Chemical Process Safety
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Lecture 47
Accident Causation Theories

Now welcome to the next module of Accident Research and Investigation so before we go ahead let us have a look about that what we had studied in the previous module. So we have described the various aspects of accidents we had a discussion about relative facts about the accidents we had gone through about the accident weed.

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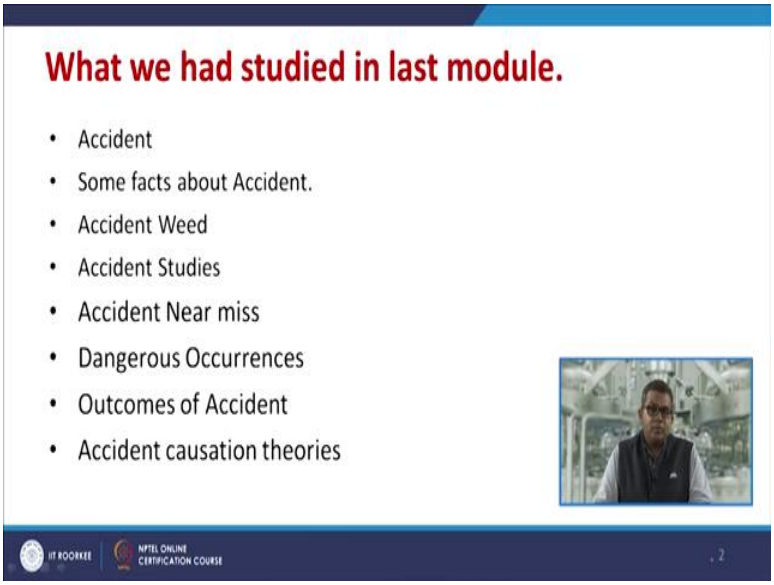

We have discussed about the various aspects of accident studies. We have gone through the concept of accident those who are near misses apart from this we have discussed the dangerous occurrence, various outcomes of accidents then accident causation theories. So when we were discussing about the accident causation theories we have gone through the various models of these theories so couple of models we have discussed in the last module so we are just going through other (modules) models of those accident causation theory. So the next is our Epidemiological theory.

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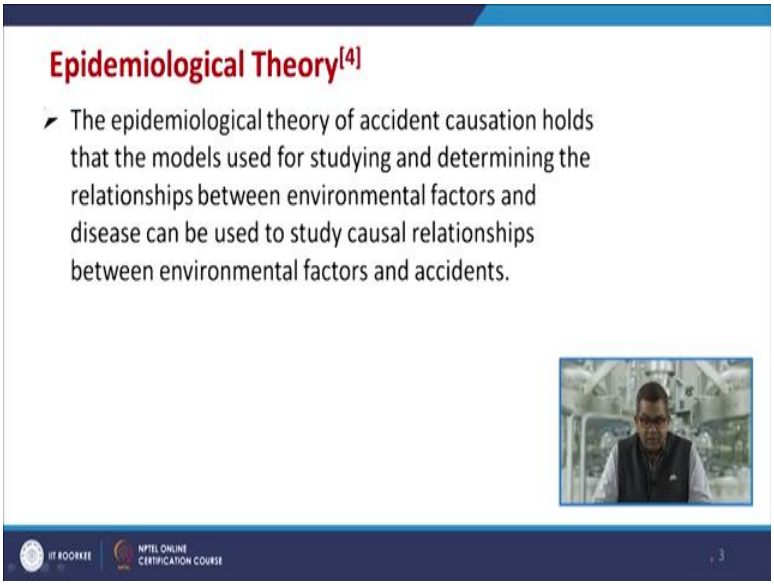

This epidemiological theory of the accident causation theory this holds that model used for the studying and determining the relationship between environmental factors and disease can be used to study the casual relationship between environmental factor and accident because the environmental factor is again a very crucial issue sometimes some accidents may lead to destroy the environment and sometimes it takes very long time to clear or the environment for the livelihood of mankind.

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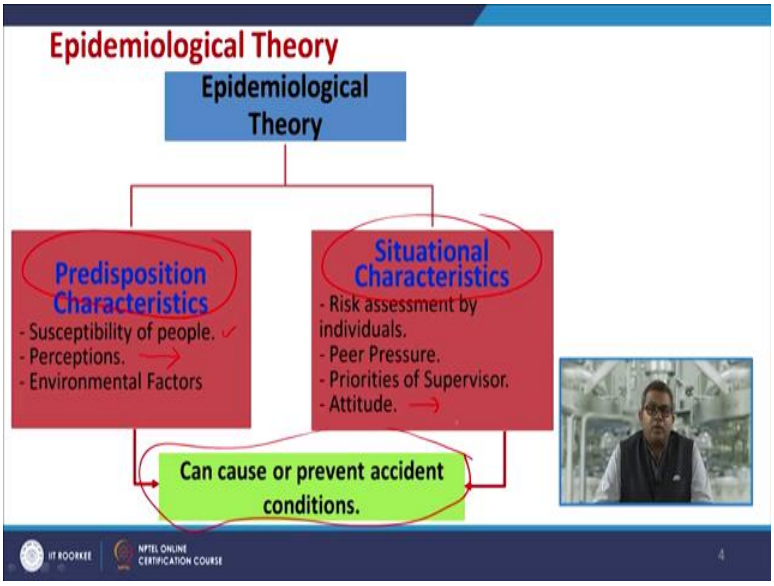

So this theory is having two aspects, one is the Predisposition Characteristic another one is the Situational Characteristic so while we were discussing about the predisposition characteristics they covers the susceptibility of the people involve within the plant periphery and the environmental aspect those who are living outside those periphery they may have include about the various perceptions related to the source then other environmental factors.

While we consider the situational characteristic they includes the risk assessment by individual, individual may be the worker, may be the outside people then they involve the concept of Peer pressure, peer pressure may be attributed to the again those who are living at the vicinity of the plant periphery or within the plant then the priorities of supervisor.

Because this priority is again very crucial in terms of supervisor because sometimes the supervisor may experience the pressure related to the production sometimes it may experience the pressure related to the environmental aspect, sometimes it may experience the pressure related to the safety, safety of the plant plus safety of other aspect like monetary gains etc. Then it includes the attitude, attitude may be towards the maximum production or attitude towards the safety of the system.

Now in case of any you need to have a proper optimization of all this factor now these any kind of imbalance all this predisposition characteristics or situational characteristics may cause accident so proper balance can cause or prevent the accident condition. So this is extremely important now you may change these predisposition characteristics or situational characteristics as per the requirement.

