**Cryogenic Engineering**
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**Lecture No. # 42**
**Safety in Cryogenics**

So, welcome to the 42nd lecture of cryogenic engineering under the NPTEL program. We have covered various topics till now; and consider the fact that it is 42nd lecture. We are coming at the end of cryogenic engineering lecture.

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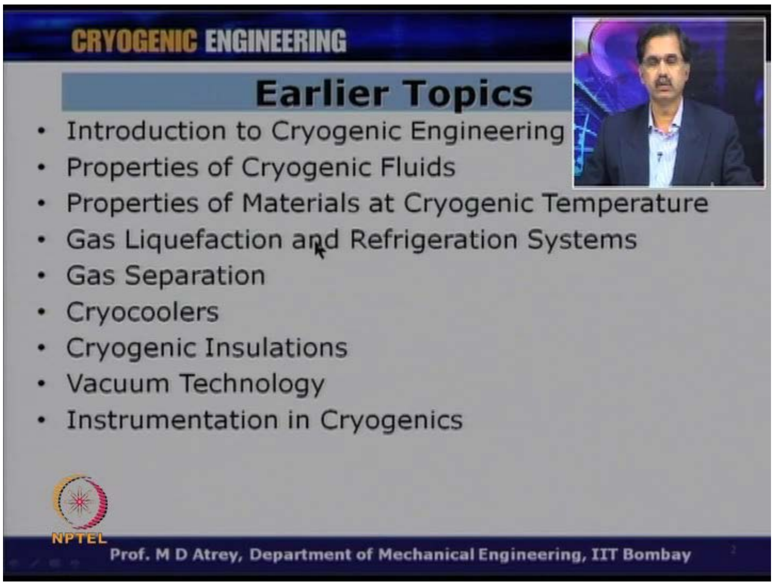


Just to summarize which topics we have studied till now, and let us go to the topic by topic just the name, we introduced all of you to cryogenic engineering, properties of cryogenic fluids, properties of materials at cryogenic temperature, so cryogens and materials. Then, gas liquefaction and refrigeration systems, gas separation, cryocoolers to generate low temperature in a closed cycle manner, cryogenic insulation, vacuum technology, which goes hand in hand with cryogenic experiments and instrumentation in cryogenics. We have studied all these things in fairly good details. What was missing through all these things? The important aspect is related to cryogenic safety; the safety in cryogenic operations, which is very, very important, and very critical.

As you know that we are dealing with very, very low temperature; there also it come with some unwanted accidents, unwanted aspects, which normally we would we would like to deal with in actual case, but it is a very important aspect, and we have to deal with it, and we have to overcome it with good knowledge. Therefore, we have to understand what are the safety aspects related to cryogenic operation or while handling cryogens, while transferring liquid nitrogen, liquid helium from (()) a to (()) b, all this aspects have to be understood, and we have to take measures to overcome such hazards; and therefore, this particular lecture is devoted to aspects related to cryogenic safety. So, the current topic is safety in cryogenics.

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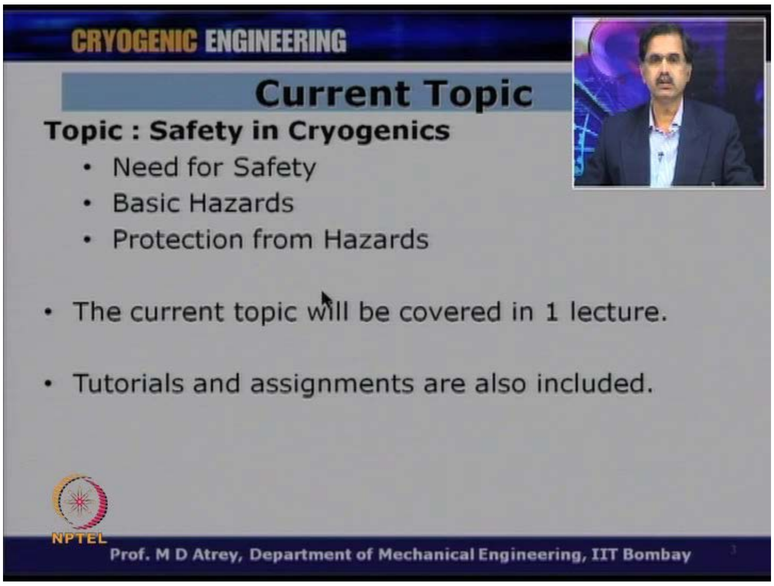


Under this topic, we will understand, what is the need for the safety? What are basic hazards that we have to really bother with in cryogenic safety operations? Protection from hazards; once we know the hazards, how to protect ourselves from these hazards that is very important aspect. And these topics we will cover in this particular lecture. And then we got assignments and tutorials at the end of this lecture.

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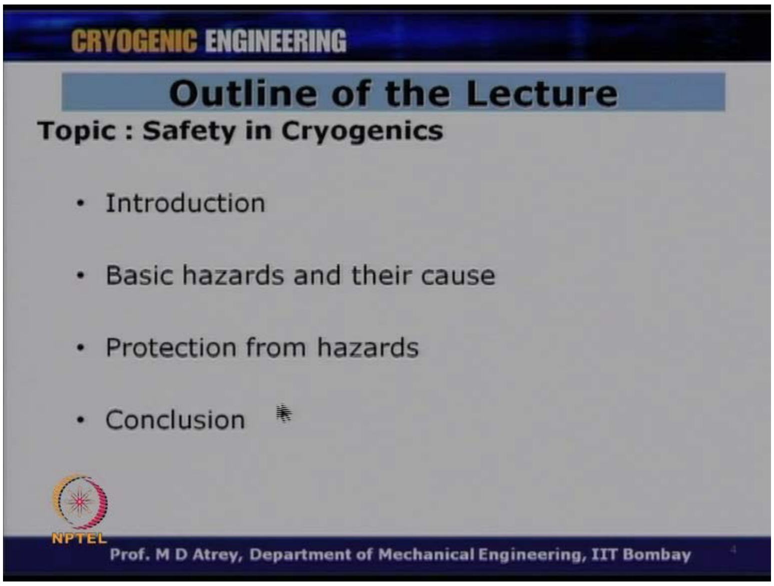


So, we will introduce what is safety in cryogenics; why do we need that; the basic hazards and their cause; protection from the hazards and the conclusions.

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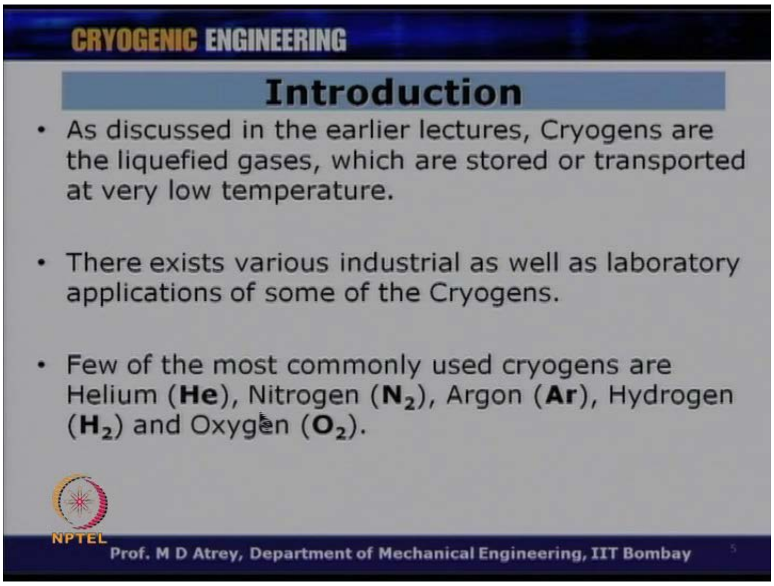


As discussed in the earlier lectures, cryogens are the liquefied gases, which are stored or transported at very low temperatures. When I deal with cryogenic engineering, it also involves transporting of this vessels, dears to a long distance or from laboratory a to laboratory b or you know whenever you are going to have these experiments. So, safety also will take in to account, what can happen during transport from a place a to place b. There exists various industrial as well as laboratory applications of some of the cryogens.

So, on a laboratory scale, you may handle liquid nitrogen, liquid helium; on a industrial aspects, industrial levels, you may you may handle argon, liquid argon, liquid oxygen, because that is used for steam production, that is used for welding and different operations. And therefore, we will always land up in transport of this cryogens from port to port, from city to city, and these are very important aspects. So, while handling such cryogens, lot of safety issues have to be dealt with. Few of the most commonly used cryogens are helium, nitrogen, argon, hydrogen and oxygen. In addition to that, we have several actually; you may have neon, for example methane. But let us look at fairly representative cryogens, and let us see what happens while dealing with such cryogens.

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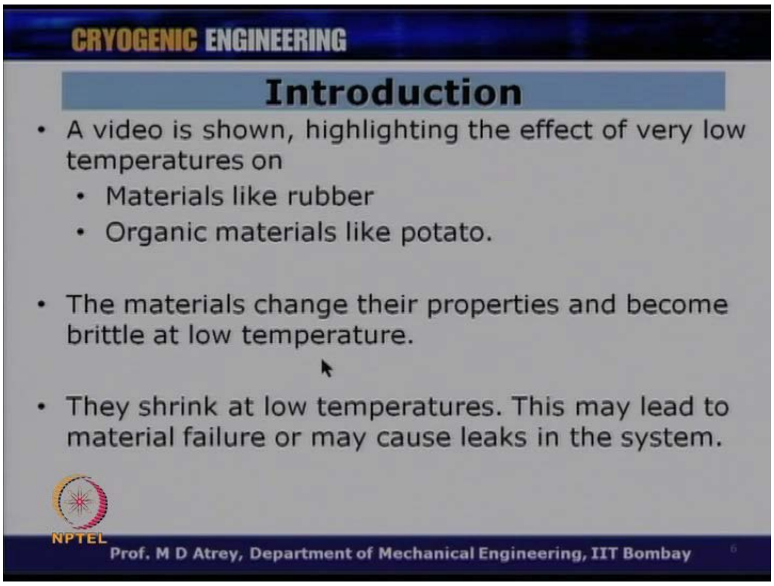


A video is shown, highlighting the effect of very low temperatures. If you remember in the first or the second lecture, you had shown a video showing the effect of very low temperature on materials like rubber. We are also seen the effect of low temperature organic material like potato, and we had seen that the rubber had become absolutely brittle, it become hard rock alright; it has lost its flexibility or elasticity. While even potato, it has become like as hard as stone. So, we have understood from that, and we have understood from theory later on that the significant change of properties that happens, when such material gets subjected to very, very low temperature.

So, we understood that the materials change their properties and become brittle at low temperature. This is an important aspect, which we understood from the experiments as well as when we dealt with the topic on materials properties at low temperature. We had seen that the materials shrink at low temperature, and this may lead to material failure or may cause leaks in the system. So, material shrinking at low temperature, some material shrink more, some material will shrink less, but if I know that the material shrinks at low temperature, and if I know how much it shrinks at various temperatures, I will like to take care of that shrinkage right in the design aspect. I should have this flexibility allowed; I should have some elasticity component kept over there; so that shrinkage of material or expansion of this material, when they get warmed up at room temperature is allowed, and this aspect has already been taken to account in design.

If I do not take that aspect in design, it will lead to material failure, because as soon the shrinkage happens, the failure will happen; or as soon as shrinkage happens, the leak it can cause leak also. And therefore, these are important aspect that should be taken into account, and these are all aspects, design aspect related to safety, because the leaks you know high pressure gas can come out or material can completely get broken down and it can cause some accident also. So, material property related safety aspect normally should be taken into account at a design level itself.

