Chemical Process Safety
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Module 01
Lecture 01
Safety and Accident Loss Statistics

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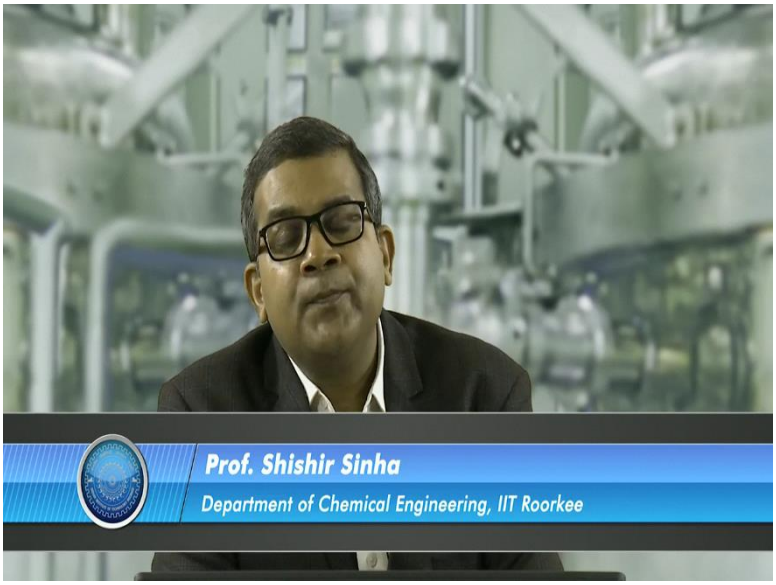

Welcome to this particular course and safety and accident loss statistics, now safety is the integral part of any chemical process plant because it deals with the economy of that particular plant and loss statistics simultaneously tells you that how vulnerable this particular plant or particular process is? Now there are 3 different concepts: safety, hazard and risk, so safety and loss prevention is the prevention of accidents by the use of appropriate technology to identify the hazards of a chemical plant and to eliminate them before an accident occurs.

So first thing is that you need to find out that what are the hazards present at your workplace and then what is a gravity of those hazards, those who are at the workplace, then you need to find out the probability that particular hazard may occur and in case if it occurs, then what is the consequence and how we can eliminate, how we can control those hazards? So, now a hazard the first thing is that you need to find out that what is hazard?

Hazard is anything with the potential for producing an accident, so practically everything is having the hazard, the room in which you are sitting, the roof may collapse, the seat over which you are sit, then it may collapse, so that everywhere, everywhere if you are moving to a road, then definitely some vehicle may hit or sometimes by any accident you may fall into a sewerage line, etc. So hazard is everywhere, now only thing is that you need to find out that what is the probability?

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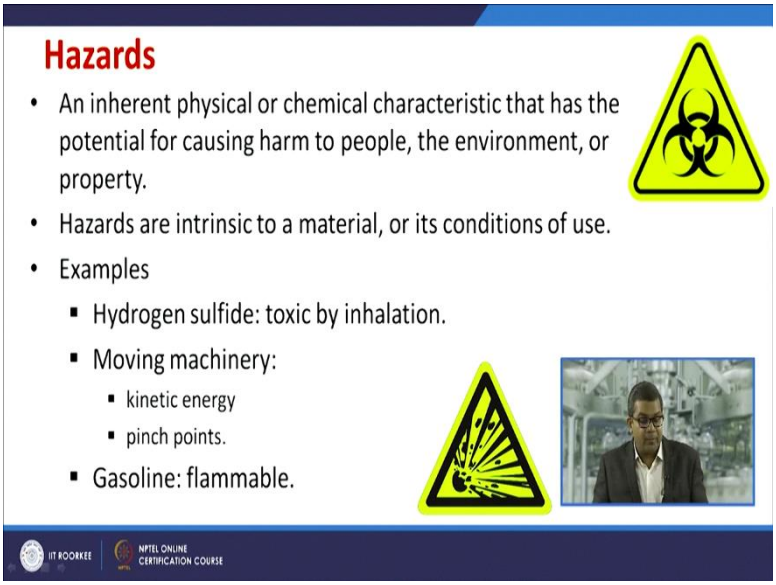

So risk is the probability of a hazards resulting in an accident, so you need to find out that what is a probability of that particular hazard? Now hazard this is an inherence physical or chemical characteristic that has the potential for causing harm to people, the environment and the property because whenever we are dealing with this loss statistics or economy aspect then all 3 key factors plays a very vital role that in suppose a particular person may get injured or ill, then you need to pay the compensation or you take the medical treatment, than the environment, there may be substantial environmental losses and a property losses in case of any fire.

So hazard they are intrinsic to a material and its condition of use, you cannot eliminate all kind of hazard of an any workplace, example, there are few examples, hydrogen sulfide, they are toxic by inhalation, moving machineries, sometimes the belt may broken, then the person those who are working in and around may got injury, the gasoline they are inflammable in nature.

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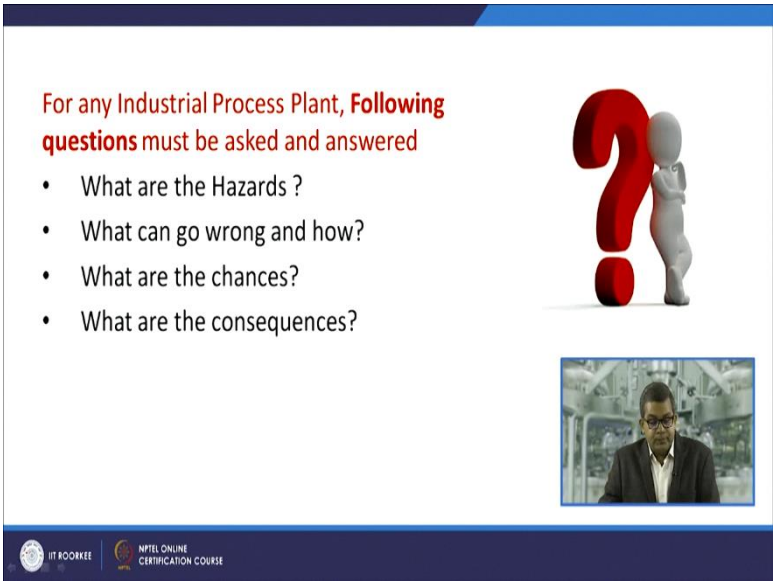

So anything if you wish to carry out these type of analysis, then you need to follow the certain question, these questions are what are the hazard at the workplace? You need to find out with the different tools, what can go wrong and how? What are the chances? That means you need to calculate the probability, then what are consequences? What will happen in case of suppose LPG leaks in your kitchen, so you need to find out like again the example is that, if you go to your domestic kitchen the LPG is the biggest hazard.

What can go wrong and how? Sometimes the regulator is malfunctioning, then definitely the LPG may get leak, what are the chances it may catch fire, sometimes by mistake, by any chance you try to lit the gas stove, then definitely there are chance of fire, then what are the consequences? All the property, all the environment and sometimes the human being may got injured, etc. So these are the consequences, so you need to find out the different questions as per the hazard available to workplace.

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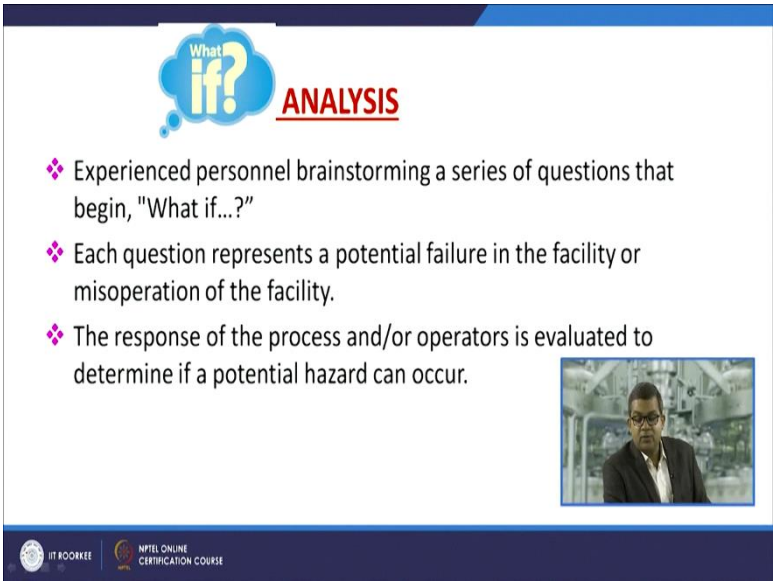

Now certain experience person they used to carry out what if analysis? The experience person, the brainstorming of series of questions that begin, what if? Suppose it happens. Then what if? Each question represents a potential failure in the facility or mis-operation of the facility, the response of the process and or operator is evaluated to determine if a potential hazard can occur, so you need to find out what if answer, there are sample questions.

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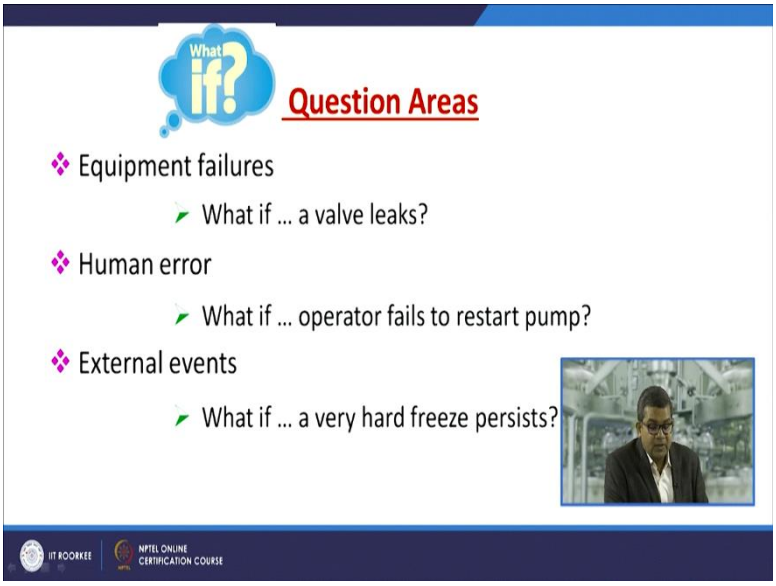

Sometimes equipment failure, what if, if a valve leaks? Human error, what if, if operator fails to restart pump? External events, what if, if very hard freeze persists or storm may occur? So you need to carry out the what if analysis, these are the simple question areas, you may be high localized in terms of question, what if the raw material contains impurities, sometimes the

impurities are dangerous, like if suppose you are dealing with a chemical which is 95% pure and 5% are adulteration, sometimes those adulterative component may cause several thermal runaway reactions, then you will not be able to control all those reactions, then the accident may occur.

