Principles and Practices of Process Equipment and Plant Design
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Module - 05
Lecture - 60
Engineered Safety

Wishing you all a good day, and welcome to the course back again and we are going to talk about Engineered Safety in today's class.

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Safety is a one aspect of design which has got an implicit mandate and it is of course, an essential component that has to be incorporated in the process of design. The plant has to be safe; it has to be safe to construct, it has to be safe to operate, it should be safe to maintain and certainly we would not like, but still we have to be design it is in such a fashion that it safe to dismantle it at the end of its life.

Perhaps I will give you an example. See the caustic chlorine plant in a of the earlier days had the mercury cell and a mercury cell after its end of life use to leave traces of mercury all around. And there has to be some specific way or procedure so, that it can be disposed of in a safe fashion. Similarly, the construction, operation and maintenance all three have to be sufficiently safe and this has to be incorporated and thought of in the design stage itself.

Often we hear two terms; inherently safe and wherever we say inherently safe which is basically an utopia. It really means that well there is absolutely no compromise on safety which can never happen, there will always be a risk to safety or a risk of hazard however small it can be.

There is another term which is often heard in industry particularly the electrical engineers all the time say that; that say that it is an intrinsically safe instrument or a piece of equipment. What they really mean is it has got a limited threat to safety which is small, but it is still there. So, we should never confuse between inherently safe what we mean by that and intrinsically safe what it is.

When we talk about safety we relate it to safety of personnel, safety of plant and equipment and environment. It is not that the owner is benevolent and that is why he invest in making this plant safer. It involves cost naturally the cost aspects are the capital investment and the operating cost which goes up with the design making provisions for making the plant safer.

But, the effort in this saves some money in terms of insurance and particularly in case of large plants it is a substantial amount and it is a recurring amount and it in general adds to the goodwill and acceptance. And it certainly adds to the share market value of the company particularly in case of large institutions.

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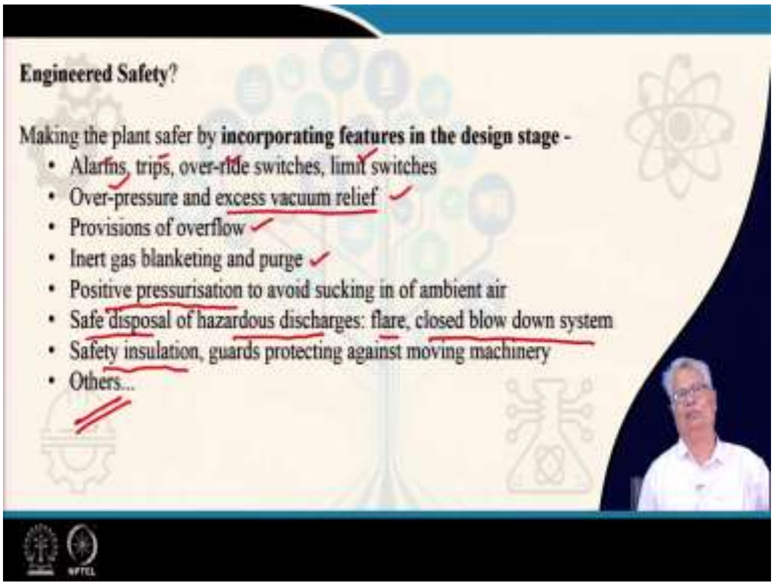

Now, the question comes what exactly is meant by Engineered Safety. So, when I say engineered safety what I really mean is making the plant safer by incorporating certain features in the design stage and implementing it while it is being constructed.

These features could be as we have already discussed in instrumentation alarms, trips, over-ride switches, limit switches certainly. We have talked about the over pressure and excess vacuum relief; we have not talked about excess vacuum relief, but we have certainly talked about a over pressure when we discussed pressure vessels and piping.

A very common thing is to ensure that you have a provision of safe overflow outlet. So, that is also one of the ways of improving the safety in a plant. We have provisions of inert gas blanketing and purge particularly when you have either some toxic material or an inflammable material or something which can lead to an explosive mixture.