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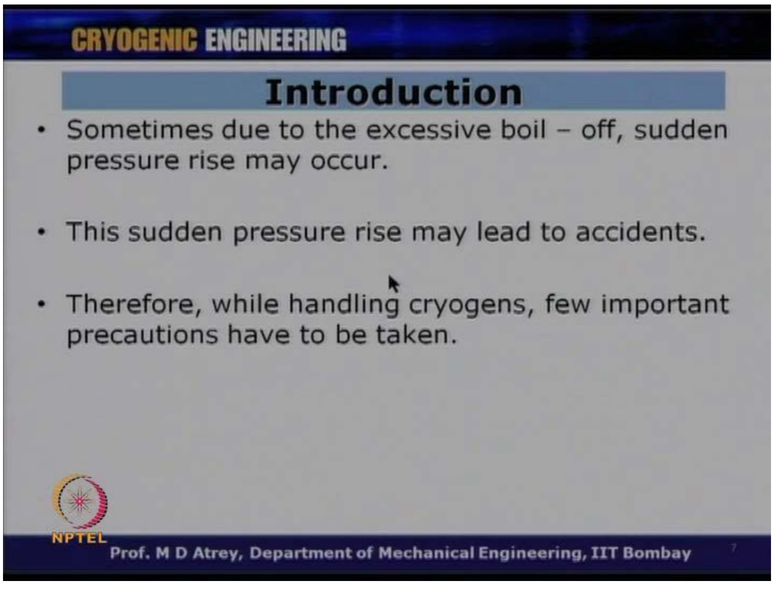

Sometimes due to the excessive boil off, sudden pressure rise may occur. Now, this can occur because of various reasons. Suddenly the vacuum gets broken, suddenly the additional heat comes from somewhere else, and all the cryogen can suddenly get boiled off; and this boil off will increase the inside pressure of a cryogenic container or a (()). So, the pressure raise may occur, because of various results; sudden pressure raise may lead to accidents. So, as soon as the pressure raises, and the pressure raise could be sudden, and you may have some safety devices also, but sometime the safety devices may not work, and it can suddenly lead to you know, some kind of accident and your entire (()) can get completely broken, and this can cause real damage to the surrounding over there.

Therefore, while handling cryogenics, a few important precautions have to be taken, and we will see in this lecture what those precautions would be. Now, all these damages or all this safety aspects associated with cryogenic operations, cryogenic experiments cryogenic activities can be clubbed under something called as basic hazards. And there are several hazards under which all these you know, accidents or precautions or anything that could be clubbed under. So, what those hazards will be?

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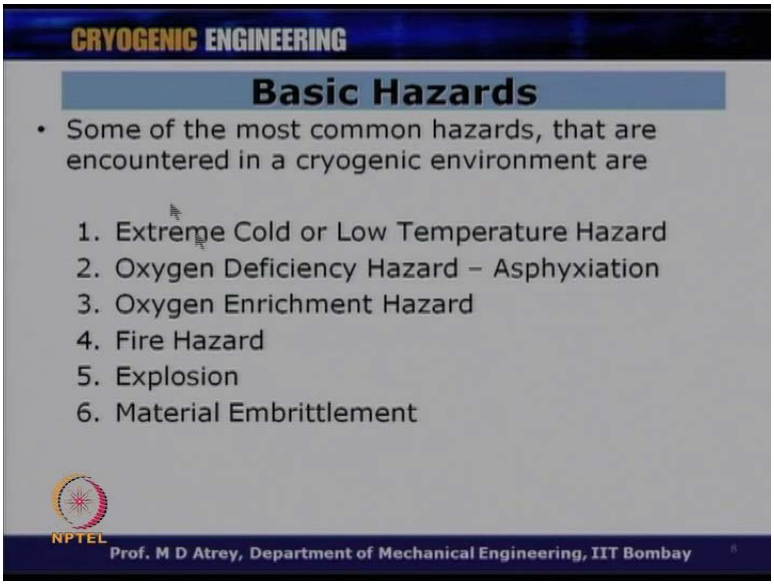


Some of the most common hazards that are encountered in cryogenic environment are extreme cold or low temperature hazard. So, one is you know important, it is a low temperature, and its suddenly low temperature, you are subjected to if cryogen fall on your body for example, or material or surrounding. So, the very important aspects and therefore, important hazard associated with cryogenics as compared to any other thing is extreme cold or low temperature hazard. Then one more critical thing related to cryogenic basic hazard is, it can produce oxygen deficiency hazard, it can produce an environment where we can have oxygen deficiency, and this is called in technical term as Asphyxiation.

So, Asphyxiation is a condition, in which you got an oxygen deficiency environment around you, and this is very, very damaging for human beings. So, this aspect is very important to to be dealt with, when you are dealing with cryogens or cryogenic gases. Then on the country, you may have the opposite one also, which is oxygen enrichment hazards. You can have a situation, where the environment around you has got more oxygen than required, and it can lead to some other hazards, which we deal with, which will understand during this lecture. We can have fire hazard alright; depending on the cryogens, you are handling for example, you are handling liquid hydrogen, they are very flammable gases and therefore, it can lead to fire hazard, and these aspect has to be dealt with while dealing with such cryogens.

Explosion, handling such gases, handling high pressure equipments can lead to explosion, which is common knowledge and therefore, this aspect also has to be understood in while handling cryogens. Material embrittlement we just talked about earlier that material can fail, material can shrink, material can lead to leaks and therefore, it can cause material embrittlement, and again this is one of the failures, one of the hazards that has to be looked into while designing, while operating such cryogenic systems. So, these are the six categories under which basic hazards can be classified.

Now let us try to go one by one through each hazard, and try to understand what is it mean? Let us try to understand first what is it mean; when you are subject to test extreme cold, what happen; when you are in oxygen deficient environment, what happens. So, let us try to understand, what kind of damage it can do, and how will occur. And later on, we will try to cover up how to take care of these hazards, how to deal with this hazards, what kind of protections one should have in order to deal with such hazards that we can deal with after understanding everything about this hazards in short.

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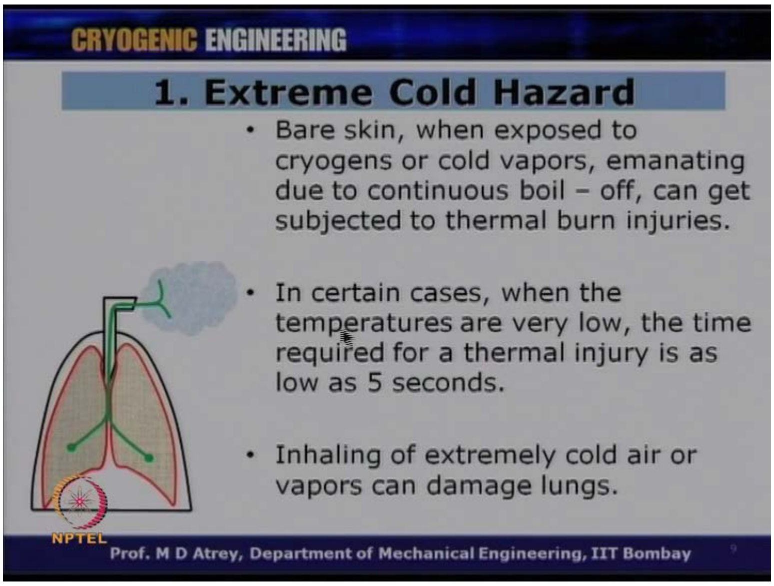


So, let us come to extreme cold hazards, you know that the bare skin when exposed to cryogens or cold vapors, emanating due to continuous boil – off, can get subjected to thermal burn injuries. And this you must have dealt with you know, when you go for example, hiking in Himalayas for example, you can have frostbites; and frostbite is nothing but your your skin is or your hands or legs are subjected to cold for a long duration, and this can leads to fatal accidents. So, bare skin when exposed to cryogens or cold vapors can you know, cause thermal burn injuries.

In certain cases, when the temperatures are very low, the time required for a thermal injury is as low as 5 seconds for example, if your body gets subjected to liquid nitrogen, liquid helium for whatever reasons by some mistake you know, it can lead to thermal injury, and the damage could be in as good as 5 seconds, as low as five seconds, you have to you have to be very, very careful while handling such cryogens. And also inhaling of this extremely cold air or vapors can damage the lungs.

So, if you are in a atmosphere, where you got a lot of liquid nitrogen in air you know, where the plant for example, where liquefied, air liquefied, nitrogen or any other liquid gases or the boil off is in in the air; and if you inhale those cold boil off for example, they are not at ambient temperature, but they are still cold, it can lead to damaging damage the lungs. So, it is a very important that you know, what your environment is; and you have to take special precautions to avoid these conditions.

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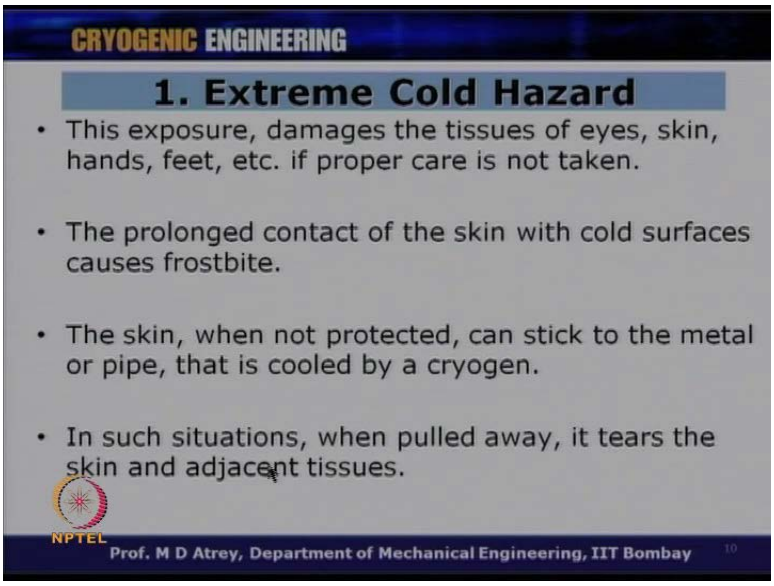


This exposure, damages the tissues of the eyes, skin, hands, feet etcetera if proper care is not taken. So, you should see that all these body parts are not exposed to such low temperatures or not exposed to these cryogens and therefore, we will have to take care to see that we are not getting exposed. The prolonged contact of the skin with cold surfaces causes frostbite. As I just told that if you you know, walk for a long time in icy conditions for a day for two days for example, there are zero degree centigrade alright what will happen all the veins taking the bloods will get blocked alright, they will get contracted and therefore, they will not be flow of blood to those particular parts, especially the the parts which are away from the heart for example, hands, legs etcetera your feet.

Similarly, if your skin gets subjected to such cold temperature for a long duration, your veins, your arteries can get blocked, it can get choked; therefore, the flow of blood will not be there to that particular part, it can result in frostbite, which is very, very dangerous, the skin when not protected. So, frostbite the skin, when not protected can stick to the metal or pipe that is cooled by a cryogen; for example, you had a pipe, and it is you know it has a cryogenic, which is flowing through it, and if your skin comes in contact with an open part of this pipe right your skin can get you know, because our icing can get formed, and your skin can get connected to this ice to this cold part, and if you pull your skin, your skin can be actually peeled off from that region. So, it can be really, really fatal if you see to it that your skin is not touching those you know, pipes or surfaces, which has got cryogen under with it is a very important aspect.

In such situation, when pulled away, it tears the skin off and adjacent issues. Tears the skin and adjacent tissues which is going to be very, very you know, fatal in many cases. So, once you see that your skin does not see such cold surfaces or you are not in physical contact with such pipes, with such surfaces, which have got cryogen underneath, and which are not exposed, which are not well insulated basically; you should ensure that you are not in contact with such things.

