Plant Design and Economics
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Lecture No -51
Introduction

Welcome to module 11 of plant design and economics. In the first lecture of this module we will give a brief introduction to chemical process safety. And in this module we will talk about mainly three different types of hazards namely fire, explosion and toxic gas release. How to prevent them and will also briefly talk about what you mean by inherently safe design and also briefly discuss few case studies that has forced us to think more and more about safety aspects of chemical process industries.

So, let us start with brief introduction to chemical process safety. We will introduce certain definitions.

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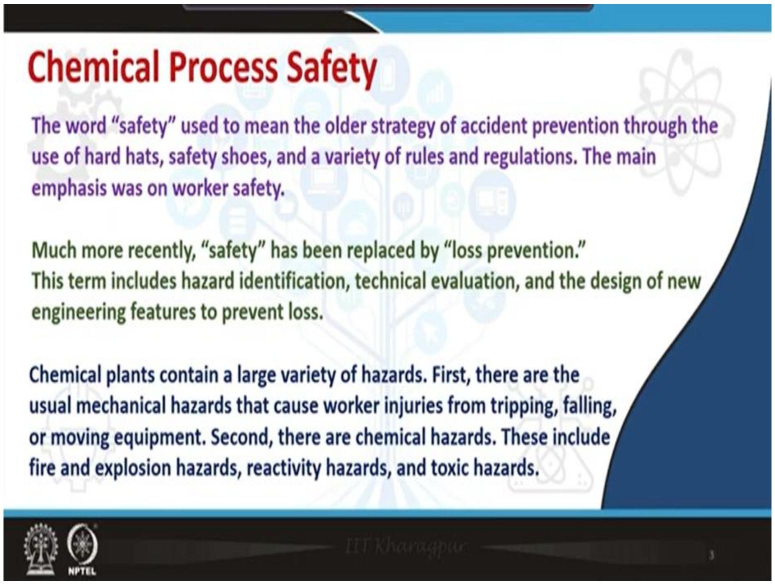

Certain statistics certain measures to have a quantification of safety measures. The word safety used to mean the older strategy of accident prevention through the use of certain gadgets or tools, such as hard hats, safety shoes and also by imposing several rules and regulations at the workplace. So the main emphasis was given on safety of the workers at workplace such as industry.

But more recently safety has been replaced by loss prevention. So this term includes hazard identification, technical evaluation and the design of new engineering features to prevent loss. Chemical plants contain a large variety of hazards. For example there will always be usual mechanical hazards that cause worker injuries say from falling or moving equipment or tripping etcetera.

Next, there are chemical hazards which are specific to chemical process industry. This will include fire and explosion hazards, reactivity hazards as well as toxic gas hazards.

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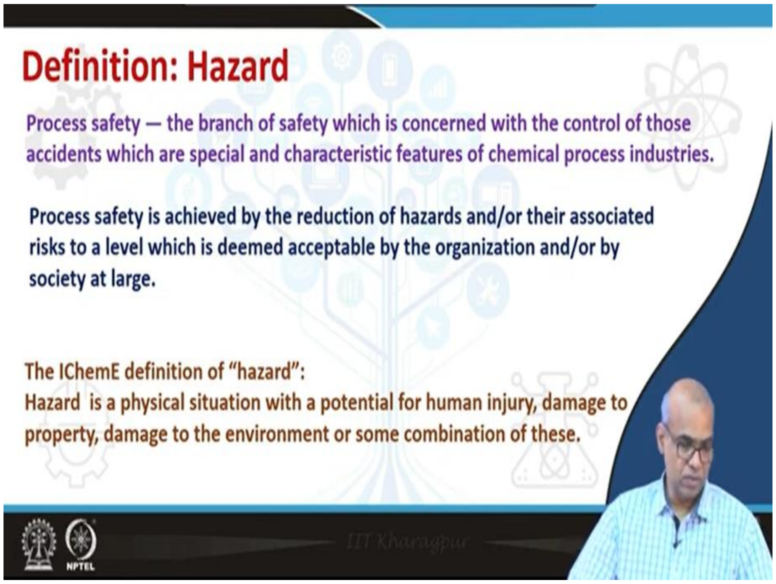

So, what do you mean by hazard? So let us first define the term hazard. Before that process safety is the branch of safety which is concerned with the control of those accidents which are special and characteristic features of chemical process industries. How do we achieve process safety? Process safety is achieved by the reduction of hazards and or their associated rates to a level which is deemed to be acceptable by the organization wherein the people are working or by the society at a large.

Note that you perhaps will not be able to completely eliminate the hazards. But you must be able to minimize the risk associated with the hazard to a level which is acceptable. So, what do you mean by acceptable hazard we will discuss later. So now let us define hazard. The institute of chemical engineering definition of hazard is as follows. Hazard is the physical situation with a potential for human injury.

It also has a potential to cause damage to property and also to cause damage to the environment or some combination of this. So, hazard is basically a physical situation with a potential for human injury, damage to property, damage to environment or some combination of these. That means the combination of human injury, damage to property or damage of environment.