We often use positive pressurization this is something very common with electrical installations to avoid sucking in of ambient air. Typically you have the switches where there is a chance of a explosion if the ambient air containing hydrocarbon enters it. So, they are kept pressurized with air so that the outside hydrocarbon vapour cannot come in.

You have in the design stage itself arrangements for safe disposal of hazardous discharges to either flare or closed blow down systems. You also have safety insulations. Normally if any surface temperature exceeds around 60-65 degree centigrade you are supposed to provide an insulation primarily to guard against any scalds and burn that can happen to the operating personnel.

You do not save much in terms of the heat loss but this is essential to protect your people. You have to provide guards to protect against the moving machinery parts and there are several others and in fact, the list can go on and on. But, remember all of these add to the safety, but in most of the cases with some amount of cost right at the design stage, but it can save a lot later on.

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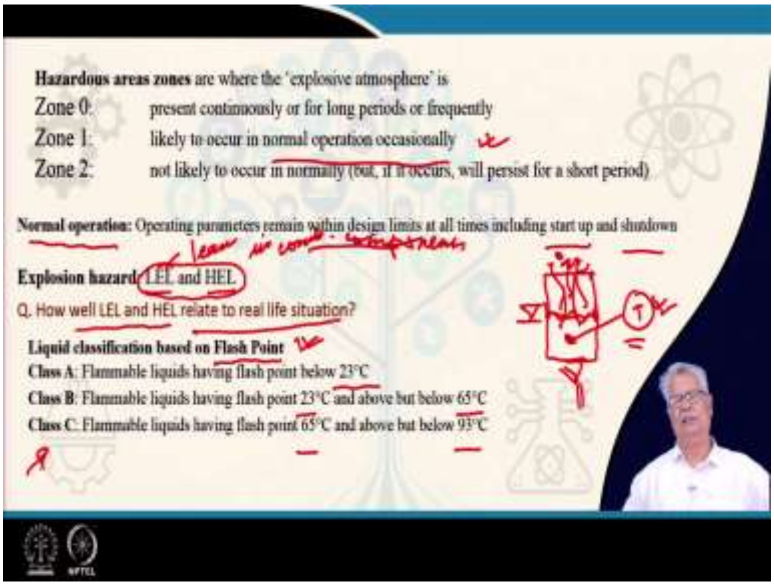

Normally, in case of a hazardous plant there are three zones; the first is zone 1 where the hazard may be present continuously or for long periods or frequently. Typical for this could be if you find; if you are going for a LPG cylinder plant the filling area you have always some amount of vapour of LPG mixed with air particularly whenever the filling operation takes place. And there is a frequent discharge of LPG as the filling carousel is fitted.

In zone 1, the threat is likely to occur in normal operation, but occasionally. An example of this could be in a plant you may have to change over your pumps or you may have to change over your pump which is servicing which is serving or pumping a hydrocarbon and hand it over to maintenance.

For that you got to drain the casing, well it is a normal operation which needs to be done possibly maybe once in a month. But it is a regular thing and it provides some amount of additional threat to the safety. So, these are the areas which are zone 1.

In zone 2 which normally is around zone 1 what you find is where such threat is not expected to normally occur. And even if it occurs it will persist for a short period only. Depending may be on the winds direction there could be a blast with some amount of hydrocarbon coming in provided there is some sort of bleeding of hydrocarbon which is taking place upstream, but it is not definitely not a normal affair.

Now, when we talk about normal operation we always have been stressing on normal operation there has to be a definition for this. We really mean is that a operating parameters during normal operation remain within the design limits always including the period of startup and shutdown. Because quite often in periods of startup and shutdown one may have to go for either draining, bleeding or which type of operation which is not very common.

Now, what to protect against? You have to protect against fire hazards and explosion hazards. The moment you say talk about it two things will come into your mind one is lower explosive limit and the higher explosive limit. Higher explosive limit is also called upper explosive limit in some cases.

What it really means is there if you have a mixture of inflammable gas or vapour with air; now its and you have a source of ignition, in that case if the mixture is too lean in your combustible material. It is basically lean in combustible component; that means, you have mostly air hardly anything which burns in that case it may not catch fire or there may not be an explosion.

