Chemical Engineering
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Lecture 38: Hazard Identification Methods & HAZOP

Welcome to this module of Hazard Identification & HAZOP study.

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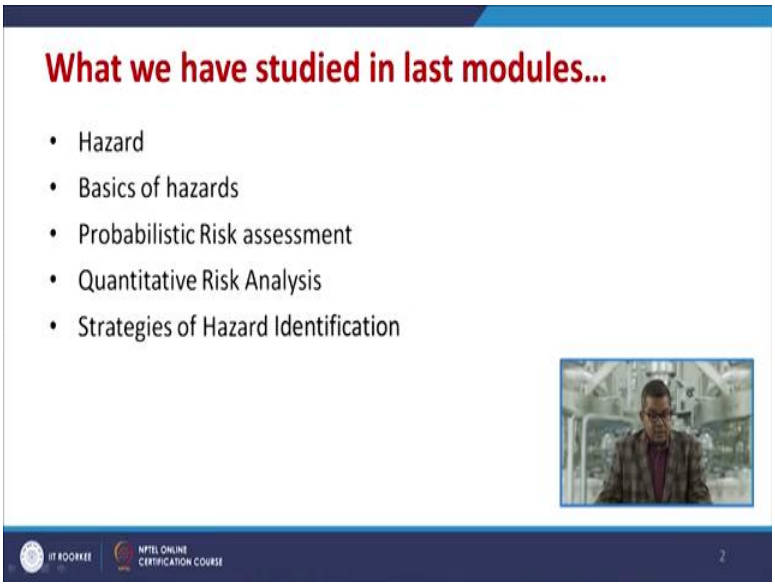

In the previous modules we have studied about the hazard the basic definition of hazard and risks what are the basics of hazards. We had the discussion about the probabilistic risk assessment and the quantitative risk analysis and a brief about the strategies of hazard identification.

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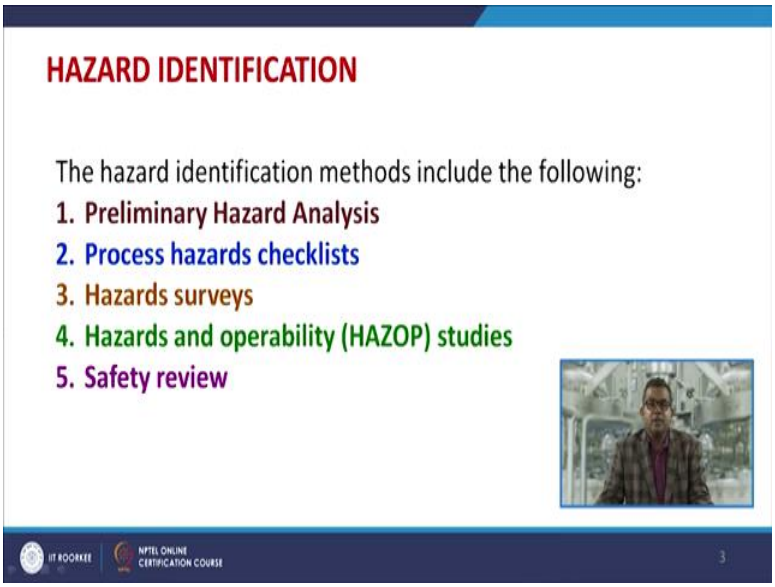

So, in continuation to that particular aspect the hazard identification methods this may include the following aspect like preliminary hazard analysis, then we have to construct the process hazard check list on the basis of the different hazard analysis and identification protocol. Then we need to perform the hazards surveys, go for the hazard and operability studies that is called the HAZOP studies and we need to perform the safety reviews.

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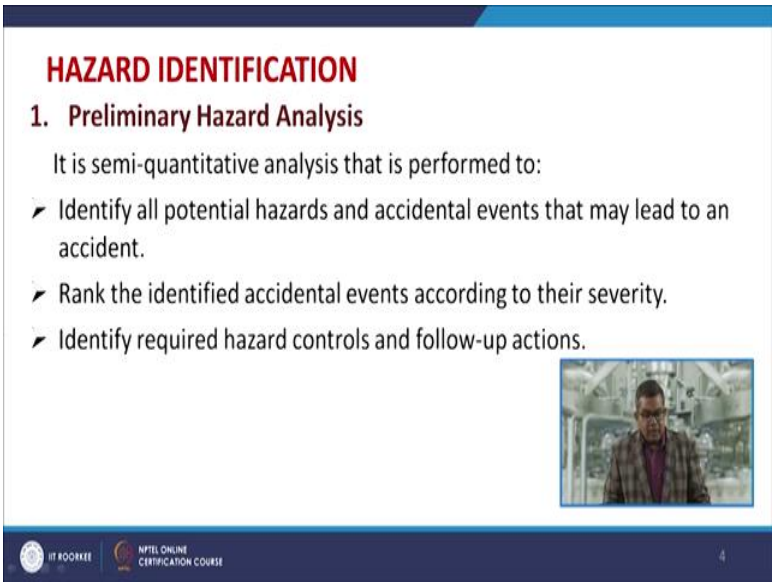

So, let us have a look about the first task right that is the preliminary hazard analysis this is some sort of a semi quantitative analysis that is performed to identify all potential hazards

and accidental events that may lead to an accident. So, you need to identify all those things, then basis of your, on the basis of your identification you need to 1rank the identify the accidental event according to their severity. And then identify the required hazard control and follow up actions.

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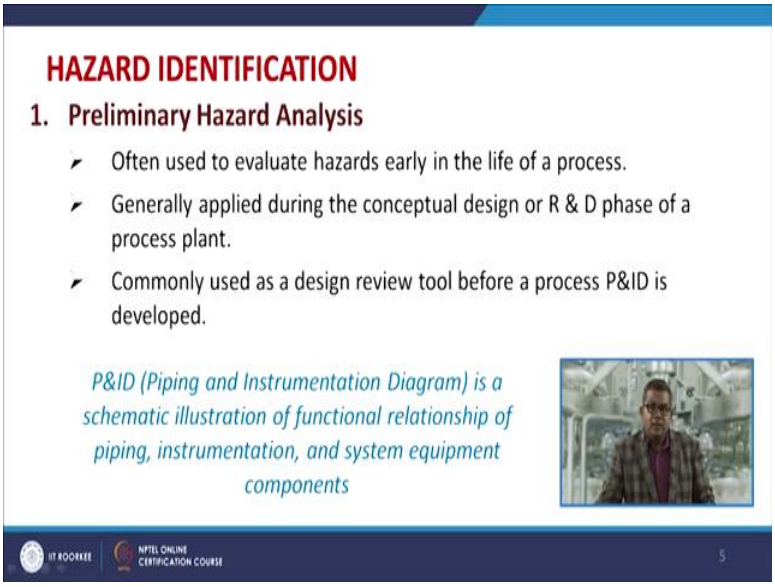

So, sometimes they are used to to evaluate the hazard early in the life of a process and generally applied during the conceptual design or R & D phase of a process plant so that once you go far the implementation then you must know that what kind of the probable hazard represent at the work place. They are commonly used as a design review tool before a process P&ID developed so the piping an instrumentation diagram is a schematic illustration of functional relationship of a piping instrumentation and our system equipment components.

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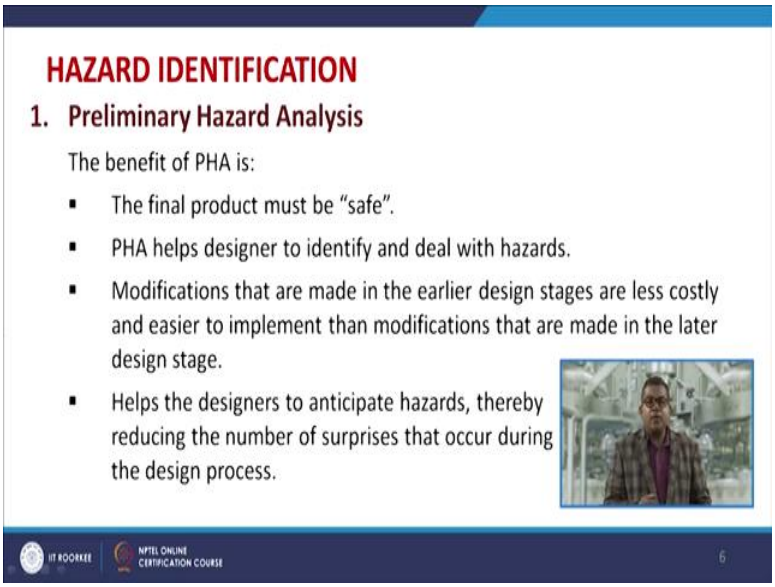

So the benefit of this preliminary hazard analysis they are in the states as below. The final product your basic motto is that your final product must be safe so PHA help in that particular aspect. PHA helps designer to identify and deal with the various kind of the hazard. This benefits the modification that are made in the earlier design stages.

They are less costly and easier to implement then the modification that are made in the later design stage. So this helps the designer to anticipate the hazards thereby reducing the number of surprises that occur during the design process.

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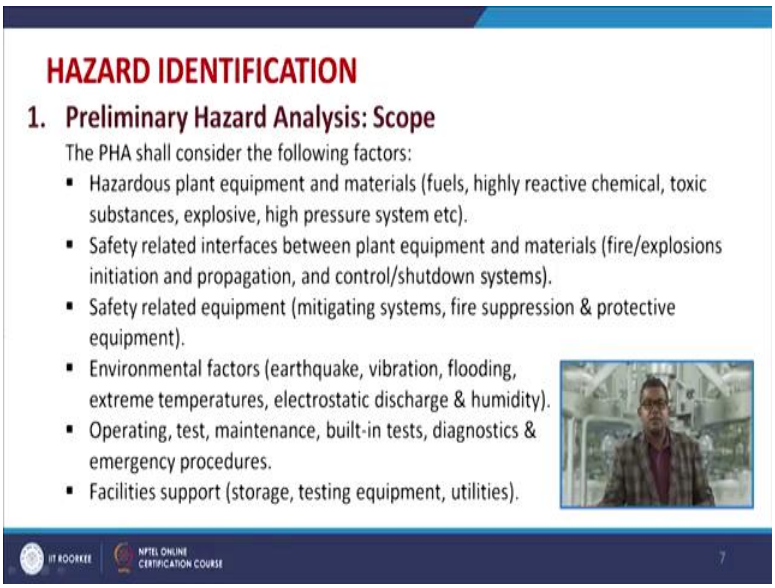

Let, us have a look about the scope of the preliminary hazard analysis. This shall consider the different factors like hazardous plant equipment and materials like fuel, highly reactive chemical, toxic substances, explosives, high pressure systems, etc. Then the safety related interfaces between the plant equipment and material again the examples are the fire explosion initiation, propagation and control shut down systems.

Then the safety related equipments that is mitigating the system like, like fire suppression protective equipments, etc. The environmental factors like earthquake, vibration, flooding, extreme temperatures, electrostatic discharge and humidity, operating test and maintenance, built in test diagnostic and emergency protocols etc. Then the facilities support like storage, testing equipment, utilities, etc.

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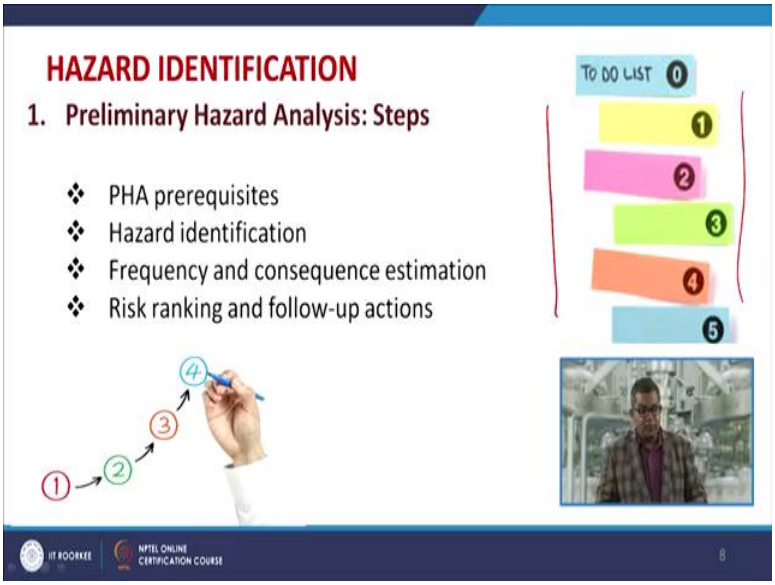

Now, there are various steps involved in this preliminary hazard analysis one is so we are going to in detail, that what has the PHA prerequisites. You must have a proper hazard identification list with you, you must have a frequency and a consequences estimation, then you must have a risk ranking and a follow up action. So by this way you can go for this to do list.