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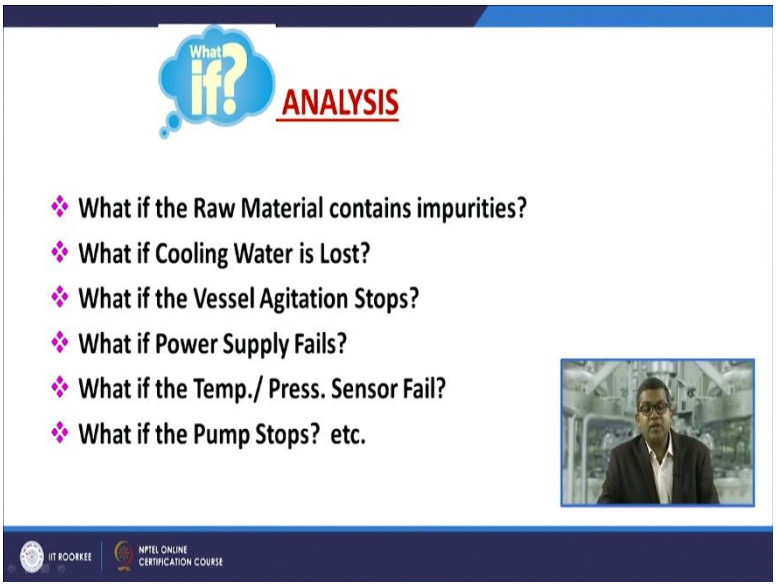

What if the cooling water is lost? Sometimes you are dealing with the exothermic reaction and you need to extract the excess amount of heat being liberated during the course of time, then you need to pump in the cooling water or the cooling fluid for that particular system, so what if, if the cooling water is lost or supply of the cooling water or the cooling fluid fails, what if the vessel agitation stops? What if, if the power supply fails? There are so many accidents that you heard in the chemical industry, those who belong to the vessel agitation aspect or a power supply failure.

What if the temperature, pressure sensor fails? Then sometimes you may not be able to record the things and the reaction will go away, what if the pump stops? So, etc there are so many questions you can frame accordingly, so how you can frame the system, so there are various steps you need to follow to carry out this what if analysis, divide the system into the smaller logical subsystems, so if you divide the system into various smaller things or logical subsystems that the quality of the response on the higher side.

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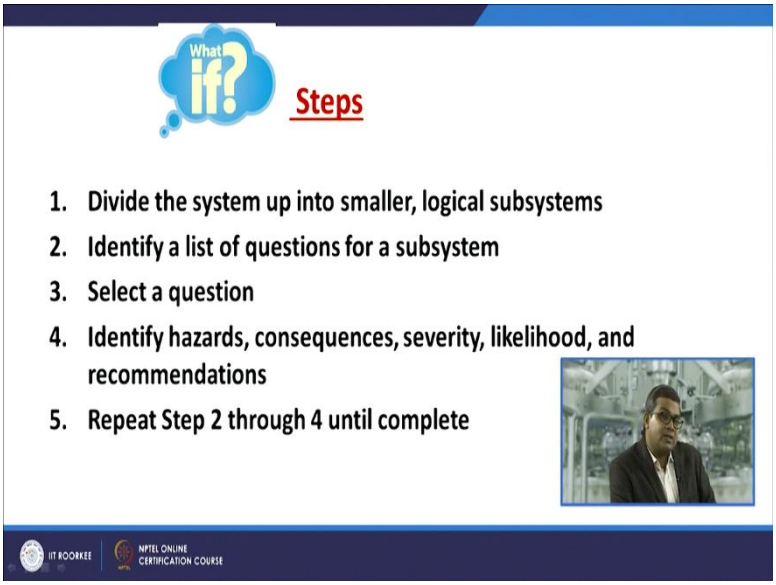

So you need to identify a list of questions for the various subsystems right, that depends on your knowledge, your competency, you select a question identify the different types of hazard available, then consequences, what is severity? What is the likelihood that means you need to carry out the probability analysis and what are your recommendations based on your technical knowledge, technical competency, now if you are not satisfied with all this things, then you repeat the steps number 2 to 4 until it completes or until as an engineer you satisfy with the responses.

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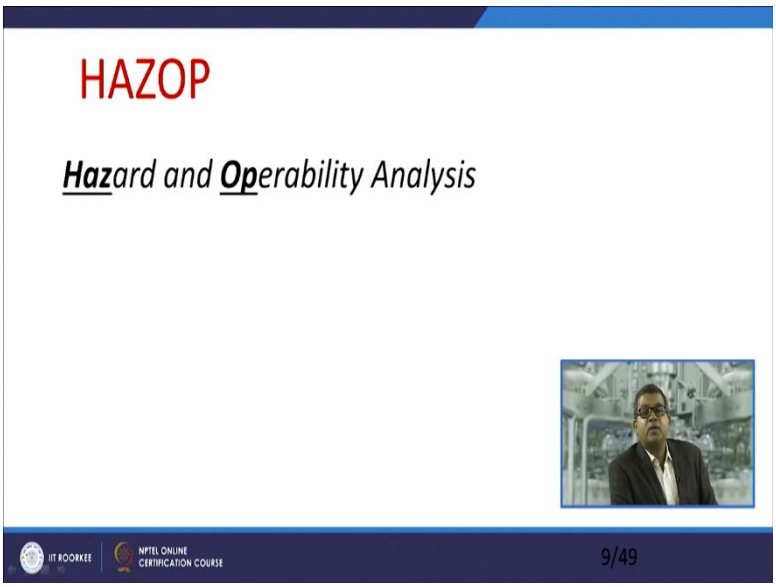

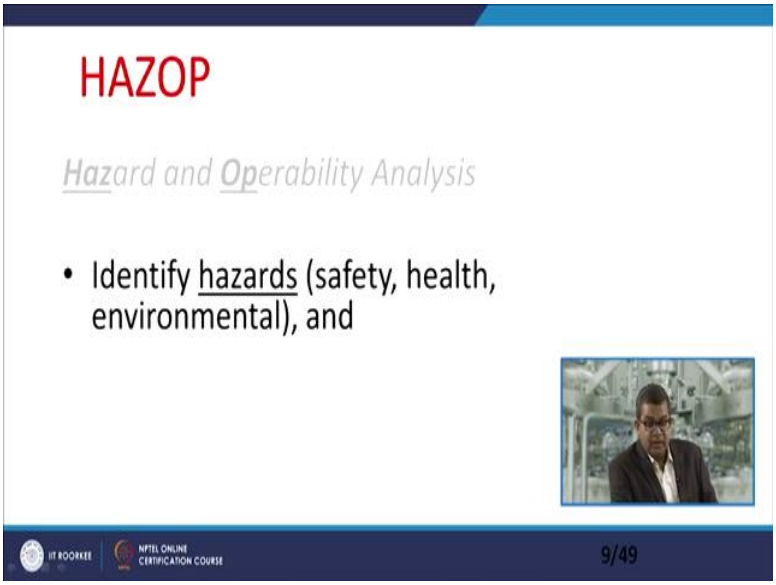

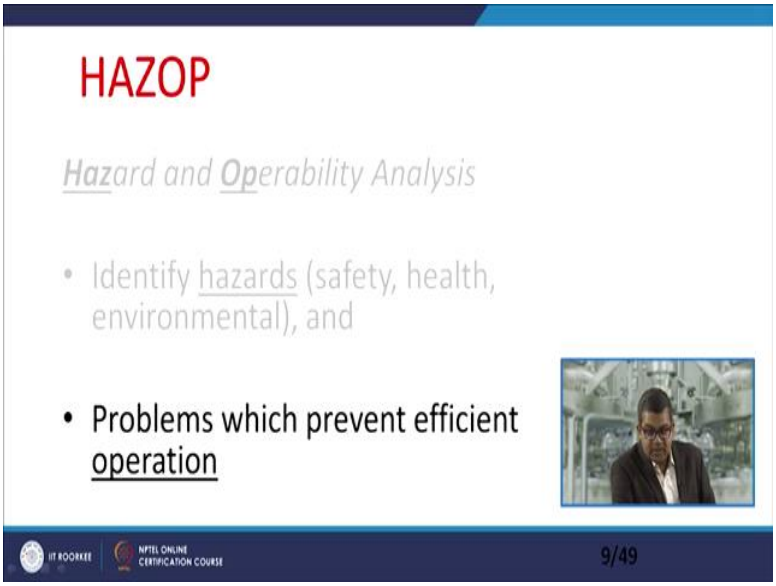

Sometimes you need to carry out the hazop analysis, so we defined out that hazard and you need to carry out how you can deal with those hazards, so you need to carry out the hazop analyses, identify the hazards with respect to the safety, health, environment and the problem which prevents efficient operation, so you need to find out, you need to carry out all those analysis because sometimes in hypothetical manner in a classroom you sit with the complete covers type of thing with the helmet, goggles, then you will not be able to perform, you are efficiency will be a negative side, so in that particular aspect you need to find out the appropriate level of the safety in the particular work place.

