FLAMMABLE GAS SAFETY CODE Annex A

Flammable Gas Safety Manual

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SECTION I

THE DANGERS OF FLAMMABLE GASES AND PROCEDURES FOR THEIR SAFE USE IN EXPERIMENTS AND TESTS

1. INTRODUCTION

The aim of this manual is to provide adequate information to enable persons to design and/or use flammable gas systems safely. It is focused on the use of flammable gas systems in physics experiments. It opens with a summary of the dangers of flammable gases because on several past occasions these have been forgotten by qualified personnel and have had serious consequences.

This first section explains the formalities to be completed before a flammable gas system is put into operation. It introduces the concept of risk classification and indicates how a system can be classified even at its design stage. The class of a gas system determines the safety requirements which must be fulfilled before it can be commissioned.

The second section gives guidelines for the design of gas mixing and distribution systems with illustrations of typical examples. Its primary aim is to provide information to help design and construct gas systems.

N.B. The first safety formality to be met, when planning an experiment, test or other system involving the use of flammable gas, is to appoint a Group Leader in Matters of Safety (GLIMOS) who must complete an ISIEC (Initial Safety Information for Experiments at CERN) form and send it to the DSO (Divisional Safety Officer), usually of PPE division, from whom blank ISIEC forms are available.

2. THE FLAMMABLE GAS CODE

Safety Code G, the CERN Flammable Gas Safety Code, defines the rules which must be followed in the use of flammable gas at CERN. It is published in application of the Staff Rules and Regulations.

Copies of the Flammable Gas Safety Code may be obtained from the secretariat of TIS Division.

3. SCOPE

This manual complements the Flammable Gas Safety Code.

It is particularly relevant for the use of flammable gas in experiments, test beams and laboratories. It does not cover the use of gases for industrial purposes, for which the national codes of the host

states should be referred to, nor the special requirements of liquid hydrogen systems or bubble chambers. For these latter systems, the FGSO and TIS should be consulted at the conceptual stage of the experiment.

The manual provides an approach to designing and constructing flammable gas systems of acceptable safety standard. However, no such approach can ever be assumed to guarantee absolute safety. Alternative methods to those given in this manual may be proposed and adopted if the FGSO and TIS agree that they enable an equivalent or higher level of safety to be attained.

4. THE DANGERS

Many flammable gases have no smell and their presence cannot be detected by human senses and therefore specific gas detectors must be used.

<u>Accumulation</u> of gas can be produced by <u>leaks</u> which result in the build up of pockets of gas. These pockets of gas can in turn lead to fire, explosion, asphyxiation or intoxication. Pockets of gas will accumulate at an upper or lower level depending on the gas density and the air currents in the region. The relevant gas density is that of the final gas mixture and not the flammable gas component. The final gas mixture may also be dependent on the degree of mixing in air either by diffusion which is slow or by turbulence.

<u>Fire</u> results from a flammable gas/air mixture burning after ignition. There are many sources of ignition such as naked flames, sparks, hot surfaces, static electrical sparks etc.

<u>Explosion</u> requires the simultaneous presence of a flammable mixture of gas and oxygen (air) and a source of ignition in a confined space. Such an explosion is usually a <u>deflagration</u> in which the flame front moves with a velocity less than that of sound and the overpressure can exceed 8 bars. In narrow passages and tubes a deflagration can develop into a <u>detonation</u> in which the flame front travels at a velocity greater than the speed of sound and the overpressure can exceed 50 bars. All flammable gases can cause explosions in the right circumstances.

<u>Asphyxiation</u> can result when any gas mixture is present in sufficient quantity to reduce the level of oxygen in the air breathed. Dizziness and fatigue can already occur below 18% oxygen, and below 12% there is great danger of immediate unconsciousness and death.

<u>Intoxication</u>, the state of being poisoned, can result when certain gases are either breathed in or come into contact with the skin.

N.B. Once gases have been mixed they will not subsequently separate out into the original constituent gases. However if a mixture is cooled or pressurised the individual components may condense out. Gases diffuse through porous equipment at rates inversely proportional to their molecular weights, and the use of plastic pipes and plastic membranes in gas systems and detector construction can change the composition of the gas and in particular dramatically increase the contamination by oxygen, nitrogen and water vapour from the air.

5. GAS FLAMMABILITY

5.1 GENERAL

A <u>flammable gas</u> is one which reacts with oxygen whether pure, or diluted as in air, releasing a large quantity of heat and producing a flame.

N.B. The word inflammable is synonymous with flammable and does not mean non-flammable.

Flammable gases may be diluted with inert gases to the point where the mixture is not flammable. When using such a mixture in a particle detector, precautions must be taken to ensure that the mixture is below the flammable limit, i.e. to ensure that the flammable gas component of the mixture is below the concentration at which the mixture is just non-flammable. Although a mixture may be non-flammable, its mixing system will involve the use of flammable gas and hence be subject to the CERN Flammable Gas Safety Code.

A list of mixtures measured to be non-flammable is given in Annex 1. Values found in the literature for the concentration of the flammable gas component of mixtures which are just non-flammable should be treated with great care as they may refer to old measurements which have since been shown to be in error. If any doubt should arise about the flammability of a mixture, it should be tested by TIS.

The <u>Lower Explosive Limit (LEL)</u> of a gas is the minimum concentration of gas or vapour in air in which a flame can be propagated. Below this concentration the mixture is too lean to burn as the energy from the combustion of one molecule is dissipated before it can activate another molecule to propagate the flame.

The <u>Upper Explosive Limit (UEL)</u> of a gas is the maximum concentration of a gas or vapour in air in which a flame can be propagated. Above this concentration the mixture is too rich to burn; i.e. oxygen is used up in the combustion of one molecule leaving insufficient oxygen to burn the next adjacent molecule of fuel.

The Lower and Upper Explosive Limits (LEL and UEL) are identical with the Lower and Upper Flammable Limits. The <u>Flammable Range</u> consists of all concentrations between the LEL and the UEL. Values found in the literature should be treated with great care and in the case of missing data or of doubt TIS can arrange to measure them.

The <u>Flash Point</u> of a <u>liquid</u> is the lowest temperature at which it gives off sufficient vapour to form an ignitable mixture with the air at its surface. Care should be taken when using this parameter, its value being dependent on the method of measurement.

The <u>Autoignition Temperature</u> of a gas or vapour is the minimum temperature required to initiate or cause self-combustion, without ignition from an external source of energy.

A list of accepted values for LEL, UEL, Flash Point and Autoignition Temperature for mixtures containing flammable gases or vapours, is given in Annex 1. Data for other gases and mixtures not covered by this list may be obtained in the European Standard document EN 50054 or from TIS-CFM.

5.2 THE SPECIAL CASE OF OXYGEN

Special requirements exist for equipment used with oxygen.

Although oxygen is not a flammable gas, it is a very powerful oxidising agent and must be treated with extreme care if fires and explosions are to be avoided. All valves and fittings used in oxygen systems must be chosen and maintained with care. Oils and greases must be avoided and not allowed into contact with oxygen. All systems where oxygen is to be used must be referred to TIS for approval before being designed, constructed and put into service

6. **RISK CLASSIFICATION**

6.1 INTRODUCTION

Risk classification for flammable gas systems is used to help define the level of precautions to be adopted to arrive at an acceptably safe installation. For a given system, even at its conceptual stage, its Class of risk may be estimated by following the procedure given in Form F1 which may be found below in the chapter on Formal Requirements.

N.B. The risk classification procedure does not consider the risks of asphyxiation or intoxication, which may be present in any gas system, but only the risks due to gas flammability.

The procedure is based primarily on the quantity of gas used in the system. The location of the system and its potential for producing leaks must also be taken into account. Since different gases release different amounts of heat on combustion, the quantities of gas involved are expressed in hydrogen equivalent, by scaling according to their relative heats of combustion, a list of which is given in Annex 1 for some commonly used gases. These quantities are summed to give Q_{tot} , the total amount of gas involved expressed in kilograms of hydrogen equivalent. There are four Risk Classes :

Risk Class 0	$: \mathbf{Q}_{\text{tot}}, = 0$
	the use of non flammable gases or mixture(s)
Risk Class 1	: Q _{tot} ,< 0.4 kg (approximately equivalent to 1 kg of hydrocarbon) risk of a small local flash fire or explosion
Risk Class 2	: 0.4 kg < $Q_{\rm tot}^{},$ < 40 kg (approximately equivalent to100 kg of hydrocarbon): risk of a local fire or explosion
Risk Class 3	: Q_{tot} , > 40 kg (approximately equivalent to 100 kg of hydrocarbon): risk of a general fire or explosion

Most systems may be subdivided into a gas storage and primary distribution area, a gas mixing area, and the detector area with its local distribution. Annex 2 of this manual contains a sketch of such a

system. Physically separated areas can be treated individually for risk classification. This is particularly relevant to storage areas which will often be of Risk Class 3. (see chapter 12)

6.2 **REQUIREMENTS TO BE MET BY FLAMMABLE GAS SYSTEMS**

The requirements listed in this section are generally applicable. However the FGSO, in agreement with the TIS Commission, has the discretion to decide on additional requirements or exceptions for an individual gas system.

6.2.1 RISK CLASS 0

Risk Class 0 does not necessarily mean there is zero risk. It applies only to the use of non flammable mixtures. The area where the mixture is produced may be of a higher Risk Class especially if the mixture has a flammable component.

6.2.2 RISK CLASS 1

A Flammable Gas Zone must be declared formally by means of form F3 (see chapter 10 below) for all places at CERN where flammable gases are used or stored. It is defined by the GLIMOS of an experiment in agreement with the FGSO as being the region where there is a risk of fire and/or explosion should a leak of flammable gas occur, and which thus is subject to special precautions.

Standard warning notices giving the names of the flammable gases used must be visible at all entrances to Flammable Gas Zones. These are available from the CERN Stores under SCEM 50.55.82.001.1 to 590.9

Copies of the completed form F4 shall be posted at all entrances to Flammable Gas Zones. This form is available in colour from TIS in A3 format, and a copy is included in chapter 10 below.

Pipework for flammable gases should be metallic. Vessels and pipework shall be identified by coloured bands according to CERN Safety Code A3, or by standard CERN labels.

Although pipework should be metallic, an exception may be allowed for piping close to detectors where flexibility is required.

Combustible materials and sources of ignition shall be reduced to a minimum within 5 m of gas handling equipment, piping or apparatus.

Appropriate pressure regulators shall be used. If a regulator does not include a flow limiter, an adequate flow limiter must be added after the regulator.

Enclosed volumes shall be incapable of becoming overpressurised, and be fitted with pressure relief devices if necessary.

The complete system shall be tested for leaks. The total bak rate shall be measured and must be sufficiently small to ensure that there is no danger of a dangerous concentration of flammable gas accumulating. Each system must be studied individually to determine the maximum acceptable leak rate.

The Flammable Gas Zone must be well ventilated.

Hot Work Welding Permits/Permis de Feu shall only be issued for Flammable Gas Zones with the written approval of the TSO/GLIMOS.

Exhaust gases shall be vented to a safe place agreed with the FGSO.

All metallic equipment must be grounded.

Should the FGSO consider it necessary, local extraction ventilation and flammable gas leak detectors may have to be installed which produce local alarms and cut off the gas supply and electricity to the system.

6.2.3 RISK CLASS 2

Risk Class 2 systems are subject to the following additional requirements.

Pressure relief devices shall be provided to limit pressure to the maximum working pressure foreseen in the various parts of the system. Bubblers may be used as relief devices in low pressure systems provided they are suitably protected from mechanical damage.

Relief devices shall be vented to a safe place outdoors via an exhaust line.

Exhaust locations shall be chosen to minimise fire hazards and shall be at least 3 m from any air intake.

Provision shall be made to purge the entire system with inert gas. This includes the vent lines which may also need to be kept under an inert atmosphere.

Electrical equipment in the Flammable Gas Zone must be protected according to the norms of the IEC and CENELEC publications. IEC 79 deals with electrical apparatus for explosive atmospheres. Equivalent national standards may be employed in cases where apparatus conforming to the above norms cannot be obtained. In regions of the Flammable Gas Zone where flammable gas should only be present accidentally, normal electrical apparatus may be accepted if it is provided with specific protection such as inertion or overpressurisation. The FGSO, together with TIS, must approve non-standard electrical equipment.

Ground level retention bunds or overhead collection hoods shall be installed where appropriate. These aid efficient gas detection and ventilation extraction.

Flammable gas detectors shall be installed near detector systems, mixing systems and indoor storage/dispensing areas. A low level alarm, normally 10% of LEL, should produce a local warning. A high level alarm, normally 20% of LEL, should produce the following actions :-

Sound a local klaxon and activate a flashing warning lamp.

Cut off the supply of flammable gas to the system.

Cut off all electrical power to the system except for explosion proof equipment.

Transmit the alarm to the Fire Service and to the Technical Control Room (TCR).

Switch on or increase the ventilation speed.

The FGSO, in agreement with the TIS Commission, may approve the setting of higher level alarm thresholds in certain installations.

A plan of the experimental zone showing the position of the flammable gas detectors shall be posted beside the gas detector warning panel which should be near an entrance to the zone.

A portable flammable gas detector shall be available in each Flammable Gas Zone, and it shall be regularly calibrated.

Fire detectors shall be installed in the Flammable Gas Zone. A high level fire alarm shall activate the same actions as a gas alarm excepting that the ventilation speed shall not necessarily be increased. Smoke extraction may be activated if required by the Fire Brigade.

The flammable gas system shall shut down automatically in the case of failure of services (electricity, compressed air, water etc).

Written instructions to shut down the gas mixing/distribution system manually and in a safe manner shall be available beside it.

An operating manual containing an accurate flow diagram of the complete system shall be available near the gas mixing/distribution system. It shall include the procedures for purging the system both before and after the use of flammable gas.

All written instructions shall be up-dated as necessary and particularly after modifications to the sytem or to the operating procedures.

An Emergency Stop button shall be provided.

6.2.4 RISK CLASS 3

All systems which fall into Risk Class 3 will be subject to special examination by TIS and the FGSO who may demand further safety requirements in addition to those defined above for Risk Class 2.

Flammable gas systems of Risk Class 3 are not permitted underground.

7. OPERATION AND MAINTENANCE

7.1 GENERAL

The organizational requirements for operation of a flammable gas system are given in the CERN Flammable Gas Safety Code where the roles of the FGSO, GLIMOS etc are defined. The existence

of these specialists does not relieve the user of a flammable gas system of his own responsibility for safety. However these specialists have the authority to stop dangerous operations immediately.

After a flammable gas system has been Risk Classified, it has to be formally commissioned in accordance with the requirements of Form F2 before being operated. A copy of form F2 may be found in chapter 10 below.

7.2 TESTING FOR COMMISSIONING

Flammable gas should not be introduced into a system before it has been commissioned.

Flammable gas systems shall be tested for leaks, normally at a pressure higher than that foreseen for their operation. Any leaks detected shall be eliminated. The final test must be carried out in the presence of a member of TIS. More details on leak and pressure tests may be found below in chapters 15, 18 and 19.

The correct performance of pressure gauges, flowmeters, non-return valves etc shall be verified.

Tests shall be made of the safety related automatic actions triggered by flammable gas detectors, fire detectors etc.

If the introduction of flammable gas into a system is necessary before full commissioning can take place, this must be authorized beforehand, in writing, by the FGSO.

7.3 COMMISSIONING

All flammable gas systems of Risk Classes 1, 2, and 3 shall be commissioned following the procedure given in Form F2, a copy of which is included below in the chapter on Formal Requirements. This procedure results in the production of a commissioning report whose requirements must be fulfilled before the system is authorized to be operated normally with flammable gas.

N.B. Written procedures for purging the system before and after the use of flammable gas are mandatory, as is the availability of an accurate flow diagram of the complete system.

Equipment modified after commissioning shall undergo a new commissioning procedure.

7.4 ROUTINE MAINTENANCE, TESTS AND PROCEDURES

Flammable gas installations must be tested for leaks at least once per year.

Safety devices such as over pressure relief valves, gas detectors, smoke detectors etc, must be maintained in accordance with their manufacturers' instructions and CERN regulations. Overpressure relief valves must be checked by the TIS Commission every second year.

Tests of automatic actions in response to safety alarms shall be carried out at least once per year.

Maintenance which involves disconnecting piping shall only be carried out after a system has been purged of flammable gas.

