Control Engineering
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Module - 4
Lecture - 19
Industrial Safety

A very warm welcome to all of you in this lecture on industrial safety. In the series of lectures on industrial engineering, we have been discussing a large number of topics related to the different aspects of industrial engineering. We have covered inventory management, we have covered other topics related to sales forecasting, we have covered product design and development reliability and a large number of other topics which come under the broad umbrella of industrial engineering.

So, the topic for today is industrial safety. Safety: as we all know is a very important aspect of any particular activity. Suppose, we are playing a game, we have to play it in a very safe mode otherwise, we will get injured. If we are driving a vehicle; we have to be very safe while driving, otherwise we may encounter an accident. Similarly, if we are doing some household work; we have to keep into the account the safety aspects. But, whenever a manufacturing activity is taking place; there are always chances of certain accidents that may take place.

Therefore, we have to design the systems in such away so that even if a worker is not performing his duties according to the laid out principles in the manual, he may not encounter any accident. Because if an accident takes place, it has large number of implications; the material loss, the man hours lost, as well as the person may also suffer some injuries. So, we have to take into account all these points and we have to design the systems in such away, so that the accidents are minimal or we should say the accidents are to a closing to 0 or the number of accidents is closing to 0.

How that is possible? That is possible; if we design the system, if we educate our workers in order to follow the safety norms and practices, as well as we keep into account that whenever there is an accident, whenever there is a problem, then that problem does not escalate into a catastrophic manner or into a catastrophe. Sometimes, 1 accident leads to another accident and another accident leads to another accident those

kind of effects we have to check. How those can be check? Those things are very simple; we have to follow certain design principles, whenever we are laying out the machines, whenever we are laying out the buildings. And if we follow those principles religiously, then the accident prevention can be done.

So, in today's lecture, it is a very simple lecture, in which we will see that what precautions, what are the important guidelines that we should keep in mind, while we are laying out a plant or when we are doing a plant layout? Similarly, we have to keep in mind certain things in order to check the fire, in order to check the explosions. Then we will towards the end, see a case study in which there was a accident and what were the things those are found out which should have been done in order to avoid the accident. So, let us start the discussion that the regarding the topic on industrial safety.

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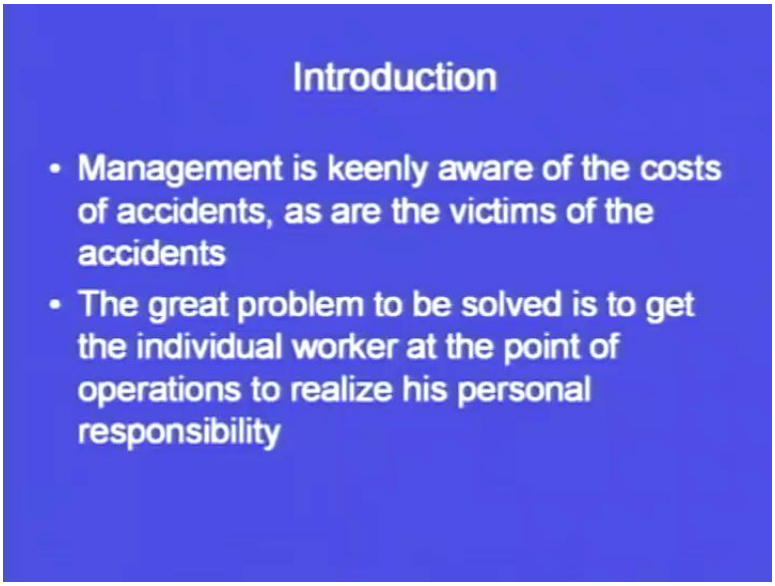

Management is keenly aware of the costs of accidents, as are the victims of the accidents. So, a person who is a victim or who has suffered some accident, he knows that what cost he has paid for go undergoing that accident. Similarly, the management is also keenly aware of the cost of accident. So, the management knows that if a accident takes place, what are the costs involved? There are direct costs involved, there are indirect costs involved.

Whenever, there is a accident the person may suffer a injury, the machine may get damaged. So, the management has to do the troubleshooting of the machine or sometimes they may have to get a new machine. Similarly, they have to bear the cost of

hospitalization of the worker. Then, there are other workers who are involved in getting that worker or transporting or putting that worker into the hospital. In those cases also, the man hour is lost the productivity is less and there are other indirect costs also, like the company may have to pay the compensation to the worker or the insurance companies may come in picture at that point.

But, all in all if we say whatever we have been discussing till now, there are costs involved in accidents which may be direct costs or the indirect costs and the management is keenly aware of these costs of accidents. And similarly, the person also knows that if he meets an accident what is going to happen. He may sometime loose a part of his body, which is completely undesirable from the company point of view, as well as from the workers point of view. So, the great problem is to be resolved and how this can be resolved? This can be resolved to get the individual worker at the point of operations, to realize his personal responsibility.

So, although we have started the discussion related to industrial safety by saying that we have to layout the system in such a way that the accidents do not happen. But, the majority of the accidents usually take place by the negligence of the workers or due to the failure of the equipment. So, the first important point is the negligence of the worker

If each and every worker knows, that according to his negligence or because of his negligence some particular accidents may take place, then if he is vigilant, he is performing the operations religiously, he is following the instructions religiously, then there are no chance, there are no chances sorry which would relied into an accident.

Although, still there are chances that the equipment may fail and some accident may take place, but that is beyond the control, but the important point is to educate the worker so that they take the personal responsibility in avoiding the accidents. The management also has to pay an important role in the design of the system

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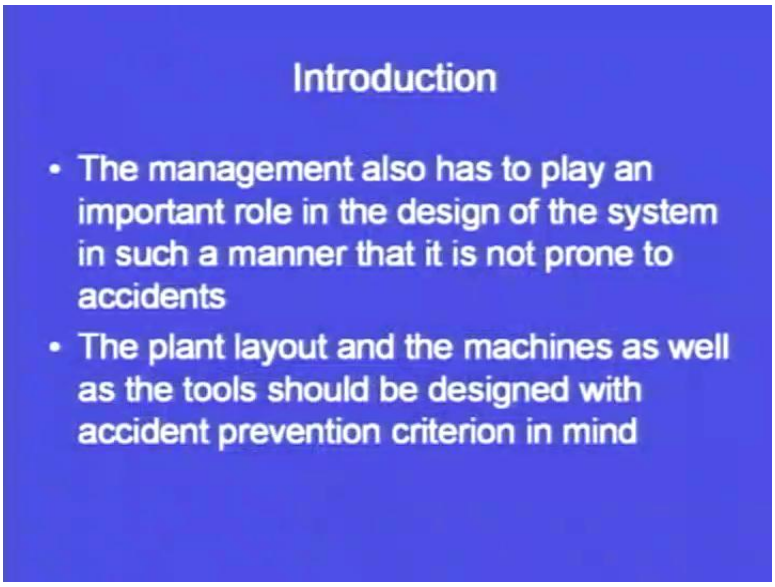

In such a manner, that it is not prone to accidents. So, the design of the system or the design of the plant or the design of the building should be such that no accidents take place. Now, which guidelines, what precautions or what rules and regulations have to be followed while laying down the building or a plant? That we will see in subsequent slides.

The plant layout and the machines, as well as the tools should be designed with accident prevention criterion in the mind. So, always we should design the tools, machines, plant layout in such a way so that the accidents do not take place. Now, subsequently in the subsequent slides, we will see that how these criterions can be incorporated into the design. These are simple things, but sometimes we do not give adequate attention to these things.

So, initially we will see that in a general layout, whenever we are putting the machines and the other paraphernalia in place. What are the precautions? What are the guidelines that we should keep in mind? So, the general principles of a plant layout. So, what are the general principles that should be kept in mind whenever we are designing a plant layout? If you remember in one of the lectures, on facility layout design, we have seen what are different types of layout? We have seen that there is a product type of layout, there is a process type of layout, and there is a fixed position type of layout. Also, there are certain cells that fall under the category of cellular manufacturing or group technology.