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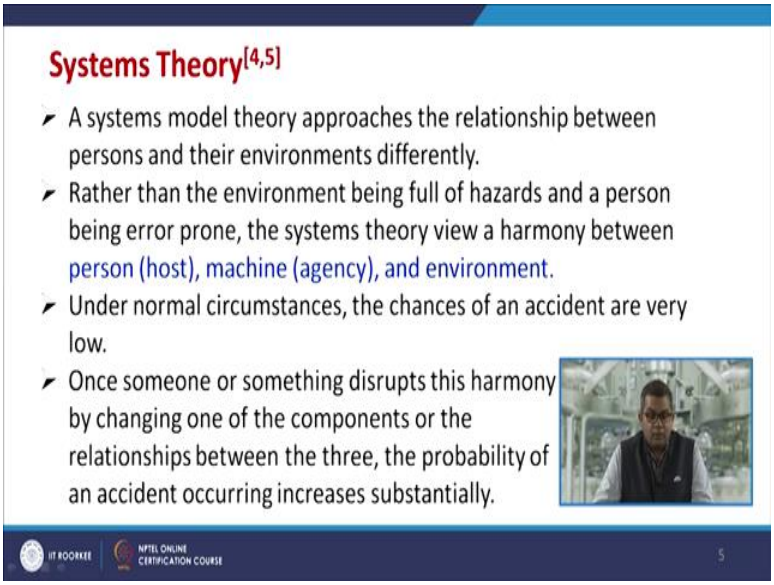

Now other theory is the System Theory, now a system model theory approaches the relationship between the persons and their environment differently. Now rather than the environment being full of hazard and a person being error prone the system theory view a harmony between the person may be sometimes a host, machine that is the agency and the environment. So again it has the three different variables person, host, machine, agency and environment. So under normal circumstances the chances of an accidents are very low so that means whenever there is any chance that means the harmony among person, machine and environment is on the different track.

So once someone or something disturbs this harmony by changing one of the component or the other relationship between among three the probability of an accident occurring increases substantially. The reason is that any kind of suppose you are changing a parameter then definitely there would be a change in the machine then the person though or host must be in a position to adopt those changes so that the imbalance should be stabilize.

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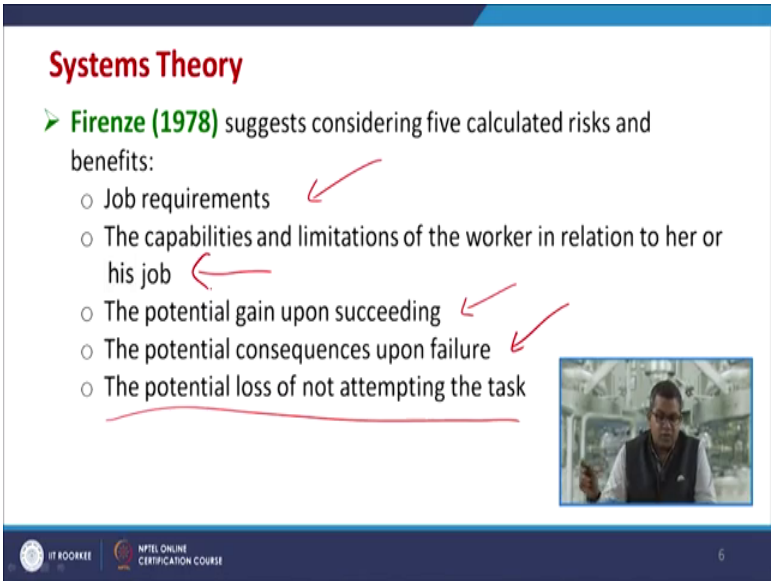

Now this theory was modified by a Firenze in 1978 he suggested that considering the five calculated risk and benefits so he has given the five risk which are enlisted in this particular slide that is one is the job requirement, second is the capabilities and limitations of the worker in relation to her or his job. The potential gain upon succeeding, the potential consequences upon various failure, the potential loss of not attempting the task, sometimes you may not be in a position to follow the guidelines or follow the orders given by your superiors then there may be a chance that you may suffer substantial loss sometimes the loss of job, sometimes the loss of any kind of you can say the bonus and other thing.

So you may suffer this type of aspect so you must consider the potential loss for not attempting any kind of assign task sometimes what kind of potential gain you may have once you have succeeded that particular job assigned to you sometimes you may need to assists that what kind of the potential consequences may happen upon the failure of any kind of thing.

So he analyzed al this five calculated risk sometimes job requirement may pose certain restrictions so you have to consider all you may have to take the calculated risk and sometimes it may be beneficial and sometimes it may not be then you need to assist the capabilities and limitations of the worker in relation to his or her job then you must be in a proper position to assist this thing.

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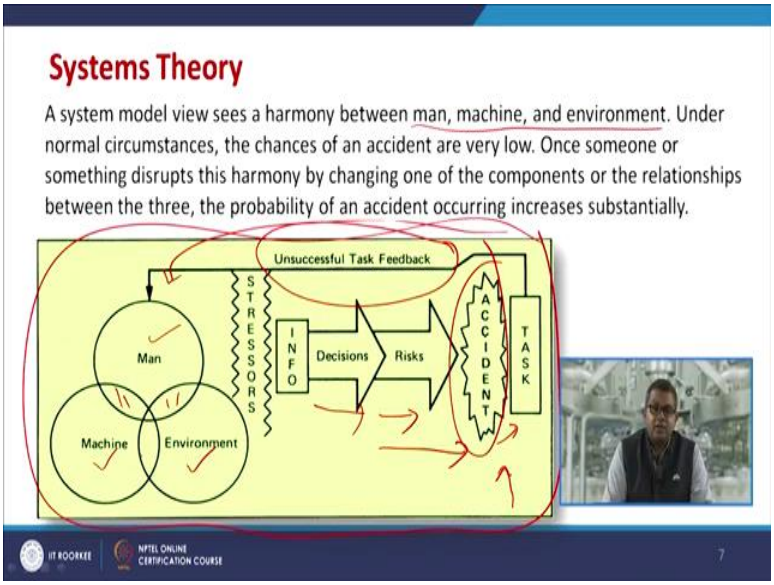

Now this, a system model this views sees a harmony between the man, machine and environment that we have discussed in previous slides so under normal circumstances the chances of an accident are very low that means all three parameters or all three approaches they are working well in order. So once someone or something is imbalanced or sometimes it may happen that some cause disturbs this harmony then there may be a chance that the accident may happen.

Now in this particular figure we have shown this particular aspect and we can explain this thing more precisely so once the host the machine and the environment all three are in a good condition then there is no problem but if anyone or all three this is the problem then there may be chance of certain overlapping and this causes the problems in decision making and this may cause the severe risk and this risk may attributed to the cause of an accident.

So you need to take the proper feedback of those accident so that you can adopt the corrective measures among all three aspects or all three parameters. So once you analyze or once you assist the risk then based on those risk you can assign the task which gives the feedback that you are task is unsuccessful it provides the feedback to all three stake holders to adopt the corrective measures. So that is the system theory. Now another theory is the Multiple Causation Theory it is an outgrowth of the domino theory which we have discussed in the previous module.

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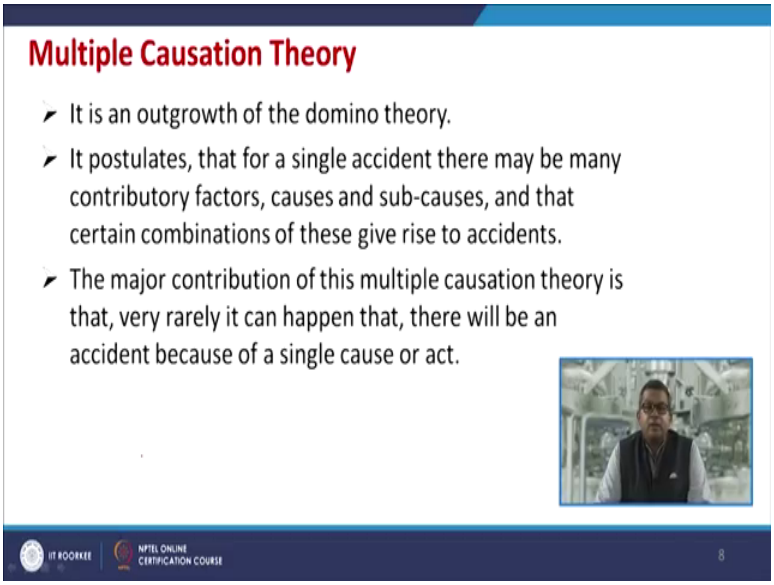

Now it postulates that for a single accident there may be many contributory factors there may be certain causes, there may be certain sub-causes and that certain combinations of these things give rise to an accident or sometimes multiple accidents. So the major contribution of this multiple causation theory is that a very rarely it can happen that there will be an accident because of a single cause or act.

