

Safe Handling of Cryogenic Liquids

低温液体的安全操作

Introduction

引言

A cryogenic liquid is defined as a liquid with a normal boiling point below -240°F (-150°C). The most commonly used industrial gases that are transported, handled, and stored in the liquid state at cryogenic temperatures are argon, helium, hydrogen, nitrogen, and oxygen.

低温液体定义为正常沸点在 -240°F (-150°C)以下的液体。氩、氦、氢、氮和氧是在低温以液体状态运输、操作和储存的最常用的工业气体。

There are a number of general precautions and safe practices that must be observed because of the extremely low temperatures and high rates of conversion into gas of all the cryogenic liquids. There are also specific precautions that must be followed where a particular liquid may react with contaminants or may present other hazards associated with that particular product such as asphyxiation or flammability.

由于所有低温液体的极低的温度和极高的气化率，必须遵守许多的通用防范措施和安全惯例。在特定液体可能和污染物反应的地方，或者在存在同那种特定液体相联系的其它危险，如窒息和易燃性的地方，还要有专门的防范措施。

The user of any cryogenic liquid covered in this Safetygram should be familiar with both the general and specific precautions outlined. Safetygrams for individual cryogenic liquids are available and should be consulted for additional information. Please consult supplier to determine which Safetygrams may be of assistance. As always, end users should have and be thoroughly familiar with the Material Safety Data Sheet (MSDS) for their specific product. All operators must be familiar with the instructions provided with the equipment to be used with the cryogenic liquid.

本文所涉及的任何低温的使用者都应对所概括的通用和专门的防范措施很熟悉。现在有单个低温液体的安全程序，要得到另外的资料可以参考它们。请咨询网址供应商以确定哪个安全程序会对你有帮助。一如既往，终端用户应该拥有和彻底熟悉他们的特殊产品的产品安全数据表(MSDS)。所有操作员必须对用于低温液体的设备所提供的说明书很熟悉。

General Safety Precautions

通用的安全防范

Many of the safety precautions observed for gases in the gaseous state also apply to the same gases in the liquid state. However, each cryogenic liquid has its own unique properties. Also, all cryogenic liquids involve potential hazards that stem from the following properties:

对于气态的气体适用的安全防范中的许多还可以应用于液态的同样气体。但是，每种低温液体有它自己独特的性质。所有低温液体还涉及来自下列性质的潜在危险：

1. All cryogenic liquids are extremely cold. Cryogenic liquids and their vapors can rapidly freeze human tissue and can cause many common materials such as carbon steel, rubber, and plastics to become brittle or even break under stress. Cryogenic liquids in containers and piping at temperatures at or below the boiling point of liquefied air [-318°F (-194°C)] can actually condense the surrounding air and can cause a localized oxygen-enriched atmosphere. Extremely cold cryogenics such as hydrogen and helium can even freeze or solidify the surrounding air.

所有低温液体的温度都极低。低温液体和它们的蒸气能够迅速冷冻人体组织，而且能导致许多常用材料，如碳素钢、橡胶和塑料变脆或者甚至在压力下破裂。容器和管道中的温度在或低于液化空气沸点[-318°F (-194°C)]的低温气体实际上能够浓缩周围的空气，导致局部的富氧空气。极低温液体，如氢和氦甚至能冷冻或凝固周围空气。

2. All cryogenic liquids produce large volumes of gas when they vaporize. For example, one volume of liquid nitrogen at atmospheric pressure vaporizes to 694 volumes of nitrogen gas at 68°F (20°C). A cryogenic liquid cannot be indefinitely maintained as a liquid even in well-insulated containers. If these liquids are vaporized in a sealed container, they can produce enormous pressures that could rupture the container. For this reason pressurized cryogenic containers are normally protected with multiple devices for over-pressure prevention. Common pressure-relief devices are a pressure-relief valve for primary protection and a rupture disc for secondary protection. All sections of equipment that may allow for the liquid to become trapped must be protected by a pressure-relief device as shown in Fig. 1. The product vented by these relief devices should be routed to a safe outdoor location.

