Hydrogen Energy: Production, Storage, Transportation and Safety
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Lecture - 68
Regulations, Codes and Standards

In the previous class, we have seen the various Hydrogen Related Hazards. Now, in order to have a safe usage of hydrogen, at the point of production or storage or transport or utilization, there are different regulation, codes and standards in place and this is actually a very vast field and it is evolving. So, in this class, we will be looking at what are the different hydrogen safeties related Regulation, Codes and Standards. Before let us see how we can do a Risk Assessment.

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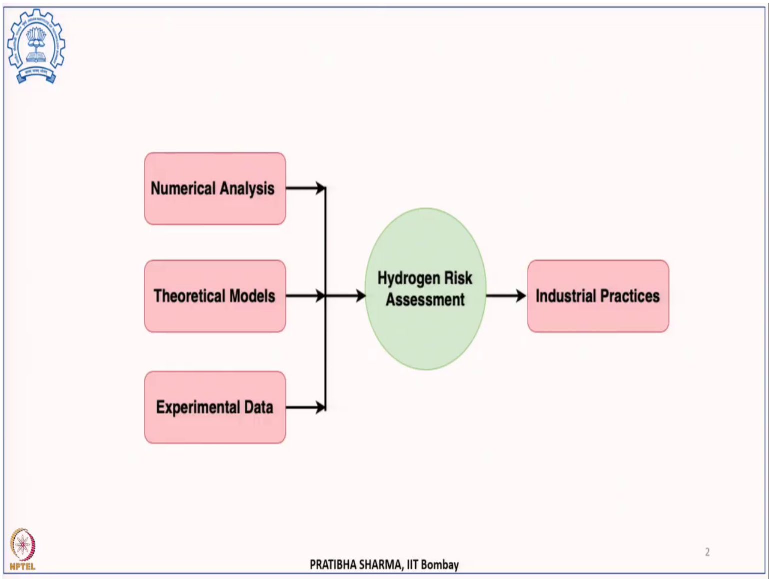

Now, hydrogen risk analysis it provides a reliable connection between the scientific knowledge which is gained from numerical analysis, theoretical models, and experimental data and together with the best industrial practices. Now, here industrial practices are important in the sense we know that hydrogen has been very safely used in industries for more than a century, and they have established a very good safety record.

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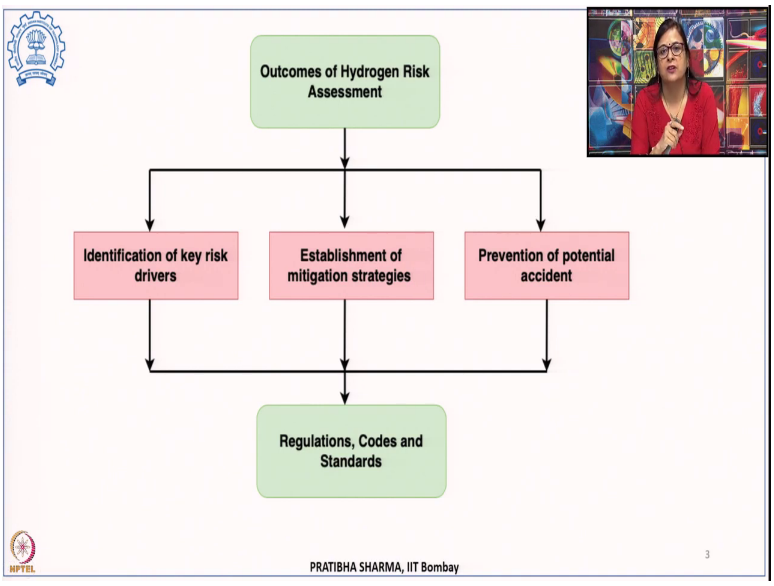

Now, the important part in the hydrogen risk analysis is, first of all to identify what are the key risk drivers which can lead to certain hazardous situations, what are the influencing parameters. Then, establishing the mitigation strategies, prevention of potential accidents. Now, these are the 3 major outcomes of hydrogen risk assessment.

And based on the outcomes of the hydrogen risk assessment that in fact, forms a basis for the regulation codes and standards. Based on both the preventive as well as the protective measures that forms the basis of regulation codes and standards. And that can be used to reduce the chances of leakage of hydrogen or that can be used to reduce the impact of any hydrogen related accident, to reduce the frequency of such accidents, occurrence of such accidents.