So, we have seen different types of layouts are there. So, the basic guidelines that we have seen there is that there should be minimum transportation of the material within the

plant because, it adds to the cost as well as, here we will see that it may result into accidents also. So, we have to minimize the transportation of materials within the plant.

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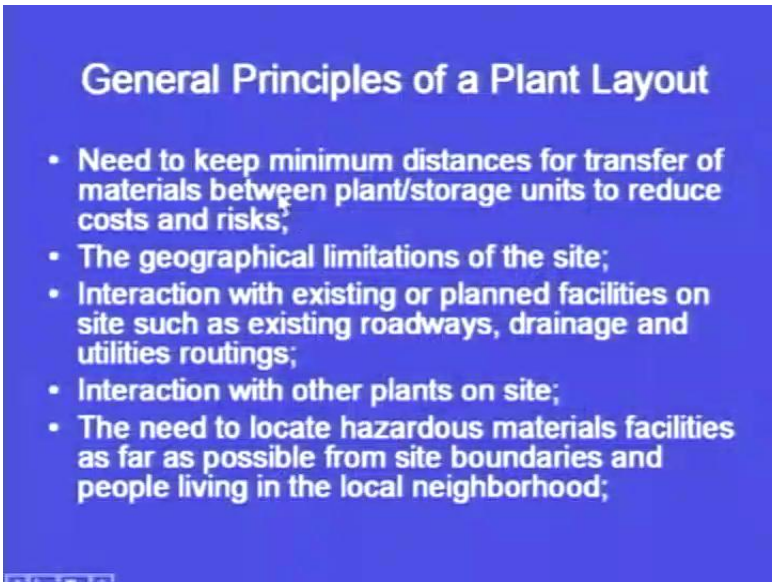

So, the very first point on your screen you can see, that need to keep minimum distances for transfer of materials between plant or storage units, to reduce the costs and risks So, first thing when we were discussing plant layout, we have seen that the transportation of material in between the storage and the shop, as well as between thus in between the shop also should be minimum why because, it involves cost.

So, cost was the main criteria there, but keeping in mind the industrial safety point of view we will say, that the risk involved is also more. So, we have to minimize the risks of accident. So, therefore, the transportation of material should be such. So, we should layout the plant in such a way so that this transportation is avoided or it is minimal. Then, the geographical limitations of the site; interaction with existing or plant facilities on site such as: existing roadways, drainage and utilities routings. So, we have to see the geographical limitations of the site as well.

So, those things should be kept in mind. So, sometimes if we are placing our industry or our plant on hills, those things we have to keep in mind that what are the types of accidents, that may take place in such a area or such an area. Then interaction with existing or plant facilities, already we have a building suppose, and we want to increase the capacity, we want to make another roof or another floor. Then, we have to see that whether the existing facilities can bear the load of that particular floor or not or what kind of machines we should put on those floor? Or the extra of roof that we are adding or extra floor that we are adding?

So, all these things have to be kept in mind; the first thing is minimization of the transportation of material, the second point is the geographical location we have to keep in mind, third point is the interaction between the existing facilities and the new facilities that we are creating, then interaction with other plants on site. So, we have to see that there are some plants already existing, we are adding some more plant or some more factory or some more particular shop we are adding. So, how it is going to interact with this particular existing facility?

Then, the need to locate hazardous materials, know hazardous materials are those: which are prone to accidents or prone to fire or prone to we can say explosion. So, the need to locate hazardous material, facilities as far as possible; from the site boundaries and people living in the local neighborhood. So, wherever hazardous kind of material has to be stored, we have to keep in mind that this should be at a distance from the existing plant or from the neighborhood where people are staying.

If, you take an example of the fire crackers that are burst during the diwali season; we will see that these days the government is taking adequate steps that all the shops which are having the fire crackers would be set up at a distance from the neighborhood or from the site or from the location where people are staying. Why this has been done? Because, there are always chances of an accident or the risk involved is very high.

So, same thing or same principle we have to follow in the factories, as well as in the industries which states, that the hazardous material should be kept, always kept at a distance from the plant as well as from the site where people are staying. Then, keeping in regularity, the principles of plant layout take talking about those principles.

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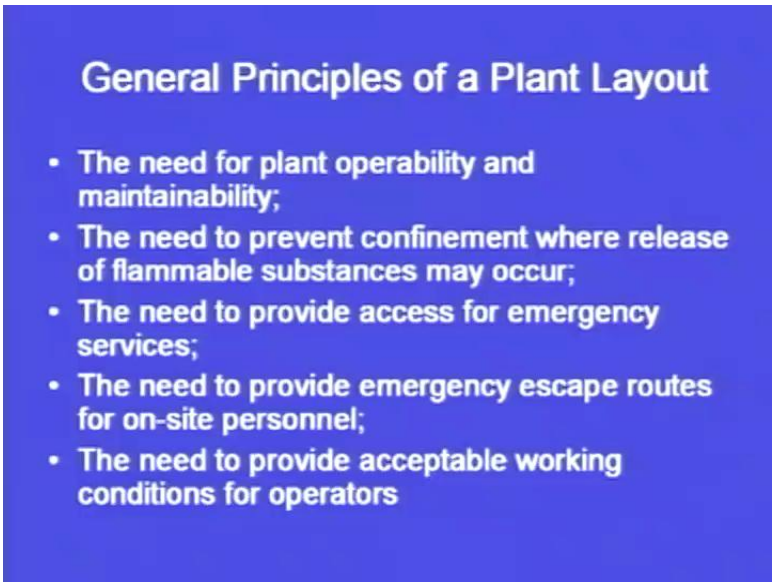

We will further go to discuss some more important principles like the need for plant operability and maintainability; we have to keep in mind this particular need that what is the operability what is the maintainability of the plant. The need to prevent confinement; where release of flammable substances may occur. So, we have to see that wherever there is a release of flammable substances the confinement should not be there. Which means: that there should be adequate ventilation, there should be adequate open space that whenever the flammable substances, they are released into the environment or there are released into the atmosphere, they should get a path to go out. If, they do not get a path to go out, there are always chances of fire as well as explosion.

So, the need to prevent confinement, where release of flammable substances, may occur.

So, wherever there are chances, we should restrict the confinement, we should make it open as open as possible. Then, the need to provide access for emergency services, so wherever we there are chances, there are risks of accidents; the plant layout should be such design that emergency services could be provided at that point. If the access is not there to the emergency services; the emergency service is or the emergency team will, not be able to reach to the accident side and will not be able to rescue the workers or the machines whatsoever may be the case.

So, that is also an important aspect that has to be born in mind. So, the access to the emergency services should always be there in the, in case of an accident or whenever we are designing a plant, whenever we are laying out the plant, we have to keep all these things in mind. Then, the need to provide emergency escape routes for onsite personal, so the people who are working on that particular site. They should have an escape route; they should have a route from in, from which they can go out.

Suppose, an important example to mention here is; that if you are flying by air; in the very beginning or at the start of the flight only you would be told, that these are the escape routes in case of an accident. So, those things help you to react in case of an emergency. So, similarly in a plant or in a building, whenever accident or whenever a problem arises or whenever there is a catastrophe that has struck the industry or the plant there should be escape routes available. First thing is we have to ensure the availability of the escape route and second thing which is not mentioned on your screen is that there should be adequate know how to the workers that yes these are the escape routes. Even on the floor also, you can mark certain linings which would help the workers to go out of the plant in case of emergency.

Sometimes, whenever there is a problem, whenever there is a fire or whenever there is an explosion, usually if the power is switched off. So, when the power is not there and if it is the night shift, there be there would be complete darkness, the workers would not be able to know which direction they should rush out. So, the facility could be provided that there is a certain fluorescent path or we can say some guidelines or some strips of fluorescent light, which would help the workers to trace out the path and go out of the plant.

