	Jet fire facility	LPG vapour jet fire facility	PFP material and components testing, Jet-Fire Resistance Test (JFRT)
HSL-5	High pressure hydrogen facility	gas supply and pipe work to enable pressurised releases	ignited and unignited jet releases
HSL-6	366m gallery/tunnel	concrete test enclosure/tunnel	combustion and ventilation controlled overpressures fragmentation
HSL-7	Frictional ignition apparatus	ignition test facility with vented explosion vessel	frictional rubbing events in flammable atmospheres, spark and hot surface
HSL-8	75 mm gas gun	impact test facility	dynamic impact on components/tanks etc.
HSL-9	190 mm gas gun	impact test facility	dynamic impact on components/tanks etc.
HSL-10	Impact test track	impact test facility	dynamic impact on components/tanks etc.
HSL-11	Drop tower 3.3 m	impact test facility	dynamic impact on components/tanks etc.
HSL-12	Drop tower 25 m	impact test facility	dynamic impact on components/tanks etc.
INA-1	SSRT equipment	autoclave+ tensile testing	effect of hydrogen on the behaviour of materials - hydrogen embrittlement
INA-2	NACE TM 01-77 testing equipment	corrosion cells + load applying rings	effect of hydrogen on the behaviour of materials - hydrogen embrittlement
INA-3	Fatigue testing equipment	Servohydraulic universal tensile testing machine	effect of hydrogen on the behaviour of materials in fatigue – corrosion
INA-4	LECO TCH 600	-	chemical analysis of hydrogen in metals
INA-5	SHS reactor	-	metallic hydride production by SHS
INA-6	PEMFC Testing Equipment	Fuelcon C050	Evaluation of PEMFC components behaviour
INA-7	SOFC Testing Equipment	-	Evaluation of SOFC components behaviour
INE-1	The “Basket”	large scale test area	rupturing of confinements and investigation of fracturing and missiles
INE-2	ISO-1 m³ chamber, Dust-gas explosion room (DG1m3)	vented or closed vessel	Kst and Kg meas., turbulence/mixing, flame propagation, safety device tests
INE-3	10 m³ chamber, Dust-gas explosion room (DG10m3)	vented vessel	turbulence/mixing, flame propagation, safety device tests
INE-4	INERIS-100 m³ chamber, Dust-gas explosion room (DG100m3)	vented vessel	turbulence/mixing, flame propagation, safety device tests
INE-5	Flame Acceleration Pad (FAP)	pipes	flame propagation in tubes and pipes, vents and flame arrester testing
INE-6	Flexible Ignition Facilities (FIF)	small vessel with various igniters	characteristics of “practical” ignition sources, fundamentals of flame initiation
INE-7	High pressure-high temperature-2 m³ sphere (HPT2m3)	closed vessel	flammable limits, auto-ignition delay, explos. param. (high press. and temp.)
INE-8	High press.-high temp. 500ml expl. chamber (HPT500ml)	closed vessel	max. press. meas. at very high press. and temperatures, ignition behaviour
INE-9	Open Fire Area (OFA)	large scale test area	ignition and fire of gaseous jets and liquid pools
INE-10	Unconfined Cloud Area (UCA)	large scale test area	flammable gases and liquids releases from high press. tanks, unconfined expl.
INE-11	Sensors and Safety Devices Laboratory	environmental testing for explosive/toxic gases	sensors performance testing

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

INE-12	leak detection unit (LDU)	medium scale	measurement of leakage rate from pressurised components (up to 1000
JRC-1	Hydrogen solid-state storage assessment laboratory (SolTeF)	Volumetric, gravimetric and spectrometric sorption	H2 capacity meas., PCI, reaction thermodynamic and kinetics prop.
JRC-2	Sensor Testing Facility (SenTeF)	environmental sensor test bench	sensors performance testing
JRC-3	High-pressure hydrogen tank facility (GasTeF)	N2-inertised room with pressure vessels	HP cycling+permeation meas. on compr. H2/CH4 storage systems for vehicles
KI-1	Spray	Sprayer for liquid fuels	Studies on critical energy initiation of detonation in motor fuel - air clouds,
KI-2	Sphere	Semi-sphere for gaseous fuel air mixtures	Studies on blast wave and thermal radiation parameters of gaseous
KI-3	Koper	vented explosion chamber with semi-cylindrical volume	studies on turbulent combustion and detonations, vented explosions
KI-4	Vortex	explosion chamber	studies on flame - vortex interaction, turbulent flame, ignition - extinction
KI-5	Minirut	system of channels	studies on turbulent combustions detonations and scaling effect
KI-6	Channel	Rectangular channel	studies on turbulent combustions detonations and scaling effect
KI-7	Chamber	Rectangular channel joined with cylindrical chamber	studies on turbulent combustions and flame vortex - shock interaction
KI-8	Driver	cylindrical tube	studies on turbulent combustions and detonations, scaling and venting effects
KI-9	Torpedo	cylindrical tube	studies on turbulent combustions and detonations, scaling and venting effects
KI-10	Venting	system of cylindrical tubes	studies on turbulent combustions and detonations, scaling and venting effects
KI-11	RUT 2200	system of channels and chambers	studies on turbulent combustion and detonation
KI-12	Globus	spherical bomb	studies on laminar combustion and turbulent deflagration
KI-13	High Pressure Jet Facility (HPJF)	open hydrogen gas fire	combustion of high pressure hydrogen jet in specific environment
TNO-1	1 litre vessel	closed bomb	measure explosion limits and ignition temperatures and energies
TNO-2	20 litre vessel	closed bomb	measure explosion limits and ignition temperatures and energies
TNO-3	500 litre vessel	closed bomb	measure explosion limits and ignition temperatures and energies
TNO-4	1 m^3 vessels	vessel (closed bomb)	closed bomb experiments with high initial press. and linked vessels
TNO-5	5 m^3 vessel	vessel (closed bomb)	test of equipment and protective systems for use in explosive atmosph.
TNO-6	GEC	cubic shaped vessel	test constructions that can reduce or protect against explosion overpressures
TNO-7	IBBC Bunker	reinforced concrete bunker	vented gas explosions
TNO-8	FAST	open air gas explosion facility	gas explosions in open air; flame propagation and blast wave experiments
TNO-9	GFEF	flow reactor	integrated studies on explosion control and process optimisation
TNO-10	Large scale blast simulator	long tube	blast wave response in atmosphere
TNO-11	Laboratory for ballistic research (LBO)	internal firing ranges and a massive target bunker	kinetic energy projectiles can be fired at targets
TNO-12	Test Facility 3 (TF3)	H2/O2 igniter test facility	testing small rocket motors, igniters, combustors etc. requiring H2 or O2
TNO-13	Large indoor rocket test stand	rocket test facility	testing large rocket motors etc. and activities like combustion research etc.
UP-1	CVE	vented room	vented explosions
UP-2	HPBT	pipeline	hydrogen release and jet-fire
WUT-1	WUT Detonation Channel	square cross-section channel	H2 fast deflagrations, detonations, DDT, explosion initiation, mitigation of det.
WUT-2	WUT Detonation Tube	circular cross-section tube	H2 fast deflagrations, detonations, DDT, explosion initiation, mitigation of det.
WUT-3	WUT 1.25 m^3 Explosion Bomb	near spherical chamber	studies on hydrogen ignition, flame propagation and quenching

In order to provide a unified overview of the experimental possibilities of the partners, the format for the descriptions of the experimental facilities had been defined as documented in deliverable D05. The descriptions are divided into the sections

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

The full compilation of facilities descriptions is given in Annex I. An on-line version of the facility descriptions is available via the HySafe website.

3 Categorisation of facilities

The categorisation of the facilities has been performed as further development of D09. The main objective is to facilitate the overview of the experimental possibilities of the HySafe partners in order to

- identify specific expertise,
- map research needs with research possibilities in order to identify gaps,
- enhance the presentation of the facilities.

IEF provides the facilities the network needs for research. Consequently, the phenomena and parameters related to accidental events and possible consequences if an ignition of a flammable gas mixture occurs introduced in the PIRT have been used as a basis. The ***main***

Tab. 2: Sub-categories 'geometry'

Main categories	***Sub-categories 'geometry'***
Gaseous release	• **confined - lab/small scale** • **vented - lab/small scale** • **open air** • **confined - larger scales** • **vented - larger scales**
Dispersion	• **confined - lab/small scale** • **vented - lab/small scale** • **open air** • **confined - larger scales** • **vented - larger scales**
Ignition	• **confined - lab/small scale** • **open air** • **confined - larger scales**
Combustion/Explosion	• **confined - lab/small scale** • **vented - lab/small scale** • **open air** • **detonation tubes** • **confined - larger scales** • **vented - larger scales**
Liquid release	• **confined - lab/small scale** • **vented - lab/small scale** • **open air** • **confined - larger scales** • **vented - larger scales**
Expl. of liquid storage	• **confined - lab/small scale** • **open air** • **confined - larger scales**
Mitigation	
Equipmt./device testing	

categories characterising the main field of application of a facility are:

- Gaseous release,
- Dispersion,
- Ignition,
- Combustion/explosion,
- Liquid release,
- Explosion of liquid storage,
- Mitigation,
- Equipment and device testing.

'Equipment and device testing' was not included in the PIRT table but represents an important type of experimental research activity within HySafe.

Tab. 3: Sub-categories 'phenomena'

Main categories	***Sub-categories 'phenomena'***	
Gaseous release	• permeation • subsonic release • choked flow (sonic) release	• full bore rupture (pipe), full vessel rupture • turbulent flow in pipes, transport of H2
Dispersion	• impinged jets • obstacle-generated turbulence • effect of obstacles on flow patterns • atmospheric conditions incl. wind • heat transfer from environment • natural ventilation (for partially conf. atm.) • forced ventilation	• buoyancy effects • stable stratification • turbulent mixing (in pres. of large vel. grad.) • turbulent mixing (decaying conditions) • laminar diffusion • compressible eff. (shocks, under-expanded jets, contacts)
Ignition	• auto-ignition (incl. effect of additives) • shock ignition • weak / mild ignition (incl. static electricity) [forced ignition] • strong ignition [forced ignition]	• direct initiation of detonation • jet ignition (ignition by hot jet or combustion products) radiative ignition • hot surface ignition • flammability limits
Combustion/Explosion	• laminar flame • cellular flame • wrinkled flame • self turbulising flame • flame acceleration / deceleration (due to obstacles, conc. grad.) • triple flame • turbulent deflagration DDT (due to flame acceleration, shock reflection, etc)	• detonation • quenching (global or local) • standing flame (diffusion flame) • jet fire • spill fire • multiphase combustion (for liq. H2) • heat radiation & absorption
Liquid release	• liquid (two-phase) flow through orifice • full bore liquid (pipelines), full vessel rel. • formation of spill - pool spreading • spill evaporation	• two-phase flow in liquid, incl. boiling • heat transfer from ground • condensation (20-90K) and evaporation (>90K) of air
Expl. of liquid storage	• heat conduction in storage material • Boiling Liq. Expanding Vap. Expl. BLEVE	
Mitigation	• natural ventilation • forced ventilation • post-accident inerting • recombiners • preventive ignition, igniters	• venting of deflagration • pressurisation of zone to avoid entry of H2 • shut down systems • blast wave protective wall interaction
Equipmt./device testing	• performance tests: sensors, igniters, recombiners • storage tests • material tests	• impact tests: explosion, thermal, mechanical, dynamic pressure

In addition, two sets of sub-categories are introduced characterising the geometry and scale of the facility (***sub-categories 'geometry'***) and the phenomena addressed in the experiments (***sub-categories 'phenomena'***).

In order to avoid too much confusing and complex sub-categories when using all existing scale terms (lab, small, medium, large, full etc. scale), only two ***scale terms*** have been used:

- 'lab/small scale' for detailed experiments,
- 'larger scales' for integral experiments.

The following ***sub-categories 'geometry'*** are assigned to the different main categories in combination with relevant scale terms as given in Table 2:

- confined,
- vented,
- open air.

'Combustion/Explosion' includes detonation tubes as specific geometry. 'Mitigation' and 'Equipment/device testing' are considered to be independent of scale and hence not further subdivided at this level.

The ***sub-categories 'phenomena'*** given in Table 3 are applied according to the PIRT.

'Equipment and device testing' (not represented in the PIRT) includes the fields

- performance tests: sensors, igniters, recombiners,
- storage tests,
- material tests,
- impact tests: explosion, thermal, mechanical, dynamic pressure.

On the next pages, Table 4 gives the complete overview of the categorisation performed including the total of 109 HySafe facilities Figure 1 gives an illustration of the table structure.

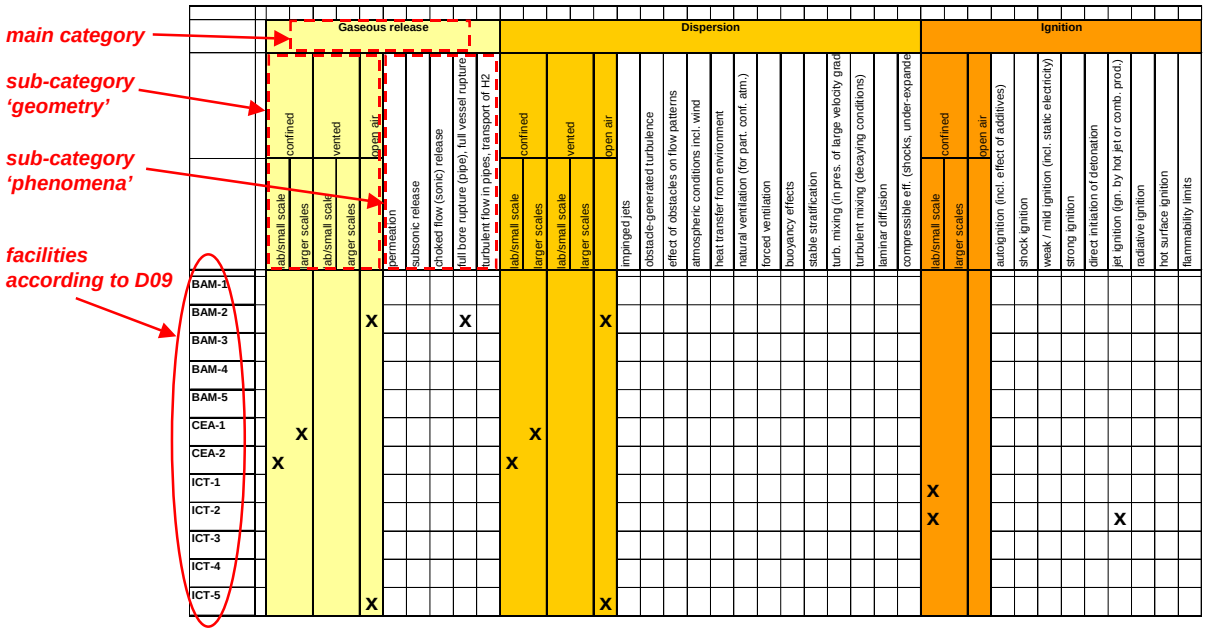

Fig. 1: Illustrative extract from the table sheet

Table 4: Categorised facilities of the HySafe partners

	Gaseous release										Dispersion																		Ignition												Combustion / Explosion																					
	conf		vent		open						confined		vented		open air														confined		open air										confined		vented		open																	
	lab/small scale	larger scales	lab/small scale	larger scales		permeation	subsonic release	choked flow (sonic) release	full bore rupture (pipe), full vessel ruptu	turbulent flow in pipes, transport of H2	lab/small scale	larger scales	lab/small scale	larger scales		impinged jets	obstacle-generated turbulence	effect of obstacles on flow patterns	atmospheric conditions incl. wind	heat transfer from environment	natural ventilation (for partially confined	forced ventilation	buoyancy effects	stable stratification	turbulent mixing (in presence of large v	turbulent mixing (decaying conditions)	laminar diffusion	compressible eff. (shocks, under-expa	lab/small scale	larger scales		autoignition (incl. effect of additives)	shock ignition	weak / mild ignition (incl. static electric	strong ignition [forced ignition]	direct initiation of detonation	jet ignition (ignition by hot jet or combu	radiative ignition	hot surface ignition	flammability limits	lab/small scale ('bomb	larger scales ('vessels	lab/small scale (bomb	larger scales (vessels	lab/small scale	larger scales	detonation tubes	laminar flame	cellular flame	wrinked flame	self turbulising flame	flame acceleration / deceleration (due	triple flame	turbulent deflagration	DDT (due to flame accelaration, shock	detonation	quenching (global or local)	standing flame (diffusion flame)	jet fire	spill fire	multiphase combustion (for liq. H2)	heat radiation & absorption
BAM-1																																																														
BAM-2					X				X						X																															X																
BAM-3																																																														
BAM-4																																																														
BAM-5																																																														
BAM-6																																																														
CEA-1		X										X																																																		
CEA-2	X										X																																																			
ET-1															X				X	X	X										X			X	X				X																							
ET-2																																																														
ET-3																																																														
ET-4		X		X	X	X	X	X		X																					X			X	X				X																							
ICT-1	X	X				X		X	X		X	X													X			X	X	X		X									X	X																	X			
ICT-2																													X			X		X	X				X		X																					
ICT-3																														X							X					X		X											X				X			
ICT-4																													X					X	X						X							X		X	X							X				X
ICT-5		X		X			X					X		X				X				X		X						X			X	X	X	X	X		X			X		X											X	X				X		X
ICT-6		X						X				X		X	X	X	X	X	X		X	X	X		X	X				X		X	X	X	X	X	X		X			X		X		X				X	X							X	X	X	X	X
ICT-7		X		X			X	X				X		X	X	X	X	X			X	X		X	X	X							X	X	X	X	X		X						X																	
ICT-8					X		X	X	X			X		X	X		X	X	X		X	X		X	X	X																				X									X	X				X		X
ICT-9	X					X	X	X																					X			X		X	X			X	X		X										X											X
FZJ-1																																																														
FZJ-2																																																														
FZJ-3																																																														
FZJ-4																																																														

Table 4 (contd.): Categorised facilities of the HySafe partners

	Liquid release												Explosion of liquid storage					Mitigation										Equipment and Device Testing									
	confined (vessel		vented		open air								confined		open air																							
	lab/small scale	larger scales	lab/small scale	larger scales		liquid (two-phase) flow through orifice	full bore liquid (pipelines), full vessel re	formation of spill - pool spreadijng	spill evaporation	two-phase flow in liquid, incl. boiling	heat transfer from ground	condensation (20-90K) and evaporatio	lab/small scale	larger scales		heat conduction in storage material	Boiling Liq. Expanding Vap. Expl. BLE		natural ventilation	forced ventilation	post-accident inerting	recombiners	preventive ignition, ignitors	venting of deflagration	pressurisation of zone to avoid entry of	shut down systems	blast wave protective wall interaction		sensors performance	igniters performance	recombiners performance	storage	materials	explosion impact	thermal impact	mechanical impact	dynamic pressure load
BAM-1																											X				X			X		
BAM-2															X		X										X						X	X	X	
BAM-3																											X				X	X				X
BAM-4																											X	X								
BAM-5																											X					X				
BAM-6																											X	X								
CEA-1																																				
CEA-2																																				
ET-1		X		X	X	X	X	X	X	X		X															X	X	X		X		X	X		
ET-2		X		X	X	X	X	X	X	X		X															X	X			X	X		X		X
ET-3																											X	X			X	X		X		X
ET-4																											X	X			X	X		X		X
ICT-1																															X	X				
ICT-2																											X						X	X		X
ICT-3																																				
ICT-4																																				
ICT-5																			X	X	X	X			X											
ICT-6	X		X		X			X	X				X				X		X	X	X		X											X	X	X
ICT-7					X										X			X	X	X			X	X				X					X	X		X
ICT-8					X										X		X	X	X	X			X	X				X					X	X	X	X
ICT-9																											X							X		
FZJ-1																											X			X						
FZJ-2																											X			X						
FZJ-3																											X			X						
FZJ-4																											X			X						

