Industrial Safety Engineering
Prof. Jhareswar Maiti
Department of Industrial and Systems Engineering
Indian Institute of Technology, Kharagpur

Lecture - 08
Hazard and Operability Study (HAZOP)

Welcome today we will continue we will discuss Hazard and Operability Study, HAZOP, which is one of the hazard identification techniques and it is in continuation with our previous hazard identification techniques like we have disused PHL and PHA and HAZOP is a very interesting one.

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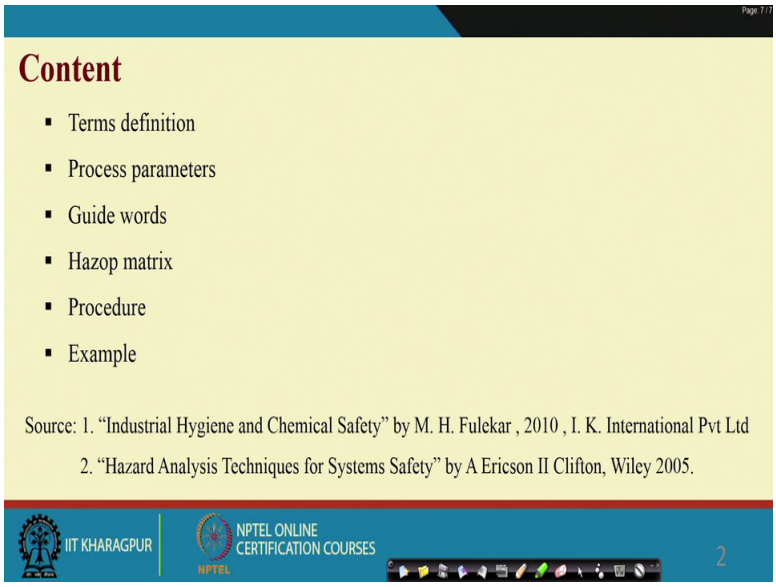

And you will see that, you will learn a lot in terms of identifying hazards in process industries, particularly where you are dealing with continuous processes which is characterized by several process parameters and there is design intent. And accordingly the parameters may deviate from intend intended design and you will find out many guide words and then a list of deviations.

And then finally, we will see the HAZOP matrix, but all those things will be will be identified or other way I can say the HAZOP matrix will be developed using certain procedures, that is called hazard procedure. And we will also discuss some an example that how to conduct hazard. Primarily the source of this lecture material is of two books one is the industrial hygiene and chemical safety by M H Fulekar, 2010, I K International

Private Limited and Hazard Anlaysis Techniques for System Safety by A Ericson two Clifton Wiley 2005. So, this is what is the content of today's presentation.

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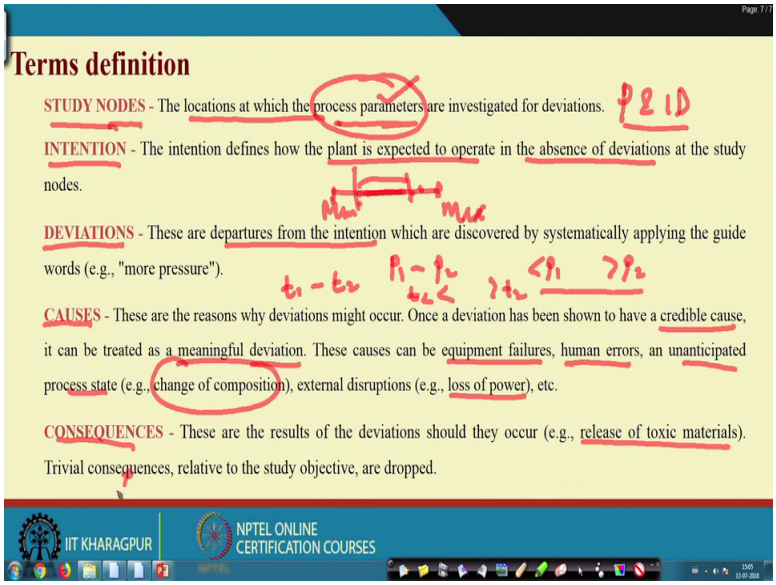

So, in order to understand HAZOP you require to define some of the terms. Which we are saying that term definitions, and under this few important things one is study nodes, second one is intention then deviation, causes, consequences.