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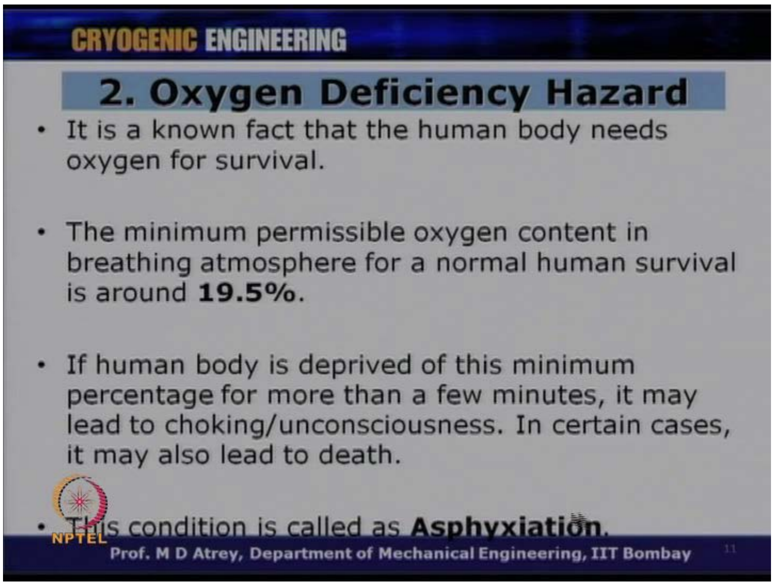


The second aspect, which we talk about after extreme cold, is oxygen deficiency hazard, and this is very important again. So, what happens here, it is well known, it is a known fact that human body needs oxygen for survival; everybody knows this. The minimum permissible oxygen content in breathing atmosphere for a normal human survival is around 19.5 percent for example, in air we know that there is a 21 percent of oxygen and 79 percent broadly nitrogen. And if a human being can tolerate having this oxygen up to 19.5, minimum 19.5 percent should be there, and we got 21 approximately in the air.

However if ever the atmosphere, where the oxygen percentage is less, it cannot be less than 19.5, minimum 19.5 should always be there; this is the minimum permissible oxygen content that should be there for breathing. If human body is deprived of this minimum percentage for more than few minutes, so suppose I have got a atmosphere, which where it has got only 18 percent oxygen for more than you know, 5 minutes, it may lead to choking or unconsciousness. In certain cases, it may also lead to death. So, you see the importance of having correct percentage of oxygen around us in the environment, where you breathe. As we know that as you go up the oxygen percentage becomes less and less, and you know that you can become you know, breathing is a problem, but still you are not you know gone in to atmosphere when when it is less than 19.5 percent or 19 percent. If it is less than 19 percent, you can, it can lead to unconsciousness, it can lead to choking, it can… Certain cases, it can lead to death also.

So, important thing is the percentage of oxygen around you is very, very important. This condition where you know, you can come across a condition, where oxygen has got less than 19.5 percent is called Asphyxiation. So, such a condition of having less that your human body is deprived of minimum percentage of oxygen is called as Asphyxiation, and one should not get asphyxiated.

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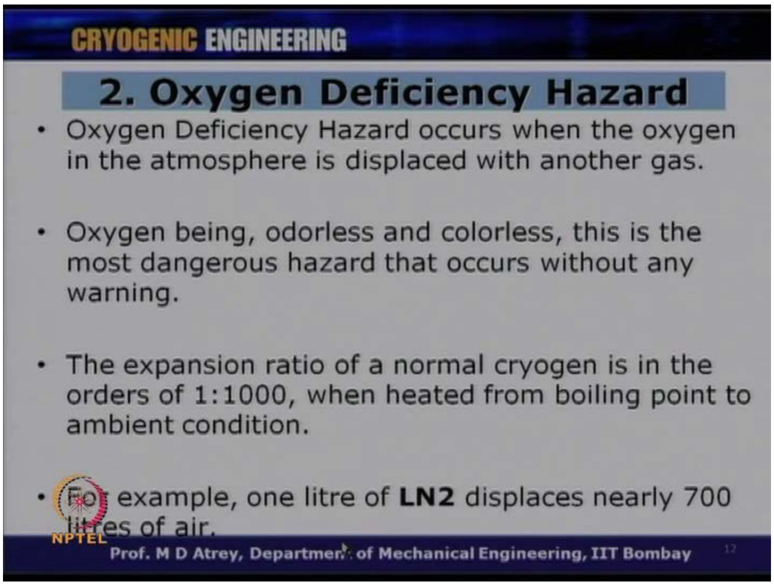


Therefore, oxygen deficiency hazard occurs when the oxygen in the atmosphere is displaced by another gas, and this is what can happen in cryogenic environment that liquid nitrogen, nitrogen boil off, helium boil off can replace oxygen atmosphere around you, which means that you have got an oxygen deficient atmosphere and therefore, you have a problem of breathing.

Oxygen being odorless and colorless, this is the most dangerous hazard that occurs without any warning, because you never understand that oxygen around you is being you know displaced, because its odorless and colorless, and you will never notice that while it is happening. You will notice, when it is too late possibly; when a percentage of oxygen around you has gone less than 19 percent, and the notice is basically by becoming unconscious or having breathing problems. And therefore, this is very important to ensure that you are in open atmosphere, you are not subjected to you know, deficient oxygen environment and therefore, these gases should not replace oxygen or air around you.

Why does this happen? The expansion ratio for a normal cryogen is in the order of 1 to 1000, when heated from boiling point to ambient condition. What does it mean? If you have one litre of let us say liquid oxygen or liquid air, when it becomes air at ambient temperature, when it becomes gas at ambient temperature, 1 litre can become 1000 litre around you. So, one litre of cryogen, if it gets heated to ambient temperature, it will become gas, and at room temperature, it will have 1000 litre of that gas.

So, a small quantity in liquid form, we need gas into gaseous form at room temperature, the ratio is approximately 1 to 1000 that is you can see that even 1 litre gets evaporated, you will have 1000 litres of that gas around you, which is very dangerous thing, because that can replace the oxygen around you. For example, 1 litre of liquid nitrogen displaces nearly 700 litres of air. As soon as your 1 litre of liquid nitrogen gets evaporated, you will have 700 liters of liquid nitrogen gas around you that means, it has replaced 700 liters of air around you, which means that you have got a oxygen deficient atmosphere now. When will this happen? If you are confined to a room, where plenty of air is not coming, there is no clear air flow basically in this; in a in a place, this can happen and therefore, one can straightaway become unconscious, if subjected to oxygen deficient atmosphere.

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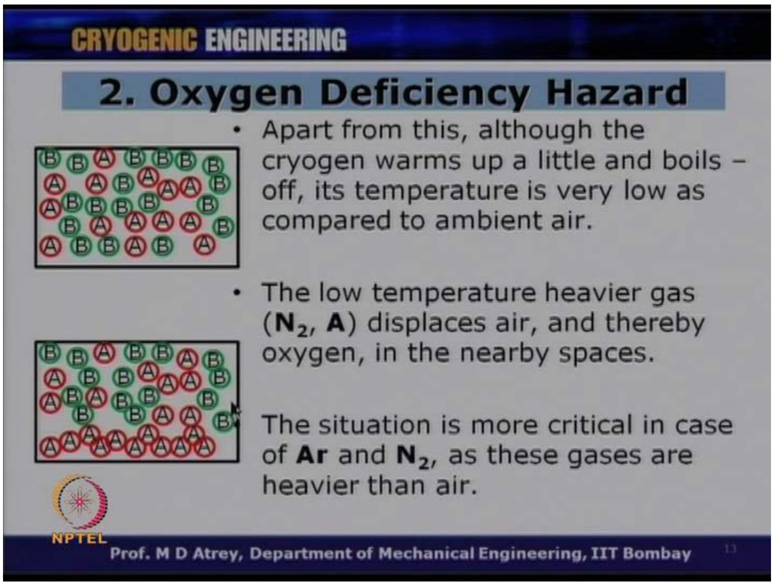


Apart from this, although the cryogen warms up a little and boils-off, its temperature is very low as compared to ambient air. So, one condition was that other than that also if you have got a low temperature gas available in the atmosphere around you that means, you have got a liquid nitrogen, and nitrogen is not warmed to the room temperature, it has got still you know, it is at minus 20 minus 30 degree centigrade, it is at low temperature. But compared to ambient condition, it can the low temperature heavier gas, because that gas is now at low temperature, and it is a heavy gas for example, nitrogen let us say A particles here are nitrogen molecules and the B are lighter molecules which could be air for example.

So, as soon as you got an ambient around you with nitrogen increased atmosphere now, it will displace air, because nitrogen being heavier than air, it will displace air therefore, oxygen in the nearby places. When I say oxygen it is basically the air, so nitrogen now still it is a gas, but being at low temperature, it will replace the air around you that means, the oxygen around you; and this can result again in oxygen deficiency hazard. You can see here the situation is more critical in case of argon and nitrogen, as these gases are heavier than air. So, you can see the gas at low levels that means, at lower height gas around you will definitely therefore, would be nitrogen rich and oxygen deficient, therefore. So, these are subjected now nitrogen enriched atmosphere around you or oxygen deficient atmosphere around you, which can lead to Asphyxiation. So, one should see to it that such gases are not around you or they will not replace or displace air around you.

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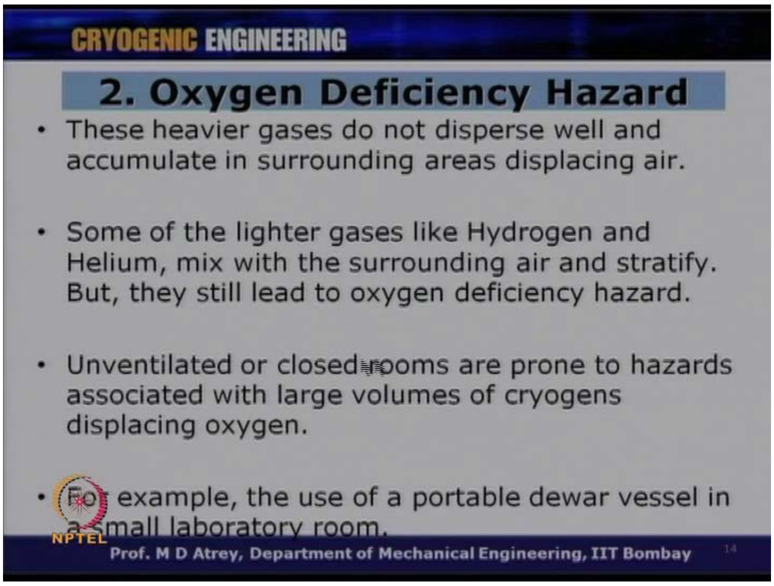


These heavier gases do not disperse well and accumulate in surrounding area displacing air. Some of the lighter gases like hydrogen and helium mix with surrounding air and stratify. So, this can happen in lighter gases like hydrogen and helium, they will mix with surrounding air. And you can have some stratification, depending on the density differences, you can have some oxygen rich, oxygen deficient, hydrogen helium rich or whatever, you know you can have oxygen deficiency hazards in this cases also.

Unventilated or closed rooms are prone to hazards associated with large volumes of cryogen displacing oxygen. So, as I said that such conditions can occur, when you got a unventilated or closed rooms, where there is no you know, air circulations. And therefore, these can lead to oxygen deficient atmosphere, which can lead to Asphyxiation. And therefore, we should have a very big ventilation, and we should have a all open rooms, you should have full of windows and doors and all open and therefore, air circulation will be the best over there.

For example, the use of portable (()) vessel in a small laboratory room can lead to such cases, because you bring a (()) in your room, where you want to do experiments, and everything in that experiment area could be sort of air conditioned area and therefore, it will not be kind of exposed to atmosphere, it will not have doors and windows open all the time, this has to be taken into consideration while devising, while having this experiments at low temperature. If you are handling cryogens, you should always have doors and windows open to atmosphere to ensure that lot of air circulation is taken place around you.