Table 4 (contd.): Categorised facilities of the HySafe partners

	Gaseous release										Dispersion																Ignition											Combustion / Explosion																			
	conf		vent		open						confined		vented		open air												confined		open air										confined				open															
	lab/small scale	larger scales	lab/small scale	larger scales		permeation	subsonic release	choked flow (sonic) release	full bore rupture (pipe), full vessel rupt	turbulent flow in pipes, transport of H2	lab/small scale	larger scales	lab/small scale	larger scales		impinged jets	obstacle-generated turbulence	effect of obstacles on flow patterns	atmospheric conditions incl. wind	heat transfer from environment	natural ventilation (for partially confine	forced ventilation	buoyancy effects	stable stratification	turbulent mixing (in presence of large \	turbulent mixing (decaying conditions)	laminar diffusion	compressible eff. (shocks, under-expa	lab/small scale	larger scales		autoignition (incl. effect of additives)	shock ignition	weak / mild ignition (incl. static electric	strong ignition [forced ignition]	direct initiation of detonation	jet ignition (ignition by hot jet or combu	radiative ignition	hot surface ignition	flammability limits	lab/small scale ('bomb	larger scales (vessels	lab/small scale (bomb	larger scales (vessels	lab/small scale	larger scales	detonation tubes	laminar flame	cellular flame	wrinkled flame	self turbulising flame	flame acceleration / deceleration (due	triple flame	turbulent deflagration	DDT (due to flame accelaration, shock	detonation	quenching (global or local)	standing flame (diffusion flame)	jet fire	spill fire	multiphase combustion (for liq. H2)	heat radiation & absorption
FZK-1		X		X				X	X			X		X			X	X									X													X			X								X		X	X	X	X				
FZK-2		X	X					X	X			X	X														X													X			X								X		X			X				
FZK-3		X		X				X	X			X		X													X													X			X								X		X			X				
FZK-4																												X			X	X	X													X						X		X	X	X	X				
FZK-5		X		X			X	X			X			X		X	X	X				X	X	X	X	X		X															X								X		X		X	X		X			X
FZK-6																												X																		X						X		X	X	X	X				
FZK-7		X	X					X	X			X	X														X													X			X								X		X			X				
FZK-8																												X		X		X	X				X	X	X								X	X								X				
FZK-9					X		X	X					X			X	X	X				X	X		X	X		X				X	X				X																				X			X
GC-1																																													X					X	X		X							
GC-2		X					X	X				X						X				X																					X							X	X		X							
GC-3																																							X		X								X						X				
GC-4																																										X							X	X		X							
GC-5																																								X		X							X	X		X	X	X					
GC-6																																							X		X							X			X			X				
GC-7		X					X	X				X					X	X					X		X	X																																	
GC-8																																							X							X			X			X						
GC-9																																									X								X			X							
GC-10																																									X	X							X		X	X							

Table 4 (contd.): Categorised facilities of the HySafe partners

	Liquid release											Explosion of liquid storage				Mitigation										Equipment and Device Testing									
	confined (vessel		vented		open air							confined		open air																					
	lab/small scale	larger scales	lab/small scale	larger scales		liquid (two-phase) flow through orifice	full bore liquid (pipelines), full vessel re	formation of spill - pool spreadijng	spill evaporation	two-phase flow in liquid, incl. boiling	heat transfer from ground	condensation (20-90K) and evaporatio	lab/small scale	larger scales		heat conduction in storage material	Boiling Liq. Expanding Vap. Expl. BLE		natural ventilation	forced ventilation	post-accident inerting	recombiners	preventive ignition, ignitors	venting of deflagration	pressurisation of zone to avoid entry of	shut down systems	blast wave protective wall interaction		sensors performance	igniters performance	recombiners performance	storage	materials	explosion impact	thermal impact	mechanical impact	dynamic pressure load
FZK-1												X			X						X	X	X		X	X	X	X	X	X			X	X		X
FZK-2												X			X						X	X	X		X		X	X	X	X			X	X		X
FZK-3												X			X						X	X	X		X		X	X	X	X			X	X		X
FZK-4																										X									
FZK-5			X			X				X		X					X		X		X		X				X			X			X	X		X
FZK-6																	X						X												
FZK-7												X			X						X	X	X		X		X	X	X	X			X	X		X
FZK-8																	X				X														
FZK-9			X			X	X			X		X																							
GC-1																																			
GC-2																	X						X										X	X		X
GC-3																																			
GC-4																																			
GC-5																	X						X				X						X		
GC-6																	X						X				X						X		
GC-7																																			
GC-8																	X																		
GC-9																	X						X												
GC-10																																			

Table 4 (contd.): Categorised facilities of the HySafe partners

	Gaseous release									Dispersion															Ignition										Combustion / Explosion																			
	conf		vent		open					confined		vented		open air											confined		open air									confined		vented		open															
	lab/small scale	larger scales	lab/small scale	larger scales		permeation	subsonic release	choked flow (sonic) release	full bore rupture (pipe), full vessel rupt	turbulent flow in pipes, transport of H2	lab/small scale	larger scales	lab/small scale	larger scales		impinged jets	obstacle-generated turbulence	effect of obstacles on flow patterns	atmospheric conditions incl. wind	heat transfer from environment	natural ventilation (for partially confine	forced ventilation	buoyancy effects	stable stratification	turbulent mixing (in presence of large \	turbulent mixing (decaying conditions)	laminar diffusion	compressible eff. (shocks, under-expa	lab/small scale	larger scales		autoignition (incl. effect of additives)	shock ignition	weak / mild ignition (incl. static electric	strong ignition [forced ignition]	direct initiation of detonation	jet ignition (ignition by hot jet or combu	radiative ignition	hot surface ignition	flammability limits	lab/small scale ('bomb	larger scales ('vessels	lab/small scale (bomb	larger scales (vessels	lab/small scale	larger scales	detonation tubes	laminar flame	cellular flame	wrinked flame	self turbulising flame	flame acceleration / deceleration (due	triple flame	turbulent deflagration	DDT (due to flame accelaration, shock	detonation	quenching (global or local)	standing flame (diffusion flame)	jet fire	spill fire	multiphase combustion (for liq. H2)	heat radiation & absorption
HSL-1	X									X																									X																			
HSL-2					X									X											X																													
HSL-3																																						X																
HSL-4																																																						
HSL-5					X																																																	
HSL-6																																						X																
HSL-7																									X																													
HSL-8																																																						
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HSL-10																																																						
HSL-11																																																						
HSL-12																																																						
INA-1																																																						
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INA-4																																																						
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	Liquid release											Explosion of liquid storage				Mitigation										Equipment and Device Testing									
	confined (vessel		vented		open air							confined		open air																					
	lab/small scale	larger scales	lab/small scale	larger scales		liquid (two-phase) flow through orifice	full bore liquid (pipelines), full vessel re	formation of spill - pool spreadijng	spill evaporation	two-phase flow in liquid, incl. boiling	heat transfer from ground	condensation (20-90K) and evaporatio	lab/small scale	larger scales		heat conduction in storage material	Boiling Liq. Expanding Vap. Expl. BLE		natural ventilation	forced ventilation	post-accident inerting	recombiners	preventive ignition, ignitors	venting of deflagration	pressurisation of zone to avoid entry of	shut down systems	blast wave protective wall interaction		sensors performance	igniters performance	recombiners performance	storage	materials	explosion impact	thermal impact	mechanical impact	dynamic pressure load
HSL-1																		X		X								X						X			
HSL-2					X																																
HSL-3																			X	X	X																
HSL-4														X			X											X							X		
HSL-5																																					
HSL-6																												X							X		
HSL-7																																					
HSL-8																												X								X	
HSL-9																												X								X	
HSL-10																												X								X	
HSL-11																												X								X	
HSL-12																												X								X	
INA-1																												X					X				
INA-2																												X					X				
INA-3																												X					X				
INA-4																												X					X				
INA-5																												X					X				
INA-6																												X					X				
INA-7																												X					X				

Table 4 (contd.): Categorised facilities of the HySafe partners

	Gaseous release										Dispersion																		Ignition												Combustion / Explosion																					
	conf		vent		open						confined		vented		open air														confined		open air										confined		vented		open																	
	lab/small scale	larger scales	lab/small scale	larger scales		permeation	subsonic release	choked flow (sonic) release	full bore rupture (pipe), full vessel ruptu	turbulent flow in pipes, transport of H2	lab/small scale	larger scales	lab/small scale	larger scales		impinged jets	obstacle-generated turbulence	effect of obstacles on flow patterns	atmospheric conditions incl. wind	heat transfer from environment	natural ventilation (for partially confine	forced ventilation	buoyancy effects	stable stratification	turbulent mixing (in presence of large v	turbulent mixing (decaying conditions)	laminar diffusion	compressible eff. (shocks, under-expa	lab/small scale	larger scales		autoignition (incl. effect of additives)	shock ignition	weak / mild ignition (incl. static electric	strong ignition [forced ignition]	direct initiation of detonation	jet ignition (ignition by hot jet or combu	radiative ignition	hot surface ignition	flammability limits	lab/small scale ('bomb	larger scales (vessels	lab/small scale (bomb	larger scales (vessels	lab/small scale	larger scales	detonation tubes	laminar flame	cellular flame	wrinkled flame	self turbulising flame	flame acceleration / deceleration (due	triple flame	turbulent deflagration	DDT (due to flame accelaration, shock	detonation	quenching (global or local)	standing flame (diffusion flame)	jet fire	spill fire	multiphase combustion (for liq. H2)	heat radiation & absorption
INE-1																																														X								X	X	X		X	X			
INE-2												X													X	X			X					X			X			X		X		X				X		X		X		X								
INE-3												X											X	X	X	X				X				X			X							X				X		X		X		X								
INE-4												X										X	X	X	X	X				X				X										X				X		X		X		X								
INE-5																														X						X	X			X		X					X	X		X	X	X		X	X	X	X					
INE-6																													X					X	X			X	X	X	X							X	X	X	X											
INE-7		X				X	X	X	X			X											X	X	X	X			X			X	X	X	X	X	X	X	X	X		X						X	X	X						X						
INE-8																													X			X		X	X	X	X	X	X	X	X							X	X	X						X						
INE-9																																														X											X			X	X	X
INE-10					X		X	X	X	X					X	X	X	X	X						X			X																		X		X		X	X	X		X	X	X		X				X
INE-11																																																														
INE-12	X					X	X	X																																																						
JRC-1																																																														
JRC-2																																																														
JRC-3																																																														
KI-1																															X				X	X															X				X	X						
KI-2																															X					X																		X		X						
KI-3																															X						X																		X							
KI-4																													X												X											X					X					
KI-5																													X																		X					X		X	X	X						
KI-6																													X																		X	X	X	X	X	X		X	X	X	X					
KI-7																													X																		X		X	X	X	X		X	X	X						
KI-8																													X						X	X				X							X	X				X		X	X	X	X					
KI-9																														X										X							X					X		X	X	X	X					
KI-10																													X														X				X					X			X	X	X					
KI-11																														X					X							X																				
KI-12																													X					X							X							X				X											
KI-13					X			X							X																X															X																

Table 4 (contd.): Categorised facilities of the HySafe partners

	Liquid release											Explosion of liquid storage				Mitigation										Equipment and Device Testing									
	confined (vessel		vented		open air	liquid (two-phase) flow through orifice	full bore liquid (pipelines), full vessel re	formation of spill - pool spreadjing	spill evaporation	two-phase flow in liquid, incl. boiling	heat transfer from ground	condensation (20-90K) and evaporatio	confined		open air	heat conduction in storage material	Boiling Liq. Expanding Vap. Expl. BLE	natural ventilation	forced ventilation	post-accident inerting	recombiners	preventive ignition, ignitors	venting of deflagration	pressurisation of zone to avoid entry o	shut down systems	blast wave protective wall interaction	sensors performance	igniters performance	recombiners performance	storage	materials	explosion impact	thermal impact	mechanical impact	dynamic pressure load
	lab/small scale	larger scales	lab/small scale	larger scales									lab/small scale	larger scales																					
INE-1													X				X	X								X	X				X		X	X	X	X
INE-2																	X						X		X		X	X								
INE-3																	X						X		X		X	X								
INE-4																	X						X		X		X	X				X				X
INE-5																	X						X		X		X	X				X				X
INE-6																											X	X	X							
INE-7																											X	X	X							
INE-8																											X	X	X							
INE-9					X																															
INE-10					X	X	X	X	X	X	X	X					X									X	X	X					X	X		X
INE-11																											X	X								
INE-12																											X	X		X		X				
JRC-1																											X				X	X				
JRC-2																											X	X								
JRC-3																											X				X					
KI-1																																				
KI-2																																				
KI-3																																				
KI-4																																				
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KI-11																																				
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KI-13																																				

Table 4 (contd.): Categorised facilities of the HySafe partners

	Gaseous release										Dispersion																		Ignition												Combustion / Explosion																					
	conf		vent		open						confined		vented		open air														confined		open air										confined		vented		open																	
	lab/small scale	larger scales	lab/small scale	larger scales		permeation	subsonic release	choked flow (sonic) release	full bore rupture (pipe), full vessel ruptu	turbulent flow in pipes, transport of H2	lab/small scale	larger scales	lab/small scale	larger scales		impinged jets	obstacle-generated turbulence	effect of obstacles on flow patterns	atmospheric conditions incl. wind	heat transfer from environment	natural ventilation (for partially confine	forced ventilation	buoyancy effects	stable stratification	turbulent mixing (in presence of large v	turbulent mixing (decaying conditions)	laminar diffusion	compressible eff. (shocks, under-expa	lab/small scale	larger scales		autoignition (incl. effect of additives)	shock ignition	weak / mild ignition (incl. static electric	strong ignition [forced ignition]	direct initiation of detonation	jet ignition (ignition by hot jet or combu	radiative ignition	hot surface ignition	flammability limits	lab/small scale ('bomb	larger scales ('vessels	lab/small scale (bomb	larger scales (vessels	lab/small scale	larger scales	detonation tubes	laminar flame	cellular flame	wrinked flame	self turbulising flame	flame acceleration / deceleration (due	triple flame	turbulent deflagration	DDT (due to flame accelaration, shock	detonation	quenching (global or local)	standing flame (diffusion flame)	jet fire	spill fire	multiphase combustion (for liq. H2)	heat radiation & absorption
TNO-1																													X					X						X	X							X														
TNO-2																													X					X						X	X							X														
TNO-3																													X					X						X	X							X														
TNO-4																													X					X							X		X					X														
TNO-5																														X				X								X		X				X														
TNO-6																														X				X	X							X		X				X			X			X								
TNO-7																														X				X	X							X		X				X			X			X								
TNO-8																														X	X			X	X	X	X		X			X				X		X			X	X		X	X	X		X	X			
TNO-9																														X		X		X					X			X						X			X	X		X								
TNO-10																														X			X		X	X											X									X						
TNO-11																																																													
TNO-12																															X	X		X			X									X		X						X					X			
TNO-13																																																													
UP-1		X					X	X				X		X			X				X	X	X	X						X				X	X									X										X								
UP-2					X			X	X						X	X			X												X			X	X									X															X			
WUT-1	X		X																																						X		X				X				X	X		X	X	X						
WUT-2	X		X																																						X		X				X				X	X		X	X	X						
WUT-3	X		X																																						X		X				X				X	X		X	X	X						

Table 4 (contd.): Categorised facilities of the HySafe partners

	Liquid release											Explosion of liquid storage					Mitigation										Equipment and Device Testing									
	confined (vessel		vented		open air							confined		open air																						
	lab/small scale	larger scales	lab/small scale	larger scales		liquid (two-phase) flow through orifice	full bore liquid (pipelines), full vessel re	formation of spill - pool spreadjing	spill evaporation	two-phase flow in liquid, incl. boiling	heat transfer from ground	condensation (20-90K) and evaporatio	lab/small scale	larger scales		heat conduction in storage material	Boiling Liq. Expanding Vap. Expl. BLE		natural ventilation	forced ventilation	post-accident inerting	recombiners	preventive ignition, ignitors	venting of deflagration	pressurisation of zone to avoid entry o	shut down systems	blast wave protective wall interaction		sensors performance	igniters performance	recombiners performance	storage	materials	explosion impact	thermal impact	mechanical impact	dynamic pressure load
TNO-1																																				
TNO-2																																				
TNO-3																																				
TNO-4																											X						X			X
TNO-5																							X				X	X					X			X
TNO-6																				X			X			X	X	X	X			X	X		X	X
TNO-7																			X	X		X		X			X	X	X		X		X	X		X	X
TNO-8																			X								X						X	X		X	X
TNO-9																					X									X							
TNO-10																										X	X						X	X		X	X
TNO-11																											X	X		X	X	X	X	X		X	X
TNO-12																											X		X								
TNO-13																		X	X	X		X					X	X		X							
UP-1																			X	X				X				X									X
UP-2																			X																		
WUT-1																		X						X			X	X					X		X	X
WUT-2																		X						X			X	X					X		X	X
WUT-3																		X						X			X	X					X		X	X

4 Descriptions of instrumentation

In order to complement the facility descriptions and to support the sharing of equipment in common experiments, the HySafe partners have provided unified descriptions of specific equipment and instrumentations. Similar to the facility descriptions, the descriptions of instrumentation are subdivided into two sections:

- Overview, and
- Technical details.

While the overview section gives a short introduction to the specific device by providing

- Name,
- Type, and
- Application

the technical details section helps assessing the specifications with regard to the specific experiments. Here, detailed information concerning

- General description,
- Dimensions / weight / mobility,
- Temperature and pressure range,
- Media,
- Commercial availability (in-house development or commercial), and
- References

are given.

The full compilation of instrumentation descriptions is given in Annex II. The compilation at hand is intended to serve as a tool for future common experiments in the HySafe context. However, the importance of an intensive personal exchange of experience must not be underestimated. This aspect is specifically considered in the series of IEF workshops on instrumentation techniques.

5 Conclusions

Although there will be a final update of this document at the end of the final funding period, the present deliverable D96 can already be regarded as the final formal result from the IEF activity of the HySafe project. In order to conclude the successful integration work in the final funding period and to prepare a good basis for the HySafe follow-up organisation, the present work programme will focus on the tasks

- Initiation of internal studies
- Continuation of the series of workshops
- Finalisation of the IEF documentation

While the series of workshops has already demonstrated the readiness of the IEF partners to share knowledge in the field of experimental work, the internal studies on challenging measurement tasks will demand a further level of co-operation. Especially with regard to the HySafe follow-up organisation this activity will give insight in the way how future common projects could be performed.

Annex I – Compilation of 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)*
- *Facility for testing and calibration of gas sensors*

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*

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	*open air test site*
Scale	*large scale*
Experiments	*fire, drop, impact and other tests for flammable, pressurized or otherwise dangerous goods or vessels containing them*

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*

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*

Technical details

Dimensions	*Facility: approx. 2.0 x 1.0 x 0.8 meters* *Test chamber: approx. 2.5 litres volume* *Test chambers are equipped with five (or up to ten) sensors of different types. 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).*
Further particulars	*Test gas mixtures of defined composition are generated dynamically from appropriate parent gases in cylinders and 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 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*
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	thermal 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*

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*

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?