Now, the outcomes of hydrogen risk assessment that can be utilized, so as to operate the different hydrogen systems, so as to do a failure analysis of the different related hydrogen technologies or systems.

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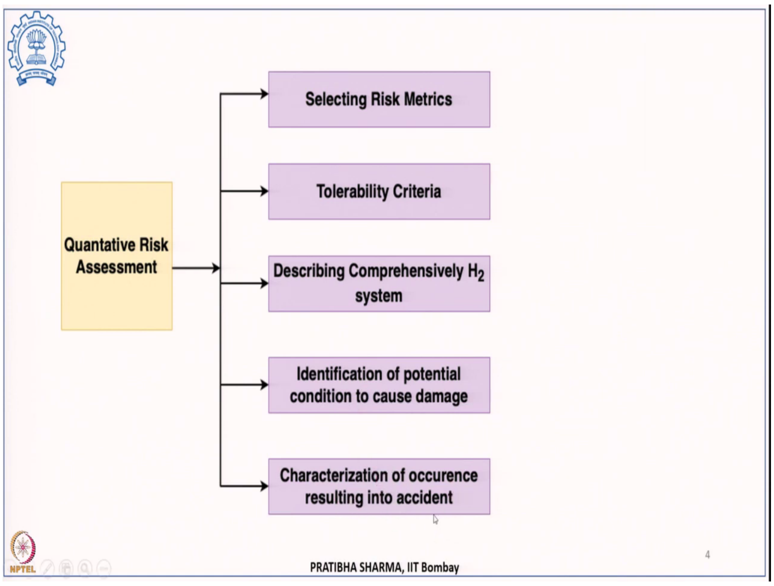

When it comes to quantitative risk assessment, there are different procedures followed and there are different approaches which can be used then there are different ways in which this can be carried out.

Now, usually the process involves selecting the risk matrices, identifying the tolerability criteria, describing comprehensively what are the hydrogen systems which we are targeting, then identification of the condition that has been the potential cause of that damage, and finally, characterization of the occurrence of resulting incident.

Now, there can be several deciding parameters that can be used to either build, to operate or to modify, such hydrogen systems based systems or technologies or products. Now, we have to there are different data driven approaches which are available, which can in fact, act as a baseline to predict the different or to give the different guidelines associated with the hydrogen energy systems.

And then there are different computational techniques, like there are different CFD techniques which can be used, so as to understand what could be the hazardous situations, what could be the accidental scenario, what could be the physics behind the hydrogen which can lead to catastrophic incident.

Now, when it comes to modeling the quantitative risk assessment, it could be like a single step in QRA or it could be integration of the different steps in QRA. There can be different models which can be used.

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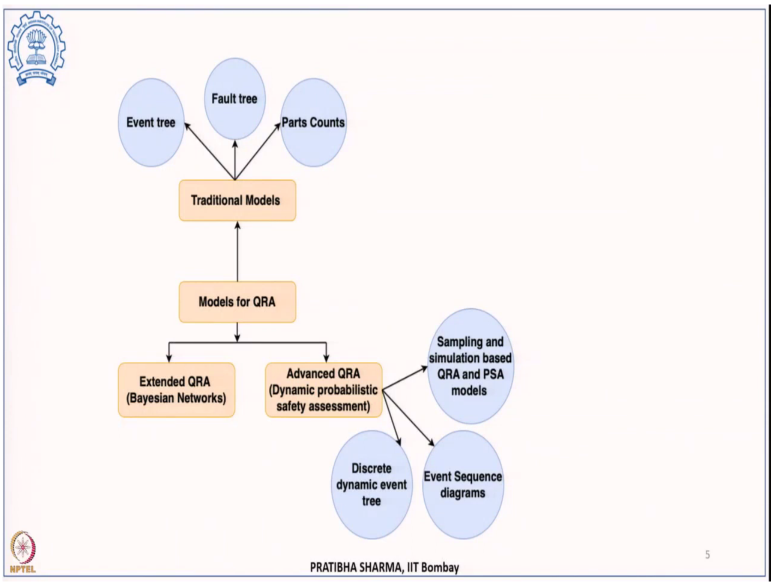

These models could be either traditional model, like event tree analysis, wherein we can first look at what has been the initiating step which has resulted into a catastrophic incident.

So, it could be some nearby fire which has resulted or it has been an over pressurization or it has been a certain leak which has developed because of embrittlement. So, identifying the initiating event, there after looking at what has been the influencing parameter which has led to the catastrophic incident, then how these influencing parameters have interacted with the initiating event resulting into the consequences.