The same thing is true if you have hardly any air mixed with the combustible material the explosion may not happen. So, basically your hazard lies between the two levels of concentration and since we normally talk about mixture with air these are percentage volume levels.

Now, the question is this is tested in standard laboratory conditions or using certain small instruments which give the result of these. Now, the question comes here is how well the LEL and HEL relate to the real life situation. In real life it will be giving you only an indication.

For example the standard of hydrocarbon free in a refinery zone in a refinery is when your concentration of hydrocarbon there is below 5 percent of the lower explosive limit. And not only that the hydrocarbon calibration of the instrument which measures it is typically a gas meter and it is calibrated with respect to methane. But, in reality the gas need not be only methane and in most of the cases it will be mixture of other hydrocarbons as well.

So, what I would like to say is, the indication of the LEL and HEL is going to give you a qualitative comparison only just because you find that your concentration is below LEL and it will not have any explosion chance it is not correct to decide that. But, you can always say if I have two situations in which I am below the LEL and I am much above the LEL, whenever I am much above the LEL that my chance of explosion is more compared to the other situation.

So, what I would like to emphasize here is; LEL and HEL are just indicative relative terms of the threat and it is not an absolute range within which the real life situation can lead to an explosion. It is also possible that there has been a spark your concentration has been between LEL and HEL, but the explosion did not happen. Yes.

So, I would like to see again an emphasize I am emphasizing this over a very specific reason that these are generated data in the laboratory, but should not be translated to the real life situation. The real life situation should definitely derive guidance from these values, but should be led by the wisdom of the person who is dealing with it.

There is another test which is called a flash point. The flash point is a temperature; the experiment is a very simple one. What you will have is a flash point apparatus which will have up to a particular level the liquid will be there and you will have a temperature measurement here. And periodically as the temperature rises it is going to give out vapour and it is going to come out.

In this standard apparatus there will be a 2 millimeter flame which will be introduced periodically. Initially when your temperature is low the rate of vapour generation is small. So, there will not be any flash which will be visible. The first time you see a flash you will be noting this temperature and you will be calling it the flash point.

And based on this the flammable liquids are classified as class A, class B and class C. If the flash point is below 23 degree centigrade; that means, it is even at a low temperature it generates sufficient vapour in this particular specific apparatus, in that case you will say that it belongs to class A; that means, it is a very volatile inflammable liquid. If it is between 23 and 65 it belongs to class B which is less inflammable. And in case of class C it is between 65 and 93 it is even less inflammable.

Now, the point is again there is a situation when I have a class C liquid like furnace oil and I have a source where the flame size is 2 millimeters again in a real life situation, but it remains for a long time and it has accumulated or generated sufficient vapour over a longer period.

In that case it can still have or it can still catch fire and that does not mean that it does not belong to the class C. What I would like to say is again the classification A, B and C tells you about the relative hazard that can lie or that can be posed by these particular liquids.

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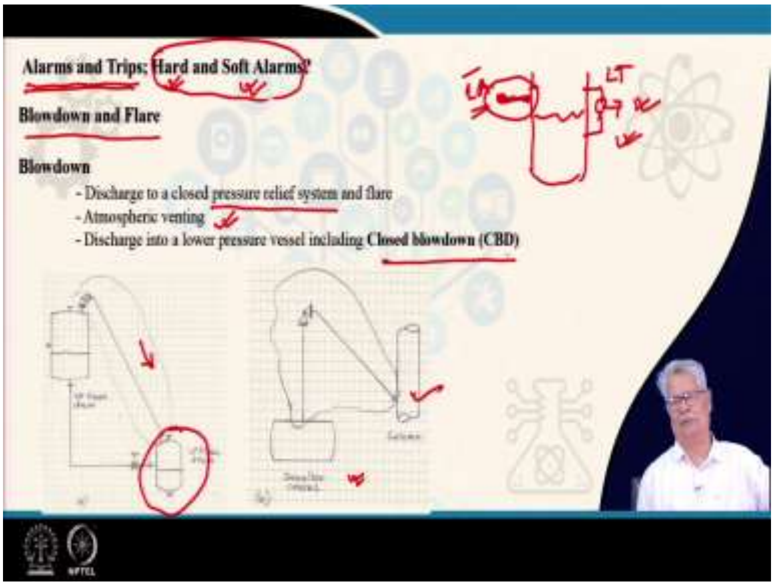