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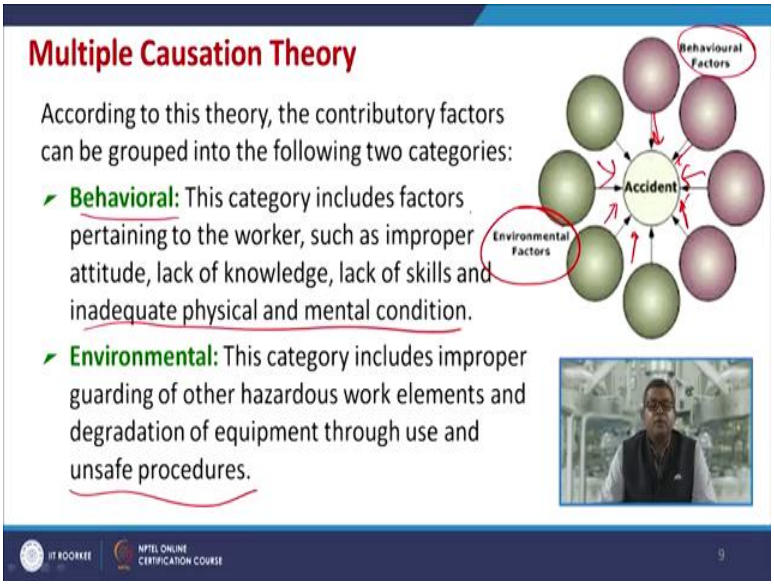

Now according to this theory the contributory factor can be grouped into several categories but the majority there are two categories one is related to the behavioral and then second is the

environmental. So behavioral theory this category includes the factor pertaining to the worker such as improper attitude, sometimes because of limitations of training there may be attributed to the lack of knowledge and the lack of knowledge may lead to the lack of excuse to handle the scenario and inadequate physical or mental condition may be because of some variety of reasons may be because of the family issues, may be because of some job stress etc.

So these contributing factors may lead to the accident. The other is the environmental aspect, now this category includes improper guarding of other hazardous work element and degradation of equipment through use and unsafe procedures. Now this type of things may happen during the course of multiple of use or prolong use of equipment. One example is that suppose you are using particular equipment for a long time without any kind of maintenance or repair or a modification then it may happen that the wear and tear way possible so the condition may become the unsafe.

Now those unsafe conditions may become may contribute towards he accident. Another example is that suppose you are using a pulley system which is duly guarded by the fencing or the covers. Now continuous use of that particular thing may be because of the vibration, may be because of other environmental conditions the fencing is degrade so and if you have not taken care of any kind of repairing or modification or a good housekeeping then you it may lead to the unsafe condition or unsafe protocol and this may lead to an accident. So these environmental factors are again important under the head of a multiple causation theory.

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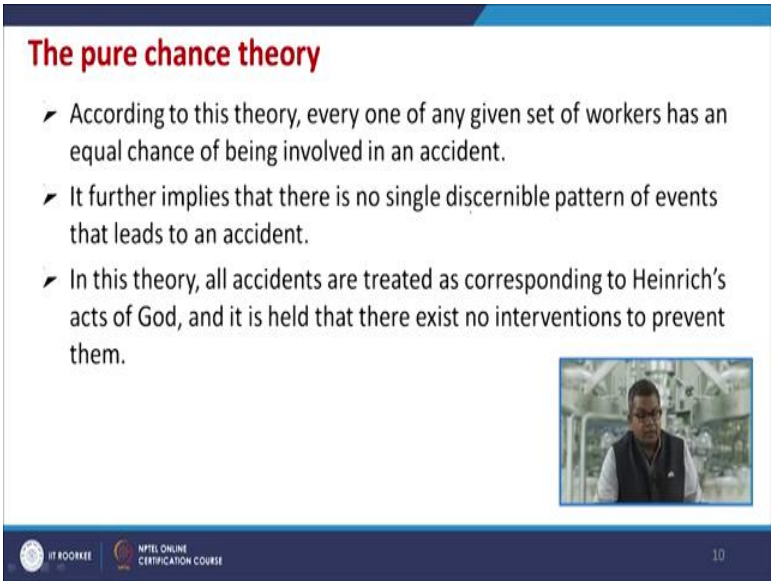

Now other theory is the Pure Chance Theory, now according to this theory every one of any given set of worker has an equal chance of being involved in an accident. So it further implies that there is no single discernible pattern of event that leads to an accident. So under this theory all accidents are treated as corresponding to Heinrich's act of God and it is held that there exist no interventions to prevent them.

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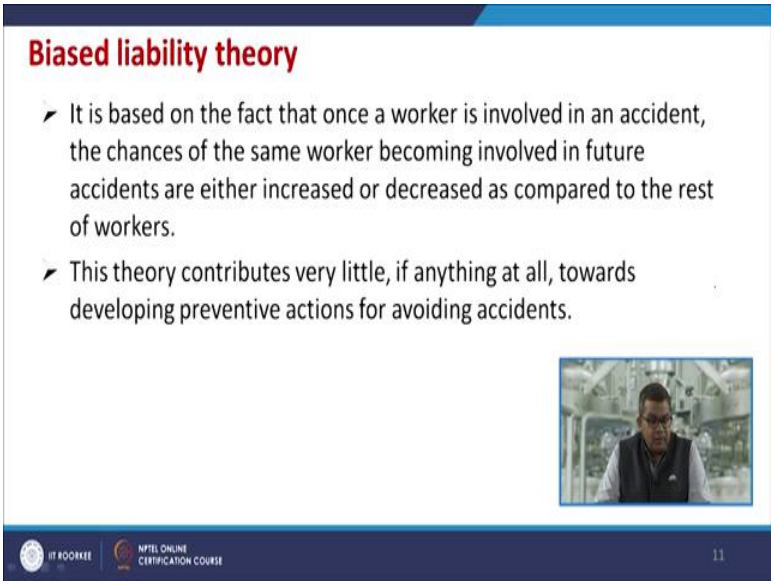

Another theory that is the Biased Liability Theory, now it is based on the fact that once a worker is involved in accident the chances of the same worker becoming involved in future accidents are

increased or decreased as compare to the rest of the worker. So you may say in other words the (chances of) chances may not become stagnant because sometimes it may increase or sometimes it may decrease and this again this liability theory suggest that because if any accidents suppose in for an example accident happens then the worker may be charged or it may be trained. So if it is charged then probably he may not be in a mental condition to repair the things or to enhance its mental ability.

In that particular case the involvement of worker has become decreased, sometimes it may happen that by any means the worker is involved in any kind of accident and then if it is being trained or it has been you can say got the knowledge of that particular incident then it may be in a position to decrease the ability of the accident probability. So in that particular case both the things increased or decreased may happen. Now, this theory contributes very little if anything at all, towards developing the preventive action for avoiding the accidents.