If you recall PHL or PHA you have seen that we have disused that the total system will be broken down into subsystem and then subsystem will be broken down to sub system. And finally, to the compound level, and then may be at the compound level or at the sub, sub system level or the system level you will you try to find out the hazards. And the easiest way to find to go for this is start with the component level and compare with hazardous, hazardous energy sources, hazardous process and events and you will ultimately find out the hazard elements initiating mechanisms and target threats in terms of hazard triangle.

So, that mean that is the starting point; that means, you have to find out that hazard for what. So, similarly in the HAZOP the issue is that a given a system where you want to study the deviation. The location at which you study the deviation is known as study nodes, the location at which you study the deviation.

For example, if we talk about the pressure tank system and if we are interested to know the deviation in terms of pressure inside the tank, then the tank itself could be a study node. So, that is why and the process the remitters which will be which will be of interest is the pressure there. Suppose, if you think of the palm then palm overrun is the deviation and then basically the time of running is the time is the parameters too long, too short.

Now, similarly if you think of a chemical reaction there you may find out that there the reaction time could be of importance and there the reactor will be the location at which you are interested to conduct hazard study and find out the deviations. So, that is why the location at which the process parameter are investigated for deviations. Obviously, the process parameter is important we will come to all those mitigate, but for the time being you understand you are given a system. Now you will not you will not study for process duration at each and every equipment, each and every pipeline or each and every valves all those things it is impossible.

So, what you will do you will choose a select, a selective locations and in such a way you choose. So, that that the system process parameters all will be investigated ok. And usually then what will be the guideline basically if I talk, I am talking about a chemical process. Where P and ID piping and instrumentation diagram is very important you just see a starting point will be the I and ID see the P and ID there will be lot of pipelines valves and all those things the most vulnerable part you must take ok.

And either, either the location could be a pipeline, location could be a particular valve a equipment or anything, but selection of that location is a typically a difficult what, but with a teaming about having a team will be required process knowledge, design knowledge and hazard knowledge. It is possible to find out the minimum number of locations or study node which help in conducting an efficient hazard study ok.

Second one is the intention; intention means how the plant is expected to operate in the absence of deviation. So, for this is a normal operating condition that is the intention; for example, if I talk about the pressurized tank then definitely there is a maximum value of pressure which is designed or minimum value of pressure which is designed. So, that the gas should be filled to that amount that the pressure within the tank will be at a minimum pressure to maximum pressure some range will be there, so minimum to maximum.

So, this is may be, may be you are operating normally may be you are operating within this range, but this what is the designing designed one. So, you may you may consider that if it is beyond this normal one this is a deviation ok.

So, similarly when you running a machine speed there is the range speed there is a range. Suppose the time or suppose the current flowing the voltage. All those things they have designed intend design range, nor for normal operating conditions and basically we are talking about absence of deviation.

Then what is deviation, deviation is departure from the designing intension departure from the intention is deviation. That mean you your pressure should be P 1 to P 2, but if it is less than P 1 that is also deviation, greater than P 1 that is also deviation. You should run a pump suppose for t 1 time, or may be if you say it ranges t 1 to t 2. Then if you run it less than t 1 that is also deviation greater than t 2 that is also deviation, sometimes deviation can be one sided also ok.

So, this deviation is determined in HAZOP study using processed parameters and some guide words ok. So, what are the process that are commonly used process parameters and what are the guide words we will be discussing next, but for the time being you understand you have a big system you divided into small system. You find out the locations where the hazard study will be conducted, you identified the parameters applicable to that particular locations and you have appropriate guide words guide words like if I say my parameter is pressure then more pressure, then more pressure is the deviation more is the guide word less pressure is deviation less is the guide word I will show you all those things a substantial number of guide words will be discussed.

Then if there is deviation for example, over pressure is a deviation then what you require to know you required to find out, what are the causes of those work pressure. So, that mean you have to find out find out the factors responsible for that deviation. So, the reasons finding out the reasons you have to look why analysis, why over pressure that mean pump overrun why pump overrun current to pump is too long, why current to pump too long timer fail all those things with refer with reference to pressure time example we have disused earlier. So, you have to find out ok.