So, the need to provide emergency escape routes for onsite personal is very important, whenever we are laying out a plant. Then, the need provide acceptable working conditions for operators. So, sometimes the humidity levels are very high, somewhere the heat that is generated is very high. So, the important point is that the plant layout should be such that acceptable working conditions are provided to the operators Sometimes the workers have to do some minute task and if the adequate lighting arrangement is not there, the worker may not feel comfortable and his eyes may not be lasting for too long or his eye sight may get defected or impaired.

So, important thing is that whenever the plant layout is done or the designing of the plant is done, these particular important aspects, that is the need to provide the acceptable working conditions to the operator should be addressed. Now, from safety point of view some important things that have to be born in mind, that we are going to see in subsequent slides, but the important point that we have seen till now from a general principles of a plant layout is that there are certain guidelines, there are certain principles. If we keep those principles in mind, then they always there are chances that the, number of accidents that take place in a well designed plant are minimal or we can say are very close to zero. Now, from safety point of view we have to see, we have to prevent limit.

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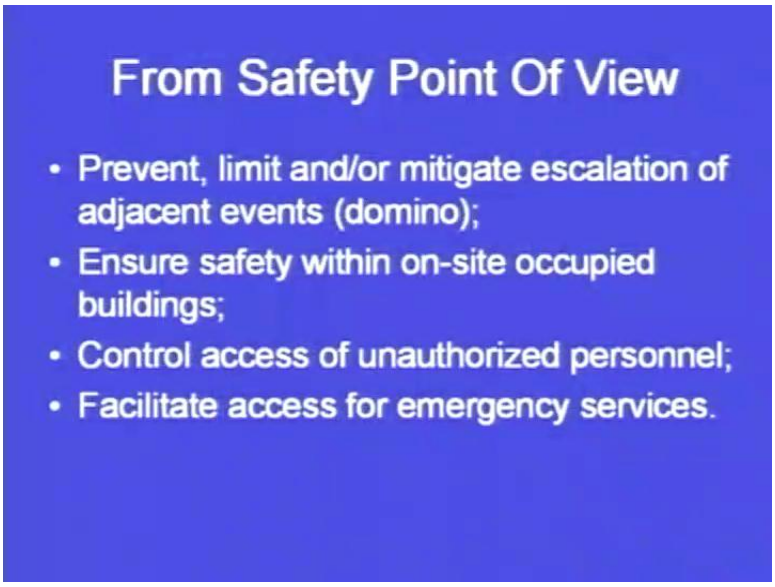

And or mitigate means, lesson escalation of adjacent events or the domino effect. So, basically this point states: that if one event happens, it should not lead into another event and another event should not lead into the third event. Suppose, let us take an example of a cycles parked in row; if we push 1 cycle the 1 first cycle will fall on the second cycle, second cycle will fall on the third cycle and similarly, the whole row of cycles would be on the ground and that kind of conditions we do not want. Because, whenever there is a accident that has taken place or fire that has taken place or explosion that has taken place; it should not spread to the other parts of the factory or other parts of the plants. So, that is the domino's effect.

So, we have to prevent or even if, it takes place we have to limit it is, we can say limit its extent; the extent to which it is going to cause the damage. So, first thing is we should prevent, it should not happen. Even if it happens we have to limit the extent to which it is going to cause the damage and the otherwise, we have to mitigate the escalation of adjacent events.

So, if 1 event takes place the other event should not take place. So, we have to put some barriers in between so that the 1 event does not lead into the other event. So, ensure safety within onsite occupied building. So, we have to provide safety within the onsite occupied building. So, occupied building means: that where people are present. So, we have to provide safety for those buildings also.

Then, control access of unauthorized personnel which is very clear, that only authorized personnel should be given entry into the plant. Then facilitate access for emergency services. So, that point we have already seen, that we have to provide the access the

emergency services. If the accident take place, we should have escape route as well as we should have a access through which the emergency service is can go in or the fire tenders can go in or the other people who are going, to take out the people from the plant they should have a adequate access.

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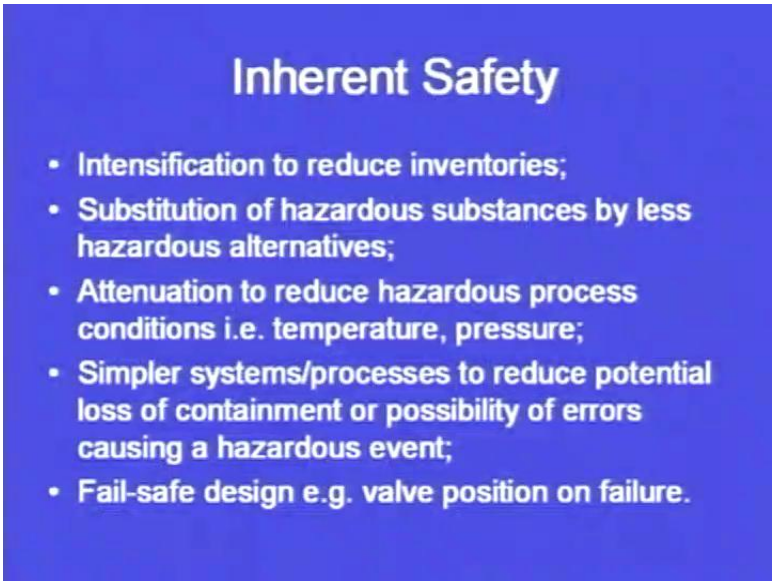

Now, let us talk about the inherent safety. Intensification to reduce inventories; so first thing is, we should only put only those materials inventory which are required. Sometimes there are certain things that are lying in the inventory, which are not at all required or which were required at some stage of time and now they are not required, but these may lead to certain kinds of accidents. So intensification means: that we have to keep a focus in order to reduce the inventories.

If you remember our lectures, on inventory management, we have seen that access inventory is never desirable. So, from safety point of view also the inventory should be less. So, intensification to reduce inventories is the first point if we want to have a inherent safety in our plant, then substitution of hazardous substances by less hazardous alternatives. So, in designing of the plant layout, we have seen that we should keep a separate space for hazardous substances.

Then, inherent safety says that if we even if we have to keep certain hazardous substances, we should keep those substances which are less hazardous as compared to the very or we can say high prone or we can say the substances which are more hazardous. Then, attenuation to reduce hazardous process conditions, temperature, pressure. So, wherever there are chances that the temperature rise is very high and it may

lead into some kind of accident. So, we have to see to it that those type of conditions do not prevail.

So first point is, material should be less, second point is less hazardous material in place of more hazardous material and third point is the conditions we have to focus, that the temperature and pressure should be maintained in such away so that the accidents do not take place. Then simpler systems processes to reduce potential loss of containment or possibility of errors causing hazardous events. So, sometimes the systems are so complex that that may lead into a hazardous event.

So, we have to design the system in such a way, that it is very simpler and it is very simple and it does not lead into any kind of accident. So, another thing is to reduce the potential loss of containment. So, containment means: that we have no escape route and we are contained in a particular area. So, simpler systems or processes to reduce potential loss of containment or possibility of errors causing a hazardous event; then fail-safe design for example: valve position on failure.

So, fail-safe design means: that even is some failure takes place, then you should have a valve or some kind of sensors to check that yes, there is bound to be a failure or there is going to be a failure in this region and we can attack the problem before it happens or we can stop the equipment, we can stop the machine in order to prevent the accident. So, just to summarize 3, 4 points are there on in inherent safety, we will carry forward this discussion in the next slide.

First thing is to reduce the inventories, second thing is hazardous substances should be replaced with less hazardous substances and then hazardous operating condition should be minimized. Temperature and pressure should be contained properly; simpler systems processes to reduce potential loss of containment or possibility of errors causing a hazardous event; so to reduce potential loss of containment. So, there may be some loss that may take place, because of containment that we have to avoid. Then the fail safe design where we have to install sensors and valves in order to prevent the accidents.