We talked about alleviating the hazards by alarms and trips. I would last; this we have covered when we were talking about the instrumentation. I just add here today there are hard alarms and soft alarms. Hard alarms are those for which you have dedicated sensors.

For example, normally what you have is a column bottom, you have a level transmitter which is sending out the signal of the level itself if you have a separate level sensor which is basically level alarm sensor in that case you will be calling it a hard alarm. If it is based on this level transmitter reading which is used for the normal instruments and normal reading and normal operation you are enunciating an alarm it is called a soft alarm.

Now, naturally hard alarm, if you have to implement you have to pay more. That means, you have to invest more the cost is higher because of the dedicated sensor that you are going to incorporate. So, it will be used whenever you feel that that particular alarm is very important.

You can have different levels of alarms like high alarm, low alarm, high-high alarm at the next higher level of the upper limit and low-low alarm below the lower limit as we have already discussed in the instrumentation class.

We talked about or we mentioned about the blow down and flare. The blow down means normally it discharge to a closed pressure from a closed pressure relief system. That means, the discharge will go to some place where you have an enclosure at a lower pressure.

An example of this in a refinery, the crude disalter vessel has got a safety which discharges to the flash zone of your main distillation column. You can have a high pressure flash drum safety discharging to a low pressure flash in that second stage; low pressure drum.

So, these are the examples of discharges to a second lower pressure closed system. It is also possible for you to have blow down to the atmosphere which is venting. Sometimes, in refineries or in other hydrocarbon processes. Where just allowing or draining or letting out the process fluid into the open may pose a hazard particularly inflammable material, you discharge the material to closed drums which are mostly underground.

These are called closed blow down drums and typically they are supposed to be emptied every day and a minimum of 20 minutes of hold up is used in sizing of this drums; sometimes more even.

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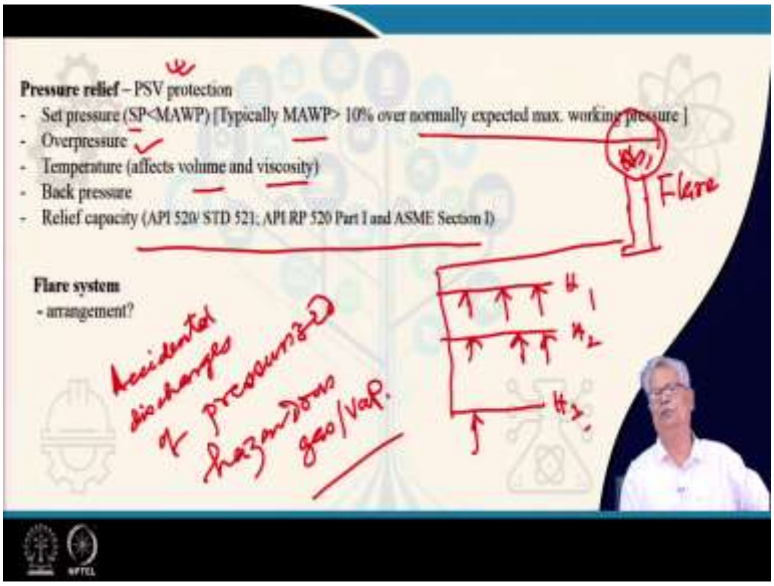

We talk about the pressure relief. That means, the pressure safety valve provides the protection against overpressure. Sometimes, you will be required to protect, it protect against high vacuum as all also.

Now, there are few terms which is related to pressure relief and a PSV, the first is the set pressure. The set pressure will be below the maximum allowable working pressure. And what is maximum allowable working pressure? It is above the 10 percent of the normally expected maximum working pressure. Overpressure is what?