So, once a deviation has been shown to have a credible cause, it can be treated as a meaningful deviation. So, there can be many deviation there can be many trivial

deviation there can be many significant deviation. There will be some deviations which are obvious and which can be a rectified immediately. But there are some there will be many deviations which requires intensive causal analysis and then lot of credible causes will be identified and finally, you will all those min deviations will be treated as a meaningful deviations.

These causes now causes can be equipment failure can be human error can be an unanticipated process stage the change of composition external disruptions also can be the causes ok. So, as I told you if you say overpressure is the deviation then obviously, immediate cause is pressure pump overrun. Then if you dig down further, then pump overrun because, because that means, connect pump is allowed to run more means the contact is not separated current to the pump is driven more than the design time.

And even if you go further you will find out that the timer does not work or the operator manually could not remove the switch or other way you can describe a switch. So, many things are there, so this kind of analysis once you do they will give you the causes.

Then consequence is what these are the result of the deviations once there is a deviation for example, over pressure what is a consequence? If over pressure is there then the system immediately what happen react again overpressure. There are relief valve there are discharge valve there is a pressure gauge alarm all those things. So, under over pressure situation relief valve should work. So, what relief valve releases certain amount of gas with reference to the pressure tank system, but if that fills what will happen. So, ultimately you have to think, that what will happen next what some kind of events you have to anticipate that is what is consequence. And finally, due to the over pressure situation the tank rupture will take place.

So, here you see release of toxic materials, trivial consequences relative to study objectives are dropped trivial consequences we will not consider ok. So, this is what is basically the definitions and HAZOP if you, if you see that it is extensively used in chemical industries.

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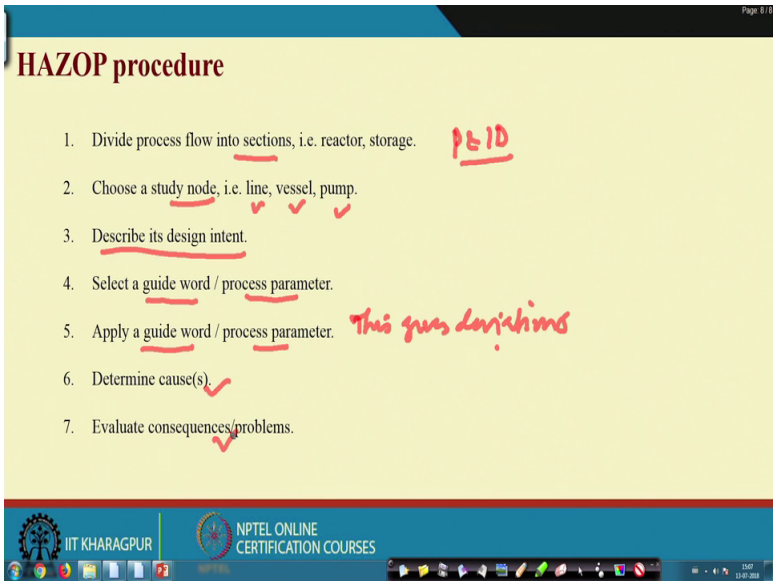

Now, what is the HAZOP procedure I think I have explained the procedure, now I am repeating the same. First is divide process flow into sections better, better you find out your P and ID diagram, P and ID diagram. Then in the P and ID diagram I say that you segregate the diagram in such a manner that get some small sub subsystem maybe upgrade the compound level also. So, you divide into sections, then for section where choose a study node study node can be a line a vessel, a pump. I told you it can be a component, it can be pipeline, it can be a subsystem as a whole also.

Then you find out the design intent means what at what is design intent, you know the process parameters here. So, every parameter is based on design there is some kind of range or some intention is there it should be high low less all those things. Then select a guide word and a process parameter apply the guide word to process parameter, then find out this will give you deviation this gives deviation. Now once you have the deviation for every deviation identify causes, then also for every deviation find out the consequences.