所有低温液体在蒸发时都会产生大量的气体。例如，一个大气压下的单位体积的液态氮在 68°F (20°C)时蒸发成694个单位体积的氮气。即使在隔热良好的容器内，低温液体不能无限地维持在液态。如果这些液体在密封容器内蒸发，它们会产生能够使容器破裂地巨大压力。由于这个原因，一般用多种装置来保护受压低温容器，以防止过压。常用的减压装置是一个作为主要保护的减压阀和一个作为二级保护的破裂盘。

3. Vaporization of a cryogenic liquid, except oxygen, in an enclosed area can cause asphyxiation by displacing the air. Vaporization of liquid oxygen in an enclosed area can cause oxygen-enrichment which could saturate combustibles in the area such as workers' clothing. This can cause a fire if an ignition source is present. Although oxygen is not flammable it will support and vigorously accelerate the combustion of other materials.

除了氧以外，在封闭区域内的低温液体会通过取代空气导致窒息。在封闭区域内的液氧蒸发会导致氧富集，它会充满该区域的可燃物，如工人的衣服。如果存在火源，这会导致起火。尽管氧本身是不可燃的，它能支持和大大加速其它材料的燃烧。

Most cryogenic liquids are odorless, colorless, and tasteless when vaporized into the gaseous state. Most liquids also have no color except liquid oxygen, which is light blue. However, extremely cold liquids and their vapors have a built-in warning

property that appears whenever they are exposed to the atmosphere. The cold "boil-off" gases condense the moisture in the surrounding air, creating a highly visible fog. This fog can also be formed around cold equipment when no release of the cold liquid or vapors has occurred. **Fog clouds do not define the vapor cloud.** They define the area where the vapors are still cold enough to condense the moisture in the air. The vapors can extend well beyond the fog cloud depending on the product and atmospheric conditions. Although fog clouds may be indicative of a release, they must never be used to define the leak area and should not be entered by any one. The dense fog clouds associated with the handling or transfer of cryogenic liquids can obstruct visibility. Care should be exercised so that any clouds do not interfere with vehicle traffic or safety escape routes. 当蒸发到气态时，大多数低温液体是无嗅、无色和无味的。除了液氧是淡蓝色外，大多数液体也是无色的。但是极低温液体和它们的蒸气具有一种固有的警告性特征。无论它们什么时候暴露在空气中，该特征就会出现。低温汽化气体浓缩周围空气里的水份，产生非常显著的雾。当低温液体没有泄漏或已经产生了水蒸汽时，这种雾也会在低温设备附近生成。雾云不能确定蒸汽云的界限。它们只是界定了水蒸汽仍然冷得足够浓缩空气中的水分的区域。依赖于产品和空气的状况，蒸汽可以在雾云上延伸得很宽。尽管雾云可以指示泄漏，但它们不能用来界定泄漏的区域，而且任何人不能进入雾云。同低温液体的操作或转移相关的浓密雾云会影响能见度。应该十分小心，不能让任何雾云干扰车辆交通或安全撤离路线。

Handling

操作

Always handle cryogenic liquids carefully. Their extremely low temperatures can produce cryogenic burns of the skin and freeze underlying tissue. When spilled on a surface, they tend to spread as far as the quantity of liquid spilled and the physical confines of the area permit. They can cool large areas. The vapors coming from these liquids are also extremely cold and can produce burns.

总是小心地操作低温液体。它们的超低温会造成皮肤冻伤和皮下组织冻结。当溅在某个表面上时，它们就会在飞溅液体的数量和该区域的物理界限允许的情况下蔓延得足够远。它们能够冷却很大的区域。这些液体产生的蒸气温度也很低，能造成冻伤。

Exposure to these cold gases, which is too brief to affect the skin of the face or hands, may affect delicate tissues, such as the eyes. Stand clear of boiling and splashing liquid and the cold vapors that are released. Boiling and splashing always occur when charging a warm container or when inserting objects into the liquid. Always perform these operations slowly to minimize the splashing and boiling. Never allow any unprotected part of your body to touch uninsulated pipes or vessels containing cryogenic liquids. The extremely cold material may stick fast to skin and tear the flesh when you attempt to withdraw it. Even nonmetallic materials are dangerous to touch at these low temperatures. Use tongs to immerse and remove objects from cryogenic liquids. In addition to the hazards of frostbite or flesh sticking to cold materials, objects that are soft and pliable at room temperature, such as rubber or plastics, are easily broken because they turn brittle at low temperatures and may break when stressed.