Overpressure is in a pressure relief system you have a set pressure and over pressure and your popping will normally happen if this set pressure is exceeded. The amount by which the set pressure is exceeded is called overpressure.

Now, it is very important to note the temperature at which the relief takes place. The relief is to reduce the pressure to a safe value. Now, the rate at which this relief takes place is absolutely important. The temperature decides the viscosity and the volume of the material which is getting discharged through the safety valve. So, quite naturally the temperature of the actual relief or discharge affects the rate and is to be seen in order to have an effective pressure relief.

Now, the pressure relief valve may discharge through the atmosphere where the this downstream pressure is fairly constant it varies by maybe a few millimeters of mercury. But, if it is discharging to some other system a closed system which also has got a pressure which is called this back pressure to this pressure relief system keeps on changing.

So, you may have to have some special pressure relief valves which are not much effect who said; whose overpressure is not much affected by the back pressure variation it could be a piston operated valve.

Now, regarding the relief capacity requirement pressure relief valves are bought out items. The relief capacity estimates are usually done as per these codes these are API refinery practices and API codes and also ASME section 1, there is a BIS code for this as well.

Often we hear about the flare system. The flare system is to handle accidental discharges, it is supposed to handle only accidental discharges of pressurized hazardous gas or vapour. What you have is you in a large plant normally you have a network of flare header; this is header 1, header 2 and this is header 3.

In plant 1 you will have a supply here you will have a supply from here. Say, possibly several amount of safeties will pop into these headers everything will get combined and finally, go to the flare stack. And if it is a hydrocarbon flare normally if you go to any refinery or any petrochemical you will find the flare stack top there is a burning flame. So, this basically is the flaring arrangement which you find.

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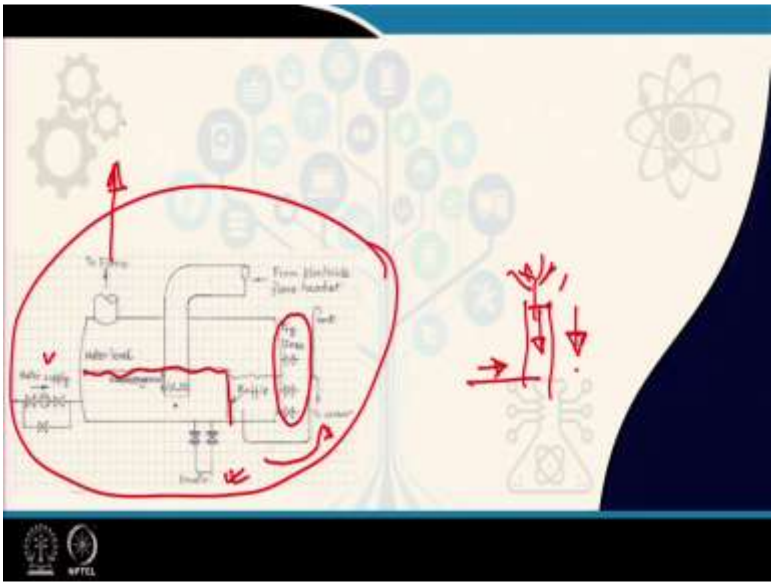

Now, just by if its I am talking again of the hydrocarbon flare and I would like to have from give you an idea that normally the hydrocarbon flare if you just have all the gas coming in going out and it is catching fire. It is also possible that there could be a strike back of the flame, because the flared gas which comes in may also contain something which may support this combustion a small quantity of air may be present though it is not supposed to be there.

But, in order to I mean avoid this strike back it is put through a ceiling arrangement, it is a water seal if you see this. There is a drum the flare header comes and you have a liquid level here. You have the discharge submerged in the liquid water and you have a water supply which continuously drains out as well. You have in order to know what where exactly your level is a dam or a baffle here and you have an overflow here as well.

You may have try lines to ensure, to verify by going there and opening these lines what exactly is the exact position of your water line water level. From here it finally, goes to your the flare stack.