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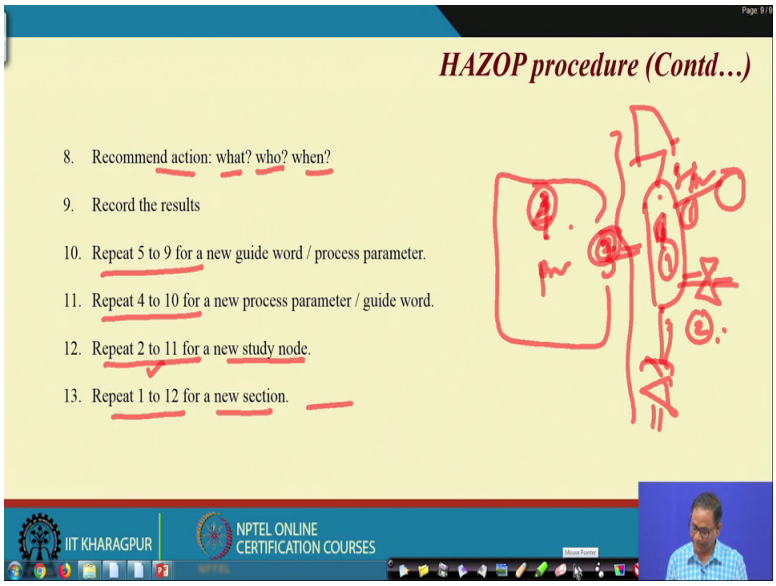

Then repeat, what I can say you have to repeat everything, but in between what happened you write down some action. What to what to do? Who will do? And when it will be done? Your results will be documented then repeat 5 to 9, repeat 4 to 10, repeat 2 to 11, repeat 1 to 12 for every new guide word 5 to 9, for every process parameter guide word then 4 to 10, for a new study node 2 to 11, for new section 1 to 12 ok.

Now, if I consider the pressure tank system with this system suppose I will consider this is my study none 1, tank is pressure pump is starting out 2 and the rest is starting out 3 ok. So, that mean what happened I have considered let it be two sections one is the storage another one is the pumping. So, in the storage section I we have consider the tank itself be known or maybe you have the relief valve design important one another one may be this is one and another one relief valve will be two there is another valve that is called discharge valve. So, it may not be reequipped with may be it may con very pressure, pressure gauge there is alarm so many things are there.

So, in section 1 2 node in section 2 may be this is 3, so this one 4. So, what happened pump another node and you have the circuit is another node. So, you just what happened that mean first you divide into sections then in every section find out nodes and then what happened for every node what you require to do for every node you. Suppose node number 1 is my tank, node number 1 is pressure tank what is the design intent what is the basically that the pressure at of gas which will be hold here.

So, then for that for that select the guide word pressure and apply guide word and guide word may be high and low like this. And in this process and if it is a high pressure find out the sorry determine the causes determine the causes if overpressure is there what will be the consequence I shut the tank rupture. And in this way you recommend what to do then record the detail.

Then repeat 5 to 9 new guideword here it is more pressure now less pressure repeat this thing. Then apply 4 to 5 new process parameter you take another process parameter may be it is not only pressure it may be your temperature or something else repeat this, then repeat 2 to 11 new study none 1 one is completed go to two ok. So, one is completed go to two, then when two will be competed go to three, three will be completed go to four, in this way what will happen all the study node will be considered.

Now, let us see when we talk about, we talk about sorry talk about the procedure. Now you may be interested to know that what are the guide words what are the process parameters some guidelines you are looking for, that guidelines I am giving you now.

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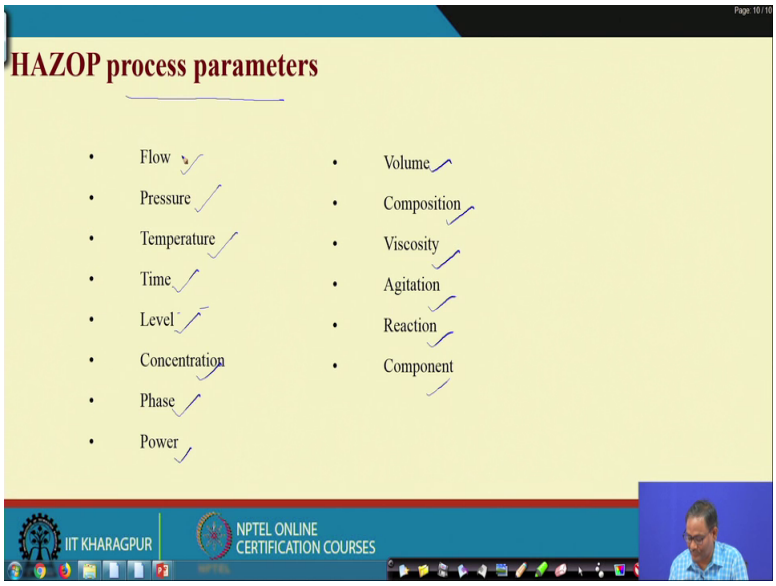

So, common a common process parameters flow, pressure, temperature, time, level, concentration, phase, power, volume, composition, viscosity, agitation, reaction, component, so all may not be applicable.