时间太短而没有影响面部或手部皮肤的在这些低温气体中的暴露,可能影响脆弱的组织,如眼睛。避开沸腾和飞溅的液体及其释放的低温蒸气。当向温暖的容器内灌装或把物体插入液体时,总是要发生沸腾和飞溅的。总是要慢慢地进行这些操作,把沸腾和飞溅减少到最小。禁止允许你的身体的任何未受到保护的部分接触不隔热的装有低温液体的管道或容器。超低温物质会迅速粘住皮肤,当你试图拉开时会把肉撕裂。在这种低温下,甚至接触非金属材料也是危险的。用夹具浸入低温液体中来移动物体。除了冻伤和肉粘在低温材料上的危险以外,在室温下柔软而有弹性的物体,如橡胶和塑料很容易断裂。这是因为它们在低温下变脆,当受力时断裂。

Personal Protective Equipment

个人防护装备

Personnel must be thoroughly familiar with the properties and safety considerations before being allowed to handle a cryogenic liquid and its associated equipment.

在允许操作低温液体和它的相关设备之前,人员必须对性质和安全的考虑完全熟悉。

The eyes are the most sensitive body part to the extreme cold of the liquid and vapors of cryogenic liquids. The recommended personal protective equipment for handling cryogenics includes a full face shield over safety glasses, loose-fitting thermal insulated or leather gloves, long sleeve shirts, and trousers without cuffs. In addition, safety shoes are recommended for people involved in the handling of containers. Depending on the application, special clothing suitable for that application may be advisable.

眼睛是对低温液体的液体和蒸气的超低温最敏感的人体部分。推荐用于操作低温液体的个人防护装备包括套在安全眼镜外的全封闭面罩、干净的宽松的隔热或皮手套、长袖衬衣和无翻边裤子。另外,向与操作容器有关的人员推荐使用安全鞋。根据应用的不同,可能需要适合于那种应用的专门服装。

A special note on insulated gloves: Gloves should be loose-fitting so they are able to be quickly removed if cryogenic liquid is spilled on them. Insulated gloves are not made to permit the hands to be put into a cryogenic liquid. They will only provide short-term protection from accidental contact with the liquid.

有关隔热手套的一个特别注意:手套应该是宽松的,这样如果低温液体溅在上面才能迅速地取掉。隔热手套不是做来让手放进低温液体的。它们只能对偶然接触液体提供短时间的保护。

In emergency situations, self-contained breathing apparatus (SCBA) may be required.

在紧急情况下,可能要求有自给式呼吸器。

Special Inert Gas Precautions

惰性气体的特别防范

The potential for asphyxiation must be recognized when handling inert cryogenic liquids. Because of the high expansion ratios of cryogenic liquids, air can quickly be displaced. Oxygen monitors are recommended whenever cryogenic liquids are handled in enclosed areas. People should not be permitted in atmospheres containing less than 19.5% oxygen without supplied air.

必须认识到，在操作惰性低温液体时存在窒息的可能性。无论什么时候在封闭区域操作低温液体时，推荐使用氧监测仪。在没有补给空气的情况下，禁止任何人进入含氧量低于19.5%的空气中。

Liquid helium has the potential to solidify air, which can block pressure-relief devices and other container openings. This can result in pressure buildup that may rupture the container.

液氦有凝固空气的潜力，这会阻塞减压装置和其它的容器开口，导致可以使容器破裂的压力积累。

Special Oxygen Precautions

氧的特别防范

Do not permit smoking or open flames in any areas where liquid oxygen is stored or handled. Do not permit liquid oxygen or oxygen-enriched air to come in contact with organic materials or flammable or combustible substances of any kind. Some of the organic materials that can react violently with oxygen when ignited by a spark or even a mechanical shock are oil, grease, asphalt, kerosene, cloth, tar, and dirt that may contain oil or grease. If liquid oxygen spills on asphalt or other surfaces contaminated with combustibles, do not walk on or roll equipment over the spill area.