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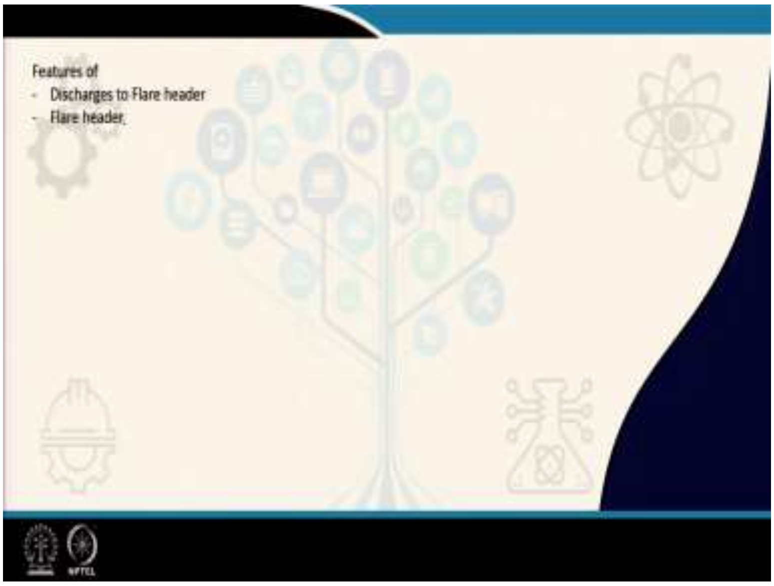

The flare header is a very important thing, it is possible whatever is discharged to the flare is a saturated vapour at a high temperature. A typical thing could be the safety popping from a stabilizer. Once it enters the flare header it is possible that it will cool down and there will be some amount of condensation in the header itself.

So, flare header headers are never perfectly horizontal and it slopes down. There are situations in which the discharge to the flare header is not direct. There may be a knockout drum within the plant itself to which all the safety discharges will be connected.

If there is any liquid formation it will get settled in that particular drum and that drum will be connected to the flare header. This is a more common practice with current hydrocarbon industries. That particular knockout drum will be emptied usually once a shift or at least once a day.

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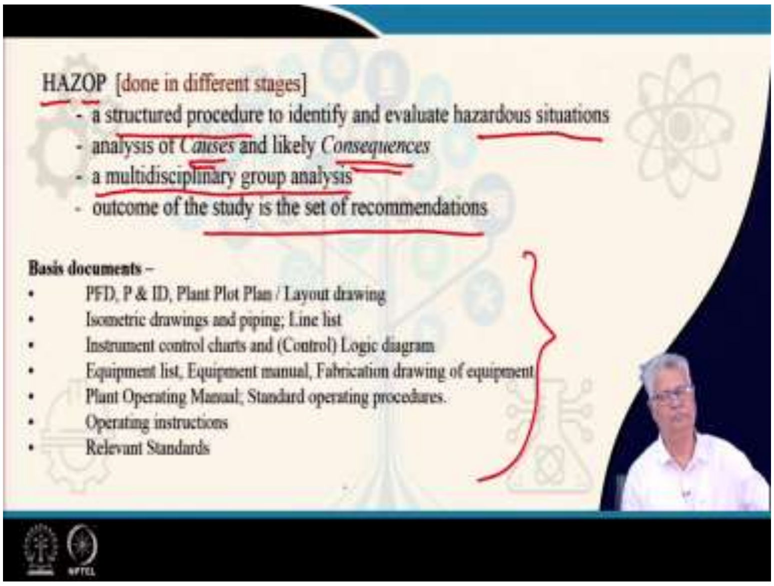

We talked about various standards and various ways of improving the safety. Now, we are particularly concerned about identification of the hazard and mitigating those in the design stage. This is done by hazard and operability study; it is Hazard and Operability Study put together it is said as HAZOP. It is done in different stages, it is done in the design stage, it is done after the plant has been constructed, it is also done when the plant is in its normal operation.

The purpose is to identify the hazards before it has affected the system. It is a structured procedure to identify and evaluate hazardous situations. It basically analyzes what could be the causes of the hazard and what could be the consequence of this particular hazard. In fact, it does it by asking certain set of questions which have specific keywords we will talk we will see that just after this.