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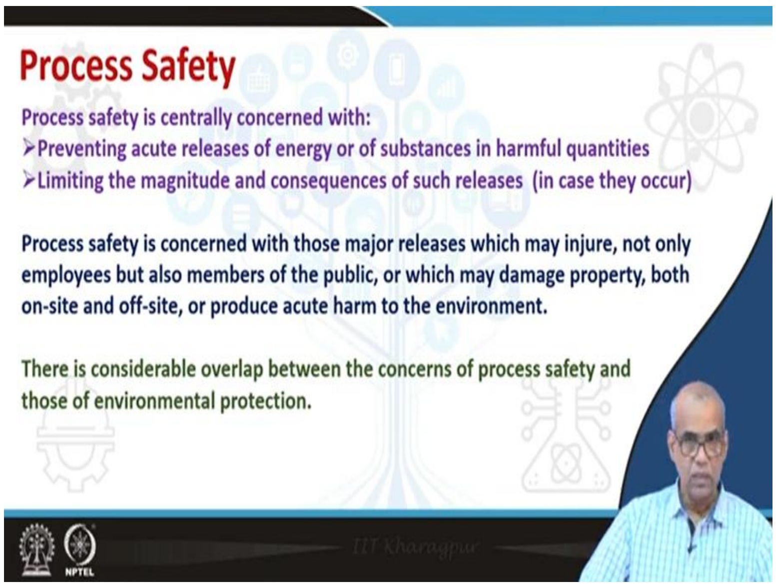

So process safety is centrally concerned with preventing acute release of energy or of substances in harmful quantities. And in case there is release of such energy and substances in harmful quantity process safety is also concerned with limiting the magnitude and consequences of such release. So the process of is primarily concerned with preventing acute release of energy or substances in harmful quantities and secondly it is concerned with reducing the magnitude and consequences of such releases in case they occur.

Process safety is concerned with those major releases which may ensure not only employees but also members of the public or which may damage property both on-site and off-site or produce acute harm to the environment. So it is not only about the injury of the work employees at your industry, but also members of the public. It is also about the damage of property both on onsite and off-site.

So causing harm to employees, causing harm to general public they are staying off-site as well as damage to property within the industry as well as outside the industry. You will notice that there is considerable overlap between the concern of process safety as well as the concerns of environmental protection and that is why several organizations will try to address both the subjects simultaneously.

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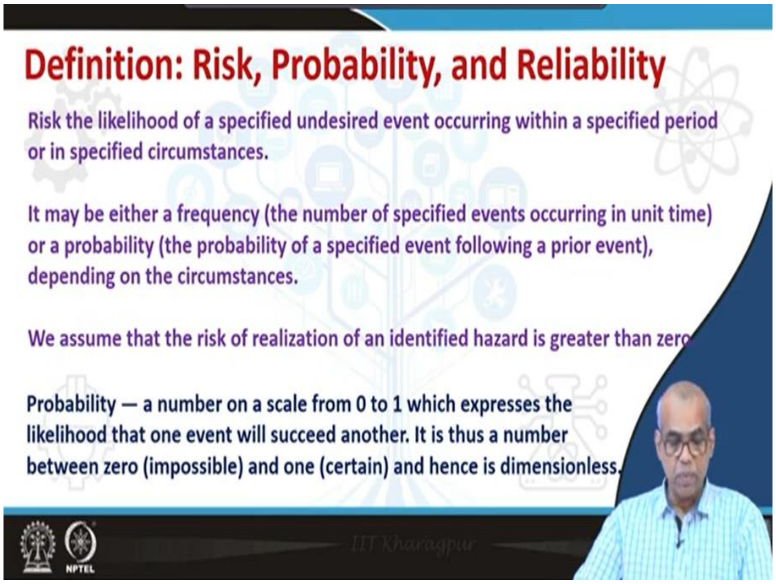

Now, let us introduce the definition of risk, probability and reliability. Risk is the likelihood of a specified undesired event occurring within a specific period or in specified circumstances. So by risk we mean the likelihood of a specified undesired event occurring within a specified period time period or in specified circumstances. It may be either a frequency or a probability depending on the circumstances.

By frequency we mean the number of specified events occurring in unit time. And when you talk about probability, we talk about the probability of a specified event following a prior event. We of course assume that the risk of realization of an identified hazard is greater than zero. So if we know that there is risk of realization of an existing hazard is zero then actually you are assigning no risk to the hazard.

So we assume that the risk of realization of an identified hazard is greater than zero. So it can cause harm or injury. Probability is a number on a scale from 0 to 1 which expresses the likelihood that one event will succeed another. It is thus the number between 0 and 1 where 0 will indicate impossible or will not happen and one will indicate that is going to happen certainly.

So by probability we mean a number on a scale from 0 to 1, which will express the likelihood that one event will succeed another and it is a dimensionless quantity.