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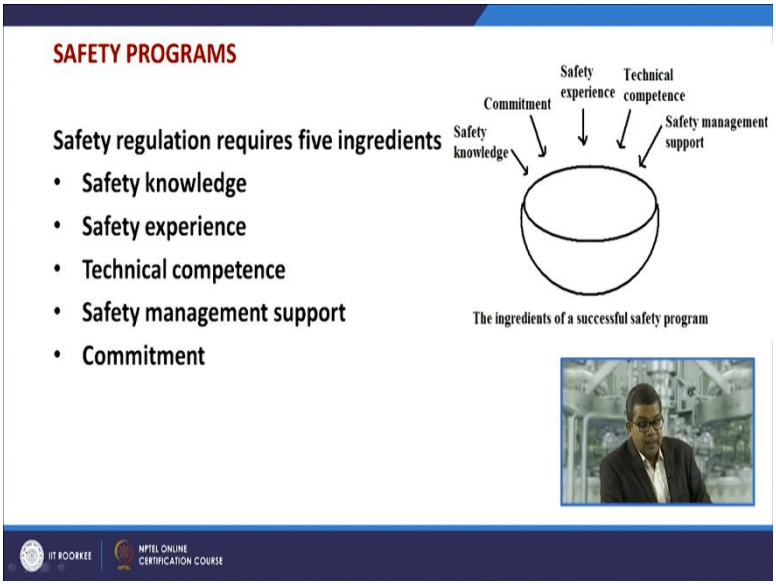

Now as far as the safety programs are concerned because this is again a very important thing, usually it is called a cup of tea with 5 different ingredients, these ingredients are the safety knowledge, safety experience, technical competency, safety management and the support and commitment, now suppose you are working in a particular plant you must know that what kind of hazardous component, chemicals, equipments present at your workplace, then in case, that deals with the safety knowledge.

Now how to deal upon, suppose you are working in a toxic environment and if any toxic substances releases then what your experience says that how to deal upon, it is just like your kitchen, if any, if LPG leaks then your safety experience says that this is the LPG leak because you can identify the LPG through its peculiar smell, then how to handle a scenario that is covered under the head of technical competency, you must be well-equipped, you must be knowledgeable about to deal that particular scenario with your knowledge, with your experience.

Then there must be a safety managerial support because whenever you are performing any kind of safety aspect, your management or if you are part and parcel of management, you must support all kinds of safety activities because whenever any kind of accident this may deal with the severe economic losses to the industry and you must be committed towards the safe environment because it not only helps to you, but your plant but your environment and all the people nearby.

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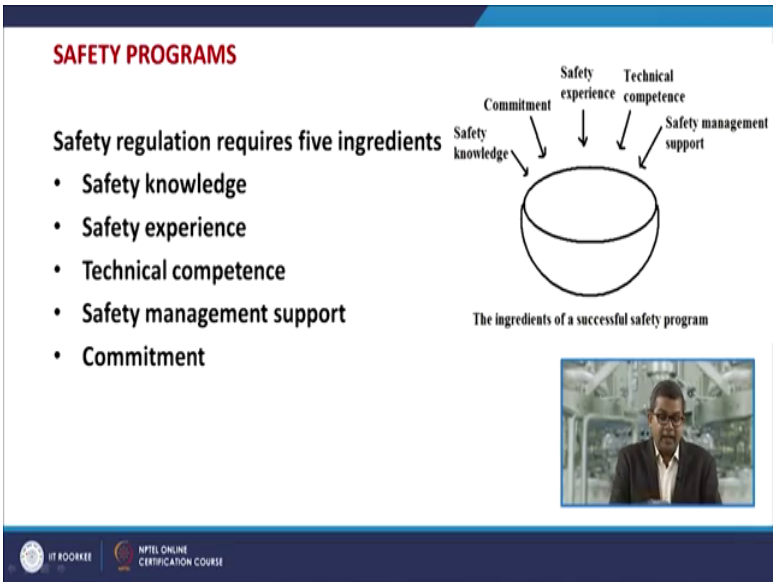

Now there are various scopes of that process safety management, that is what is accountability, process knowledge and documentation, your documentation because if your documentation are incomplete, then definitely you wont be able to go through the entire process because whenever you are dealing with the safety then the documentation or the process requirement, process knowledge is essential because if we go back to this previous slide, the safety knowledge and safety experience both things are essential.

Then capital project review and design procedures because whenever there is any expenditure towards safety then definitely it is a project, it is a design procedures, it is just like if you are riding a scooter or if you are riding a car, then you are advised to use the seatbelt or helmet that is the capital expenditure in addition to the vehicle cost, then you must adopt the process risk

management, then your management must be in a mood to change the things as and when required, then you must learn that what is the process and equipment integrity, it gives a human factors because if anybody recalls the Bhopal accident, it was a complete failure of human factors and that is why the union Carbide was asked to leave the country.

The training and performance, you are all employees must be well-trained to handle all kinds of ontoward incident, you must identify the incident and you need to carry out the proper incident investigation because a near miss may cause a fatal accident, you must have certain company standards and you need to follow, there are all chemical industries they are having certain codes, you need to follow all the codes, there are certain regulations, both for the Central level as well as state-level you need to well versed all those kind of regulations, you must adopt the audits and corrective actions, you go for both internal and external audit and in case any deficiencies found out then you need to go for the corrective actions, you must effort for the enhancement of process safety knowledge.

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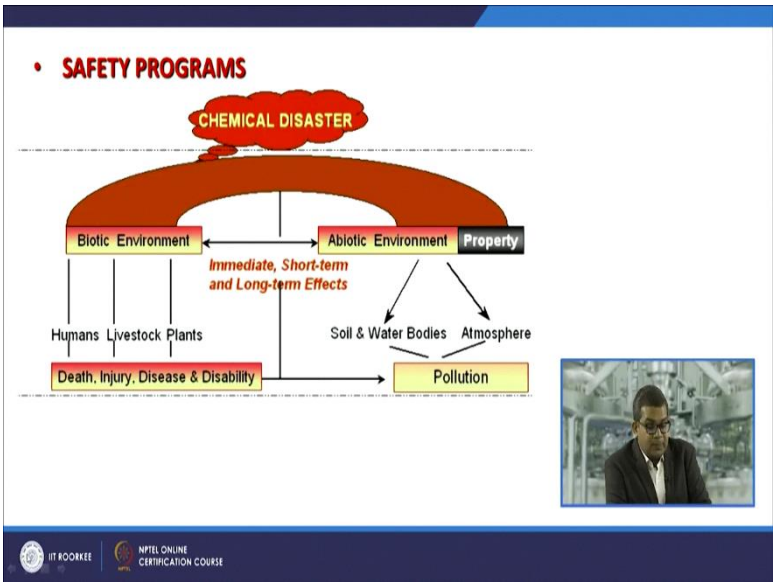

Now this safety program, this deals with 4 different types of basic aspects or rather you can say the 2 basic aspects biotic environment and abiotic environment, the biotic environment deals with the human and environmental that covers the livestock, plants, so in all, there are 4 different parameters for this biotic environment, one is a death, injury, disease, disability, in the subsequent lecture, I will tell you that what is the impact of any kind of occupational injury, occupational illness, fatality, etc and how it impacts to the economy of the plant, the abiotic environment deals, basically deals with the property, basically the soil and water bodies,

atmosphere pollution and if go to the Bhopal gas tragedy, still the arena of union Carbide is polluted and we are unable to completely cardinate off from the different environments.

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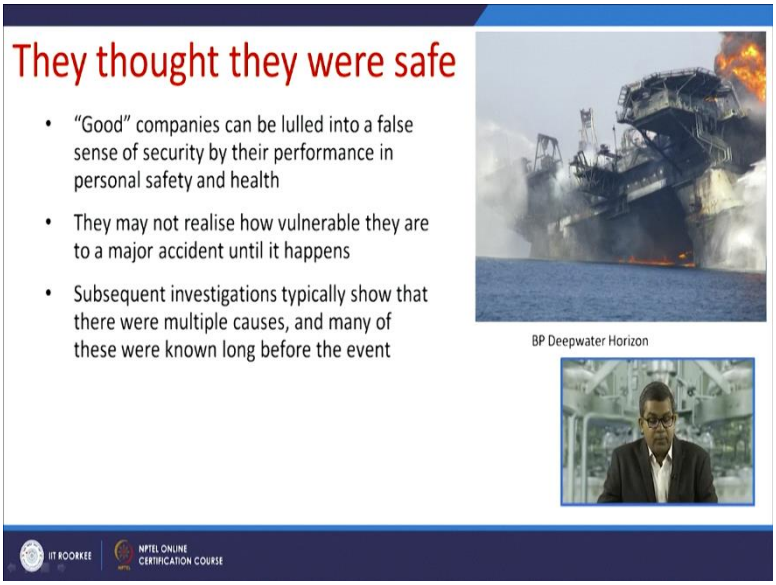

There are various industries, they thought, they were safe, now sometimes good company they are under the imagination into a false sense of security by their performance in the personal safety and health, they may not be realise how vulnerable they are to a major accident until it happens, subsequent investigations typically they show that there were multiple causes, and many of these were known long before the event.

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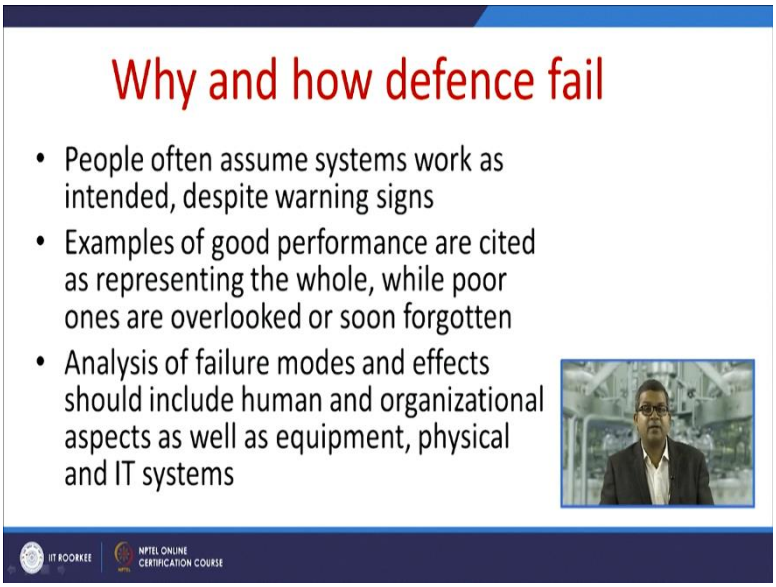

Now this one of the example is the BPD water horizon, why and how defence fails? People often assume the system work as intended, despite of various warning signs, it is just like a human body, sometimes you feel some laziness, etc, or yawning etc that is body gives you signal that something is going wrong in within your body system, you need to identify and you need to adopt the corrective measures, so example of good performance they are cited as a presenting the whole, while poor ones are overlooked as soon as they forgotten, so analysis of failure modes, you need to go for those analysis and effect, they should be the included in the human as well as the organizational aspect.