  -

Overview

Name	***Facility for testing and calibration of gas sensors***
Type	*test gas mixture system and test chamber*
Scale	*lab scale*
Experiments	*testing and calibration of gas sensors*

Technical details

Dimensions	*Facility: approx. 2.0 x 1.0 x 0.8 meters / 150 kg*
Temperature range	*- 40 to +180 °C*
Pressure range	*Test chamber 0.8 to 1.3 bar*
Media	*hydrogen, air, water vapour and up to 3 gases (e.g. CO_2, SO_2, NH_3, propane… and up to 2 other vapours (e.g. ethanol, isooctane)*
Description	*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.*
In-house/commercial	*in-house*
References	*BANACH, U. and HÜBERT, T.: Detection of hydrogen with catalytic sensors, in Gerlach, G. (Hrsg); Dresdner Beiträge zur Sensorik, Band 29, 8. Dresdner Sensor-Symposium, 10.-12. Dezember 2007, Dresden: TUDpress, S.133-136; ISBN-13: 978-3-940046-45-1*

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*

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***
Type	*cubic polycarbonate vessel*
Scale	*small scale*
Experiments	*detailed studies of H2 (simulated by He) release and distribution in a 3D confined geometry*

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: *ET*

Facilities:
- *Liquid hydrogen vacuum insulation rupture rig*
- *Liquid hydrogen tank test equipment*
- *Liquid hydrogen test rig for material tests*
- *High pressure hydrogen tank and component test equipment*

Overview

Name	***Liquid hydrogen vacuum insulation rupture rig***
Type	*LH_2-car tank*
Scale	*full scale*
Experiments	*Experimental behaviour of LH_2-car tank under spontaneous rupture of vacuum insulation*

Technical details

Dimension	*0,2 m^3*
Temperature	*20 K*
Pressure	*4 bar*
Media	*LH_2*
Special features	*Safe and flexible handling and test area* *LH_2 supply in adequate quantities (10.000 litre)*

Experiments – Equipment

Experiments	*Experimental behaviour of LH_2-car tank under spontaneous rupture of vacuum insulation*
Instrumentation	*pressure* *temperature* *mass-flow*
Schedule	*Short availability, upon agreement case by case*
Tools	*High speed camera recording*

Overview

Name	***Liquid hydrogen tank test equipment***
Type	*Tank test installation*
Scale	*Full scale*
Experiments	*Experimental study of tank and component failures*

Technical details

Dimension	*Full scale*
Temperature	*20 °K*
Pressure	*4 bar*
Media	*LH_2*
Special features	*Adequate LH_2 supply (10.000 litre)* *flexible test installation to meet various technical requirements*

Experiments – Equipment

Experiments	*Experimental study of tank and component failures*
Instrumentation	*LH_2-sensors* *temperature* *pressure* *mass-flow* *leak-rate, filling level etc.*
Schedule	*Short availability, upon agreement case by case*
Tools	*10.000 litre LH_2 storage and supply tank* *Safe hydrogen infrastructure*

Overview

Name	***Liquid hydrogen test rig for material tests***
Type	*Vessel*
Scale	*Subscale, probes*
Experiments	*Behaviour of liquid hydrogen structures under mechanical and thermal loads*

Technical details

Dimension	*Vessel diameter 800 mm (probes Ø 250 mm)*
Temperature	*20 – 600 °K*
Pressure	*Vacuum to 1.5 bar*
Media	*LH_2, LN_2 and GH_2, GN_2, GHe*
Special features	*Test of monitoring systems for composite containers (high pressure and LH_2)*

Experiments – Equipment

Experiments	*Behaviour of liquid hydrogen structures under mechanical and thermal loads*
Instrumentation	*permeation* *temperature* *pressure*
Schedule	*Short availability, upon agreement case by case*
Tools	*Mass-spectrometer*

Overview

Name	***High pressure hydrogen tank and component test equipment***
Type	*Test chambers (various)*
Scale	*Full scale*
Experiments	*Experimental study of tank and component failures* *Extreme temperature tests* *Fast fill and drain tests*

Technical details

Dimension	*Adapted to test specimen*
Temperature	*- 40 to + 85 °C*
Pressure	*up to 1500 bar*
Media	*GH_2*
Special features	*Flexible test installation to meet various technical requirements*

Experiments – Equipment

Experiments	*Experimental study of tank and component failures* *Extreme temperature tests* *Fast fill and drain tests*
Instrumentation	*pressure control* *temperature control etc.*
Schedule	*Short availability, upon agreement case by case*
Tools	*mass-spectrometer* *high-pressure compressor* *large storage volumes (1.5 m^3 / 800 bar)*

Partner: *Fh-ICT*

Fraunhofer Institut Chemische Technologie

Facilities:
- *H_2 high pressure compressor*
- *Heatable high pressure vessel*
- *Device for flame jet ignition*
- *High pressure vessel with windows*
- *Closed detonation room*
- *Splinter protected test box / area*
- *Testing area*
- *Test stand*

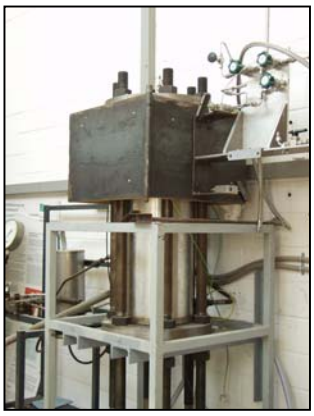
Overview

Name	***H_2 High Pressure Compressor***
Type	*Remote controlled system based on Maximator DLE 75-2 compressor*
Scale	*all*
Experiments	*medium and large scale material, component and system tests, burst tests.*

Technical details

Dimensions	*B 1,30m x T 0,6m x H 1m / 160kg*
Temperatures	*Media Temperature 50°C max.*
Pressure	*1.500 bar max.*
Media	*Hydrogen, others possible*
Media inlet press.	*45…250 bar*
Media Throughput	*350…50 l_N/min @ 200…1000 bar*
Drive air pressure	*10 bar*
Drive air consumption	*4000 l_N/min max.*
Description	*The compressor station is a mobile air driven remote controlled system*

Overview



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

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.*
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*

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.*
Instrumentation	*pressure; gas composition; flame speed*
Schedule	-
Tools	-

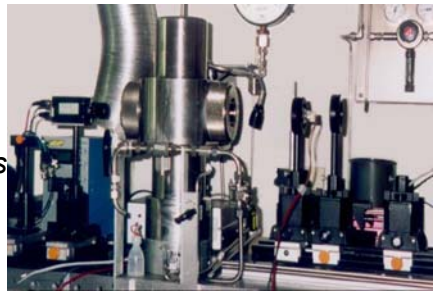
Information for the preparation of integration

- **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*

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

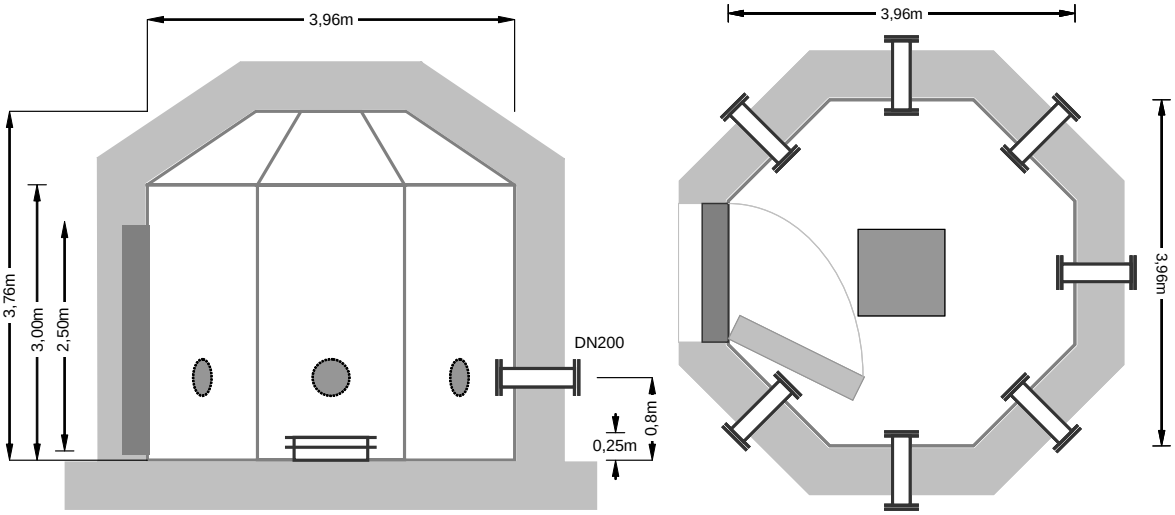
Experiments	*Quantitative measurement of molecular band radiation in correlation to pressure and time, pressures, flame front velocities, laminar burning velocities depending on pressure*

Overview

Name	***Closed detonation room***
Type	
Scale	*2 Kg TNT equivalent*
Experiments	*detonation experiments with explosive gases, liquids and solids*

Technical details

Dimensions	*45 m³*
Temperatures	-
Pressure	*1 bar max. static burst pressure, dynamic overpressures up to 20 bar*
Media	*high explosives, explosive gases and liquids*
Description	*detonation chamber built of reinforced concrete with additional 20mm steel inliner. The room is equipped with a remote controlled door, overpressure outlet valve, exhaust chimney and venting system. For instrumentation purposes 7 Tubes ∅ 200mm and 2 optional Windows are implemented in the walls.*



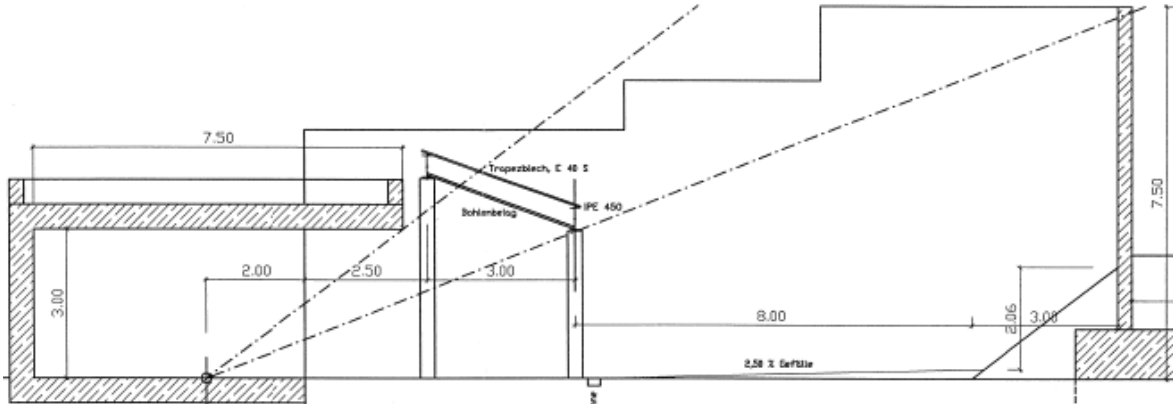
Cross and horizontal section of the detonation chamber

Overview

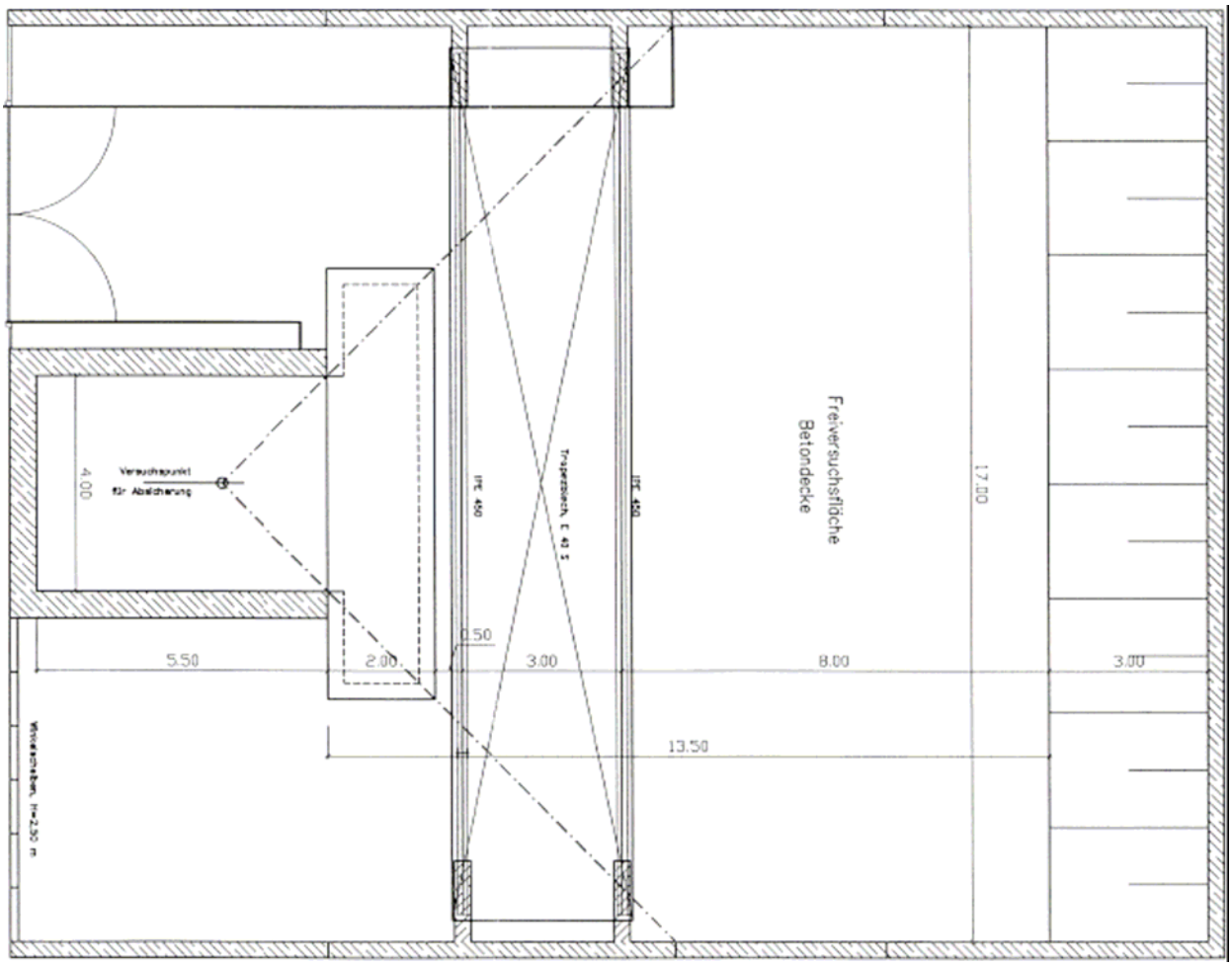
Name	***Splinter protected Test box / area***
Type	
Scale	*1 Kg TNT equivalent*
Experiments	*high pressure, free jet, burning and medium size explosion experiments*

Technical details

Dimensions	*Box: B x H x T = 3m x 3m x 6m* *Area outside Box: B x L = 17m x 15m*
Temperatures	-
Pressure	-
Media	-
Description	*Splinter protected energetic material testing Box constructed of reinforced concrete. The area in front of the box is protected by a splinter protection roof and walls around. Protected control-room nearby. Universal testing-equipment and instrumentation setup possibilities.*



Splinter protected Box - horizontal section



Splinter protected Box - cross section

Overview

Name	***Testing area***
Type	*open-air*
Scale	*full scale*
Experiments	*studies on explosions, tank testing, hydrogen-release…..*

Technical details

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

Overview

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

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*

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*

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 catalyst 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.*	
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	*small scale*
Experiments	*studies on catalyst elements for H2 recombination*

Technical details

Dimensions	*height: 1 m, volume: 156 litres*
Temperatures	*up to 150 °C initial gas temperature*
Pressure	*10 bar*
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.*	
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?

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  Which additional equipment could enhance the results of your experiments?

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Overview

Name	***REKO-3***
Type	*flow reactor*
Scale	*small scale*
Experiments	*studies on catalyst elements for H2 recombination under forced flow conditions*

Technical details

Dimensions	*46 x 5 cm² rectangular 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.*	
Instrumentation	*gas temperature*	*thermocouples*
	catalyst temperature	*thermocouples inserted inside the plates*
	gas composition	*hydrogen and oxygen analysers*
	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?

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  Which additional equipment could enhance the results of your experiments?

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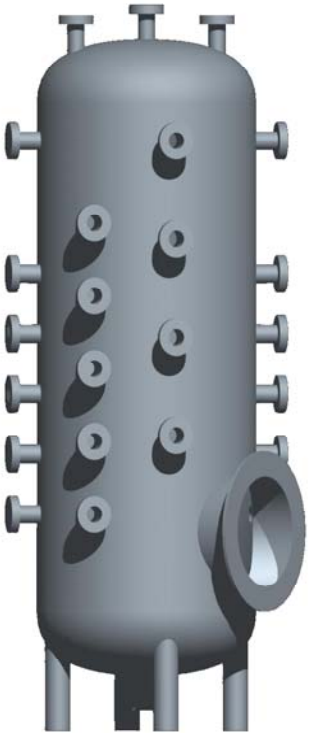


Overview

Name	***REKO-4 (under construction)***
Type	*pressure vessel*
Scale	*medium scale*
Experiments	*studies on catalytic recombiners under natural flow conditions*

Technical details

Dimensions	*height: 4.0 m, diameter: 1.5 m*
Temperatures	*250 °C gas temperature*
Pressure	*25 bar*
Media	*hydrogen, air, nitrogen, water steam*
Special features	*flow field measurements with Particle Image Velocimetry (PIV)*

Experiments – Equipment

Experiments	*Studies on the operational behaviour of catalytic hydrogen recombiners under natural flow conditions. Testing parameters are gas composition (hydrogen, nitrogen, air, water steam), gas temperature.*	
Instrumentation	*gas temperature*	*thermocouples*
	catalyst temperature	*thermocouples*
	gas composition	*hydrogen analysers*
	flow field	*PIV*
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*
- *A8 Vessel*
- *12 m detonation tube (DT)*
- *Flow Test Chamber (TC)*
- *Partially Vented Explosion Tube (PET)*
- *Explosion Bomb*
- *HyJet (Hydrogen Jet)*

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*

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*

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*	*thermocouples*
	pressure	*piezoelectric, piezoresistive*
	gas composition	*mass spectrometer, gas flow control*
	hydrogen distribution	*sonic hydrogen sensors*
	velocity	*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*

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* *gas composition*	*thermocouples* *piezoelectric, piezoresistive gauges* *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	***A8 Vessel***
Type	*cylindrical vessel*
Scale	*large and medium scale*
Experiments	*studies on gas combustion and detonations, vented explosions, hydraulic and pneumatic equipment explosions, integrity and fracture of mechanical structures under high pressure load, blast vessels*

Technical details

Dimensions	*8.8 m³ vessel, internal diameter 1.8 m, length 3.7 m*
Temperatures	*ambient*
Pressure	*up to 120 bar of static pressure*
Media	*hydrogen, hydrocarbons, air, inert gases, pressurized gases themselves.*
Special features	*large or medium scale; licensed static pressure limit 120 bar; multiple entries possible*
Further particulars	*several vents up to 300 mm in diameter;* *8 glass windows for visual observations Ø150 mm;* removable flange with opening of 1.8 m in diameter

Experiments – Equipment

Experiments	*- experiments on turbulent combustion in uniform and nonuniform gas mixtures at different initial pressures ;* *- jet initiation of detonation;* *- blast vessels;* *- exploding pipes, valves;* *- bursting membranes*
Level of detail	*integral*

Instrumentation	*gas temperature*	*thermocouples*
	pressure	*piezoelectric, piezoresistive transducers*
	gas composition	*mass spectrometer, gas flow control;*
	velocity	*photodiodes, ion probes*
	deformations, fracture	*strain gauges, high speed camera*
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 (LabView) required for data acquisition system to convert analogous signals to digital ones (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 and/or fracture of gas equipment (piping, valves, and membranes) either pressurized or under detonation pressure load could be done using A8 vessel as secure shell against missiles.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Large and medium scale experiments on turbulent combustion and detonation, experiments under elevated pressures and extremely high pressure load, testing of high pressure equipment.

  What more/better results could you obtain if you had additional equipment?

  -

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.*

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*	*thermocouples*
	pressure	*piezoelectric, piezoresistive gauges*
	gas composition	*mass spectrometer, gas flow control*
	velocity	*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?

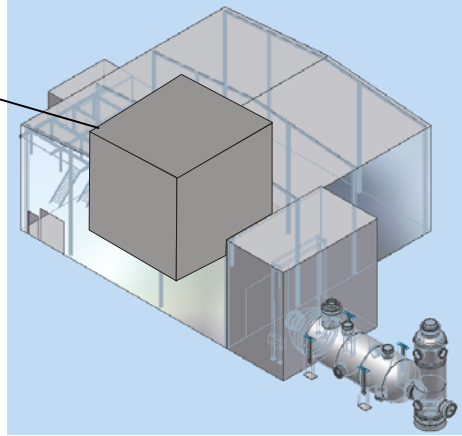
  Medium scale experiments on turbulent combustion and detonation, experiments under elevated and reduced pressures, experiment on ignition and flame propagation limits.

  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*



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 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*	*thermocouples*
	pressure	*piezoelectric, piezoresistive gauges*
	gas composition	*mass spectrometer, gas flow control*
	hydrogen distribution	*sonic hydrogen sensors*
	velocity	*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*

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

  -

Overview

Name	***Explosion bomb***
Type	*spherical vessel*
Scale	*laboratory scale (8.2 dm^3)*
Experiments	*flammability limits, minimum ignition e* *chemical kinetics, flame structure*

Technical details

Dimensions	*8.2 dm³ vessel, internal diameter 25 cm, wall thickness >34 mm*
Temperatures	*20 – 300 °C*
Pressure	*up to 800 bar of static pressure*
Media	*hydrogen, hydrocarbons, oxygen, air, steam, inert gases*
Special features	*laboratory scale; licensed static pressure limit 800 bar; quartz windows for optical observations*
Further particulars	*2 quartz windows for optical observations Ø50 mm;* *blind flanges instead of windows*

Experiments – Equipment

Experiments	*- experiments on flammability limits at elevated initial pressures and temperatures;* *- minimum ignition energy at elevated initial pressures and temperatures;* *- laminar flame velocity at elevated initial pressures and temperatures*	
Level of detail	*integral*	
Instrumentation	*gas temperature*	*thermocouples*
	pressure	*piezoelectric, piezoresistive transducers*
	gas composition	*mass spectrometer, gas flow control;*
	velocity	*high speed schlieren cinematography*

Schedule	*preparatory work of experimental set-up to specific test series requires one month;* *1–3 hours are needed for preparation and conduction of one experiment in the series (depending on an initial pressure);* *1-2 days are needed for processing of raw experimental data*
Tools	*standard software (LabView) required for data acquisition system to convert analogous signals to digital ones (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?