All may not be applicable to your study node, some will be applicable like I say the pressure tank is the study node pressure is applicable, temperature may not be applicable not go for this. If I go for the your that pump may be here a flow, pressure, temperature this may not important time is important with reference to this pump ok. May be power is important because there is a power if it is high power, low power problem will be there ok.

Suppose if you if you think of a think of a chemical reaction suppose sulfuric acid and ammonia. Then what will happen the amount a study node you may choose where the amount of ammonia or amount of sulfuric acid will be important. And in that case the flow may be returned in amount then flow will be a process parameter ok. I will give you one example related to this.

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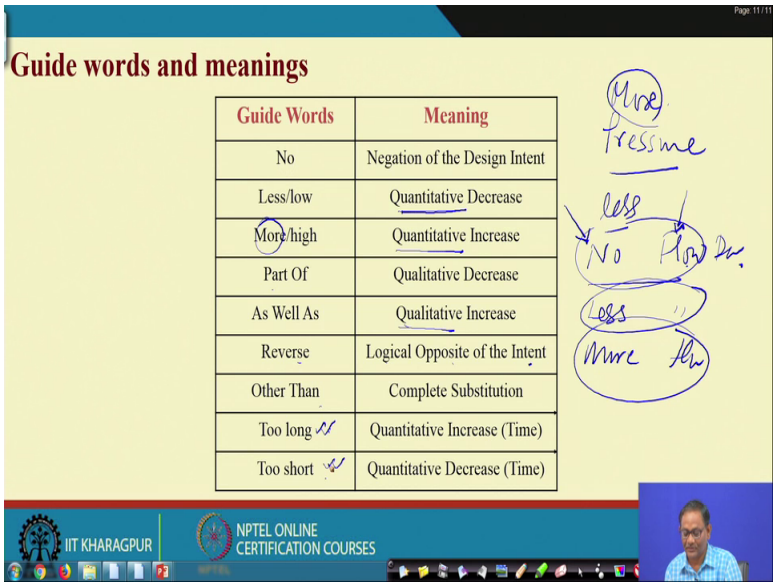

So, then what are the guidewords, guide words are as I told you suppose if I say pressure. If you say more then there is more pressure, so guideword is more. What is more quantitative increase you may say less pressure? If you consider flow you may say no flow this is negation you may say less flow, you may say more flow. So, there will be no flow less, flow more flow, these are deviation.

So, what is deviation the deviation is a combination of the process parameter flow and the guideword, so no flow deviation. So, here this way it is given you see no means negation of the design intent. Design intent is there must be flow there must be flow of

the sulfuric acid to the reactor. There is no flow no material is going, less qualitative decrease more high quantitative increase part of first one is quantitative decrease quantitative increase part of qualitative decrease as well as qualitative increase reverse logical opposite of the intent other than too long, too short.

So, what happened once you get some case for you and you will find out that some of these guidewords will be applicable to the process parameter? So, you combine the guideword with the process parameter and when you combine that two you will get the deviation ok, like current to current to the pump too long it is a time. So, too long basically pump overrun, similarly too short pump under run will be there and in the as a result the pressure at the tank will be less.

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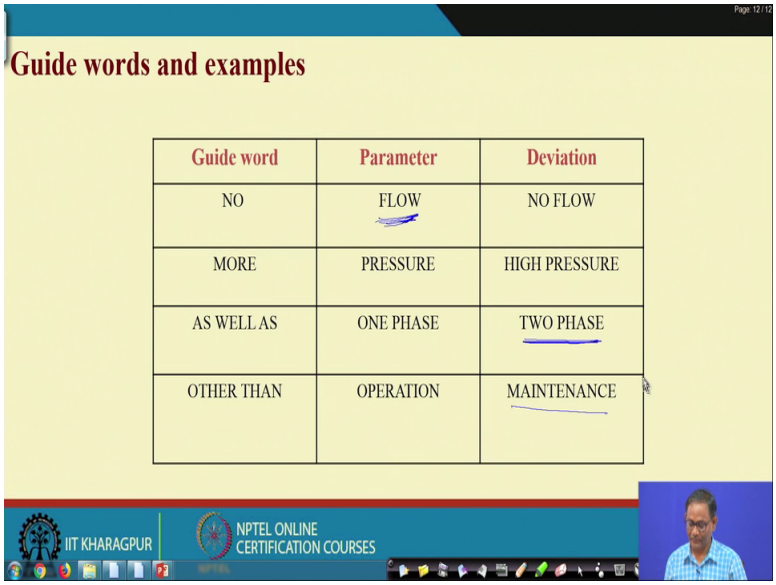