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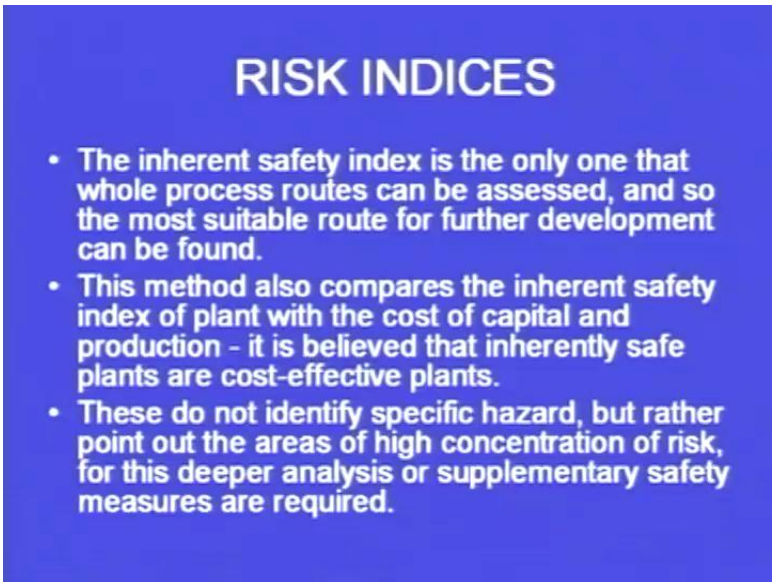

Then the inherent safety index is an in other important point that we are going to discuss

So, we have seen that there are different ways in which the accident may take place; we have to provide for a particular system, for a particular working condition in which the accidents do not take place. The operators feel safe in discharging their duties or in working in the plant, but still accidents do happen. And then we have to have a quantified technique, which would help us to check the risk that how much is the risk involved in this particular type of system or process?

So, the inherent safety index is the only 1 that whole process routes can be assessed and. so the most suitable route for further development can be found. So, always we have to minimize the risk. This method also compares the inherent safety index of a plant with the cost of capital and production. It is believed that inherently safe plants are cost effective plant or cost effective plants.

So, basically we mean to say here is, that inherent safety index of a plant with the cost of capital and production. So, always there are risks involved and we have to minimize these risk. So, if we design the plant in such a way so that the risk is minimum, the accidents are less and then we will say these are the most cost effective plants. Because, we are not incurring any direct costs of accident, we are not incurring any indirect cost of accidents and therefore, the plants are very cost effective. These do not identify specific hazard; these means: these indices or risk indices.

Risk indices do not identify specific hazard, but rather point out the areas of high concentration of risk for this deeper analysis supplementary-safety measures are required. So, basically we would be able to understand we would be able to quantify the

areas where the risk is high. Or the risk indices would help us to identify the areas where the risk is high.

So, wherever the risk is high that area is prone to accident. And wherever, the risk is less we will say "The chances of accidents are very less here". So, these indices will help us to understand that which areas we should focus in order to reduce the accidents in our plant.

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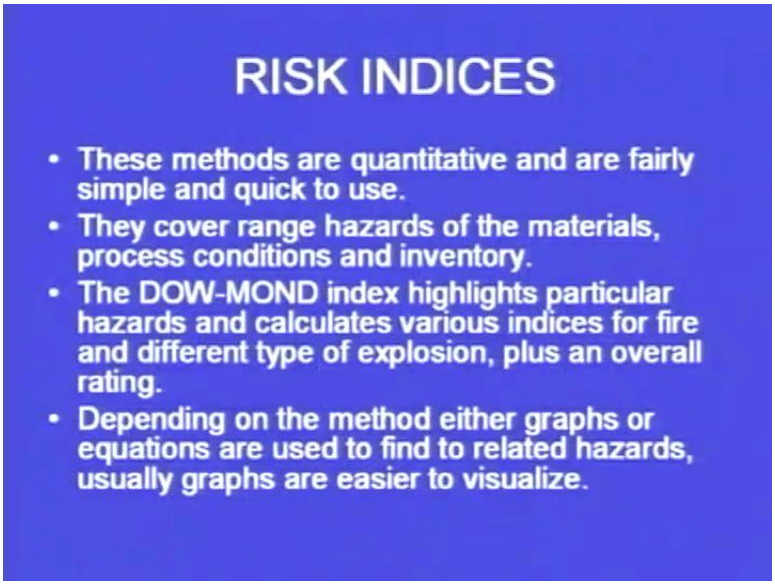

These methods are qualitative quantitative. And are fairly simple and quick to use. So, quantitative means we were some value some numerical value for these indices. And, then for different areas within a plant we will have different values for the risk indices. And we have to check that where the chances of accident are more? And where the chances of accident are less?

So, these are quantitative in nature. They cover range hazards of the material process conditions and inventory. So, we will get a range that this material is hazardous in this range. Similarly, process hazards also we will get as well as inventory we will get that this is the range in which this is going to be hazardous. So, they cover range hazards of the materials process conditions and inventory.

Now, there is one such index called the DOW-MOND index highlights particular hazards and calculates various indices for fire and different types of explosion, plus an overall rating. So, once we get the rating we know that yes this is the danger level or this is the risk level in this particular area of the plant. So, depending upon the method either graphs or equations are used to find to find to related hazards. Usually graphs are easier to visualize.

So, what has been said in these 2 slides is? That there are certain Quantitative techniques which can be used to assess the risks involved at different stages of the process or at different locations of the plant. And these indices would be helpful to us in order to understand the prevention of the accidents. So, wherever the indices give us an idea that yes this area is prone to accident we can focus as a management. On those areas that we should have adequate risk prevention or accident prevention policies and procedures to be followed in that particular area. Wherever, the chances of accidents are more. So, indices are very important. Otherwise, it would be all subjective in nature it would vary from person to person. Some person will say "Yes, that this particular machine is more prone to failure". Some person will say "It is less prone to failure".

But in order to counter that subjectivity a kind of objectivity is introduced into by into a system with the help of these risk indices. And these would help the management in taking adequate preventive measures in order to avoid the accidents. Now, Domino Effects already we have seen I have explained with an example of a cycle which all the cycles are parked in a row. If, you push 1 cycle all the cycles would fall. So, 1 cycle would push the other cycle other cycle will push the third cycle and all the cycles would be on flow if you give a slightest of push. So, that basically is the domino effect.

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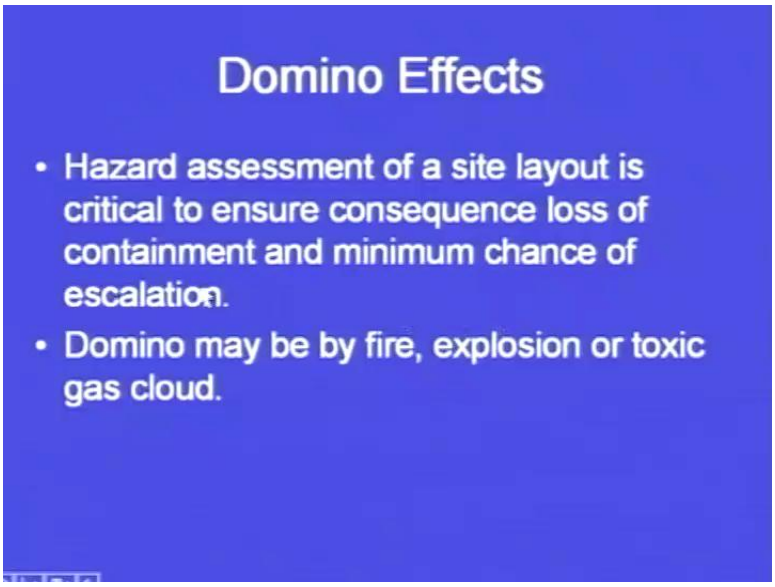

So, hazard assessment of a site layout is critical to ensure consequence loss of containment and minimum chance of escalation. So, we have to ensure that there are minimum chances of escalation. That if, 1 event has taken place it should not lead into the other event. Or there should be some valve or some control mechanism in between the happening of the 2 events and that has to be avoided. And if, that happens then the

event or the Domino's Effect would take place and it would lead into a complete catastrophe. So, hazard assessment of a site layout is critical to ensure consequence loss of containment and minimum chance of escalation. Domino may be by the fire, explosion or toxic gas cloud. So, the domino may take place, because of any reason it can be by fire, it can be by explosion or toxic gas cloud.