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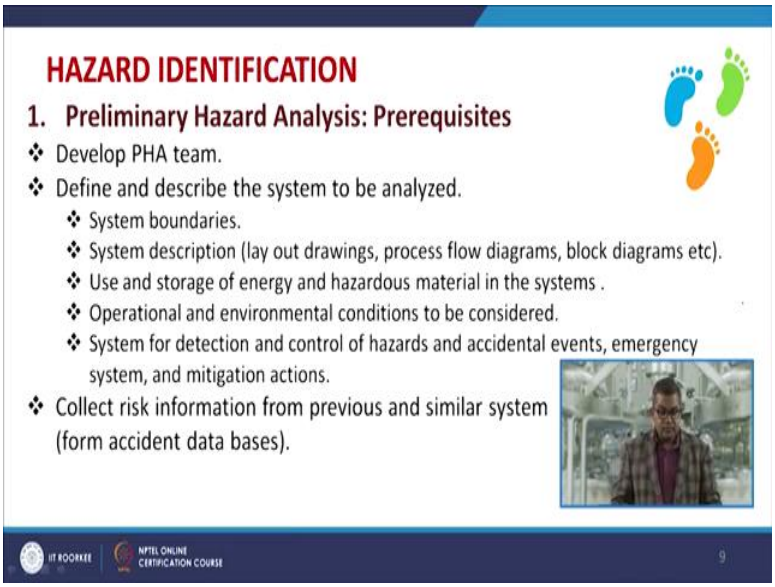

So, let us have a look about the prerequisites, now, first thing is that you need to develop the preliminary hazard analysis team. Now, this team may include those who are very much aware about the process, those who are very much about the safety reviews of that particular process, etc. Then define and describe the system to be analysed like what are the system boundaries, you may go give the system description, layout drawing process pro diagram, block diagram and flowsheets etc.

Use and storage of energy and hazardous material in the system, you must have a proper MSDS, etc. The operational and environmental conditions to be considered, it is a well-documented, system for detection and control of hazards and accidental event, emergency system and a mitigation actions. Now, collect all information from the previous and similar system, so you may get all those information from the accidental database.

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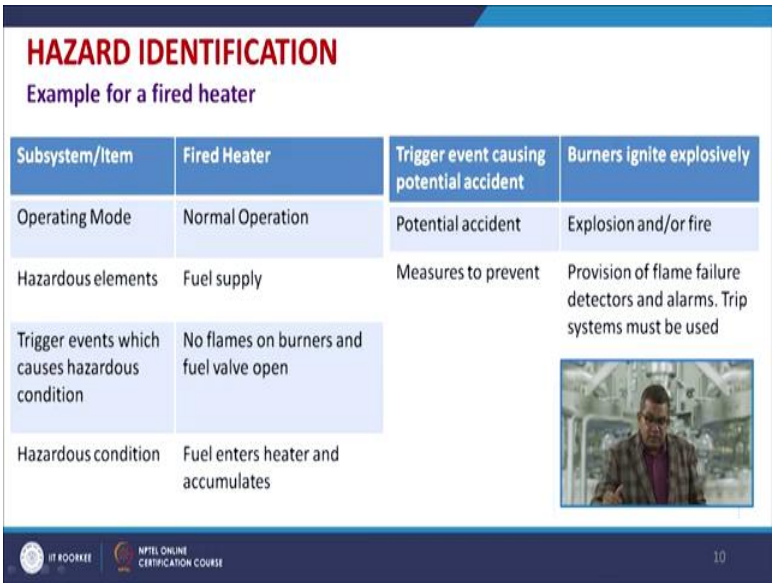

Now, let us have an example of a fired heater. This gives you a good clue about this PHA. There are various subsystems and item like operating mode sometimes fired heater normal operation hazardous element may present like that is called the fuel supply. The triggered event which is which causes the hazardous condition that may be no flame on the burners or a fuel valve open.

Sometimes Hazardous conditions like fuel enters into the heater accumulates, so triggered events they are also enlisted like potential accident sometimes it may lead to the, to the explosion or fire. Now, measures to prevent that is a provision of a flame failure detectors and alarm and trip systems must be used. So, this gives you the brief outline about this these fired heaters.

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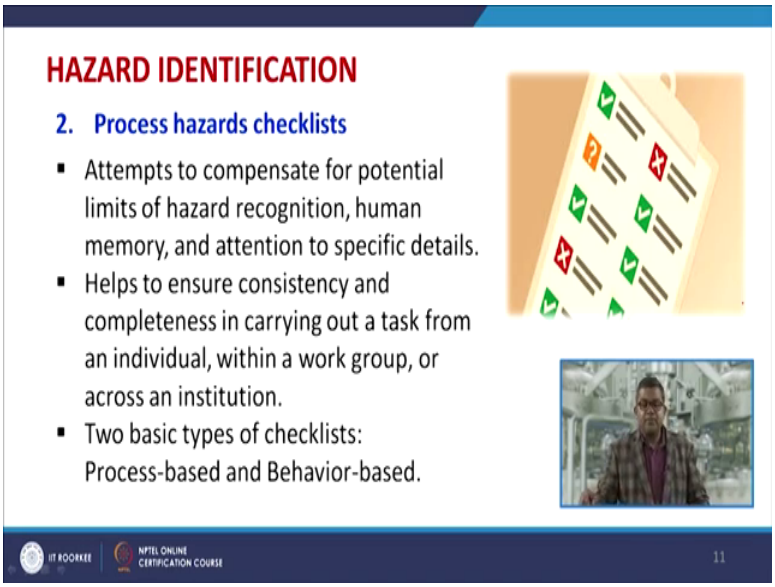

Now, next step is that the process hazard checklist now this is attempt to compensate for the potential limit of hazard recognition, human memory and attention to specific details. This helps to ensure the consistency and completeness in carrying out a task from an individual within a workgroup or across an institution.

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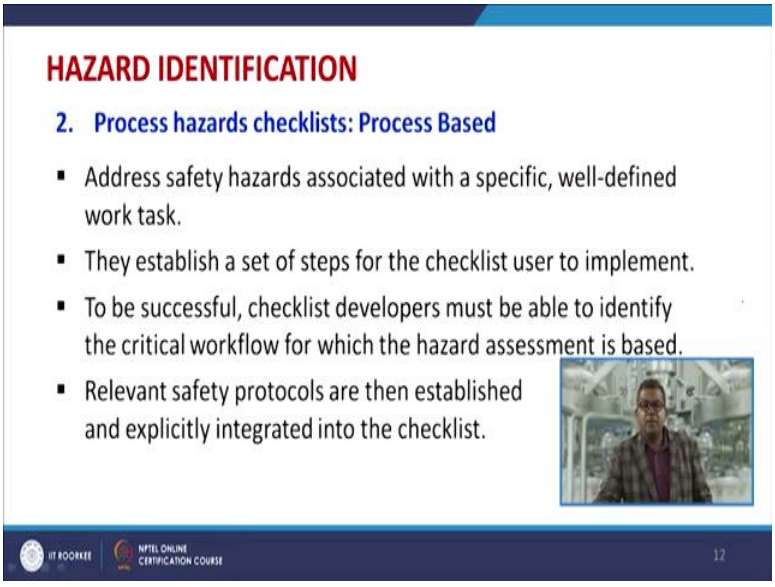

Now, there are 2 basic type of checklist one is that process based another one is the behaviour based. Now, let us have a look about the process based checklist, this addresses the safety hazard associated with a specific well defined work task. Now usually they establish a set of

the steps for the checklist user to implement. Now, to be successful checklist developer one must be able to identify the critical work flow for which the hazard assessment is based. And you must have a relevant safety protocols then established an explicitly the, integrate all those protocols in to the checklist.

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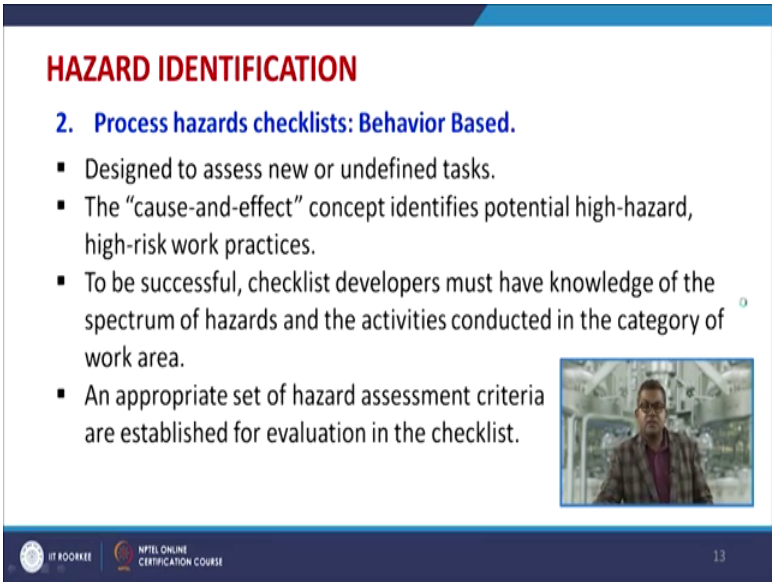

Second is the behaviour based they are designed to assess new and undefined task or scenarios. The cause and effect this concept identifies the potential high hazard high risk work practice. To be successful checklist developer or engineer must have a knowledge of the spectrum of hazard and activities conducted in the category of work area. An appropriate set of hazard assessment criteria they are established for evaluation in the checklist.

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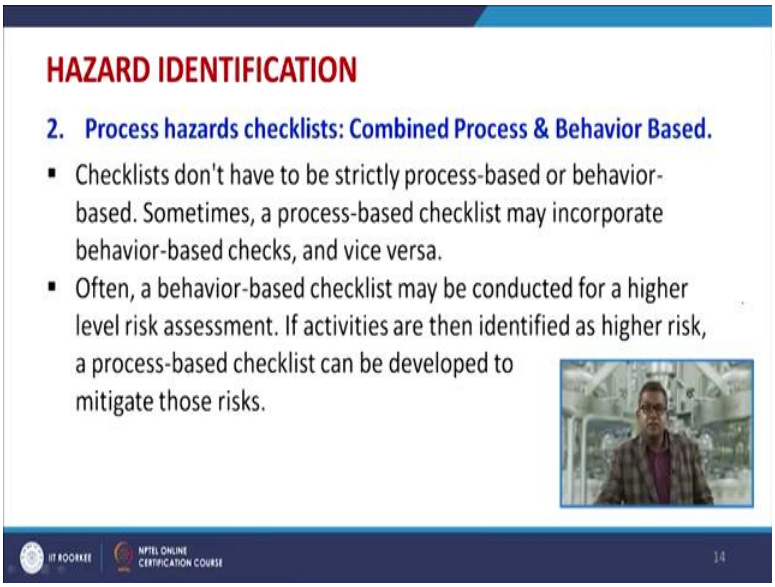

Now, sometimes we may need to have a combine process and behaviour based system. Now checklist do not have to be strictly processed based or a behaviour based. Sometimes, a process based checklist may incorporate behaviour based checklist or vice versa that depends on the need of the system. So often behaviour based checklist may be conducted for a higher level risk assessment. Now, if activities are then identified as higher risk a process based checklist can be developed to mitigate those kind of risk present at the work place.