So, this I have already discussed, interestingly you were looking for some example definitely. Flow is very import in a important one at the same time very easy to understand no flow more flow high flow you will get. So, will more pressure low pressure ok, but when you talk about as well as which is qualitative increase. As well as means, it is basically parameter is one phase then as well as one phase we will get basically deviation means you are deviating to qualitative increase that is two phase not is one phase.

Similarly, there is another guideword other than suppose it is in time to do the actual operation, but that time other than operation maintenance work was going on. So, then

that mean other than will operation lead to maintenance, so this is the deviation. Suppose you require a particular job to use to produce something, but maybe different material given to you so then other than that particular material.

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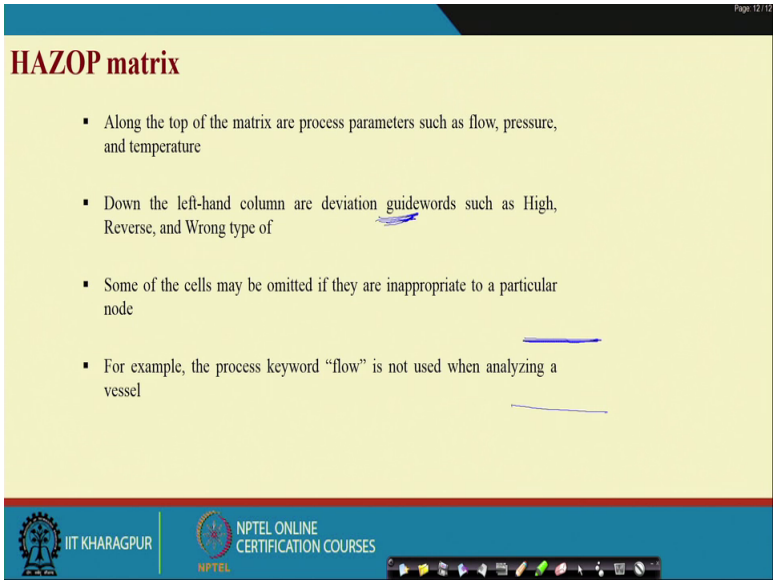

So, then with this background, now you are in a position to develop hazard matrix, and what is this hazard matrix along the top of the matrix process parameters, down the left hand column or deviation of guidewords. Some of the cells may be omitted for example; the process keyword flow is not used when analyzing a vessel let us see what is this.

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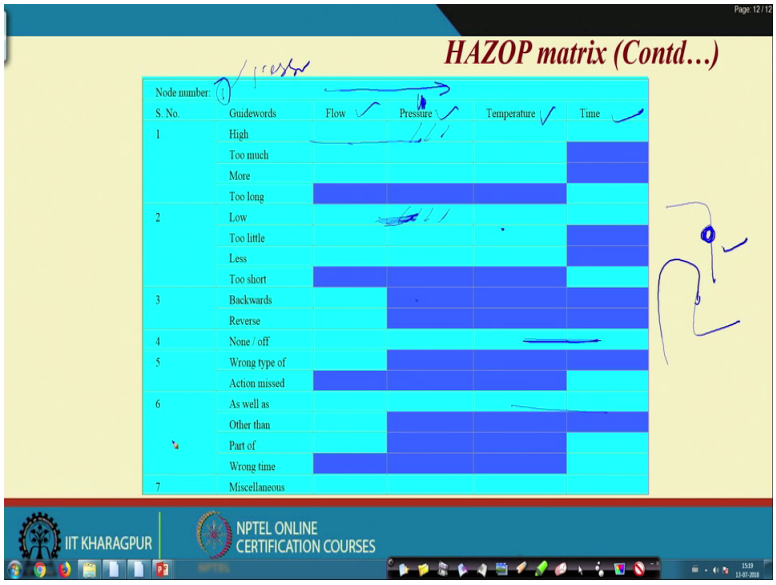

See these are the guidewords these are the parameters sorry this is; what is the parameter, flow, pressure, temperature, time these are the guidewords maybe study node, study node 1, pressure tank. Then what e what guide parameter is important this parameter is important. What will be the guideword high pressure this is or high or more that is giving you the same, similarly too long is not applicable.