  1-2 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 self ignition temperature, experiments on turbulent flames, and experiments on chemical kinetics and minimum ignition energy.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  What more/better results could you obtain if you had additional equipment?

  Detailed flame structure using laser techniques and high speed photo.

Overview

Name	***HyJet***
Type	*horizontal/vertical hydrogen jet*
Scale	*small and medium scale (up to 3 m)*
Experiments	*studies on hydrogen release from pressurized vessel, dynamic hydrogen concentrations and flow velocity profiles, investigations on flammability of the turbulent hydrogen jet.*

Technical details

Dimensions	*0.16, 1, 5, 10 mm nozzle diameter, up to 10 g/s hydrogen mass flow (stationary) or up to 100 g/s (maximum, temporary)*
Temperatures	*from cryogenic (20K) to ambient*
Pressure	*up to 260 bar*
Media	*pressurized hydrogen, air, inert gases, heterogeneous cryogenic gas release.*
Special features	*small or medium scale; sub- or supersonic flow velocity, buoyant jet,*
Further particulars	jet *interactions with obstacles grid, barriers, hood and so on.*

Experiments – Equipment

Experiments	*- spatial and temporal hydrogen and velocity distribution in a jet;* *- vertical and horizontal free jets;* *- jet interaction with obstacles and barriers;* *- subsonic and supersonic jets, buoyant jets* *- ignition, combustion and explosion of hydrogen jets;* *- steady-state and non steady-state jets*
Level of detail	*integral*

Instrumentation	*gas temperature*	*thermocouples, infrared camera*
	pressure	*piezoelectric, piezoresistive transducers*
	heat radiation	*infrared camera, heat flux sensors*
	gas composition	*mass spectrometer, ultrasonic Doppler velocimetry; Background Oriented Schlieren* (BOS) *method*
	velocity	*ultrasonic Doppler velocimetry; BOS method high speed camera*
	noise level	*microphone, piezoelectric sensors*
Schedule	*preparatory work of experimental set-up to specific test series requires 2 weeks;* *1 – 2 hours are needed for preparation and conduction of one experiment in the series;* *1-2 days are needed for processing of raw experimental data*	
Tools	*standard software (LabView) required for data acquisition system to convert analogous signals to digital ones (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?

  Hydrogen and velocity distribution in a hydrogen jet using laser techniques (Mie and Rayleigh scattering, LDV)

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Critical conditions for ignition, combustion and explosion of hydrogen jets.

  What more/better results could you obtain if you had additional equipment?

  -

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*

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.*
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*

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.*
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

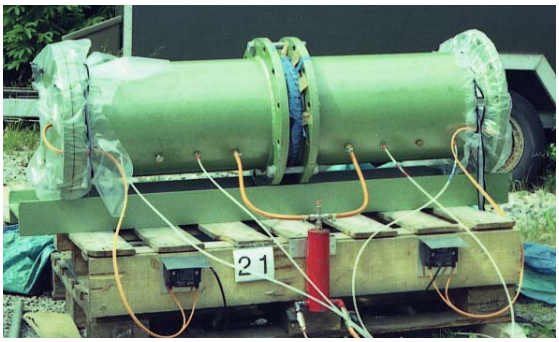
  Structural response

- **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*

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.*
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*

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.*
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)*

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.*
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*

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.*
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**

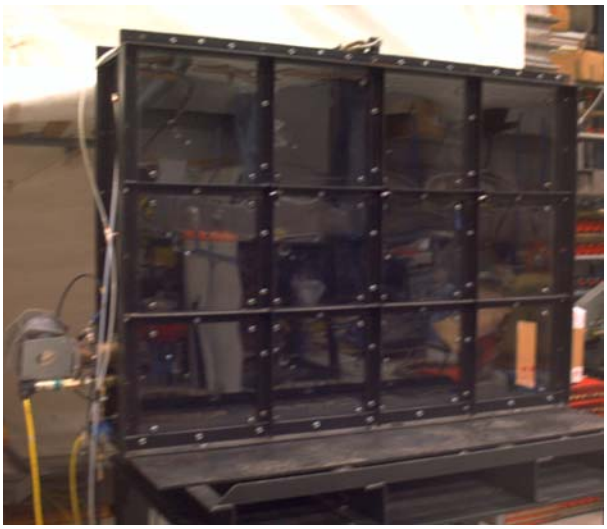
  What features/possibilities would you like to promote?

  -

  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*

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.*
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**

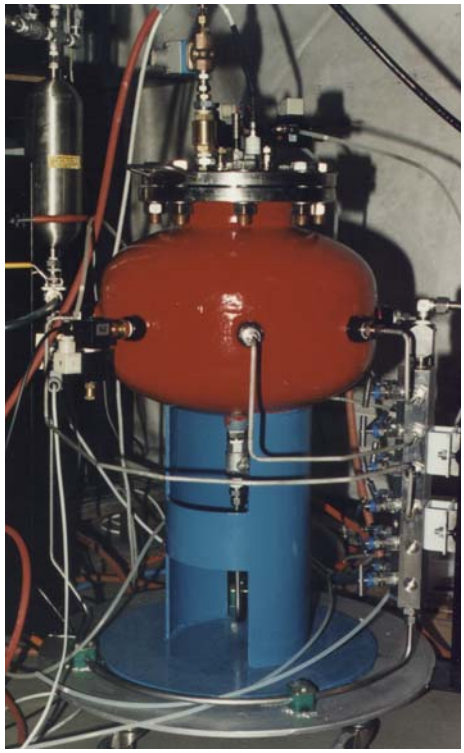
- **To prepare promotion and specialisation**

  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*

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.*
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**

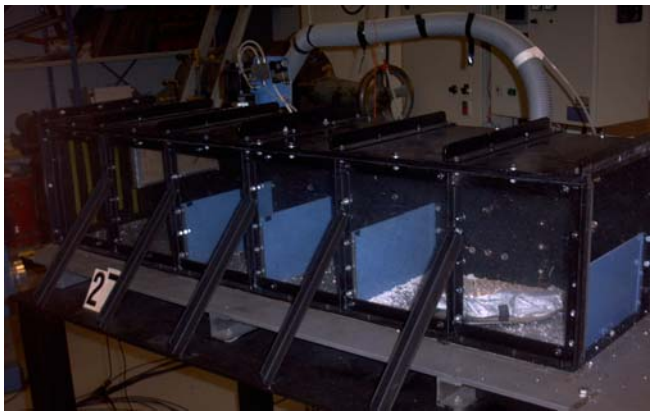
  What features/possibilities would you like to promote?

  -

  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*

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.*
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

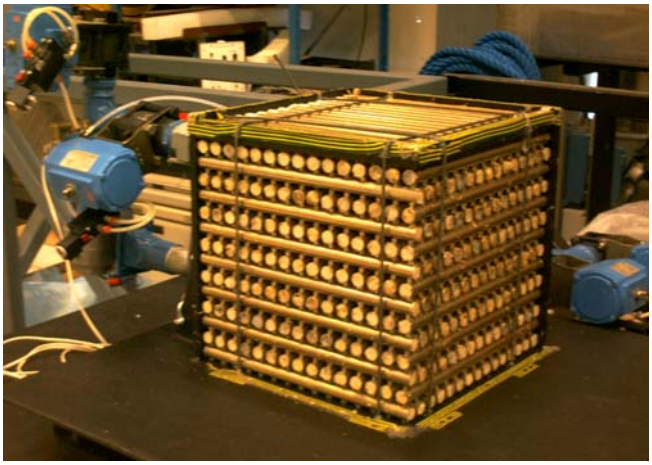
  Structural response and explosion loading

- **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*

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.*
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*

Facilities:
- *Ventilated dispersion and explosion facility*
- *Gas dispersion facility*
- *Under water gas release and explosion facility*
- *Jet fire facility*
- *High pressure hydrogen facility*
- *366m gallery/tunnel*
- *Frictional ignition apparatus*
- *75 mm gas gun*
- *190 mm gas gun*
- *Impact test track*
- *Drop Tower 3.3 m*
- *Drop Tower 25 m*

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, ...*

Technical details

Dimensions	*Enclosure with internal dimensions of 2.5 m x 2.5 m x15 m. 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 etc. on dispersion and overpressure*	
Level of detail	*High using large thermocouple and transducer arrays.*	
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 (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*

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*	
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	***Under water gas release and explosion facility***
Type	*48 m³ enclosure*
Scale	*Full scale tests of gas releases up to 800 litres*
Experiments	*Studies of explosions in ullage spaces*

Technical details

Dimensions	*Enclosure with internal dimensions of 4m x 4m x 3m.*
Temperatures	*Ambient temperature – outdoor facility*
Pressure	U*p to 1 bar over pressure*
Media	*Hydrogen or other gases*
Special features	*Ventilation system capable of 2900 m^3hr^{-1}* *Different ventilation configurations multiple entries possible* *Windows for imaging*

Experiments – Equipment

Experiments	*Characterisation of hydrogen release, ignited and un-ignited into the ullage space with controlled ventilation flow.*	
Instrumentation	*gas temperature*	*thermocouples*
	pressure	*pressure transducers*
	gas concentration	*oxygen concentration cells*
	flame size	*thermal imaging camera high speed video*
	logging	*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?

- **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	***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*

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)*
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	***High pressure hydrogen facility***
Type	*Gas supply compressor, reservoir and pipe work to enable pressurised releases*
Scale	*Full scale tests, with releases up to 1000 bar, 9.5mm dia. release orifice ,*
Experiments	*Study of ignited and unignited jet releases of hydrogen*

Technical details

Dimensions	*Release orifice up to 9.5 mm diameter, pressure up to 1000 bar*
Temperatures	*Ambient temperature*
Pressure	*1000 bar*
Reservoir Volume	*2 x 50 litres*
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.* *Study of spontaneous ignitions*
Instrumentation	*gas temperature thermocouples* *pressure pressure transducers* *gas concentration oxygen & hydrogen 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?

  Up to 8 (dependent on explosion severity)

  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.
  Filling high pressure tanks etc.

- **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.

  Spontaneous ignition studies.

  Which additional equipment could enhance the results of your experiments?

  Background Oriented Schlieren Imaging

Overview

Name	***366m gallery/tunnel***
Type	*Concrete test enclosure/tunnel*
Scale	*Full/large scale*
Experiments	*Combustion and ventilation controlled overpressures Fragmentation.*

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*
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 20 m/s, 5 kN loads in a 0.3 m^3 vented explosion vessel*
Experiments	*Studies into frictional rubbing events in flammable atmospheres. Research into spark and hot surface ignition events.*

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 H_2.*	
Instrumentation	*gas temperature* *pressure* *fuel concentration* *flame*	*thermocouples* *pressure transducers* *mass flow meters* *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 H_2 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 H_2 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	***75 mm gas gun***
Type	*Impact test facility*
Scale	*Full scale tests*
Experiments	*Small projectiles.*

Technical details

Dimensions	*up to 120m.s^{-1}.*
Temperatures	*Ambient temperature*
Pressure	-
Media	
Special features	

Experiments – Equipment

Experiments	*Testing of storage vessels*
Level of detail	-
Instrumentation	*High speed video also available.*
Schedule	*time needed for:* *preparation (),* *conduction (),* *interpretation of experiments()*
Tools	

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?

  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 the results of your experiments?

  -

Overview

Name	***190 mm gas gun***
Type	*Impact test facility*
Scale	*Full scale tests*
Experiments	*up to 25 kg projectiles.*

Technical details

Dimensions	*up to 25 kg projectiles at up to 300m.s^{-1}.*
Temperatures	*Ambient temperature*
Pressure	-
Media	
Special features	

Experiments – Equipment

Experiments	*Testing of storage vessels*
Level of detail	-
Instrumentation	*High speed video also available.*
Schedule	*time needed for:* *preparation (),* *conduction (),* *interpretation of experiments()*
Tools	

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?

  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 the results of your experiments?

  -

Overview

Name	***Impact test track***
Type	*Impact test facility*
Scale	*Full scale tests*
Experiments	*Dynamic impact tests on components/ tanks etc.*

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*
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?

  -

Overview

Name	***Drop Tower***
Type	*Impact test facility*
Scale	*Indoor*
Experiments	*up to 10 tons.*

Technical details

Dimensions	*up to 10 tons over 3.3m.*
Temperatures	*Ambient temperature*
Pressure	-
Media	
Special features	

Experiments – Equipment

Experiments	*Testing of storage vessels*
Instrumentation	*High speed video also available.*
Schedule	*time needed for:* *preparation (),* *conduction (),* *interpretation of experiments()*
Tools	

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?

  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 the results of your experiments?

  -

Overview

Name	***Drop Tower***
Type	*Impact test facility*
Scale	*Full scale tests*
Experiments	*drops of up to 25 m.*

Technical details

Dimensions	25 m.
Temperatures	*Ambient temperature*
Pressure	-
Media	
Special features	

Experiments – Equipment

Experiments	*Testing of storage vessels*
Instrumentation	*High speed video also available.*
Schedule	*time needed for:* *preparation (),* *conduction (),* *interpretation of experiments()*
Tools	

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?

  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 the results of your experiments?

  -

Partner: *INASMET*

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

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*

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*

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.*
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*

Technical details

Dimensions	*Five desktop Rings for different load ranges*
Temperatures	*ambient*
Pressure	*atmospheric*
Media	*corrosive media with gas bubbling (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)*

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.*
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*

Technical details

Dimensions	-
Temperatures	-
Pressure	-
Media	-
Special features	-

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.*
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*

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.*
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*

Technical details

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

Experiments – Equipment

Experiments	*Metallic Hydride as hydrogen storage materials are produced by the Self-Propagating High-Temperature Synthesis (SHS) method.*
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?

  -

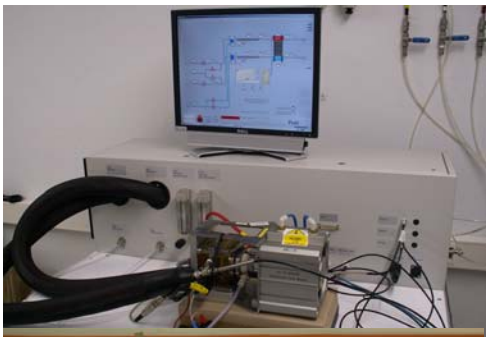
- **To prepare promotion and specialisation**

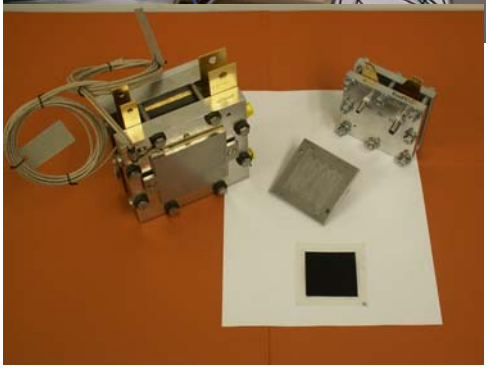
  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance your results?

  -





Overview

Name	***PEMFC Testing Equipment***
Type	*Fuelcon C050*
Scale	*lab scale*
Experiments	*Evaluation of PEMFC components behaviour*

Technical details

Dimensions	-
Temperatures	-
Pressure	-
Media	*different gases (hydrogen, air, nitrogen, steam, ...)*
Special features	*up to 500w*
Further particulars	-

Experiments – Equipment

Experiments	*Electrochemical testis. V/I curves. Duration test.*
Level of detail	-
Instrumentation	*temperature, pressure, flow*
Schedule	*hours / weeks*
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	***SOFC Testing Equipment***
Type	-
Scale	*lab scale*
Experiments	*Evaluation of SOFC components behaviour*

Technical details

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

Experiments – Equipment

Experiments	*Electrochemical testis. V/I curves. Duration test.*
Level of detail	-
Instrumentation	*temperature, pressure, flow*
Schedule	*hours / weeks*
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)*
- *Leak detection unit (LDU)*
- *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)*
- *Sensors and Safety Devices Laboratory*

Overview

Name	***The "Basket"***
Type	*large scale test area*
Scale	*large scale*
Experiments	*rupturing of confinements and investigation of fracturing and missiles*

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

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*

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*

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*

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 m³ 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

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 mirror)*

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*

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*

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 ?

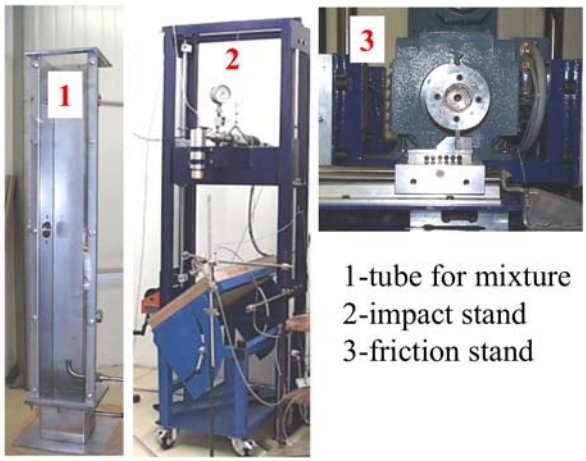
  This versatile equipment with the afore mentioned battery of equipments proved very useful for the investigation of flame dynamics especially in view of flame transmission from or towards a pipe. New injection techniques should be thought about to be able to master non homogeneous mixtures.

  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*



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	***Leak detection unit (LDU)***
Type	*10 to 40 litre volume*
Scale	*medium scale*
Experiments	*measure leak rates of components*

Technical details

Dimensions	*very tight vertical cylinder*
Temperatures	*ambient regulated ± 0.02 °C*
Pressure	*ambient inside but component may be pressurised up to 1000 bar*
Media	*flammable gases*
Special features	leak rates measurable from 10^{-4} cm^3/s to 1000 cm^3/s
Further particulars	may be adapted to other temperature conditions

Experiments – Equipment

Experiments	*Measurement of the leakage rate of pneumatic components whatever the leakage path and rate. Measurement is achieve via pressure detection inside the chamber*
Level of detail	10^{-4} cm^3/s to 1000 cm^3/s, ±1 Pa, ±0.02°C

Instrumentation

nature	***principle***	***range***	***error***
temperature	*regulated*	*293 K*	*±0.02 °C*
pressure	*Piezoresistive/capacitive device*	*0 to 100000 Pa*	*± 1 Pa*
data acquisition	*SEFRAM 100 kHz*		

Schedule	*1 technician 10 days for a few components, 1 engineer or data reduction*
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 ?

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote ?

  Additional testing with other components than vehicle

  Which additional equipment could enhance your results?

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.*

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,…)

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**

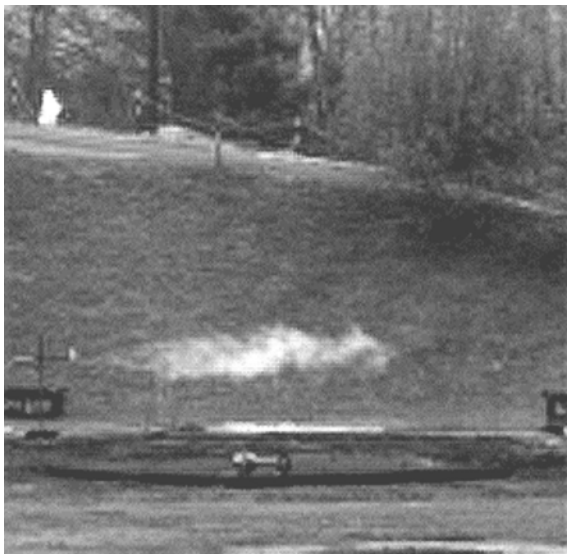
  What features/possibilities would you like to promote ?

  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*

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

Instrumentation

nature	***principle***	***range***	***error***
temperature	*thermocouple*	*-273 to 1700 K*	*±0.5 °C*
irradiance	*thermopiles*	*up to 50 000 kW/m^2*	*±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 flow rate.

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*

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, flow rate) 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)*

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.