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Now process safety management is a very good concept, this focuses on the process rather than the individual worker and many of the key decision influencing safety may be beyond the control of the worker or even the sites, if you recall to the previous slides, then there are certain external factors, so sometimes you need to find out, you need to analyse all those factor, they causes because from those of the personal safety, so you need to look at the whole material, equipment and the system and consider individual and procedures as a part of the system, so you need to go for the management system approach for control.

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Now safety aspect, nowadays it is everyones responsibility, the reason is that previously the people thought that you need to appoint a safety officer and it will be a whole heartedly responsible for all kind of safety activities, but nowadays it is everyones responsibility, the older concept was to identify a few employees to be responsible for safety, usually it is inadequate by the todays standard, because now safety has been replace by the term loss statistics, so economy is involved, so now it is everyones responsibility, it is your responsibility to work around safely, so if you are safe enough then definitely the other people will be safe, it is important to recognize the distinction between the good and outstanding safety aspects.

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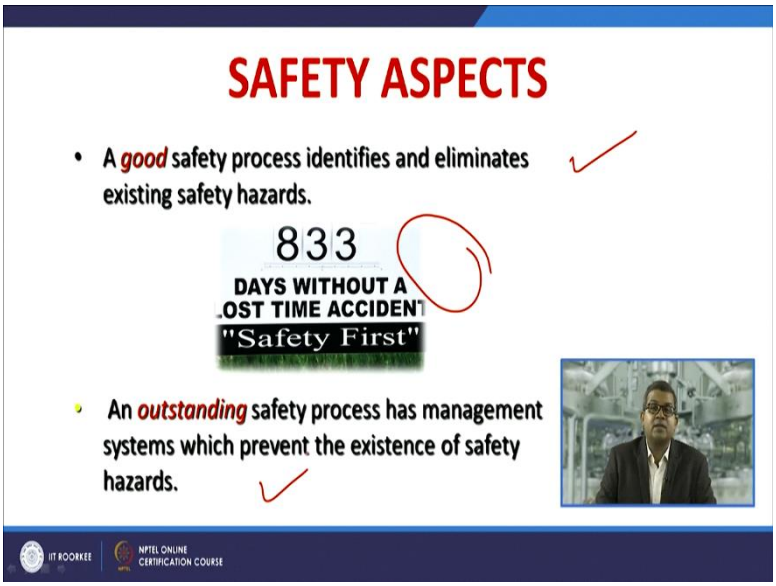

Now a good safety process identifies, eliminates the existing safety hazards, you may find this type of sign everywhere, this one, now outstanding safety process has a management system which prevents the existence of any safety hazards, now first thing the good safety process, this one is the most spectacle one and this is the hypothetical scenario because you cannot eliminate all kinds of hazards at your workplace, so you need to go ahead with identification and elimination of any kind of existing safety hazards.

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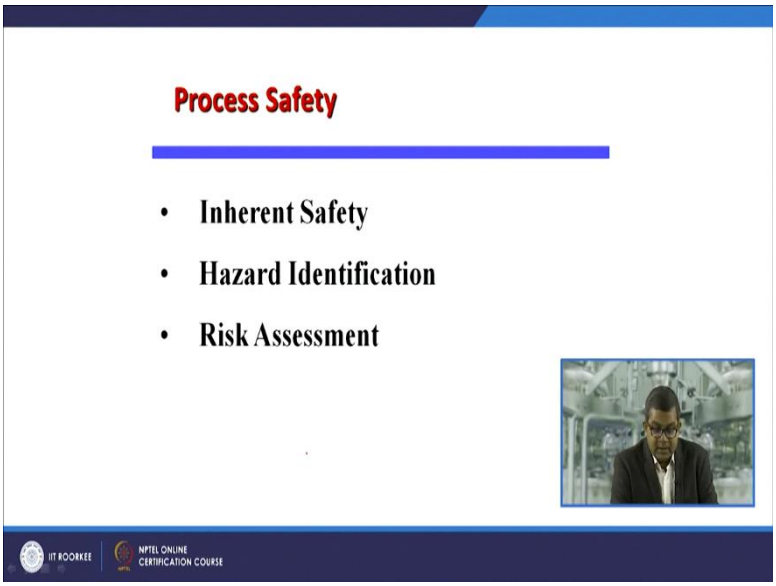

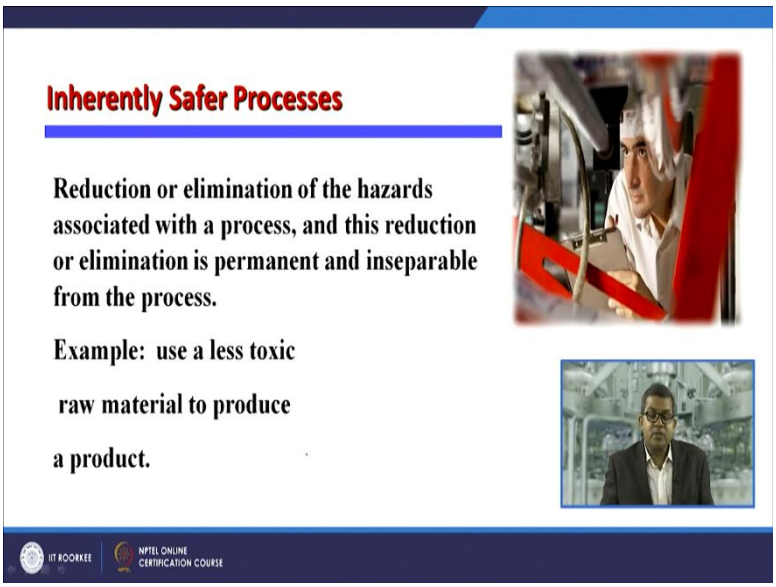

Now as far as process safety is concern, there are three integral part, inherent safety, hazards identification, risk assessment, now inherent safety that is reduction or elimination of hazard associated with the process and this reduction or elimination is permanent, inseparable from the process, first and foremost example is use a less toxic raw material to produce a product,

sometimes you may need to compromise with chemical kinetics but if you optimize the things with respect to the chemical kinetics and the economy, sometimes you may find that this particular aspect is more useful.

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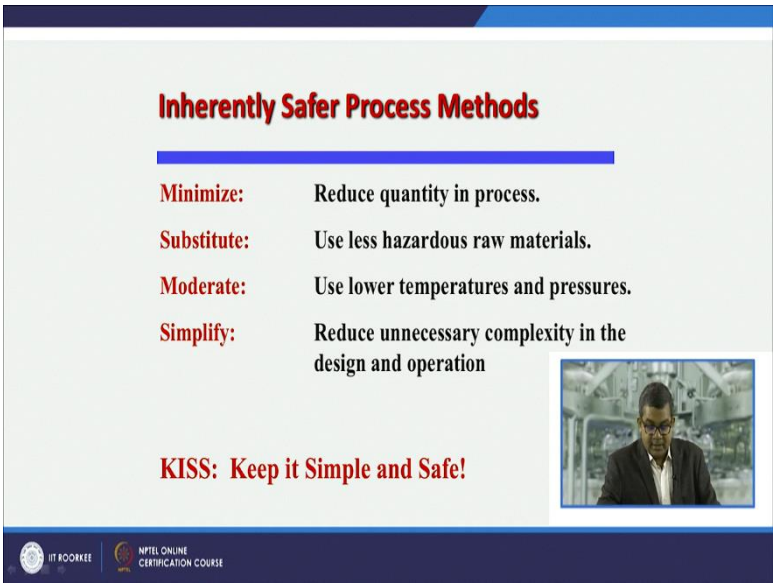

There are again four integral part of inherent safety safer process, minimize, reduce the quantity in the process again go back to your optimization process and chemical kinetics. Then substitute, use less hazardous raw materials, sometimes you will find that dealing with concentrated H_2SO_4 is more complicated compared to the lower concentration of H_2SO_4, moderate use lower temperature and pressures, you need to simplify and reduce unnecessary complexity in the design and operation, sometimes you may find that there are a lot of complex system and those complex system again creates a lot of noise, a lot of complexity and sometimes a safety hazard, so always follow the concept of KISS, kiss, keep it simple and safe.

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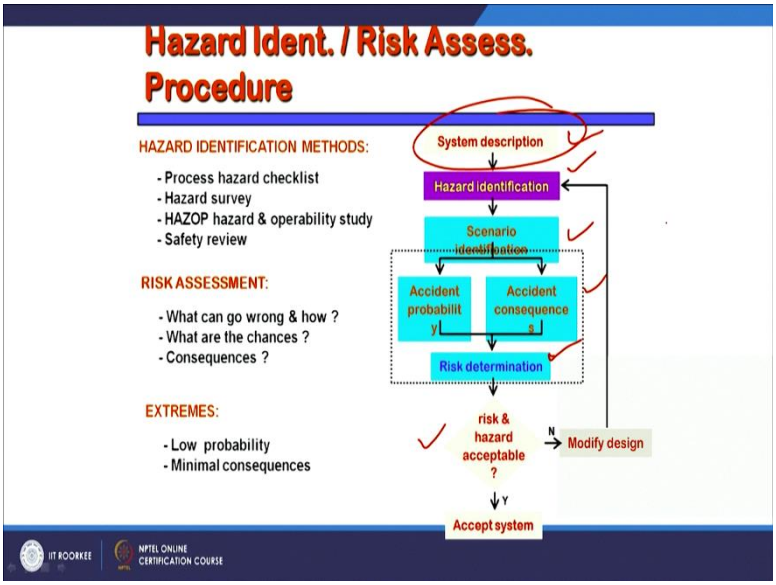

Now this is a simple layout for the hazard identification and risk assessment process, now first thing is that you must have the system description with you like plant layout, what the process is going on? What kind of different chemicals you are using? What are the process conditions, etc? So what an earlier, if you recall difference type of set of questions, then you need to identify the hazard, there are various tools to which you can find out that different hazard, one is the, one foremost tool is your MSDS material safety data sheet.