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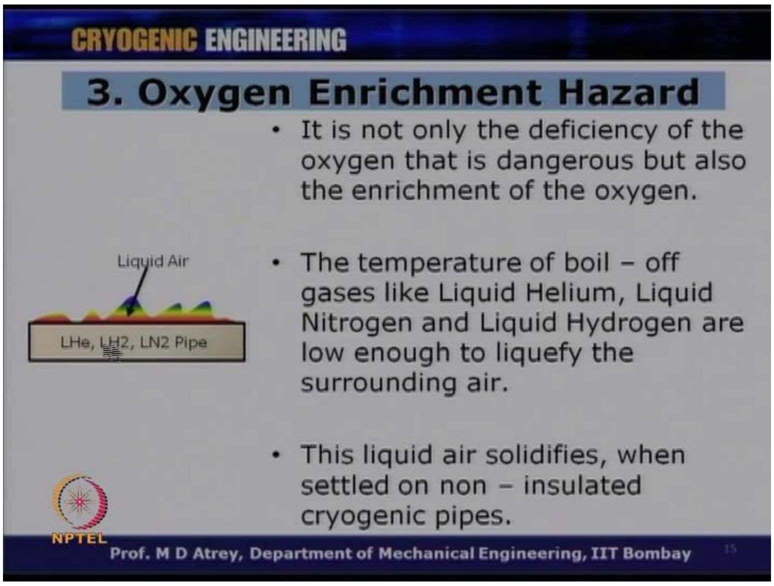


The third is oxygen enrichment hazard: We have talked about oxygen deficient hazard, and now you have got oxygen enrichment hazard. It is not only the deficiency of oxygen that is dangerous, but also the enrichment of oxygen. So, if you have got other side also, where oxygen has enriched in the atmosphere that also will cause problems. The temperature of boil off gases like liquid helium, liquid nitrogen and liquid hydrogen are the low enough to liquefy the air. So, if you got a pipes, if you got surfaces, we see these temperatures, liquid helium, liquid nitrogen, liquid hydrogen, it can actually liquefy the air around it; air has a boiling point of 78 kelvin. And therefore, these temperatures can result in liquefaction of surrounding air over there.

This liquid air solidifies, when settled on non insulated cryogenic pipe for example, you have got a liquid helium and liquid liquid hydrogen pipelines can be seen over here. You can have liquid air, you can have air getting condensed over it also; and sometimes if the temperatures are low enough, and the insulation is not working properly, this air can get even solidified out there, this is the possibility.

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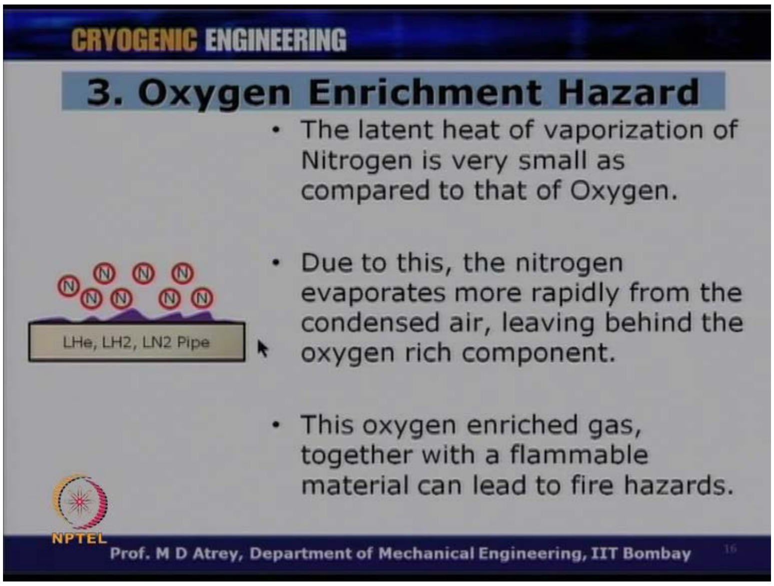


Now, when the air is condensed or solidified, the latent heat of vaporization of nitrogen is very, very small as compared to that of oxygen. So, air is nothing but it is a nitrogen plus oxygen. So, the latent heat of vaporization of nitrogen is very small as compared to that of oxygen and therefore, nitrogen will get evaporated from there. With the with the latent heat, you know giving it to basically the low temperature hydrogen or helium; nitrogen gas can get evaporated, and it can result in nitrogen going away and oxygen getting retained over there. Due to this, the nitrogen evaporates more rapidly from the condensed air, leaving behind the oxygen rich environment. So, what we can have here is oxygen while nitrogen will go to the atmosphere; you can have oxygen enriched environment over here now.

This oxygen enriched gas, together with flammable materials can lead to fire hazards. Now in that atmosphere for example, if you have got kerosene alright, if you have got some magnesium, sodium these are all flammable materials; you could have gasoline for example, together oxygen plus this can become a very flammable mixture, and it can result in fire hazards. So, one can have fire hazards, only because you could not understand what happened, what mechanism happened over there. So, one should ensure that insulation takes care of all these things; you should ensure that no flammable materials should be there in the surroundings.

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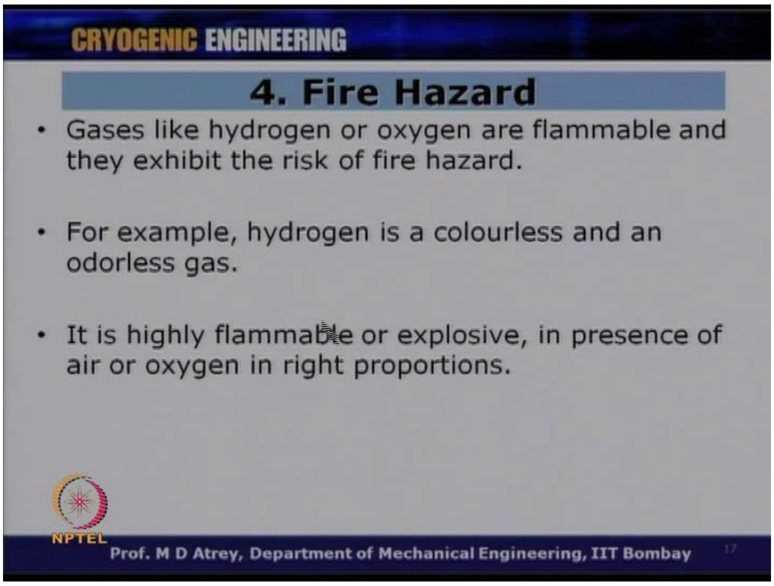


So, fire hazards coming to; gases like hydrogen and oxygen are flammable and they exhibit the risks of the fire hazard; this is what we just talked about, wherever you have got oxygen enriched atmosphere, we got hydrogen enriched atmosphere, you can have now risk of fire hazards; one should ensure that such fire hazards should not occur. For example, hydrogen is a colorless and an odorless gas, it is highly flammable or explosive in presence of air or oxygen in right proportion. So, when hydrogen is there, and suppose oxygen is there, it can become very explosive mixture. So, presence of hydrogen in the surrounding is absolutely unwanted.

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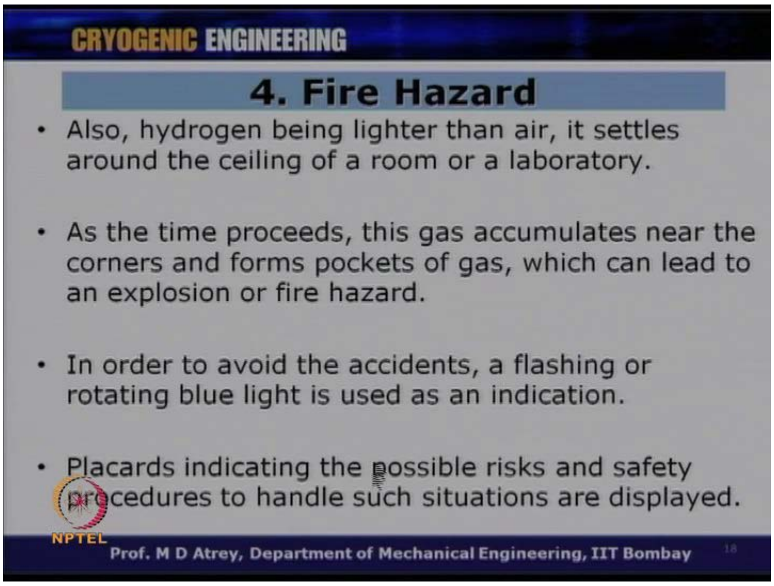

Also, hydrogen being lighter than air, it settles around the ceiling of a room or a laboratory. So, you will never notice that, but in corners, you know in tallest basically you can have some hydrogen pockets over there, and you will ever realize that. So, this has to be always seen to it that you know ensure that there is no hydrogen pocket. As the time proceeds, this gas accumulates near the corners and forms pockets of gas, which can lead to an explosion or fore hazards.

So, we should ensure that such pockets do not get formed in your laboratory. In order to avoid the accidents, a flashing or a rotating blue light, which is indicating the kind of urgency required is choose as an indication; one should have always indication; one should always have some kind of flashing to ensure that to basically let others know that there is a danger over here you know, you should not there is a flammable gas, there could be possibility that we can have flammable gas around and therefore, all those actions, which can lead to fire hazards should be avoided; already there is a very important aspect by dealing with hydrogen especially.

Placards indicating the possible risk and safety procedures to handle such situations are always displayed. It is a very important, if you are dealing with liquid hydrogen for example, such safety precautions, such placards that you have got a some unsafe atmosphere around the possibility that you can have flammable gases around should always be indications, should always be given in the laboratory.

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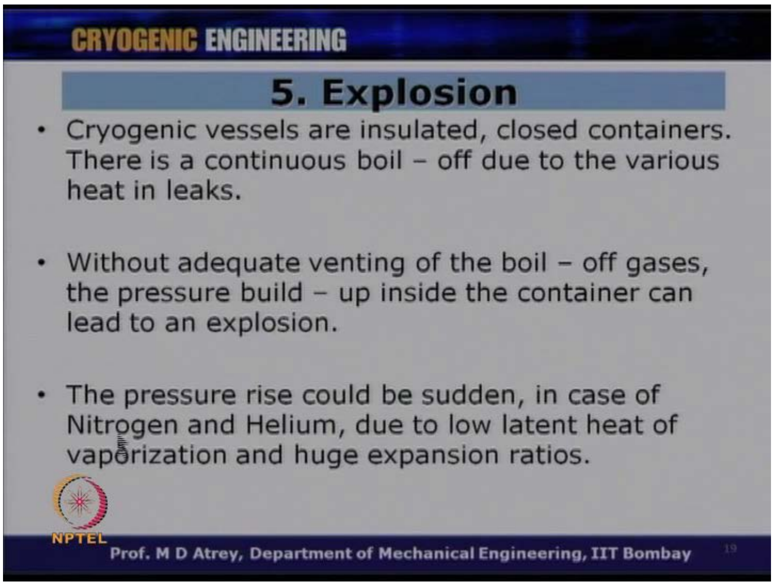

Fifth one is explosion. So, fifth hazards, after fire we talked about is explosion. Cryogenic vessels are insulated closed containers. There is a continuous boil - off due to various heat in leaks. This is a well known fact. Without adequate venting of the boil - off gases, the pressure build up inside the container can lead to an explosion. So, this if adequate venting has not been you know taken care of, and sometimes the heat, because of the heat in leaks or sudden heat in leaks, the boil off pressure build up can happen inside the cryostat, inside the container. And suppose your safety devices do not function properly or suppose the safety devices are not taken into consideration, it can lead to an explosion; and this explosion can be very, very bad, it can be fatal again you know. So, these aspects are very important therefore, all the safety devices have to be first understood, and they should be part of your design.