Keep sources of ignition away for 30 minutes after all frost or fog has disappeared. 在任何储存和操作液氧的区域，严禁吸烟或明火。严禁液氧或富氧空气接触有机材料或任何种类的可燃或易燃物质。当被火星，甚至是机械震动点燃时，一些有机材料能够同氧剧烈反应。这些有机材料包括油、润滑脂、沥青、煤油、焦油和含油或润滑脂的污垢。如果液氧溅到沥青或者其它被可燃物污染的表面，不要在上面行走或碾压设备。远离火源30分钟，直到所有的霜和雾都消失。

Any clothing that has been splashed or soaked with liquid oxygen or exposed to high oxygen concentrations should preferably be removed immediately and aired for at least an hour. Personnel should stay in a well-ventilated area and avoid any source of ignition until their clothing is completely free of any excess oxygen. Clothing saturated with oxygen is readily ignitable and will burn vigorously.

必须立刻脱掉任何被液氧喷溅或浸湿或暴露于高氧浓度的衣物，并使之通风至少一个小时。人员应一直呆在通风良好的区域，避开任何火源，直到他们的衣物彻底没有任何多余的氧为止。吸饱了氧的衣物很容易点燃，而且燃烧剧烈。

Special Hydrogen Precautions

氢气的特别防范

Do not permit smoking or open flames in any area where liquid hydrogen is stored or handled. All major stationary equipment should be properly grounded. All electrical equipment and wiring should be in accordance with National Fire Protection Association Pamphlet 50B and/or National Electrical Code, Article 500. Boil-off gas from closed liquid hydrogen containers used or stored inside buildings must be vented to a safe location.

在任何储存和操作液氢的区域，严禁吸烟或明火。所有大型固定设备都要接地良好。所有的电力设备和配线都要符合国家消防协会手册50B 和/或国家电力法Article 500的规定。

Liquid hydrogen should not be poured from one container to another, or transferred in an atmosphere of air. If this is done, the oxygen in the air will condense in the liquid hydrogen, presenting a possible explosion hazard. Liquid hydrogen also has the potential of solidifying air which can block safety relief devices and other openings, which may lead to rupture of the container. Dewars and other containers made of glass are not recommended for liquid hydrogen service. Breakage makes the possibility of explosion too hazardous to risk.

不能把液氢从一个容器倒入另一个容器，或者在空气气氛里转移液氢。如果这样做，空气中的氧会浓缩在液氢里，造成可能的爆炸危险。液氢有凝固空气的潜力，这会阻塞减压装置和其它的容器开口，可能导致容器破裂。对于液氢建议不要使用杜瓦瓶和其它玻璃制成的容器。破碎会造成爆炸的可能性，这样太危险，不值得冒这个险。

Every effort must be made to avoid spills, regardless of the rate of ventilation, because it is impossible to avoid creating a flammable vapor cloud.

无论通风率怎么样，液氢一旦溅出，不可避免会产生蒸气云，所以必须想尽一切办法避免飞溅。

Containers

容器

Cryogenic liquids are stored, shipped, and handled in several types of containers, depending on the quantity required by the user. The types of containers in use are the dewar, cryogenic liquid cylinder, and cryogenic storage tank. Storage quantities vary from a few liters to many thousands of gallons. Since heat leak is always present, vaporization takes place continuously. Rates of vaporization vary depending on design of the container, ambient conditions, and the volume of stored product.

根据用户要求的量，使用高压钢瓶、管道或管道拖车来运输和储存液态氧。使用中的容器类型包括杜瓦瓶、低温液体钢瓶和低温储存罐。储存量从几升到成千上万加仑。由于热泄露总是存在，蒸发不断地发生。蒸发率随容器的设计、周围环境和储存容量而变化。

Containers are designed and manufactured according to the applicable codes and specifications for the temperatures and pressures involved.

钢瓶的设计和制造是按照相应的压力和温度所适用的法规和规范。

Dewars

杜瓦瓶

A typical, vacuum-jacketed dewar. A loose-fitting dust cap over the outlet of the neck tubes prevents atmospheric moisture from plugging the neck and allows gas produced from vaporized liquid to escape. This type of container is non-pressurized. The most common unit of measure for the capacity of a dewar is the liter. Five- to 200-liter dewars are available. Product may be removed from small dewars by pouring, while larger sizes will require a transfer tube. Cryogenic liquid cylinders which are pressurized vessels are sometimes incorrectly referred to as dewars.