Overview

Name	***Sensors and Safety Devices Laboratory***
Type	*Environmental testing for explosive/toxic gases*
Scale	*Laboratory scale*
Experiments	*Sensors performance testing*

Technical details

Dimensions	*Facility: Test chambers approx. 1 to 5 litres volume*
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. methane, propane, butane, CO, CO2, SO2, NO2, NH3, Cl2, HF...) and up to 2 other vapours (e.g. ethanol, isooctane, BTEX, chlorinated solvents...)*
Special features	*Reliable method by using certified gas mixtures, a specific system designed by the laboratory to generate vapours and calibrated electrical controlling / measuring devices. A sophisticated gas handling and environmental control system allows to simulate real conditions using context of the sensors (complex gas mixtures, humidity, temperatures, altitudes (pressure), air velocity, vibration) designed in view of testing sensors performance and providing assistance to manufacturers during the development of their sensors (flammable, toxic and oxygen).*
Further particulars	*Environmental testing is carried out in an appropriate test chamber with walls resistant against gases or/and vapours used. The test chamber is put in a climatic chamber for environmental testing.* *Test gas and/or vapours mixtures are generated dynamically by using analogic and digital mass flow controllers from appropriate gas standard cylinder and a specific vapour generation system. All generated mixtures can contain an inert carrier gas (synthetic air, nitrogen or dioxide carbon) and humidity.* *Tests can be automated. Gas flow rate, temperature and humidity are controlled by PC.* *The sensors and safety devices laboratory is able to design specific test facilities according to customer / manufacturer specifications.*

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* *- Response/recovery time* *- Ageing and reproducibility* *- Air velocity* *- Response time (in dynamics and static)* *- Electromagnetic compatibility*

Instrumentation

Instrument type	*Further details*
Digital and analogic mass flow controllers	0.5 cm^3/min to 5 l/min
Pressure controllers	800 to 1300 mbar
Thermostatic bathes	4.5 litres -25 to +200 °C 6 litres -15 to +100 °C 6 litres -30 to +150 °C
Chilled mirror hygrometer	Dew point: –40 to +85 °C Frost point: -25 to +180 °C
Capacitive probes (humidity measuring)	0 – 100 % RH
PT 100	-50 to +200 °C
Hot wire (air velocity measuring)	0 to 10 m/s, 0 to 15 m/s
Soap bubble flow meters	1 cm^3/min to 6 l/min
Electrodynamics vibration table	0 to 100 Hz – peak 0.9 mm
Recorders up to 16 channels	250 KHz with 16 channels
Data acquisition systems with 20 channels	100 kHz with 20 channels
Climatic chambers	540 l / -40 to +180°C / 5 to 95 %RH - 15 to 95°C 100 and 250 l / -25 to +125°C / 5 to 95 %RH - 15 to 95°C
Electromagnetic devices	All devices needed by NF-EN 61000-6
Syringe pump system	10^{-4} µl/hour to 220 ml/min
Air velocity loop	2 to 15 m/s

Schedule *The laboratory has assessed gas sensors performance over 20 years. The time needed for preparation of experiments will be about 1 to 4 day (depending on the demand), the time needed for conduction of experiments will depend on the test. The sensors output data are visualised in real time, and recorded on general laboratory software platforms and processed if needed.*

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 is integrated in a multi-purpose laboratory at INERIS, and is not suitable to be moved.

- **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:
  - Response time at different temperature.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

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

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

Partner: *JRC*

Facilities: *- Hydrogen solid-state storage laboratory (SolTeF)*
- Sensor Testing Facility (SenTeF)
- High-pressure hydrogen container testing facility (GasTeF)

Overview

Name	***Hydrogen solid-state storage laboratory (SolTeF)***
Type	*Laboratory for the assessment of hydrogen solid-state storage performance parameters*
Scale	*Laboratory scale*
Experiments	*The laboratory consists of various analytical instruments for the study of the hydrogen sorption and de-sorption behaviour. The instruments are based on volumetric or gravimetric principle. In the former case they consists of Sievert's type apparatus (3 instruments) while in the latter they are a modification of thermal-gravimetric apparatus (2 instruments). Many instruments are coupled to mass spectrometers permitting also spectroscopic studies. The laboratory performs assessment of potential hydrogen storage materials with respect to storage capacity, thermodynamic and kinetics quantities and cycling stability.*

Technical details

General aspects of laboratory equipment are given in the following, for details on individual instruments see HySafe document D35 "Compilation of descriptions of instrumentation".

Dimensions	*The individual instruments of the SolTeF have dimensions typically of 1 × 1 × 1 m.*
Temperatures	*Typical temperature ranges, depending on the instrument, are from room temperature to 773 K or from 77 K to 1273 K.*
Pressure	*The gravimetric instruments have range from high vacuum to 20 bar. The volumetric instruments can reach 100 and in one case 200 bars.*
Media	*Hydrogen, nitrogen and other inert gases*
Special features	*The systems are fully automated and can perform repeated sorption cycles, at a range of temperatures, without user intervention. The material samples can be loaded on and unloaded from the reaction chambers under protective atmosphere. Resolution of gravimetric measurements of is 1 µg, minimal sample mass for volumetric is approximately 1 mg.*
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%)*
2) *Pressure-Composition-Isotherms (PCI) behaviour*
3) *Enthalpy and Entropy of formation/reaction (van t'Hoff method)*
4) *Thermal Desorption Spectroscopy (TDS)*
5) *Sorption/desorption rates*
6) *Cycling Stability*
7) *Thermal-Gravimetric Analysis (TGA-MS)*
8) *HE-picnometry for the measurement of true densities*
9) *Specific surface analysis by BET method*

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* *Rotatory, membrane and turbo-molecular vacuum pumps* *Automation system* *Glove boxes for the preparation, weighting and loading of material samples under protective atmosphere.* *Integrated quadrupole mass spectrometer. Calibration of the molar flow using a reference gas.* *Ball mill for the size-reduction and mixing of material powders.*
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 Pressure-Composition isotherm for an intermetallic hydride will take less than 24 hours, while for a $NaAlH_4$ could require a week. 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?

  1 technician or scientist

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

  The laboratory is part of the JRC-IE infrastructure and cannot be moved. Access to external users is granted 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?

  The purchase of a high-pressure hydrogen calorimetry will allow the direct measurement of thermodynamic quantities.

  The finalisation of an in-house volumetric instrument with external reaction chamber will allow testing of solid-state storage micro-tanks under near-real-life conditions.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  JRC is highly interested in participating 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	***Sensor Testing Facility (SenTeF)***
Type	*Environmental sensor test bench*
Scale	*Laboratory scale*
Experiments	*Sensors performance testing*

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 + up to 2 other gases (e.g. CO_2, H_2S, SO_2 or NH_3) and up to 2 other vapours (e.g. Ethanol, Isooctane)*
Special features	*A sophisticated gas handling and environmental control system allows simulating real or atypical ambient conditions (complex gas/vapour mixtures, variable temperature, variable pressure, variable humidity). Accurate independent gas analysis by gas chromatography.*
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, alkanes) are released at concentrations down to ppm levels through gas and liquid mass flow controllers and evaporators. The gas composition can be stabilised in buffers or mixed online and can be determined with a 5-column (3 channel) gas chromatograph equipped with multiple detectors. Humidity is measured with a chilled mirror hygrometer.*

Experiments - Equipment

Experiments	*Assessment of hydrogen sensor performance with respect to:* *- Sensitivity to target gas* *- Influence of temperature, humidity and altitude (reduced pressure)* *- Cross sensitivity to other gases/vapours* *- sensors response time* *- reaction to sudden changes of environment (temperature, pressure, humidity)*
Instrumentation	*Mass flow controllers* *Pressure controllers* *Liquid mass flow controllers* *Controlled evaporator mixer* *Gas Chromatograph equipped with 2 TCD and 1 FID detectors for independent gas analysis (H_2, CO, NH_3, SO_2, CH_4, i-octane, CH_3OH, C_2H_5OH, i-propanol)*

	Circulating bath for chamber temperature control *PT100s chamber temperature measurement* *Chilled Mirror Hygrometer for humidity measurement* *Pressure transducers for pressure measurement*
Schedule	*The facility is in operation since 2005.* *The time needed for preparation of experiments is about 1 day.* *The time needed for conduction of experiments depends on the type pf tests to be performed* *The sensors output data is collected and visualised in real time, and recorded on general laboratory software platforms (Labview®, Excel®).*
Tools	*General laboratory software*

Information for the preparation of integration

- **Exchange of instruments and personnel**

  How many persons are needed to prepare/conduct experiments?

  2 persons are needed

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

  The facility is integrated in a multi-purpose laboratory at JRC Petten, and is not scheduled to be moved after installation. Access to external users is 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 applying additional instrumentation?

  The system has been designed with the possibility of two major upgrades (depending on demand):

  1. Installation of a <u>multiple test chamber with actuated sample holders</u>, to enable the system to carry out the following tests:

  - *resistance to thermal shocks/cycling*
  - *accelerated lifetime testing*

  2. Installation of a <u>vibrating table</u>, 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 co-operating with manufacturers, end-users and standardisation bodies to help develop a unified procedure for testing hydrogen sensor performance in a controlled environment. JRC is also interested in collaborating with other testing/certification laboratories for inter-laboratory comparisons and round robin testing purposes.

Overview

Name	***High-pressure hydrogen tank testing facility (GasTeF)*** *Under commissioning beginning 2008*
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*

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 CH_4) and 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 and its operation automatised. 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. E.g. 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?

  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 is located in a safety bunker at JRC Petten, and cannot be moved. 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 2009 order to increase the maximum static pressure from ca. 350 to ca. 800 bar.
  Tests involving hydrogen / natural gas mixtures will be possible after some modifications.

- **To prepare promotion and specialisation**

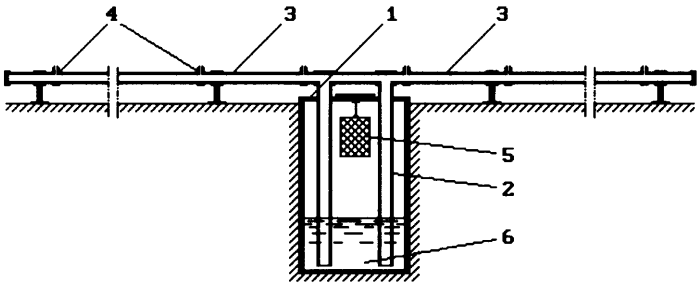
  What features/possibilities would you like to promote?

  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: *KI*

Facilities:
- *Spray*
- *Sphere*
- *Koper*
- *Vortex*
- *Minirut*
- *Channel*
- *Chamber*
- *Driver*
- *Torpedo*
- *Venting*
- *RUT 2200*
- *Globus*
- *High Pressure Jet Facility*

Overview



Name	***Spray***
Type	*Sprayer for liquid fuels*
Scale	*full or large scale*
Experiments	*Studies on critical energy initiation of detonation in motor fuel - air clouds, heterogeneous detonations, shock wave interaction*

Technical details

Dimensions	*length 15-20 m, semi-cylindrical fuel-air cloud up to 2000 m³.*
Temperatures	*ambient*
Pressure	*ambient*
Media	*liquid fuels with air*
Special features	-
Further particulars	*droplet size 50 mkm - 1 mm*

Experiments-Equipment

Experiments	*- experiments on critical energy of detonation initiation in motor fuel - air clouds* *- investigations of heterogeneous detonation mechanisms* *- experiments on shock wave interaction with burning clouds*
Level of detail	*integral*
Instrumentation	*temperature* *pressure* *velocity* *concentration* *integral heat*
Schedule	*preparatory work of experimental set-up to specific test series requires two weeks; 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?

  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 heat transfer.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Large scale experiments on turbulent combustion and detonation of liquid fuel spray, experiment on ignition and flame propagation limits .

  Which additional equipment could enhance your results?

  High-speed photography technique

Overview

Name	***Sphere***
Type	*Semi-sphere for gaseous fuel air mixtures*
Scale	*full or large scale*
Experiments	*Studies on blast wave and thermal radiation parameters of gaseous detonation*

Technical details

Dimensions	*diameter 8m, semi- sphere for gaseous fuel air mixtures V=134 m3*
Temperatures	*ambient*
Pressure	*ambient*
Media	*gas fuels incl. hydrogen with air*
Special features	*large scale semi-sphere*
Further particulars	

Experiments-Equipment

Experiments	*studies on blast wave and thermal radiation parameters of gaseous detonation*
Level of detail	*integral*
Instrumentation	*gas temperature* *pressure* *gas composition* *thermal radiation fluxes* *velocity*
Schedule	*preparatory work of experimental set-up to specific test series requires one month; one 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?

  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?

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

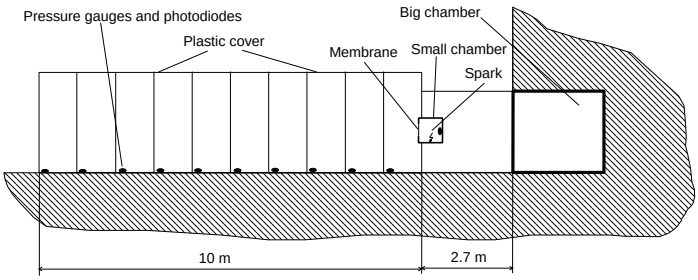
  Large or full scale experiments on turbulent combustion and detonation in open volume, thermal radiation effects.

  Which additional equipment could enhance your results?

  High-speed photography technique

Overview

Name	***Koper***
Type	*vented explosion chamber with semi-cylindrical volume*
Scale	*full or large scale*



Experiments	*studies on turbulent combustion and detonations, vented explosions*

Technical details

Dimensions	*small chamber 0.5m^3, big chamber 17m^3, semi-cylindrical volume length 10m, diameter 7.4m, volume 134 m^3*
Temperatures	*ambient*
Pressure	*ambient*
Media	*gas fuels incl. hydrogen with air*
Special features	*system of volumes*
Further particulars	*large scale vented explosion chamber*

Experiments-Equipment

Experiments	*investigation of fuel-air detonation initiation mechanisms by turbulent jet of combustion products, combustion and detonation processes in a system of open and closed volumes.*
Level of detail	*integral*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity* *heat flux*
Schedule	*preparatory work of experimental set-up to specific test series requires 1-2 months; 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?

  5-6 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 in closed and open volume

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

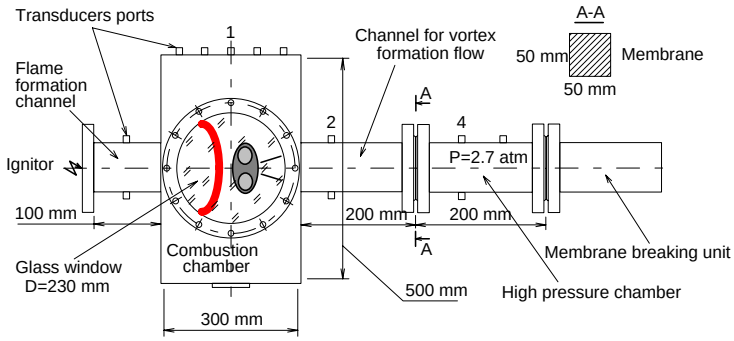
  Large scale combustion and detonation processes in a system of open and closed volumes

  Which additional equipment could enhance your results?

  High-speed photography technique

Overview

Name	***Vortex***
Type	*explosion chamber*
Scale	*medium scale*
Experiments	*studies on flame - vortex interaction, turbulent flame, ignition - extinction phenomena*



Technical details

Dimensions	*length 80cm, height 50cm, diameter 5cm*
Temperatures	*ambient*
Pressure	*0-1 bar*
Media	*combustible gas mixtures*
Special features	*optical window for high speed shadow photography*
Further particulars	

Experiments-Equipment

Experiments	*- experiments on flame - vortex interaction,* *- investigations of turbulent flame structure,* *- peculiarities of ignition-extinction phenomena*
Level of detail	*microscopic to integral*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity* *high-speed shadow photography*
Schedule	*preparatory work of experimental set-up to specific test series requires 1-2 weeks; 1 – 2 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?

  1-2 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?

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

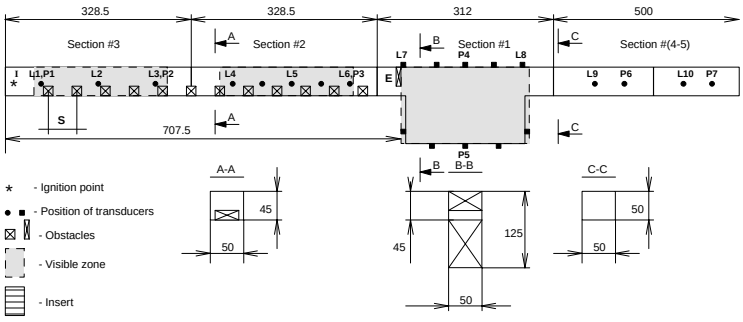
  medium scale experiments on flame - vortex interaction, turbulent flame, ignition - extinction phenomena

  Which additional equipment could enhance your results?

  High-speed photography technique

Overview

Name	***Minirut***
Type	*system of channels*
Scale	*small scale*
Experiments	*studies on turbulent combustions detonations and scaling effect*



Technical details

Dimensions	*length 1450mm, height 45mm, width 50mm*
Temperatures	*ambient*
Pressure	*0-1 bar*
Media	*combustible gas mixtures*
Special features	*optical window for high speed shadow photography*
Further particulars	*RUT facility geometry 1:50 of real size (50x45x1470 mm) with obstacles (BR=0.3-0.6)*

Experiments-Equipment

Experiments	- *experiments on flame acceleration* - *investigations of DDT conditions* - *scaling effect*
Level of detail	*microscopic*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity* *high-speed shadow photography*
Schedule	*preparatory work of experimental set-up to specific test series requires 1-2 weeks; 1 – 2 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?

  1-2 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

- **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**

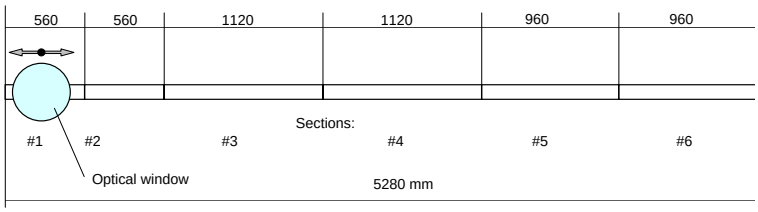
  What features/possibilities would you like to promote?

  Scale effect experiments

  Which additional equipment could enhance your results?

  Digital high-speed photography technique

Overview



Name	***Channel***
Type	*Rectangular channel*
Scale	*medium scale*
Experiments	*studies on turbulent combustions detonations and scaling effect*

Technical details

Dimensions	*length 5280mm, height 80mm, width 80mm*
Temperatures	*ambient*
Pressure	*0-1 bar*
Media	*combustible gas mixtures*
Special features	*optical window for high speed shadow photography*
Further particulars	*channel could be filled with regular obstacles grid spaced by tube diameter, blockage ratio BR = 0.1, 0.3, 0.6, 0.9; tube is equipped with gas filling system and data acquisition system, spark/glow plug for ignition*

Experiments-Equipment

Experiments	- *experiments on flame acceleration* - *investigations of turbulent flow peculiarities* - *laminar and turbulent flames behaviour* - *investigations of DDT condition* - *scaling effect*
Level of detail	*microscopic*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity* *high-speed shadow photography*
Schedule	*preparatory work of experimental set-up to specific test series requires one month; 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?

  1-2 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

- **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?

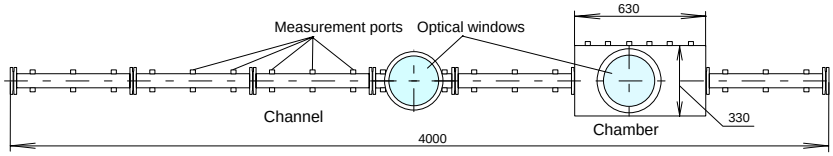
  medium scale experiments on turbulent combustions detonations and scaling effect

  Which additional equipment could enhance your results?

  Digital high-speed photography technique

Overview

Name	***Chamber***
Type	*Rectangular channel (50x50x3400 mm BR=0.3, 0.6) joined with cylindrical chamber*
Scale	*medium scale*
Experiments	*studies on turbulent combustions and flame vortex - shock interaction*



Technical details

Dimensions	*length 3400mm, height 50mm, width 50mm*
Temperatures	*ambient*
Pressure	*0-1 bar*
Media	*combustible gas mixtures*
Special features	*optical windows for high speed shadow photography*
Further particulars	*channel could be filled with regular obstacles grid spaced by tube diameter, blockage ratio BR = 0.3, 0.6; tube is equipped with gas filling system and data acquisition system, spark/glow plug for ignition*

Experiments-Equipment

Experiments	- *experiments on flame acceleration* - *flame vortex-shock wave interaction* - *laminar and turbulent flames behaviour* - *jet initiation of detonation*
Level of detail	*microscopic*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity* *high-speed shadow photography*
Schedule	*preparatory work of experimental set-up to specific test series requires 1-2 weeks; 1 – 2 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?

  1-2 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

- **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?

  medium scale experiments on turbulent combustions and flame vortex - shock interaction

  Which additional equipment could enhance your results?