Agreed operating procedures shall only be changed with the approval of the FGSO in collaboration with TIS. This is of particular importance for purging and filling procedures.

8. UPGRADES AND MODIFICATIONS

N.B. Modification covers changes in procedures as well as changes to physical layout and equipment.

Modifications made to a system at its construction stage, and after it has been Risk Classified, must be submitted to the FGSO who will judge whether the Risk Classification should be modified subsequently.

The same procedure applies to all modifications and upgrades to a commissioned system.

In the case of a major modification, the Risk Classification and Commissioning procedures must be carried out in the same manner as for a new system.

9. FIRE PROTECTION

The fire protection strategy shall be defined as early as possible in collaboration between the designer, the user, the FGSO and TIS (in particular the Fire Brigade). Representatives of the Fire Brigade must inspect all Flammable Gas Zones before they are declared for the first time.

A fire detection system must cover the Flammable Gas Zone and relay alarms to the Fire Brigade and the TCR. In addition, it will usually provoke automatic actions such as closing gas valves and cutting electrical supplies.

A telephone should be available in the vicinity of flammable gas installations. Dependent on its location, this telephone may have to conform to the requirements for electrical apparatus in Flammable Gas Zones given in chapter 24 below.

Suitable portable fire extinguishers shall be available in the vicinity of the flammable gas system and, where necessary, fixed fire fighting equipment will have to be installed. Fire blankets or other supplementary emergency equipment shall also be installed if requested by the Fire Brigade.

N.B. Because of the danger of re-ignition and explosion, gas fires should normally not be extinguished until the supply of flammable gas has been shut off. However, all possible steps should be taken to protect nearby materials at risk and prevent the fire from spreading.

CERN Safety Code E sets out the fire prevention and protection rules and lays down the procedures to be followed, including the procedure applicable to the fire permit for work with "hot" tools. A copy of the Fire Permit is included in chapter 10 below.

10. FORMAL REQUIREMENTS

An ISIEC form must be filled in when a flammable gas system is first planned. (Initial Safety Information for Experiments as CERN) A copy of the ISIEC form is included below.

All flammable gas systems must undergo Risk Classification following the procedure given in form F1 below.

Before being put into operation with flammable gas a system must be commissioned following the procedure given in form F2 below. It must then be declared (and later cancelled) by means of form F3 below.

All Flammable Gas Zones must be delimited with signs as defined in chapter 6 above, and copies of the completed form F4 must be displayed at the entrances. This form, also referred to as the Blue Poster, is available in colour from TIS in A3 format.

In the case of Flammable Gas Zones of Classes 2 and 3, a plan indicating the location of the flammable gas detectors shall be displayed near the gas detector warning panel.

Flammable gas may only be purchased by authorised personnel. Authorisation is issued by CERN Stores on request from the user after completion of the form F5 below which requires the signature of the FGSO.

All work with "hot" tools within CERN requires the application of the procedures defined in the Fire Permit, a copy of which is included below. CERN Safety Code E deals with Fire Protection. Its Appendix V explains how to assess the risks involved in the use of hot tools and elaborates the procedure for applying for a fire permit.

CERN FLAMMABLE GAS SAFETY CODE

FORM F1

RISK CLASSIFICATION

(1) Risk Classification is mandatory for all flammable gas systems covered by the CERN Flammable Gas Safety Code.

The Risk Classification depends principally on the amount of flammable gas in the system and covers four Risk Classes.

- Risk Class 0: the use of non-flammable mixturesRisk Class 1: risk of small local flash fire or explosionRisk Class 2: risk of local fire or explosionRisk Class 3: risk of general fire or explosion
- (2) System to be classified for risk :-

Experiment or Group :....

System :

Location of system :.....

(3) Quantities of flammable gas involved.

Annex 1 of the CERN Flammable Gas Safety Manual gives the hydrogen equivalent coefficients for the most commonly used gases. e.g. for methane it is 0.4 which means that 1 kg of methane corresponds to 0.4 kg of hydrogen

The System indicated in (2) above contains the following quantities of flammable gas (total quantities within its Flammable Gas Zone).

Type of Gas	Mass	H2 Equivalent	H2 Equivalent Mass
	kg	Coefficient	kg
Totals	kg		$Q_{tot'} = kg$

(4) Classification

(a)	If $Q_{tot'} = 0$	Risk Class 0
(b)	If $0 < Q_{tot'} < 0.4 \text{ kg}$	Risk Class 1
(c)	If 0.4 kg < $Q_{tot'}$ < 40 kg	Risk Class 2
(d)	If $Q_{tot'} > 40 \text{ kg}$	Risk Class 3
		unless it is a storage area which may be treated as Risk Class 2 if its location and construction are appropriate.

(5) Conclusion of the FGSO

This system is classified as Risk Class.....

(6) The present Risk Classification was carried out on.....(date)

by	Name	Signature
GLIMOS/Group Leader		
FGSO		
Representative of TIS Div.		
TSO		

CERN FLAMMABLE GAS SAFETY CODE

FORM F2

COMMISSIONING REQUIREMENTS FOR FLAMMABLE GAS SYSTEMS

EXPERIMENT OR GROUP :					
SYSTEM :					
LOCATION :					
ISEC FORM		RISK CLASS			
ELECTRICAL PROTECTION	FLAMMABLE GAS	S DETECTION			
EUROPEAN STANDARD	ACTIONS:	STOP GAS SUPPLY			
OTHER STANDARD		STOP ELECTRICAL SUPPLY			
CERN SPECIFICATION		HIGH SPEED VENTILATION			
INERTION		LOCAL ALARM			
GROUNDING		ALARM TO FIRE BRIGADE			
		ALARM TO TCR			
TESTS AND PROCEDURES I	EQUIPMENT & DO	CUMENTATION			
PRESSURE TEST		PORTABLE GAS DETECTOR			
LEAK TEST		FIRE EXTINGUISHERS			
SAFETY VALVES		FIRE DETECTION			
PERMANENT PURGING		EXHAUST LINES			
INTERMITTANT PURGING		AREA DELIMITATION			
START-UP PROCEDURE		OPERATING MANUAL			
CLOSE-DOWN PROCEDURE		FIRE BRIGADE INFO.			
EMERGENCY STOP		SAFE SHUT-DOWN SHEET			
FLOW DIAGRAM		TELEPHONE			

ADDITIONAL REQUIREMENTS AND TESTS

The undersigned authorise the system to be operated normally with flammable gas subject to the conditions listed above under 'Additional Requirements and Tests' being fulfilled.

	Name	Signature
Group Leader/GLIMC	os	
TIS Representative		
FGSO		
TSO		
Others		

CERN FLAMMABLE GAS SAFETY CODE

JULY 1995

FORM F3

DECLARATION/CANCELLATION OF A FLAMMABLE GAS ZONE

Copies to :	Fire Brigade, TIS, FGS0), TS	O, T(CR, ST/MC, ECP/ESI	
From :	:(GLIMOS/Group Leader or his representative)				
Signature		Dat	e		
The Flammable	Gas Zone in Building				
which includes th and which is of I Commissioning 1	e following gas systems Risk Classification Form F2 have been met,	, a	and fo	r which all the requirements of its	
is	DECLARED]	CANCELLED	
All requirements F2 have been me	and conditions of Form et			The system and vent lines have been purged of flammable gases:-	
The system and v of air before flam	vent lines will be purged nmable gas is introduced			according to the agreed writtem procedure	
according to the procedure	agreed written			according to a provisional procedure	
according to a pr	rovisional procedure			All warning notices have been removed or covered	
Standard Warnir	ng Notices are displayed		1	The system has been disconnected from all flammable gas supplies	
Tests have taken	place successfully on:-		1	The following storage vessels for flammable gas remain in the	
Alarms and Inter	locks			vicinity of the system :-	
Flammable Gas	Detectors			None	
Ventilation Equip	oment			vessels with a total capacity of	
Signal Transmiss	ion Systems			m=kg	
The operating cr	ew have received				
written safety do	cumentation				
The following eq	uipment is available in		Ado	ditional details :-	
the vicinity of the	installation:-				
Operating Manu	al				
Portable Gas De	tector (explosimeter)				
Log Book		Ι			
Fire Extinguisher		Ι	1		
Fire Blanket		Ι	1		
Safety Torch		1	1		
First Aid Kit		1	1		

FORM F4

IRUUP				
ETECTOR AREA: ONE DETECTEUR:	BEAM:	TEL.:		TE:
OUNTING ROOM: ALLE DE COMPTAGE	:	TEL.:		IGN. GLIMOS:
ARTICULAR HAZARD	S / DANGERS SI	PECIAUX:		
ERSONS TO CALL IN (ERSONNES A CONTAG	CASE OF EMER(CTER EN CAS D'	GENCY: URGENCE:		
ESPONSIBILITY	NAM	E	TELE	PHONE
ESPONSABILITE	NOM		CERN	HOME/PRIVE
GLIMOS				
GAS				
				·
				·
SECRETADIAT				·
EA CONTR. ROOM /	SALLE DE CON	TR. DE LA Z	ONE:	
ERRITORIAL SAFETY	OFF. / DELEGUE	E A LA SECU	RITE TERRITORIA	LE:
ом:	TEL.:		PRIVE	: (
	ΟΤΕΩΤΙΟΝ / ΡΔΙ	<i>/</i> ///////////////////////////////////		
OCAL RADIATION PRO	DTECTION / RAI		PRIVE	: (
OCAL RADIATION PRO			PRIVE	:
OCAL RADIATION PRO OM:	TEL.:		PRIVE	:
DCAL RADIATION PRODUCT CONTRACTOR	S) / INGENIEUR S		IS): PRIVE	
	DTECTION / RAI		IS): PRIVE	2201
	DTECTION / RAI		PRIVE	: :

CERN FLAMMABLE GAS SAFETY CODE

FORM F5/FORMULAIRE F5

Subject	: Request for a Flammable Gas Purchase Authorisation
From/de	: GLIMOS or Group Leader/Chef de Group
To/a	: CERN Stores

Please deliver an XGAS card to the person listed below who accepts the responsibilities as defined overleaf.

Veuillez délivrer une carte XGAS à la personne suivante, qui déclare s'engager à assumer les responsabilités telles que décrites au verso.

Surname/Nom :

First name/Prénom : Div :

Gas system/Sytème de gaz :

Budget code/ Code budgétaire :

Authorised amount/Montant authorisé :

Expiry date of the card (2 years max.) : Date d'expiration de la carte (max. 2 ans) :

For issuing Division only	:	Card no.
Réservé à la Division émettrice	:	No. carte

GLIMOS or/ou	FGSO host division/ division-	Proposed holder of XGAS
Group Leader/Chef de	hôte	card
Groupe		Futur détenteur de la carte
		XGAS
Surname/Nom:	Surname/Nom:	Surname/Nom:
Date :	Date :	Date :
Signature :	Signature :	Signature :

Completed copies to/Copie complétée à :

GLIMOS, Group Leader/Chef de Groupe, FGSO host-division/division hôte, Leader TIS/Chef de TIS

TERMS OF REFERENCE OF THE HOLDER OF AN XGAS CARD

- 1. XGAS Cards are issued according to the procedure given in chapter 5 of the CERN Flammable Gas Safety Code.
- 2. The Holder of the XGAS Card is responsible for the correct operation and maintenance of the gas distribution facilities for which he orders the gas. The Group Leader or GLIMOS concerned shall give him the necessary authority and means to meet these responsibilities. In particular, the Holder of the XGAS Card has the right to stop gas supply to an installation of which he considers the technical or organisational conditions unsafe. The Holder of an XGAS Card shall keep to a minimum the local stock of flammable gas in experimental halls and laboratories, and shall arrange the return of empty gas vessels to the Stores as soon as possible.
- 3. The Holder of the XGAS Card has the right to make his card (or prestamped Material Request Forms) accessible to other users of the installations under his authority, if he considers that this does not impair the safety criteria. However, the ultimate responsibility for the compliance with these criteria remains with him and cannot be delegated. XGAS Cards shall not be issued to persons who will be absent from CERN for long periods during the operation of the flammable gas installation in question.
- 4. A sign displayed at the entrance to the flammable gas installation shall indicate the name, division and telephone number of the Holder of the XGAS Card as the supervisor of the gas supply for the installation.

ATTRIBUTIONS DU DETENTEUR D'UNE CARTE XGAS

- 1. Les cartes XGAS sont délivrées selon la procédure indiquée au chapitre 5 du Code de Sécurité du CERN pour les systèmes à gaz inflammables.
- 2. Le détenteur de la carte XGAS est responsable de l'utilisation et de l'entretien corrects des installations de distribution de gaz pour lesquelles il commande le gaz. Le Chef du Groupe ou GLIMOS concerné lui donnera le pouvoir et les moyens nécessaires pour faire face à ces responsabilités. En particulier, le détenteur de la carte XGAS a le droit d'interrompre l'alimentation en gaz d'un installation dont il estime que les conditions techniques ou d'organisation n'offrent pas toute sécurité. Le détenteur de la carte XGAS s'attachera à limiter au minimum le stock local de gaz inflammables dans les halles d'expérimentation et les laboratoires et à retourner aux magasins les récipients de gaz vides dès que possible.
- 3. Le détenteur de la carte XGAS a le droit de mettre sa carte (ou des formulaires de demande de matériau portant déjà son empreinte) à la disposition d'autres utilisateurs de l'installation placée sous son autorité s'il considère que cela ne contrevient pas aux mesures de sécurité. La responsabilité finale en ce qui concerne le respect de ces mesures lui incombe cependant et elle ne peut pas être déléguée. Les cartes XGAS ne doivent pas être délivrées à des personnes qui s'absentent du CERN pendant des périodes prolongées durant l'exploitation de l'installation à gaz inflammables en question.
- 4. Un panneau d'affichage placé à l'entrée de chaque installation à gaz inflammables indiquera le nom, la division et le numéro de téléphone du détenteur de la carte XGAS chargé de la surveillance des installations d'alimentation en gaz.

CERN		S	S		E		С
	INITIAL	SAFETY	INFORMATION	on	EXPERIMENTS	at	CERN

DATE: INSTALLATION START:	EXPERIMENT:AREA/BEAM:
SPOKESMAN:	
GLIMOS:	TEL.:
FILLED IN BY:	TEL.:

TEST BEAMS: _____ LABS AT CERN (Bldg/room):

GASES, LIQUIDS, CRYOLIQUIDS used in detectors (or kept in nearby containers):

Device Type	Fluid 1 + % Fluid 2 etc.	Volume	Abs. press.	Max. flow
			-	



Other CHEMICALS

toxic / corrosive / flammable metals, solvents, additives etc.:

Z

24/03/93

	TS	Magnet type	Power		Field	Gap	vol.	Max. water press		
WAGNETS.				_						
HIGH VOLTA (> 1 KV	GE ′)	Detector Type	Voltage	Curre	nt S	Stored energy		of HV nnels	Remote shut-off?	
SHORT POWEF	-CIRC R dissir	UIT currents > 5 m/ bated by all electror	A for >50 V	possi podet	ble anyv	/here?	_			
			b) c	off det	ectors: -					
5)	Weig Spec For v	ING AND HANDLING : Jht of heaviest single piece to install?								
$\overline{\mathbf{a}}$	VAC	UUM AND PRESS	URE tanks	(°1;	atm.):					
6		Tank	Abs. press	sure	Volume	l w	/eakes	t part(s)	of wall	
					Volumo					
$\overline{\mathcal{D}}$	RAD Bean	ATION n intensity, radioact	. sources, c	deplet	ed urani	um, lase	ers, m	nicrowa	ives etc.:	
8)	OTH	ER HAZARDS (or r	emarks):							
				THE		THE P	PF I	NVISI	ON	
P	LEAS	E RETURN THIS I								

SECTION II

GUIDELINES FOR THE DESIGN OF FLAMMABLE GAS SYSTEMS

A Flammable Gas System shall be understood to include any area or zone where flammable gases are stored or used.

11. LOCATION OF EXPERIMENTS AND TESTS USING FLAMMABLE GASES

All experiments and tests using flammable gases shall be located in areas which have been designed or adapted to be suitable for the safe use of such gases.