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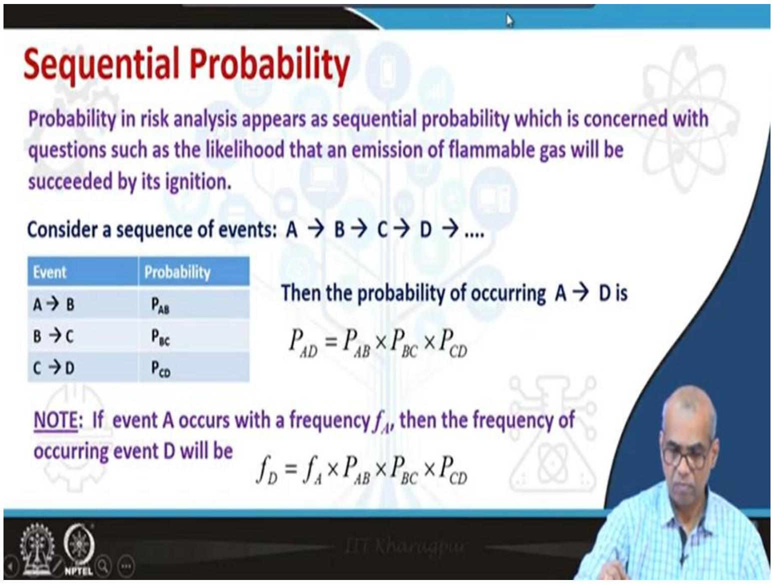

Probability in risk analysis appears as a sequential probability which is concerned with questions such as follows. Suppose there is an emission of flammable gas. So now ask the question what is the likelihood that this emission of flammable gas will be succeeded by its ignition. So, this is what is meant by probability in risk analysis appears as sequential probability. For example, we consider a sequence of events A to B to C to D, etcetera.

Let us say the events A to B has a probability P of A B. Similarly the event B to C has probability P B to C and even C to D has a probability P C to D. Then the probability of occurring the event A to D will be the product of probability of occurring A to B multiplied by probability of occurring B to C multiplied by probability of occurring C to D. If the event A occurs with the frequency f A.

Then the frequency of occurring event D will be f A multiplied by probability of occurring event A to B multiplied by probability of occurring B to C multiplied by probability of occurring even C to D,

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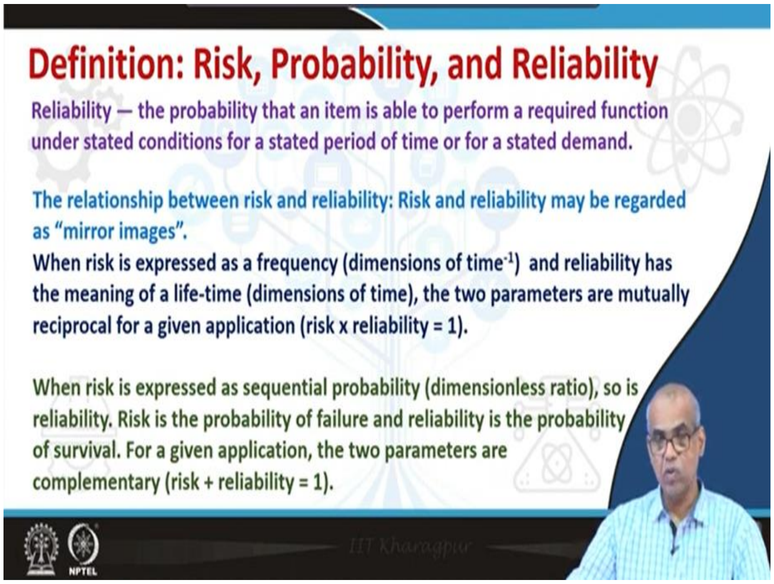

Now introduce the definition of reliability. The reliability is the probability that an item is able to perform a required function under stated condition for a stated period of time or for a stated demand. So we define reliability as the probability that an item is able to perform a required function under stated condition for a stated period of time or for a stated demand. That means the probability that an item will perform as expected under stated conditions for stated period of time.

Note the relationship between the risk and the reliability. The relationship is basically the mirror images. When risk is expressed as a frequency that means it will have a dimension of time inverse. The reliability will have meaning of a lifetime. So it will have a dimension of time. So these two parameters are then mutually reciprocal for a given application, that means there is risk multiplied by the reliability will be unity.

On the other hand when risk is expressed as a sequential probability so in that case, it will have no dimension. It will be a dimensionless ratio. So in risk is expressed as sequential probability the reliability also be expressed the same way. Note that risk is the probability of failure and then the reliability is the probability of success or survival. So in this case for any given application the risk and the reliability are complementary to each other.

That means the sum of probabilities of risk and reliability will be equal to 1. Note that the presence of one automatically signifies the absence of the other. Because the risk; indicates the probability of failure whereas reliability indicates the probability of success or survival.