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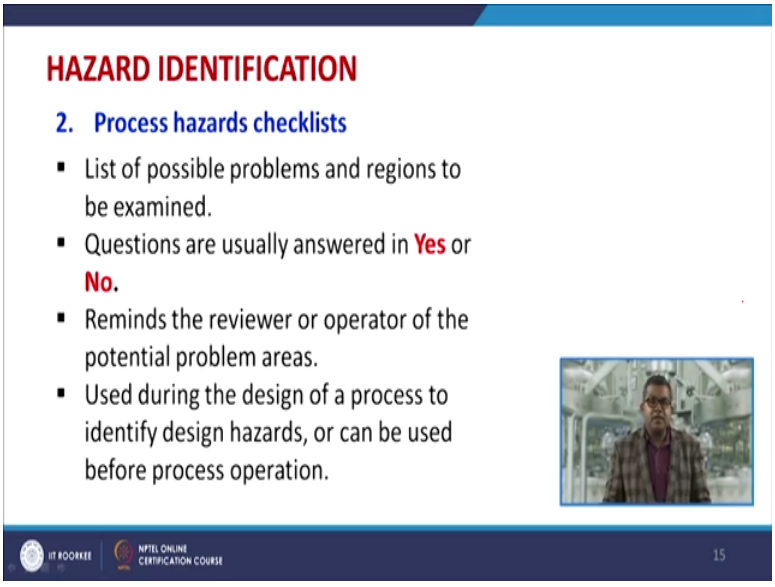

Now, a we may have certain things in our mind that list of the possible problem and region to be examined that is extremely important by this way you can identify those regions which are problematic. Now, questions are usually answered in terms of yes or no whether the hazard is present yes or no.

Now reminds the reviewer or operator or the potential problem area this is again in the good practice sometimes you may adopt a loop that whether this particular system operates, yes ok then go ahead and then again you may ask the reviewer that whether this particular thing is good or not, reassure the things. Now, use during the design of a process to identify the design hazard or can be used before the process operation.

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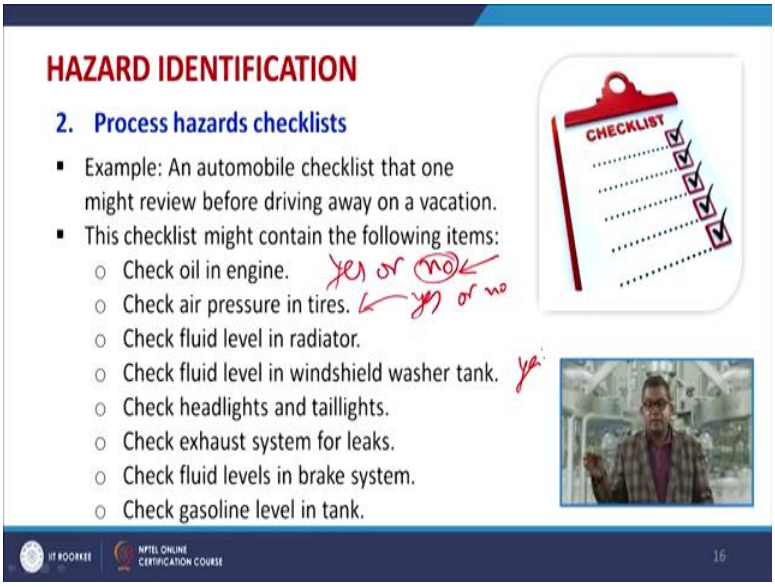

There are several examples of process hazard checklist one example is that an automobile checklist that one might review before driving away on a vacation the checklist might contain the following item – check oil in engine - yes or no. Now if it is no then go ahead then again relook that whether the oil in the engine is at the proper level or not check air pressure in the tier - yes or no, check fluid level in the radiator if it is not if it is not then try to go for replenishment.

Then check fluid level in the windshield washer tank – yes or no, if it is not up to the mark then refill it. Check headlight and tail light if it is not working properly then go for the correction, check exhaust system for the leak if it is not functioning properly then go for repair, check fluid level in the break system if it is not up to the mark then refill it up to the

desired level, check gasoline level in the tank so you have to assure yourself that the petrol or fuel in the level in the tank is up to the mark.

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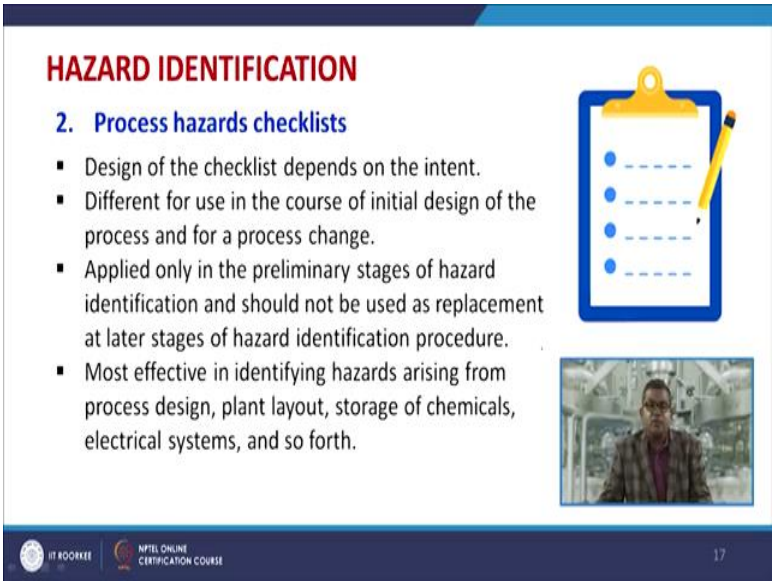

So design of this checklist depends on the intent. What kind of intent you are having? So based on your intent you may design the checklist as per your requirement. Now different for users in course of initial design of the process and for a process change so they apply it only in preliminary stages of hazard identification, it should not be used as the replacement at later stage of hazard identification. First of all so most effective in identifying hazard arising from process design, plant layout, storage of chemicals, electrical systems and so on.

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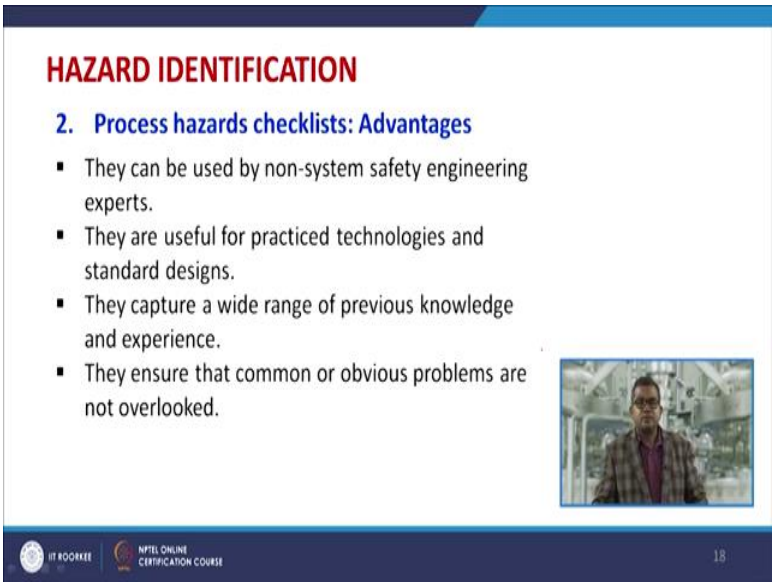

Now, now what are the advantages associated with process hazard checklist? Some of them some of advantages are listed over here, now they can be used as a non-system safety engineering experts. They are useful for the practiced technologies and standard designs. They capture a wide range of previous knowledge and experience and they ensure that the common or obvious problem are not overlooked because you are reaffirming that whether you have checked or not.

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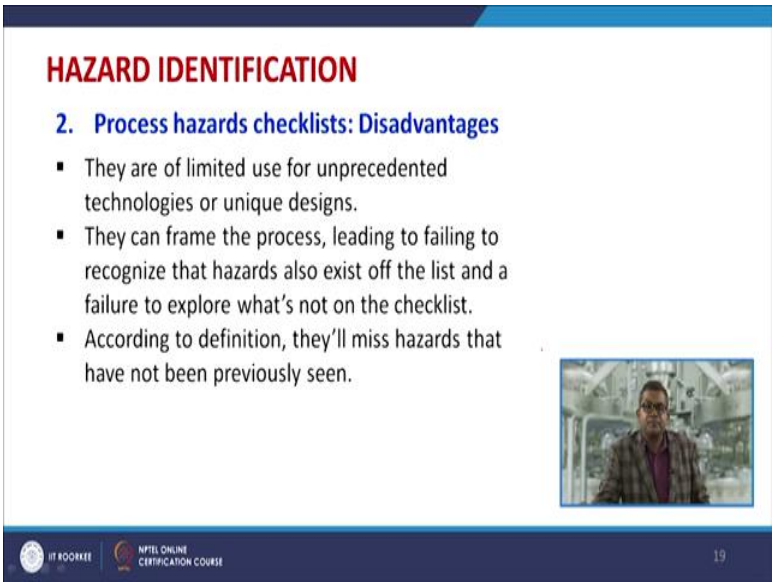

Then we are having so many advantages of these process hazard checklist there are certain disadvantages. Now, these disadvantages are they are limited use of unprecedented technologies or unique design. They can frame the process leading to, failing to recognize the hazard also exist in the list and a failure to explore what is not on the checklist, sometimes you may overlook any kind of things which need to be listed in checklist.

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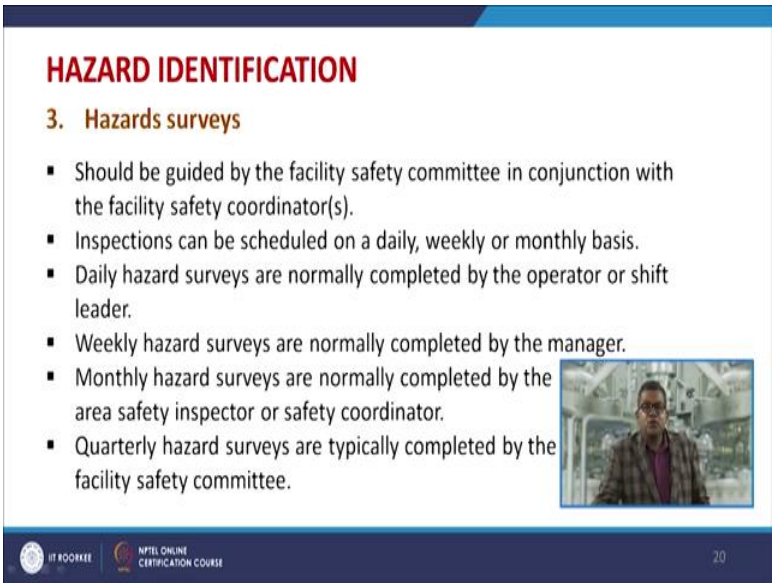

According to definition they will miss hazard that have not been previously seen. So that is again a very crucial issue. So based on these particular things you need to perform the hazards survey. Now, these hazards surveys they should be guided by the, the facilities safety committee in conjunction with the facility safety coordinators. So you need to perform all those things in consideration with these 2 bodies. The inspections can be scheduled on a daily weekly, monthly or yearly basis, usually yearly basis it is performed in case of safety audit.

Now, daily hazards surveys are normally completed by the operator or shift leaders. Weekly hazards surveys are normally completed by the manager or supervisors. Monthly hazards surveys are normally completed by the area safety inspector or safety coordinators. And above all the quarterly safety hazard survey are typically completed by the facilities safety committee.

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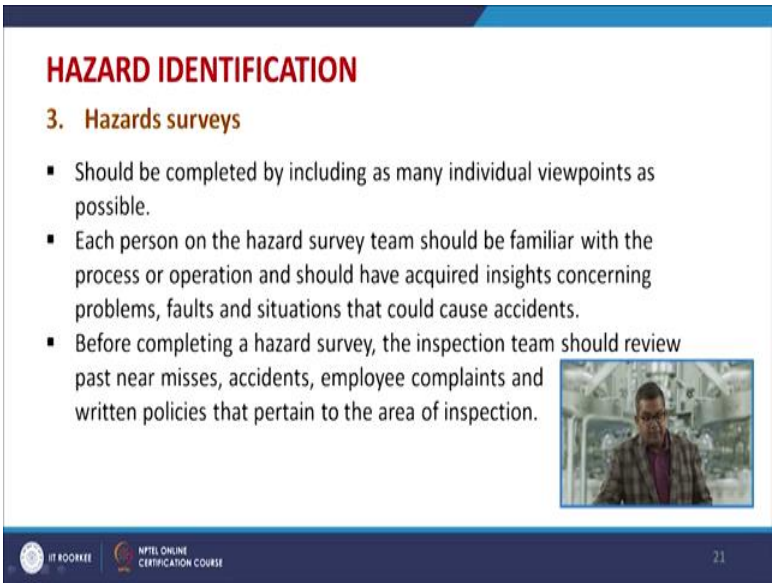

Now, these should be completed by including as many individual view point as possible, so that you must have a number of n number of resources because if you are having the large number of resources the quality of those survey will be on the higher side. So each person on the hazard survey team should be familiar with the process or operation and should have acquired the insights concerning problems fault and situation that could cause the accidents.