11.1 SPECIFICALLY DESIGNED AREAS

These are areas which have been designed specifically to house a particular experiment or experiments (eg. the LEP experimental areas). The facilities in such areas are defined by the the experimental team together with CERN experts with the agreement and approval of the FGSOs of the Divisions involved and of the TIS Commission. Such areas will have the necessary infrastructure to detect and reduce the danger from any dangerous gas leaks (e.g. flammable gas leak detection and extraction ventilation), as well as any other safety equipment considered necessary. (e.g. fire detection and emergency stops) The areas will be clearly marked and delimited in accordance with the requirements defined in chapters 6 and 10 of this manual.

Problems concerning safety will have been studied and resolved at an early stage in the life of the project for which the area has been designed.

11.2 EXPERIMENTAL HALLS AND BEAM LINES

When experiments and tests are to be placed in experimental halls or beam lines, the permission of the responsible Division must first be obtained. The area where the test or experiment is to be carried out must be studied by the GLIMOS and other experts from the experiment, along with the FGSO of the territorially responsible Division and the FGSO of the experimental team's host Division (usually PPE). The necessity for a safety infrastructure (e.g. flammable gas leak detection and extraction ventilation) will be decided by the FGSOs. This infrastructure must be installed and commissioned before any work with flammable gases begins. The area will be clearly marked and delimited in accordance with the requirements defined in chapters 6 and 10 of this manual.

11.3 OTHER HALLS

PPE Division has at its disposal a number of halls and laboratories which are already equipped (or can easily be equipped) with the necessary safety infrastructure for flammable gas use. These halls can be used for tests. All persons wishing to use such facilities must contact the FGSO of PPE Division who will study the proposal and indicate any special precautions that have to be taken. After he has agreed to the proposal, he will recommend to the Division that the required space be allocated.

The area will be clearly marked and delimited in accordance with the requirements defined in chapters 6 and 10 of this manual.

11.4 OFFICES AND BARRACKS ETC

The installation of experimental equipment using flammable gases, and the storage of such gases, is strictly forbidden in offices, barracks and other premises which are unsuitable for their use or have not been approved for their use. Derogations from this rule can only be authorised by the Territorial Division Leader in agreement with the TIS Commission Leader.

12. STORAGE OF FLAMMABLE GASES

12.1 INTRODUCTION

Flammable gases are normally delivered to the CERN stores in cylinders, having sizes of up to 50 litres capacity. If larger quantities are required batteries, frames or racks of up to 12 cylinders may be available. The gases in these cylinders may be stored as a gas at high pressure, up to 200 bar, or as a liquid under its own vapour pressure.

All gas cylinders must be stored in zones which are defined for that purpose and which are accessible at all times. In particular, it is forbidden to store cylinders in halls or laboratories. (Exception is made for specially designed storage areas inside large surface experimental halls as described below.)

12.2 REGULATIONS CONCERNING FLAMMABLE GAS STORES

Stores for gas cylinders must not be situated above, below, or in an inhabited building or in the basement of any building.

Stores must be isolated by a protection zone of at least 5 m horizontally from :-

openings in buildings inhabited by third parties

public roads or the limits of properties belonging to third parties

openings in buildings in which there are naked flames

low points or traps where vapours might accumulate (openings to basements, grids, drains not protected by syphons etc.)

This protection zone shall be increased to 6 m with respect to depots and distributors of flammable substances and oxidising agents (except compressed air).

If the capacity of the store is greater than 15,000 kg of hydrocarbons, the protection zone shall be increased to 7.5 m.

The protection zone can be reduced to 1 metre if there is a fire resistant wall (with 2 h resistance) between the buildings concerned, and this wall is at least 2 metres high and is higher than the gas storage building by at least 0.5 m. The length of the wall must be such that the distance corresponding to the protection zone is respected in passing round the wall from any opening.

A flammable gas store may be located inside a building provided the following additional requirements are met :-

its walls should have a fire resistance of one hour

its roof should be of light material with a "Low" fire contribution^{*} and should not have any visible wooden components except for its framework which must be fireproofed.

it shall have ventilation openings at both high and low levels, each with an area of at least 16 square decimetres. Forced ventilation may be required in certain cases.

The floor of all flammable gas stores must be horizontal and made of material with a "Minimal" fire contribution^{*} or be of road quality asphalt. It must be at the same level as, or higher than, the surrounding ground for at least 25% of its perimeter.

Flammable gas stores which are not located in a building must be isolated by a wire fence at least 2 m high and at least 0.6 m from the cylinders. The gate or door shall be in a material of "Minimal" fire contribution^{*}. It shall open outwards and be kept locked. The CERN Fire Brigade shall be provided with a pass key to the store.

All electrical equipment within the Flammable Gas Zone shall conform to the requirements of CERN Safety Code C1 "Electrical Safety Code" which are explained in chapter 24 below.

Stores must be kept clean and tidy and free from all combustible waste material. In particular, they must be kept free of paper, rags, dry grass and leaves.

Stores must have good access to allow the rapid evacuation of cylinders in the case of a fire in the neighbourhood. Sufficient fire extinguishers and fire blankets shall be available as requested by the CERN Fire Brigade.

Smoking and the use of naked flames or incandescent apparatus is forbidden within a store and its protection zone. Any heating shall be by electrical equipment conforming to the requirements of CERN Safety Code C1 "Electrical Safety Code", which are explained in chapter 24 below, or by indirect means such as hot water or air from remote heaters.

^{*} as defined in Table 1 of CERN Safety Instruction 41.

Gas cylinders shall not be stored in places where their temperature risks rising above 50° C. If necessary, they shall be shaded from direct sunlight by a light open sided covering of "Low" fire contribution^{*}.

Gas cylinders should only be delivered to recognised gas delivery points (not offices). They must be stored in a vertical position and must be securely attached to prevent them from falling.

Full cylinders shall be stored separately from nominally empty cylinders and cylinders of different gas content shall be segregated.

All maintenance and repair of gas cylinders is forbidden within a store and its protection zone.

12.3 HANDLING AND CARE OF GAS CYLINDERS

When cylinders are empty it is the responsibility of the user to ensure their prompt return, either to the CERN stores, or directly to the supplier. Unidentified cylinders will be collected and disposed of by CERN.

Nominally empty cylinders awaiting return must be stored in the same manner as full cylinders, and must be appropriately labelled to indicate that they are empty. Cylinders which are classified as nominally empty must not be neglected as they frequently contain a substantial quantity of gas.

All cylinders in a storage area must be equipped with their valve protection caps even if they are nominally empty.

Cylinders should never be rolled along the ground or used as rollers for moving equipment. The cylinder protection caps must be in place when they are being moved.

Only cylinders that are properly labelled and colour coded should be accepted from the stores. The label should be checked against the requirements, to ensure that the correct cylinder has been selected.

Gas cylinders should be checked for leaks. Any defective cylinders must be moved to a safe place, preferably in the open air, and the supplier should be informed.

Any damage or contamination of a cylinder should be immediately reported to the CERN stores or a TIS representative. No attempt should be made to open a cylinder valve which is thought to be damaged, and no attempt to repair cylinders or their valves should be made at CERN.

Persons using or handling gas cylinders should wear appropriate low-flammability clothing, safety shoes and suitable eye protection.

Cylinder valves should always be closed when the cylinder is not in use.

Except with the agreement of the FGSO and TIS, gas must never be transferred from one cylinder to another for mixing purposes, or for any other reason.

^{*} as defined in Table 1 of CERN Safety Instruction 41.

Grease or oil should never be allowed to come into contact with gas cylinders, their valves or equipment.

Gas cylinders must never be heated by a naked flame. If a liquefied gas cylinder has to be heated to increase its gas flow, this can be done either by immersing it in a water bath or by surrounding it with hot air from a remote supply. Electrical heating may be used provided that the heating system and its supply are completely EEx (see chapter 24 which deals with electrical equipment in Flammable Gas Zones).

The cylinder's temperature must never exceed 50°C.

Safety Instruction 42 gives the rules for use of compressed gas cylinders.

13. GAS DISTRIBUTION

13.1 INTRODUCTION

Flammable gas distribution concerns the distribution of gases from the storage containers (cylinders etc) right through to the individual sub detectors built within complex experiments and includes :-

- a) The primary distribution from the cylinders to the mixing units.
- b) Secondary distribution from the mixing units to the particle detector distribution system, usually located in the proximity of the experiment.
- c) The final distribution to the individual sub detector components and the return of the gas for recycling or exhaust.
- d) The exhaust lines.

Annex 2 of this manual contains sketches of typical gas distribution systems.

Storage containers, cylinders, valves, regulating equipment and other accessories should be readily accessible and be protected against physical damage.

Consideration must be given to thermal expansion and contraction of pipelines exposed to large temperature fluctuations. In such cases, sufficient intrinsic flexibility must be provided to avoid excessive strain. This can be achieved by the use of flexible elements, whereas sliding supports should be provided in long pipe runs.

Gas distribution systems should be entrusted to specialists having experience in the design, construction and operation of such systems.

13.2 PRIMARY GAS DISTRIBUTION SYSTEMS

Primary gas distribution is carried out at pressures lower than the storage pressure.

Primary gas distribution systems must be equiped with suitable pressure release devices (relief valves or rupture disks) and tested as described below.

Pipelines, fittings, pressure regulators, valves etc must be suitable for the type of gas being handled. Gas cylinders must be checked for correct contents before being connected.

Fittings used to connect cylinders to the gas system must be those recommended by the supplier or alternatives accepted by TIS as being suitable for the application. All parts must be in good condition, threaded sections must be checked regularly, and parts that exhibit signs of substantial wear must be discarded. In particular, O-rings have a relatively short lifetime and require regular replacement.

Devices other than those recommended, such as parts with comparable but different threads from those of standard items, must not be used. It may be physically possible to make connections with non-standard devices but their use may cause serious leaks and catastrophic failure.

Pressure reducing valves located on individual storage cylinders shall be equipped with flow limiting devices to limit the flow to a value agreed with the FGSO in order to minimise the rate of gas leakage in the case of damage to the line.

When two or more cylinders are coupled together, manifolds must be provided to allow for correct purging of the pipeline after cylinder change over.

All piping used in a primary distribution system shall be metallic, preferably of stainless steel or copper, and joints shall be either welded or brazed. Soft soldering must not be used because of its low resistance to vibration and heat.

Other joints, such as compression couplings, may be used provided that the pressure rating and joint materials are carefully chosen to suit the pressure and the gas being transported. They must also have been tested and accepted by TIS.

Safety valves shall be incorporated in the primary distribution system to protect the pipework from the overpressure resulting from a pressure regulator fault which transmits full cylinder pressure to the system. The safety valve must exhaust outside the building to a safe place agreed with the FGSO.

Individual gas lines must be equipped with non-return valves to prevent the back flow of gas from higher pressure systems to those at lower pressure.

Pressure gauges should be provided at all stages of a system to indicate the pressure within each stage and they should be fitted with an isolation valve.

A clear indication must be given on each supply pipe as to its contents, and the direction of flow of the gas. Standard self adhesive labels are available from CERN stores for this purpose.

All piping must be suitably grounded.

Pressure driven devices which automatically switch over an empty cylinder or battery to a full one can provide a higher level of safety for the experimental apparatus as well as the environment.

13.3 SECONDARY GAS DISTRIBUTION SYSTEMS

In large gas systems, secondary gas distribution includes all the pipework from the output of the mixing systems to the units where the final distribution to the detectors takes place. All piping in such systems shall be metallic and the recommendations given in section 13.2. above for materials and connection methods shall apply.

All secondary piping must be suitably grounded.

13.4 FINAL GAS DISTRIBUTION

Final gas distribution systems are used to circulate the gases through the sub detectors and typically operate at a pressure just above ambient. It is important that such systems never work below ambient pressure.

Pressure regulators and fittings must be chosen to comply with the gas being circulated within the system.

The use of plastic piping must be Imited to those places where flexibility is required. Polyurethane tubing is the currently recommended type. The low resistance of plastics to fire and radiation must be taken into account as well as the contamination of the gases by air and water vapour dffusing through the pipe wall.

All piping shall be protected from mechanical damage and be supported in a safe manner. It shall not run on cable trays with electrical conductors and shall be at least 50 cm from such conductors.

13.5 EXHAUST LINES

Exhaust lines must be correctly dimensioned to allow the safe escape of flammable gas under the worst conditions of flow which could be provoked in its system e.g. safety relief valve opening etc.

Exhaust lines should normally terminate in the open air. The position of the exhaust outlet must be chosen so as to eliminate any risk of forming an explosive concentration of gas, and also to avoid flammable gas mixtures being sucked into ventilation inlet grills. Outlets should not be placed near doors or windows. The position of all exhaust outlets must be agreed with the FGSO.

If it is impracticable to exhaust outdoors and only a small flow of gas is involved, the outlet of the exhaust may be placed in the direct suction of an air extraction system, provided that the mixture therein will be diluted to <10% LEL.

The exhaust vents for gases which are heavier than air must not be situated near drains or other openings which might allow the accumulation of dangerous quantities of the gases.

13.6 TESTS AND COMMISSIONING

Gas distribution systems shall be checked for leaks and tested in the presence of TIS to the requirements of the CERN Code D2 "Pressure Vessels and Pressurised Pipelines" before being put into operation.

If a system has been out of service for a period greater that one year, it shall be re-tested before being put back into operation.

All safety relief devices must be checked every second year to determine if they are still operable and properly set in accordance with the CERN Code D2 "Pressure Vessels and Pressurised Pipelines".

Gas distribution systems which form part of a flammable gas system of Risk Class 1, 2 or 3 shall be commissioned as described above in chapter 7.3.

13.7 MAINTENANCE

Distribution systems must be correctly purged of flammable gas and any residual pressure remaining within the system relieved before maintenance or modifications are undertaken. The system must be be purged of air before being put back into service.

Purging can be done by vacuum evacuation (pumping) or by purging with inert gas. The purging procedures must be agreed with the FGSO when the Risk Classification is carried out. More information on purging is given below in chapter 16.

14. GAS MIXING

14.1 NON-FLAMMABLE GAS MIXTURES

Only inert gases and pre-mixed gases certified as non-flammable by TIS are considered as non-flammable. All other gas mixtures which contain a flammable gas component must be mixed in a Flammable Gas Zone even though the final mixture may be non-flammable. (See Annex A1)

14.2 MIXING FLAMMABLE GASES

Mixing must be carried out in a zone separated from the gas storage area. It may be carried out near the experiment or test area provided the safety standards required in this manual are fulfilled.

Each line carrying gas to a mixer must be fitted with a non-return valve.

All overpressure relief valves must be connected to an exhaust.

If the final gas mixture is subsequently to be treated as non-flammable, the mixture must be monitored to ensure that this is so. The output flow must be stopped automatically if the mixture reaches TCi. (see Glossary)

14.3 GAS MIXERS

Gas mixtures may be made by filling a pressure vessel in sequence with each component gas to its desired partial pressure. However, the component gases are most often mixed by passing them through flowmeters into a mixing vessel at the rates required to provided the desired final mixture. The two most commonly used types of flowmeter are visual mechanical rotameters and mass flowmeters. Both need to be calibrated for the particular gas or mixture to be used. Rotameters can be equiped with optical systems to give warnings when their flow passes outside set limits. Similar warnings can be generated electronically by mass flowmeter control circuits. More details on flowmeters can be found below in chapter 21.

Some mixtures contain components which are supplied as liquids. Alcohols, n-pentane and TMEE are examples of these. The dosing of the carrier gas with such a component can be carried out by bubbling it through a bath of the liquid maintained at the temperature required to provide the desired final mixture i.e. the higher the temperature the greater the take-up of the vapour from the liquid. However, dosing can be carried out in a simpler and better controlled manner by pumping the liquid into an evaporator where it is mixed with the carrier gas. The desired mixture is obtained by varying the rate at which the liquid is introduced to the evaporator.

The quality of a mixed gas may be monitored using the methods described in chapter 17 below. A feedback system can be used to maintain the mixture within the required limits.

Annex 2 of this manual includes sketches of typical mixing systems which have individual components in the form of gas and/or liquid.

14.4 GAS RECIRCULATION, PURIFICATION AND RECOVERY SYSTEMS

The recirculation and recuperation of gases is recommended when the gas in question has harmful environmental properties. In addition, recirculation can produce economic benefits where the gas costs will be amortised during the lifetime of the installation.

As gas returning from a particle detector will normally contain impurities such as water vapour and oxygen absorbed through plastic piping or the detector itself, it is often necessary to purify the gas before recycling it. Gas may often be maintained sufficiently clean for the correct operation of a detector by rejecting a fraction, say 10%, of the return gas and adding 10% of fresh mixture before recycling the gas through the detector. This can limit the build up of impurities to an acceptable level, though in such systems it is sometimes necessary to apply additional purification procedures at regular intervals.