Then you need to go ahead with the scenario identification, now this scenario identification is attributed to two different aspect, one is the accident probability, you need to carry out that what if analysis? Sometimes it happens, sometimes it may not, than if this accident happens, then what are the consequences, suppose LPG cylinder blast then what are the consequences, entire 15 kilogram of LPG exposed to the atmosphere, it may catch fire or it may not, if it catches the fire then what is the impact, what is enthalpy? How it can impact the atmosphere?

So based on this particular analysis you need to determine the risk, now if this particular risk is acceptable go ahead with the process and if it is not, then again you need to relook the entire study, so there are various subcomponent of all step like hazard identification method it attributes to process hazards check list that is purely based on your system description, hazards survey, HAZOP hazards safety reviews, sometimes you may find that your worker or the plant person it gives valid information okay, gentlemen something is leaking inside, it gives you the things that some process is malfunctioning, so do not ignore those safety reviews.

You need to carry out the risk assessment, what can go wrong? What are the chances? What are the consequences as earlier discussed, you go for extreme that what is the low probability, slight probability may deal to the severity, what are the minimum consequences? So you need to carry out this type of layout analysis for your hazard identification and safer operation.

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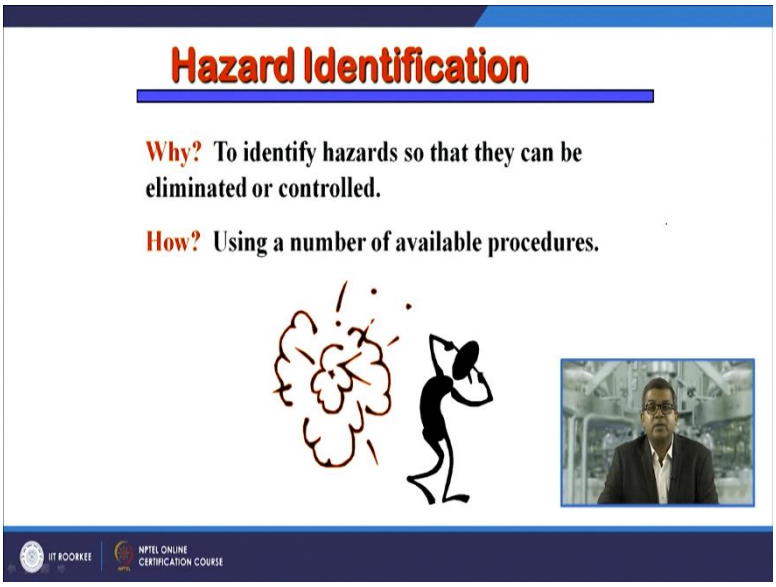

Now again why? Why to identify the hazards so that they can be eliminated or controlled and how? Using a number of available procedures, so these two things are very crucial, why I am interested to find out that what is hazard at my workplace and if it is present, then what are the different tools available to rescue me.

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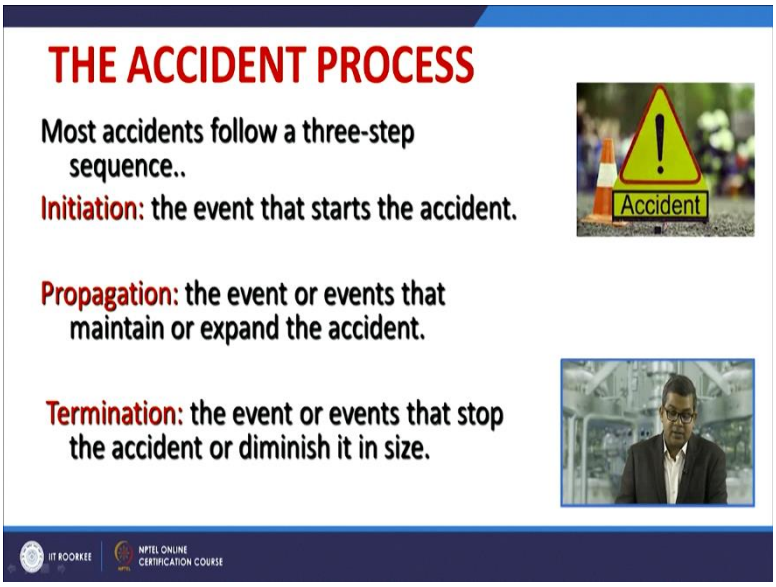

Now, these two things are related with three-step accidental process, the first thing is that initiation, the event that starts the accident, the propagation, the event or events that maintain or expand accident, the termination, the event or events that stop the accident to diminish it in size, so probably if you go ahead then this type of accidental process then you must be in a position to diminish the aspect of initiation, you must be in a position to diminish the aspect of propagation and you must propagate the termination because in case of any initiation you have to kill it as quickly as possible.

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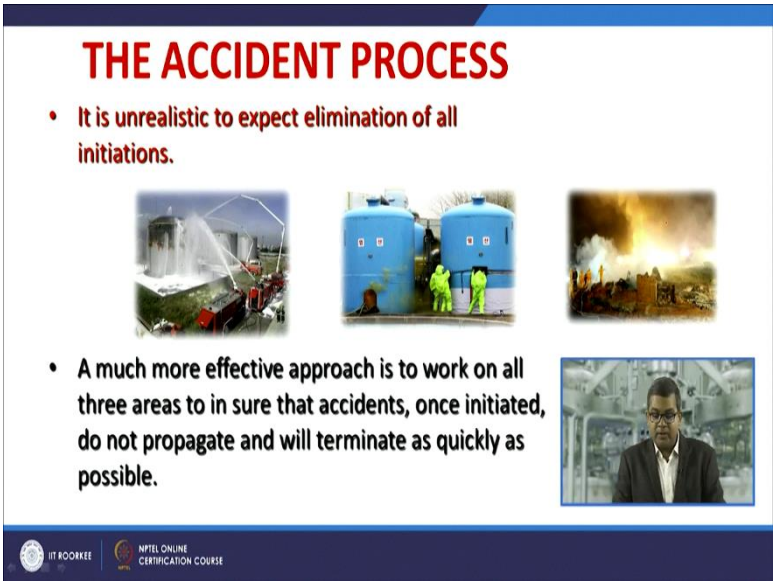

Now it is unrealistic to expect elimination of all initiations, it is practically impossible if you are dealing in any kind of chemical plant, it is unrealistic to eliminate all initiation. A much more effective approach is to work on all these areas to sure that accidents, once initiated do not propagate and will terminate as quickly as possible.

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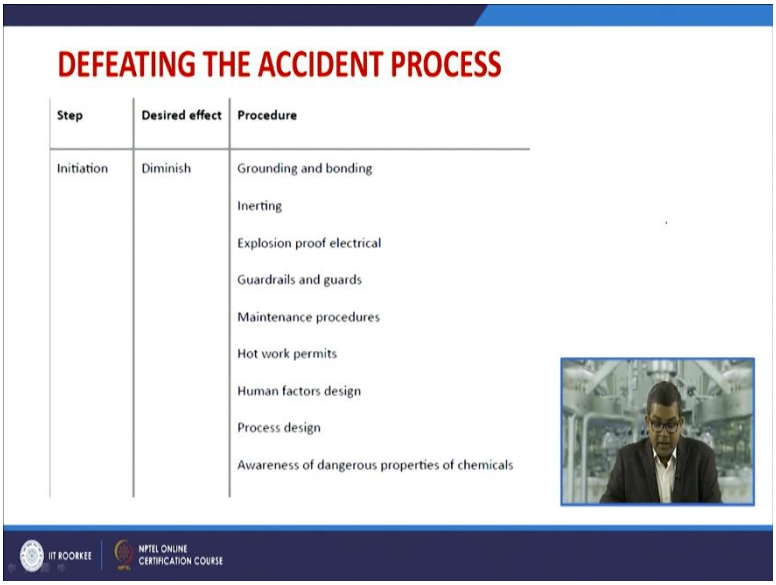

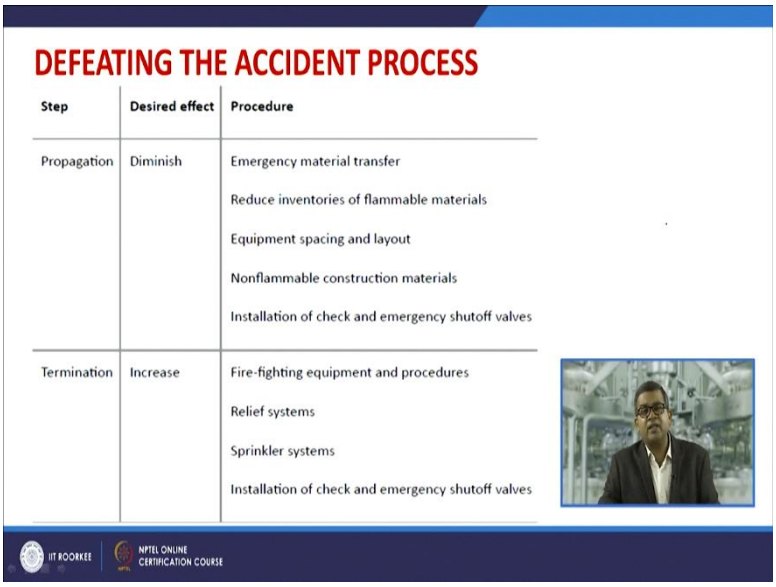

Now there are various tools to defeat the accident process initiation, these are the various procedures in listed over here like you need to diminish all those thing, then grounding, bonding, inerting, explosion proof electrical, appliances, etc, propagation, it should be diminish, it should be decrease, you must have an emergency like emergency material transfer, reduce inventories and so on, that you can devise on your own based on technical knowledge and technical competency.