The pressure rise could be sudden, in case of nitrogen and helium due to low latent heat of vaporization; that means, as soon as some heat in leak happens, your helium and nitrogen especially can suddenly get boiled off, and sudden pressure can get build up, and therefore, because you have got a huge expansion ratio also; you know 1 to 1000 1 to 800 that kind of ratios we are talking about, when one liter of liquid nitrogen becomes, you know almost 800 liters of gas at room temperature. And therefore, this pressure rise could be sudden now, this, the very important aspect that has to be dealt with.

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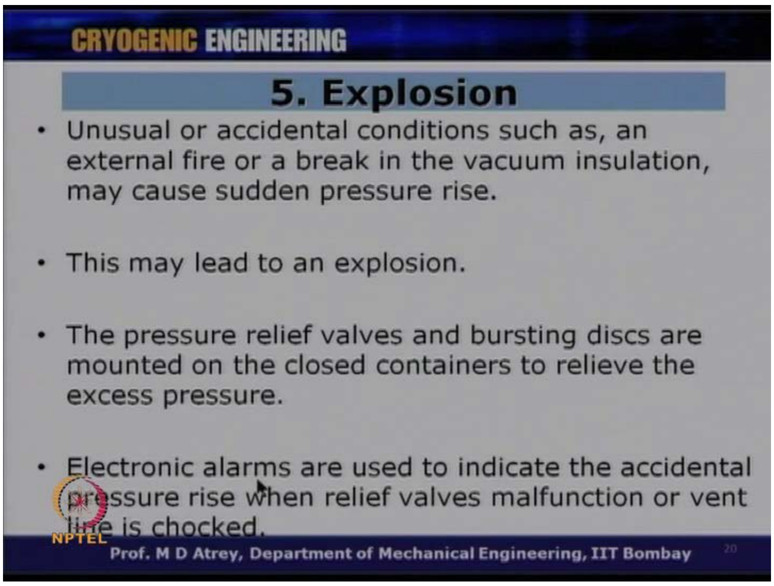

Unusual or accidental condition such as an external fire or a break in the vacuum insulation may cause sudden pressure rise. So, because of such aspects, you can get lot of heat energy, you can get lot of heat in leaks to the cryogens, which can result in sudden pressure rise. This may lead to an explosion. The pressure relief valves and the bursting discs are mounted on the closed containers to relieve the excess pressure. So, these aspects are very important while dealing with design of these cryo containers. We will see in detail what does relief valve and bursting discs are all about.

And we should have some electronic alarms also. The electronic alarms are used to indicate the accidental pressure rise, when relief valves malfunction or vent line is choked. So, this also can happen. So, as soon as some pressure builds up, it goes beyond a particular set value, if you have even electronic alarms in place, so that you know immediate measures can be taken to avoid such explosive conditions.

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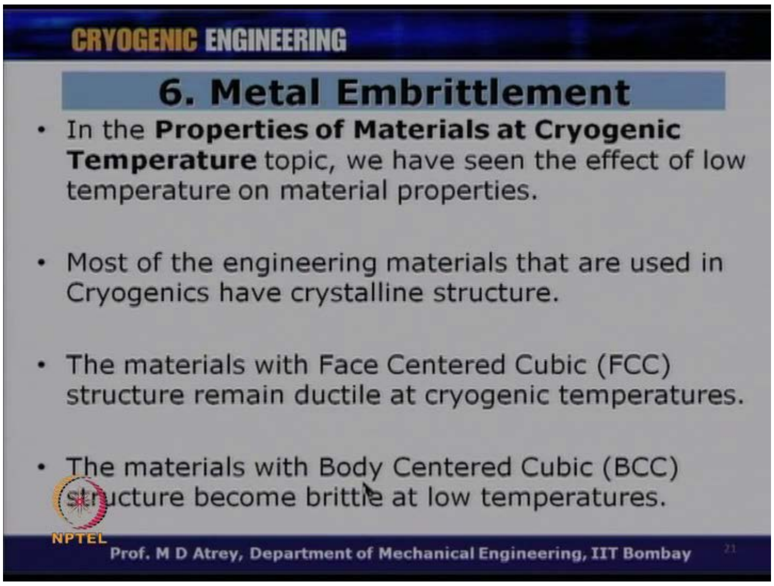


And lastly, we got a other hazards led to metal embrittlement. In the properties of metal at cryogenic temperature topic, we have seen the effect of low temperature on material properties. Most of the engineering materials that are used in cryogenics are crystalline structures. The materials with face centered cubic or FCC structures remain ductile at cryogenic temperature, but if your material is of BCC type, and if your design is not in correct, then if you have taken such BCC materials, the material with BCC structure become brittle at low temperature. So, suddenly when they subjected to low temperature, this materials can crack, this material can get broken down leading to pressure rise, leading to leaks and things like that.

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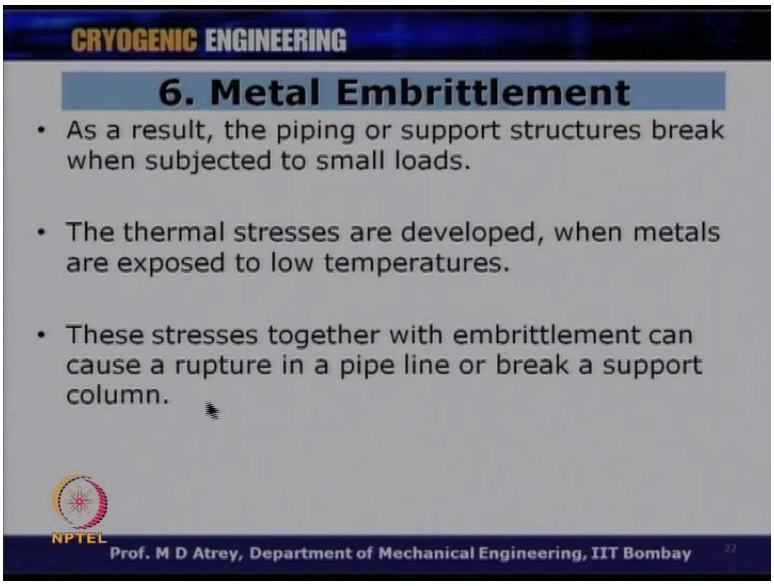


As a result, the piping or support structures, it could be BCC material, break when subjected to small loads. The thermal stresses are developed; because of the shrinkage also we have thermal stresses when metals are exposed to low temperatures. You can have material break down here that means, some leak can happen, the material can break or you can have some thermal stresses, when the metal is getting exposed to low temperatures. These stresses together with embrittlement can cause a rapture in pipeline or break a support column. And this can lead to as an accident.

So, you can have thermal stresses, you can have material failures over there, and both of them can you know result in some kind of rupture of a pipe or break of a support column and therefore, it can result in a failure of a structure also. So, we have seen till now what are the different hazards while dealing with cryogens; you have seen all the basic hazards, and also understood why do they occur? Now, let us see if I want to protect myself from such hazards, what should I do? This is a very impotent that every one of you should keep in mind; and therefore, I have been understood those hazards let us understand how to protect ourselves while working with cryogenics.

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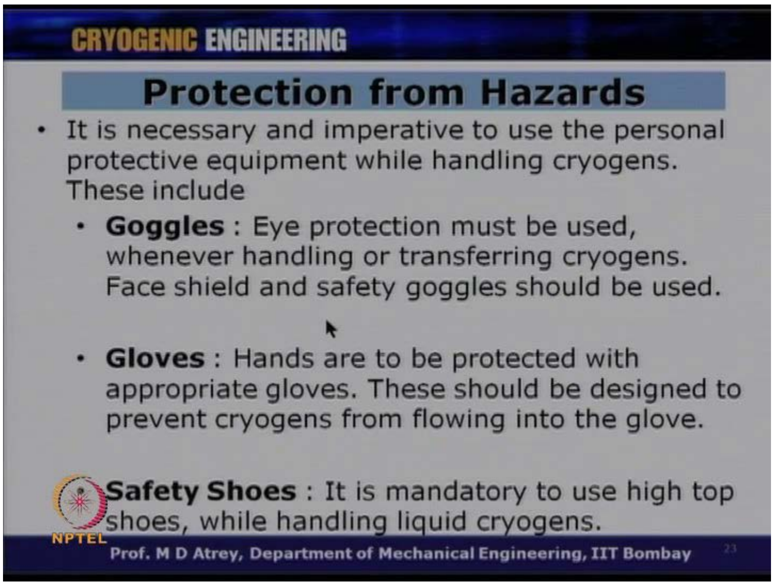


It is necessary and imperative to use the personal protective equipment while handling cryogens. This is very important while handling cryogens, we have to protect ourselves. Also we have to protect our equipment. So, how do I do that? These include Goggles; so, I should use some protective equipment like goggles. Eye protection must be used, whenever handling or transferring cryogens. Face shield and safety goggles should be used. So, one should see that, your face, your eyes are not exposed to low temperature; you are not seeing the fumes, you are not seeing the evaporated boil - off, which could be at low temperature and therefore, eye, your face is not seen all those things. So, goggles are very, very important to take care of your face and eyes.

Similarly, Gloves, your hands; hands are to be protected with appropriate gloves, not normal gloves; their gloves have a level for handling nitrogen only. These should be designed to prevent cryogens from flowing into the gloves. So, it should ensure that liquid nitrogen does not enter your gloves; it should prevent cryogen from flowing into the gloves. So, goggles, gloves, safety shoes, your legs, it is mandatory to use high top shoes while handling liquid cryogens. So, they are impotent for your face, your hands for your legs.

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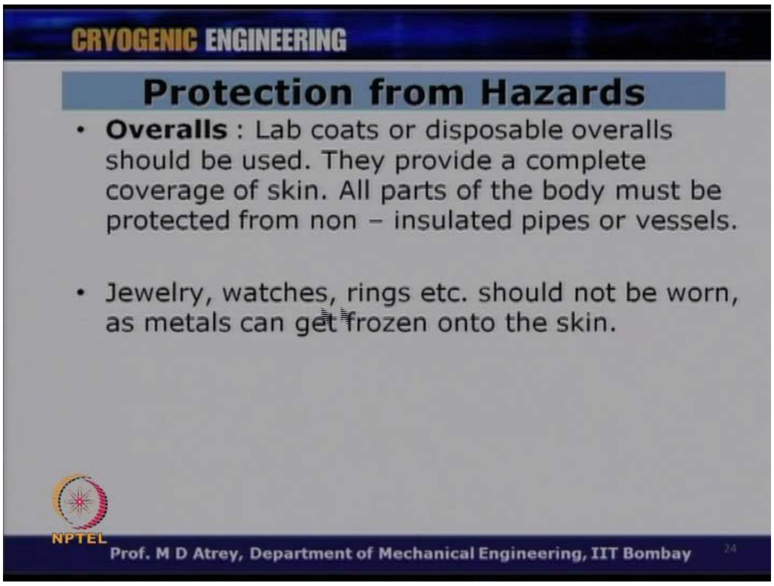


Similarly, we should have overalls; lab coats or disposable overalls should be used. So, entire body should be covered with some kind of gum, some kind of coats. They provide complete coverage of skin. It ensures that, you know nothing is exposed to such low temperatures or cryogens. All parts of the body must be protected from non - insulated pipes or vessel; one should also ensure that you are protected from non - insulated pipes or vessels. And therefore, the goggle, the shoes, the gloves and the overalls are very, very important while dealing with cryogens.

Similarly, some precautions in jewelry, watches, rings etcetera should not be worn, as metals can get frozen onto the skin. So, one can you know, because of the ice gets formed, your jewelry, watches etcetera can get bonded to the skin, and the skin can be peeled off, if you want to remove these things; one should not wear such things while dealing with cryogens.