Water vapour may be removed from a gas mixture either by passing the gas through a cold trap or an absorber such as silica gel. Care must be taken to ensure that flammable gas does not liquify and accumulate in cold traps. Care must also be taken with the disposal of silica gel which has become saturated with water, as it will also have absorbed some flammable gas. Oxygen can be removed from a gas mixture either by passing it over a reducing agent such as pure copper, or by the controlled burning of hydrogen. Such systems require careful design because of the high temperatures involved in regeneration and should only be treated by experts.

Certain gases can be recuperated by condensing them out of a mixture. This is done by refrigeration, with the gas mixture often being compressed beforehand to increase the efficiency of the recuperation.

15. LEAK TESTING

The presence of leaks in an operating system may be indicated by changes in flow rates and replenishment rates. Differential flowmeters which respond to changes in the difference between input and output gas flow are particularly useful in this respect.

Spot checking for leaks is a fundamental part of the pre-commissioning or checking procedures. It does not replace the installation of flammable gas leak detection systems whose continual monitoring is necessary to detect the presence of any leak which might appear. All joints on pipework should be tested at least once per year. The method used for flammable gas detection should **not** be capable of igniting the leaked gas.

There are several accepted methods of leak testing, not all of which may be applicable to a given gas system. The principal methods are listed below.

- a) **Noise.** Large leaks in pressurised or evacuated systems may often be heard by ear, and any hissing sounds should always be investigated.
- b) Odour. Many gases have a characteristic smell (e.g. ammonia, hydrogen sulphide etc) and can be detected by the human nose at very low levels. Flammable gases used for domestic purposes (e. g. natural gas, propane, butane) are given an odour by adding organic sulphur compounds to them. Any peculiar smell in or around domestic gas systems should be investigated and the supply shut off until the problem is solved. However the nose, although sensitive, is notoriously unreliable and should not be depended upon to give warning of leaks.
- c) **Portable flammable gas leak detectors**. These can spot fairly small leaks and are usually explosion-proof. An explosion-proof portable flammable gas leak detector should be available at each Flammable Gas Zone.
- d) **Soap or detergent solution.** A soap spray (e.g. CERN stores SCEM 58.81.09.900.6) may be used to detect leaks on pressurised fittings. Washing up liquid may also be used. Such a solution brushed on pipework can identify very small leaks by the bubbles they produce. Attention should be paid to whether a given spray may corrode or contaminate the system. The soap should be wiped off after use. This method has the advantage of being highly sensitive while being fundamentally explosion-proof.
- e) **Pressure change.** A system may be pressurised and then isolated so that any decrease in pressure would indicate the presence of a leak.

- f) Specific portable detectors. A system may be filled with a gas for which a specific portable detector exists. Helium and Argon are most often used and portable Argon detectors are particularly easy to operate. For systems filled with an operating gas which contains hydrocarbons, generalised leak detectors for hydrocarbons are often useful to detect leaks when the system is in operation.
- g) Helium detectors. The system is put under vacuum and connected to a helium detector. Helium is squirted onto each joint in turn and any leaking joint is quickly identified. It is a very sensitive method used principally in vacuum systems. It can only be realistically used for precommissioning tests.
- h) **Ultrasonic detectors**. The ultrasonic noise created by gas escaping through a small hole can be detected by special equipment and is the basis of a range of instruments. They are not usually explosion-proof and their effectiveness is limited.
- i) **Catharometers or Thermal Conductivity Detectors**. The heat lost from a heated electrical element is a function of the flow rate of gas over it and the thermal conductivity of the gas. In these instruments, air is drawn through a probe to the heated element and the thermal conductivity changes if the air contains other gases. The change in the heat lost by the element is detected by an electrical circuit which gives a signal. They are very sensitive but are not normally explosion-proof and they do not work in a magnetic field.

Systems must be leak tested before commissioning and thereafter tested at least once per year as part of their regular maintenance. Screw fittings often slacken due to vibrations in the system and this can lead to leaks. The final commissioning test must be carried out in the presence of a member of TIS.

16. PURGING AND FILLING

16.1 PURGING

In order to remove the risk of explosion, all systems must be purged of air (oxygen) before being filled with a flammable gas. Similarly, when a system is being shutdown after operation with flammable gas, it must be purged of its gas filling before air is allowed to enter. This is of particular importance when maintenance is planned or when a system is being decommissioned. Serious accidents have happened when incorrectly purged systems have been scrapped and then welding or metal cutting has taken place, or when HT has been switched on to imperfectly purged systems.

There are two standard methods of purging :-

- a) A system may be pumped to low residual pressure (= 50 Torr) before being filled with either gas mixture or air. Only certain types of pump are approved for use with flammable gases.
- b) Inert gas may be flowed through the system to replace the existing filling. A sufficiently large number of changes of gas volume must be made so as to ensure that the final gas mixture is

non flammable. (As a guideline, 2 volume changes are needed for tubular chambers but at least 4 volume changes are needed for large volume chambers.)

When filling a system with flammable gas, its residual oxygen content must be less than 5% before any flammable gas is allowed to enter it.

When purging a system to free it of flammable gas, the purging must continue until the residual flammable gas concentration is less than the TCi. (see Glossary)

Purging procedures must be agreed with the FGSO when the Risk Classification is carried out and any changes to these procedures must be agreed by the FGSO in collaboration with TIS.

16.2 FILLING

Before filling with flammable gas, a system must be purged as described above.

When the final gas mixture contains a large percentage of flammable gas, it is good practise to start by flowing the flammable gas at a much reduced concentration, and then to increase the percentage in stages to reach the final operating mixture.

17. GAS QUALITY MONITORING AND GAS ANALYSIS

17.1 MONITORING

The proportions of the individual component gases of a mixture usually have to be maintained within well defined limits in order to ensure the optimum performance of the particle detector to which they are supplied. If the final mixture is classified as non-flammable, the proportion of the flammable component must be monitored to ensure that it does not increase to the point which renders the whole mixture flammable. The degree of accuracy required may determine the method of monitoring to be adopted. Simple two component gases mixed via flowmeters may be controlled via readout of the flowmeters themselves. More sophisticated methods include passing the mixed gas through :-

- a cell to measure its velocity of sound.
- a particle detector equiped with a radioactive source whose spectrum is measured to determine the gas gain.
- o an infra red analyser for specific gases.

The output gas from the particle detector may be sampled by an oxygen detector to monitor the absence of oxygen which could be introduced via leaks in the system.

17.2 ANALYSIS

It is often necessary to analyse the gas(es) going to a particle detector to measure impurities such as oxygen, water vapour or halogenated compounds which can affect the detector's performance. This

can be done either at the cylinder or at the outlet of the mixing rack. Oxygen meters are also used when purging a system free of air with an inert gas before the introduction of flammable gas and for measuring the oxygen content of an inert gas blanket to ensure that the oxygen concentration is well below that required to produce combustion. Although the measurement principles may be similar to those of instruments used for flammable gas leak detection, analysis instruments cannot usually be employed as leak detectors.

Table 1 lists several types of instrument available for the analyses of gases including those for the measurement of impurities. The list does not pretend to be exhaustive.

Component to	Typical	Analytical	Remarks
be Measured	Range	Principle	
Oxygen	1-20ppm to 0 - 100%	Electrochemical Cell	Reasonably cheap. Cell has to be replaced periodically. Range has to be specified. Portable ones available.
Oxygen	0 - 30%	Para-magnetism	More expensive than above but no cell replacement. Not ppm range. Very stable. Portable ones available. Does not work in magnetic fields.
Oxygen	0.1ppm - 100%	Zirconia sensor	All ranges in one instrument. Precise. Cannot be used with flammable gases.
Oxygen	to ppb	Gas phase chromatograpy	Accurate but expensive. May be used to detect other contaminants at the same time (e.g. HC, H ₂ , H ₂ O, N ₂ , Ar)
Water Vapour	to ppb	Gas phase chromatograpy	See above
Water Vapour	to low ppm	Near Infra Red (NIR)	Can be used in liquid phase.
Water Vapour	low ppm to %	Infra Red (IR)	Usually single gas or dual gas measurement. Multiple gas possible.
Water Vapour	1ppm- 1000	Silicon sensor	Fast response time (about 5 mins).
Water Vapour	1ppm-4%	Aluminium Oxide sensor	Slow response time.
Water Vapour	ppm	Lithium chloride sensor	
Hydrocarb-ons (HC)	to ppb	Gas phase chromatograpy	See above. Can also be used to control the concentration of components of a gas mixture.
HC	ppm	Ultra-violet (UV)/visible photometry	Can be used to measure certain organics in inorganic gases and paraffin hydrocarbons. Can be used in liquid phase.
НС	low ppm	Flame ionisation	Sensitive but not specific. Can be used for measurements in inorganic gases or hydrogen
HC	ppm to %	IR	Depending on the specification, the apparatus can be used measure traces or to control the concentration of components of a gas mixture. Can measure several components.

Table 1. Instruments suitable for Gas Analysis
Component to	Typical	Analytical	Remarks
be Measured	Range	Principle	
HC	to ppb	Mass spectrometry	Sensive and specific. Can be used in line with
			a gas chromatograph to identify species.
Hydrogen	ppm	Catharometer.	Sensitive but not specific.
		Thermal Coductivity	
Hydrogen	ppm	Gas phase	See above
		chromatograpy	
Rare Gases-	ppm	Gas phase	See above
Traces		chromatograpy	
Rare Gases-	ppm	Catharometer.	Sensitive but not specific.
Traces		Thermal Coductivity	

18. PRESSURE VESSELS

18.1 INTRODUCTION

Pressure vessels are defined as enclosed containers for liquids or gases not exposed to open flame, which are or may be exposed to an internal or external pressure.

Very stringent design and construction standards are applicable to pressure vessels. The CERN Safety Code D2 deals with pressurised vessels and pipelines and should be consulted by all groups who wish to install such equipment at CERN or who intend to build vessels which comply with CERN standards.

18.2 PROCEDURES FOR PRESSURE VESSEL CONSTRUCTION

All projects involving the construction of pressure vessels to be used at CERN require the prior approval of the TIS mechanical safety section.

To obtain TIS approval, the person at CERN responsible for the project must arrange the submission to TIS of an *Engineering File* containing :-

- the design specifications
- the operating conditions and procedures for the use of the vessel
- the design calculations
- a complete set of drawings
- the planned safety inspections, safety checks and quality control
- a description of the safety devices foreseen

Construction of the pressure vessels should only begin after TIS has approved the Engineering File. TIS may require that additional safety inspections and tests to those planned by the design group are carried out during the construction.

Each pressure vessel must be provided with a non-reusable identification plate indicating its relevant characteristics in English or in French, and it shall be identified with a number issued by TIS.

18.3 WELDING REQUIREMENTS

All welders performing work on pressure vessels at CERN must hold a valid welding certificate issued by an official body. These certificates or copies thereof shall be transmitted to TIS.

In addition, each welder called in to work on pressurised pipes or vessels on a CERN site must undergo an examination supervised by TIS. (see TIS/GS/IR/94-01 "Welders' qualifications for welding work on pressurised pipes and vessels at CERN")

For pressure vessels constructed outside CERN, the manufacturer shall transmit to TIS the following information about the welding :-

the welding material (filler and base material) welding procedures employed the welders' qualifications the names of the welders (who must hold a valid certificate) the results of destructive and non-destructive tests.

19. GAS PIPING

19.1 INTRODUCTION

Pressurised pipelines are defined as pipes which may normally or accidentally contain a gas or liquid under pressure. The CERN Safety Code D2 deals with pressurised vessels and pressurised pipelines.

The design pressure^{*} of a piping system is the maximum pressure at which it must operate reliably under the most unfavourable operating conditions. It is often the pressure of the relief device used in the system.

At least one safety device must be incorporated into a pressurised system to eliminate any risk from overpressurisation.

19.2 DESIGN REQUIREMENTS AND TESTS

The wall thickness of pipes must be calculated and sized in accordance with the internal pressure requirements.

^{*} In this section of the manual pressure is always given relative to atmospheric pressure. (i.e. it is gauge pressure)

Metallic flexible piping shall have a safety factor of 3 between its design pressure and its bursting pressure.

Pressurised pipework shall conform to the European Directive CE 93/C246 and shall be designed, constructed and tested according to:

"Recommendation for the design, construction and fitting of pipe installations", drawn up by the European Committee of Boiler, Vessel and Pipework Manufacturers (CECT), issued by the "Syndict National be la Chaudronnerie, de la Tolerie et de la Tuyauterie Industrielle, Maison de la Mecanique, 39-41 rue Louis Blanc, F-92400 Courbevoie".

All designs for piping systems used for carrying flammable gases must be submitted to, and be approved by, TIS before construction may begin.

X-Ray examinations shall be carried out on welds before pressure tests are undertaken. The person responsible for the system, the FGSO and TIS shall agree on the percentage of welds to be X-Rayed. The procedures for non-destructive (X-ray) testing of welds on pressurised pipelines are defined in the document TIS/GS/CM/IR95-03.

All new pipework shall be tested as defined in the CERN Safety Code D2, "Pressure Vessels & Pressurised Pipelines". These tests shall be carried out in the presence of a representative of TIS or of an accredited official body.

All gas pipework shall be pneumatically tested with clean dry nitrogen gas. Hydraulic fluids or water are not recommended for testing as they may contaminate the system.

Flammable gas piping systems shall only be designed by technically competent persons who are fully aware of the safety regulations and construction norms applicable to pressurised pipework.

19.3 MATERIALS FOR PIPING

Stainless steel or copper is the preferred material for use in piping systems at CERN.

For most applications, low carbon stainless steel to the AISI 304L standard is recommended for its welding qualities. Fittings are readily available in the same alloy.

Plastic pipes and tubes should not be used because of their low resistance to fire and ionising radiation, as well as their being more susceptible to breakage, cutting and leakage at joints. Where the use of plastic is necessary for its flexibility or low mass, it must conform to the CERN Safety Instruction 41, "The use of plastic and other non-Metallic Materials at CERN with respect to Fire Safety and Radiation Safety". All non-metallic tubing requires the authorisation of the FGSO.

It should be remembered that there will be contamination of the gases by air and water vapour diffusing through the wall of plastic tubes.

Special care in the choice of material has to be taken with circuits containing hydrogen to eliminate the possibility of hydrogen embrittlement.

Cold drawn and rolled-and-welded stainless tubes are both acceptable. The price of the latter is usually more favourable.

The bending of tubes on-site is allowed provided that the correct bending equipment is used. This is normally acceptable up to diameters of approximately 20mm. Fittings are generally used for larger diameter pipes.

19.4 JOINING TECHNIQUES

General

The ideal pipe joint is free from any dimensional change which would restrict the fluid flow, increase the pressure drop, or prevent complete drainage of the system. It contains no crevices in which contamination or corrosion can build up.

When deciding on the method of joining pipes, consideration should be given to the frequency with which a joint is expected to be dismantled.

Preparation of pipes

Pipes should be cut to length using a roller type tube cutter or other such tool which gives a clean cut without producing swarf. If a metal saw is used, particular attention must be paid to the removal of free metallic particles before welding.

Welding

Face to face butt welding of stainless steel pipes is usually recommended. This may be either with or without filler material. If a filler material is used, care must be taken to ensure that it is compatible with the base material.

The TIG (Tungsten Inert Gas) method is the recommended welding process. Care must be taken to ensure that the insides of pipes to be welded are correctly purged with argon or reducing gas to prevent oxidation before, during, and immediately after welding. In particular, the gas should flow through the weld section and exhaust on the outside.

Great care should be taken to avoid discolouring the base metal due to overheating. Although full penetration of the finished weld is important, care has to be taken to ensure that the internal diameter of the tube is not reduced.

Stainless steel piping may only be welded at CERN by recognised welders. (see section 18. 3. above)

Brazing

Copper pipes may be **silver brazed**, this being especially relevant for small installations. After brazing is complete, the brazing flux must be cleaned from the inside surfaces as well as the external surfaces. This may present a problem on large installations. Soft soldering should not be used because of its low resistance to vibration and heat.