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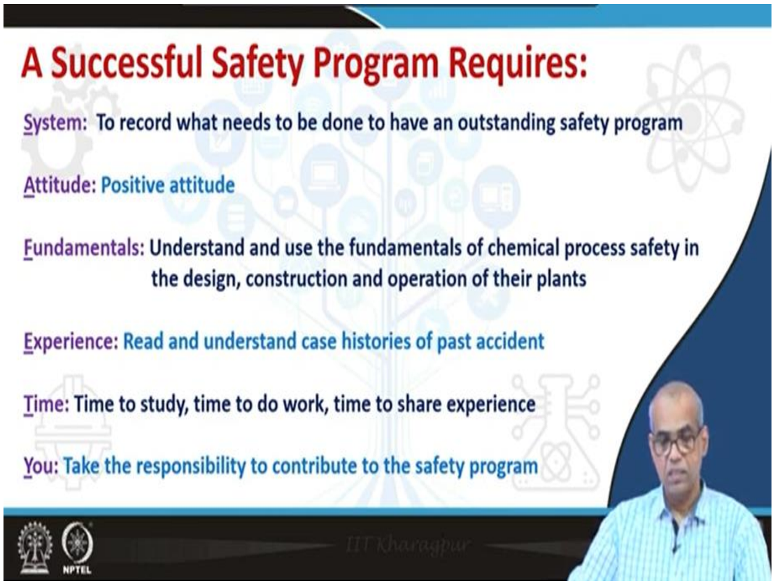

Now, let us look at the ingredients of a successful safety program. All industries all organizations should introduce safety programs at their workplace. Be it industry, be it research labs, be it workplace there are always hazards associated with their workplace. So the management should always implement a safety program. So what are the ingredients of a successful safety programs? A successful safety program requires system which will record what needs to be done to have an outstanding safety program.

It will also record what has been done. So it will record what needs to be done and then will also record what has been done. All the people who are participating in the safety program must have positive attitude towards safety. So first ingredient is system next is attitude then fundamentals. The participants must understand and use the fundamentals of chemical process safety in the design, construction and operation of their plants.

Next ingredient is experience. So you must read and understand case histories of past accidents and thereby learn from the past. Next ingredient is time. The participants must understand that safety needs time. So we must devote time to study, time to do work and time to share experience. And the last ingredient is you. That means everybody must take responsibility to contribute to the safety program.

So all these gives S A F E T Y, thus these are the ingredients which will constitute a successful safety program.

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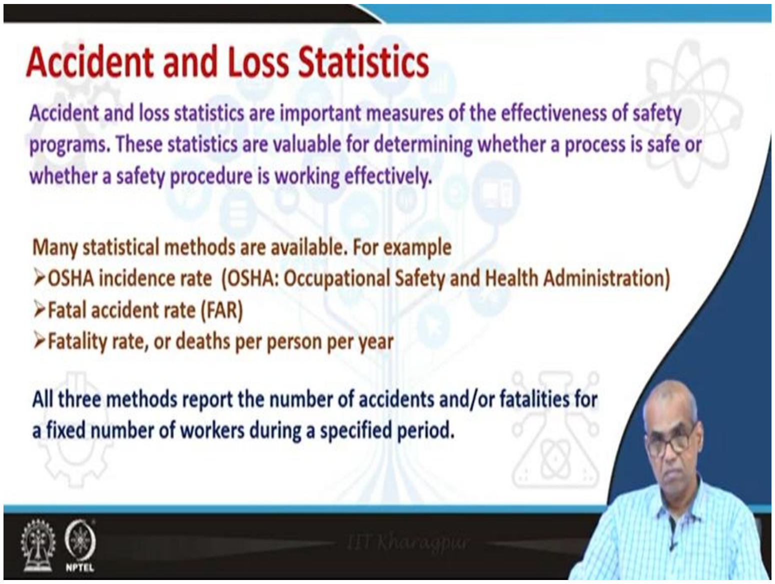

Now, let us talk about certain statistics related to accidents and loss. Accident and loss statistics are important measures of the effectiveness of safety programs. So it is necessary to quantify the effectiveness of the safety program. So there this accident and loss statistics are important measures. These statistics are valuable for determining whether a process is safe or whether a safety procedure is working effectively.

So this gives us quantitative measure of the effectiveness of the safety program. There are several statistical methods which are available and let us talk about just three methods. First OSHA incidence rate. O S H A it stands for occupational safety and health administration of United States of America. Next fatal accident rate abbreviated as F A R. Finally, fatality rate or deaths per person per year.

So, these are three common statistical measures which indicate quantitatively the effectiveness of a safety program. Note that all three methods report the number of accidents and or fatalities for a fixed number of workers during a specific period. All these methods report the number of accidents and or fatalities for a fixed number of workers during a specified time period.