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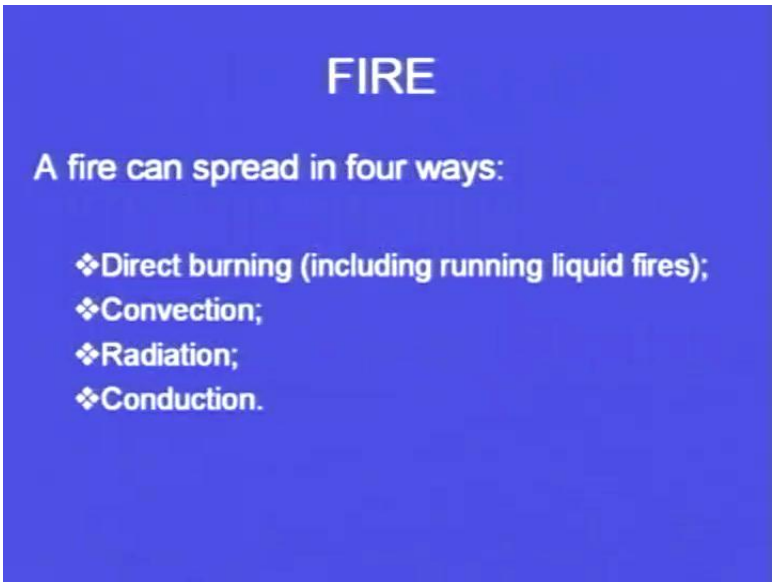

Now, we will see by 1 by 1. How these things are going to be there? And how these can be avoided? A fire can spread in 4 ways direct burning including running liquid fires; convection, radiation or conduction. The spread of fire from its origin to other parts of the premises can be prevented by vertical and horizontal compartmentation using fire-resisting walls and floors.

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So, basically compartmentation is going to help. If, we have a very large hall and suppose, 1 area of the hall catches fire. Then, the fire is bound to spread to the complete hall, but if we have different compartments and the whole hall is divided into 5 or 6 different compartments and fire takes place in one particular area, then if we have fire resistant walls as well as fire resistant roof. Then that fire would be contained in that particular compartment only.

So, it would not spread to the other compartments. So, the spread of fire from its origin to other parts of the premises can be prevented by vertical and horizontal compartmentation using fire-resisting walls and floors. So, that I have already explained. That it can be divided into different compartments and this would help us to arrest the fire that has taken place in any particular area of the plant.

Then, consideration should also be given to the spread of flammable material via drains, ducts and ventilation systems. So, if in 1 area the fire has taken place it can go to the other area through the drains or through the ducts or through the ventilation system. So, that also has to be avoided. So, that consideration should be there whenever we are designing the building or the plant.

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Delayed ignition following a release may result in spread of flames through such systems via dispersed flammable gases and vapours. So, these are the some of the Domino Affect that in 1 area the damage has taken place or the fire has taken place. How it is going to spread to the other areas? And that we have to arrest and that we have to check. So, we have to check the flammable gases and vapours from causing fire into the other areas.

Then, protection against so Domino Effects by convection, conduction and radiation can be prevented by inherent safety principles. So, we have already seen what are the inherent safety guidelines? And if, we follow those guidelines if we layout the plant in such away. Then domino because of or the Domino Effects. Because of conduction, convection and radiation cannot be can be avoided and will not be able to cause much damage.

Or the extent of the damage could be minimized. So, the other method such as Active or Passive fire protection measures may be considered. So, we will see what are these active and passive fire prevention measures? So, what are these Active and Passive fire protection measures?

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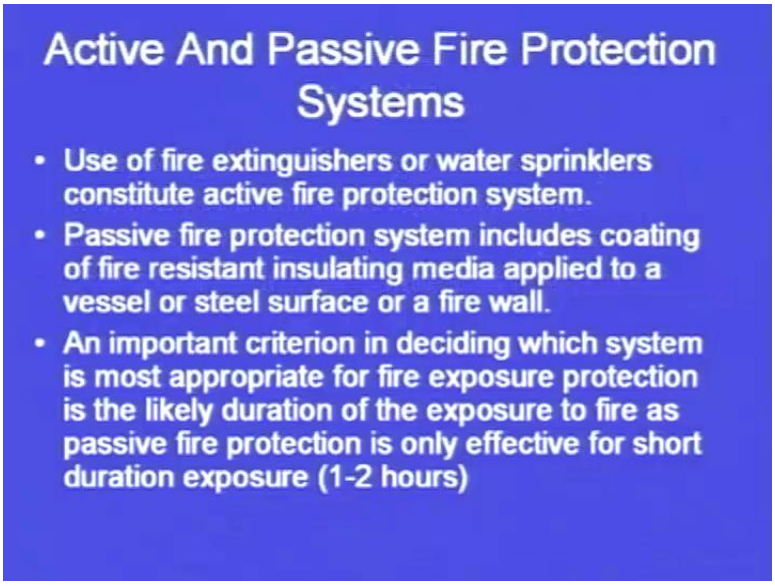

So, we have to check that the fire does not spread. So, use of fire extinguishers or water sprinklers constitute Active Fire Protection System. So, this is very clear fire extinguishers all of us have seen water sprinklers also we have seen. So, these are the Active Fire Protection System. Passive Fire Protection includes coating of fire resistant insulating media or the insulating material applied to a vessel or steel surface or a fire wall.

So, we can coat the surface or a fire wall by fire resistant material. So, that is the Passive Fire Protection System. So, the Passive fire protection system includes coating of the fire resistant insulating media applied to a vessel of steel surface or a fire wall. An important criterion in deciding which system is most appropriate for fire exposure protection is the likely duration of the exposure to fire as Passive fire protection is only effective for short duration exposure.

So, we can see that if the short duration exposure is there to the fire may be 1 to 2 hours then the Passive Fire Protection is only effective. And if, the fire is for long duration then we have to go for the Active Fire duration Prevention System or Fire Protection System. The following site factors should be considered in determining whether Active and Passive Fire Protection measures are required.

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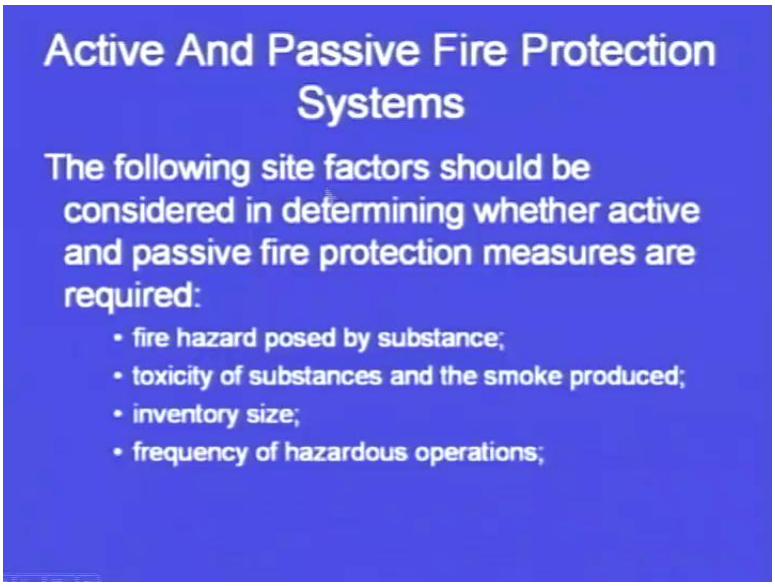

So, we have to see that certain points we have to bear in mind when we are making this decision. Then, we have to see fire hazard posed by substance that what is the hazard? What is the substance? That is burning should we go for Active or should we go for Passive. Or what are the chances of the material that we are storing? If it is, the very hazardous material, then we have to check a decision whether Active or Passive or a combination of both.