So, these are the different traditional models like the event tree analysis or fault tree analysis or parts counts or it could be an extended QRA, wherein we can use Bayesian networks or it could be advanced QRA models, wherein dynamic probabilistic safety assessment tools are used. Like these could be discrete dynamic event tree, it could be event sequence diagrams, it could be sampling and simulation based QRA and PSA Probabilistic Safety Assessment models that can be used.

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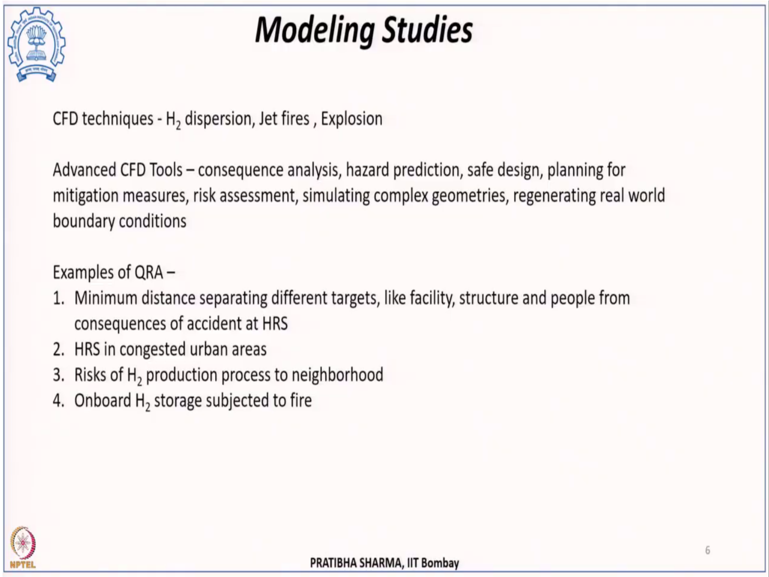

Now recently there have been different techniques which have been used, so as to model the different hazardous situations. Like, there have been CFD techniques which are used to understand, how the hydrogen will diffuse if there is a release of hydrogen, how the jet fires can cause the loss of property or the damage to the structures, how an explosion can be hazardous, and what could be the consequences.

And there have been several CFD tools, advanced CFD tools to look at the consequence analysis to see what would be the possible hazard prediction, what could be the safe designing of the infrastructure or the equipment or the product. It helps in planning to take the mitigate measures to understand what could be the risks associated to do the risk assessment. Even with these advanced CFD tools, it is possible to simulate complex geometry which is very difficult to analyze as such.

And with these tools we can regenerate the real word boundary conditions. Although, we have in the previous class we have seen that experimental techniques they can provide a better insight, but then there are limitations to the experimental techniques. They are quite expensive and at times large scale accidents cannot be replicated, so as to do a risk analysis. And there the computational technique plays a important role.

Now, some of the examples of quantitative risk assessment include wherein like the minimum distance between the target like the facility, structure, and people at a hydrogen refueling station could be identified.

What should be the separation between the facility and the structure or the people surrounding, people who are coming at a hydrogen refueling station? So, that safe distance can be predicted using these QRA. Or if hydrogen refueling station is located in a congested urban area, then what should be the design of such hydrogen refueling station.

What could be the risk associated with the hydrogen production process to the neighborhood of that plant? If onboard hydrogen storage system it is subjected to fire, what could be the resulting hazards. So, these are some of the examples which have used QRA and there are studies which have been carried out to understand the hazards associated with these situations.

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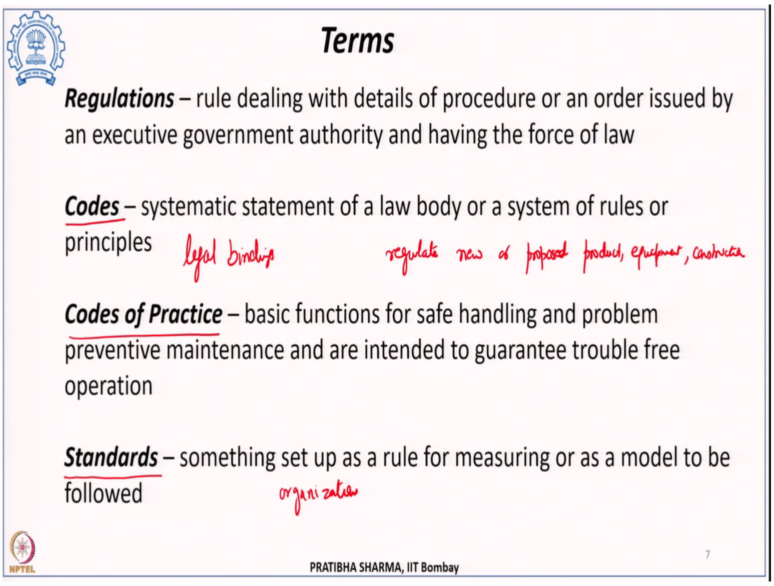