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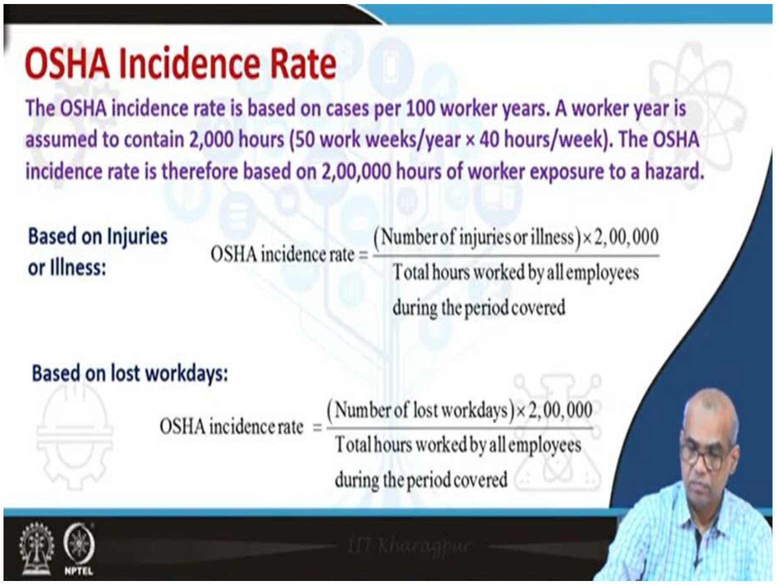

So let us first define OSHA incidence rate. Occupational safety health administration. The OSHA incidence rate is based on cases per 100 worker years. So what is worker year? A worker year is assumed to contain 2,000 hours, where do you get 2,000 hours from there are 52 weeks in a year, so let us consider 50 work weeks. So, 50 work weeks per year and then one worker will work 40 hours a week.

So 40 times 50 gives me 2,000 hours in a year, so a worker year will contain 2,000 hours. Now the OSHA incidence rate is based on 100 worker years. So 100 worker years means 100 into 2,000 that means 2,00,000 hours. So the OSHA incidence rate is based on 2,00,000 hours of worker exposure to a hazard. So that is the basis. So the basis is 2000 hours of worker exposure to a hazard.

So this may be based on either injuries or illness or it may also be based on lost work days. So based on injuries or illness the OSHA incidence rate is defined as number of injuries or illness multiplied by 2,00,000 divided by total hours work by all employees during the period covered. So this is based on injuries or illness. Similarly based on the lost work days the OSHA incidence rate will be the number of lost work days multiplied by 2,00,000 divided by total hours work by all employees during the time period covered.

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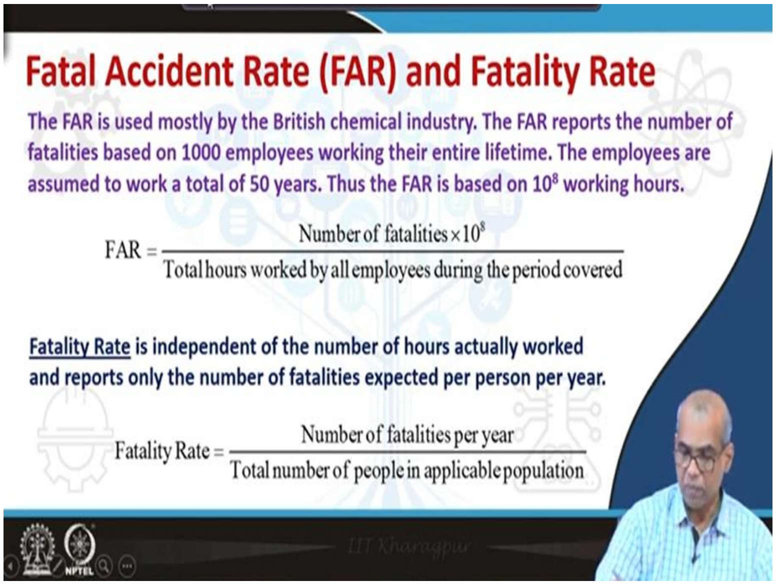

Now let us come to the next statistics fatal accident rate or FAR. The fatal accident rate or F A R is used mostly by the British chemical industry. The FAR reports the number of fatalities based on 1,000 employees working there entire life. The employees are assumed to work a total of 50 years. Thus the fatal accident rate is based on 10 to the power 8 working hours, so how do you get 10 to the power 8 working hours?

We have already seen that 1 worker hour is 2,000 hours. Employees are assumed to work a total of 50 years. So, I have 10 to the power 5 years. And then it is based on 1,000 employees. So this gives me 10 to the power 8. So the fatal accident rate is defined as number of fatalities multiplied by 10 to the power 8 divided by total hours work by all employees during the time period. The third statistics which is fatality rate is independent of the number of hours actually work and reports only the number of fatalities expected per person per year.

We have seen that the OSHA incidence rate and the fatal accident rate is basically based on the number of hours employees work, but the fatality rate is independent of the number of hours actually work and it reports only the number of fatalities expected per person per year. So fatality rate is number of fatalities per year divided by total number of people in applicable population. So this gives you the number of fatalities expected per person per year.