Toxicity of substances and smoke produced it is also a criteria which we have to bear in mind. While taking a decision regarding the Active or the Passive Fire Protection System. Similarly, inventory size what is the size of the inventory? If the inventory size is very big and the fire takes place. And we are not able to arrest the fire within 4 or 5 years. Then, we have to go for the Active Fire Protection Systems like, sprinklers. But if we it could be contained in half an hour 145 minute, then we may even think of Passive Fire Protection Systems.

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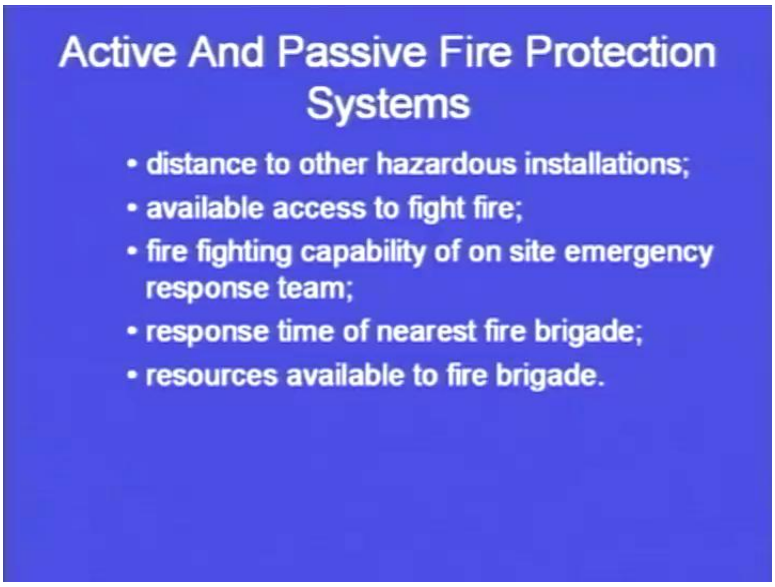

Then frequency of hazardous operation is also an important criterion which has to be born in mind. Then, we also have to see the distance to other hazardous installations; also available access to fight fire; we have to keep all these things in mind whenever, we are taking our decision regarding Active and Active and Passive Fire Protection Systems. That where whether, we have a access to fight the fire or not. Then, if we do not have access or water sprinklers cannot go and pore the water out there.

So, then we have to go for a Passive Fire Protection System. Then fire-fighting capability of onsite emergency response team; that has to be born in mind similarly, the response time for the nearest fire brigade; that also we have to take into the account as well the resources that are available with the fire brigade. So, all these things we have to keep in mind whenever we are going to fight against the fire.

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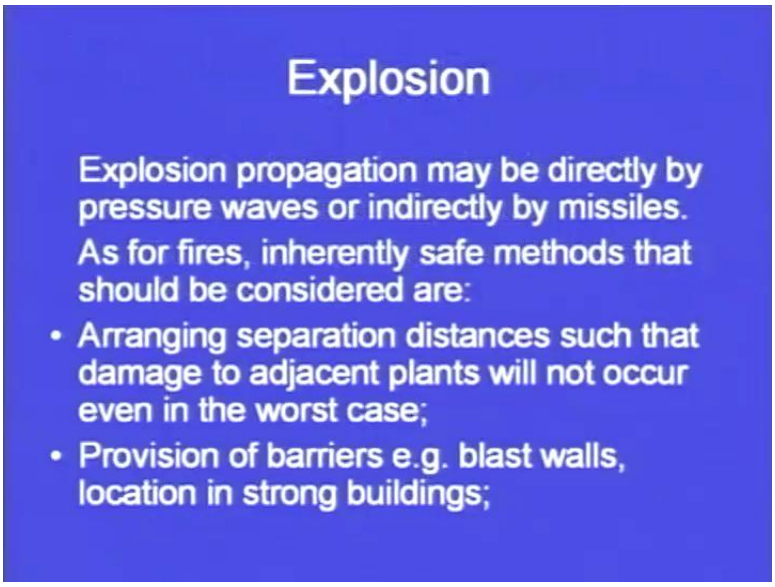

Now, coming onto Explosion. We have seen that how fire takes place? They we have to bear in mind so many numbers of guidelines which would help us to prevent fire. We have to also bear in mind that what kind of Fire Protection System we should put in place? We can have Active Fire Protection System, we can have Passive Fire Protection System. Similarly, we have to take into account certain guidelines whenever we are designing the system in order to be safe according to the explosion.

So, if explosion takes place the plant or the system should be safe. So, the explosion propagation may be directly by pressure waves or indirectly by missiles. So, we have to see that how the explosion is going to take place? Or how the explosion may take place? And what principles or guidelines we should bear in mind whenever we are designing a plant or a building which is safe to explosion.

So,, then as for fires as we have already seen inherently safe methods that should be considered are: we have seen that there are some inherently safe methods that help us to prevent the fire. Similarly, for explosion also we have to see what are these methods? So, arranging separation distances such that damage to adjacent plants will not occur even in the worst case. So, that is the same kind of inherent safe mode or inherent safety method that we have considered for fire.

So, there we have seen that the fire may spread to the other portion or to the other side through radiation, conduction, convection. So, we have to check that that thing does not happen in case of an explosion also. So, those things have to be arrested provision of barriers for example, blast walls, location of strong buildings; So, we have to provide

blast walls or which the walls which would prevent the explosion to transfer from 1 part of the building to the other part of the building as well as location in strong buildings.

So, we have to provide adequate safety measures or adequate valves or sensors or accident control devices which would not allow the explosion to cause explosion to cause extensive damage. Protecting plant against damage for example: provision of thicker walls on vessels. So, that is another important point of avoiding the damage due to explosion.

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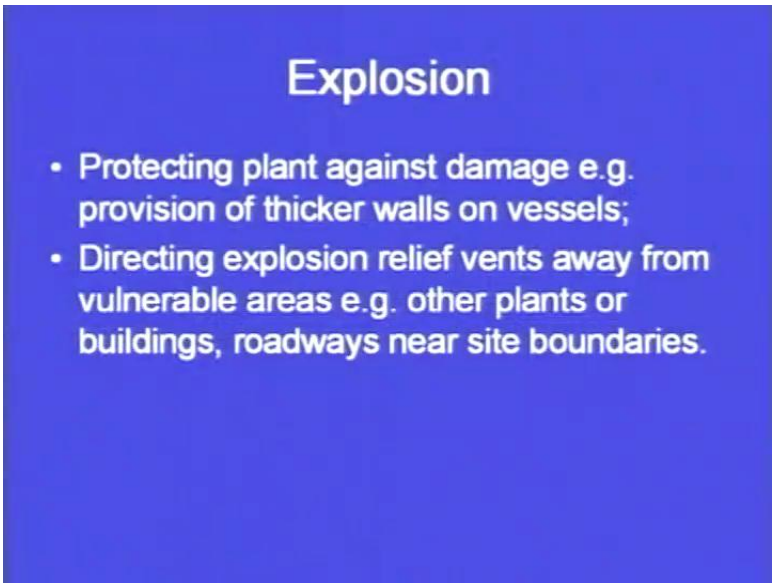

Direct explosion relief vents away from the vulnerable areas for example: other plants or buildings, roadways near site boundaries. So, we have to provide explosion relief vents. So, these vents would help to avoid the damage that may be caused due to explosion. Now, another kind of hazard or another kind of accidents that may take place are due to toxic gas releases. So, toxic gas releases may cause Domino Effects by rendering adjacent plants in operable and injuring operators.