Then termination, you must increase by firefighting equipments, procedures, relief systems, sprinkler systems, etc, so you need to devise based on the technical knowledge, safety knowledge, technical competency, manager supports, so based on all this aspects you can go ahead with these three steps initiation, propagation and termination.

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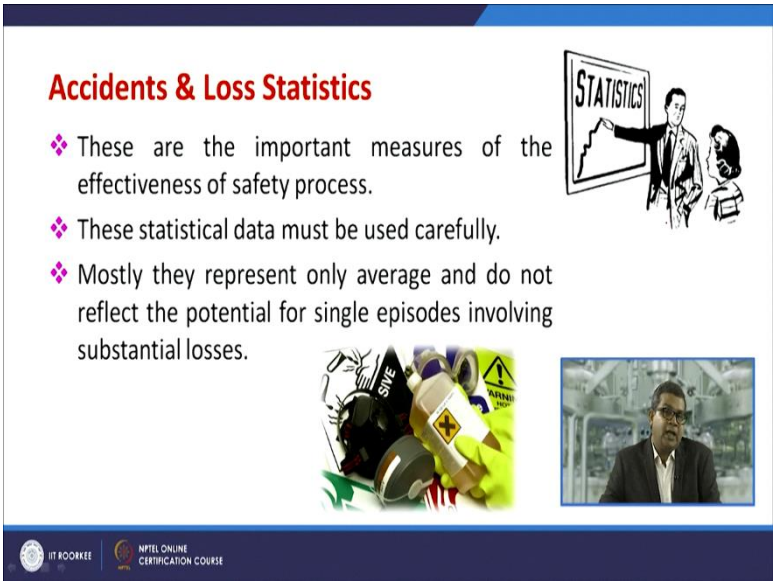

Now whenever we talk about accidents and loss statistics, they are important measure for various effectiveness of safety process, now whatever data is available to you, this statistical data must be used carefully, most of them, they represent only the average value and they do not reflect the potential for a single episode involving the substantial losses.

I would like to give you an example that suppose a fatality rate of any component is say X, that means if you are for working for an stipulated time, you may have X fatalities, but it does not mean that every time if you work for stipulated hours you wait for fatality, that is why mostly they represents only the average value, maybe it is an outcome of n number of accidents.

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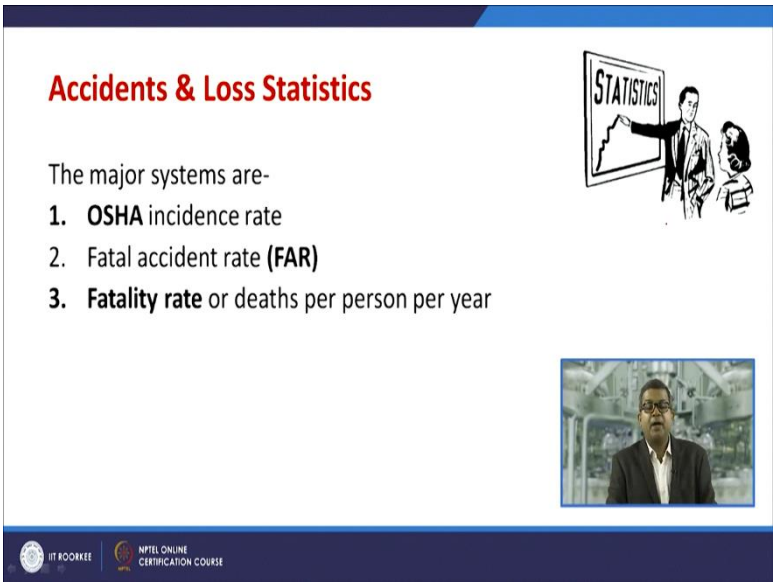

Now whenever we talk about the statistical information, there are three major system to deal upon, one is the OSHA incidence rate, OSHA stands for Occupational Safety and Health Administration U.S.-based agency, the fertile accident rate, the fatality rate or deaths per person per year.

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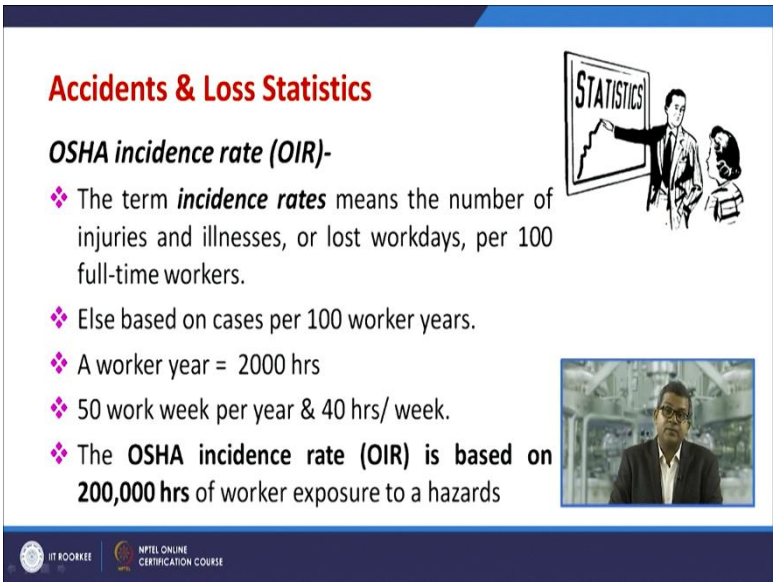

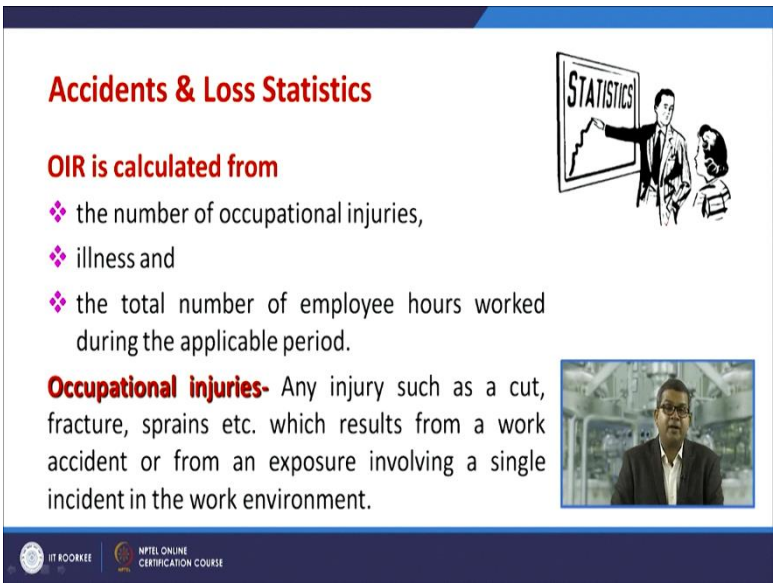

Now the OSHA incidence rate OIR, the term incidence rates means the number of injuries and illness or lost work days per 100 full-time workers, else they are based on the 100 workers years, so usually a worker year is almost 2000 hours, this attributed to the 50 work week per year and 40 hours per week, so the OSHA incidence rate is based on 200,000 hours of worker exposure to a hazards, this is purely an statistical information and usually this OSHA incidence

rate is calculated from the number of occupational injuries, remember there are two types of injuries, one is the recordable one, another one is non-recordable one.

So the number of occupational injuries deals with the recordable occupational injuries, the illness and the total number of employees hours worked during the applicable period, there are certain things related to the occupational injuries, any injuries such as cut, fracture, sprains, etc, which results from a work accident or from an exposure involving a single incident in the work environment, this is the standard definition for the occupational injury.

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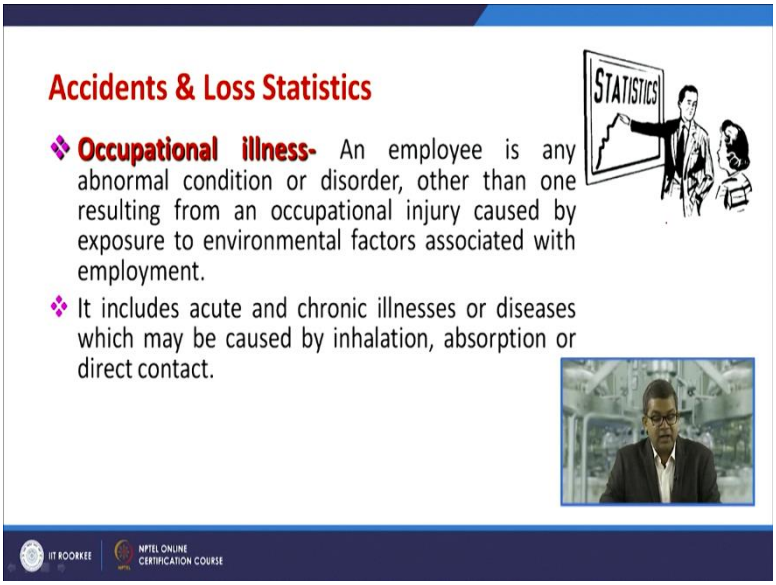

Occupational illness and employee is any abnormal condition or disorder other than one resulting from an occupational injury caused by exposure to environmental factors associated with the employment. It includes acute and chronic illness or diseases which may be caused by inhalation, absorption or direct contact, now the role of these occupational illness or occupational injury is that sometimes a worker may away from the workplace, so if he or she is away from workplace, then definitely there would be a loss to the industry, so these type of things must be recorded, so whenever there, he or she is away from workplace, maybe in terms of hours, maybe in terms of days then there is a concept of lost work days.