Similarly, low pressure or less suppose is I talk about the ka the reaction part chemical, but where sulfuric acids coming. And another side it is ammonia coming suppose my study node is here this one will a explain little later here then flow is important no flow high flow something like this ok. So, this is this what is basically talking about hazard matrix means, you just think of for every study node what will happen you will have different parameters that is applicable and different guidewords applicable.

These are if you do node specific this and finally, superimposed what you superimpose? You will basically from this node what are the guidewords parameter applicable then write down what do the second node write down then you (Refer Time: 27:20) this. So, you will be getting you will be getting different study nodes different deviations. So, this entire list will be HAZOP matrix.

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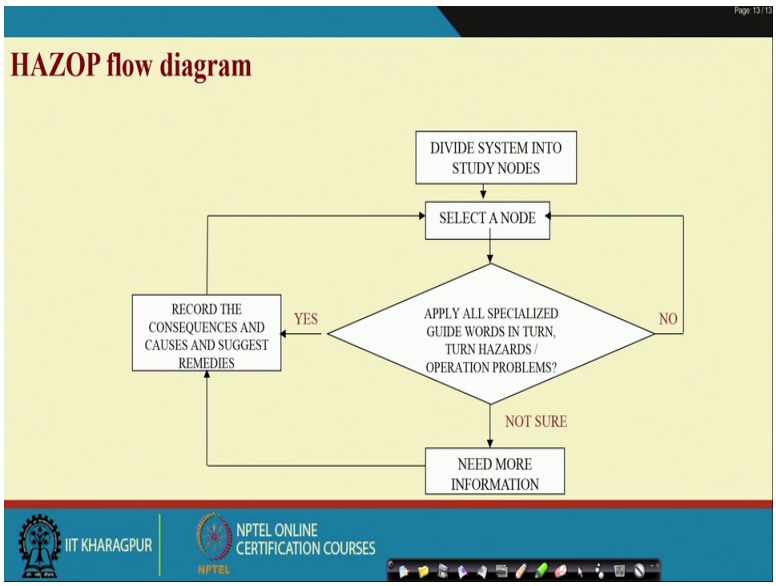

Repeating the same in terms of diagram divide the system into study node select a node apply all specialized guidewords in turn, turn hazards operations problem. Then what

will happen if it is not go for next one. If it is not sure need more information if it is yes record the consequence and causes and suggest remedy.

What additional information you are getting here, additional information is when you are selecting a node. Then when you are trying to apply the guidewords finding out the deviation, and if you find out that this deviations are not going to have any kind of hazardous situation then you forget about it, but if you are not sure you collect more data if you are sure then you record the consequences causes and also the remedies you mention. So, this way a list will be ha hazard list will be prepared.

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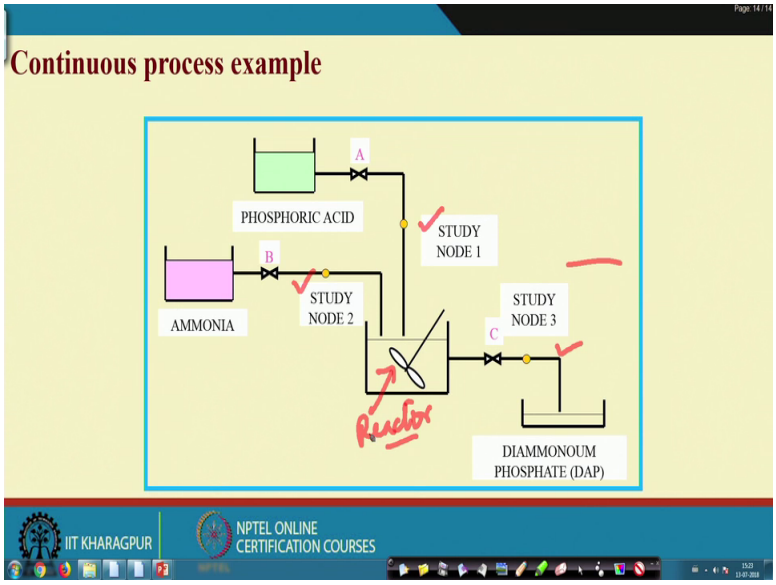