Connectors

The connection of stainless steel or copper pipes of diameters up to approximately 20 mm can be made with **compression type fittings**. Care has to be taken with rolled-and-welded tubes and especially those with thin walls. Attention must be paid to the torsional forces when tightening connectors. The main advantage of this type of fitting is that modifications can be quickly and economically carried out. A range of standard compression fittings is available from the CERN stores. All fittings must be approved and accepted by TIS.

Self-sealing couplers

The use of self-sealing couplers is recommended when a joint has to be frequently disconnected, as they prevent both the escape of flammable gas and the inflow of air to the system. Such couplers are commercially available for different operating pressures and flow rates. When several joints in the same region have to be dismantled at the same time, keyed couplers may be used to prevent cross over errors during reconnection of the piping.

Tapped threaded joints can only be used on thick walled tubes as the threading process leads to a loss of strength in the tube wall. The thread must be sealed to block its spiral leakage path, and the choice of sealant is important as it may lead to contamination of the gas system.

Parallel threaded joints using a flat seal are often employed for connecting instruments to piping systems. As with compression fittings, attention must be paid to torsional forces when tightening threaded joints.

Flanges

When it is foreseen that pipework needs to be dismountable, the connection of pipes of large diameters (>20 mm) is usually made by flanges. Flanged joints with O-ring seals are generally employed in gas systems. They have the disadvantage of occupying more space than most other types of connections. The CERN store keeps a stock of joints with rotatable flanges for use with gas pipes.

Joints and Gaskets

When using O-rings, seals, or gaskets, care must be taken to ensure that the material is compatible with the gases to which the seal will be exposed. This also applies in the case of metallic seals.

The resistance of the sealing material to radiation should be considered. Several CERN Yellow Reports have been published giving data on the radiation resistance of materials most commonly used at CERN, and in particular of rubbers and plastics. These reports may be obtained from the CERN library or TIS.

19.5 CLEANING AND PASSIVATION

The requirements of the physics community with regard to the cleanliness of gases have become more stringent in recent years. The cleanliness of piping can play a significant part in the overall purity of a gas. As a result, the cleaning of pipes for new installations has become of increasing importance.

The internal surface of pipes must be clean and free from grease to maintain the cleanliness of the gases flowing within them.

It is possible to dismantle small installations for cleaning before the final pressure tests are carried out. For larger installations, such as long pipe runs, it is advisable to have the pipes cleaned before installation and subsequently to take precautions to keep them clean.

The cleaning and passivation of piping systems on the CERN sites should only be undertaken after TIS has agreed on the precautions to be taken to eliminate the risk of fire, explosion, intoxication, or contamination of the environment.

A passivation process is often applied to new piping and fittings before mounting them in a system. It is typically carried out by specialist firms.

After cleaning or passivation, tubes may be kept clean by sealing their ends with foil or plastic film.

19.6 HEATING & INSULATION

A pipe system may sometimes need to be kept at a temperature higher than that guaranteed for its environment. In such cases it will be essential to heat and insulate the system.

Trace heaters.

If trace heating is to be used to keep a piping system at a defined temperature, particular attention must be paid to the type of heater to be employed. Standards have been prepared by CENELC (European Committee for Electrical Standarisation) with respect to electric heaters in potentially explosive atmospheres.

Conventional heating cables with a fixed ohm value per meter must have temperature and current limiters which shall be of explosion proof standard if flammable gas is involved.

Self-limiting linear trace heaters may be used without any thermostatic controller. In these heaters, the semi-conductor heating element, which is located between the leads of the conductors, changes its resistance as a function of its temperature and limits the temperature to a maximum of 65°C. This self regulating property ensures that these heating cables cannot overheat or burn out. Such heating cables may be overlapped without risk of damage, thus facilitating the heating of flanges and valves etc.

Insulation.

Fibre glass wool is the preferred type of insulation as it eliminates the risk of fire. Its risk of suffering mechanical damage may be reduced by the use of an external cover of aluminium. Other materials may also be acceptable provided that they conform to CERN Safety Instruction 41.

N.B. Personnel should wear masks and protective clothing when handling friable insulation and especially fibre glass.

19.7 ROUTING OF PIPEWORK

Piping systems carrying flammable gases must be routed at least 0.5 m from electric cables. Exemptions may only be given by the FGSO in co-operation with TIS/GS.

Pipe routes should be chosen to minimise the possibility of mechanical damage.

For pipes which contain gases which may condense out of the mixture at low temperature (butane etc), care should be taken to prevent condensation especially if the pipes have to pass near doors or ventilation openings where local heating of the pipes may be required.

Pipes should be supported in such a manner as to allow expansion and contraction to take place without inducing additional stress on the system.

The gaps around pipes which pass through walls must be filled with material having at least the equivalent fire resistance properties as the wall itself. There are many such materials commercially available.

19.8 EXHAUSTS

Flammable gases must be exhausted to a safe place outdoors. The position of the exhaust outlet must be chosen so as to eliminate any risk of forming an explosive concentration of gas and also to avoid flammable gas mixtures being sucked into ventilation inlet grills. Outlets should not be placed near doors or windows. The position of all exhaust outlets must be agreed with the FGSO.

If it is impracticable to exhaust outdoors and only a small flow of gas is involved, the outlet of the exhaust may be placed in the direct suction of an air extraction system, provided that the mixture therein will be diluted to <10% LEL.

The exhaust vents for gases which are heavier than air must not be situated near drains or other openings which might allow the accumulation of dangerous quantities of the gases.

19.9 LABELLING

All pressure vessels and pipework shall be labelled according to their contents as defined in CERN Safety Codes A3 and B (the CERN Chemical Safety Code). This is of particular importance where the pipes are visible and in regions where potentially dangerous work, such as cutting or welding, may be carried out. Labels may be obtained from the CERN stores (SCEM No. 50 55 82 700).

20. VALVES

20.1 GENERAL

Valves serve two principal purposes :-

to regulate the flow of fluids.

to isolate piping or equipment for maintenance without interfering with other connected units.

The term "valve" covers a very broad range of products which differ widely in appearance and complexity but have one common physical function: each is designed to control the flow of liquid, vapour or gas.

The choice of valve type depends on the specific application and on whether it is required to shut-off a section of pipework or to regulate a flow or pressure.

20.2 VALVE STEM SEALS

The method of sealing of the valve stem is of importance when there are purity requirements. The fluid used in the system may also have consequences for the choice of stem seal.

Packed stems

These are normally used where high purity is not an important factor and are typically used on water systems. The packing material is usually impregnated with some form of lubricant.

O-rings

They are generally used on Ball valves or valves whose stems rotate during opening and closing. This type of seal is also often used on larger diameter piping systems.

Diaphragms

In diaphragm valves, the diaphragm also forms the stem seal and is in contact with the product. The diaphragm is often made of elastomeric material but for high purity gas systems the diaphragm may be metallic for small diameters, or of a metallic coated synthetic material for larger valve sizes.

Bellows

Valves with bellows type stem seals are prefered for extremely pure gas systems because all their components are metallic, which enables a very high degree of cleanliness to be maintained and also reduces contamination to an absolute minimum. They are often used for cryogenic applications. Such valves are rather expensive.

Valves for use with liquefied gases require special attention as they must be equipped with extended spindles to prevent seizure.

A brief description of the most commonly used types of valve is given below.

20.3 VALVE TYPES AND PRESSURE REGULATORS

Gate valves

Gate valves are used for shut-off purposes and where minimum pressure drop across the valve is important. They require a minimum space for installation. They are not suitable for flow or pressure regulation.

Globe valves

The pressure drop through globe valves is much greater than for gate valves. It should be noted that globe valves installed in horizontal pipework prevent complete drainage of a system unless a drain cock is included. The pressure drop through these valves is much greater than that through gate valves but **h**ey are suitable for crude regulation purposes and can be manually or automatically controlled.

Ball valves

Ball valves offer a very low pressure drop since the aperture through the valve has usually the same diameter as the pipe itself. They are used as shut-off valves as it is difficult to regulate their flow unless they are of the special V-notch type. Shut-off is normally accomplished with a quarter turn which simplifies identification of the open and shut positions. Ball valves are not recommended for cryogenic applications.

Butterfly valves

These occupy the least in-line space of any valve type. The pressure drop across them is somewhat higher than for gate valves. They are not suitable for controlling precision flow or for pressure regulation, but they are often used to regulate flow in air conditioning ducts and similar high flow rate/low pressure applications. They are often referred to as dampers.

Needle valves

Needle valves are used for flow and pressure regulation but they produce large pressure drops. Needles can be cone shaped or be of a more sophisticated form. Such valves can be either manually or automatically controlled.

Diaphragm valves

These valves are used for shut-off and control applications. A diaphragm acts as the sealing medium and the operating stem is located behind the diaphragm. Diaphragms are made from many materials and may be metallic where gas purity is of great importance. Most diaphragms have a limited lifetime but can usually be replaced without removing the valve from the system.

Such valves may be motorised for use as flow control or shut off valves. They may be operated from a remote location either automatically or on demand.

	SHUT-OFF	CONTROL	CRYOGENIC
Gate valve	X		
Globe valve	X		Χ
Ball valve	X	\mathbf{X}^*	
Butterfly valve	X		
Needle valve	Х	Χ	Χ
Diaphragm valve	X	Χ	

Non return valves (Check valves)

Non return valves are incorporated into systems to prevent reverse flow of the fluid. The three most common in-line types are either swing, lift or spring-loaded. The latter are available as standard items from the CERN stores.

Safety relief valves

Pressure relief devices are used to protect systems from overpressure. The diameter of a safety device must be chosen according to the required flow rate. They may be either spring loaded safety valves, pilot-operated safety valves or rupture discs. Simple bubbler devices may be adequate for very low pressure systems. (Safety Instruction No. 19 describes safety relief devices for pressure vessels holding liquified gases.)

It should be noted that a dual system of a rupture disc followed by a spring loaded safety relief valve is often used where high purity is required. The rupture disc prevents any back diffusion of air from the safety relief valve. However, if an overpressure occurs, the rupture disc bursts allowing the spring loaded relief valve to open. This relieves the overpressure after which the valve will re-seat, thus preventing the total loss of gas and minimising the size of the potentially dangerous flammable gas cloud released from the relief line exhaust.

N.B. The positioning of relief line exhausts has to be chosen to prevent the escaping gas cloud from entering doors, windows or other openings in building, or reaching potential ignition sources. The FGSO, in consultation with TIS, should decide on the positioning of such exhausts.

No valves shall be installed in the line either before or after a relief device.

All pressure relief devices should be regularly inspected for leakage and, if appropriate, frosting.

Under certain conditions leaking or "feathering" of relief valves can result in excessive ice formation on the valve body which may prevent the proper operation of the valve. In the worst case, this can lead to plugging of the discharge line and make the pressure relief system inoperable.

CERN carries a stock of pressure relief valves whose operating pressures are set by TIS. These valves must be checked by the TIS Commission every two years.

When the closing down of an installation for checking the safety relief valve is not practical, a three way valve with two safety valves in parallel may be employed.

^{*} V-notch type

Pressure regulators

Pressure regulators are used to reduce the inlet gas pressure to the value that is required downstream. They may be connected directly onto a gas cylinder or installed into fixed piping systems.

Careful attention must be paid to the pressure rating of regulators to ensure they are capable of withstanding the applied input pressure.

Pressure regulators may either be dome or spring loaded, and it is the down stream pressure which acts against the dome or spring to action the valve.

A series of pressure regulators is available from the CERN stores for connection to gas cylinders. These and all other pressure regulators must be tested by TIS/GS before being put into service.

N.B. Pressure regulators are often equipped with pressure relief devices between the high and low pressure stages to protect the **regulator itself** from overpressurisation should a fault occur. This device does **not** protect any downstream equipment from overpressurisation. When used on flammable gas circuits, the discharge from such devices must be exhausted to a safe location.

Back pressure regulators

Back pressure regulators are used to regulate the upstream pressure. As for pressure reducers, they may be either of the dome or spring loaded type.

Annex 2 gives typical examples of gas distribution systems in which the uses of different valve types are illustrated.

21. FLOWMETERS

The two types of flowmeter most commonly used on gas systems at CERN are the variable area meter (Rotameter) and the thermal mass flowmeter. Both require the gas to be clean and free from dust.

A new type of flowmeter has started to be commercialised which makes use of ultrasonic time-offlight measurement techniques. These meters can be obtained for a wide range of flowrates and special models have been developed for extremely low flow rates. Several interesting optional features are available which include an integral inlet fire cut-off valve and a comprehensive range of diagnostic functions. The latter comprises the detection of reverse flow, the detection of air in the meter, and the detection of electrical and acoustic interference.

21.1 ROTAMETERS

The Rotameter consists of a tapered glass tube which contains a sliding float. The height at which the float settles is determined by the flowrate. Both spherical and conical floats are used and they can be made of glass, ceramic, plastic or metal. When a spherical float is used, the flowrate is measured at the centre of the sphere. When a conical float is used, the flowrate is measured at the top of the float.

Rotameters must be operated in a vertical orientation, and the pressure drop across the float should be kept constant to maintain a precise flow.

The precision of the flow measurement depends on the length of the glass tube and is typically between $\pm 1\%$ to $\pm 5\%$. The precision increases with the length of the tube. Variations in temperature and pressure affect the readings. Most commercial flowmeters are calibrated for air at 1 bar absolute and at 20°C. The reading may be in cc/min, l/min, l/h or m3/h depending on the size of the tube. A correction factor must be applied in order to obtain a precise flow measurement for a gas other than air. This correction factor is supplied by the manufacturer for the specific glass tube and the gas to be used.

A precision needle valve is usually installed before or after the glass tube to enable the flow to be regulated. It is important to size this valve for the required flowrate. Rotameters with needle valves should only be used to supply gases. If a flowmeter is to be used to measure the return gas flow then the needle valve should be removed and replaced with a plug.

21.2 MASS FLOWMETERS

Mass flowmeters operate on the principle of measuring changes in temperature along a heated capillary tube. There are two main methods of making the measurement. In the first, both ends of the tube are heated and two sensors placed near the heaters measure the difference in temperature (at zero flow the sensors are at the same temperature). In the second, the heaters are operated to maintain the same temperature and difference in the power consumption provides the measurement of the flow. In both these types of mass flowmeter only part of the gas flow goes through the capillary tube where the sensors are situated, the rest being bypassed. This enables a large flow range to be obtained with one instrument.

Mass flowmeters are more precise than Rotameters provided that they are calibrated for the type of gas and the flow required. Their typical precision is of $\pm 1\%$ FSD and they are not very sensitive to variations of temperature and pressure. In addition, mass flowmeters can generally be installed in any orientation.

Mass flowmeter can be used with or without a control valve. When no valve is present, the mass flowmeter serves only to measure the flow. When a valve is installed, the mass flowmeter is called a mass flow controller and can be used to control the flow. This is done electronically and normally a potentiometer is used to regulate the flow. Several flowmeters can be controlled by one multiplexed digital readout meter. In some units, externally derived input signals may be employed instead of potentiometers to control the flow, and an analogue output signal proportional to the flowrate can be provided.

Most commercial mass flowmeters are unsuitable for very low pressures as they require about 25 mbar differential pressure across them.

22. FLAMMABLE GAS LEAK DETECTION AND SURVEILLANCE

The use of flammable gases in particle detectors, which are often of "flimsy" construction, makes it imperative that there is good detection of leaks coupled with good general ventilation and/or local extraction ventilation. Ventilation and natural air currents may dilute leaking gas so that it will not be detected unless the whole system is well designed. Good ventilation and good detection may be achieved simultaneously by capturing leaking flammable gas in zones by means of a bund at ground level or an overhead hood depending on whether the gas mixture is heavier or lighter than air. The extraction ventilation and the flammable gas leak detector are positioned in the bund or hood and the probability of detection is increased while assuring good dissipation of leaks. Unless otherwise agreed with the FGSO, a flammable gas leak detector must give the following actions:

- At 10% LEL Give an audible and visual alarm at the experimental area. Give a warning at the TCR.
- At 20% LEL (in addition to the above) Shut off all electricity. Shut off all gas flow. Switch on the high speed ventilation. (where applicable) Give an alarm to the Fire Brigade and to the TCR.

None of these actions shall be capable of being annulled until the alarm has been identified and corrected. Safety Instruction 37 covers the rules and procedures for equipment which generate alarms.

There are many types of flammable gas detector but those in most common use are based on one of the two following principles.