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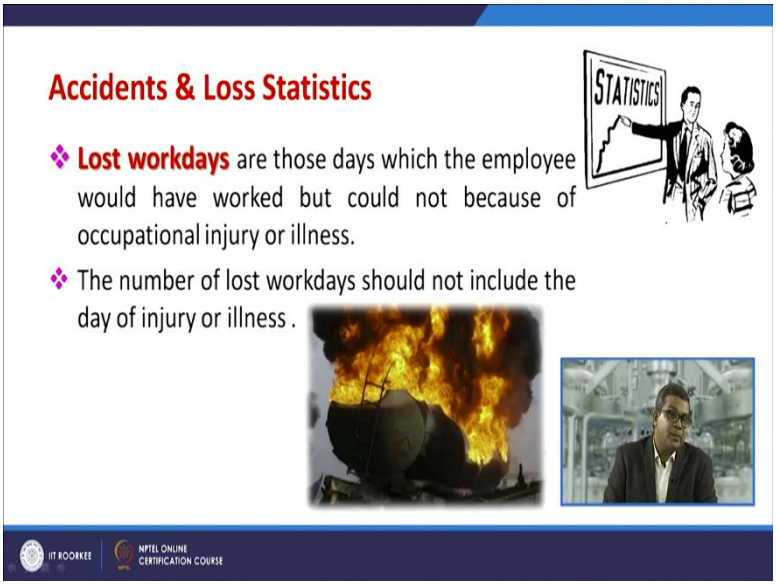

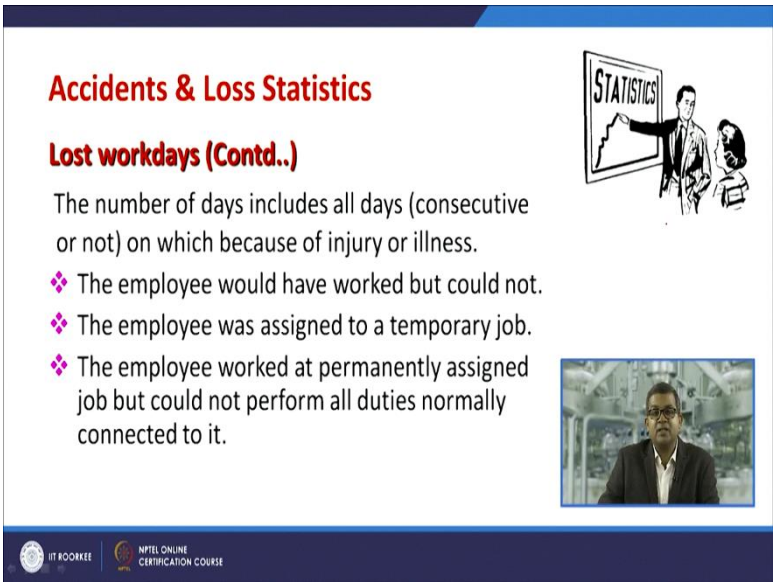

So lost work days are those days which the employee would have worked, but could not because of occupational injury or illness, remember whenever we are dealing with trained employee that means an industry has implemented certain quantum of resources towards the training of that particular employee, so the number of lost work days should not include the day of injury or illness because the person has reported on that very day.

The number of days includes all days consecutive or not on which because of injury or illness, the employee would have worked but could not, the employee was assigned to a temporary job, this not only deals with the two type of work, one is that he is away from its original workplace and simultaneously some other standby person he or she was assigned to do the same type of job with that particular environment, the employee worked at permanently

assigned job, but could not perform all duties normally connected to it, so these are the few points which are attributed towards lost work day.

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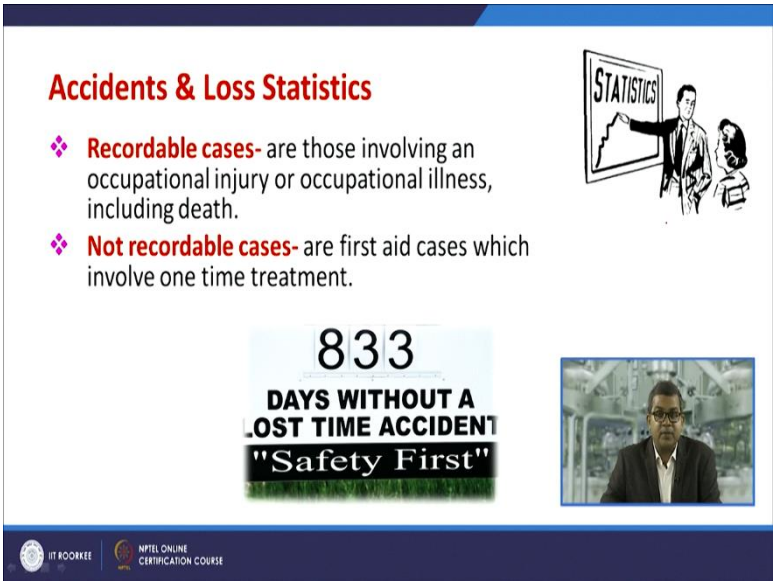

Now again there are two things as I earlier talk that about the recordable cases or a non-recordable cases, so recordable cases are those involving an occupational injury or occupational illness, this including death, non-recordable cases they are the first aid cases which involved one-time treatment, so this may not be contributing towards the statistical information of that particular process or chemical.

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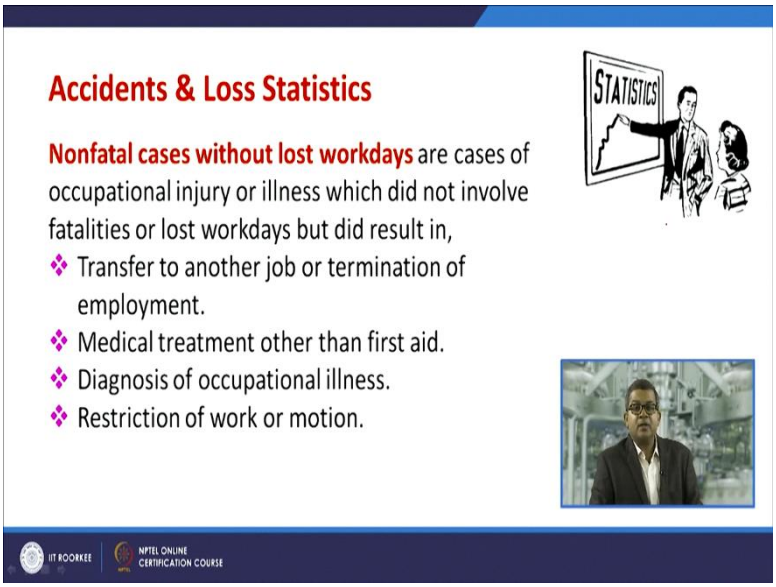

They are certain non-fatal cases without lost work days, these are the cases where the occupational injury or illness which did not involve fatalities or lost work days, but did result in transfer to another job or termination of employment again, the economy is involve, the medical treatment other than the first aid again, the economy is in at that stake, diagnosis of occupational illness and sometimes the efficiency of the worker plus plant is at stake, restriction of work or motion again, the economy is involve, so these type of things should be taken into the consideration.

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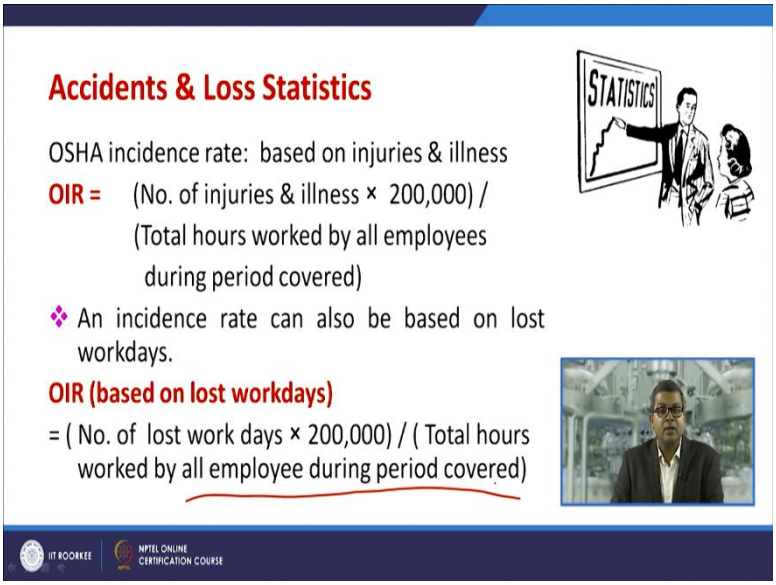

So OSHA incidence rate based on the recordable injuries and illness there is a statistical formula:

OIR = (No. of injuries & illness × 200,000) / (Total hours worked by all employees during period covered)

An incidence rate can also be based on lost workdays.

OIR (based on lost workdays) = (No. of lost work days × 200,000) / (Total hours worked by all employee during period covered)

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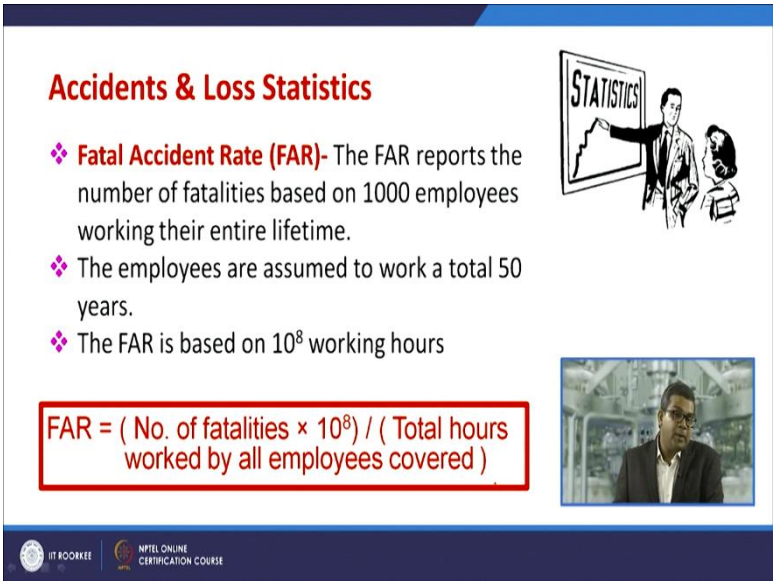

Apart from this OSHA incidence rate, another parameter is that fatal accidental rate, this reports the number of fatalities based on 1000 employees working their entire lifetime, so usually this is a figure of a 50 years where an employee is assume to work, the FAR is based on 10^8 working hours, so,

FAR = (No. of fatalities × 10^8) / (Total hours worked by all employees covered)

Now remember, we are dealing with the industry in question, both of these formula, both of these are statistical methodology, they are not dealing with the outer periphery or the people residing outside the industrial premises.