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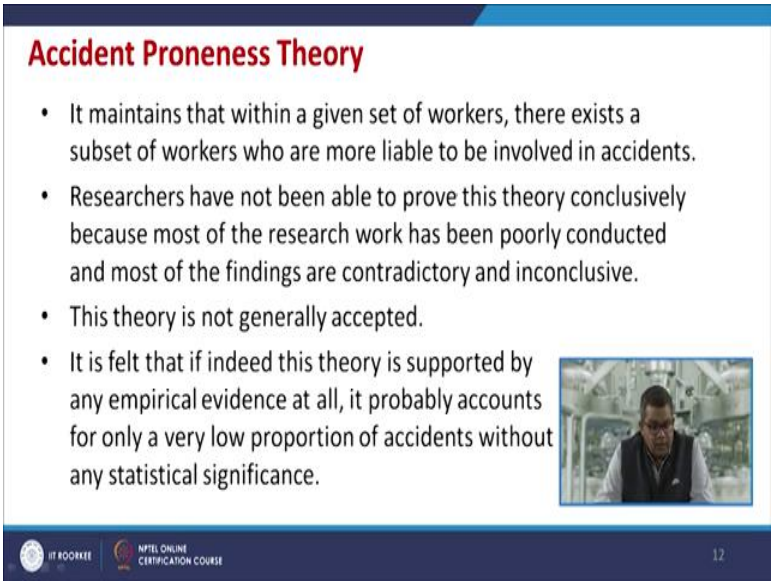

Another theory is related to the Accident Proneness Theory, now it maintains that within a given set of worker there exist a subset of worker who are more liable to be involved in an accident. Now you have to find out those subset of workers to make your process safe. So researchers have not been able to prove this theory conclusively because most of the research has been poorly conducted and most of the findings are contradictory and inconclusive.

The one of the foremost reason is that the experimental determination of all the accidents is extremely difficult so therefore this theory is not generally accepted. Now it is felt that if indeed this theory is supported by any empirical evidence at all it probably accounts only a very low proportion of accident without any statistical significance because statistical significance or statistical data is extremely difficult in this case.

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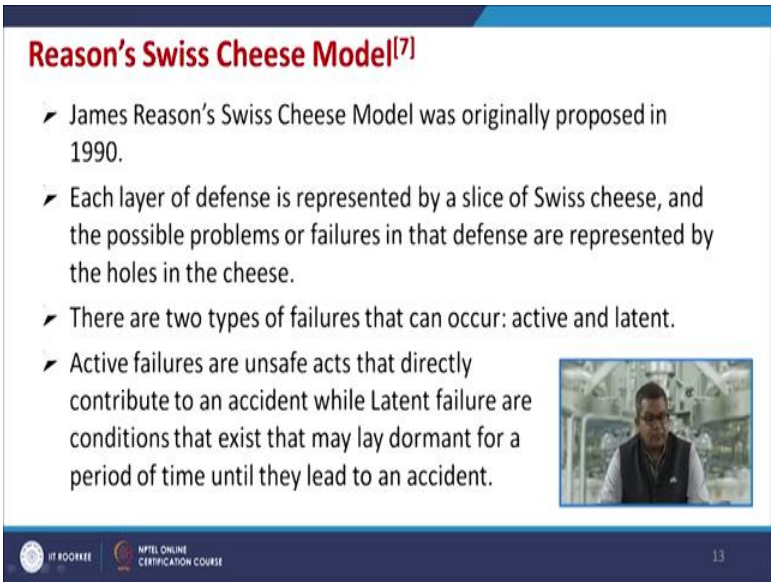

Another model is the Reasons Swiss Cheese Model, so this was given by James Reason and the James Reasons Swiss Cheese Model was originally proposed in 1990. So each layer of defense is a represented by a slice of Swiss Cheese and the possible problem or failure in that defense are represented by the holes in the cheese and these holes in the Swiss Cheese they are deliberately created.

So there are two type of failures that can occur either active or latent, the active failures are unsafe acts they directly contribute to an accident while latent failure are conditions that exist that may be may lay dormant for a period of time until they lead to an accident. So sometimes there may be a scenario where the things are there but they are dormant they are not contributing any kind of activity within the process area but if they find the suitable time then it may be populated and it may lead to an accident. So these are called the latent failure.

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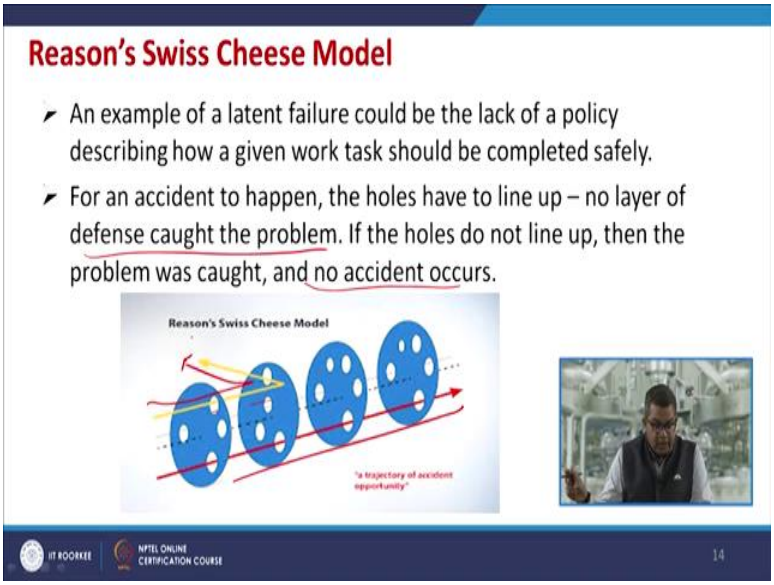

Now another example of the latent failure could be the lack of policy describing how a given work task should be completed safely. For an accident to happen the holes they are like this (they) these holes are line up then no layer of defense caught in the problem. Now if holes they do not line up then the problem was caught and no accident occurs like this, these holes are line up then there may be chance that no accident occurs. Now if these holes are not a line then there may be chances the system may diverted to some unsafe condition.

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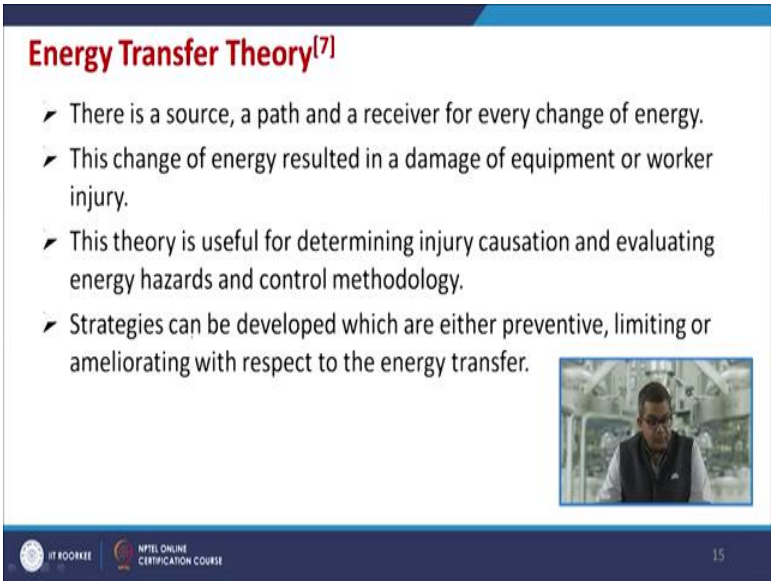

Another theory is that Energy Transfer Theory, now there is a source, there is a path and there is a receiver for every change of energy. Now this change of energy resulted in a damage of equipment or worker injury. So this theory is useful for determining the injury causation and evaluating energy hazard and control methodology. Sometimes you can adopt or you can develop the strategies which are either preventive or limiting or ameliorating with respect to the energy transfer.