Now, before completing the hazard surveys the inspection team should review the past near misses because this may give a proper clue. Accidents, employee complaints and return policies that pertain to the area of inspection because these return policies may give a clue and sometimes these return policies may include the local rules or the rules and regulations those who are applicable to the area in question.

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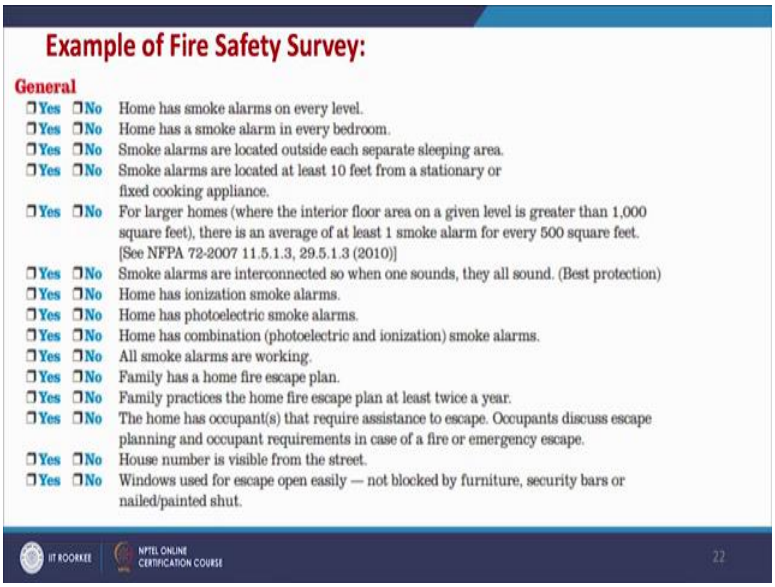

Now, as far the example of this sight survey or hazard survey one example which we have enlisted is the fire safety survey. Now, this is you can see we have asked these things in responses in terms of yes or no. Now, these are the general things like home has this smoke alarm on every level, suppose you put ‘no’ then again you need to go for the collective measures.

Home has a smoke alarm in every bedroom, smoke alarms are located outside at each separate sleeping area, smoke alarms are located at least 10 feet from a stationary or fixed cooking appliances. Sometimes you put yes no, yes no so if yes then you are relatively safe and if no then you need to go for the corrective measures.

Again that home has ionization smoke alarms, home has a photoelectric smoke alarms, so home has a combination of photoelectric ionization smoke alarms, so all now the crucial question is that all smoke alarms are working if they are no, if you put no then definitely it will look into the previous aspects.

It gives you an opportunity that you can relook the different responses. Now, family has a home fire escape plan, if it is not then definitely you have to work upon. So this particular survey gives you a proper information about the problems associated in the particular facility.

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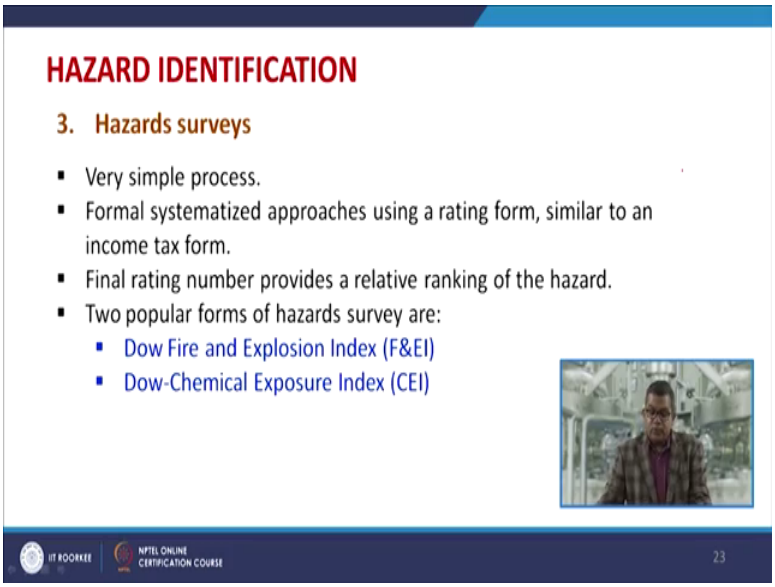

Now, these hazards surveys are very simple process as we have shown in the, this particular slide. These are the simple questions which you need to ask, then formal systematized approach using a rating form similar to an income tax form. Now final rating number provides a relative ranking to the hazard. Now, there are 2 popular forms of hazard surveys they are, one is the Dow Fire and Explosion Index that is F&EI another one is the Dow Chemical Exposure Index that is CEI.

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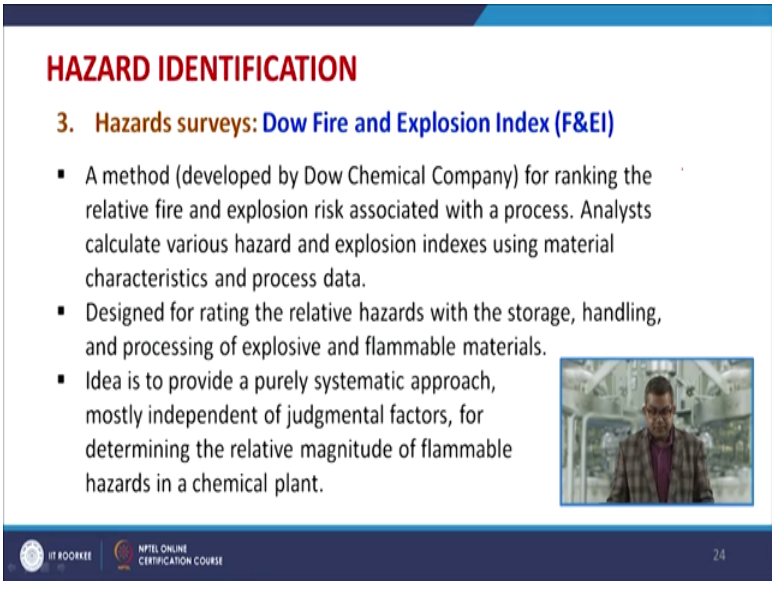

So let us have a look of the one by one, the first one is the Dow fire and explosion index, F&EI that is a method developed by the Dow chemical company for ranking the relative fire and explosion risk associated with the process. Now, analysis, the analyst calculate the various hazard and explosion indexes using the material characteristics and process data available.

Now, they are designed for rating the relative hazard with the storage handling and the processing of explosive and the flammable materials. Now, the basic idea is to provide a purely systematic approach mostly independent of judgement factors for determining the relative magnitude of flammable hazard in the chemical plant.

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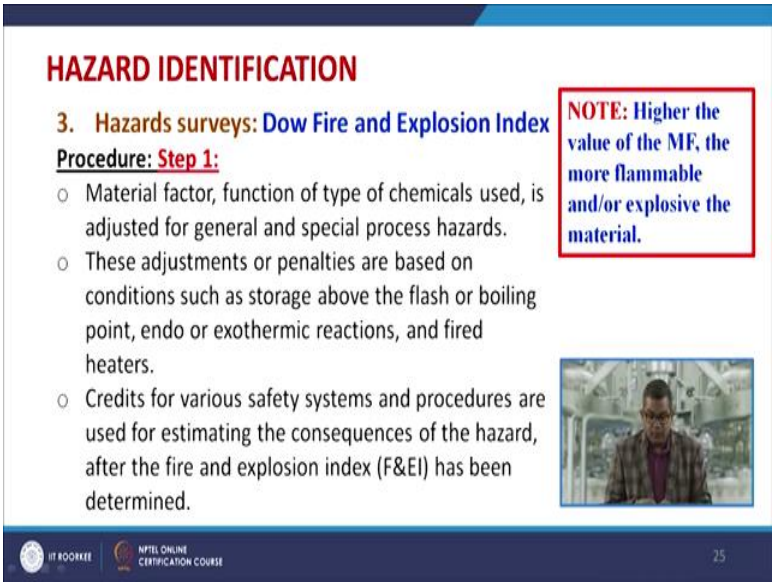

Now, this is a multistep process and the first step in this to perform the hazard survey pertaining to the Dow fire and the explosion indexes the material factor, function of type of material used, is adjusted for the general and special process hazard. Now, these adjustment or penalties are based on the conditions such as storage above the flash or a boiling point, endo or exothermic reactions and fired heaters.

Now, credits for various safety systems and procedures are used for estimating the consequences of hazard and after the fire and explosion index has been determined. So one must note that higher the value of MF the more flammable and explosive the material.

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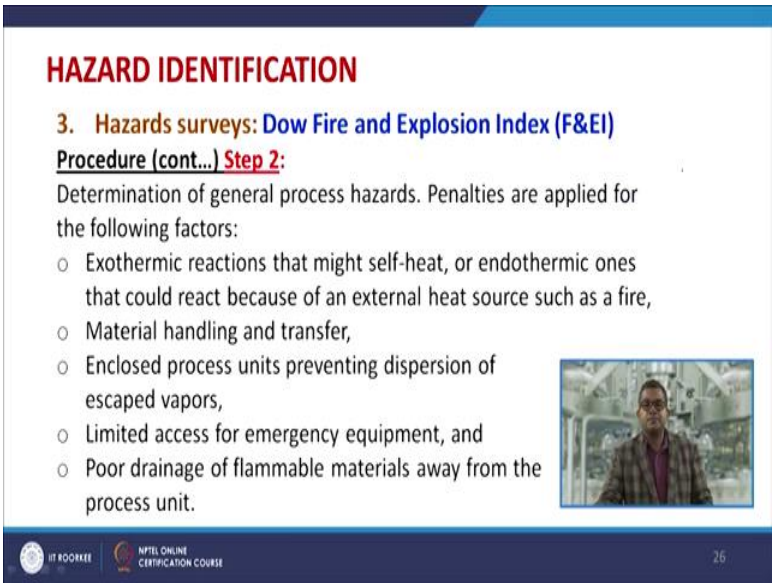

The second step is that determination of general process hazard. Now, penalties are applied for different factors like exothermic reactions that might self-heat or endothermic ones that could react because of an external heat source, such as fire, etc. The material handling and transfer the enclosed process units preventing dispersion of escaped vapours, the limited access for emergency equipment that is a very serious issue and poor drainage of flammable material away from the process units. So penalties may be Imposed for if the process facilities having such type of system.

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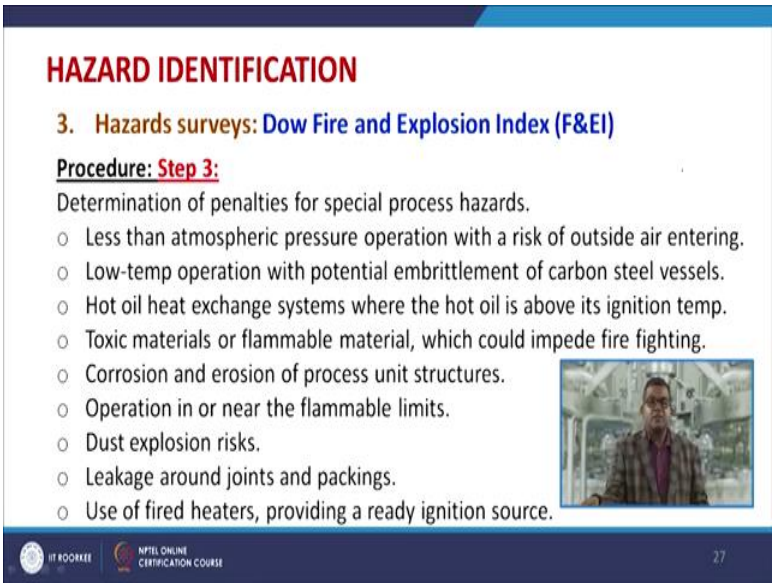

The next step is the determination of a penalties for special process hazards that is less than atmospheric pressure operation with risk of outside air entering, so that there may be a chance of flammability. Low temperature operation with the potential embrittlement of carbon steel vessel. Hot oil heat exchange system where the hot oil is above its ignition temperatures sometimes it may lead to the auto ignition scenario.