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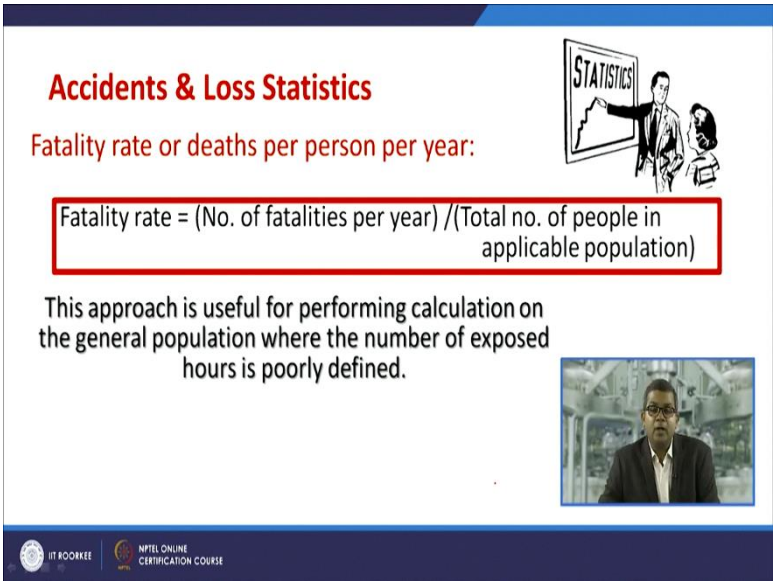

The third one is the fatality rate or death per person per year,

Fatality rate = (No. of fatalities per year) / (Total no. of people in applicable population)

That means you may cover the plant as well as the outer periphery, just like in the Bhopal gas tragedy, none of the fatality was attributed within the plant premises, but whatever the fatality took place that is around the plant side, so fatality rate was on the higher side, irrespective that FAR was the same as the previous one, this approach is useful for performing the calculation on general population, where the number of exposed hours poorly defined.

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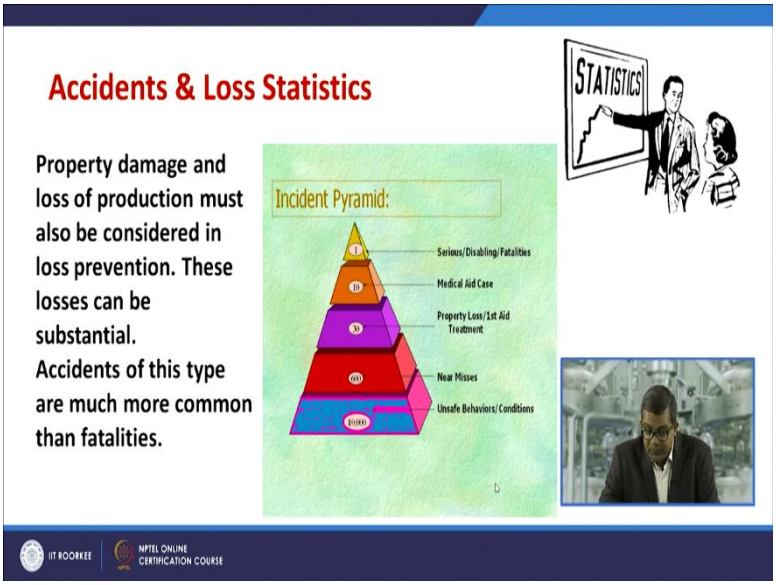

Now usually accidental and loss statistics are a paramedical type of incidence, you need to look into various kind of unsafe behavioral conditions, you need to find out the near misses in which the accident may occur or may not, there may be certain cases that obviously the less number of cases compared to the near misses that is, in which the property loss or you may experience the first aid treatment, there may be certain other cases where the occupational injury or occupational illness may reported, they are the medical aided cases and a very few number, less number of cases where the serious disability or the fatality may take place, but you cannot ignore all kind of unsafe behavior conditions because ultimately all these reviews give you proper information that gentleman something is going wrong within the plant itself, so you need to vigilant, you need to find out and you need to record all those statistical information.

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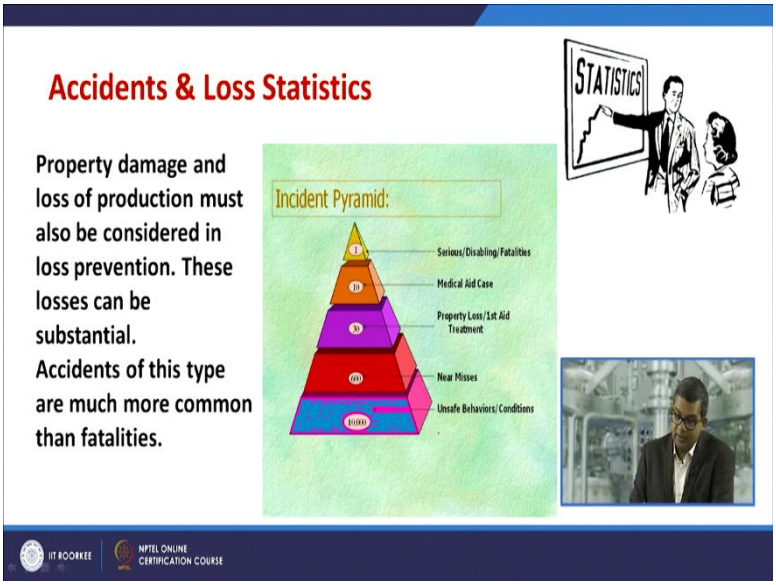

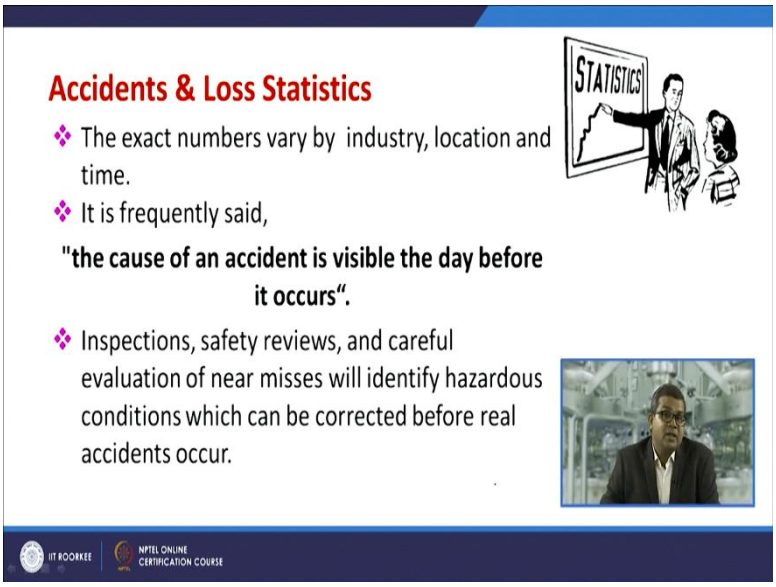

Now the exact number, usually vary by the industry, location and a time, your industry suppose deals with say insecticides, pesticides, then it is more harmful, maybe hazardous compared to the industry those who are producing the drinking water, it all depends on the locations, if it is situated at the populate, densely populated area, maybe the older one.

But the densely populated area may be more hazardous compared to the industry those who are situated at the remote location and the time because sometimes it may happen that the accident may took place at general shift, then the number of persons may be on the higher side compared to the time, when say midnight when the persons they are poorly defined, so it is frequently said that the cause of an accident is visible the day before it occurs, only thing is that you need to find out based on your technical knowledge competency, you need to find out

those near misses, so how you can find out the proper inspection, by the proper safety reviews and careful evaluation of all circumstances which are listed in this particular slide.

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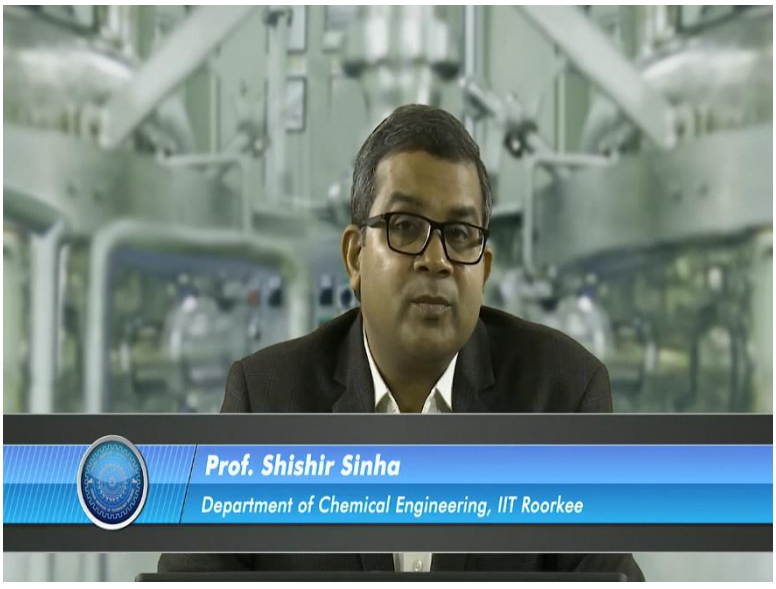

Now again, you may say that a safety this is a very general notion that safety should have management support, it must have a proper attitude, you must have a proper understanding of fundamental, you must be properly experienced to handle such type of scenario it is just like a LPG leaks and if it you are just by any, by any unexperienced people may immediately turn it, turn on the ventilation fan, but it may cause a problem, then the time to do the thing safely and actively participation of all those who involve.

So in the first lecture we deal with loss statistics because ultimately it gives a very good information about the economic of this chemical industry, second thing is that how the accident

takes place initiation, propagation and termination? How we can identify the things? What is the impact? And how we can analyse the things in gravity? So in subsequent lectures we will discuss that what is the impact of those statistical information to the safety aspect by this way, thank you very much.