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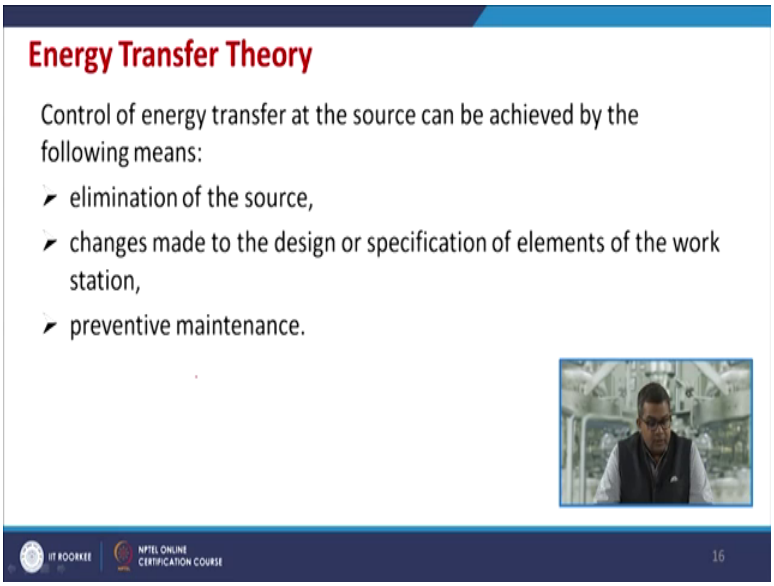

The control of energy transfer at the source can be achieved by the various reasons (three of) three reasons are enlisted here that is you may eliminate the source the you may change the changes made to the design or specification of elements of the workstation and sometimes the preventive maintenance.

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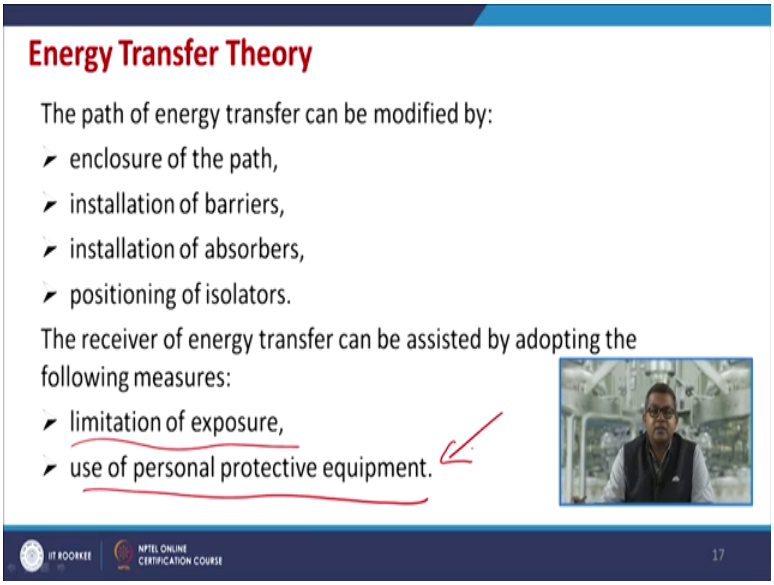

The path of energy transfer can be modified by various enclosure of the path, sometimes you may need to install the different barriers to prevent the things, sometimes by the installation of absorbers and it is very common in chemical engineering. Sometimes by changing or providing the positioning of various isolators. Now the receiver of energy transfer it can be assisted by adopting the different measures like limitation of exposure and the use of personal protective equipment. Remember we have already discussed this PP in various modules.

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Another or you can say the important concept is Management Oversight and Risk Tree that is referred as MORT. The management oversight and risk tree is a complex analytical procedure that provides the disciplined method for determining the causes and contributing factor of various accidents. Now it has provided a technique for thorough searching investigation of occupational accident and analysis of safety program. Now this MORT is sufficiently searching and a revealing that full scale analysis of only few serious accident or accident will point to many needed program improvements.

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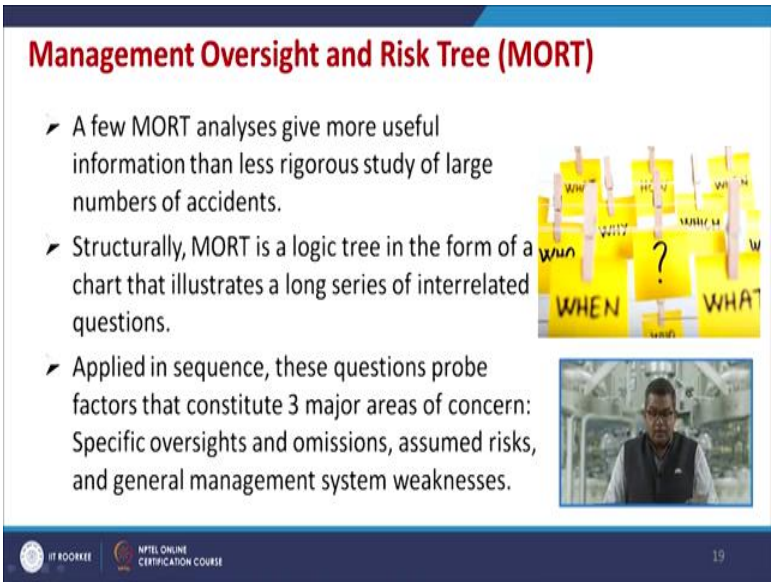

Now few MORT analysis give more useful information then the less rigorous study of large number of accident. Now usually this is the risk analysis protocol so structurally MORT is a logic tree in the form of a chart that illustrate a long series of interrelated questions. Now you may recall the fault tree analysis and event tree analysis in which the different interrelated things or interrelated scenarios they are link together and there are several set of questions being framed to interlinked all those things. So these questions they are applied in sequence and these questions probe factors that constitute three major area of concern, specific oversights and omissions, assumed risk and general management system, weakness etc.

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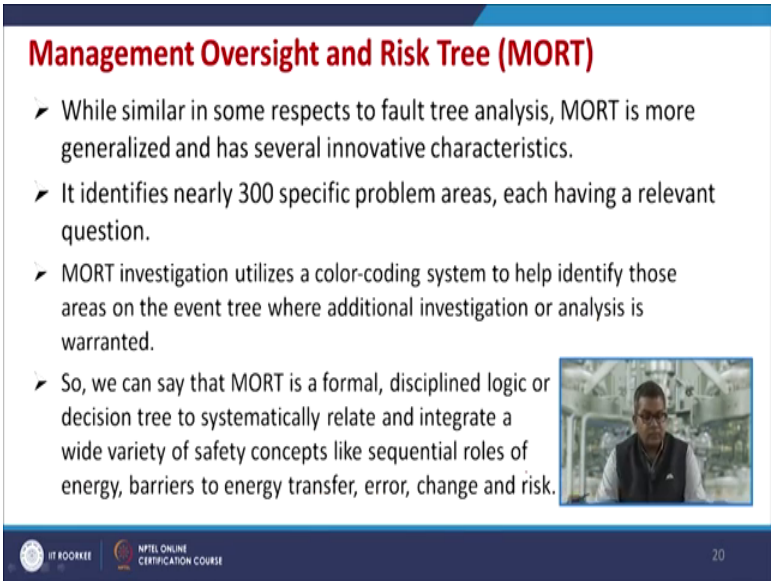

So while similar in some aspects to fault tree analysis but it is reconsider is a modified version of our old fault tree analysis so MORT is more generalized and has several innovative characters. So it identifies nearly 300 specific problematic areas each having a relevant question. Now this management oversight and risk tree that is MORT investigation utilizes a color coding system to help identify those areas on the event tree where additional investigation or analysis is required.