The toxic material or the flammable material which could impede the firefighting equipments. Corrosion and erosion of process unit structures. Operation in or near the flammable limits like UFL and LFL. Dust explosion risks. Leakage around joints and packing. Use of fired heater, providing the ready ignition sources, etc. So these are the, these were the, the things which need to be addressed.

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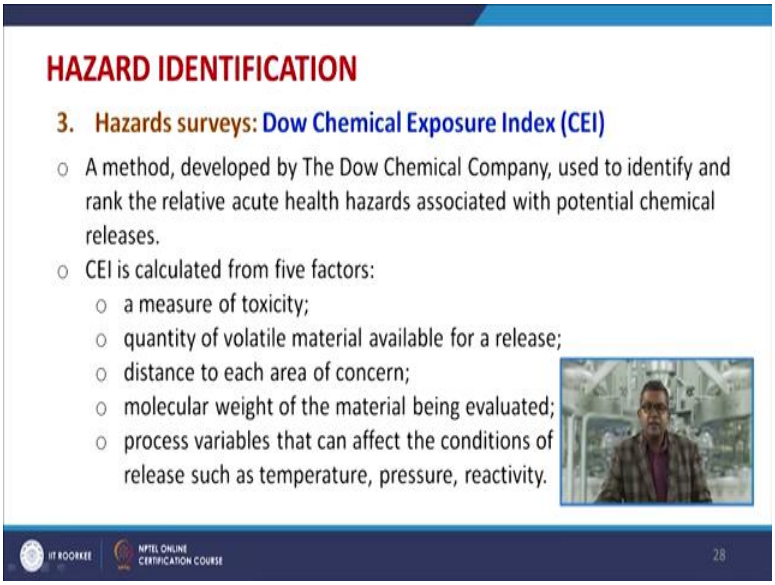

Now, next is you Dow chemical exposure index, this is again method developed by the Dow chemical company used to identify and rank the relative acute health hazard associated with the chemical releases. So this chemical exposure index is calculated from a 5 broad factors that is a measure of toxicity, the quantity of volatile material available for release, the distance to each area in question, the molecular weight of the material being evaluated and the process variables that can affect the conditions of release such as temperature, pressure, reactivity, etc.

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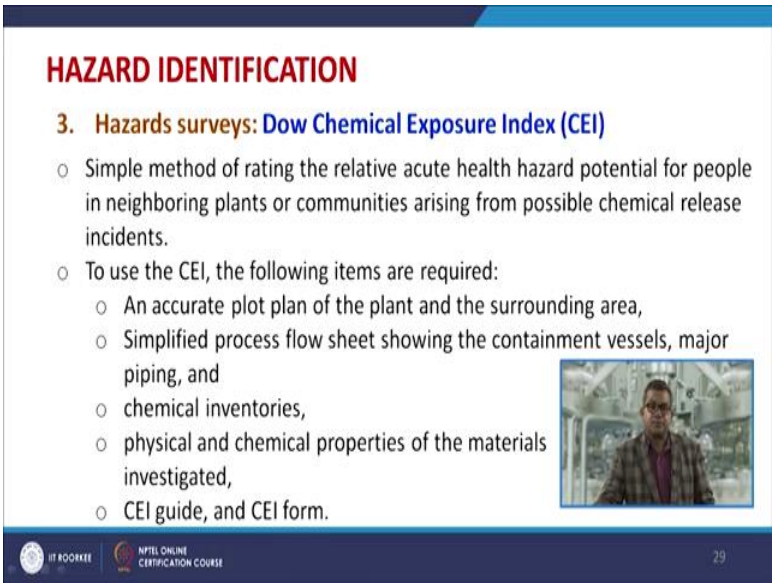

Now, this simple method of rating the relative acute health hazard potential for people in neighbouring plants or communities arising from the possible chemical release incidents. Now, the use of this chemical exposure index you need the following items, one is that accurate plot plant of the plant and the surrounding area, the simplified process flow sheet showing the containment vessels, measure piping, you must have a proper chemical inventory data with you, the physical and chemical properties of material investigated and chemical exposure index guide and chemical exposure index form.

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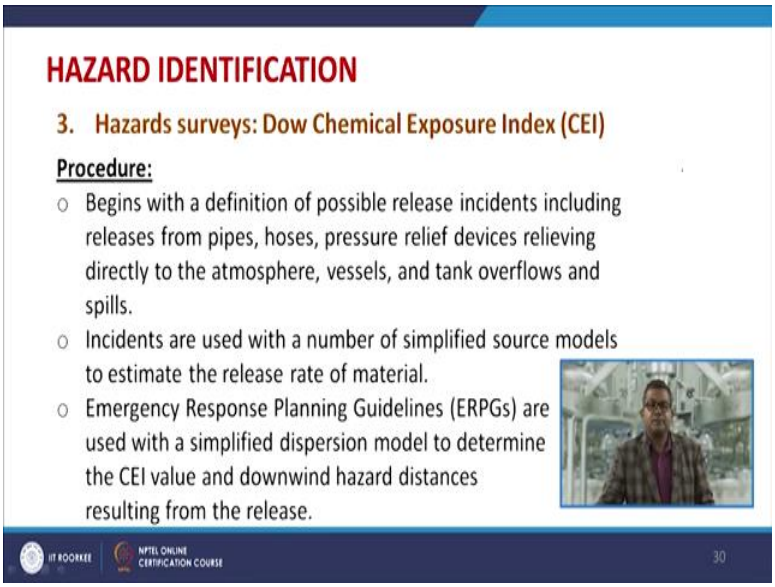

Now, the process for this hazard survey pertaining to CEI is this relatively simple that this begins with a definition of possible release incidents including releases from pipes, hoses, pressure relief devices relieving directly to the atmosphere, vessels, tank overflows and spills. Now, sometimes incidents are used with the number of simplified source models to estimate the release rate of material. We have already discussed these source models. Now, emergency respond planning guidelines (ERPGs) that are used with the simplified dispersion model to determine the, the chemical exposure index value and downwind hazard distances resulting from the release.

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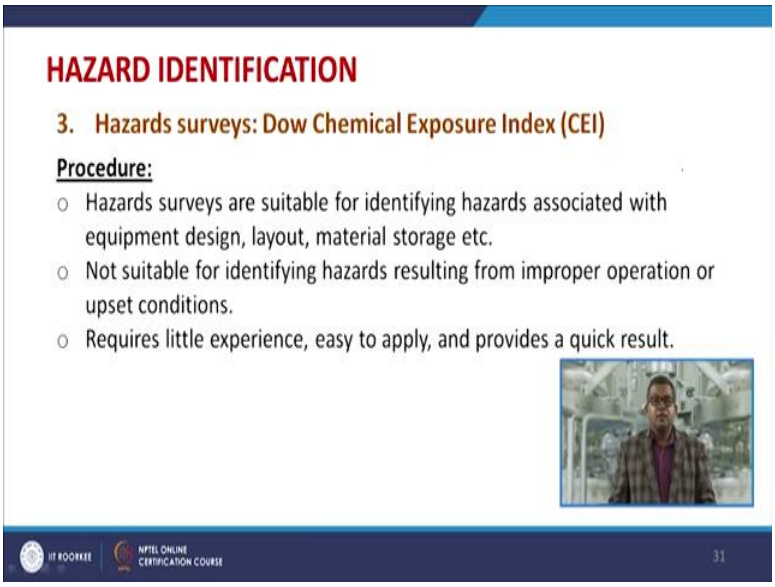

The hazards survey is they are suitable for identifying the hazard associated with equipment design, layout, material storage, etc. They are not suitable for identifying the hazard resulting from improper operation or upset conditions. And they require little experience easy to apply and provides a quick result.

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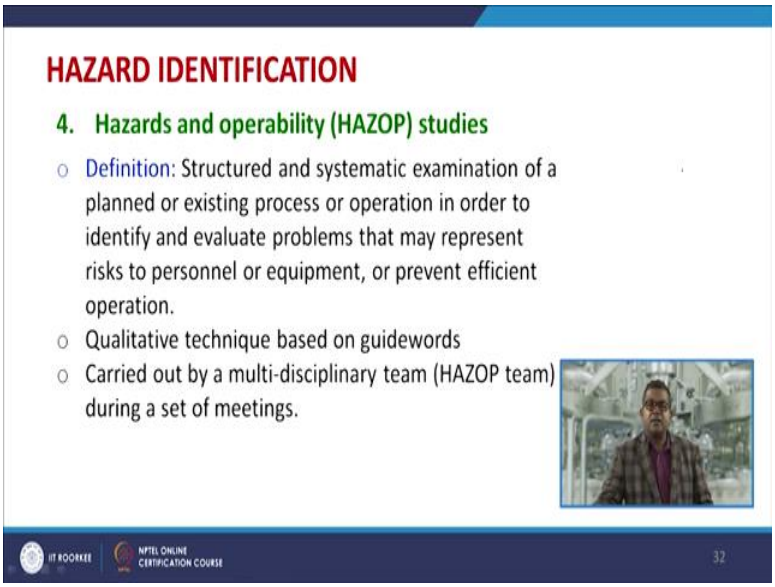

Now, next is the Hazard and Operability Studies (HAZOP). The basic definition of this HAZOP is that this is structured and systematic examination of plant or existing process or operation, in order to identify and evaluate problem. That may represent risk to personal or equipment or prevent efficient operation. This is the qualitative technique based guidewords carried out by multidisciplinary team that is called the HAZOP team during the set of meeting.

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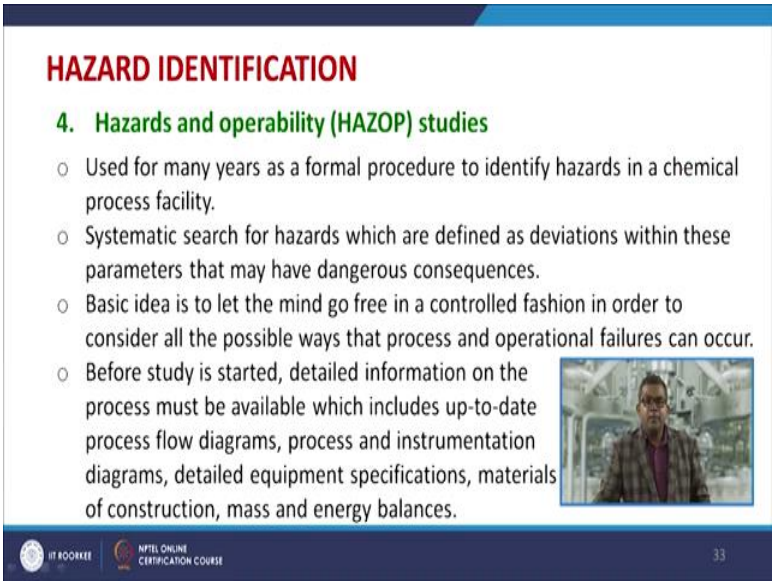

They are used for many years as a formal procedure to identify hazard in chemical process facility, the systematic search for hazard which are defined as deviation within these parameters that may have a dangerous consequences. Now, the basic idea is to let the mind go free in a controlled fashion in order to consider all the possibilities that process and the failure can occur. Now, before studies started detailed information on the process must be available which includes up to date process flow diagram, process and instrumentation diagram, detailed equipment specification, material of construction, mass and energy balances may be in terms of equations.

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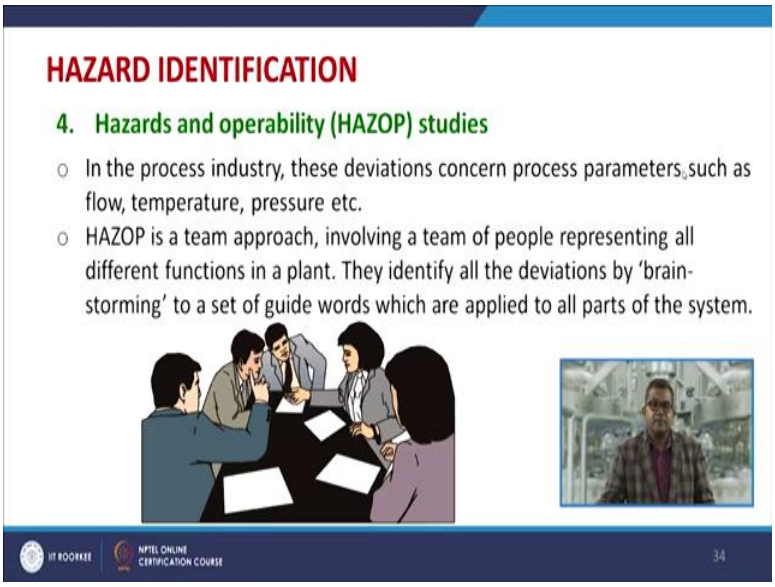

Now, in the process industry these deviation concerned process parameters such as flow, temperature, pressure etc. Now, HAZOP analysis is a team approach having a team of people representing all different functions of a plant. They identify all deviation by the brainstorming among themselves to a set of guide, words which are applied to all parts of the system.