Now, before we talk about the standard existing standards, what are the governing bodies, what are the organizations which are involved in regulation codes and standards, let us first understand the terms which are involved, like what are the regulation codes and standards.

Now, when we talk about regulations we should understand that regulations these are legal requirements or regulations these are laws which the citizens need to follow. Now, these can be treated as, regulations can be treated as the highest level of coding.

And this is this not only describes the physical properties or the sort of operational features of a particular product or a technology, but it also tells about the performance indices. Like, what will be the limiting values, what will be the tolerance limits, what will be the efficiencies and at the same time it puts a implicit restriction on the use of non-standard or non-compliance items or products.

Now, here we need to understand that standards are sufficient or enough for business use, but then regulations these are required, so as to save life, so as to save public at the same time, so as to have environmental compatibility and these are not unduly compromised. So, these regulations are laws.

However, the other term which is we commonly used is codes. Now, these codes are in fact, these codes are referred to as legal binding, now these are called legal bindings. And these can be a collection of it could be a collection of laws, it could be ordinances or regulations or certain statutory sort of requirements. But these are adopted by the governments legislative authority. In such a way, that this is involved in assuring the adequacy of physical as well physical properties or the health conditions of a product of an equipment or a technology.

Now, for code, it is essential that it should be predictable; they established a sort of predictable, acceptable, practical as well as consistent minimum harmonized requirement. In such a way, that it protects the life it provides safety and at the same time it is in the welfare of the public.

Now, the entire purpose of having code is, so that we can regulate a new or a sort of proposed product or equipment or a construction. So, that is how it differs from the regulation. Another term which we come across is codes of practice. Now, by codes of practice we mean that these are sort of basic functions for handling or problem preventive maintenance and they are intended to guarantee trouble free operation.

So, these are basic rules that we that may not be well-documented, that may not be in written text, but these are being followed in industrial practices. For example, in automotive industry, we know that there is a sequence in which the paddles in a car these are or when we turn the steering wheel then the wheels they turn on a particular direction. So, it is not well-documented, but this is well accepted. So, this is a sort of code of practice.

Now, another term that we take commonly used is the standard. Now, these standards let us first understand what the context of the standards.

Now, these standards, these it comes into picture, the context is if there is a particular technology which has to interface with other systems or if there are certain common components which need to be used with different platforms, then there should be a compatibility a documented compatibility which should be acceptable by not only the manufacturer, but also by the user, and there the standard comes into picture.

So, this is a sort of coding which refers to which is called as standard and these are developed by special organizations. And these should be such that, these are used to build a particular technology to build around the case and even that is given a branch of technology.

Now, these standards are such that usually there are global standards, such that these are developed as international standards and they sort of improve the compatibility with the market and without much of duplication or confusion.

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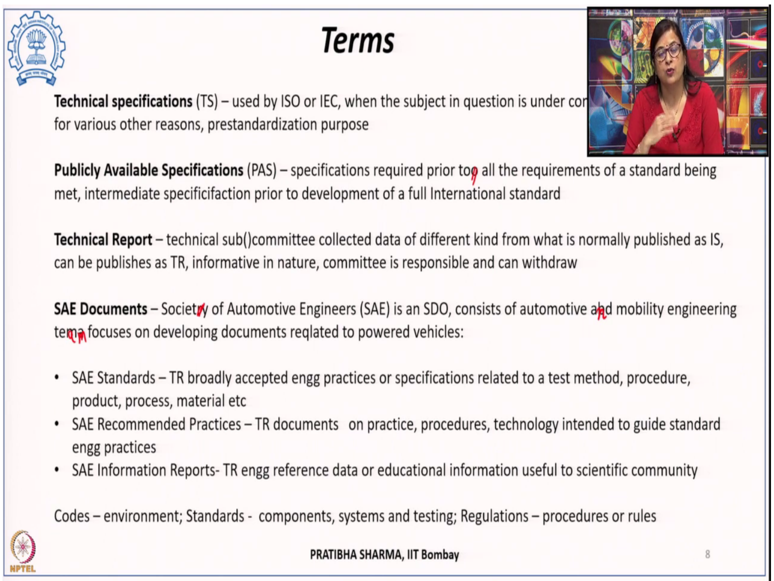

Now, there are certain more terms which are widely being used like the technical specification in short it is written as TS and this is used by ISO or IEC. Now, what are ISO and IEC? That we will see. So, these are the; these are the organization for standards.