So you can say that this is that is why we are saying that this is the modified version of event tree and a fault tree analysis. So the MORT is a formal disciplined logic decision tree to a systematically relate and integrate a wide variety of safety concepts like sequential roles of different energy barriers, to energy transfer, error change and risk.

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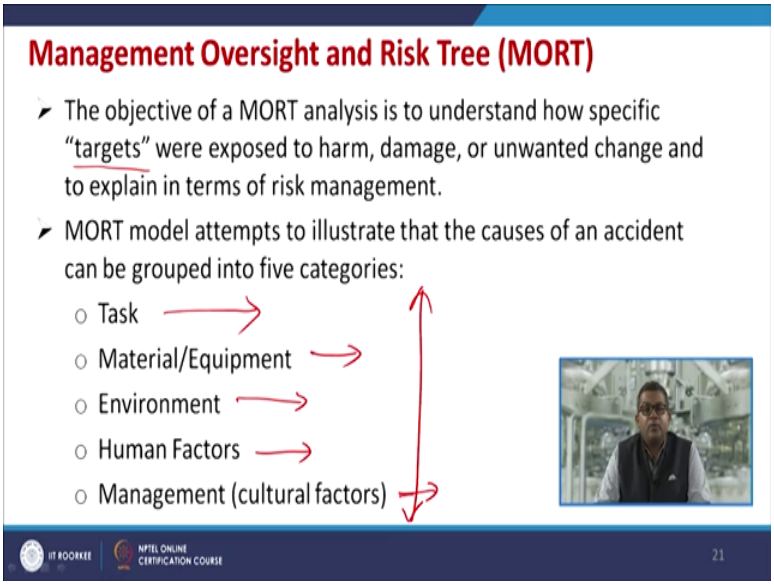

Now let us have a discussion about the objective of MORT, the objective of a MORT analysis is to understand how specific targets were exposed to harm, damaged or unwanted change and to explain in terms of risk management. Now this MORT model attempts to illustrate that the causes of an accident can be grouped into five different categories.

Now these categories are enlisted over here the task, the Material or you can say equipment, the environment associated with the process, the human factor it is not only with the human factor related to the process but also to the other environmental those who are living at the vicinity. The management that is the cultural fashion or the cultural factor because earlier we had a discussion that management play a very vital role for introduction of safety aspect within the process arena.

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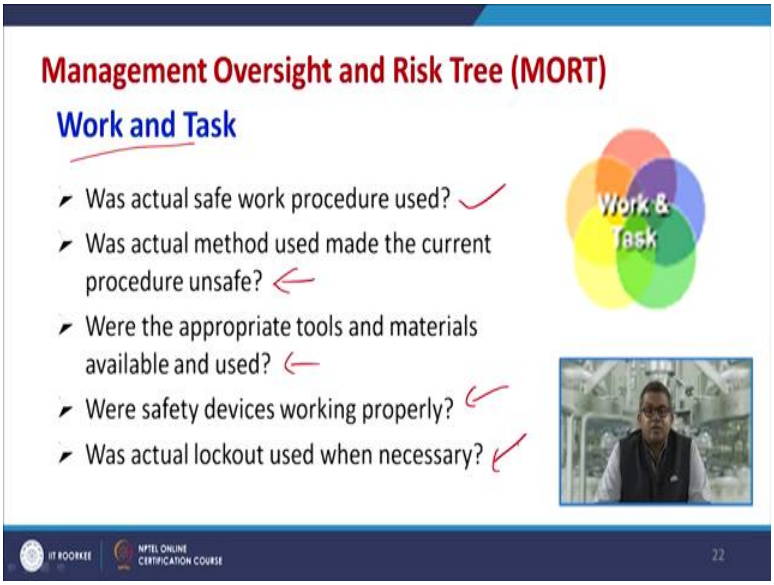

So let us have a look about the work and task, now you need to frame a various questions related to the MORT that is management oversight and risk tree so work and task related questions are that was the actual safe work protocol used? Again it is a very you can say the deliberated issue because every time you need to you must aware about the entire process plant arena, plant layout etc then the second question may be that was actual method used for the current procedure unsafe?

So you need to analyze the thing that whatever safety protocol you have implemented to for the safe operation of the process if it fails then what was it was unsafe condition or what are the causes those attributed for this unsafe condition? Now were the appropriate tools and materials available and used?

This is again a very beautiful question because it gives you an opportunity to analyze that you are having all the things with you or you are not having the required tools or material for the safe operation. Now next question may be the were the safety devices working properly? Again it is a very good question because it gives you an idea whether the proper housekeeping, maintenance, modification protocols were followed or not, safety drills were performed or not.

So it gives you an idea about all those activities, then last question may be that was actual lock out used when necessary? Sometimes it may happen when you are not in a position to control the unsafe condition then you may have to adopt the concept of lock out so that you can transfer the

workers or a human factor to the safe arena. So in that particular case you may have to analyze that actual lock out protocol was used when it was required that means this things are not in the control of all the safety devices available at the arena.

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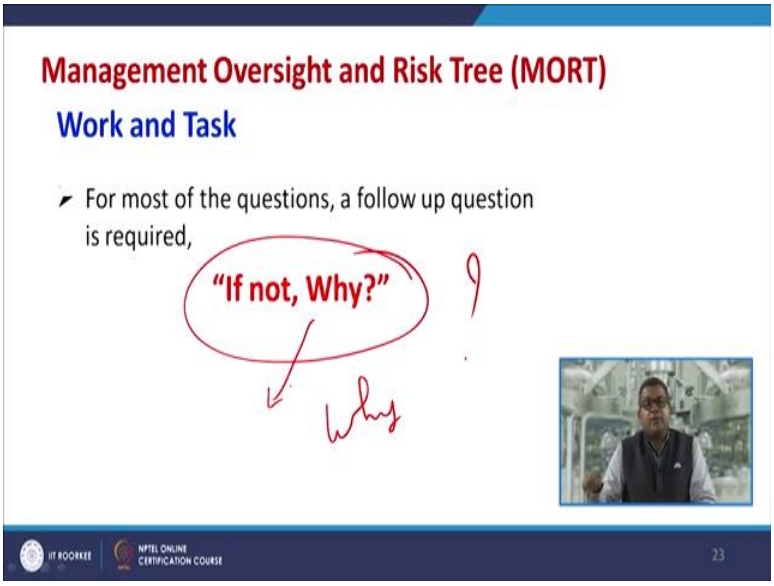

For most of the question you need to have a follow up question that is if not then why? See let us have a let us go back to the previous question, was actual safe work (protocol) procedure was used? Now if not then why? What was the reason? Because this why word is extremely important it may reflect the satisfactory answer of this why word may give you a very good information about the system procedures because if the things are not working properly then there may be certain lacuna then it gives you an idea that gentlemen you need to take a corrective measures to make your process safe like were safety devices working properly?