  Digital high-speed photography technique

Overview

Name	***Driver***
Type	*cylindrical tube*
Scale	*large scale*
Experiments	*studies on turbulent combustions and detonations, scaling and venting effects*

Technical details

Dimensions	*internal diameter 174 mm, length 12 m*
Temperatures	*ambient*
Pressure	*0-3 bar*
Media	*combustible gas mixtures*
Special features	*fast opened membrane units (t=1 ms) to use two or three different mixtures*
Further particulars	*tube could be filled with regular ring shape obstacles grid spaced by tube diameter, blockage ratio BR = 0.1, 0.3, 0.6, 0.9; tube is equipped with gas filling system and data acquisition system, spark/glow plug for ignition*

Experiments-Equipment

Experiments	- *experiments on flame acceleration criteria* - *flame propagation and detonation transition through concentration gradient* - *DDT condition criteria* - *investigations of venting effect* - *investigations of scaling effect*
Level of detail	*microscopic to integral*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity*
Schedule	*preparatory work of experimental set-up to specific test series requires 3-4 weeks; 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?

  large scale experiments on turbulent combustions and detonations, scaling and venting effects

  Which additional equipment could enhance your results?

Overview

Name	***Torpedo***
Type	*cylindrical tube*
Scale	*large scale*
Experiments	*studies on turbulent combustions and detonations, scaling and venting effects*

Technical details

Dimensions	*internal diameter 520 mm, length 34.5-50 m*
Temperatures	*ambient*
Pressure	*0-3 bar*
Media	*combustible gas mixture*
Special features	*connection unit with DRIVER facility.*
Further particulars	*tube could be filled with regular ring shape obstacles grid spaced by tube diameter, blockage ratio BR =0.1, 0.3, 0.6; tube is equipped with gas filling system and data acquisition system, spark/glow plug for ignition*

Experiments-Equipment

Experiments	- *experiments on flame acceleration criteria* - *flame propagation and detonation transition through concentration gradient* - *DDT condition criteria* - *investigations of venting effect* - *investigations of scaling effect*
Level of detail	*microscopic to integral*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity*

Schedule	*preparatory work of experimental set-up to specific test series requires one month;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?

  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 chemical kinetic and heat transfer.

- **To prepare promotion and specialisation**

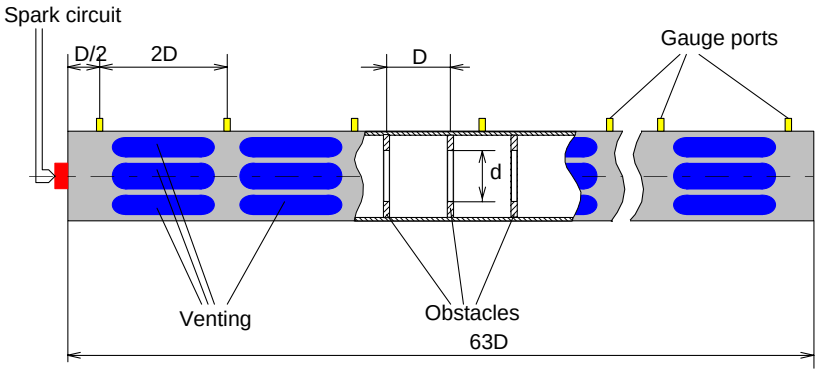
  What features/possibilities would you like to promote?

  large scale experiments on turbulent combustions and detonations, scaling and venting effects

  Which additional equipment could enhance your results?

Overview

Name	***Venting***
Type	*system of cylindrical tubes*
Scale	*medium scale*
Experiments	*studies on turbulent combustions and detonations, scaling and venting effects*



Technical details

Dimensions	*internal diameter46 mm and 92 mm, length 5796 mm*
Temperatures	*ambient*
Pressure	*ambient*
Media	*combustible gas mixtures*
Special features	*tube could be filled with regular ring shape obstacles grid spaced by tube diameter, blockage ratio BR =0.1, 0.3, 0.6; tube is equipped with gas filling system and data acquisition system, spark/glow plug for ignition*
Further particulars	*tube could be filled with regular ring shape obstacles grid spaced by tube diameter, blockage ratio BR = 0.3, 0.6; lateral vents (venting ratio 20 and 40%)*

Experiments-Equipment

Experiments	- *experiments on flame acceleration criteria under vented conditions* - *DDT condition criteria* - *investigations of venting effect* - *investigations of scaling effect*
Level of detail	*microscopic to integral*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity*

Schedule	*preparatory work of experimental set-up to specific test series requires 1-2 weeks; 1 – 2 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?

  1-2 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

- **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**

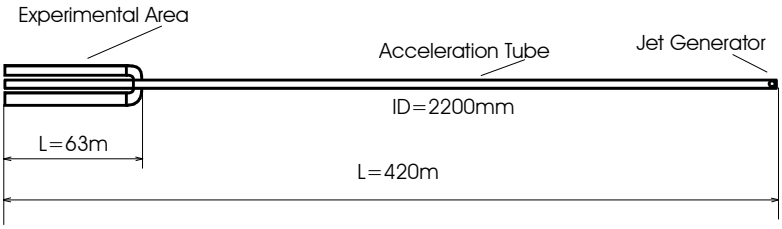
  What features/possibilities would you like to promote?

  medium scale experiments on turbulent combustions and detonations, scaling and venting effects

  Which additional equipment could enhance your results?

  High-speed photography technique

Overview



Name	***RUT 2200***
Type	*system of channels and chambers*
Scale	*large scale*
Experiments	*studies on turbulent combustion and detonation*

Technical details

Dimensions	*cross – section up to 9 m^2, length 420 m*
Temperatures	*up to 100°C*
Pressure	*ambient*
Media	*hydrogen/air, hydrogen/air/steam*
Special features	*experiments under normal and elevated (up to 100 oC) initial conditions*
Further particulars	*tube could be filled with regular ring shape obstacles grid spaced by tube diameter, blockage ratio BR = 0.3, 0.6; lateral vents (venting ratio 20 and 40%)*

Experiments-Equipment

Experiments	- *flame acceleration propagation* - *DDT, and detonations in complex geometry at large scale* - *investigations of effect of uniform and non-uniform mixtures* - *investigations of hydrogen injection, distribution, and deliberate ignition* - *simulation of accidental conditions to test the operation of different equipment under pressure and thermal loading*
Level of detail	*microscopic to integral*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity* *thermal fluxes*

Schedule	*preparatory work of experimental set-up to specific test series requires 2-3 months; 3 – 4 days are needed for preparation and conduction of one experiment in the series; 2-3 days are 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?

  5-6 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 (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?

- **To prepare promotion and specialisation**

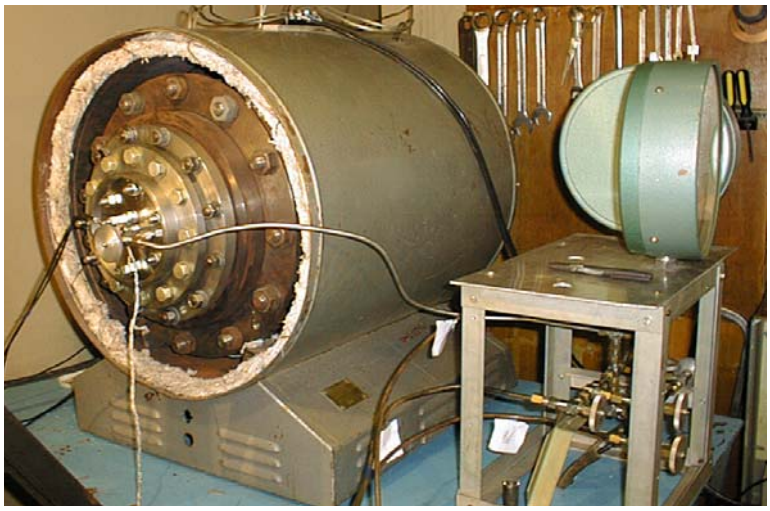
  What features/possibilities would you like to promote?

  large scale experiments on turbulent combustion and detonation

  Which additional equipment could enhance your results?

Overview

Name	***Globus***
Type	*spherical bomb*
Scale	*medium scale*
Experiments	*studies on laminar combustion and turbulent deflagration*



Technical details

Dimensions	*diameter 280 mm, volume 11.5 liter*
Temperatures	*up to 250°C*
Pressure	*up to 25 bar*
Media	*combustible gas mixtures*
Special features	*experiments under normal and elevated (up to 250°C, 25 bar) initial conditions*
Further particulars	*optical window*

Experiments-Equipment

Experiments	- *laminar flame propagation* - *laminar flame velocities measurements*
Level of detail	*microscopic*
Instrumentation	*gas temperature* *pressure*
Schedule	*preparatory work of experimental set-up to specific test series requires one week; 1 hour is needed for preparation and conduction of one experiment in the series; 2-3 hours are 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?

  1 person is needed to prepare/conduct experiments

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

  Data acquisition system

- **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**

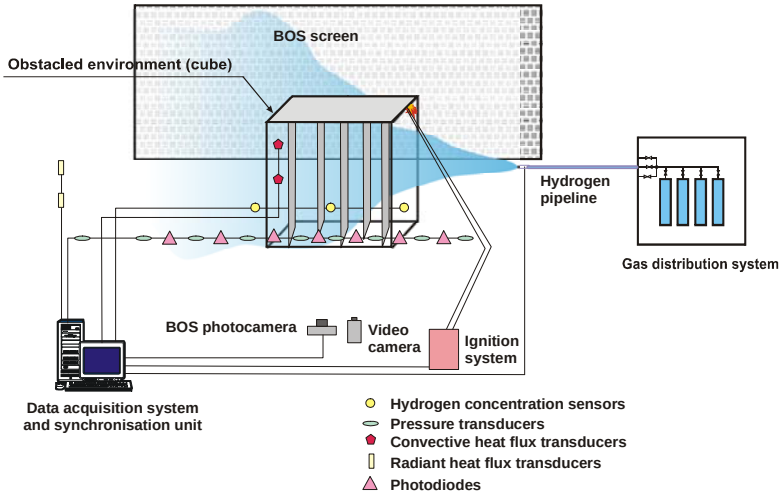
  What features/possibilities would you like to promote?

  Small scale experiments on laminar combustion and turbulent deflagration

  Which additional equipment could enhance your results?

Overview

Name	***High Pressure Jet Facility (HPJF)***
Type	*open hydrogen gas fire*
Scale	*full or large scale*
Experiments	*combustion of high pressure hydrogen jet in specific environment*



Technical details

Dimensions	*cube 8 m^3, hydrogen pipeline length 30m*
Temperatures	*ambient*
Pressure	*ambient*
Media	*hydrogen*
Special features	*pressure in hydrogen pipeline – up to 150 bar* *hydrogen release – up to 1 kg*
Further particulars	*cube volume can be filled with obstacles*

Experiments-Equipment

Experiments	*- investigation of high pressure hydrogen jet combustion in open and obstacled environments*
Level of detail	*integral*
Instrumentation	*gas temperature* *pressure* *gas composition* *velocity* *integral heat* *BOS photography*
Schedule	*preparatory work of experimental set-up to specific test series requires 1-2 weeks; 1–2 hours are needed for preparation and*

	conduction of one experiment in the series; 3–4 hours 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?

  5-6 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 combustion in open or obstacled volume at hydrogen release pressures up to 300 bar

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  Scale effect experiments

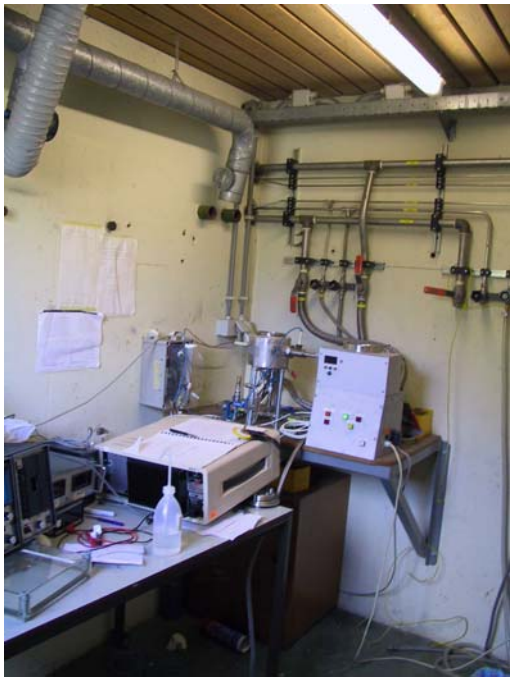
  Which additional equipment could enhance your results?

  High-speed photography technique

Partner: *TNO*

Facilities:
- *1 litre vessel*
- *20 litre vessel*
- *500 litre vessel*
- *1 m³ vessels*
- *5 m³ vessel*
- *Gas explosion chamber*
- *IBBC Bunker*
- *FAST*
- *GFEF*
- *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*

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*
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*

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*
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*

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*
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***
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)*

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.

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)***
Type	*vessel (closed bomb)*
Scale	*medium scale*
Experiments	*test of equipment and protective systems intended for use in potentially explosive atmospheres*

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.*
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?

  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*

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.*
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	*vented gas explosions*

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.*
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*

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.*
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

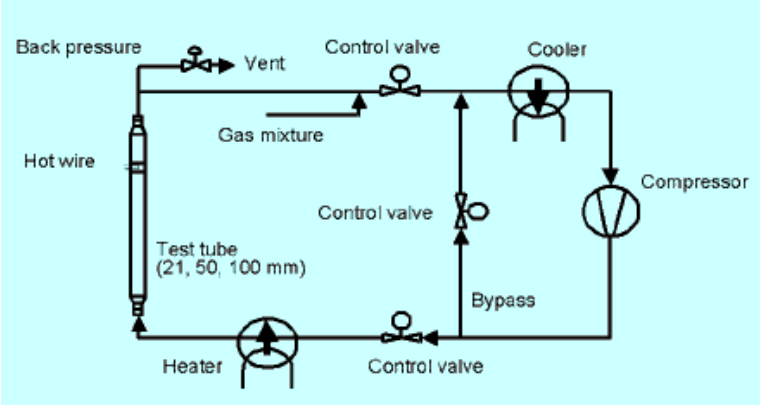
- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

  -

  Which additional equipment could enhance the results of your experiments?

  -



Overview

Name	***GFEF (Gas Flow Explosion Facility)***
Type	*flow reactor*
Scale	*small scale*
Experiments	*integrated studies on explosion control and process optimisation*

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 gases 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.)*
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	***Large scale Blast simulator***
Type	*long tube*
Scale	*medium scale*
Experiments	*blast wave response in atmosphere*

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
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™ , 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 calibre firing range, kinetic energy projectiles can be fired at targets.*

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.*
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*

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.*	
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**

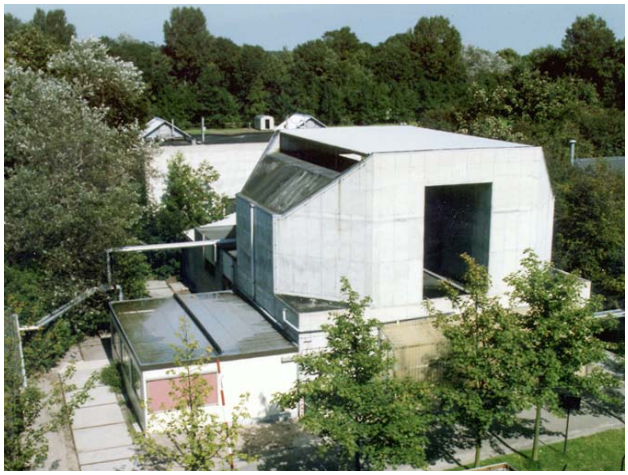
  What features/possibilities would you like to promote?

  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 mass flow 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.*

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.*	
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*
- HPBT

Overview

Name	***CVE***
Type	*Vented room*
Scale	*large scale*
Experiments	*studies on vented explosions*

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)*

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.

Overview

Name	***HPBT***
Type	*Pipeline*
Scale	*large scale*
Experiments	*Study of hydrogen release and jet-fire from pipelines and calibrated holes.*

Technical details

Dimensions	*60 m pipeline* *12 m³ storage tanks*
Temperatures	*ambient*
Pressure	*maximum pressure allowed 10 bar*
Media	*pure hydrogen*
Special features	-
Further particulars	*It is possible to modify the following parameters:* *(1) internal pressure (max 10 bar)* *(2) diameter of release hole (max 1.5 inches)* *(3) angle of release*

Experiments - Equipment

Experiments *hydrogen release into free air and jet-fires.*

Instrumentation

INSTRUMENT TYPE	N. OF ITEMS	MEASURING PRINCIPLE	RANGE	OUTPUT	MAXIMUM ERROR
Thermocouple type K	10	Seebeck effect	0 - 800 °C	4-20 mA	0.1 % of the range
O2 Concentration analyser	15	Catalytic sensor	0-30 %vol.	4-20 mA	1.5 % of the range
H2 Concentration analyser	3	Catalytic sensor	0-100 %vol.	4-20 mA	1.5 % of the range
Pressure transducer	6	Piezoelectric	0-10 bar	4-20 mA	0.3 % of the range

Schedule	*the time needed for preparation of experiments is about 1 day;*
	the time needed for conduction of experiments is about 60 minutes (hydrogen immission 40 minutes; set of instrumentation 10 minutes; release [and eventual jet fire] 10 minutes);
	the time needed for interpretation of experiments is about 1 hour
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, 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, we could carry out also methane-air blends.

- **To prepare promotion and specialisation**

  What features/possibilities would you like to promote?

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

  Which additional equipment could enhance the results of your experiments?

  With specific measurement devices we could study better the jet-fire behaviour.

Partner: *WUT*

Facilities:
- *WUT Detonation Channel*
- *WUT Detonation Tube*
- *WUT 1.25 m³ Explosion Bomb*

Overview

Name	***WUT Detonation Channel***
Type	*square cross-section channel*
Scale	*lab scale*
Experiments	*studies on hydrogen fast deflagrations, detonations, DDT, explosion initiation, mitigation of detonations*

Technical details

Dimensions	*Detonation channel 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.*

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

Overview

Name	***WUT Detonation Tube***
Type	*circular cross-section tube*
Scale	*lab scale*
Experiments	*studies on hydrogen fast deflagrations, detonations, DDT, explosion initiation, mitigation of detonations*

Technical details

Dimensions	*Detonation tube consists of a 1 m long booster and 6 m long circular cross-section (2 sections 2 m long and 2 sections 1 m long connected by flanges) tube with internal diameter of 140 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 tube 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 tube.*

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*	

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

Overview

Name	***WUT 1.25 m^3 Explosion Bomb***
Type	*near spherical chamber*
Scale	*lab scale*
Experiments	*studies on hydrogen ignition, flame propagation and quenching*

Technical details

Dimensions	
Temperatures	*room initial temperature*
Pressure	*up to 0.1 MPa initial pressure*
Media	*hydrogen, air, nitrogen, oxygen, argon, helium, carbon dioxide*
Special features	-

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

Annex II – Compilation of descriptions of devices and instrumentation

Overview

Name	***Particle Image Velocimetry (PIV)***
Type	*Laser based optical diagnostic tool used to study fluids flows*
Application	*Characterization of unsteady and turbulent flow-field by measuring velocity or turbulence*

Technical details

Description

Non-intrusive whole-field-flow technique providing real-time velocity maps in a cross-section of a flow. Measurement system includes: CCD camera, laser and micro size particles generator.

Velocity range: 0 to supersonic

- CCD Camera

Camera 1: HiSense MkII
active pixels: 1024x 1344
pixel pitch: 6.45 x 6.45 µm
camera bit resolution: 12-bit
frame rate: 5.6 Hz double frame

HiSense Mk II camera

Camera 2: Flow grabber double image 700 camera

active pixels: 768x 480
pixel pitch: 13.6 x 11.6 µm
camera bit resolution: 12-bit
frame rate: 15 Hz double frame

FlowGrabber double image 700

- Laser: continuum powerlite Nd:YAG pulsed laser
wavelength: 532 nm
average power: 25MW
energy of one pulse: 200mJ
duration of one pulse: 8ns

Powerlite Nd:YAG laser

- Particle generator

fluid: Safex standard
mean particle diameter : 1µm
size : 340 (L) x 170(D) x145(H) (mm)
fog generation: 325m^3/min
(corresponding to a range of sight of 0.5 m in a room of 5 x 8 x2.5 m)
timer: fog generation period can be pre-set from 3 to 90 seconds with pauses of 15 seconds to 10 minutes

Particle generator

- Traverse system

computer controlled 3-D traversing
range(XxYxZ): 610 x610x610 (mm)
speed: 25 mm/sec
resolution: 6.25µm
lift capacity: 60 kg
dimensions in mm(WxLxH): 1150 x1150x1330

Traverse system

Dimensions / weight / mobility	
Temperature range	*Ambient temperature*
Pressure range	*Atmospheric pressure*
Media	*Gas or liquid flows*
In-house/commercial	*Commercial (Dantec Inc.)*
References	

Overview

Name	***Laser Doppler Anemometry (LDA)***
Type	*Laser based optical measurement technique*
Application	*1D and 2D point measurement of velocity and turbulence distribution in both free flows and internal flows*

Technical details

Description

Non-intrusive, high temporal and spatial resolution, no need for calibration and the ability to measure in reversing flows. Measurement system relies on a use of a laser and micro size particles generator.