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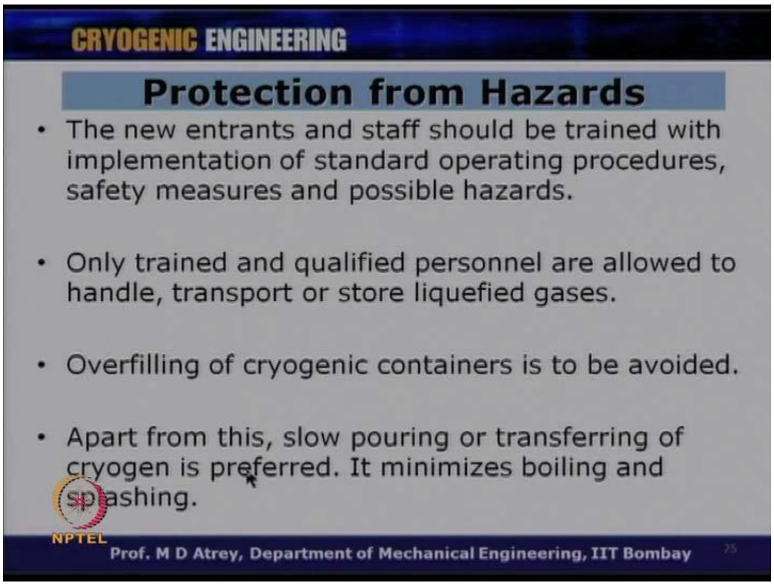


The new entrants, you should also ensures that the new entrants and stop should be well trained with implementation of standard operating procedures, safety measures and possible hazards. So, you should all be equipped with knowledge first of all, what are the possible hazards that can happen? And therefore, what should be my safety measures; what should I do to overcome those things; and what are my operating procedures? You should be a well trained person. So, he and she, whoever wants to work on cryogens, cryogen related experiments, they should all be aware of what can go wrong, what should my safety measure be, and they should all be well trained. They should not be suddenly expected to work on cryogens; they should be well trained before some demonstration has to happen in front of them, so that they know how to deal with liquid nitrogen, liquid helium and other cryogens.

Only trained and qualified personnel are allowed to handle, transport or store liquefied gases. This is very important training is very important. Training is very important component to deal with you know, to teach them the operating procedures of handling such cryogens. Overfilling of cryogenic container is to be avoided. The cryogenic container should never be filled up to the neck, you should always have some ten percent empty space in the container alright, which allows some boil - off to happen, which allows some evaporation of the cryogen to happen, the pressure will not get built up immediately. So, overfilling should never be done. They should not be filled up to the neck always some (( )) spaces they call it from the left around ten percent of the entire volume of the container, should be left over there.

Apart from this, slow pouring or transferring transferring of cryogen is preferred. So, always slow pouring or transferring, you should not transfer liquid very, very fast, it will result in a lot of evaporation of this gases with cryogens, we should have a very slow procedure, so that there is no fast evaporation or you know fast pressure build up will not happen over there. It minimizes boiling and splashing.

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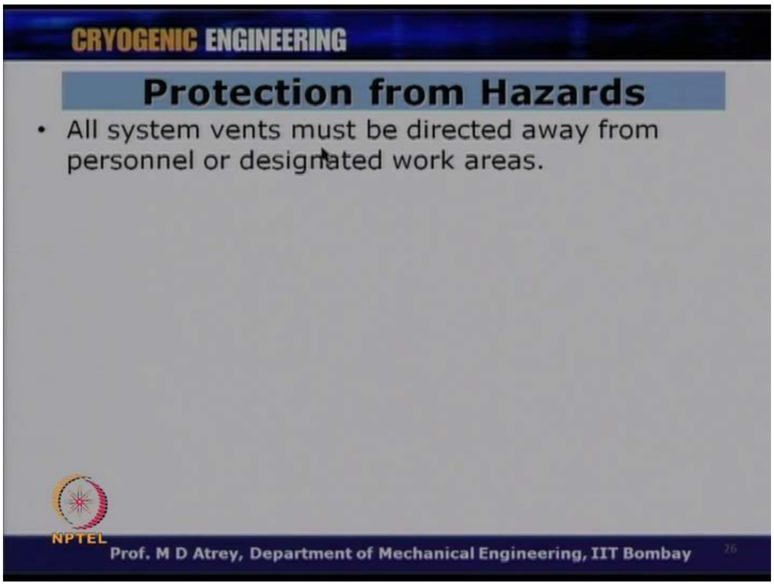


All system vents must be directed away from personnel or designated work area. You should never stand across the vent, you should not stand facing the vents or the pipes, they should all be directed away from the personnel or designated work areas.

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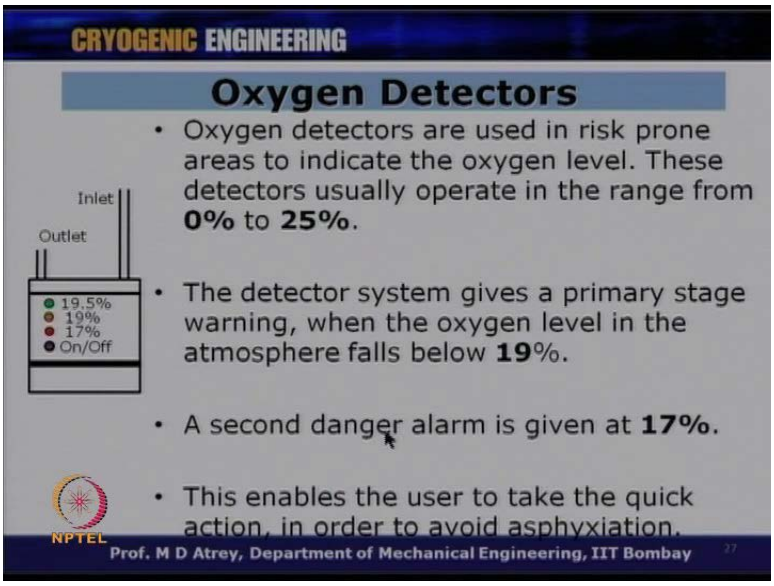


But we should have oxygen detectors. In addition to all these things, what we just talked about, we should have oxygen detectors, which basically detect the percentage of oxygen in the atmosphere around you, which is very important. So, oxygen detectors are used in risk prone areas to indicate the oxygen level. These detectors usually operate in the range of 0 to 25 percent, we know that 19.5 percent is a cut off and therefore, oxygen should be you know indicated from 0 to 25 percent.

The detector system gives a primary stage warning, when the oxygen level in the atmosphere falls below 19 percent. So, it is a wall mounted device, which can be kept near your nitrogen plant or helium plant, wherein oxygen deficiency atmosphere can be produced and therefore, this will have a inlet of the environment gas around you, and it will have a alarm giving 19.5 percent, 19 percent, 17 percent, and this always should be kept on, when you are dealing with such transfers or when you are starting your machine. So, the detector will give you primary stage warning, when the oxygen level in the atmosphere falls below 19 percent. And a second danger alarm is given at 17 percent.

So, one should always ensure that these oxygen detectors are in working conditions, and always some weekly or monthly trials should be taken to ensure that they are still in working conditions. This enables the user to take the quick action, in order to avoid asphyxiation. So, as soon as he hears the alarm, he should open the doors and windows and you should stop, you know transfer it of cryogens and thing like that to ensure that the oxygen levels do not go below a particular limit, you are not getting asphyxiated. This is very important aspect and therefore, oxygen alarm should always be there in the live atmosphere.

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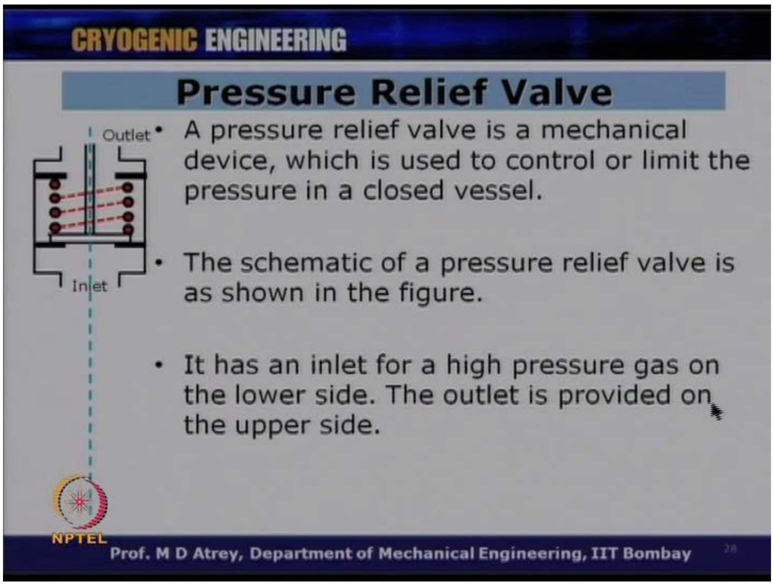


Similarly for safety devices, we should have pressure relief valves. These are very important aspects, and they should be all mounted on the various cryocontainers, as soon as the pressure builds up, the relief valve should be there to come into action. So, pressure relief valve is a mechanical device or mechanical valve, which is used to control or limit the pressure in a closed vessel. So, if the pressure build up that is happening and if pressure exits a valve, the relief valve should open. The schematic of a pressure relief valve is as shown. This is a schematic here and you can see there is a valve, which is spring lidded valve, and this is seat, which sees the inlet and outlet. It has an inlet for a high pressure gas; so this will see the cry container from inside, and this is an outlet to atmosphere. It has an inlet for a high pressure gas on the lower side. The outlet is provided on the upper side.

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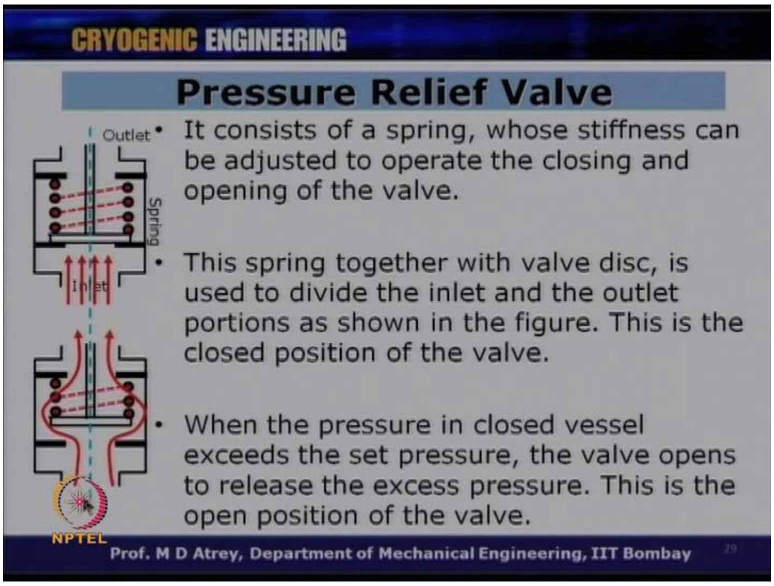


It consists of a spring, whose stiffness can be adjusted to operate the closing and opening of this valve. So, this spring basically decides at what point time, this inlet opens or this blow - off will take place from (( )) when the pressure build up happens inside. And let us say we are talking about a cryocontainer, and if the pressure build up happens beyond let us say 5 to 6 PSI above the atmosphere, they should open or sometimes it could be 2 to 3 PSI above the atmosphere; you should not wait very high pressure to build up in order of to the order of 2 or 3 bars.

So, as soon as pressure exits let us say 1.05 bar or 3 or 4 or 5 PSI, this should open up, and the gas should come out and get vented to atmosphere. The spring together with valve disc, this is the valve disc is used to divide the inlet and outlet portions as showed in the figure. This is the closed position, what you see right now is the closed position that means, the pressure is being exited from inside, because the boil - off is happening. As soon as this pressure exceeds the particular value, this seat will get lifted up; giving vent to this pressure built up, and let the gas go outside from from this gap over here.

So, when the pressure in closed vessel exceeds the set pressure, which could be 4 or 5 PSI as I said, the valve opens to release the excess pressure, and this is the open condition. This is the open condition of the valve, and the gas will find this way and get vented to outside to this. So, as soon as the pressure goes down, this valve set will come back and sit on this again, and it will again leak tight this area, and again the pressure build up can happen next time.