Now, technical specification by technical specification, we mean that this is a sort of pre standardization document, wherein prior to standardization it has not passed to the level of international standards. However, if it has been put forward and not been accepted or if the subject in question is under consideration or development. And if there are various reasons because of which it has not been approved, in that case it is known as technical specification.

Now, here it could be reasons like there is not enough of consensus to approve that technical specification or it will be debated further to take it to international standards level. Now, this particular technical specifications when these are when these are brought forward they are period of 3 years is given in that time sufficient ground work is done. So, that it could be converted into international standard.

Another term which is used is publicly available specification PAS. Now, these are again the specifications which are required prior to all the requirements of a standard being met. Now, like the technical specifications, these are again pre standardized documents. However, they have a intermediate specification, these represents the intermediate specification prior to it is being developed into full international standard.

Then, there is a term which is TR technical report. So, this technical report is let us say if it is not to be taken up to the standards level, but the committee technical committee or the subcommittee, they have collected certain data. And that is of different kind which could be normally, which could not be even normally published like an international standard. But then, in that case it is published as a technical report.

This is very informative in nature and the committee the technical committee is considered responsible for that technical report and at times it can be even withdrawn by the technical committee. Then, there are documents like SAE documents. SAE stands for Society of Automotive Engineers, SAE, and this is a Standards Development Organization SDO, which usually consist of automotive and mobility engineering teams which focuses on developing the document.

Now, these documents are usually developed for powered vehicles, and these can be categorized into like SAE standards where these are the technical reports which are broadly accepted for engineering practices or specifications which are related to a particular test method or this can even include documents like what will be the procedures that will be followed, what about the product about the process or material.

Then there are SAE recommended practices, again these are technical documents on to what will be the practices which will be followed, what will be the procedures that needs to be followed any technology that is intended to guide to the standard engineering practices.

And finally, there are SAE information reports, which are again technical reports, which are having reference data engineering reference data or these are like the educational material, information which is available or provided to the technical community or scientific community.

Now, let us understand that there is a difference between codes, standards and regulations. Regulations are procedures or rules which need to be followed. Codes are basically about the environment, about the construction, about the product. And standards these are usually to ensure the business. These are standards are about the components about the systems about the testing protocols that needs to be followed. Now, what are the governing bodies which make these codes standards?

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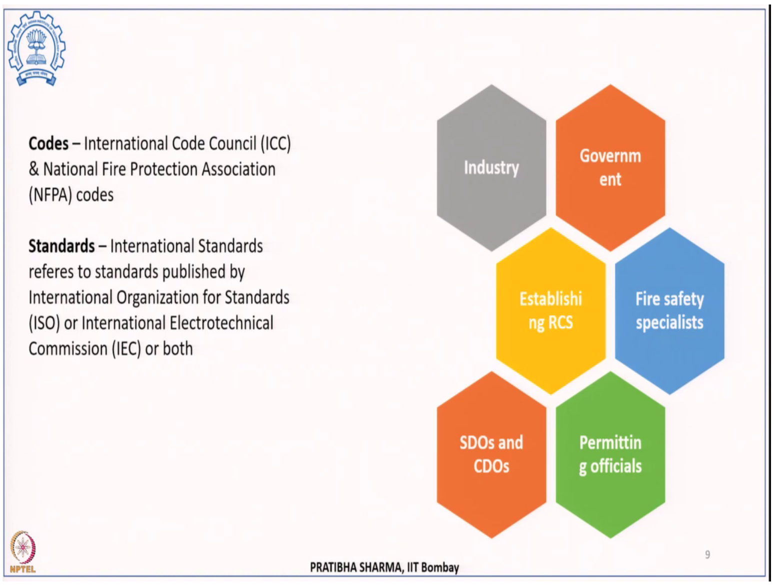

For codes the international code council they come up with different codes for hydrogen and fuel cell like national fire protection association NFPA, which develop these codes.