1) **Catalytic combustion of the flammable gas in air** - This uses the heat generated by the combustion of the flammable gas with the ambient air on a heated catalytic element. Any gas present diffuses through a protective screen to the catalytic element and the heating of the element increases its resistance which is compared to a similar but non-catalytic element in a Wheatstone bridge arrangement. The current imbalance is proportional (non-linearly) to the concentration of the flammable gas in air. Such detectors indicate the flammable gas concentration as a percentage of the LEL and give a reliable indication down to about 5% LEL. Although they will detect all flammable gases and vapours, they have to be calibrated for the gas in question. In the past these detectors have had problems of stability, and also of poisoning by gases and vapours containing halogens (e.g. Freon[®]), sulphur or lead. However many recent models are much more stable and less prone to poisoning. The detectors are usually used in fixed positions but they are also used in multipoint sequential sampling systems and as portable detectors, the latter being very useful for localising leaks. They are almost always available in explosion proof construction only. These detectors have to be calibrated at least twice per year.

2) **Infra-red spectrum of the gas** - This type of detector can detect gases and vapours that have absorption bands in the infra-red region of the spectrum. Gases with asymmetric molecules are detected and this includes all hydrocarbons and organic compounds but not elements such as oxygen, nitrogen, hydrogen, argon and the other rare gases. The infra-red spectra of most compounds are complex but each spectrum contains a small number of strong absorption bands that can be used to measure low gas concentrations in ambient air. A sample of the air to be monitored is

passed through a cell traversed by a beam of infra-red light of a wavelength at which the expected flammable gas absorbs. The signal received at a measuring device is compared with that from a similar cell in which only uncontaminated air or another non-absorbing gas is present. The difference in the received signals is a measure of the concentration of the gas. Instruments can be obtained with sensitivities ranging from a few parts per million up to several per cent. They also exist as single cell models where they are pre-calibrated for the gas in question.

The advantages of infra-red gas detectors are their sensitivity and specificity coupled with freedom from poisoning, although gas going into the cell must be dust free and the condensation of water and other vapours inside the cell must be prevented. IR detectors have to be calibrated at frequent intervals as they are prone to drift. (Recent models are much better in this respect.) They are usually used in fixed installations with multipoint sequential sampling systems. However portable instruments and fixed spot detectors are now being manufactured which are claimed to be very stable, sensitive and specific. These are available in explosion proof construction as standard and they are likely to replace catalytic type detectors. IR detectors are also used as area monitors where a single IR beam can cover a distance of many meters. This can be useful for scanning the space above an experiment where hot air currents carry small leaks, and also for scanning the interior of an experiment to give ample warning of developing leaks. In this mode the detector does not localise the position of any leak.

Other types of detectors which may be useful for specific problems include :-

- **Thermal conductivity** : measures the change in thermal conductivity of a gas due to changes in composition; gives reasonable sensitivity but is non-specific. Can be used for hydrogen for which IR does not work.
- **Semi-conductor**: works by measuring the changes in conductivity on the surface of a semiconductor due to the presence of flammable gas or vapour. They are very sensitive but CERN's experience has shown them to be relatively unstable and they respond to a wide range of nonflammable gases and vapours thus causing numerous false alarms.
- **Chromatography**: his works on the differential absorption of compounds and combines specificity with sensitivity but the instruments are expensive and need constant attention.
- **Flame ionisation**: easures the concentration of organic molecules as a function of the current which flows between two electrodes positioned across a hydrogen flame and which is due to the ions formed in the combustion. These detectors are non specific but sensitive.
- Mass Spectrome try: measures the concentration of gas molecules introduced into a vacuum by subjecting them to electron bombardment which causes them to lose electrons and form positive ions. These ions are then accelerated by a negative potential into a quadrupole mass filter where they are separated according to their mass to charge ratio. Such detectors are expensive but sensitive, specific and quantitative.

The last three types of detector are available as sampling type instruments only.

Gas detectors should conform to the standards :-

EN50054 General for gas detectors EN50055 for gases in mines up to 5% methane in air EN50056 for gases in mines up to 100% methane in air EN50057 for gases up to 100% LEL EN50058 for indicating gases up to 100% by volume.

Only three groups are mandated to install gas detection devices at CERN. The ST-MC group is responsible for installing and servicing gas detection systems for experiments, test beams etc. It is also responsible for co-ordinating the passage of their alarms and warnings to the TCR and the Fire Service, as well as for providing the signals to activate ventilation, shut off gas flow and electricity, and activate mandatory local visual and acoustic alarms. The ECP-EOS and EST-LEA groups provide specialised systems for large experiments. The positioning of fixed detectors and sampling lines within a Flammable Gas Zone should be approved by the FGSO in consultation with TIS.

The general operating procedures for experiments or tests using flammable gases must indicate the actions to be taken on the receipt of a gas alarm, and all persons working on the experiment must be aware of them.

In addition to the fixed detectors, sufficient portable detectors must be available in each Flammable Gas Zone to allow the presence of flammable gas to be verified when a warning or alarm is generated by the fixed gas detector system. They can also be used to help locate leaks. Members of the operating team and the SLIMOS's must be trained in their use.

23. VENTILATION

23.1 INTRODUCTION

The object of ventilation in Flammable Gas Zones is to ensure that leaks of flammable gases and vapours do not build up to flammable concentrations in the air. There are basically two ways of doing this. The first is by dilution in the ambient air surrounding the source of any potential leak and the second is by removing the gas near to its source of escape by local extraction ventilation. Dilution may be carried out by natural ventilation due to air currents formed by thermal gradients, density differences, natural air currents (e.g. winds), by diffusion (very slow), or by mechanical movement of the air by fans or other air movers with or without re-circulation. Local extraction ventilation can only be realistically achieved by mechanical means.

N.B. The requirements of smoke extraction and minimisation of fire propagation must be taken into account in the design of ventilation for Flammable Gas Zones.

23.2 NATURAL VENTILATION

The natural movement of air can be judiciously applied to the ventilation of gas storage buildings and to small scale experiments and tests. Gas cylinder storage depots, where the bottles are not opened, are usually ventilated naturally. The cylinders are protected from the weather and direct sunlight by a roof and perhaps one wall, but all other sides are either open or, to prevent unauthorised entry, closed by grilled partitions and doors which allow free circulation of air. To allow eventual leaks to dissipate safely, the boundaries or walls of such storage buildings should be at least 5 metres from possible sources of ignition and well away from roads and areas where there are motor vehicle movements. The cylinders must not be stored under tarpaulins or in any other way that would

obstruct ventilation. Small buildings used for the storage and distribution of gases to experimental systems may be naturally ventilated and closed by grilled partitions and doors. If the gas bottles must be kept warm (e.g. iso-butane), a storage building with fully insulated walls and doors, incorporating natural ventilation grills, may be acceptable at the discretion of the FGSO. Local extraction ventilation will otherwise be required.

Experiments and tests falling in Risk Class 1 (see chapter 6), and situated in large freely ventilated halls, may be exempted from further ventilation requirements at the discretion of the FGSO. It should be noted that, where the flammable gases used are heavier than air, the gas system must not be placed above potential sources of ignition, and in particular electrical and electronic equipment belonging to the experiment. For gases lighter than air the inverse is true. The density of the gases also determines the position of air vents and flammable gas leak detectors.

Where natural ventilation is applied, great care must be taken at all times to ensure that the free movement of air is never obstructed.

23.3 DILUTION VENTILATION

This can be used when the possible leak is very small compared with the volume of the room or hall and particularly when the system can be placed in the open air. The sources of possible leaks of flammable gases must be far away from points of possible ignition so that gases or vapours will be diluted well below the LEL before reaching such points. Dilution ventilation is used mainly in office blocks where air is supplied or re-circulated to remove offensive body odours, small solvent emissions from cleaning (e.g. typewriters), other nuisances such as cigarette smoke and combustion products from heaters. It is also used to replenish the consumed oxygen and maintain an air flow (without which the body reacts adversely). When heating is incorporated into a ventilation system the air is usually partially recirculated to conserve energy, otherwise a supply-only system is more common. Where the air is recirculated and explosive concentrations could build up, local extraction ventilation must be applied. The FGSO in co-operation with TIS experts has the responsibility for deciding on the sufficiency of the local dilution ventilation in a Flammable Gas Zone.

23.4 LOCAL EXTRACTION VENTILATION - LEV

This is a means whereby air from areas close to possible leak sources is extracted through ducting and released to a safe place, usually outside the building. **In order to combine maximum efficiency with minimum cost, the design and installation of such systems is best left to experts.** It is not, therefore, the intention of this chapter to cover the design and installation of such systems, but to give an overview of the principles, limitation and typical points of application.

LEV, as applied to flammable gas installations usually consists of four main components:

- a) **The Hood** the term given to the entry to the system, which may be a straight piece of ducting or a specially designed capture device. A ground floor **bund** (a sort of collecting tray) would fall under this description.
- b) **The Duct** this is a type of pipework to contain the exhausted air and to convey it to the fan.

- c) **The Fan** the source of power to provide a negative pressure at the collection point and move the air to the safe discharge point. Many different types and designs of fan are used as well as non-mechanical devices such as venturis.
- d) **The Stack** the duct or pipe taking the exhausted air from the fan to the safe place of discharge.

LEV is used to remove the leaking gas as it escapes, the air being used as the medium or carrier. This is achieved by imparting sufficient kinetic energy to the mass of relatively still air at the hood so as to induce the leaking gas into the hood. The air velocity which achieves this induction into the hood is termed the "capture velocity". The capture velocity needed to induce gas leaks into a hood ranges from 0.5 m/s for low velocity leaks into relatively still air to 2 m/s for high velocity leaks (say from high pressure systems) released into a zone of relatively rapid air motion. The process is equivalent to producing a slight under pressure at the hood to induce the leaking gas to enter it. It should be noted that the capture velocity produced by an open duct reduces rapidly with distance from the mouth of the duct, e.g. at one duct diameter from the mouth of a plain circular duct the capture velocity would be only about 10% of that of the air in the duct. The efficiency of LEV can be improved by the use of flanges on the duct and by the partial or total enclosure of the system.

N.B. Hoods and bunds are a type of partial enclosure and greatly improve the efficiency of LEV.

There are many types of fan and air mover, each of which has advantages and disadvantages depending on the task it is asked to perform. An explosion-proof motor must be used where there is the possibility of flammable gas being present at the motor. Two speed motors can be used to give low speed air extraction under normal conditions which still ensures that gas leaks are drawn towards a flammable gas leak detector, and to give high speed air extraction when a leak detector indicates the presence of flammable gas (>20%LEL).

24. ELECTRICAL EQUIPMENT

In conformity with the principles of the CERN Electrical Safety Code C1, electrical equipment located in a Flammable Gas Zone must be protected according to the requirements of CENELEC publications and IEC 79-10 which deal with electrical apparatus for explosive atmospheres. These norms define the degree of protection required by electrical apparatus in order to render it explosion proof according to its conditions of use and according to the gases to which it might be exposed.

24.1 CLASSIFICATION OF OPERATING ZONES

IEC 79 - 10 categorises the protection required for electrical equipment by the classification of its operating zone according to its likelihood of exposure to flammable gas as follows :-

- Zone 0: zone in which there is an explosive atmosphere during long periods.
- Zone 1 : zone in which there can occasionally be an explosive atmosphere.
- Zone 2 : zone in which there will only exceptionally be an explosive atmosphere.

Zone 0 and Zone 1 involve the risk of the intentional creation of explosive gas-air mixtures and such zones must be excluded from experimental apparatus to be used at CERN.

N.B. This Zone classification should not be confused with the flammable gas system Risk classification as defined in chapter 6.

Flammable gas operations at CERN in correctly purged particle detector systems normally fall into the Zone 2 category, where there will only be mixing of gas and air either in properly designed exhaust dilution systems, or as a consequence of leaks or operational failures. The following information, which is taken from IEC 79-10, covers operation of electrical equipment in a Zone 2 area.

24.2 PROTECTION CATEGORIES FOR ELECTRICAL EQUIPMENT

Electrical apparatus constructed according to European norms for use in a Flammable Gas Zone is marked with a code. The European Directive ATEX 100a introduced a new code marking which became active on 1/3/96 though the previous code system will still remain valid until 30/6/2003. ATEX 100a will be the only allowed code system from 1/7/2003 onwards. An explanation of these two different systems is given below.

24.2.1 EUROPEAN CODE SYSTEM VALID TILL 30/6/2003

Electrical apparatus is marked with a code of the form:-



The last three groups of symbols are defined in the following lists :-

Protection method :-

0	:	Oil immersion
р	:	Pressurisation
q	:	Powder filling
d	:	Explosion-proof container
e	:	Extra security
i	:	Intrinsic security
m	:	Moulding or potting

Explosion group :-

Explosion group I	: Protection against Methane (mining equipment)
Explosion group II	: Protection against Explosions (all other gases)
Division A	: Methane, Ethane, Propane, Isobutane, n-Butane and n-Pentane

Division B	: Alkenes, Ethers etc.
Division C	: Hydrogen and Acetylene.

Temperature class :-

Gas or vapour auto-ignition temperature

T1	$:= 450 \deg C$
T2	:= 300
T3	:= 200
T4	:= 135
T5	:= 100
T6	:= 85

24.2.2 THE ATEX 100A CODE SYSTEM VALID FROM 1/3/96

Electrical apparatus is marked with a code of the form:-



Equipment Groups and Equipment Categories

Equipment is divided into two Groups which are further subdivided into categories.

Group I applies to equipment used in mining applications where there is a risk of firedamp or combustible dust and it has two corresponding categories :-

- category M1 very high level of protection
- category M2 high level of protection

Group II applies to equipment intended for use in other places which are liable to be endangered by explosive atmospheres and it has three corresponding categories:-

- category 1 very high level of protection
 for equipment intended for use in areas where explosive atmospheres are present continuously or frequently.
- category 2 high level of protection
 for equipment intended for use in areas in which explosive atmospheres are likely to occur.
- category 3 normal level of protectionfor equipment intended for use in areas in which explosive atmospheres are

unlikley to occur or, if they do occur, are likely to do so infrequently and for a short period only.

The marking will also include the name and address of the manufacturer and the year of construction of the equipment.

Electrical equipment in Flammable Gas Zones at CERN will normally be of group II. In the years 1996 to 2003, the new coding will gradually replace the previous coding on commercial equipment.

24.3 USE OF ELECTRICAL EQUIPMENT IN A FLAMMABLE GAS ZONE

24.3.1 GAS LEAK DETECTION

A Flammable Gas Zone 2 must be equipped for detection of gas leaks, and the electrical power must be cut throughout the zone if a leak greater than 20% LEL is detected. Exceptions to this power cut are the gas detection equipment itself, emergency lighting, extraction ventilation and telephone (and any other eqipment), provided that they are approved for Flammable Gas Zone 1 operation. Safety Instruction 37 covers the rules and procedures for with equipment which generate alarms.

The switch gear which cuts the power must be situated outside the zone, or must be Ex rated.

24.3.2 VENTILATION

If the zone constitutes an effectively closed volume, e.g. a closed laboratory, barrack, or the internal atmospheric volume of a large experimental detector, this volume must be subject to forced ventilation or alternatively be filled with inert gas. Leak detection and the cutting of electrical power is required as in section 24. 3. 1. above.

24.3.3 EXPLOSION PROTECTION OF ELECTRICAL EQUIPMENT

Electrical apparatus within a Flammable Gas Zone should conform to CENELEC requirements for Zone 1 as given above. Where apparatus conforming to these norms cannot be obtained, equivalent national standards or improvised protection may be employed subject to the approval of the FGSO together with TIS.

When buying apparatus, the gas type and temperature ratings should be specified to the supplier. In general the preferred protection methods are i (intrinsic) and e (extra security), although d (explosionproof) is sometimes the only solution for power equipment such as motors and switchgear,

e.g. typical protection for isobutane systems would be $\mathcal{E}^{\times}\mathcal{E}\mathcal{E}x$ e IIA T1 in the older marking code,

and $\mathbf{E} \times \mathbf{M}$ 3 G in the new code. Particular attention must be paid to the temperature ratings when flammable liquids are involved. If the liquids are mixtures, or may become diluted during operation, seek the advice of TIS as the Auto Ignition Temperature, T_{ai} , of the mixture may be lower than that of either of the components. Values of T_{ai} for commonly used gases and vapours are given in Annex 1.