Velocity range: zero to supersonic

- laser: Argon (Coherent Innova 300)

average power: 8W
wavelength: 514.5 nm for vertical beam (green) and 488nm for horizontal beam (blue)

- Optical system:
probe diameter: 60mm
focal length: 1200mm (500 – 800nm)
beam separation at sending lens:75 mm
gaussian beam diameter at sending lens: 1.35 mm
number of fringes: 36
measurement volume: dx= 9.12mm and dy=0.29mm

Dimensions / weight / mobility	
Temperature range	*Ambient temperature*
Pressure range	*Atmospheric pressure*
Media	*Gas or liquid flows*
In-house/commercial	*Commercial (Dantec Inc.)*
References	

Overview

Name	***Laser Induced Fluorescence (LIF)***
Type	*laser based non-intrusive whole-field concentration imaging system*
Application	*To acquire instant global concentration field information of flow*

Technical details

Description	*Species specific method in which flow is marked with a fluorescent dye and laser beam is tuned to the absorption line of the species and subsequently images are recorded with a CCD camera with high spatial and temporal resolution.* *- fluorescent dye: aceton* *- Camera: HiSense Mk II (cf: PIV)* *- Laser: Continuum powerlite (cf PIV) with wavelength: 266 nm* *- Filter: 450 nm (short pass camera filter for aceton dye)*
Dimensions / weight / mobility	
Temperature range	*Ambient temperature*
Pressure range	*Atmospheric pressure*
Media	*Gas or liquid flows*
In-house/commercial	*Commercial (Dantec Inc.)*
References	

Overview

Name	***Hot wire anemometer***
Type	*Multi-channel constant temperature anemometer(CTA)*
Application	*Point measurement of velocity and turbulence distribution in gas flows*

Technical details

Description

The CTA measures velocity at a point and provides continuous velocity time series, which can be processed into amplitude and time-domain statistics. Examples are mean velocity, turbulence intensity, higher order moments, auto-correlations and power spectra.

- MiniCTA: model 54N80

number of CTA channels: 8
max. output voltage 5 volts
frequency response: 10 kHz

Multichannel CTA system

-Cable-equipped probe: 55P16

sensor material: Pt-plated tungsten

cable length: 1 m
max. ambient temperature: 120°C
sensor resistance: approx. 3.5 ohm (at 20°C)
sensor dimensions: diameter = 5µm, length = 1.2 mm

Cable-equipped probe (55P16)

Dimensions / weight / mobility	*LxWxH: 28x30x6(cm) / 1.25 kg / yes*
Temperature range	
Pressure range	
Media	*Gas flows*
In-house/commercial	*Commercial (Dantec Inc.)*
References	

Overview

Name	***Binary Gas Analyser (model 542)***
Type	*Programmable thermal conductivity method for detecting the concentration of one gas in another*
Application	*All kind of measurements where concentration of one gas in another has to be acquired (ex. hydrogen or helium in air)*

Technical details

Description	*The analyser measures the sample content of a sample/reference mixture by comparing the thermal conductivity of the mixture with that of a reference* *resolution: 0.5% or better* *accuracy: ±2% or range* *response time : 90% in 20 secs* *sample temperature: 0 – 40°C*
Dimensions / weight / mobility	*534 W x 164 H x 300 D mm / 12 kg / yes*
Temperature range	*-15 to +50°C (ambient temperature)*
Pressure range	*1 bar G (min) – 3 bar G (max) sample or reference inlet pressures*
Media	*Gas*
In-house/commercial	*Commercial (Systech Instruments)*
References	

Overview

Name	***Thermal Conductivity Gauge (model: TCG 3880Pt)***
Type	*Thin-film-thermopile conductivity sensor based on silicon technology*
Application	*Gas type measurement (measurement of thermal conductivity, binary gas-mixture composition measurement and measurement of one gas concentration in other gas etc.) and vacuum measurements.*

Technical details

Description

Measurement principle relies on the decrease in effective thermal resistance between the sensitive area of the sensor and the ambient, caused by the thermal conductance of the surrounding gas.

time constant: 9ms(in air), 36ms(in vacuum)
stability: 100ppm(short term), 1000ppm (long term)
thermopile resistance: 55 kΩ
thermal temperature coefficient: 0.05 %/K
sensor ambient temperature: -196°C(min), 240°C(max)
heater maximum temperature: 250°C

Before cabling

After cabling

Dimensions / weight / mobility *diameter 9.13 mm*

Temperature range

Pressure range

Media *Gas*

In-house/commercial *Commercial (Xensor Integration$_{bv}$)*

References

Overview

Name	***Quadrupole Mass Spectrometry (QMS)***
Type	*quadrupole partial pressure analyser*
Application	*gas analysis*

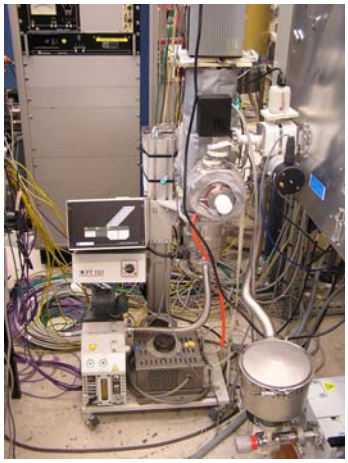
Gas sampling system

Technical details

Description

The QMS gas analysis system measures the partial pressures of gases in a mixture. A gas sampling system is attached to acquire the gas samples.

sensor model: H100M
sensor length (vacuum side): 26.4 cm
detector type: electron multiplier (EM) /Faraday cap (FC)
mass range: 1 – 100 amu
sensitivity (amps/ torr): 10^{-4}(FC) and 100 (EM)
max. sensor operating temperature: 250°C (FC), 100°C (EM)
max. operating pressure: 10^{-4}torr (EM)



QMS set-up

Dimensions / weight / mobility	-
Temperature range	*20°C – 50°C (ambient operating temperature)*
Pressure range	
Media	*Gas*
In-house/commercial	*Commercial (INFICON Inc)*
References	

Overview

Name	***Mass Flow Controllers***
Type	*Thermal mass flow sensor for gas flow control and measurements*
Application	*All kind of measurements where it is required to provide controlled flow rates of gases*

Technical details

Description

The heart of these system is the thermal mass flow sensor, which produces an electrical output signal as a function of flow rate.

rangeability: 50:1
stability: less than ±0.5% of rate per year

Injection device 1:

model : 5850S
response time: 1sec
full scale : 18NL/Min
operating scale:
0.36NL/Min±10.7%≤Q_v≥18NL/Min±0.9%

Injection device 2:

model : 5853S
response time 3 sec
full scale : 700NL/Min
operating scale:
14NL/Min±10.7%≤Q_v≥700NL/Min±0.9%

Dimensions / weight / mobility -

Temperature range *0-70°C (both ambient and process gas)*

Pressure range

Media *Gas*

In-house/commercial *Commercial (Brooks Instrument)*

References

Fraunhofer Institut Chemische Technologie

Overview

Name	***Field-emission Scanning Electron Microscope***
Type	*Supra 55 VP*
Application	*Characterisation of materials*

Technical details

Description	***Versatile High Performance VP SEM*** *Combining several instruments in one, the SUPRA™ 55VP with the improved GEMINI® column is a true nanoscience FESEM. It provides ultra high resolution imaging over the complete voltage range with the ability to handle large awkwardly shaped specimens. It is also a fully analytical FESEM with up to 20nA probe current available and comprises variable pressure technology for examining non-conducting specimens without prior time consuming preparation.*
Instrumentation	*Detector:* *- High efficiency In-Lens Detector* *- Everhard Thornley Secondary Electron Detector* *- VPSE Detector* *- BSD* *Analytic:* *EDX, EDAX Microanalysis System Type Genesis 4000*
Dimensions / weight / mobility	*Testing chamber: ∅ x H = 330mm x 270mm* *no*
Temperature range	*-30…+50°C (peltier controlled)*
Pressure range	*vacuum, 2…133Pa*
Media	*solids*
In-house/commercial	*commercial, operated with commercial ZEISS software*
References	*-*
..Schedule	*1…2 hours for preparation and study of one sample*

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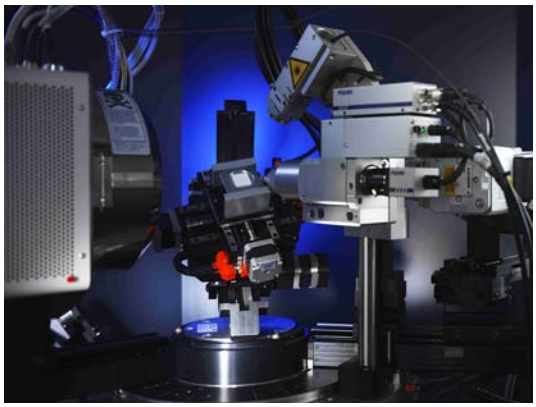
Overview

Name	***X-Ray Diffractometer***
Type	*D8 series 2*
Scale	
Experiments	*phase/structure measurements*



Technical details

Dimensions	*heating chamber for powder samples and plates with the dimension of 10x10x1mm*
Temperatures	*heating chamber with a temperature range from -190°C to 1600°C*
Pressure	*ambient*
Media	*air, He, O2, N2, Ar*
Special	*area detector with eulerian cradle*

Experiments - Equipment

Experiments	*in-situ measurements at different temperatures and different gas conditions*
	Structure and phase analysis
	Stress measurements
	Texture measurements
Level of detail	*e.g. ...*
Instrumentation	*theta/theta-diffractometer*
	HiSTAR area detector (Gadds)
	Vantec (psd-detecor)
	Szintillationcounter
	Eulerian cradle
	Different heating chambers
Schedule	*time needed for preparation: 1-2h*
	Isothermal measurements: typically 100h
	Measurements at room temperature: few hours
Tools	*TOPAS-software for structure refinement*
	EVA-software for phase analysis

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Overview

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

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 sec.

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

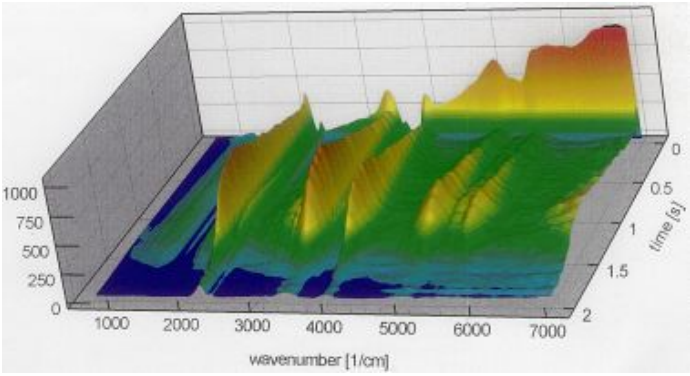
AOTF spectrometer
spectral range 1.25…2.6µm without restrictions flexible selectable with 2…1000 points
resolution <2.5nm
speed 1500 spectra per second @ 128 points resolution

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

Dimensions / weight	*between handheld and PC case / < 30 kg*
/ mobility	*yes*
Temperature range	*adaptable*
Pressure range	*adaptable*
Media	*adaptable*
In-house/commercial	*both*
References	-



typical time resolved filterwheel spectra

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Overview

Name	***IR High Speed Camera with synchronized Filterwheel***
Type	*modified CEDIP Orion / Silver System*
Application	*time resolved characterisation of solid and liquid burners, explosions, gas ignition, burning and extinguishing behaviour*

Technical details

Description	*IR High Speed Imaging system, based on CEDIP Silver Technology. Implemented in the housing of the Orion camera additional space allows to apply the ICT filter wheel module with fix interference filters. This modification provides full "Silver" camera functionality added by a fast filter wheel option.*
Dimensions / weight / mobility	*5 kg* *Yes*
Temperature range	*Filterwheel module with four interference filters (fix) to acquire four temperature ranges simultaneously with 110fps each*
Speed	*440 fps Fullframe with subwindow capabilities*
Detector / Resolution	*InSb-Detector stirling cooled, 320 x 256 pixel*
In-house/commercial	*In-house*
References	-

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Overview

Name	***High Speed Camera Systems***
Type	*various models*
Application	*time resolved characterisation of highly transient processes*

Technical details

Kodak Motion Corder
colour, 512 x 512px. @ 500fps, 8bit, subwindow capable

Weinberger SpeedCam Visario G3
colour, 1536 x 1024px. @ 1000fps, 8bit, subwindow capable

Vision Research Phantom V5.0
b/w, 1024 x 1024px. @ 1000fps, 8bit, subwindow capable (60.000fps max.)

Vision Research Phantom V9.0
b/w, 1600 x 1200px. @ 1000fps, 14bit, subwindow capable (144.000fps max.)

Vision Research Phantom V9.1
b/w, 1600 x 1200px. @ 1000fps, 14bit, subwindow capable (144.000fps max.)

Dimensions / weight	*3...10 kg*
/ mobility	*Yes*

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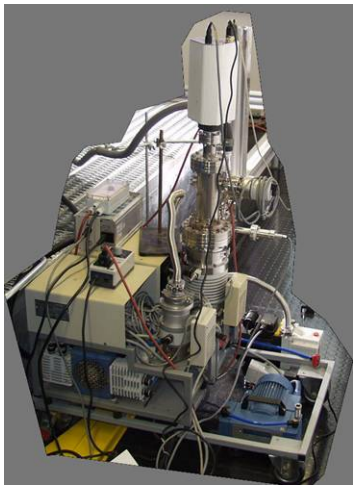
Overview



Name	***Fast 8 kS/s mass spectrometer***
Type	*Online Mass Spectrometer*
Application	*Monitoring hydrogen concentration in processes, studies on vented explosions, tank testing,…*

Technical details

Description	*This mass spectrometer is a very fast method for online monitoring of gases. Fastest possible time resolution is 0,125ms / mass at a response time of 100ms (recently realized 10ms/mass). Detectable hydrogen concentrations cover the range from low ppm to 100%.*
Dimensions / weight / mobility	*1 m³ / 55 kg* *yes*
Temperature range	*adaptable*
Pressure range	*adaptable*
Media	*any kind of gases e.g. hydrogen, air, nitrogen, steam,…*
In-house/commercial	*In-house*
References	*confidential ICT reports, security research for automotive industry*

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Overview

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

Technical details

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*
Dimensions / weight / mobility	*60 x 60 x 60 cm³ / 45 kg* *yes*
Temperature range	*ambient temperature range*
Pressure range	*0 - 1.5 bara*
Media	*hydrogen in air*
In-house/commercial	*in-house*
References	*confidential ICT reports, security research for automotive industry*

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Overview

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

Technical details

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*
Dimensions / weight / mobility	*2m x 2m x 2m working range*
Temperature range	*ambient temperature range*
Pressure range	-
Media	-
In-house/commercial	*commercial*
References	*confidential ICT reports, security research for automotive industry*

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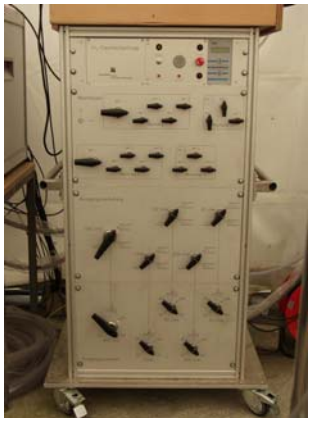
Overview



Name	***Gas Mixing Unit***
Type	*remote controlled 4 component gas mixing unit*
Application	*all kind of experiments where gas supply with defined (hydrogen-) concentrations or mass flows are needed*

Technical details

Description	*5 mass flow controllers* *0.05 - 1250 ln/min flow range* *4 mixing stages* *remote controlled* *programmable: volume, mass, setpoints*
Dimensions / weight / mobility	*60 x 40 x 110 cm³ / 75 kg* *-*
Temperature range	*5 - 30°C ambient temperature*
Pressure range	*0 – 40 bar*
Media	*calibrated for H_2, N_2, O_2, Air* *other non-condensing gases / mixtures possible*
In-house/commercial	*in-house*
References	*confidential ICT reports, security research for automotive industry*

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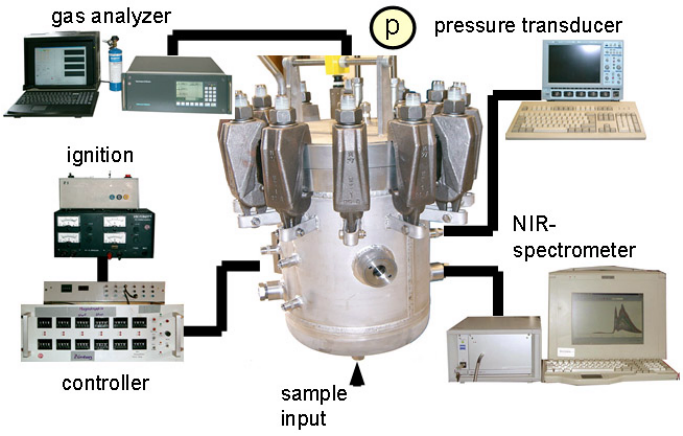
Overview

Name	***6 MPa Autoclave***
Type	*35l 6MPa autoclave with windows*
Application	*dust / gas explosion experiments*



Technical details

Description	*A special autoclave with a Volume of 35 l equipped with pressure transducers, gas analyzer and windows of a wide spectral transmittance allowing spectra evaluation of hydrogen explosions. It withstands pressures at least up to 6 MPa and enables input of different additives shortly before, during and after ignition of the gas explosion.*
Dimensions / weight / mobility	*1 x 1 x 2 m³ / 300 kg* *no*
Temperature range	*adaptable*
Pressure range	*0-60 bar*
Media	*gases / dust / …*
In-house/commercial	*in-house*
References	*ICHS2005*

Overview

Name	***Hydrogen analyser***
Type	*H2 concentration measurement with heat conduction sensor*
Application	*hydrogen concentration measurement with slow transients*

Technical details

Description	*heat conduction sensor* *response time 3..7 s* *0,2..1,5 l/min gas sampling flow* *0-100 Vol.-% hydrogen in air measurement range*
Dimensions / weight / mobility	*0.2 m x 0.5 m x 0.5 m / ~10 kg / limited*
Temperature range	*115 °C*
Pressure range	*atm. pressure*
Media	*hydrogen*
In-house/commercial	*commercial (Fisher-Rosemount)*
References	-

Overview

Name	***2 colour pyrometer***
Type	*optical temperature measurement system*
Application	*hot (catalyst) surface temperature measurement*

Technical details

Description	*measurement range: 300..1000°C* *wave lengths: 1,52 µm, 1,64 µm* *0,1-0,5 l/min gas sampling flow* *0-10 Vol.-% (+/-0.05 Vol.-%) hydrogen in air measurement range*
Dimensions / weight / mobility	*- / 2.2 kg / yes*
Temperature range	*300..1000°C*
Pressure range	-
Media	-
In-house/commercial	*commercial (Impac)*
References	-

Overview

Name	***Explosion effects measurement devices (expansive waves)***
Type	*sensors, data logger*
Application	*Measurement and analysis of the propagation of expansive waves; pressure measures in different points.*

Technical details

Description	*Several devices are included:* *<u>Sensors</u>* *Model IDA354-3,5C (NOBEL): pressure range 0-350 bar* *Model IDA354-1C (NOBEL): pressure range 0-100 bar* *Model PSE530-M5-L (SMC): pressure range 0-10 bar* *<u>Data logger</u>* *Data acquisition card* *Model DAQCard-6062E (National Instruments)*
Dimensions / weight / mobility	-
Temperature range	-
Pressure range	-
Media	-
In-house/commercial	-
References	-

Overview

Name	***Thermal conductivity analyser***
Type	*TCD sensor*
Application	Monitoring hydrogen