For the different standards, in order to have uniform standards there are committees although then certain standards these are national depending upon the countries as well these are like the national standard, but some of the standards these are globally accepted.

So, there are committees which come up with the different standards. So, the international standards, they refer to standards which are published by international organization for standards or ISO or International Electro technical Commission IEC or it could be by both.

Now, these committees these comprises of members from industry, government. These are fire safety specialist. There are different officials who are involved in providing the permits and then there are people from the different organizations like standard development organization or code development organization which form such committees, which come up with the different standards, codes and regulations.

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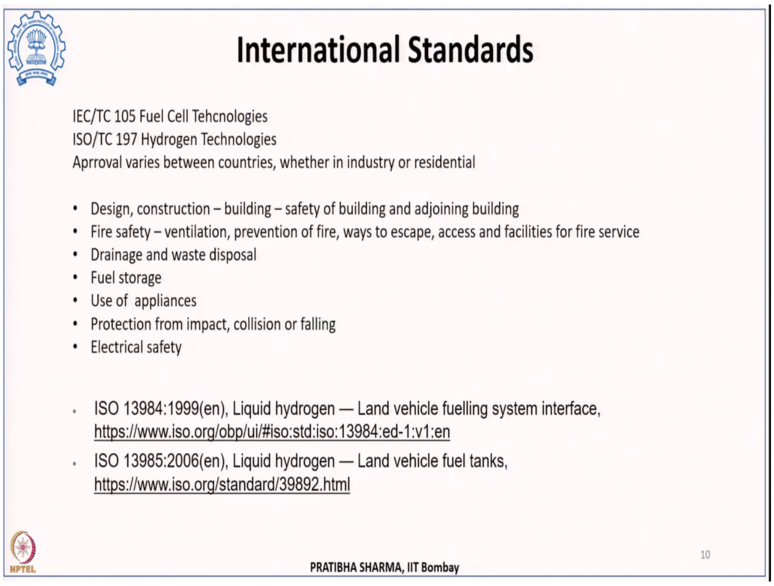

Just to give certain examples of the existing standards although it would be very difficult to present whatever standards which are existing for hydrogen and fuel cell, there are certain representative examples which are being coated here. Like for fuel cell technologies, the standard is IEC TC 105, for hydrogen technologies ISO TC 197.

Now, their approvals may be different, they may be globally accepted or they may be nationally accepted. Their approvals may vary between the countries. It may be different depending upon whether that particular technology product or equipment is meant for industrial use or for residential use.

And these standards, let us say for example, giving the building standards or the space standards, wherein these facilities will be used, hydrogen related technologies will be used, in that case these standards could cover even the design construction of these building. How safe these building will be for operating these hydrogen based technologies. The safety of not only that building, but the neighborhood buildings as well.

Then, whether fire safety has been considered in terms of having appropriate ventilation, are there measures for preventing the fire, are there ways to escape for the people to escape from that area in case of any accidental situation, is there any access or facilities for fire service being included. What are the drainage and waste disposal methods that they have used, where is the fuel storage being considered, what appliances are being used at that place protecting from any sort of impact, collision or falling and then the electrical safety.

So, like while designing such buildings wherein hydrogen technologies or equipment will be used. The standards need to be followed. Just to give certain example like ISO 13984 that is the standard for liquid hydrogen and that is for meant for land vehicle fueling system interface. ISO 13985 for liquid hydrogen again.

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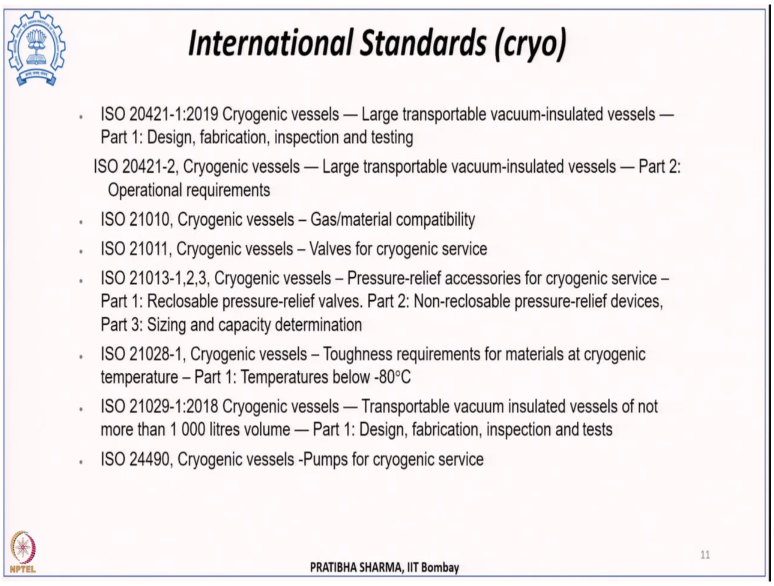

There are other standards again for cryogenic, like for cryogenic vessels ISO 20421, and these are meant for large transportation vacuum insulated vessels which has a part 1 based on how the design, fabrication, inspection and testing will be carried out for these cryogenic vessels. It has a part 2, which covers the operational requirements.