一个典型的带有真空夹层的杜瓦瓶。颈部出口上的宽松的防尘盖可以防止空气中的水蒸汽堵塞颈

部，同时允许液体蒸发产生的气体逸出。这种容器是不加压的。测量杜瓦瓶的容积最常用的单位是升。5到200升的杜瓦瓶都有。液氧可以从小杜瓦瓶中倒出来，而较大尺寸的杜瓦瓶需要传递管来取出液体。作为加压容器的低温液体钢瓶有时候被错误地称作杜瓦瓶。

Cryogenic Liquid Cylinders

低温液体钢瓶

A typical cryogenic liquid cylinder. Cryogenic liquid cylinders are insulated, vacuum-jacketed, pressure vessels. They come equipped with safety relief valves and rupture disks to protect the cylinders from excessive pressure build-up. These containers operate at pressures up to 350 psig and have capacities between 80 and 450 liters of liquid.

典型的低温液体钢瓶是一个隔热的有真空夹层的压力容器。它们配备有安全减压阀和破裂盘，以保护钢瓶，防止过多的压力积累。这些容器可以在压力小于350 psig的情况下工作，容积在80到450升液体之间。

Product may be withdrawn as a gas by passing liquid through an internal vaporizer or as a liquid under its own vapor pressure.

可以通过使液体流过内汽化器取出气态氢，或者直接取出在它自己的蒸气压下的液态氢。

Cryogenic Storage Tanks

低温储存罐

A typical customer installation (see Fig. 4) includes a tank, vaporizer, and pressure control manifold. Tanks may be spherical or cylindrical in shape. They are mounted in fixed locations as stationary vessels or on railroad car or truck chassis for easy transportation. Sizes range from 500 gallons to 420,000 gallons. All tanks are powder- and vacuum-insulated in the annular space. Tanks are equipped with various circuits to control product fill, pressure build-up, pressure relief, product withdrawal, and tank vacuum. Tanks are designed to ASME specifications for the pressures and temperatures involved.

用户使用的设备一般包括储存罐、汽化器和压力控制管。罐的形状可以使球形或柱状，作为固定容器安装在固定位置，或者安装在有轨车或卡车底座上，以便于运输。大小从500到420,000加仑的都有。所有罐都有粉末和真空环形隔热层。罐子配备有各种控制产品灌装、压力积累、减压、产品取出和罐子真空的回路。罐子根据相关的压力和温度按照ASME规范设计。

Transfer Lines

转移管

A liquid transfer line is used to safely remove liquid product from dewars or cryogenic liquid cylinders. A typical transfer line for dewars is connected to a bayonet that provides a means of using product vapor pressure build-up or an external pressure source to remove the liquid. For cryogenic liquid cylinders, the transfer line is connected to the cylinder liquid withdrawal valve.

液体转移管用于从杜瓦瓶或低温液体钢瓶中安全地提取液体产品。用于杜瓦瓶的典型的转移管连接到卡口上，利用产品积累的蒸气压或外部的压力源来取出液体。对于低温液体钢瓶，转移管连接到钢瓶的液体提取阀门上。

Liquid product is typically removed through insulated withdrawal lines to minimize the vaporization of liquid product to gas. Insulated flexible or rigid lines are used to withdraw product from storage tanks. Connections on the lines and tanks vary by manufacturer.

一般通过隔热提取管来取出液体产品，以尽量减小液体汽化的损失。使用隔热的弹性或刚性管道来从储存罐中取出液体产品。管道和储存罐上的接头随制造商的不同而不同。

Liquid cylinders designed to dispense gases have valves equipped with standard Compressed Gas Association (CGA) outlets. Suitable pressure regulating equipment maybe attached. Valves provided for the withdrawal of liquid product are also equipped with standard CGA outlets, but they are different than the connections used for gaseous withdrawal. This is to prevent accidental introduction of liquid into a gas system, or of gas into a liquid system.

设计用来输出气态氧的液体钢瓶上装有配有标准的压缩气体协会排气口的阀门。或许还附带着合适的压力调节器。用于液体产品提取的阀门也配有标准的CGA的排气口，但它不同于用于气体提取的排气口。这就避免了在使用液体或气体产品之间的交叉连接。

Shipment of Cryogenic Liquids

低温液体的运输

Containers used for transporting cryogenic liquids at less than 25 psig (40 psia) pressure are not UN/DOT authorized containers. These are containers built to other than Department of Transportation (DOT) specifications but are authorized by the DOT for use in the transport of approved products. Containers used for transporting cryogenic liquids at pressures greater than 25 psig (40 psia) must be designed, manufactured, and tested to DOT specifications. For air shipments all packages must be in compliance with International Air Transport Association/International Civil Air Organization (IATA/ICAO) Dangerous Goods Regulations, as well as the DOT regulations.