Technical details

Dimensions / weight / mobility	-
Temperature range	*System operating temperature: 32 to 122ºF (0 to 50ºC)*
Pressure range	*Pressure: 5-50psig*
Media	*Application: 0-100%H_2 in N_2*
In-house/commercial	*Commercial. Teledyne TCD Sensor 2000 Series*
Description	*Thermal Conductivity Detector (TDC) based analyzer: Teledyne TCD Sensor 2000 Series* *By using field proven filament-based and semiconductor based TC detectors, this sensor is able to continuously monitor hydrogen in either binary of multi-component sample gas streams.* *Ranges: Three ranges plus a cal range, field selectable within limits and auto ranging* *Accuracy: ±1% of full scale most binary mixtures at constant temperature; ±5% of full scale over operating temperature range once temperature equilibrium has been reached* *Response time: 90% in less than 10 seconds with a flow rate of 100 sccm* *Sensor type: Standard TC cell (4-filament detector))* *Signal output: Two 0-1 VDC and two 4-20 mADC isolated* *Alarm: Two fully programmable concentration alarm set points and corresponding Form C, 3 amp contacts.* *Cell material: Nickel plated brass block with nickel alloy filaments and stainless steel piping and end plates* *O/P interface: Full duplex RS-232* *Max load impedance: 1000 ohms*
References	-

Overview

Name	***turbulence probe***
Type	*differential pressure measurement*
Application	*measurement of turbulence in jet (gas, dust)*

Technical details

Description	*Pitot principle device already depecited by Mc Caffrey associated to a high sensitivity pressure measuring cell*
Dimensions / weight / mobility	*1 cm for the probe, 10 cm for the box, easy to handle*
Temperature range	*ambient but resists to flames*
Pressure range	*0 to 150 Pa for this version (0 to* ±10 m/s)
Media	*gas, dust clouds, flames*
In-house/commercial	*in-house*
References	…

Overview

Name	***ionisation probe***
Type	multi point *flame detector*
Application	*flame speed measurement*

Technical details

Description	*a set of high voltage low capacity ion gages able to measure from very slow deflagration (including hydrogen) to overdriven detonations*
Dimensions / weight / mobility	*the probe is 50 cm long, the box 30 cm x 30 cm x 20 cm*
Temperature range	*ambient to 2500 K*
Pressure range	*ambient to 200 bar*
Media	*inconel*
In-house/commercial	*in-house*
References	…

Overview

Name	***fast optic pyrometer***
Type	*solid temperature measurement*
Application	*fast temperature measurement of hot spots*

Technical details

Description	*classical but very fast (50 µs) monochromatic pyrometer (1.7µm) to measure the temperatuer of a point of 0.5 mm*
Dimensions / weight / mobility	*1 kg, 2 baxes*
Temperature range	*200 to 1000°C*
Pressure range	…
Media	…
In-house/commercial	*commercial*
References	…

Overview

Name	***pressure sensors***
Type	*piezozelectric, piezoresistive, capacitive pressure measurement*
Application	*inflammation, explosion, dispersion*

Technical details

Description	*various tehnologies but rather classical*
Dimensions / weight / mobility	*portable*
Temperature range	*-40 to 2000 °C*
Pressure range	*from 0.1 Pa to 1000 bar*
Media	*…*
In-house/commercial	*commercial*
References	*KISTLER, DRUCK,*

Name	***Gas Reaction Controller***
Type	*Volumetric sorption measurement apparatus based on Sieverts' method*
Application	*Assessment of hydrogen storage materials with respect to storage capacity, Pressure-Composition-Isotherms behaviour, kinetics rates, cyclic stability.*

Technical details

Description	*The instrument consists basically in a reaction and in a hydrogen distribution system. Various pressure gauges for different pressure ranges from vacuum to high pressure. Equipment's operation is fully automatised.*
Dimensions / weight/ mobility	*… Overall unit: 0.86 × 0.76 × 0.69 m, Reaction chamber: 2 cm^3. Equipment cannot be moved*
Temperature range	*-60 to + 60°C (with a cryostat) and room temperature to 500°C (with a furnace)*
Pressure range	*10^{-1} mbar to 200 bar*
Media	*Hydrogen, nitrogen and other inert gases*
In-house/commercial	*commercial (Advanced Material Corporation)*
References	http://www.advanced-material.com/

Name	***Gravimetric Analyser***
Type	*Gravimetric sorption measurement apparatus*
Application	*Assessment of hydrogen storage materials with respect to storage capacity, Pressure-Composition-Isotherms behaviour, spectrometry-assisted gravimetric analysis (TGA-MS), reaction kinetics.*

Technical details

Description	*The equipment consists basically in a balance with a reference arm and a second arm with the material sample installed in a reaction chamber. The balance capacity is up to 5g. Additional features are a dynamic pressure control, multi-stream inlet for carrier and reactive mixtures, and an integrated dynamic sampling mass spectrometer for evolved gas analysis. Analyses are performed in automatic mode. The system is fitted with a unit to transfer sensitive samples directly from a glove box to the sample chamber.*
Dimensions / weight / mobility	*Overall unit: 1.8 × 0.5 × 1.8 m. Equipment cannot be moved.*
Temperature range	*-180°C to +500°C (for SS reactor); -180°C to +1000°C (with quartz reactor)*
Pressure	*vacuum to 20 bar*
Media	*Hydrogen, nitrogen and other inert gases*
In-house/commercial	*commercial, IGA (Hiden Isochema)*
References	http://www.hidenisochema.com/

Name	***Volumetric Sorption & Thermal Desorption Analysers (two units)***
Type	*volumetric sorption measurement apparatus based on Sieverts' method*
Application	*Assessment of hydrogen storage materials with respect to storage capacity, Pressure-Composition-Isotherms behaviour, Thermal Desorption Spectroscopy (TDS), Sorption/desorption rates, cyclic stability.*

Technical details

Description	*The instrument consists basically in a reaction chamber whose temperature is controlled by a (cryo)-furnace and in a mass spectrometer for quantitative TDS. Various pressure gauges measures pressure range from vacuum to high pressure. The operation is fully automatised. The system is fitted with a unit to transfer sensitive samples directly from a glove box to the sample chamber.*
Dimensions / weight / mobility	*Overall unit: 1.5 × 0.7 × 0.7 m (Reaction chamber: 2 cm^3). Equipment cannot be moved*
Temperature range	*-180 to + 500°C*
Pressure range	*vacuum 10^{-8} mbar to 100 bar*
Media	*Hydrogen and auxiliary/calibration gases (He/H)*
In-house/commercial	*commercial, HTP (Hiden Isochema)*
References	http://www.hidenisochema.com/

Overview

Name	***Integral Pressure Transducer, Model D25***
Type	*tensometric pressure transducer*
Application	*Continuous transformation of overpressures to the electric signal*

Technical details

Description	*This miniature dynamic pressure sensor is specifically designed for shock tube and blast wave measurements and for other applications requiring very high frequency, near non-resonant response*
Dimensions / weight / mobility	*d 20x35,5 mm / - / yes*
Temperature range	*from -50°C to +80°C*
Pressure range	*0-25 bar*
Media	*gas*
In-house/commercial	*commercial*
References	*http://www.valley.ru/~orlex/preob.htm*

Overview

Name	***Dynamic Pressure Sensor, Model 113A***
Type	*Quartz pressure sensor*
Application	*shock wave pressure measurements in shock/detonation tubes and other experimental facilities*

Technical details

Description	*This miniature dynamic pressure sensor is specifically designed for shock tube and blast wave measurements and for other applications requiring very high frequency, near non-resonant response*
Dimensions / weight / mobility	*d 6x38 mm / - / yes*
Temperature range	*from -40°C to +50°C*
Pressure range	*0-200 bar*
Media	*gas*
In-house/commercial	*commercial*
References	*http://www.pcb.com/products/*

Overview

Name	***Kistler Quartz High Pressure Sensor, Model 701A***
Type	*Quarz pressure sensor*
Application	*Measurement of rapid pressure variations*

Technical details

Description	*This miniature dynamic pressure sensor is specifically designed for shock tube and blast wave measurements and for other applications requiring very high frequency, near non-resonant response*
Dimensions / weight / mobility	*d 11x28 mm / 8.5 g / yes*
Temperature range	*from -40°C to +50°C*
Pressure range	*0-250 bar*
Media	*gas*
In-house/commercial	*commercial*
References	*http://www.kistler.com*

Overview

Name	***Heat Flux Transducer, Model TPI-2M***
Type	*Integral heat flux sensor*
Application	*Measurement of integral heat flux*

Technical details

Description	*The device converts a heat energy of any type of heat radiation source in an proportional electrical signal. Measurement range: the energy range from 1 to 1000 J, wavelength - from 0.5 to 10.6 microns*
Dimensions / weight / mobility	*59x59 x100 mm / 200 g / yes*
Temperature range	*from -40°C to +50°C*
Pressure range	*normal (1 bar)*
Media	*gas*
In-house/commercial	*commercial*
References	http://inergo.ru/

Overview

Name	***Heat Flux Transducer, Model RRC KI LICHR***
Type	*Integral heat flux sensor*
Application	*Measurement of heat flux*

Technical details

Description	*Measurement range:*		*0-20 MJ/m2*
	Conversion ratio:	*1.5 MJ/m2/V*	
	Uncertainty:	*10 %*	
	Integral action time:	*10 s:*	
Dimensions / weight / mobility	*d 18x30 mm / 15 g / yes*		
Temperature range	*from -40°C to +50°C*		
Pressure range	*normal (1 bar)*		
Media	*gas*		
In-house/commercial	*in-house*		
References			

Overview

Name	***Light Flux Transducer, Model FD-10GA***
Type	*Photodiode*
Application	*Measurement of light flux*

Technical details

Description	*Spectral range:*		*0.4-1.8 microns*
	Sensitivity:	*10 mA/lm*	
Dimensions / weight / mobility	*d 10x12 mm / - / yes*		
Temperature range	*from -40°C to +50°C*		
Pressure range	*normal (1 bar)*		
Media	*gas*		
In-house/commercial	*commercial*		
References	…		

Overview

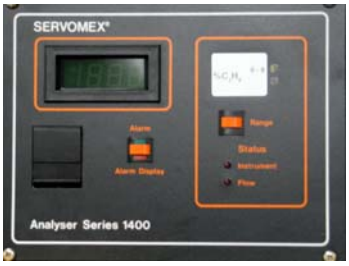
Name	***Schlieren System, Model IAB-451***
Type	*Optical shadow device*
Application	*High speed shadow photography*

Technical details

Description	*Aperture:*	*230 mm*
Dimensions / weight / mobility	*d 250x2500 mm / 200 kg / yes*	
Temperature range	*from -40°C to +50°C*	
Pressure range	*normal (1 bar)*	
Media	*gas*	
In-house/commercial	*commercial*	
References	…	

Overview

Name	***Servomex Gas Analyzers***
Type	*Series 1400 and 4000*
Application	*Measuring and monitoring Gas concentrations of Flammable gases (Hydro Carbons)*



Technical details

Description	*IR gas analyzers*
Dimensions / weight / mobility	*Mobile, 3 channels for Ethylene,1 channel methane and Propane*
Temperature range	*0 – 40 °C*
Ranges	*Methane 0 -15 %, Ethylene 0 – 10 %and Propane 0 – 8 %*
Media	*Propane, Methane and Ethylene*
In-house/commercial	*Commercial*
References	*Servome, http://www.servomex.com*

Overview

Name	***Hydrogen Gas Analyzers***
Type	*Series K1550*
Application	*Measuring and monitoring Gas concentrations of Hydrogen*

Technical details

Description	*2 Gas analyzers*
Dimensions / weight / mobility	*mobile*
Temperature range	*0 – 40 °C*
Ranges	*Hydrogen 0 – 100 %*
Media	*Hydrogen*
In-house/commercial	*Commercial*
References	*Servome, http://www.servomex.com*

Overview

Name	***Oxygen Analyzers***
Type	*Series 5000 and 570A*
Application	*Measuring and monitoring Oxygen concentrations*

Technical details

Description	*2 Oxygen analyzers*
Dimensions / weight / mobility	*mobile*
Temperature range	*0 – 40 °C*
Ranges	*(570A) 0-100% oxygen range accuracy ± 0.1% 0_2* *(5100IS) 0-100% oxygen range accuracy ± 0.01% 0_2*
Media	*Oxygen*
In-house/commercial	*Commercial*
References	*Servomex, http://www.servomex.com*

Overview

Name	***Pressure Transducers***
Type	*Piezo-resistive pressure transducers*
Application	*Measuring the face-on pressure or pressure in a explosion vessel.*

Technical details

Description	*Piezo-resistive transducers mostly manufactured by Endevco, but also Druck and Kulite*
Dimensions / weight / mobility	*mobile*
Temperature range	*-20 – 120 °C*
Ranges	*35 kPa – 20,000 kPa*
Resonant frequency	*150 – 600 kHz depending on range*
In-house/commercial	*Commercial*
References	*Endevco, http://www.endevco.com*

Overview

Name	***Free Field Pressure Transducers***
Type	*Free field pressure transducers on aerodynamic stands (Blast pencils)*
Application	*Measuring the free field (side-on) air blast propagation*

Technical details

Description	*The blast-pencils consist of an aerodynamically shaped probe or Skimmer plate supplied with a flush mounted pressure sensor.* *The sensors are miniature piezo-resistive sensors (Kulite or Endevco).*
Dimensions / weight / mobility	*mobile*
Temperature range	*-20 – 120 °C*
Ranges	*35 kPa,70 kPa, 140 kPa, 350 kPa untill 3,500 kPa for the Skimmer plates*
Resonant frequency	*150 – 400 kHz depending on range*
In-house	*The pencils and the Skimmer plates are manufactured in house*

Overview

Name	***Displacement transducers***
Type	*Micro epsilon (Laser Displacement systems) and AE (Cable actuated displacement)*
Application	*To measure response of constructions during an explosion load.*

Technical details

Description	*Laser and Cable actuated displacement measurement systems*
Dimensions / weight / mobility	*mobile*
Temperature range	*-20 – 40 °C*
Ranges	*0 – 1,000 mm*
Media	-
In-house/commercial	*Commercial*
References	*Micro Epsilon and AE.*

Overview

Name	***Accelerometers***
Type	*Serie 2270A and 2262A from Endevco; series EGE 73BQ and EGAS FS 25 from Entran; from PCB the series 350B and the M352A.*
Application	*To measure acceleration during an explosion load.*

Technical details

Description	*45 transducers, ICP and Piezo-resistive.*
Dimensions / weight / mobility	*mobile*
Temperature range	*-20 – 80 °C*
Ranges	*5,000 – 20,000 m/s^2*
Media	-
In-house/commercial	*Commercial*
References	*Endevco, Entran and PCB*

Overview

Name	***Two systems, SCADAS III and Pacific***
Type	*LMS SCADAS III and Pacific 5800.*
Application	*Signal Conditioning and Acquisition of signals of measurements.*

Technical details

Description	*68 channels of SCADAS III and 50 channels Pacific*
Dimensions / weight / mobility	*mobile*
Bandwith Amplifiers	*Pacific 400 kHz* *SCADAS 100 kHz*
Max. Sample rate	*Pacific 2 MHz* *SCADAS 202 kHz*
Resolution	*Pacific 12 bit* *SCADAS 24 bit*
Memory Capacity	*Pacific 2048 k-words* *SCADAS (limit of HD)*
In-house/commercial	*Commercial*
References	*LMS and Pacific*

Overview

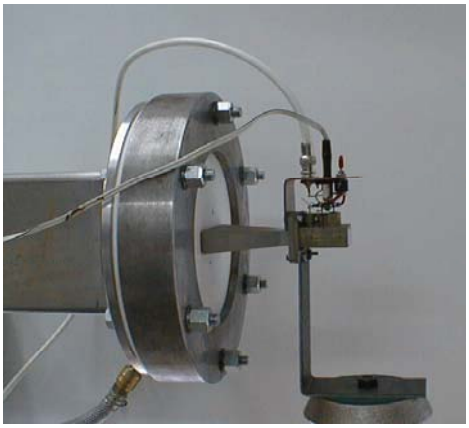
Name	***Smart 3***
Type	*H2 sensor*
Application	*continuous monitoring of hydrogen concentration*

Technical details

Description	-
Dimensions / weight / mobility	*106x160x80 mm / 0.9 kg / yes*
Temperature range	*-10 / +60 °C*
Pressure range	*80-110 kPa*
Media	*gas*
In-house/commercial	*commercial*
References	*SENSITRON S.r.l. – Cornaredo (MI) ITALY – Viale della Repubblica, 48 – www.sensitron.it*

Overview

Name	***Microwave Radar***
Type	*X-band radar Doppler unit*
Application	*continuous monitoring of the fast deflagration and detonation velocity along the tube*



Technical details

Description	-
Dimensions / weight / mobility	*10x5x3 cm / 0.2 kg / yes*
Temperature range	*no limit*
Pressure range	*no limit*
Media	*gas*
In-house/commercial	*in-house*
References	*DABKOWSKI A., KOZAK A., TEODORCZYK A.: The Initiation of Gaseous Detonations in H_2-O_2 Mixtures by Incident Shock Wave, Proceedings of the VI Seminar „New Trends in Research of Energetic Materials", Pardubice 2003, pp.89-99*

Overview

Name	***PCB pressure transducers***
Type	*set of PCB pressure transducers with 8 channel 10 MHz data acquisition system*
Application	*monitoring detonation*

Technical details

Description	-
Dimensions / weight / mobility	*30x5x5 mm / 0.05 kg / yes*
Temperature range	*250-500 K*
Pressure range	*0-10 MPa*
Media	*gas*
In-house/commercial	*commercial*
References	*www.pcb.com*

Overview

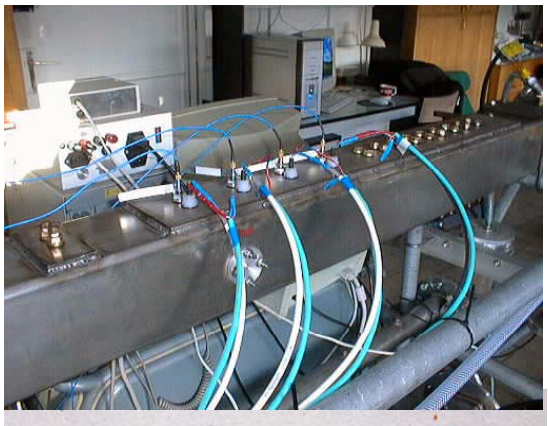
Name	***Photodiodes***
Type	*set of photodiodes with 8 channel 10 MHz data acquisition system*
Application	*monitoring deflagration and detonation waves*

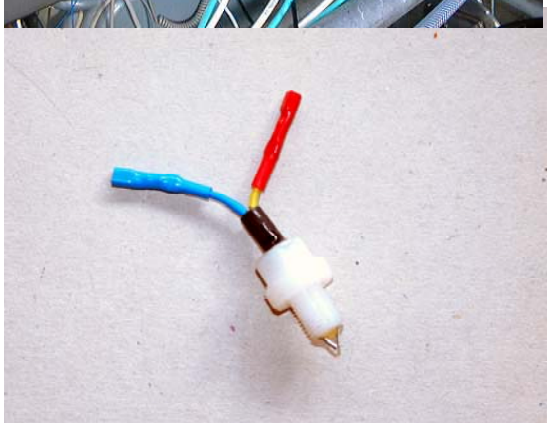
Technical details

Description	-
Dimensions / weight / mobility	*10x5x5 mm / 0.01 kg / yes*
Temperature range	*no limit*
Pressure range	*no limit*
Media	*gas*
In-house/commercial	*in-house*
References	-

Overview

Name	***Ion Probe***
Type	*set of ionization probes with 8 channel 10 MHz acquisition system*
Application	*monitoring deflagration and detonation waves*





Technical details

Description	-
Dimensions / weight / mobility	*30x5x5 mm / 0.005 kg / yes*
Temperature range	*250-1000 K*
Pressure range	*no limit*
Media	*gas*
In-house/commercial	*in-house*
References	-

Overview

Name	***Schlieren optical system***
Type	*schlieren optical system combined with recording camera*
Application	*photographic registration of deflagration and detonation waves*

Technical details

Description	-
Dimensions / weight / mobility	*3x3x2 m / 200 kg / no*
Temperature range	-
Pressure range	-
Media	*gas*
In-house/commercial	*in-house*
References	-

Overview

Name	***Rapid Compression Machine (RCM)***
Type	*combustion driven Rapid Compression Machine (RCM)*
Application	*studies of autoignition of gaseous mixtures*

Technical details

Description	-
Dimensions / weight / mobility	*100x50x40 cm / 50 kg / yes*
Temperature range	*250-500 K*
Pressure range	*0.1-10 MPa*
Media	*gas*
In-house/commercial	*in-house*
References	*A.DABKOWSKI*, T.KAWAKAMI** and A. TEODORCZYK: Preliminary Experimental Study of Autoignition of Hydrogen-Oxygen Mixture by Using Combustion Driven Rapid Compression Machine, Journal of KONES Internal Combustion Engines, Vol.8, No. 1-2, 2001, pp.45-51*