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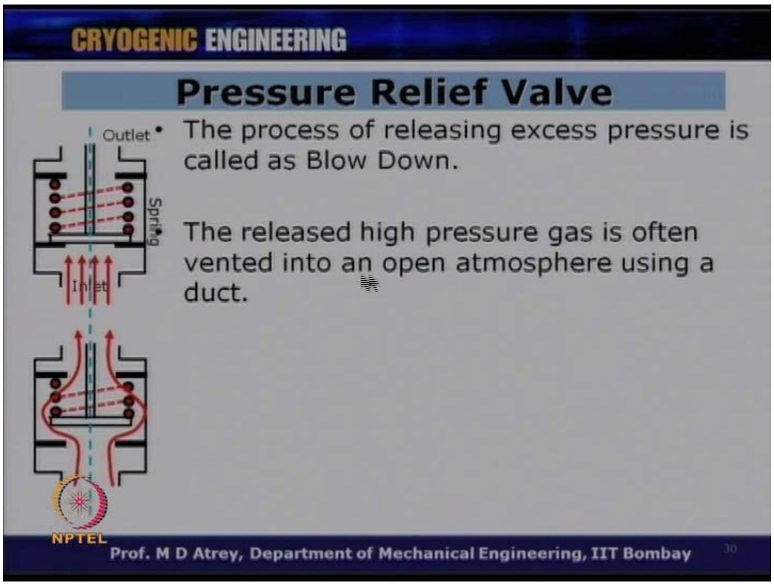


The process of realizing excess pressure is called as blow down. So, blow down will will happen as soon as the set pressure gets exceeded, this seat will go up, and the gas will get blown outside. The released high pressure gas is often vented into an open atmosphere using the duct.

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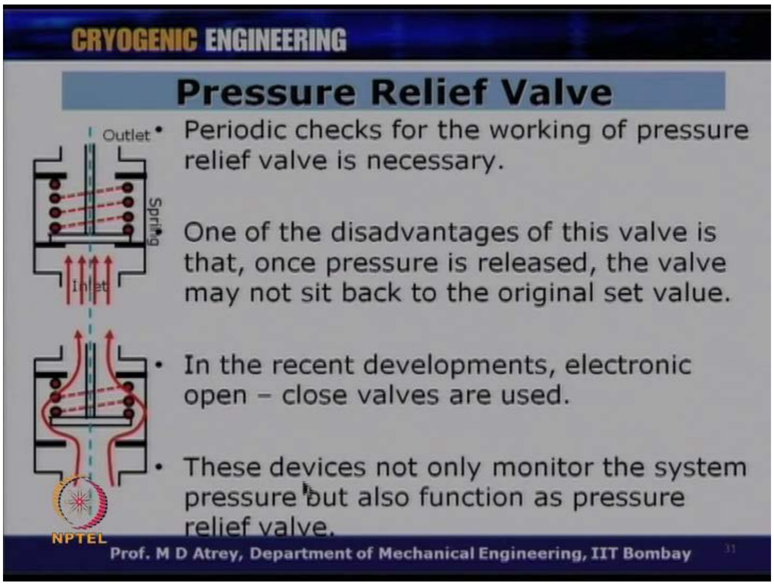

So, periodic checks for the working of this pressure relief valve is necessary. So you should ensure that it opens at the correct pressure all the time; it should not wet you know over a product time, if they do not get used to ensure that their venting still at the same pressure for which they are designed. One of the disadvantages of this valve is that once pressure is released, the valve may not sit back to the original set value; that can happen, because of the spring stiffness, when it sits back after getting blown; if when it sits back, it may not next time open at the same value, if we design for 5 PSI; next time it may open at 6 PSI for example, you do not know or 3 PSI; depending on this spring, it may need (( )) and sits on this valve seat.

In the recent developments, electronic open closed valves are used, which normally opens and closes at the same pressures, but they are costly of course. And therefore, one should ensure how to overcome this, one should ensure that you know one should see to it that some weekly cases are conducted on this to ensure that the relief valve opens at the same pressure all the time. So, the pressure set value will not change even if the valve opens many times, and this is what one should do in having periodic checks.

These devices not only monitor the system pressure, but also function as pressure relief valve. So, these electronic open closed valves also show the pressure; so it is a kind of pressure gauge also. And as soon as the pressure exceeds a set value, you can setup that value over there, this device will work as a relief valve also, it will vent out that extra boil - off bringing while the pressure to the set value again. And so it will functions as pressure relief valve as well as the pressure gauge.

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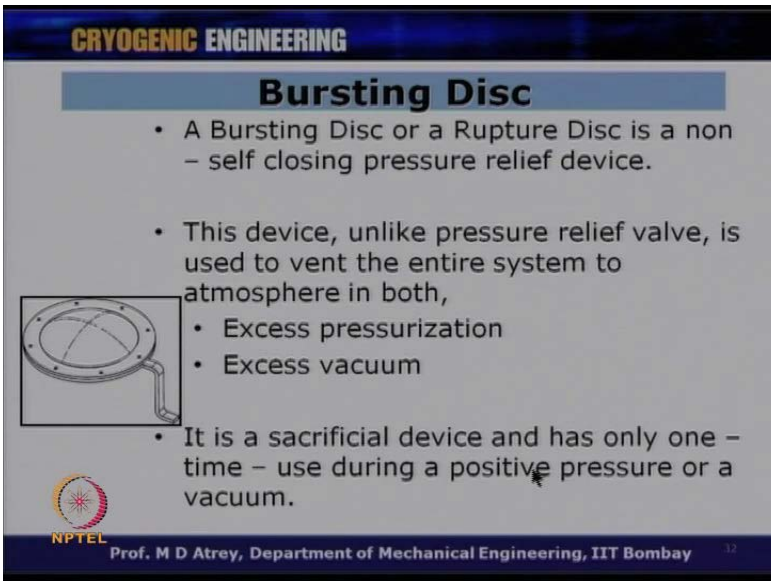


Other device we have got a bursting disc. Pressure relief valve does not function for some reason you will have bursting disc, and this is the last resort basically. So, you got a bursting disc, which is a one of burst device that means it cannot be used again. A bursting disc or a rapture disc, sometimes it is called as a rapture disc also, because it raptures when it comes into action is a non self closing pressure relief device that means, it will not close back, it will not again come back to the original condition, it has to be replaced. So, it is a non self closing pressure relief device. This device unlike pressure relief valve is used to vent the entire system to atmosphere in both conditions, when excess pressurization happens inside or excess vacuum happens.

So, you can see there is a disc over here, which can be fitted to the pipe or a container with a bolt connection, and you can have various connections also basically. And as soon as the pressure exceeds a particular value, the rapture discs will rapture, the bursting discs will burst, and all the over pressure gas will come out; it can work in opposite direction also, if this container is vacuum and this vacuum falls below a set value, then this disc also can burst in the opposite direction in that case. So, it is a sacrificial device that means, when it comes into action, it cannot be replaced, it cannot be put back again to use as we did in self in the pressure relief valve. Well, in this case, it has to be replaced by another burst disc. So, it is a sacrificial device and has only one time use during a positive pressure or a vacuum.

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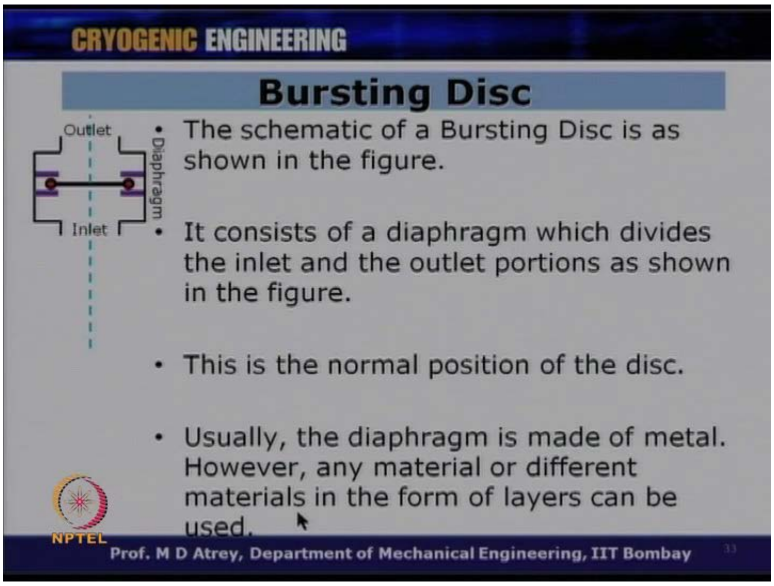


The schematic of a bursting disc is as shown in the figure. So, you can see the burst disc here, it consists of a diaphragm, which divides the inlet and the outlet portions as shown in the figure. This is normal position of the discs, when use in closed condition. Usually, the diaphragm is made of metal; however, any metal or different materials in the form of layers can be used; so various possibilities here.

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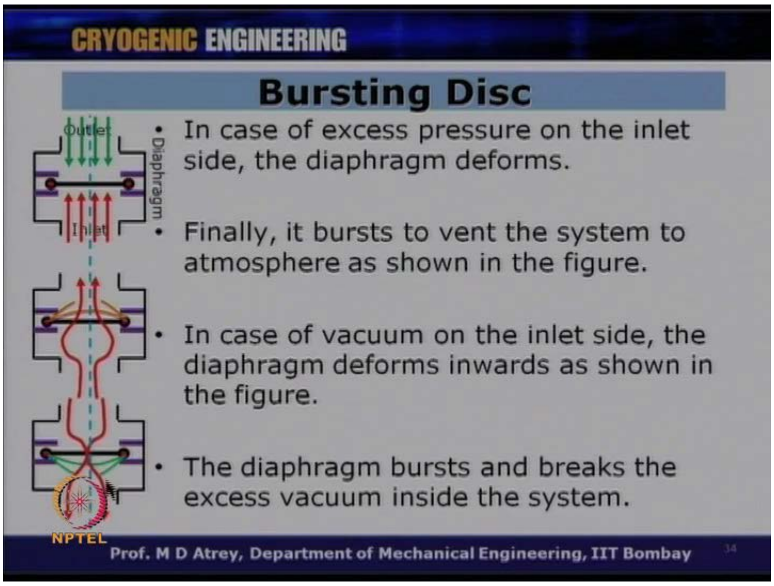


Now, how does it work? In case of excess pressure on the inlet side, the diaphragm deforms. So, we have got a inlet pressure from this side now, and diaphragms takes this shape, because it gets deformed. Finally, it bursts. So, once it goes beyond a particular pressure, once the gas pressure increases, this bursting disc will get disc intermediate shape and finally, it will burst leading all the gases to go outside or getting vented. So, finally, it burst to vent the system to atmosphere as shown in this figure.

In case of vacuum, on the inlet side for example, suppose the vacuum is on this side now, and atmosphere pressure on this side, it will take this shape now; inwards as shown in the figure, and the diaphragm will burst when the vacuum decrease or the vacuum is becoming better and better beyond a particular set value. The diaphragm bursts and breaks the excess vacuum inside the system. So, you can take care of high pressure inside the system as well as low pressure inside the system. So, it can work either way.