用于运输低温液体的压力小于25 psig (40 psia)的容器不是UN/DOT授权的容器。这些容器不符合交通部（DOT）的规范，但是得到了DOT的授权，可以用于经核准的产品的运输。用于运输低温液体的压力大于25 psig (40 psia)的容器必须按照DOT的规范设计、制造和测试。对于空运，所有包装必须遵守国际航运组织/国际民航组织（IATA/ICAO）的危险货物规定，以及DOT的规范。

Buildings

建筑物

Because of the large expansion ratio of liquid to gas with cryogenic liquids, it is very important to provide adequate ventilation where cryogenic liquids are stored and used. Monitors should be available to check for oxygen concentrations in the atmosphere when working with inert cryogenics or with liquid oxygen. The minimum permissible oxygen concentration for unprotected personnel is 19.5%, while the maximum is 23.5%. In the case of liquid hydrogen, the atmosphere should be monitored with a flammable gas detector. All pressure-relief devices should be

piped to safe areas, preferably outdoors.

因为液体到气体的大膨胀率，为正在使用液氧的地方提供充分的通风非常重要。当与惰性低温液体或液氧一起工作时，应备有监测器来检查空气中氧的浓度。对于没有受到保护的人来说，允许的最小氧浓度是19.5%，最大是23.5%。对于液氢，应当用易燃气体监测器来监测空气。所有减压装置都要通到安全区域，最好是室外。

Fighting Fires

救火

It is not possible to outline specific fire fighting techniques that will cover all types of fires involving cryogenic liquids. Such measures depend upon the quantity and nature of the cryogenic liquid involved, the location of the fire with respect to adjacent areas and occupants, and on other factors. The following general procedures are applicable to all fires involving cryogenic liquids:

概括出涵盖所有类型的同低温液体有关的救火技术是不可能的。这些措施同相关低温液体的数量和性质、火相对于附近区域和居民的位置以及其它因素有关。下述通用程序适用于所有同低温液体有关的起火：

1. Everyone not actively engaged in the fighting of the fire should leave the area. If a flammable cryogenic liquid is involved, the flammable mixture zone, under unusual atmospheric conditions, may extend beyond the normal fog cloud produced by condensing water vapor in the air. People should be evacuated well outside the fog area.

每一个不积极投入救火的人都应离开该区域。如果同易燃低温液体有关，在异常大气条件下，易燃混合物地带会延伸到空气中的水蒸汽的浓缩产生的正常雾云以外。应该把人员疏散到雾云区域以外。

2. The best fire-fighting technique is simply to shut off the flow of cryogenic liquid or vaporized gas if a flammable cryogenic liquid is involved.

如果同易燃低温液体有关，最好的救火技巧是简单地切断低温液体流或蒸发的气体。

3. If electrical equipment is involved in the fire, be sure the power supply is disconnected before fighting the fire with water. Or use carbon dioxide or dry chemical extinguishers.

如果起火涉及了电力设备，在用水救火之前要确定电源已经断开。或者使用二氧化碳或干粉灭火器。

4. When employing water, use large quantities, preferably in spray form, to cool equipment in areas surrounding the fire. Use the spray to cool any burning material below its ignition temperature. If possible, do not spray cold areas of equipment, or direct water onto the cryogenic liquid. Keep water away from vent stacks and safety relief devices that can be plugged with frozen water. Fire hoses with adjustable stream-to-spray nozzles should be available where large quantities of flammable cryogenic liquids are handled.