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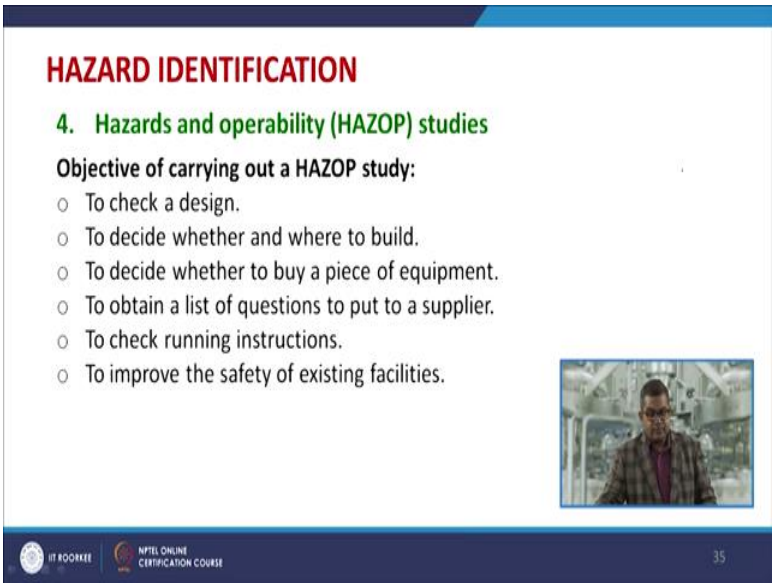

Now, there are set of objectives carrying out for the HAZOP study. One is to check the design whether it is proper or improper. To decide whether and where to build the things to decide whether to buy a piece of equipment or not, to obtain a list of a questions to put to a supplier, to check running instruction that may be imposed to a worker, to improve the safety of any existing facilities.

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Now, the team composition of HAZOP studies it still have a team leader that is an expert in the HAZOP technique. There are several technical members, like, for, if you are having the,

the new design, then design or project engineer, the process engineer usually a chemical engineer, the commissioning manager, the instrument design engineer, a chemist because sometimes you may have go through for a chemistry reaction. Now, if you are performing this thing for the existing plant then you must have a plant superintended, the process supervisor that is sometimes called the foreman, the maintenance engineer, the instrument engineer, the technical engineer, etc.

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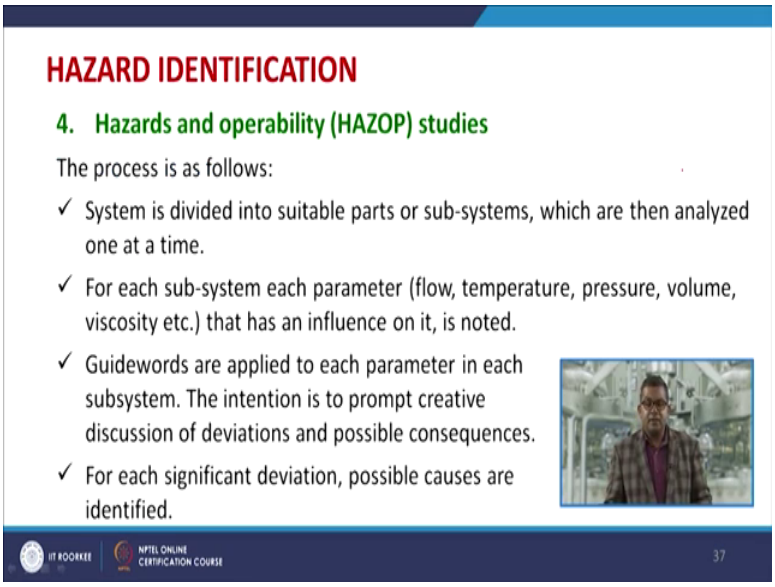

Now, as far as the process is in question this is as follows that the system is divided into suitable parts or subsystems which are analysed one at a time. Now, for each sub-system each parameter like flow temperature, pressure, volume, viscosity, etc. Has an influence on it if it is then it should be noted. The guidewords are applied to each parameter to each sub-system the intention is to prompt creative discussion of deviation and possible consequences and for each significant deviation the possible causes and they are usually identified so that you can look in to the remedial measures.

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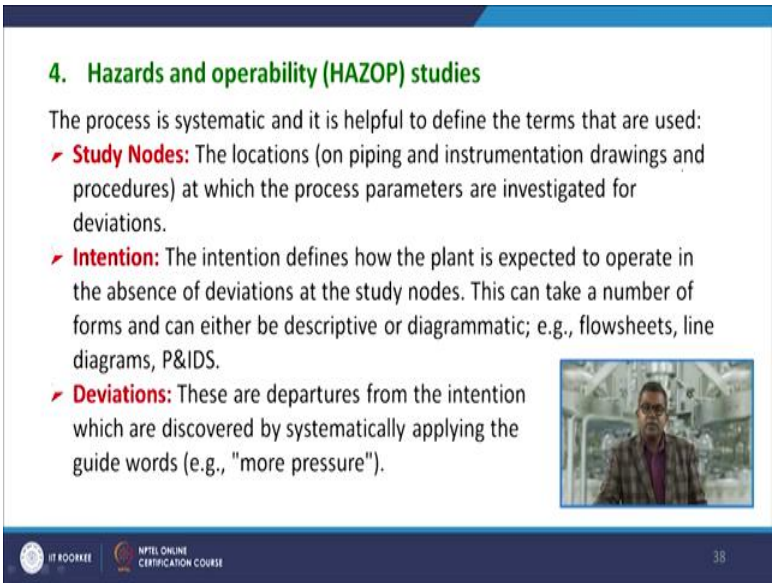

Now, this process is systematic and it is helpful to define the terms that are used like study notes the location for example on piping and instrumentation drawing and procedure. The location at which the process parameters are investigated for deviation. Then the intention, the intention defines that how the plant is expected to operate in absence of deviation at the study nodes.

Now, this can take number of forms and can either be descriptive or diagrammatic like flowsheet, line diagram, P&IDs, etc. Then you may look in to the deviations and these are the departure from the intentions which are discovered by systematically applying the guidewords like more pressure, high pressure, etc.

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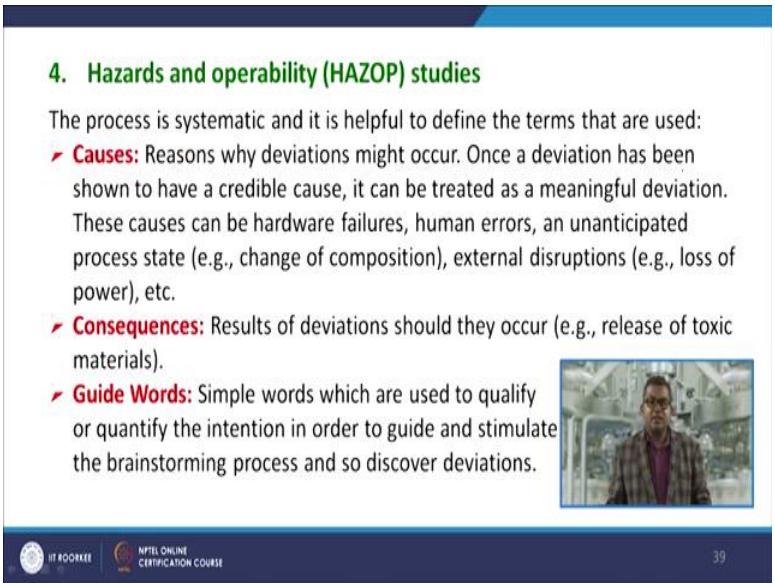

Then the causes the reason why the deviation might occur, once a deviation has been shown to have a credible cause it can be treated as a meaningful deviation. Now these causes can be hardware failure, human error, unanticipated process states, etc. or sometime external disruptions like loss of power, etc. which is not in your control. Then consequences, these are the result of deviation and should they occur like release of toxic materials etc. You may have certain guidewords like simple words which are used to qualify or quantify the intention in order to guide and stimulate the brainstorming process and discovered the deviations.

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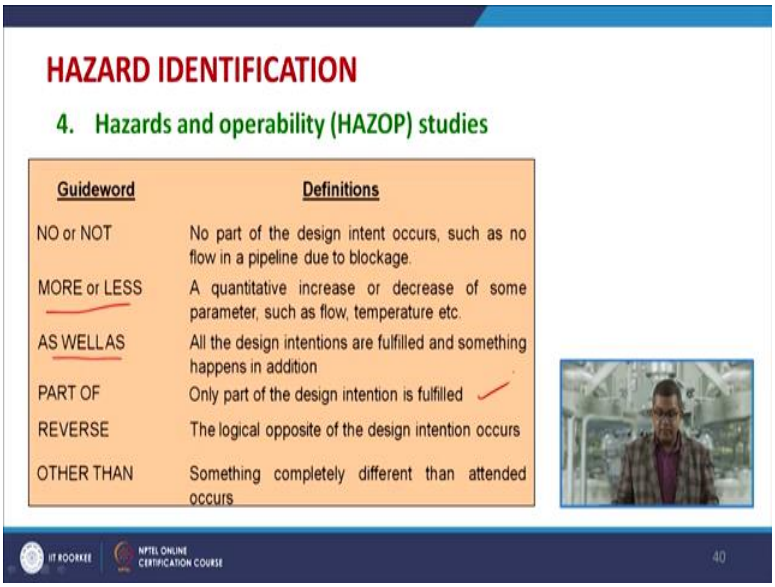

So whenever you perform these HAZOP studies there are few guidewords like no or not and the definition is no part of the design intent occurs such as no flow in the pipeline due to blockage. More or less a quantitative increase or decrease of some parameters such as flow temperature etc. As well as all the design intentions are fulfilled and something happen in addition. Part of only part of the design intention is fulfilled the reverse that is a logical opposite to the design intention occurs other than something completely different than attended occurs.

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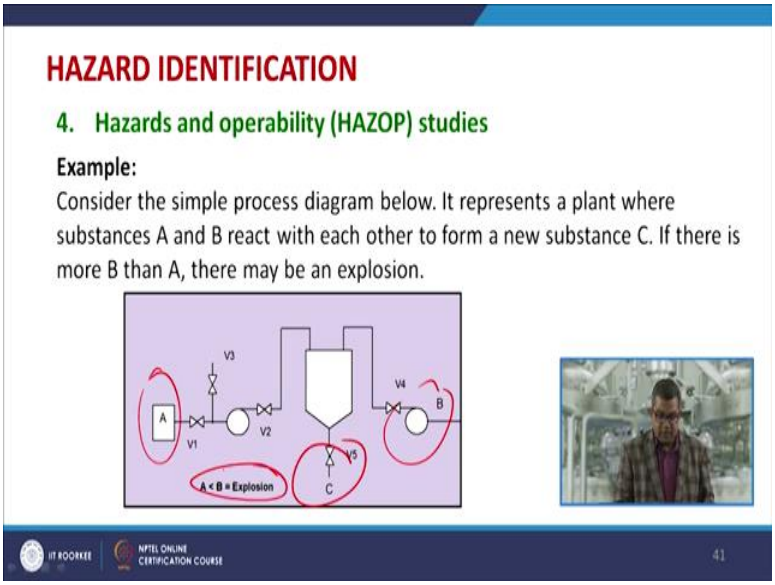

Now, one example is that consider a simple process diagram this figure it represents a plant where a substance A and B reacts with each other to form a new substance that is called C. There is if there is more B then A there may be an explosive, so this is the chance of explosive.