24.3.4 IMPROVISED PROTECTION

Electrical apparatus required for use in a Flammable Gas Zone might not be available to explosion proof specifications. In such cases, specific protection must be engineered for the apparatus concerned. This is frequently the case for electrical systems mounted on gas-filled particle detectors. Specific protection would typically be provided by :-

a) **Pressurisation/Flushing**

Where possible, the electrical apparatus should be mechanically enclosed, and this volume should be pressurised (cf. protection class p) Alternatively the volume should be continuously flushed with inert gas (e.g. nitrogen or carbon dioxide). Failure of pressurisation or flushing must be interlocked to cut the gas and electrical supplies to the system concerned. Pressurisation by air should not be employed where there is a risk of the pressurised air reaching the gas volume of a detector via cables or feed throughs.

b) Local Ventilation

Where neither pressurised or flushed enclosures can be used, free or forced ventilation should ensure that no flammable gas can collect near electrical apparatus.

c) "Effective Extra Security"

Where it is necessary to use ordinary industrial quality equipment in a Flammable Gas Zone 2, it must be inspected to ensure that it contains :-

no sparking components	(e.g. switches, thermostats, motor brushes, corona points on HT distributions, etc.)
no exposed connections	(protection from accidental short circuits, use of locked cable connectors etc.)
no hot spots	(e.g. heater elements, solenoid valves, temperatures approaching T_{ai} for the gas or fluid concerned.)

24.4 APPROVAL OF ELECTRICAL EQUIPMENT

The FGSO, together with TIS, must certify all electrical equipment for use in a Flammable Gas Zone which is not certified by a national authority as conforming to the IEC norms.

The protection required by electrical apparatus in Flammable Gas Zones must be agreeed before installation with the FGSO and TIS, and must be approved by them after installation and before gas

is admitted to the system. In particular, they must specifically approve the use of non \mathcal{E}^{XP} ated equipment and improvised protection.

25. TRANSPORT

25.1 INTRODUCTION

This chapter gives an overview of the rules for the transport of dangerous goods (gases) by road, rail and air without the necessity of reading the long and often complex legislation and the large number of rules and prescriptions contained therein. In particular, it aims to clarify the procedures for the transport of gases. **It does not replace the legal texts.**

Since most gases are transported by road this chapter concentrates mainly on this method of transport. Wherever doubts occur TIS should be consulted. Where the transport is to destinations other than the CERN sites, and particularly in the case of air transport, TIS must countersign the Shipping Request and complete all necessary documentation required by the regulations.

N.B. Private vehicles should not be used for the transport of dangerous goods.

25.2 LEGAL BASIS

The transport of dangerous goods is controlled by international and national legislation as given in section 6 of Safety Code G (Flammable Gas Safety Code).

25.3 GENERALITIES

In these regulations dangerous goods and objects are divided into 9 different classes (with subclasses) as follows :

- Class 1 Explosive substances and articles
- Class 2 Gases: compressed, liquefied or dissolved under pressure
- Class 3 Flammable liquids
- Class 4.1 Flammable solids
- Class 4.2 Substances liable to spontaneous combustion
- Class 4.3 Substances which, in contact with water, emit flammable gases
- Class 5.1 Oxidising substances
- Class 5.2 Organic peroxides
- Class 6.1 Toxic substances
- Class 6.2 Repugnant substances and substances liable to cause infection
- Class 7 Radioactive material
- Class 8 Corrosive substances
- Class 9 Miscellaneous dangerous substances and articles

Gases and mixtures of gases, compressed, liquefied or dissolved, as well as empty gas receptacles, are found in **CLASS 2** (**N.B.** This is dangerous goods Class 2 and not to be confused with Risk Classification Class 2 defined in Chapter 6.)

Only gases and mixtures of gases named in these regulations are suitable for transport.

25.4 CLASSIFICATION OF GASES FOR TRANSPORTATION

In dangerous goods Class 2, gases and mixtures of gases are divided in sub-divisions designated by an item number followed by one or two letters according to their physical, chemical or biological properties. The numbers and letters which correspond to the physical properties are attributed as follows :-

- A Compressed gases having a critical temperature below -10° C
 - 1 Pure gases and technically pure gases
 - 2 Mixtures of gases
- **B** Liquefied gases

Liquefied gases having a critical temperature of 70^oC or above

- **3** Pure gases and technically pure gases
- 4 Mixtures of gases

Liquefied gases having a critical temperature of -10° C or above, but below 70° C

- 5 Pure gases and technically pure gases
- 6 Mixtures of gases
- **C** Deeply-refrigerated liquefied gases
 - 7 Pure gases and technically pure gases
 - 8 Mixtures of gases
- **D** Gases dissolved under pressure
 - 9 Pure gases and technically pure gases
- E Aerosol dispensers and non-refillable containers of gas under pressure
 - **10** Aerosol dispensers
 - 11 Non-refillable containers of gas under pressure
- **F** Gases subject to special requirements
 - 12 Mixtures of gases (calibration gases)
 - 13 Test Gases
- **G** Empty receptacles and empty tanks
 - 14 Empty receptacles and empty tanks which are not cleaned

The substances and articles of dangerous goods Class 2 are subdivided according to their chemical properties, as follows:

- (a) non-flammable
- (at) non-flammable, toxic
- (b) flammable
- (bt) flammable, toxic
- (c) chemically unstable
- (ct) chemically unstable, toxic

Unless otherwise specified, chemically unstable substances shall be considered to be flammable.

Table 2Classification of the most commonly used gases at CERN.

GAS	Chemical Formula	Item Number and Sub-division	Physical State in Receptacle
Acetylene	C ₂ H ₂	9 (c)	Dissolved

GAS	Chemical Formula	Item Number and Sub-division	Physical State in Receptacle
Air	-	2 (a)	Compressed
		8 (a)	Liquid, deeply-refrigerated
Ammonia	NH3	3 (at)	Liquefied under pressure
Argon	Ar	1 (a)	Compressed
		7 (a)	Liquid, deeply- refrigerated
Butane	C4H10	3 (b)	Liquefied under pressure
Isobutane			
Carbon Dioxide	CO ₂	5 (a)	Liquefied under pressure
		7 (a)	Liquid, deeply refrigerated
Carbon Monoxide	CO	1 (bt)	Compressed
Chlorine	Ch2	3 (at)	Liquefied under pressure
Chlorodifluoro-	CHClF ₂	3 (a)	Liquefied under pressure
methane			
Dichlorodifluo-	CCh2F2	3 (a)	Liquefied under pressure
romethane			
Dimethylether	CH ₃ OCH ₃	3 (b)	Liquefied under pressure
Ethane	C ₂ H ₆	5 (b)	Liquefied under pressure
Ethylene	C ₂ H ₄	5 (b)	Liquefied under pressure
Helium	Не	1 (a)	Compressed
		7(a)	Liquid, deeply- refrigerated
Hydrogen	H2	1 (b)	Compressed
		7 (b)	Liquid, deeply-refrigerated
Methane	CH4	1 (b)	Compressed
Nitrogen	N2	1 (a)	Compressed
		7 (a)	Liquid, deeply- refrigerated
Nitrous Oxide	N ₂ O	5 (a)	Liquefied under pressure
Oxygen	O ₂	1 (a)	Compressed
		7 (a)	Liquid, deeply-refrigerated
Propane	C ₃ H ₈	3 (b)	Liquefied under pressure
Tetrafluoro- methane	CF ₄	1 (a)	Compressed
Neon	Ne	1 (a)	Compressed
		7 (a)	Liquid, deeply-refrigerated
Xenon	Xe	5 (a)	Liquefied under pressure
		7 (a)	Liquid, deeply-refrigerated
Krypton	Kr	1 (a)	Compressed
		7 (a)	Liquid, deeply- refrigerated

25.5 REGULATIONS CONCERNING RECEPTACLES

The regulations contain very precise technical prescriptions concerning gas receptacles, such as those appertaining to :-

- construction and equipment
- official initial and periodic tests

- marking
- maximum filling pressure
- the limiting capacity
- test pressure
- the maximum filling volume for liquefied gases

In the regulations the different receptacles for gases are defined as :-

- a) A "CYLINDER or "BOTTLE" has a capacity not exceeding **150** litres.
- b) A "FRAME", "RACK" or "BATTERY" of cylinders is an assembly of cylinders which are interconnected by a manifold and held together by a metal fitting.
- c) A "TANK" is a receptacle with a capacity exceeding **1000** litres.
- d) An "AEROSOL" is any non-refillable receptacle made of metal, plastic or glass and containing a gas, compressed, liquefied or dissolved under pressure, with or without a liquid, paste or powder, and fitted with a self-closing relief device allowing the contents to be ejected as solid or liquefied particles in suspension in a gas, as a foam, paste or powder, or in liquid or gaseous state.
- e) Gases used for filling or as dispersion agents are detailed in the regulations.
- f) A "CARTRIDGE" is a receptacle of gas under pressure which can be used only once, which contains a gas allowed by the regulations, but which does not have a self-closing relief device.

Highly refrigerated gases are transported in double walled receptacles and insulated so that they do not become covered in condensation or ice. These receptacles are subject to special rules concerning their construction and ancilliary equipment.

25.6 **REGULATIONS CONCERNING ROAD TRANSPORTATION**

National and international regulations are applicable to the transportation of dangerous goods (gases) carried out by motor vehicles, articulated vehicles, trailers and semi-trailers or, on routes open to these vehicles, by other means of transport. They apply to producers and suppliers of dangerous goods, to shippers and consignees of such goods, to those transporting and handling them as well as to manufacturers of packages or material used for their transport.

The principal provisions of the regulations relating to road transport concern :-

- Complementary third party (RC) assurance
- Types of vehicle and their equipment (emergency tools, lighting and warning panels, fire extinguishers, gas masks etc)
- Service regulations (instructions and training of drivers, prohibition of the consumption of alcohol and of smoking, surveillance of vehicles etc)
- The loading, unloading and handling of dangerous goods (limitation of quantities, prohibition of the common loads, stowage, etc)
- Vehicular traffic (marking of, and signs on vehicles, voluntary stops and parking, restrictions on, or prohibition of traffic on certain sections etc)

25.7 ADDITIONAL RULES AND PROCEDURES

Other rules and procedures which must be followed are :-

- All "Shipping Requests" for dangerous goods must be countersigned by TIS/CFM who will also indicate the regulations to be followed and precautions to be taken.
- Private vehicles should not be used for the transportation of dangerous goods even where the quantity involved is below the limiting value.
- Closed vehicles must be sufficiently well ventilated at all times to prevent the accumulation of dangerous concentrations of gas.
- Smoking is forbidden in vehicles transporting flammable or chemically unstable gases, as well as during loading and unloading of cylinders and in the neighbourhood of vehicles waiting to be loaded or unloaded.
- Compressed or liquefied flammable or chemically unstable gases or mixtures of gases must not be loaded into a vehicle transporting explosives or goods presenting a similar danger.
- Cylinders must not be thrown about or submitted to shock.
- Cylinders must be attached or chocked in such a way so as to prevent them from falling, overturning or rolling.
- Cylinders can be arranged on the floor of the vehicle either longitudinally or transversely. However all cylinders in close proximity to the partition between the load bearing area and the driving cab must be arranged transversely.
- Empty cylinders as well as full ones must be closed and capped.
- Cryogenic containers containing liquefied non-flammable gases at low temperature (numbers 7 (a) & 8 (a)) must be placed in the position for which they were designed. They must be well protected so that they are not damaged by other goods being carried.
- There are restrictions in all countries on the carriage of dangerous goods on certain routes (tunnels, bridges etc.) and the route should be checked, with TIS, before setting off.

N.B. The responsibility to see that the transport regulations are obeyed lies with the person(s) organising the transport. TIS can help in ensuring that all precautions have been taken and that the necessary paperwork has been completed. <u>Every dispatch of dangerous goods by air must be arranged by TIS.</u>

25.8 EXEMPTIONS FROM THE REGULATIONS

Exemptions from **all** the clauses is envisaged for the transport of certain merchandise. Among these exemptions are gas filled cigarette lighters, fire extinguishers containing "Halon 1211" where the capacity does not exceed 2 litres and the pressure does not exceed 15 bar at 15^oC, as well as the

fuel contained in the tank of a vehicle and used for its own power.

25.8.1 PARTIAL EXEMPTION

A **partial exemption** from these regulations is also envisaged for the transport of limited quantities of dangerous goods.

For gases and mixtures of gases, the **maximum** quantities allowed (limiting values) per transport unit^{*} are defined as follows for the sub-classes shown :-

•	Cyanogen Chloride of 3 (ct)	5 kg
•	Phosgene of 3 (at), Fluorine of 1 (at)	50 kg
•	Gases of Classes 1(a), 1(b), 2(a), 2(b)	1000 kg
•	Other gases	333 kg
•	Empty receptacles	333 kg

N.B. These are gross weights and so include the weight of the receptacle.

In the framework of a simple risk analysis the maximum quantities indicated above can be considered as representing the same degree of risk. For a mixed load, i.e. made up of full or empty receptacles of different gases, the same degree of risk must be respected for the whole load.

When the different components of a mixed load are all assigned the same limiting value, the total gross mass of the respective receptacles must not exceed the limiting value for this Class. However, when the different components are not subject to the same limiting value, the respective gross masses must be multiplied by the factor corresponding to their limiting value (as listed below) and the sum of the products thus obtained must not exceed 1000 kg.

Limiting Gross Weight	5 kg	50 kg	333 kg	1000 kg
Multiplication Factor	200	20	3	1

The following examples serve for familiarisation with the calculation methods using the values given above and the classification of the gases given in Table 2.

Example 1: How many bottles of acetylene of 40 litres capacity, each weighing 78 kg gross, can be loaded onto a vehicle without exceeding the limiting value?

- Classification of Dissolved Acetylene (from Table 2)	9 (c)
- Limiting Gross weight for Class 9 (c)	333 kg

Therefore number of cylinders allowed = 333/78 = 4.27, or 4

(4 x 78 = 312 kg < 333 kg)

Example 2: Can 15 cylinders of oxygen of 50 litres capacity and weighing 80 kg each be transported in the same transport unit without exceeding the limiting value?

- Classification of Dissolved Acetylene (from Table 2) 1 (a)

^{*} Motor vehicle with or without an attached trailer.

- Limiting Gross weight for Class 1 (a)

1000 kg

Total gross weight = $15 \times 80 = 1200 \text{ kg} > 1000 \text{ kg}$. \Rightarrow Thus not acceptable.

Number of cylinders allowed = 1000/80 = 12.5, or 12

 $(12 \times 80 = 960 \text{ kg} < 1000 \text{ kg})$. Thus a maximum of 12 cylinders can be transported.

Example 3: A mixed load is made up of

- 3 empty 12 litre propane cylinders weighing together 24.3 kg
- 2 x 40 litre cylinders filled with liquefied Nitrous Oxide, each weighing 80 kg
- 4 cylinders of compressed oxygen each weighing 78 kg.

Is it possible to transport other dangerous materials while still benefiting from a partial exemption?

- Classification of the gases (from Table 2)

Propane Nitrous Oxide Compressed Oxygen	3 (b) 5 (a) 1 (a)
- Limiting Gross weight for Classes 3 (b) & 5 (a)	333 kg
- Limiting Gross weight for Class 1(a)	1000 kg
- Multiplication factor for the limiting gross weight 333 kg	3
- Multiplication factor for the limiting gross weight 1000 kg	1
- Limiting gross weight for a mixed load	1000 kg

Calculation of the total gross weight

Gross weight of the load:

24.3 kg	Х	3 (coefficient) = 73 kg
2 x 80 kg	Х	3 (coefficient) = 480 kg
4 x 78 kg	Х	1 (coefficient) = 312 kg
		Total = 865 kg < 1000 kg

The load can thus be increased by 135 kg of dangerous goods of which the limiting gross weight is 1000 kg or by 135/3 = 45 kg of goods of which the limiting gross weight is 333 kg.

25.8.2 DEROGATIONS ALLOWED BY THE PARTIAL EXEMPTION

The partial exemption means that certain regulations are not applicable or only partially so. This is a derogation which eases and simplifies the transportation of small quantities.

The principal regulations which are no longer applicable are those relative to :-

- the type of vehicle
- the surveillance of vehicles
- instructions in writing
- special training of drivers
- increased third party insurance
- places of loading and unloading
- marking of vehicles

N.B. In spite of the partial exemption certain regulations must still be applied and those following are the principal ones :-

Dispatchers, carriers and consignees of dangerous goods must give all the necessary information so that the rules and controls can be carried out. They must allow access to their premises so that any investigations can be carried out.