当使用水时，用大量的水，最好用喷射的形式来冷却火焰周围区域的设备。用喷射的水把任何正

在燃烧的材料冷却到它的点燃温度以下。如果可能的话，不要喷射设备的温度较低的区域，或者把水导向低温液体。水要远离通风管道和安全减压装置，因为它们会被冻结的水堵塞。在对付大量易燃低温液体的地方应当备有带有可调水量喷嘴的灭火水龙带。

5. Depending upon the circumstances, it is generally not advisable to extinguish a flammable cryogenic liquid in a confined area. If the flammable gas supply cannot be shut off, the continued escape of unburned gas can create an explosive mixture in the air. The mixture may be reignited by other burning material or hot surfaces. It is usually better to allow the gas to burn itself out in a confined area and keep adjacent objects cool with water, rather than to risk a potential explosion. 熄灭狭窄空间内的易燃低温液体一般是不可取的，这取决于环境。如果易燃气体供应无法切断，不断逸出的未燃气体在空气中形成爆炸性混合物。该混合物可能被其它正在燃烧的材料或炎热的表面重新点燃。通常最好让气体在狭窄空间内自己烧完，同时用水一直冷却着临近的物体，而不是冒可能爆炸的危险。

6. If an inert cryogenic liquid is involved, there is the possibility of reducing the oxygen content of the air with the potential risk of asphyxiation of the firefighters. Judgment should be used to determine which risk is greater to firefighters—that of shutting off the supply valve, which may be in an area not easily accessible because of the fire, or the risk of an oxygen-deficient atmosphere due to the reduction of the oxygen content. 如果惰性低温液体有关，存在着空气中氧含量减少，从而导致救火人员窒息的可能性。必须做出判断，确定对救火人员来说哪种风险更大，是关闭处在由于起火而不容易接近的区域的供应阀门的风险，还是由于氧含量的减少导致的缺氧空气的危险。

7. If a fire involves gaseous or liquid oxygen, the oxygen plays the same role as oxygen in the air does in an ordinary fire. Oxygen does not burn, so there can be no fire unless combustible materials are also present. The difference is that the presence of additional oxygen will make combustible materials burn much faster and more violently or explosively. Shut off the oxygen supply if at all possible. Neither liquid nor gaseous oxygen can be effectively blanketed by agents such as carbon dioxide, dry chemical, or foam. It is necessary to cool combustible materials below their ignition temperatures to stop the fire. Use large quantities of water in spray form.

如果起火同气态或液态氧有关，氧扮演着同它在空气里的一般起火中所扮演的一样的角色。氧不燃烧，所以除非存在可燃材料，不会有火。区别是额外的氧的存在会使可燃材料燃烧的快得多和剧烈得多或更具爆炸性。无论是液态氧还是气态氧都不能被媒介，如二氧化碳、干粉或泡沫有效覆盖。必须通过把可燃材料冷却到它们的点燃温度以下来灭火。以喷射的形式使用大量的水。

First Aid

急救

For skin contact, remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts; tissue damage may result. As soon as practical, place the affected area in a warm water bath which has a temperature that does not exceed 105°F(40°C). Never use dry heat. Call a physician as soon as possible.

如果皮肤接触到液氧，脱掉任何可能限制冻伤区域血液循环的衣服。因为可能导致组织损伤，不要摩擦冻伤部位。尽可能对受伤部位进行不超过105°F (40°C)的温水浴。禁止用干热的东西。尽可能叫医生来。

Frozen tissue is usually pain-free and appears waxy with a possible yellow color. It will become swollen, painful, and prone to infection when thawed. If the frozen part of the body has been thawed, cover the area with a dry sterile dressing with a large bulky protective covering, pending medical care.

冻伤的组织通常是不痛的，看起来象黄颜色的蜡一样。解冻时，会变得肿胀、疼痛和易于感染。如果冻伤部位已经解冻，用覆盖面很大的消过毒的干衣服盖住伤处，直到医生到达。

In case of massive exposure, remove the victims' clothing while showering him or her with warm water. Call a physician immediately.

在大面积暴露的情况下，脱掉衣服，用温水给他或她淋浴。马上叫医生。

If the eyes are exposed to the extreme cold of the liquid or vapors, immediately warm the frostbite area with warm water not exceeding 105°F (40°C) and seek medical attention.

如果眼睛暴露于液体或蒸气的低温，马上用不超过105°F (40°C)的温水温暖冻伤部位，同时寻求医生的帮助。

If the body temperature is depressed, the patient must be warmed gradually. Shock may occur during the correction of hypothermia. Cardiac dysrhythmias maybe associated with severe hypothermia.

如果体温下降，必须逐渐地温暖患者。在纠正体温下降过程中，可能发生休克。使用强心剂 dysrhythmias可能带来体温下降。