Then, ISO 21010, which is about the cryogenic vessels, the gas material compatibility. About the valves which will be used in the cryogenic service. Then, ISO 21013, part 1, 2, 3 about the cryogenic vessels, what will be the pressure relief accessories with associated with the cryogenic services. Like, in the part 1, it is reclosable pressure relief valves about that. If it is non-reclosable pressure relief devices, then it is covered in part 2. In part 3 is the sizing and capacity determination.

For cryogenic vessels the international standard is ISO 21028 and that covers the toughness requirement for materials at cryogenic temperature. It has a part 1, which is which covers below minus 80 degree centigrade. Then, ISO 21029 that is about cryogenic vessels including the transportable vacuum insulated vessels of less than 1,000 litres volume. Its part 1, covers the design, fabrication, inspection and testing. And again ISO 24490, that is about the pumps used for the cryogenic service.

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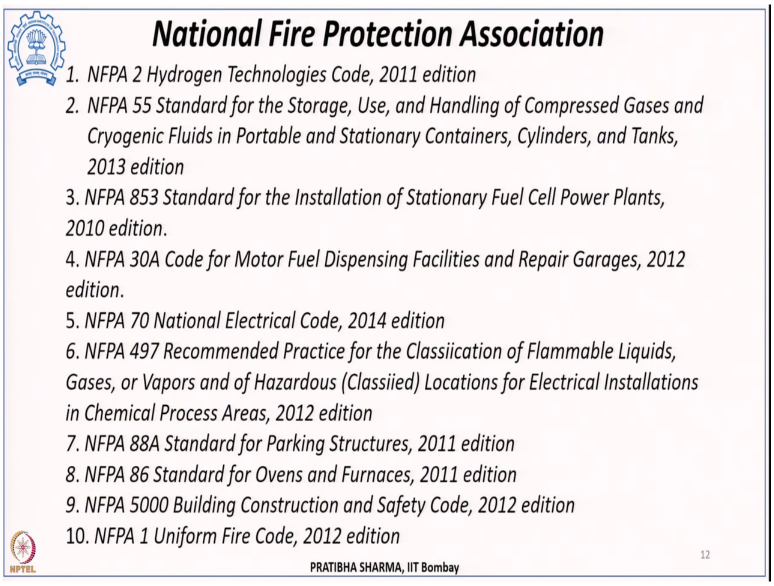

Then there are national fire protection association codes. NFPA 2 about Hydrogen Technologies. NFPA 55, this is about the Standard for Storage, Use, Handling of Compressed Gas and Cryogenic Fluids in Portable, Stationary Containers, Cylinders, Tanks. NFPA 853, about the Installation of Stationary Fuel Cell Power Plants.

NFPA 30A, this is about the Motor Fuel Dispensing Facilities. NFPA 70, about the National Electrical Code. NFPA 497, about the Classification of the Flammable Liquids. 88A, about the Parking Structure, what are the standards, about the ovens and furnace, their usage. 5000 about Building Construction and Safety Code.

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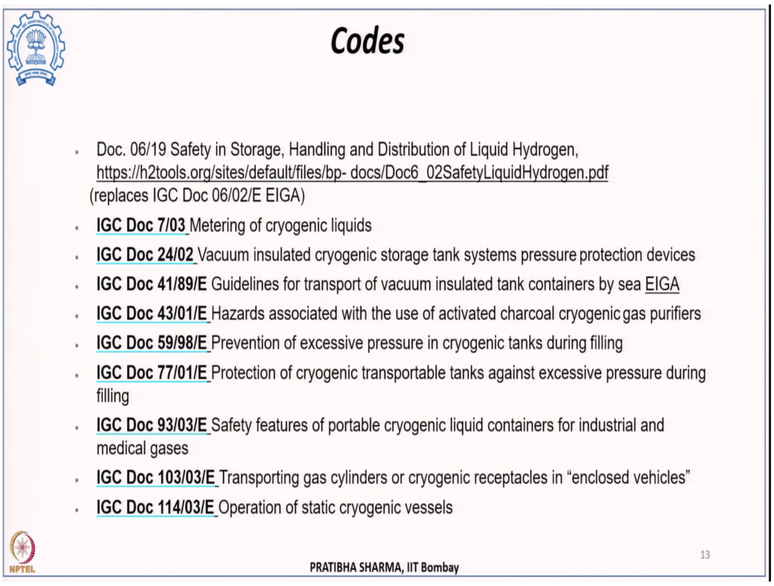