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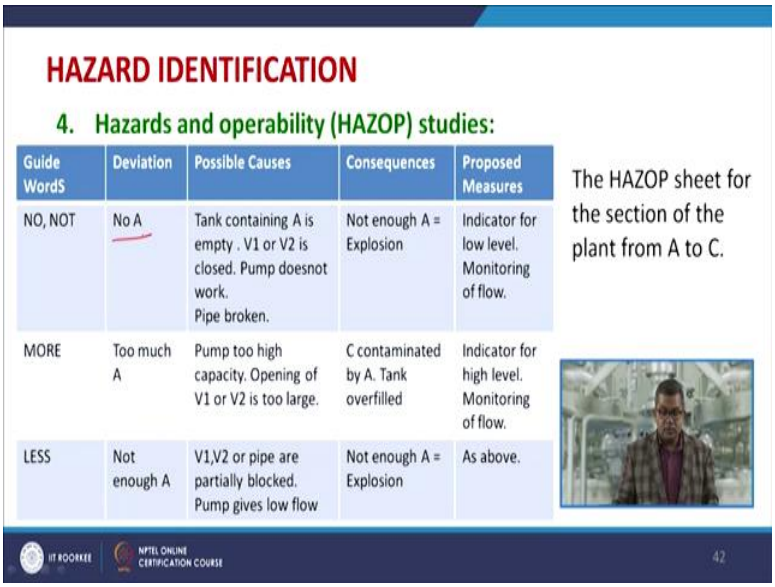

Now, let us have an analysis of this HAZOP analysis, no or not that is no A so tank containing A is empty this one.

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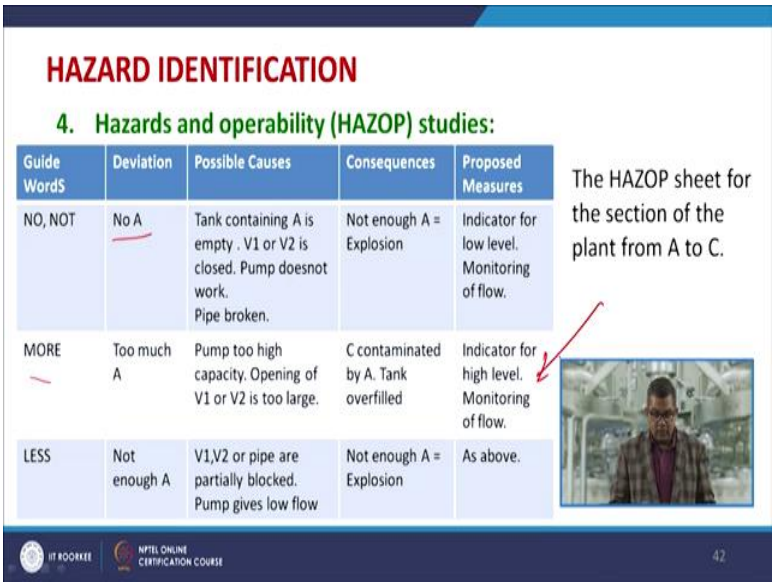

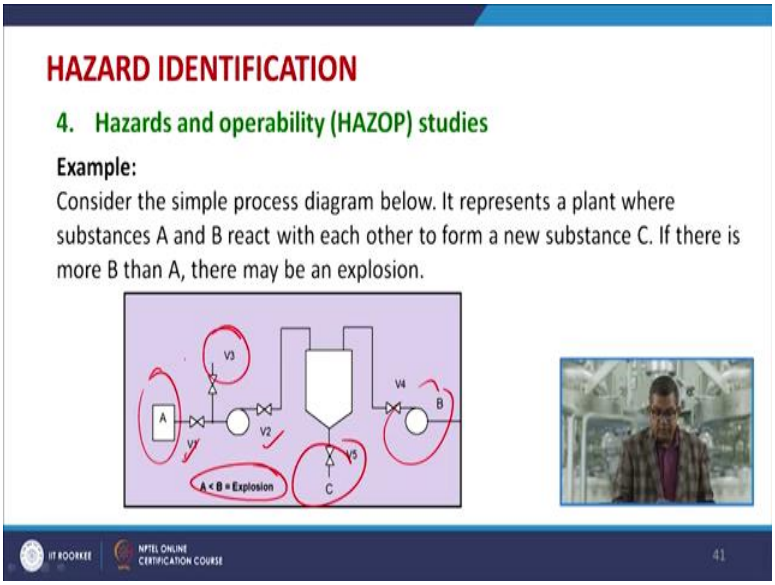

And V_1 and V_2, this V_1 and V_2 is closed so pump does not work that is pipe broken the consequences is not enough A this may lead to the explosion. Now the proposed measures are indicator for low level, monitoring of flow.

Now more that is too much A, the pump too high capacity opening of V_1 and V_2 is too large. This one V_1 and V_2 is too large. The consequences are C contaminated by A so tanks are overfilled this is indicator of high level. And the monitoring of flow is needed.

Less not enough A that is means V_1 or V_2 that the valve V_1 & V_2 the pipe are partially block and pump gives off low flow. So not enough A, this may lead to an explosion.

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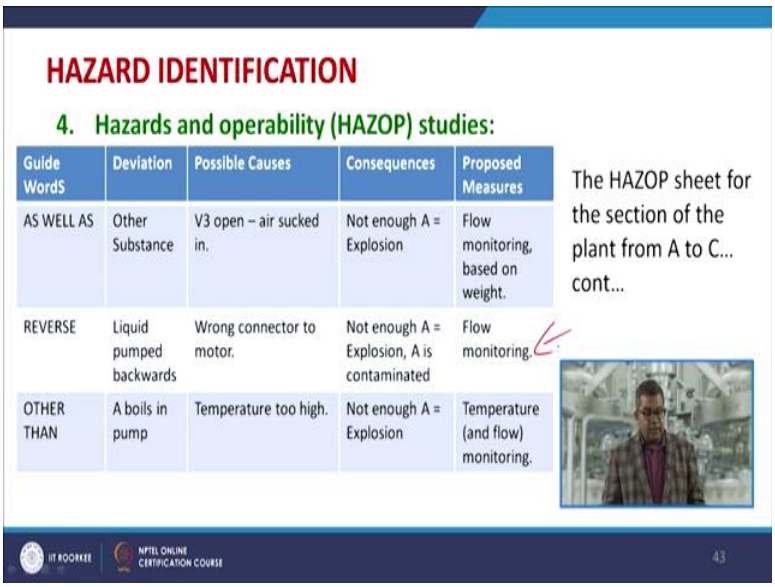

As well as the deviation is other substances may present. Sometimes V3 is open the air sucked in, so not enough A that is a consequence and it may lead up to the explosion. The proposed measures are flow monitoring based on weight.

Reverse liquid pump backward that is wrong connector to the motor, so not enough A may lead to explosion and A is contaminated so you must go for the flow monitoring,

other than the A boils in pump the temperature is too high that is not enough A in the system then it may lead to explosion. Then temperature and flow monitoring is essential.

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So, since it is a very systematic approach let us have a look about the history of this HAZOP study this is developed by Lawley in 1974 by ICI that is Imperial Chemical Industry of UK. Based on earlier account of Elliot & Owen 1968 which was developed in 1968. The technique originated in the heavy organic chemical division of ICI which was then a major British & International chemical company. So history this has been described by Trevor Kletz who was a company safety advisor from 1968 to 1982.

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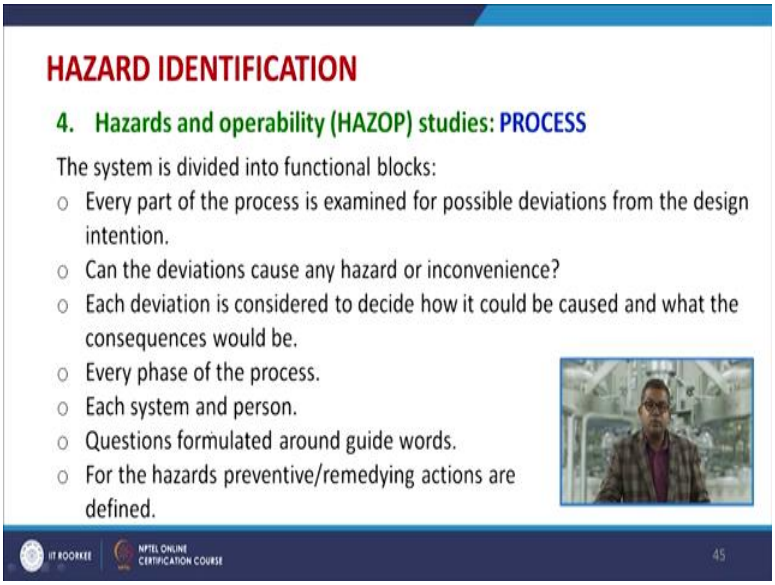

The process of this HAZOP study is the system divided into the functional blocks. So every part of process is examined for the possible deviation from the design function. Now can the deviation caused any hazard or inconvenience to the system, must analyse. Each deviation is considered to decide that how it could be caused and what the consequences would be. Now, every phase of the process must be well defined each system and person must be well defined the question formulated around the guideword this is extremely important because you are having the set guidewords for this one.

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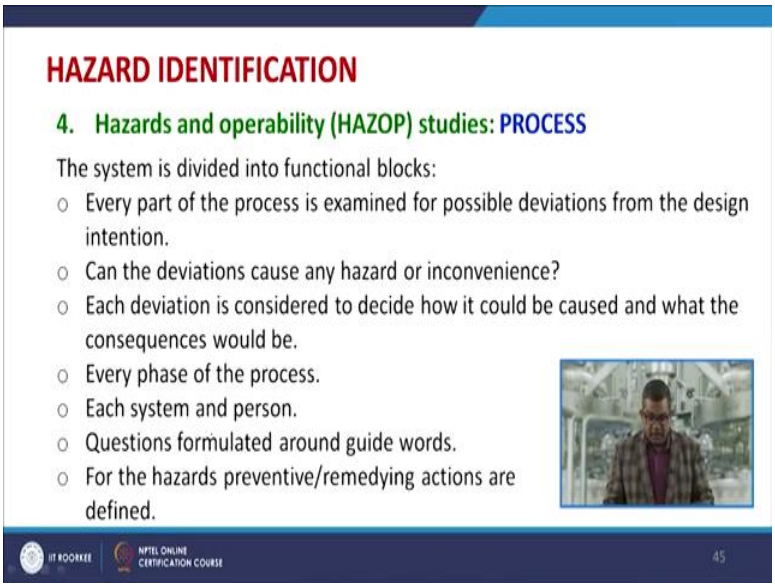

Now, for the hazard and preventive remedying action they are must be they are well defined and they must be well defined this is the primarily requirement.

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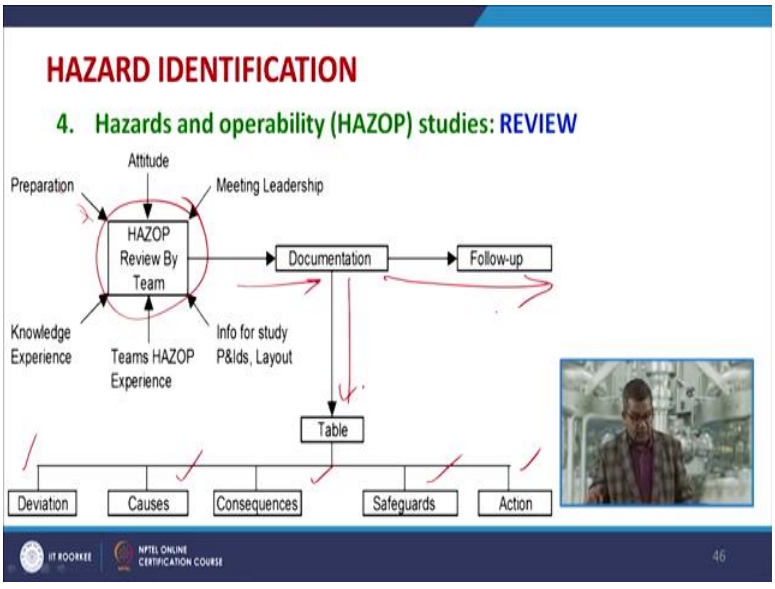

The next aspect is to go for a review. Now, here you are having a diagram where you are having a HAZOP review which was given by the team. This may lead to the preparation based on a knowledge experience teams of HAZOP experience they may have attitude meeting leadership. They give the proper documentation. Now, these documentation may lead to the various tables sometimes enlisted with the deviation various causes consequences

methodology for safeguard action and you must go for the follow up that whether your recommendation and whether the study has something so that it must be follow up.