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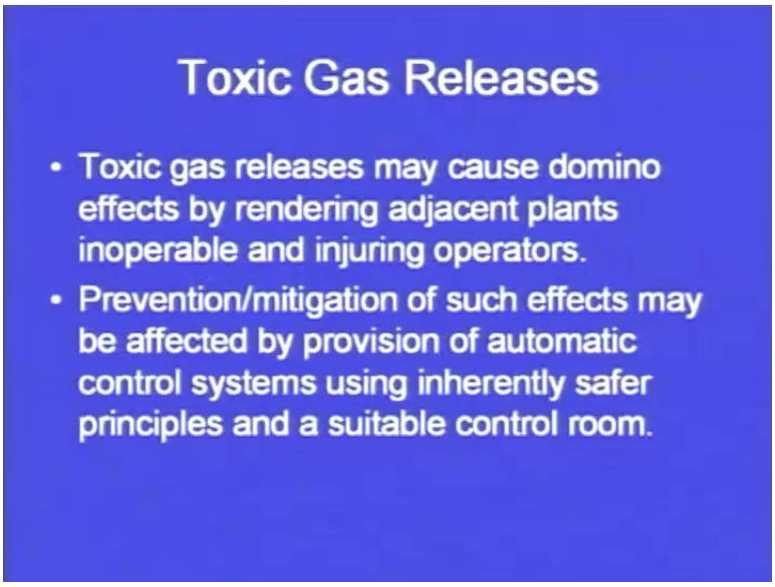

So, basically if there is a gas release or there is a toxic gas release that has happened that is going to cause the effect on the adjacent buildings adjacent plants adjacent site as well as the operators were working in the vicinity may also get affected. So, that kind of Domino Effect has to be arrested preventing, mitigating of such effects may be affected by provision of automatic control systems using inherently safer principles and a suitable control room.

So, basically we have 2 arrest these kind of damages or these kind of hazards that may take place. So, how these are happening? These are happening because, of the release of the gases. So, how we can check? We can have a control mechanism we can have a sensor in place, which could sense that yes some leakage has taken place and it would automatically generate an alarm and that alarm would make the personnel aware that yes some kind of gas release or toxic gas release has taken place and it should be plugged in.

So, if they are able to plug in the defect or the leak at the shortest possible duration then the control mechanism is very effective. And the damage would be minimal or the damage would be prevented, reduction of consequences of event on and off site.

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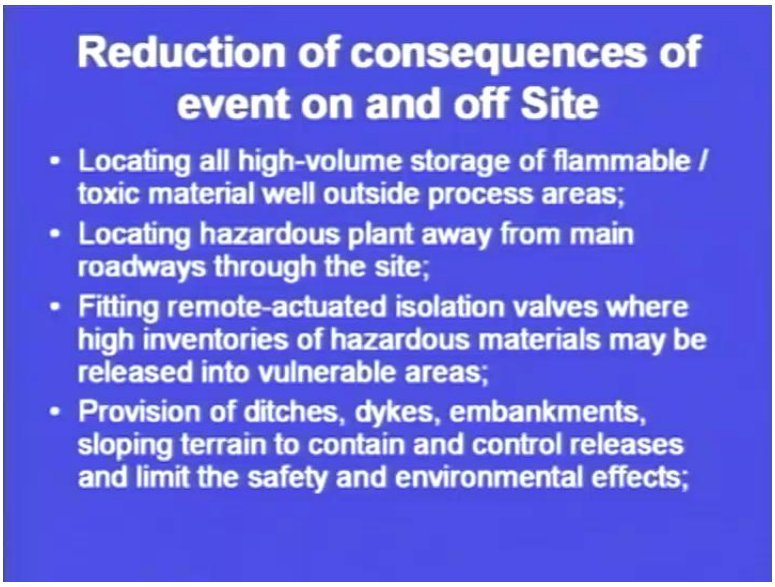

So, location or locating all high-volume storage of flammable toxic materials well outside process areas; So, first thing is regarding the storage that high-volume storage of flammable toxic materials well outside the process areas which is very clear. Locating hazardous plant away from the main roadways through the site; this is, also very clear. That hazardous plant should be at a distance.

Fitting remote actuated isolation valves where high inventories of hazardous materials may be released into vulnerable areas. So, this is kind of a control mechanism in order to avoid the accidents because, of storage or high-volume storage of hazardous materials. Then provision of ditches, dykes, embankments, sloping terrain to contain and control releases and limit the safety and environmental effects.

So, we can have ditches or embankments which would provide the, which would prevent the release of the gases or the release of the liquid from 1 side to the other side and the damage can be minimized. So, reduction of consequences of event. So, basically an event has taken place and we are going to reduce the consequences of that event On site as well as Off site. So, again carrying forward the discussion related to reduction of consequences of event on and off site, sitting of plants within buildings as secondary containment.

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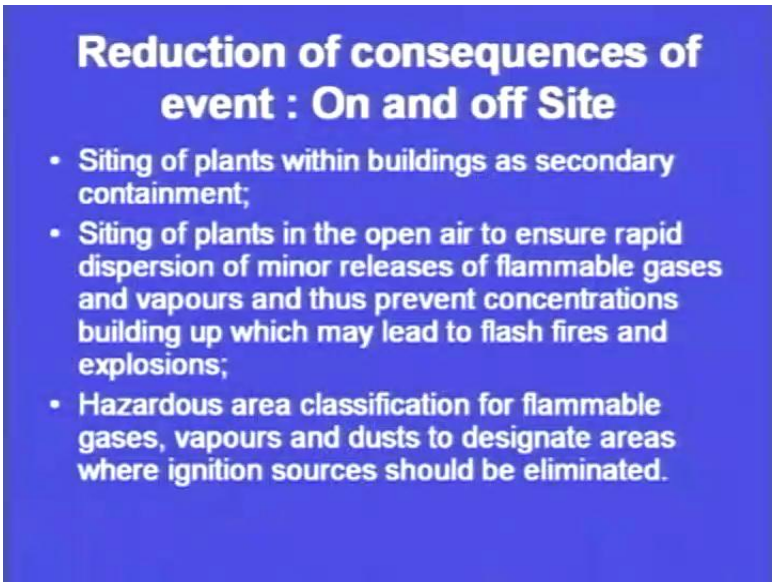

So, the siting of plants within buildings as secondary containment. So, the buildings would act as secondary containment Primary containment is the plant, secondary containment is the building. So, siting of plants within buildings as secondary containment. Siting of plants in the open air to ensure rapid dispersion of minor releases of flammable gases and vapours and thus prevent concentrations building up which may lead to flash fires and explosion.

So, sometimes the plant should be placed or those, so should be sited in such a place where there is a provision of open air. So, even if there are slight releases of toxic gases or flammable substances inside the plant it goes out to the atmosphere. But if that if that kind of scenario is not there. Open air is not available or the vents to the open air is not available then what is going to happen?

This is going to build up the flammable substance or a toxic substance is going to build up in the atmosphere within the plant and in some case it may cause a flash fire. And that may call lead to an accident or sometimes it may even take the proportion of an explosion which has to be avoided at all costs. So, we have to provide the provision for open airs Hazardous area classification for flammable gases, vapours and dusts to designate areas where ignition sources should be eliminated.

So, wherever we have some hazardous material or gases or vapours are there. There we have to avoid the use of ignition sources. So, fire has to be avoided there Lighting of match stick has to be avoided there. So, to designate areas where ignition sources should be eliminated there should be no ignition source. If you take, an example if we go to a

petroleum pump we are always advised not to light the cigarette there we are advised not to light the match stick there. Why because the area is such that it may lead to a fire.

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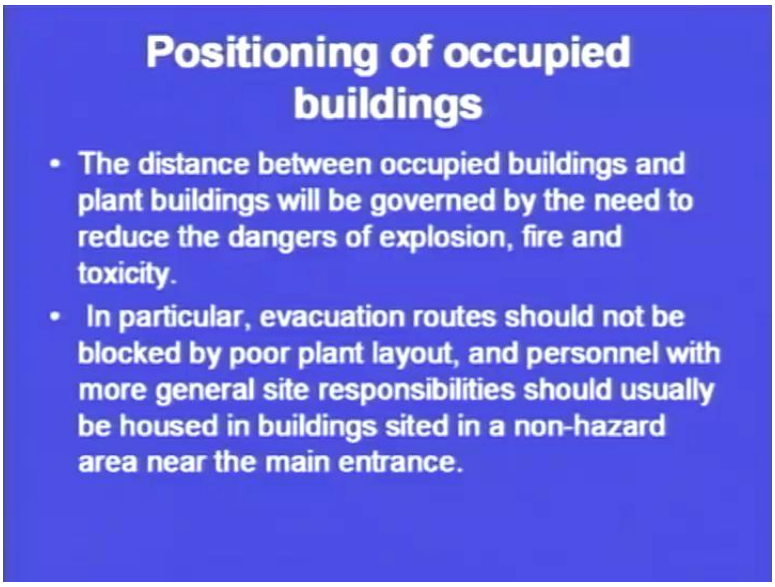

Now, positioning of occupied buildings, so whenever we are considering industrial safety where should we position the buildings? The distance between the occupied buildings and the plant buildings will be governed by the need to reduce the dangers of explosion, fire and toxicity. We have seen that the hazards are there because of explosion or fire or toxicity. So, the distance between the occupied building and the plant this is going to be dictated by the risk involved in these explosion fire and toxicity.