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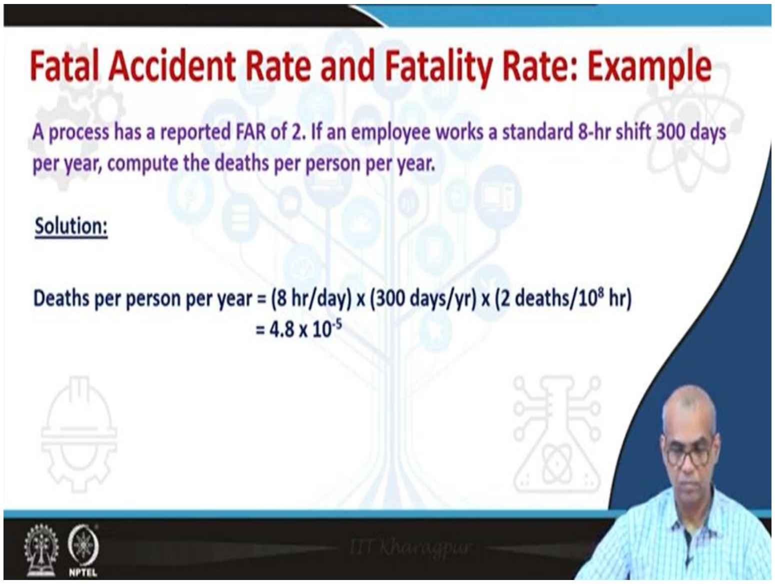

For example, let us consider a process has reported a fatal accident rate of 2. If an employee works a standard 8 hours shift 300 days per year, compute the deaths per person per year. So, how do you find that deaths per person per year will be 8 hours a day an employee is working multiplied by 300 days a year because the shift is 8 hours and 300 days per year of work and then fatal accident rate is 2 that means 2 deaths by 10 to the power 8 hour. So this gives you 4.8 into 10 power -5 deaths per person per year.

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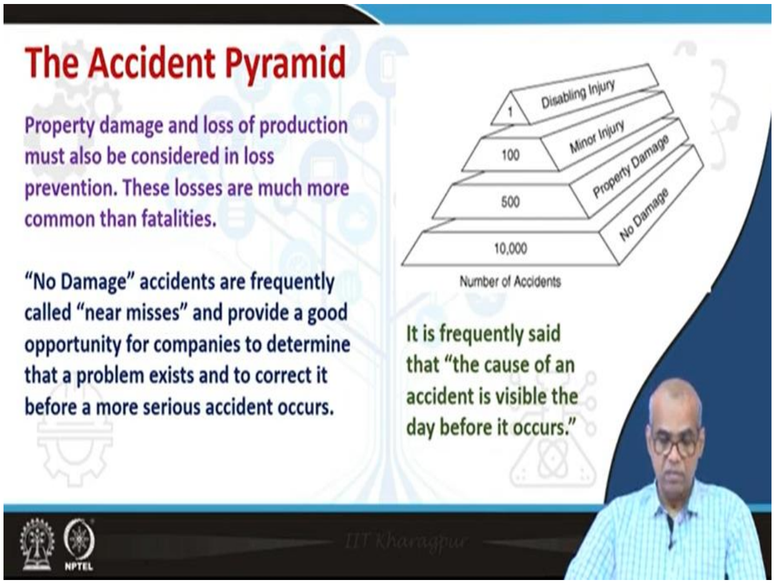

What you see is the accident pyramid. The base of the pyramid indicates no damage types accidents they are also called near misses. Then property damage then minor injury and then disabling injury. This numbers are indicating number of accidents 10,000 no damage type accidents and then 500 property damage 100 minor injury and 1 disabling injury. Now property damage and loss of production must also be considered in loss prevention because these losses are much more common than fatalities and these losses can be very significant.

No damage accidents, which we call near misses provides a good opportunity to the companies to determine that a problem exist in their system and this gives an opportunity to the management to correct it before a serious accident occurs. As it is frequently told that the cause of an accident is visible the day before it occurs. So near misses or this no damage accidents are basically signals to the management that there exists problem in the company and this must be corrected before a more serious accident occurs.

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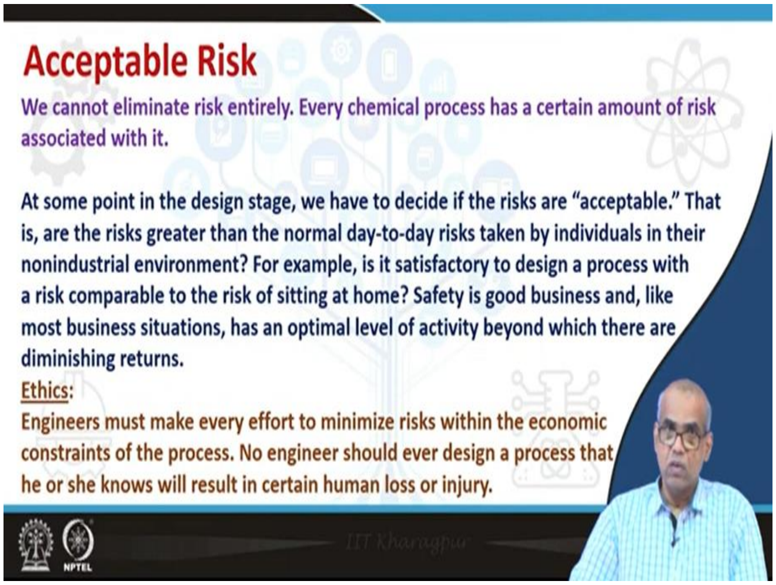