Now if the answer is not then why? May be because of the lack of the training may be because of certain things may be malfunctioning, may be the power supply issue may be certain other issues. So whenever you are in a position to answer this why it gives you the corrective measures.

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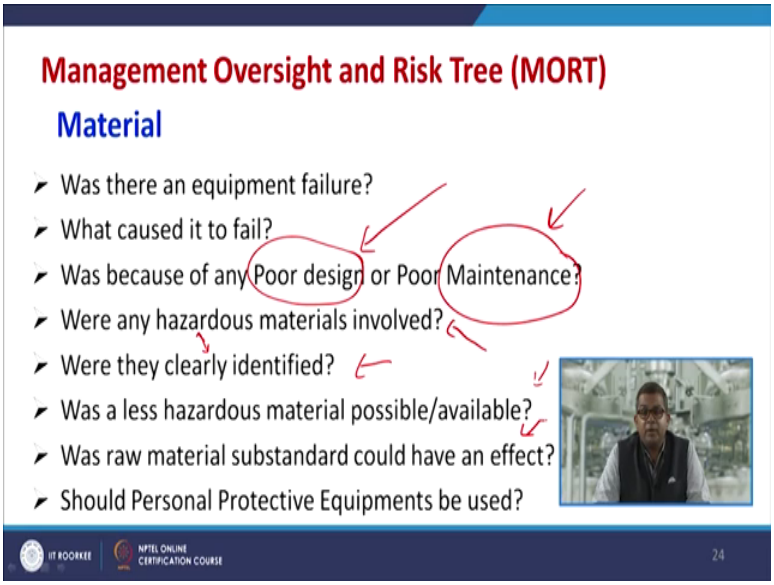

Now second aspect is the material then again you need to frame and you need to ask the question, was there an equipment failure? If yes then definitely you need to take the certain corrective measures for the future reference. Then you may ask the question, what cause it to fail? Sometimes may be the cooling water supply fail.

Sometimes may be the sensor they did not work then next question may be was because of any poor design or a poor maintenance now if the temperature sensor fails then definitely it may be covered under the head of poor maintenance. Now sometimes it may happen that you are forcefully or sometimes you are compelled for over production and your system is not designed for this kind of over production then it may be a chances of a poor design. Then next question may be were any hazardous material involved? Sometimes it may happen, the reason is sometimes the raw material may contaminated, sometimes any kind of byproducts side products it may be involved because of the certain process parameter variation.

Now next question may be were they clearly identified? So in case if it is the part and parcel of say the raw material then definitely the question may be ask that why (the) when the raw material was received then why the proper quality check was not being performed. So if they have clearly identified then you can go ahead with other options so were they clearly identified? This is again a very important question, was a less hazardous material possible or available? Now if you remember in industrial hygiene module we had discussion about the substitution, so

in case if you have any opportunity to use the less hazardous material or if it is available then try to use it.

Sometimes if you are in a position to compromise with the yield or conversion with respect to the economics etc then it is a very good option to use the less hazardous material. Now if it is they are available then why you did not use? Then the other question may be was raw materials substandard? Could have an effect?

Now if your raw material is having substandard may be sometimes certain impurities then it may create a problem. Now should personal protective equipment be used? So sometimes may be if you are working in a toxic environment or may be working in a (hazardous) other hazardous environment may be attributed to the mechanical aspect then the personal protective equipment be used.

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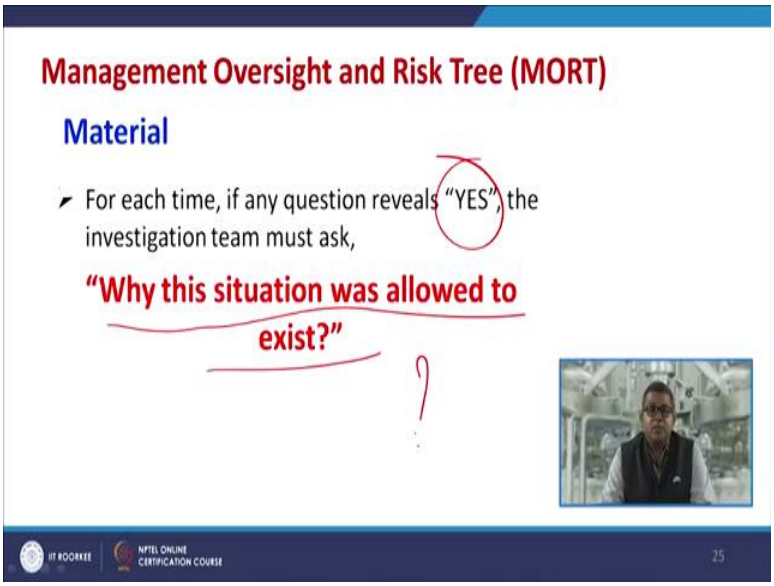

Now for each time if question reveals that yes then investigation team must ask, why this situation was allowed to exist? So once you are performing any kind of accident investigation you may frame these questions and if the answer is yes then the investigation team should ask this question why this situation was allowed to exist? Suppose if there was an equipment failure then why this situation was allowed? Or if any kind of raw material was contaminated like this then why this the system was allowed to go ahead? Because sometimes it may happen that these contamination may create the hazardous scenario so type of scenario must be addressed.

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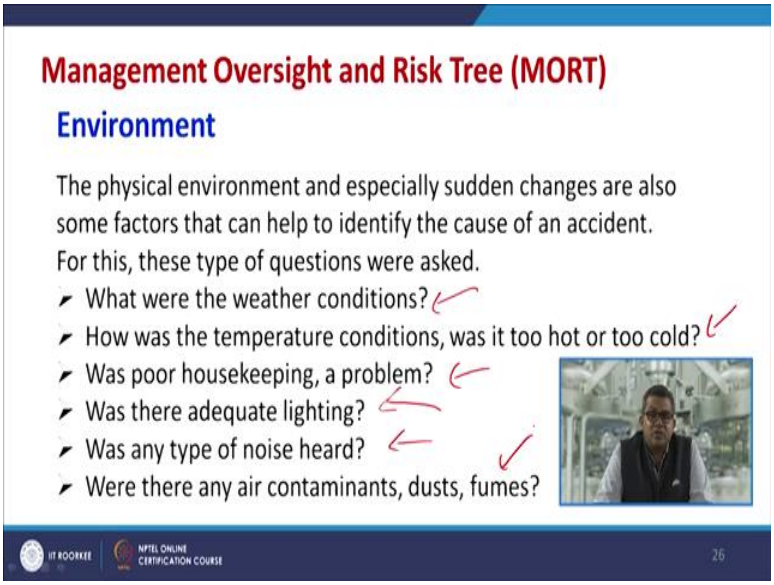

The next thing is the environment, the physical environment especially sudden changes they are also some factors that can help to identify the cause of an accident. For this type of things the sample questions may be like this that what were the weather condition? So the meteorological may provide the exact answer. How was the temperature condition? Was it too hot or too cold? Was poor housekeeping a problem?

This is again a very good question sometimes the solvent maybe drained to the sewage and without treating there maybe get discharged to the local canal or sometimes to the river so this may attributed to the poor housekeeping and the solvent may be hazardous to the environment, the solvent may create the flammability issues, the solvent may create the inhalation problem. So this was an example.