In particular, evacuation route should not be blocked by poor plant layout. This if, you remember we started today's lecture with the plant layout considerations that how the plant should be laid out in order to minimize the accident? So, evacuation route should not be blocked by a poor plant layout and personnel with more general site responsibilities should usually be the housed in buildings sited in non-hazard area around the main entrance.

So, person who have general site responsibilities those should be located just near the main entrance. So, in particular evacuation route should not be blocked by poor point layout; first point very clear to everybody and personnel with more general site responsibility. So, the officials of the company should usually be house and buildings sited in a non-hazard area near the main entrance. So, the people who are very higher up in the hierarchy or who are having the general responsibility of running the plant should be located the non-hazard area near to the main entrance, which is quite debatable.

Positioning of occupied buildings consideration should be given to sitting of occupied buildings outside the main fence, which is very clear.

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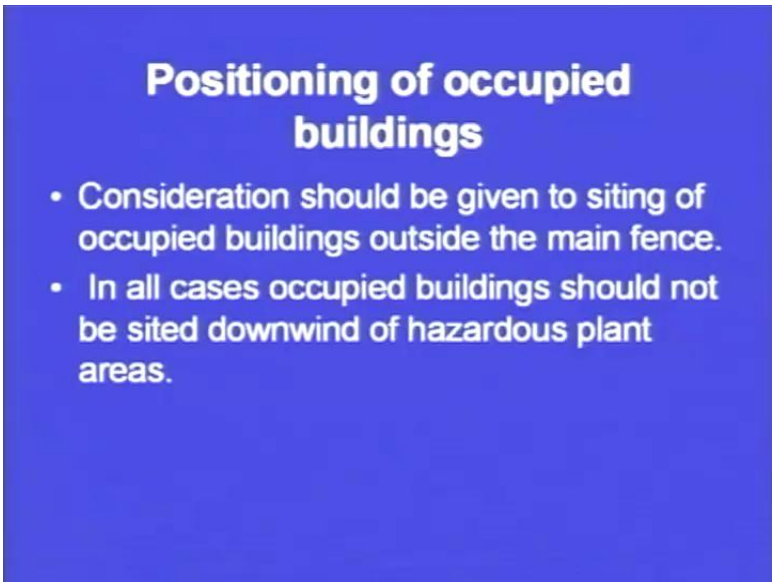

In all cases occupied buildings should not be sited downwind of hazardous plant area. So, downwind means again we have to see here that the Domino Effect may take place the fire is there in the plant, but with the wind the fire may be transferred to the housing area or the occupied buildings that has to be avoided. So, that is an important consideration that has to be born in mind.

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Now, Aggregation trapping of flammable vapours: Building design should be such that all parts of the building should be properly ventilated either forced or naturally. So, either we should we provide forced ventilation or it could be a natural ventilation, but

ventilation should always be there. Otherwise, the trapping of flammable vapours may lead to flash fires at the at any particular movement of time.

So, again to give a slight summary of what we have covered building design should be such that all parts of the buildings should be properly ventilated either forced or naturally which is very important point. Then, flammable storages should be sited in the open air. So, that the minor leaks are thermal out breathing can be dissipated by natural ventilation. We that sometime thermal out breathing takes place, some of the machines while they are in operation we will release out some heat to the atmosphere.

So, we have to provide for dissipation of that thermal breathing or thermal out. Out breathing, then flammable storages should be sited in the open air. So, wherever there are some flammable substances those should be always located in open air or there should be proper ventilation. So that even minor leakage of gases or vapour is taking place that should not add up or build up, which may lead further to the flash fire.

So, these 2 are the very important point that we have summarized twice in order to keep in mind which or which may lead into a very big accident or accident of a very large extent. Segregation of incompatible substances the following issues may contribute towards the major accident or hazard: Failure to understand the properties of substances handled.

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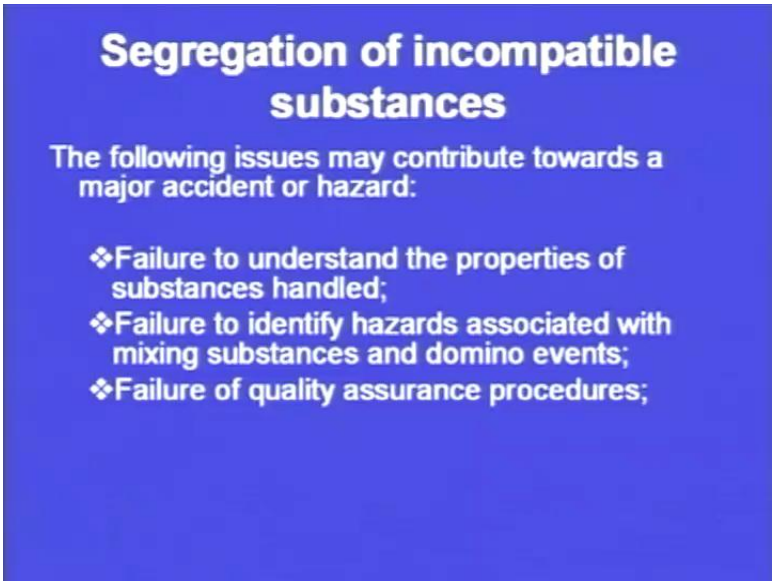

So, sometimes we are handling some substances there are some substances which are being used in the industry, but we do not know how to handle them? Although precautions are there although some guidelines are there, but a new personnel joined a

company he is not able to understand that how to handle this particular substance? And because of, wrong handling of the substance sometimes accidents may take place.

Failure to identify hazards associated with mixing substances and domino effects. Sometimes, we are not knowing that within a plant if we mixed a particular substance a with a substance b what is going other be the reaction or whether this reaction is going to lead into explosion. So, that kind of know how should always be available with all the workers who are working with those substances.

Similarly, failure of quality assurance procedures. So, we are getting some substance, but we are not ensuring the quality of that substance. So, if we are not ensuring the quality sometimes it may be of poor quality and may result into or may get or may catch fire or may result into an explosion. Or may release some vapours which may lead into a complete failure or which may lead into a toxic gas release and may cause big hazard or may cause an accident also.

So, segregation of incompatible substance is also very important. So, this addresses to the needs of inventory management where we have to manage the materials and substances in such away so that they may now lead into the accident. So, the failure to understand the properties of substances handled? Failure to identify the hazards associated with mixing substances and the domino if event thereafter? And failure of quality assurance procedures may sometimes lead into the accidents.

So, we have seen that what the various types of causes of accidents are: cause accidents may be fire, accident may be by explosion, accident may be by toxic gas releases. We have sent that there are some inherent safety principle, inherent safety methods that should always be born in mind whenever, we are designing the plant layout. We have also seen that what are the guidelines which have to be kept in mind? When, we are laying out a plant.

Similarly, for the buildings also we have seen we have summarized also for the buildings the proper ventilation should be there as well as there should not be build up of vapours or flammable gases which may result into flash fire. So, I think today's lecture would definitely give you an overview of the hazards that are associated while running a plant and the kind of principles that as an engineer we should bear in mind in order to avoid these accidents.

Thank you.