It is done always by a multi-disciplinary group. If it is to be done in a plant it has to be done by people who are chemical engineers, electrical engineers, mechanical inspection group, metallurgist everyone together, because the hazard can come from any of these discipline any discipline in fact.

The outcome of the study is a set of recommendations and this is an essential component which has to be done by the designer right at the design stage. The basic documents required for this I have a list here, but there is nothing great in it because all these are usually available in your design stage itself.

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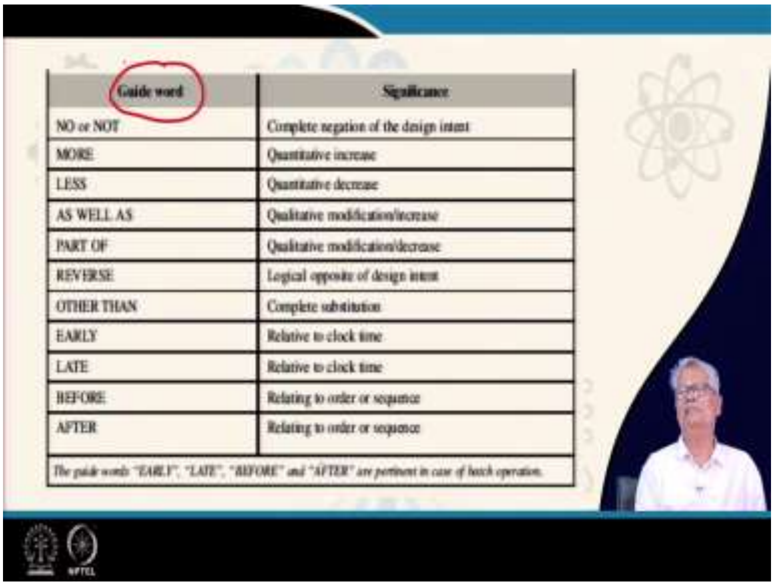

I mentioned about the keywords. In fact, these are called guide words these are called guide words. The typical example is no, not, more, less, etcetera, etcetera, late, before, after and it has got significance. For example, complete negation negation of the design intent. It could be not closed not open before after these are typically the situations that you may think of if you are making a HAZOP study.

An example of this is suppose there is a possibility of overfilling of tank by not closing a particular inlet valve to the tank in time whether this can happen or not. When we inspect a valve we have a; we have a question is it closed or it is, is it late or it is early. So, all these questions will come and the this be the cause if this be the cause what could be the sequence of this particular action or activity is evaluated. And this brings out the potential hazard.

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Now, this I believe will give you an idea that what exactly is a hazard and operability study which is done before the plant is commissioned and also after it has been commissioned and it is working. There is another type of study which is called hazard and hazard analysis this is more of a quantitative study.

For example, if you have a pipeline if you have a pipeline and there is a pipeline rupture and you are having some sort of hydrocarbon being conveyed through it there will be a spray.

Now, the hydrocarbon oil will start vapourizing depending on the location whenever you have there are certain ways of estimating; up to the vapour cloud formed by vapourization of this hydrocarbon spray how this will spread in which direction and to what extent. That means, the hazard will keep on spreading starting from this particular point of leakage.

Now, it is possible for you to under certain specific assumptions to estimate what will be your zone of influence of this hazard. There are specific softwares which in this in this particular case it is based on the chemical principles that what will be your throw of spray, what will be your rate of vapourization depending on the physical property particularly the vapour pressure of your liquid. It is possible for you to find out the zone of influence and estimate which time what will be the hazard intensity.

So, this is also another way and it is, you should be aware that HAZOP and HAZAN are techniques which are to be used definitely to understand and evaluate a threat and to mitigate those.

I think with this I will stop. Thank you for your attention to this specific thing. And I would like to emphasize before I end that perhaps any plant design will never be complete unless you have made a thorough analysis of the safety during its design to ensure that you provide finally a complete plant as safe as possible.

Thank you.