So was the poor housekeeping a problem? Was there adequate lightning? Because sometimes if lightning in the poor condition then it may create the problem within the plant, was any type of noise heard? Because sometimes rumbling sound or sometime of any whispering sound and may be a very good indication of faultiness of a process or a system. Were there any air contaminants dust, fumes etc. because it may provide a very good indication in that the system is on the wrong track.

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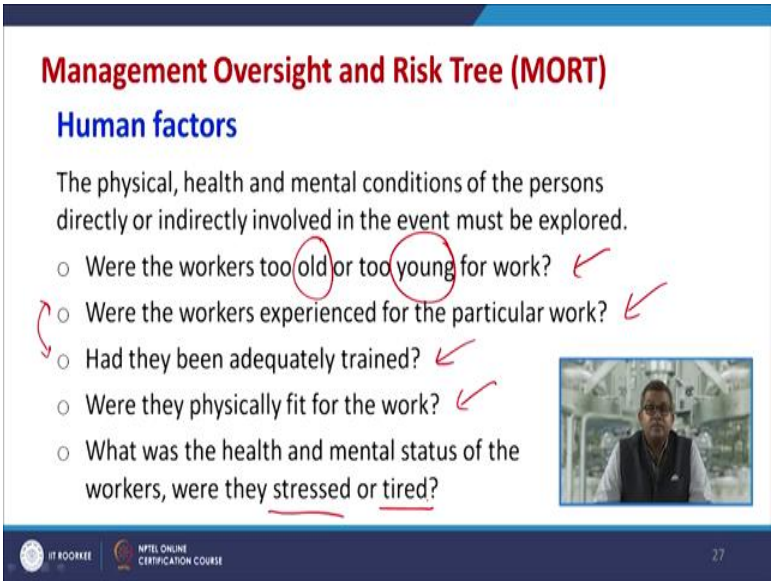

Other aspect like human factor, the physical health and mental conditions of a person directly or indirectly involved in the event must be explore, then the several questions may be asked by the investigation team that were the workers too old or too young for work? May be sometimes the workers are you can say the too old for to for that particular assign job and sometimes they are too young for that assigned job so the investigation team may ask this question. Were the workers experienced for the particular work?

That reflects the proper training of those workers if they are not tune for that particular work then again it may create a problem, had they been adequately trained? So this question is linked with the previous one and the reason is that if they are not properly trained and they are assigned to do that particular job then it may be this may lead to the problem of accident.

Were they physically fit for the work sometimes heavy loading or unloading job it may create a problem so the investigation team must assists that the workers those who are assigned for that particular job they are fit for the work or not. What was the health and mental status of the worker?

Were they stressed or tired sometimes because of the production requirement they may be assign to do the overtimes then there may be problem of stress there may be problem of tiring. So they need to assist that what was the health and a mental status of work, if they are stresses and tired

so sometimes mistakes may do happen. So these are the certain questions that should be asked by the investigating team to find out the root cause.

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Because these are the very good input for the further studies then apart from this the certain questions must be framed related to the management or organizational behavior. Now the management holds a legal responsibility of the work place and therefore the role of supervisors or higher management persons they must always be considered in an accident investigation because one thing must be remember that whenever there is a for sake of an example whenever there is a need of any kind of a training or employment of a old or young worker everywhere the management is involved because it is the management who tune the system in such a way to hire the too old or a too young person.

So it is a proper responsibility or a legal responsibility of management to look into the fact. So as far this questions are concerned the investigating team must ask were the safety rules documented and communicated? Because based on the regulatory body directives, based on the local authority issues the safety rule must be documented, followed and it should be well communicated to the all-stake holders including the workers, including the middle management level etc.

Now had the procedures been developed to address them? Because sometimes the all the workers may not have a properly educated so you need to adopt a proper procedure for proper

communication of those safety rules to them. Sometimes the play cards, sometimes the safety drills, sometimes the safety training this need to be organized for the proper communication of those safety rules to the stakeholders. Now once you communicated, you documented then you need to ask the question, were these safety rules being unforced?

Because sometimes may be because of the lackness, sometimes may be because of reluctancy we may not follow all those safety rules so there may be a chance that the accident may take place. So it is the responsibility of the management to enforce those safety rules. Now was there adequate supervision? Again this question is important because if you have documented the rules, communicated then developed and you provided the training you provided the protocol for the enforcement then there is a question that whether those things were under supervision, by a supervisor or a management?

Then this is big question. Now the last question may be like that were proper training being given to the worker? Again this is related to the previous one that all the workers must be trained because it is again essential for the good health of the organization.

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Other questions may be like that had hazards being previously identified? Again it is the responsibility of the management that they need to find out that these hazards must be previously identified. Were hazard eliminated or adequately controlled? So once you have identified then it is a responsibility of management that either you need to eliminate or you need to control them,

because sometimes it may happen that the management may not be in a position to eliminate those hazards because hazards are everywhere.

So the thing required is that they must be adequately controlled, now were work procedures available or followed? Because sometimes in any industries they are having the standard operating protocols SOPs. So the question may be ask that if you are having the SOPs then was it followed and if not may be the chance that it may be not be available with the management. So they may ask the investigator team may ask that were the work protocol available?

And if available then why it was not followed. Now were the proper maintenance and the calibration done for the equipment use because this is again a very important for the good health of any company because maintenance sometimes because of the prolong use some wear and tear may be possible and this may catastrophic.

So it is necessary that the proper maintenance protocol must be followed. Now if another foremost requirement is the calibration because sometimes the pressure, temperature, volumetric sensors may not be calibrated and it may give the faulty reading and any kind of say temperature failure or a temperature mismatch with the protocol may be catastrophic. So they may ask that question that the proper maintenance and the calibration protocol be followed, were a regular safety inspection carried out? Now this is again a very crucial because the safety section it tells you that whether the safety devices or your process is working properly or not within the regulations or within the SOPs being developed.

So it provides the corrective measures so this question may be asked that were the safety regular safety inspection be carried out or not? Now on the basis of safety inspection if anybody notice that there are certain unsafe conditions so the question may be ask, what are the all unsafe conditions be corrected or not? Now some investigators may prefer to place some of the sample questions in a various different categories so it is you can say the prerogative of those investigators however the categories are not important as long as each pertinent question is asked. Now this question must be very specific.

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Obviously (there are) there is considerable overlap between various categories now this reflects the situation in real life. So it should be emphasized that the sample question which we studied in different slides do not make up a complete check list but are some examples only. So investigators may frame their own questions as per the situation requirement.

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Now this MORT incorporates traditional safety concepts such as hazard review, lifecycle, human factor engineering and the job safety analysis and it as well it the innovative safety concepts such as a barrier analysis, the effect of change and energy transfer phenomena. So this aspect focuses

on rational assessment of management control system. Management program elements they are specified in extensive details and judge to be adequate or less than adequate.

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So once completed this MORT procedure provides an all important visibility the accident analysis process. Now it enables the investigator to review the findings present them meaningfully to others, alter the analysis as additional facts warrant and the record the total effect for later use. Now this MORT represent a major theoretical and practical contribution to safety aspect or a safety technology, so in this module we have discussed about various theories and different models and in detail we have studied about the management oversight and risk tress. In next module we will discuss about the accident investigation protocol and for your ready reference we have enlisted various references at the end of this module, thank you very much.