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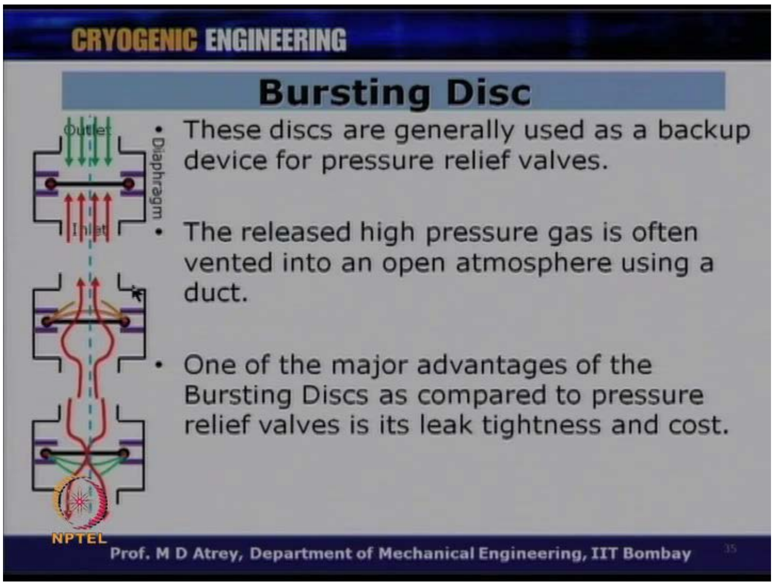


These discs are generally used as a backup device for pressure relief valve. So, when the pressure relief valve does not come into operation for reason, the last chance is the burst disc. The released high pressure gas is often vented into an open atmosphere using a duct. One of the major advantages of the bursting disc as compared to pressure relief valve is its leak tightness and cost. It can be - leak tightness can be very, of very high order as compared to the mechanical pressure self relief valve; and its costs are very, very less as compared to pressure relief valves. And therefore, the replacement of burst disc is not a very problematic.

Now at the end of this, I would like to show you a video, which is shot in our laboratory while transferring liquid nitrogen from the plant, where we produce liquid nitrogen to a (()). And this will show you what kinds of precautions have to be taken while transferring liquid nitrogen from a big (()) to a small (())? So, you can see some safety actions over there, you can protective devices that have been used, and also see how to transfer liquid nitrogen from the big (()) to a small (()).

So, please see this video carefully; you can see all this protections protection devices that are used in our laboratory. And what you see here now is our Engineer Suraj, who will just show you, how we will transfer liquid nitrogen from our plant to a cryocontainer. You can see that he is handling a face shield, and this face shield will ensure that safety of your eyes and the body parts, and again what you have got is the specially made gloves for nitrogen operation, which work at low temperature also, and these gloves are lined with some important material that is made specifically to act against low temperature for your hands.

These are important things. So, these are gloves to handle; and again you should have the shoes, safety shoes; and this is (()) in which we will transfer, we will just show you the liquid nitrogen transferred. What is most important is the the gear which he has chased for the face shield as well as for the gloves. The operations you know very well how to transfer the liquid nitrogen, and what is to be done. So, so here is he will just he is just transferring liquid nitrogen, and then you should make it on and and this is the way he will transfer. You should see that nobody is on this side alright, this is open space completely, so that nobody presses the boil - off liquid nitrogen, nobody sees it directly, nobody puts the hands on the boil - off, nobody basically exposed to liquid nitrogen boil - off; because as soon as you transfer liquid nitrogen, transfer from here, because the the vessel being warm, the boil - off will be essential much more in the beginning. And also at the end, when the container gets full again nitrogen may come out and therefore, we should be very careful in the beginning and at the end.

And now you can see that he is getting filled, and he is stop it now. So, this is how common safety operation which we follow in our laboratory and which normally everybody should follow elsewhere, while working with liquid nitrogen or any other cryogen. And put a cap on the top slowly, you can see there is some boil - off again happening, because as soon as you put a warm material, the boil - off will happen. And now you can transfer this container to various laboratories, wherever you want to work with liquid nitrogen.

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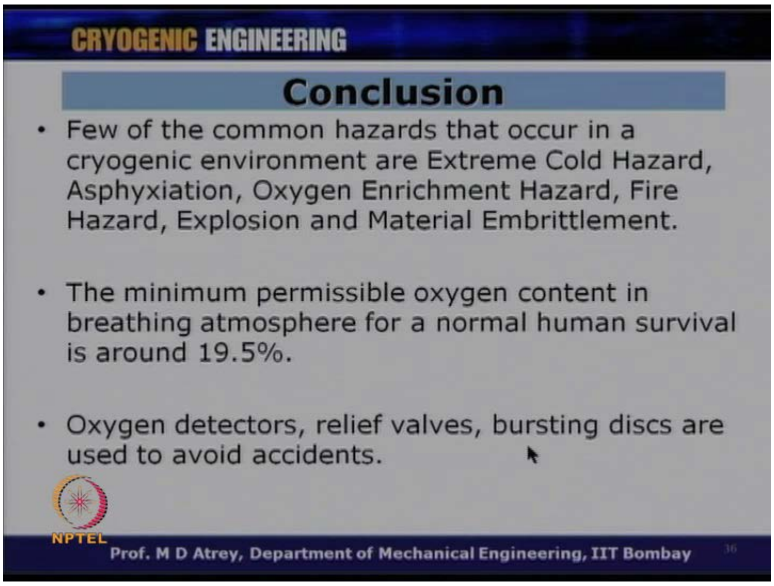


So having seen this video, let us have the conclusions from this lecture. Few of the common hazards that occur in a cryogenic environment are extreme cold hazard, asphyxiation, oxygen enrichment hazard, fire hazard explosion and material embrittlement. The minimum permissible oxygen content in a breathing atmosphere for a normal human survival is around 19.5 percent. So, one should ensure that the atmosphere around in your laboratory is never oxygen deficient atmosphere, it should never have the oxygen content which is less than 19.5 percent, it will lead to unconsciousness, you can have lot of choking breathing problems, and it can lead to sudden death also.

Oxygen detectors, relief valves, bursting discs are used to avoid accidents. So, very important devices that could be kept in places in your laboratory and relief valve and bursting discs are some design aspects that should be ensured while designing cryocontainers or big (()).

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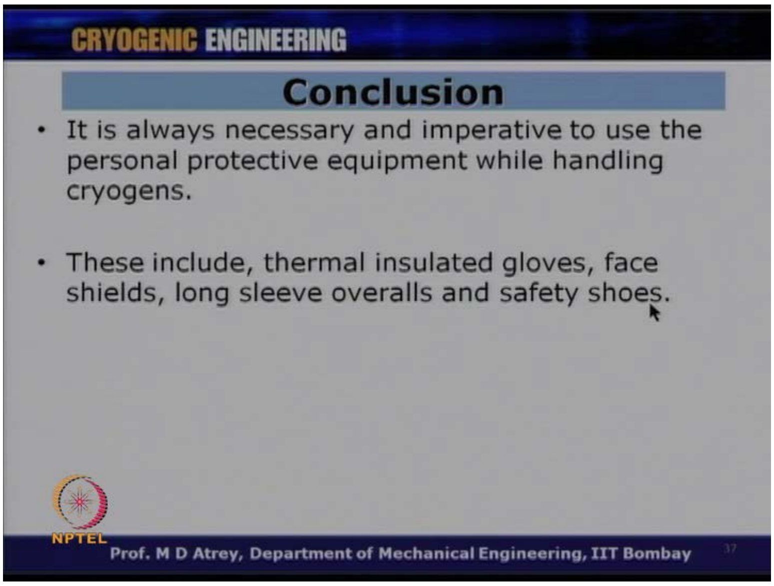


It is always necessary and imperative to use the personal protective equipment like goggles, gloves, overalls, boots are very important devices while handling cryogens. So, all entire body should be seen that none of your body parts are getting exposed to the low temperature gas environment around you. These include thermal insulated gloves, face shields, long sleeve overall and safety shoes.

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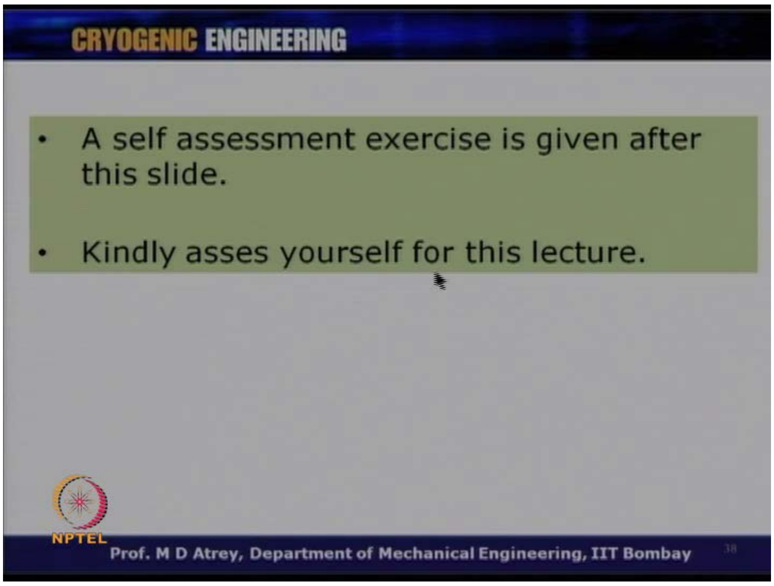


At the end, we have got some self assessment exercise is given after this slide; please go through these exercises. Kindly assess yourself for this lecture.

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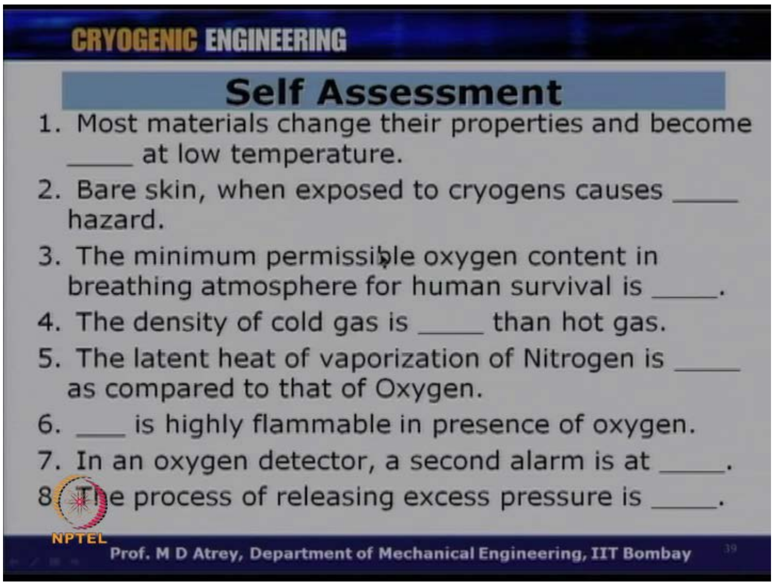


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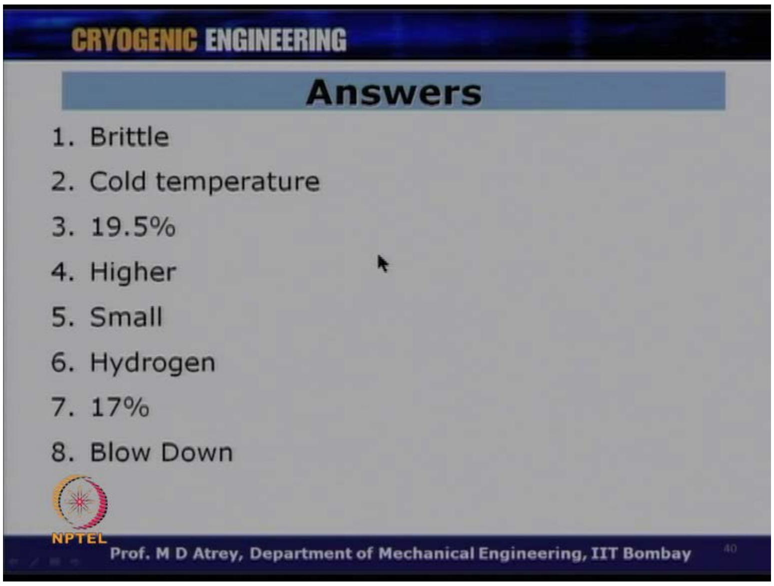


It has also given some answers thank you very much.