Now let us talk about some acceptable risk. We cannot eliminate risk entirely every chemical process has a certain amount of risk associated with it. At some point in the design stage then we have to ask ourselves whether the risk that we are estimating are acceptable or not. What it means is as follows. See when we do day to do activity they are also risk associated with it. Even when we stay at home there is this associated with it.

So during so when I am designing my plan and I come across an element of risk and estimate the risk. Then we consider that if there is are greater than the normal day to day risk taken by individual in their non-industrial environment. For example, is it satisfactory to design a process with a risk comparable to the risk of sitting at home. Some element of risk has to be taken it cannot be completely eliminated.

As I told you that even when you are sitting or relaxing comfortably in the comfort of your home it also involves certain amount of risk. Say the chair can collapse. Even bigger hazards are also possible so some amount of risk must be taken. We cannot go on investing money to eliminate something which cannot be completely eliminated. So we have to understand the safety is a good business and like most business situations it has an optimum level of activity beyond which the returns will start decreasing.

Now an ethical issue all engineers must make every effort to minimize risk within the economic constraint of the process. No engineers should ever design a process that he or she knows will result in certain human loss or injury or damage to environment.

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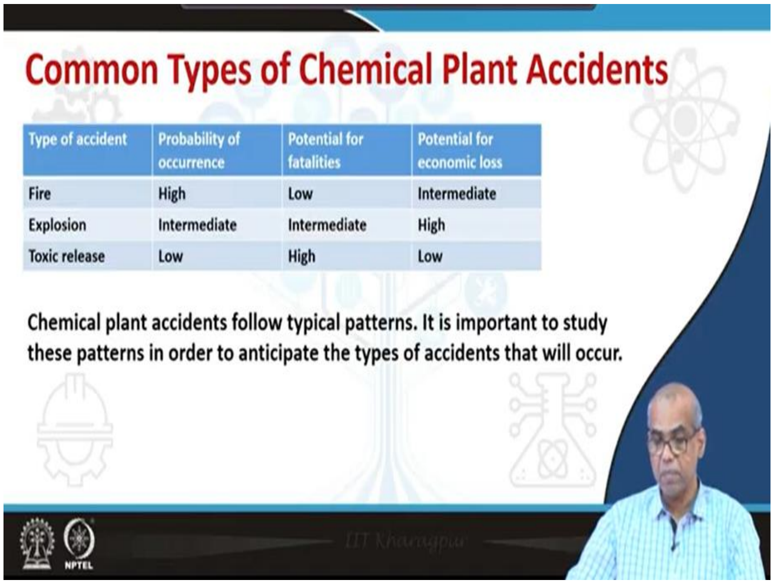

Three common types of chemical plant accidents are fire, explosion and toxic release. The probability of occurrence of fire is highest next explosion and next toxic release. However, the potential for fatalities is reverse. So the fire has low potential for fatalities explosion as intermediate and toxic release has very high potential for fatalities. Potential for economic losses for fire is our intermediate, explosion very high and toxic releases low.

Chemical plant accidents follow these typical patterns and it is important that we study these patterns in order to anticipate the types of accidents that will occur.

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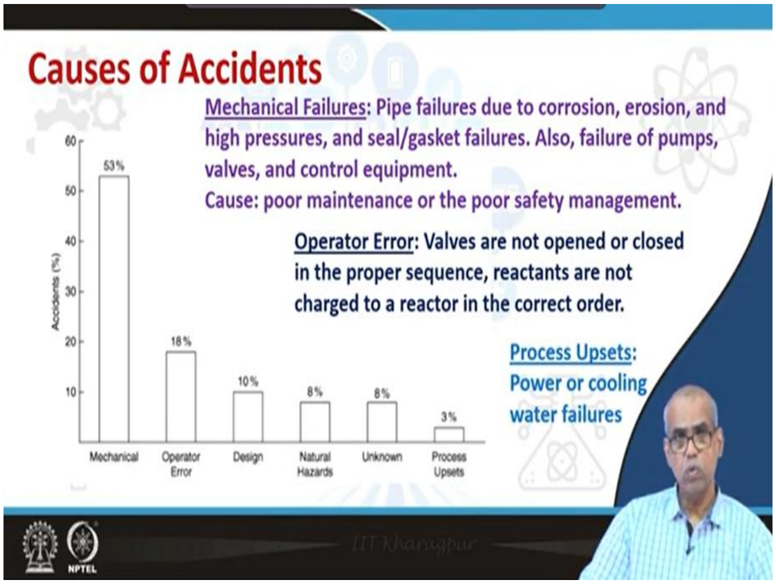

So here you see certain graphs. Certain presentation of data indicating causes of accidents. The causes are mechanical, operator error, design, natural hazards, unknown and process upsets. You can see that the mechanical failure contributes to the maximum extent. What are the constituents of mechanical failures pipe failures due to corrosion, erosion and high pressures and seal gasket failures. It may also involve failures of pumps, valves and control equipment.