And similarly there are different other codes which are being utilized, about the metering of cryogenic liquids, about the cryogenic storage tanks, what will be the guidelines for transportation of vacuum insulated tank containers, what would be the hazards associated with cryogenic gas purifiers, on to the prevention of excessive pressure in cryogenic tanks and then there are several codes and guidelines which are there. So, as to ensure the safe usage of hydrogen.

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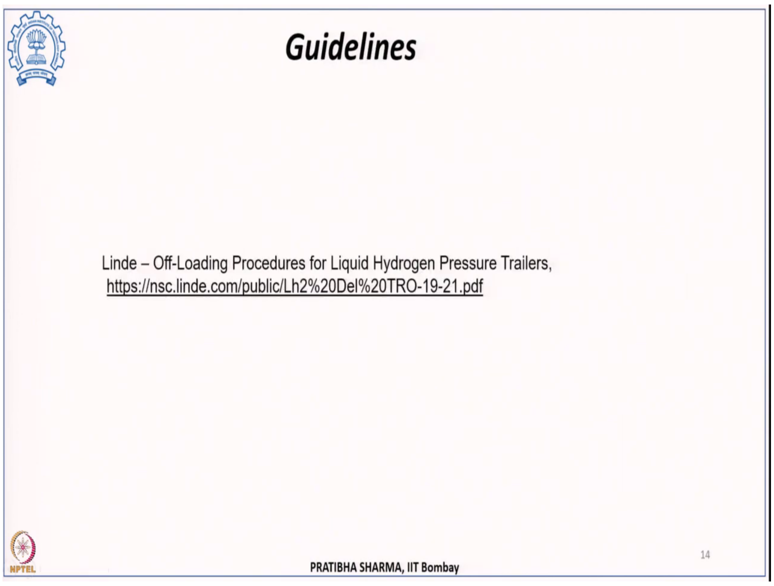

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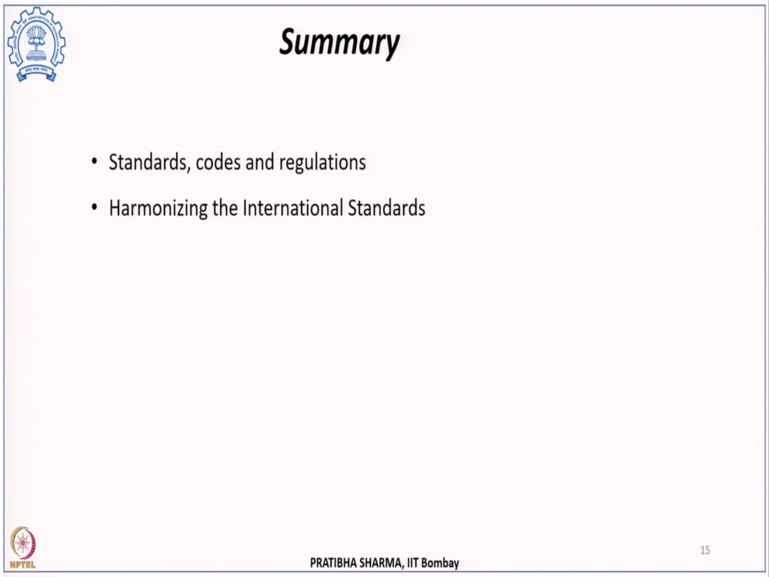

To summarize what we have seen today is, we have understood the terms like the standards, codes, and regulation. And we have seen what are the bodies what is the constitution of the organizations or the working committees which come up with the different standards, codes, and regulation.

And we have taken certain examples of the existing codes and standards related to hydrogen safety. The requirement is having uniform international standards, so that the international, when it comes to cross border or when it comes to international trade of hydrogen, in that case harmonizing these international standards becomes at most important.

Thank you.