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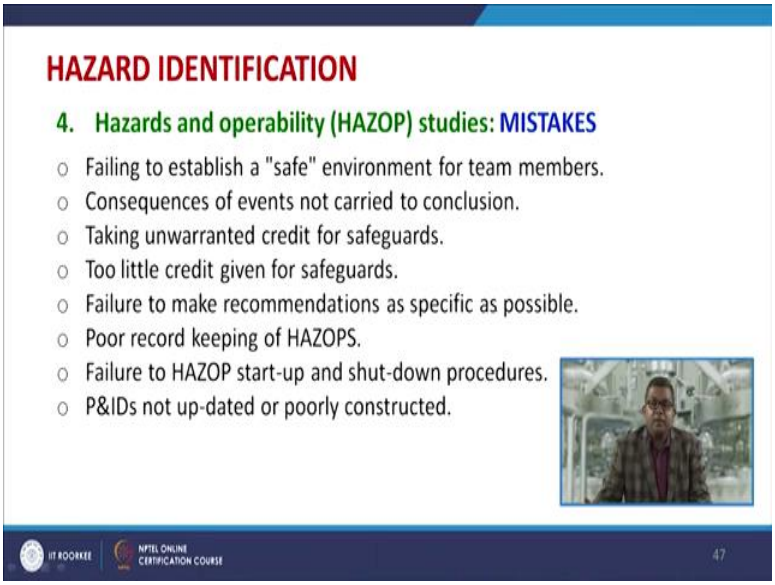

Now, sometimes certain mistakes may take place that may be attributed to the failing to establish a safe environment for the team members. Consequences of events that not carried out to conclusion taking unwanted credit of for safeguard too little credit given for safeguard failure to make the recommendation as specific as possible. Poor record keeping of all those HAZOPs failure to HAZOP a start-up and shutdown procedure. P&IDs are not up to dated, updated or poorly constructed.

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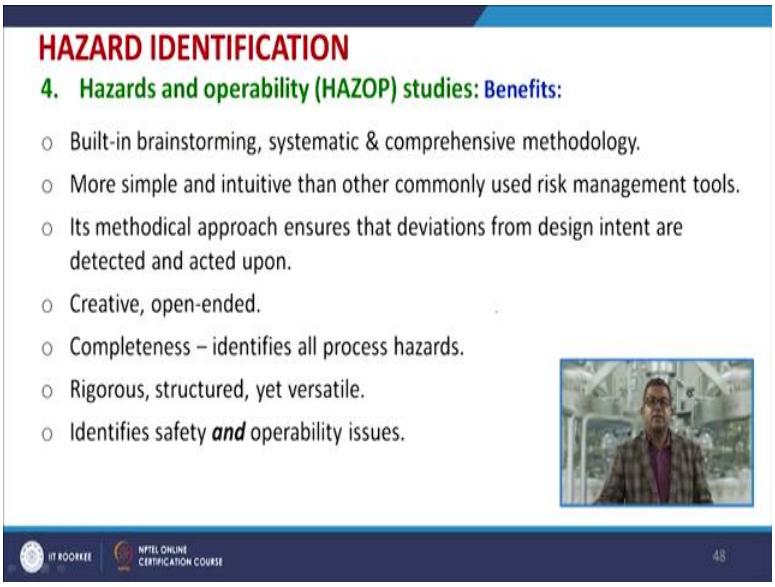

Now, there are certain benefits associated with these HAZOP studies. They are having the built in brainstorming and systematic and comprehensive methodologies you may develop all those things they are more simple and intuitive then other commonly used risk management tools. It is methodical approach ensures that deviation from design intent are detected and acted upon they are very much creative and open ended. They gives the completeness and identifies all kind of process hazards, they are rigorous, structured and yet very versatile. It identifies the safety and operability issues, they are helpful when confronting hazards that are difficult to quantify.

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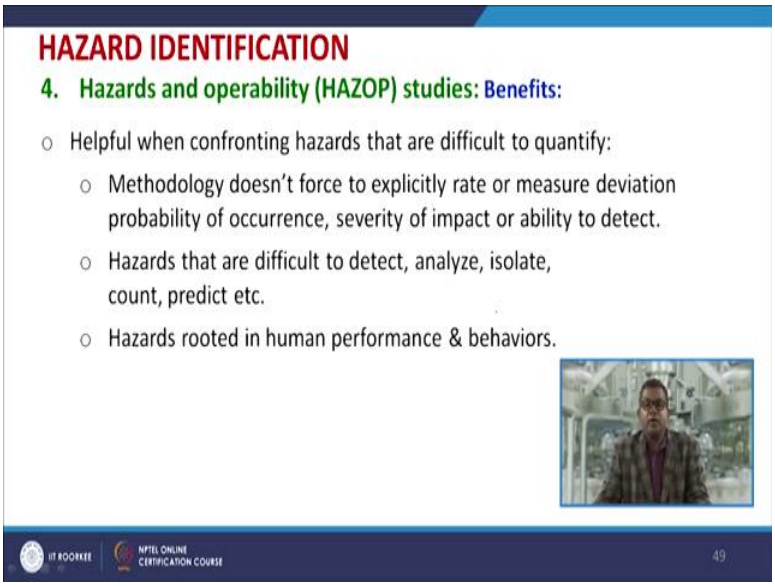

The methodologies does not force to explicitly rate or measured deviation probability of occurrence severity of impact or ability to detect. The hazards that are difficult to detect, analyse, isolate, count, predict etc. These hazards are rooted in human performance and behaviour.

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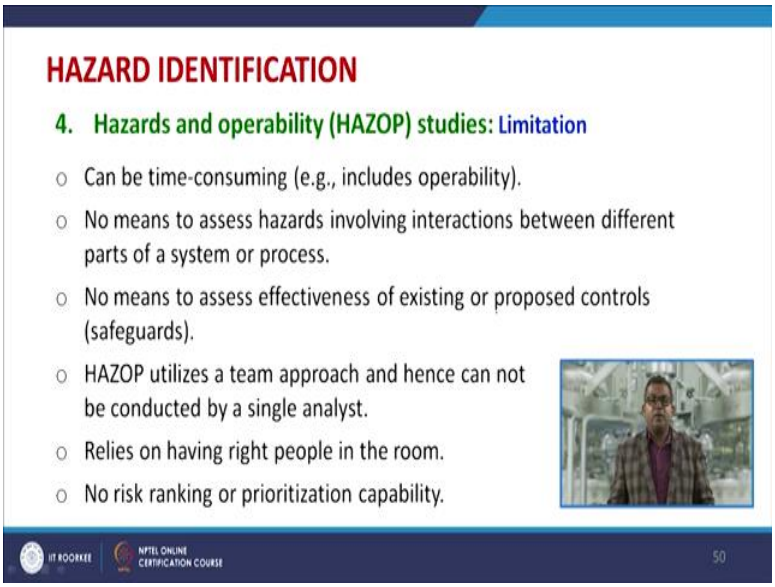

There are certain limitations attributed to these HAZOP studies, they are enlisted in these particular slides. Now they can be time consuming this because they have included the operability. No means to assess the hazards involving the interaction between the different parts of system or a process, there is no mean to assess the effectiveness of existing or proposed controls. HAZOP utilizes a team approach and hence cannot be conducted by a single analyst so you must have a well formulated team. They relies on having right people in the room. No risk ranking or prioritization capabilities.

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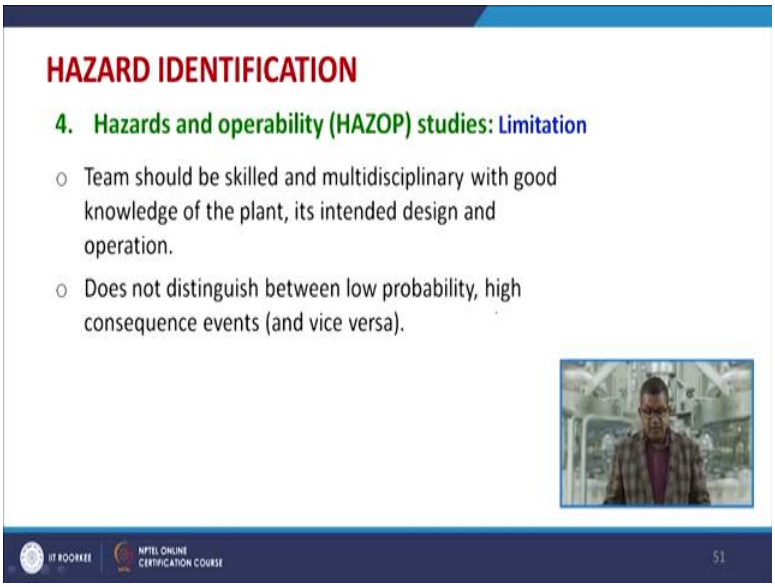

And one more requirement is that the team should be skilled and multi-disciplinary with good knowledge of plant, now, its intended design and operations so all thing all the team members should have well acquainted with the all aspect of the plant. And they does not distinguish between the low probability high consequences event or vice versa. So in this particular module we have discussed about the hazard identification tool we have performed the, we have discussed the various kind of HAZOP studies, given one example for this one.

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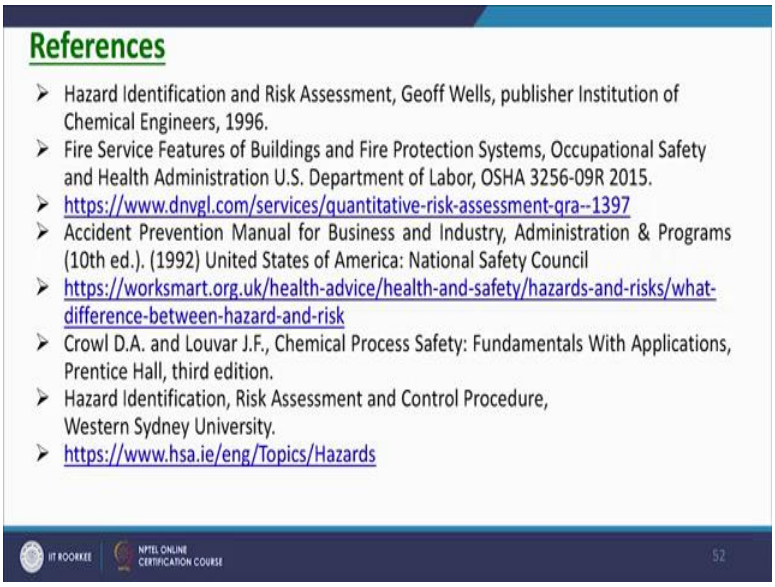

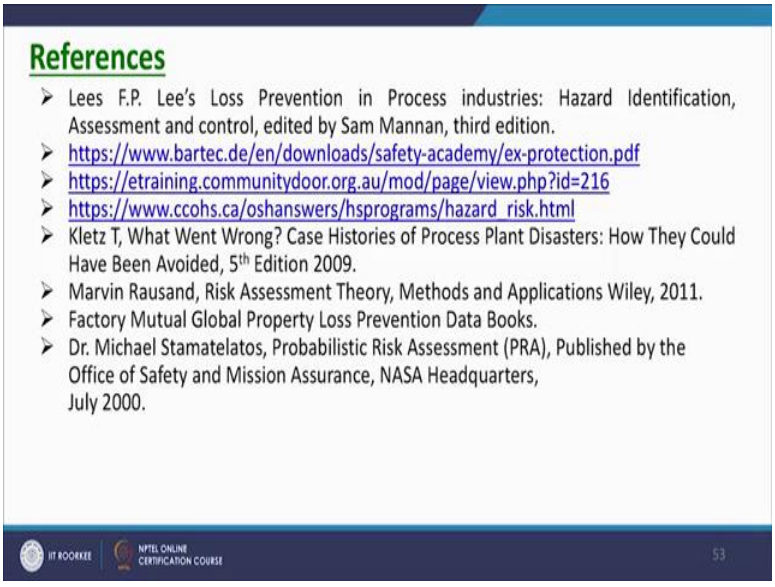

And in case if you wish to have further reading there are lot of references enlisted. Thank you.