The causes of these mechanical failures are usually poor maintenance or there is very poor safety management in place. Operator’s error or human error also involves significant amount. Note in the figure it is 18%. How the operators error come into the picture. Let us say valves are not open in the proper sequence or they are also not closed in the proper sequence, reactants are not added to the reactor in the correct order.

So similar human error also causes accidents and that occurrence of such accident is quite significant. Process upsets can happen due to power failure or cooling water failure, which causes about 3% of the total accidents.

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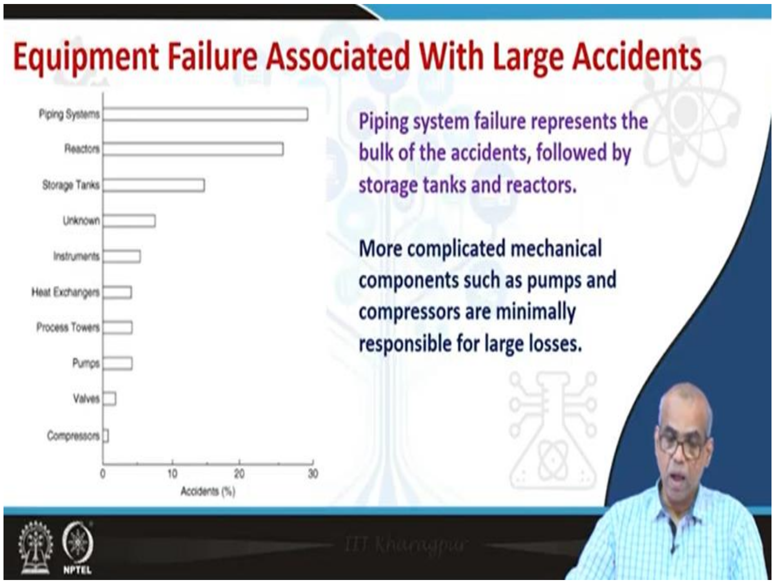

Now, if you look at the equipment or hardware failure associated with large accidents we see three pieces three different types of equipment which mostly fail and cause large accidents. They are piping systems, reactors and storage tanks. Note that more complicated mechanical components, such as pumps or compressors they are responsible minimally compared to simpler mechanical systems such as piping system.

So this is clearly visible from this statistics. This statistics is for several large accidents that happen in hydrocarbon processes.

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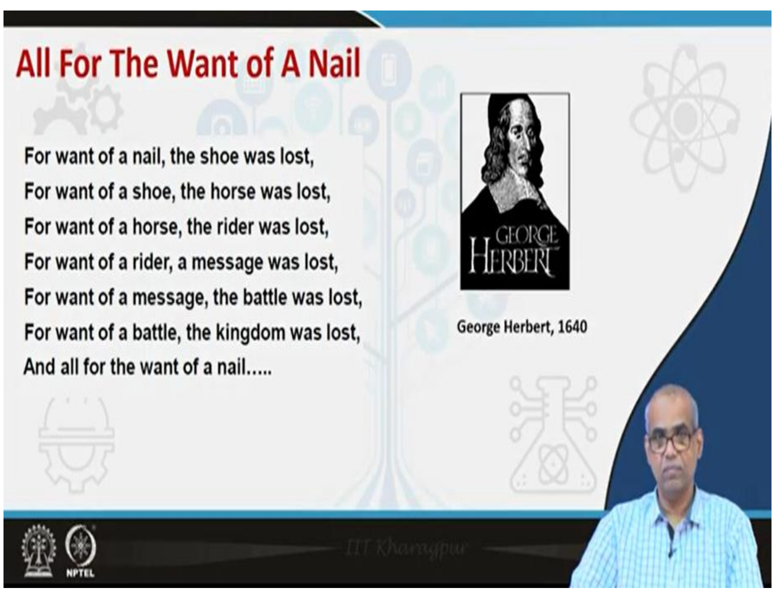

So in a safety measure, every step is extremely important and should be followed religiously. We stop this lecture with this poem from George Herbert. For want of a nail the shoe was lost, for want of a shoe the horse was lost, for want of a horse the rider was lost, for want of a rider, a message was lost, for want of a message the battle was lost, for want of a battle the kingdom was lost and all for the want of a nail.

So is extremely important that we take every step's however small it is in the process safety measures, very, very seriously to avoid to the extent maximum extent possible occurrence of accidents in chemical processes or other workplaces. Thank you for watching.