The carrier must be in possession of a transport document, the type of which is not specified, but which can be a commercial document such as a delivery order, a transport voucher or a railway consignment note, on condition that the description of the goods corresponds to the following requirements :-

- a) Pure gases and technically pure gases of item numbers 1,3,5,7 & 9 as well as pressurised aerosol containers of item 10 and gas cartridges of item number 11 <u>must</u> be described as written in Table 2.
- b) Mixtures of gases of item numbers 2,4,6,8,12 & 13 must be described as "mixture of gases" with an indication of the different components and the % by volume or by weight. Components less then 1% do not have to be given.
- c) The above descriptions must be underlined and completed by the indication of the class, item number and the characteristic letter(s) and the initials RID or ADR*. (e.g. <u>oxygen</u> 2, 1(a) ADR)
- d) The transport document must also contain the phrase
 "Transport not exceeding the limit given in the marginal 10 011 (1)".
 During the transport one copy of this document must be carried in the driving compartment.

^{*} RID refers to the international regulations for transport by rail, and ADR for transport by road. These are referenced in the CERN Flammable Gas Safety Code

GLOSSARY

N.B. Definitions are given for use with this document and are not always the rigorous definition of a particular term.

Asphyxiation	The action of producing the condition of suspended animation due to a deficiency of oxygen in the blood.
AutoignitionTemperature (Tai)	The lowest temperature at which a mixture of air and a flammable gas ignites spontaneously without ignition from an external source of energy.
Battery	An assembly of cylinders interconnected by a manifold and held together by a metal fitting. Also known as a Frame or Rack of cylinders.
Bottle	Synonymous with cylinder.
Bund	A low retaining wall at floor level to trap leaking gases with a density greater than air, to enable them to be detected and extracted more efficiently.
Bursting Disc	A pressure relief device consisting of a disc, usually of metal or graphite, designed to burst at a given pressure to relieve an accidental overpressure on a gas system.
CEN	The European Committee for Standardisation which makes standards recognised by the European Union as does CENELEC below.
CENELEC	The European Committee for Electrotechnical Standardisation
Cylinder	A gas container (usually made of metal) designed to be transportable.
Deflagration	An explosion in which the flame front moves relatively slowly (< velocity of sound). In hydrocarbon/air mixtures the deflagration velocity is typically of the order of 1 m/s.
Density	The mass of a given volume of gas, at a standard temperature and pressure. Usually expressed in kg/m3
Detonation	An explosion in which the flame front travels as a shock wave followed closely by a combustion wave which releases the energy to sustain the shock wave. The shock front moves with a velocity greater than the velocity of sound. In hydrocarbon/air mixtures the detonation velocity is typically of the order of 2000-3000 m/s (cf. velocity of sound in air at sea level is 330 m/s). A detonation creates greater pressures and is more destructive than a deflagration.

Diffusion	The movement of gases due to the velocity of their molecules and not to pressure differentials. This means that gases will slowly mix even when no external mixing is provided, and they will pass through porous membranes (including the walls of plastic pipes)
DSO	Divisional Safety Officer
Emergency Stop	A device (usually a large button or switch retained by a breakable glass panel) which when actuated causes shutdown of designated electrical equipment in a defined area.
Explosion	The sudden and violent release of energy. In this document it refers to the explosion due to the ignition of a flammable gas/air mixture in a confined space provoking a deflagration or detonation.
Explosion Group	Electrical equipment is grouped according to the properties of the gases and vapours involved. Group I for application in coal mining; Group II for application in other industries. At CERN it is only Group II which is of interest. This is further subdivided into subgroups A, B and C according to the increasing reactivity and decreasing ease of extinction of an explosion of the gases concerned.
Ex, EEx, Ex-proof or Ex-rated	Electrical equipment which has been constructed to be explosion proof.
Extraction (Ventilation)	A ventilation system designed to remove a contaminent (flammable gas) at source and to transport it to a safe place.
FGSO	Flammable Gas Safety Officer
Fire	The rapid reaction of a substance with air, accompanied by heat and flame or glowing.
Flammable Gas	A gas which reacts with oxygen, either pure or diluted as in air, releasing a large quantity of heat and producing a flame.
Flammable Gas Leak Detector	A device, usually electronic, to detect low concentrations of flammable gas coming from leaks well before the Lower Explosive Limit is reached. They may be fixed or portable. Fixed devices give alarms and may shut off gas and electricity and actuate extraction ventilation.
Flammable Gas Zone	A zone defined by the GLIMOS of an experiment in agreement with the FGSO as being that where there is a risk of fire and/or explosion should a leak of flammable gas occur, and which thus is subject to special precautions.
Flammable Range	All concentrations of flammable gas in air between the Lower and Upper explosive limits.
Flammable Vapour	The flammable gas evaporated from a substance which is liquid at ambient temperatures.
Flash Point	The lowest temperature at which a liquid gives off vapour sufficient to form an ignitable mixture with the air at its surface.

Frame	A metal frame specially designed to hold a number of gas cylinders which are connected to one outlet valve. Synonymous with Battery or Rack of cylinders.
Gas	An element or compound in a state of matter charactarised by a marked sensitivity of volume to changes in temperature and pressure and by the fact that it has no bounding surface and so tends to fill completely any avaiable space.
Gas Distribution System	A sytem of pipes or tubes together with pressure and flow regulating devices, valves etc, which distributes gas from one fixed point to another. This may be from storage to mixing room, from mixing room to experiment or from experiment to a safe discharge point.
Gas Rack	A framework supporting and centralising a gas distribution or a gas mixing sytem. As well as pipework it will usually contain valves, flowmeters and manometers etc.
	The term Rack is also used synonymously with Battery or Frame of cylinders as an assembly of cylinders interconnected by a manifold and held together by a metal fitting.
Gas Storage Area	A building or area specifically designed to store cylinders of gas either fully closed or connected to a gas distribution system.
Gas System	The whole system containing gas from the storage area to the safe discharge point via mixing devices and experiment and including the pipework.
GLIMOS	Group Leader in Matters of Safety. The GLIMOS has the overall and direct responsibility for all aspects of safety of an experiment. He is a member of the collaboration and has full authority over it for safety matters.
Hood	An overhead collecting cowl or similar device to aid the detection and extraction of leaks of gases lighter than air
Hot Tools	Fires and explosions can be caused by work done with hot tools which includes: grinding or cutting producing sparks or hot fragments; electric, oxyacetylene or plasma welding or cutting; heating with a blow lamp or propane lance; soldering.
Inflammable	Synonymous with "flammable" Does NOT mean non-flammable.
ISIEC	Initial Safety Information for Experiments at CERN. Refers to a form on which the information must be forwarded to the DSO concerned.
LEL	Lower Explosive Limit. Synonymous with Lower Flammable Limit defined below.
Lower Flammable Limit	The minimum concentation of a gas or vapour in air in which a flame can be propagated. Below this concentration the mixture is too lean to burn, the energy from the combustion of one molecule being dissipated before it can activate another molecule to propagate the flame.

Minimum Ignition Energy	The minimum energy of an electrical discharge required to ignite a flammable gas-air mixture. This minimum usually occurs close to the stoichiometric mixture.
Nominally Empty Cylinder	A cylinder from which most, if not all, the contents have been discharged but which may still contain residual gas or vapour.
Passivation	The treatment of stainless steel electrochemically or by an oxidising acid (e.g. nitric or chromic acid) to thicken the naturally occurring protective oxide layer and thus increase the corrosion resistance.
Pressure Vessel	A totally enclosed container, not exposed to open flame, but which is or may be subjected to an internal or external pressure.
Purge	To replace air in a flammable gas system with an inert gas before the introduction of flammable gas, or to replace flammable gas in a system with an inert gas before allowing the ingress of air.
Rack	An assembly of cylinders interconnected by a manifold and held together by a metal fitting. Also known as a Battery or Frame of cylinders.
Safety Relief Valve	A valve used to relieve excess pressure and characterised by rapid full opening or pop action. There are many types but the most common type used at CERN is the spring loaded direct acting relief valve.
SLIMOS	Shift Leader in Matters of Safety. When an experiment is run in shifts, the SLIMOS takes on the responsibilities of the GLIMOS during the latter's absence.
Tai	Autoignition temperature, which is the lowest temperature at which a mixture of air and a flammable gas ignites spontaneously without ignition from an external source of energy.
TCi	The concentration of a flammable gas in a mixture with an inert gas for which the mixture is just not flammable in air.
TCR	Technical Control Room which is manned 24hours/day 365 days/year. The operators are informed of warnings and alarms produced on the CERN site via computer screens. They either correct faults themselves or call in expert help.
Temperature Class	Equipment is assigned a maximum surface temperature which should not be exceeded. This corresponds to the autoignition temperature of the gases or vapours involved.
TIS	The Technical Inspection and Safety Commission supervises and enforces safety at CERN. Its executive tasks involve the Fire Brigade, the Medical Service, Radiation Protection and the two groups listed immediately below.
TIS-CFM	The TIS group dealing with Chemistry, Fire and Materials.
TIS-GS	The TIS group dealing with General, Electrical and Mechanical Safety.

UEL	Upper Explosive Limit. Synonymous with Upper Flammable Limit defined below.
Upper Flammable Limit	The maximum concentration of a gas or vapour in air in which a flame can be propagated. Above this concentration the mixture is too rich to burn, the oxygen being used up in the combuson of one molecule leaving insufficient oxygen to burn the next adjacent molecule of fuel.
Vapour	A gaseous substance at a temperature below its critical temperature. Often regarded as being the gaseous part of a substance which is liquid at ambient temperatures.
Ventilation	The natural or forced movement of air to dilute or remove a dangerous contaminent.

GAS FLAMMABILITY TABLES

This table gives the TCi value for some mixtures of gases commonly used in detectors.

nert gases			Flammable	gases			
	Hydrogen (H2)	Methane (CH4)	Ethane (C2H6)	Propane (C3H8)	Iso-Butane (i-C4H10)	n-Butane (n-C4H10)	DME
<purity></purity>	٥	<35>	<24>	<35>	<35>	٥	٥
V2 <45>		%6'6	4.94%	4.25%	4.1%		
202 <30>		22.45%	60.6	7.95%	7.95%		
He < 46>		11.86%	5.45%	4.41%	4.15%		
Ne <40>		9.2%	4.37%	3.45%	3.26%		
Ar <46>		6.15%	3.05%	2.76%	2.4%		
SF6 <30>		50.4%	20.4%	20.4%			
CF4 <>		33.4%			9.5%		
č134a <>							
EL (%)		4.4%	2.4%	1.8%	1.55%		
JEL (%)		16.9%	14.6%	10.4%	8.4%		

Flammability Characteristics of Commonly Used Gases and Binary Mixtures

GAS	HEAT OF CO	MBUSTION	K = ratio of Heat of
	(H2O & CO2	Gas)	Combustion to that of
	Kcal./mole Ko	al/Kg	hydrogen
HYDROGEN	57.7979	28900	1.0
METHANE	191.759	11988	0.42
ETHANE	341.261	11377	0.39
PROPANE	488.527	11002	0.38
iso-BUTANE	635.384	10955	0.38
n-BUTANE	635.384	10955	0.38
n-PENTANE	782.04	10861	0.38
DIMETHYL ETHER (DME)	359.33	7811	0.27

Although the heat of combustion of hydrogen is more than twice that of methane. ethane etc, these gases have a greater heat of combustion per unit **volume** because of their higher density.

PHYSICO-CHEMICAL PROPERTIES OF FLAMMABLE GASES AND VAPOURS IN COMMON USE AT CERN

Gas	Mol.	LEL	UEL	Auto-	Minimum	Explo-	Tempera-	Relative	Physical	Boiling	Pressur
	Wt.	%v/v	%v/v	Ignition	Ignition	sion	ture	Density	State in	Pt. oC	e in
				Temp.	Energy	Group	Class (Ex)	Air=1	Bottle		Bottle
				oC	mJ	(Ex)					@15 oC
											Bars
											Abs
Acetylene (C2H2)	26	1.5	100	305	0.02	IIC	T2	0.91	Dissolved	-84	16-19
Hydrogen (H2)	2			560	0.019	IIC	T1	0.695	Gas	-253	180-200
Methane (CH4)	16	4.4	16.9	537	0.29	IIA	T1	0.55	Gas	-161.5	180-200
Ethane C2H6)	30	2.4	14.6	515	0.24	IIA	T1	1.05	Liquid	-89	33.8
Propane (C3H8)	44	1.8	10.4	493	0.25	IIA	T1	1.56	Liquid	-42	8,8
n-Butane C4H10)	58			372	0.25	IIA	T2	2.05	Liquid	-1	1.76
iso-Butane	58	1.55	8.4	462	0.25	IIA	T1	2.05	Liquid	-11.7	2.56
(CH3CH(CH3)CH3											
)											
n-Pentane (C5H12)	72	1.4	8.0	258	0.25	IIA	T3	2.48	Liquid	+36	
Dimethyl Ether	46	3.0	27.0	350		IIB	T2	1.59	Liquid	-25	4,24
(CH3-O-CH3)											

PHYSICO-CHEMICAL PROPERTIES OF NON-FLAMMABLE GASES AND VAPOURS IN COMMON USE AT CERN

Gas	Mol. Wt.	Relative Density Air=1	Physical State in Bottle	Boiling Pt. oC	Pressure in Bottle @15 oC Bars Abs
Helium (He)	4	0.14	Gas	-268.93	180-200
Neon (Ne)	20	0.7	Gas	-252.77	180-200
Argon (Ar)	40	1.38	Gas		180-200
Krypton (Kr)	83.8	2.91	Gas	-153.35	180-200
Gas	Mol. Wt.	Relative Density Air=1	Physical State in Bottle	Boiling Pt. oC	Pressure in Bottle @15 oC Bars Abs
----------------------------	-------------	------------------------------	-----------------------------	-------------------	--
Xenon (Xe)	131.3	4.56	Gas (above 16.58C)	-108.1	8,8
Nitrogen (N2)	28	0.97	Gas	-195.8	180-200
Oxygen (O2)	32	1.1	Gas	-182.97	180-200
Carbon Dioxide (CO2)	44	1.53	Liquid	-78.5*	51
Carbon Tetrafluoride (CF4)	88	2.84	Gas	-127.94	180-200
Sulphur Hexafluoride (SF6)	146	5.11	Liquid	-63.8*	18.4
R 134a (CH2F - CF3)	102		Liquid	-26.5	4.9
Air	29	1	Gas	-194.35	180-200

*Sublimation Point @ 1 Bar Abs.

ANNEX A2

TYPICAL EXAMPLES OF GAS MIXING AND DISTRIBUTION SYSTEMS

This annex contains illustrations of typical gas mixing and distribution systems.

Figure 1. A complete gas distribution system divided into three separate areas; the storage and mixing areas and the experiment itself. These are physically isolated from each other and can be treated individually for Risk Classification.

The flammable gas undergoes primary distribution from its storage room. The non flammable gases have their own storage and primary distribution area, and one of these gases is shown as being distributed from a Dewar. The mixed gas is split into many individually monitored channels in the experimental area before being passed through the detector units.

In this simple system, the output gas from the detectors is exhausted directly to the atmosphere.

Figure 2. A mixing system in which one of the components is supplied as a liquid which is evaporated into the carrier gas which is itself a mixture of gases.

Figure 3. A mixing system in which the return gas is recirculated.

Normally the return gas will pass through a purifier and some fraction of it will be exhausted to avoid the build up of impurities. The main flow is then topped up from the mixer.

Figure 4. Standard symbols used to represent components of gas distribution systems.









GAS CYLINDER



COMPRESSOR



BLOWER



FILTER

FLOW METER



MASS FLOW METER



BUBBLER



MASS FLOW CONTROLLER





THROTTLE VALVE



PRESSURE GAUGE



PNEUMATIC VALVE

SOLENOID VALVE



THROTTLE VALVE

THREE WAY VALVE



PRESSURE REGULATOR

BACK PRESSURE REGULATOR

TYPICAL FLOW SHEET SYMBOLS

A MORE COMPREHENSIVE LIST MAY BE FOUND ON SERVER ------?

Figure 4.

SAFETY RELIEF VALVE



 \rightarrow QUICK ACTING COUPLING

QUICK COUPLING WITH AUTO CLOSING

 ∇

THERMOMETER

PRESSURE SWITCH

т

INDEX

to be added here after final draft