Now, you see one example yes, what is the example here example here this is the reactor. So, here phosphoric acid is mixed ammonia is mixed and then the reaction takes place diammonoum phosphate is produced, suppose you are given this system for hazard studies. So, what you will do this is the total system it is a some simple system. So, you do not mean, you do not require to break it into sub system sub subsystem. So, it is a work itself. So now, in this section you identify the study nodes, what is the study node 1, then study none 2, and study node 3 you see the study node are taken actually on the pipeline. The interesting point here is that this study node ultimately talks about the health of this acid tank the valve the pipelines also.

This one is also similarly talks about the this ammonia tank valve and the pipeline, also before preceding path means upstream and downstream also can be understood with the

study nodes also. And another study node here which is basically after the reactor because if this two study node say things are correct then this is this is the next.

What will happen here may be the problem and this can be understood if we consider study node here. One may say I want say that consider study node this tank 1, 2, 3, 4, 5, 6, then pipeline here seven valves eight another pipeline nine, another pipeline ten it will be many. But if you if you do that way also and finally, if you compare with the results having three study nodes you will find out that almost all the deviations are identified here also in the three study node that is called judiciously considering.

Why pipelines are usually considered because they are the most vulnerable more vulnerable points. By saying this I am not saying that you do not take reactor you ma you also take it all depends on the safety criticality. Now, it is you who will determine that how many study node will be there you mean the first the team expert team having the system knowledge, design knowledge, hazard knowledge, different relations already learnt all those things prerequisites must be there.

Please follow, please do not consider that you alone an expert and you will be able to do it single handedly, hazard study is a team m and it is a be work. And it is not done every day, it is done at a particular periodical intervals may be once in a year suppose or when the new system will come or something like this ok. So, with reference to this let us see what is what will happen how do we go for this study node business, hazard business.

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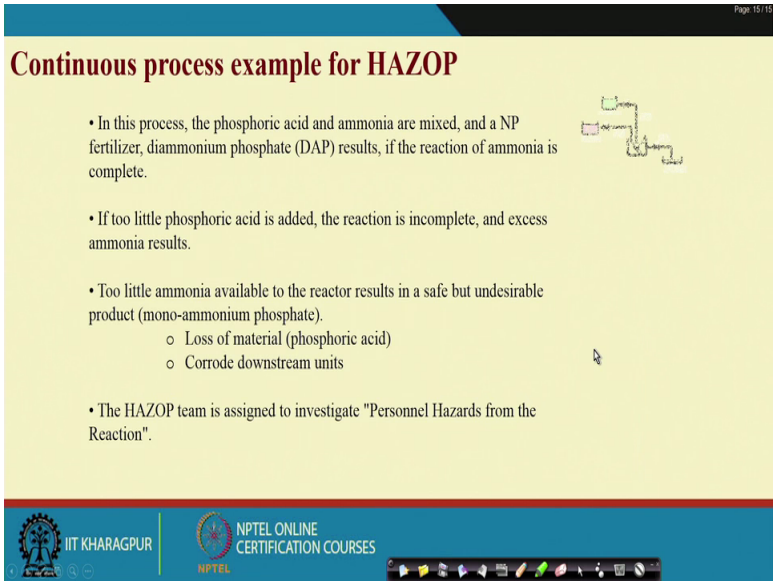

I want to read it out because this will give you that what is happening in this process the phosphoric acid and ammonia are mixed and n NP fertilizer, diammonium phosphate results if the reaction of ammonia is complete. If too little phosphoric acid is added the reaction is incomplete, and excess ammonia results, if too little ammonia is available to the reactor results in a safe, but undesirable product which is mono-ammonium di ammonium phosphate. And there will be loss of material there will be corrosion downstream because of this product is corrosive in nature.

The HAZOP team is assigned to investigate personnel hazard from the reaction only personal hazard you can, you can you know that there will the target threat and target will be people property and environment, here it is people leave the consulate.

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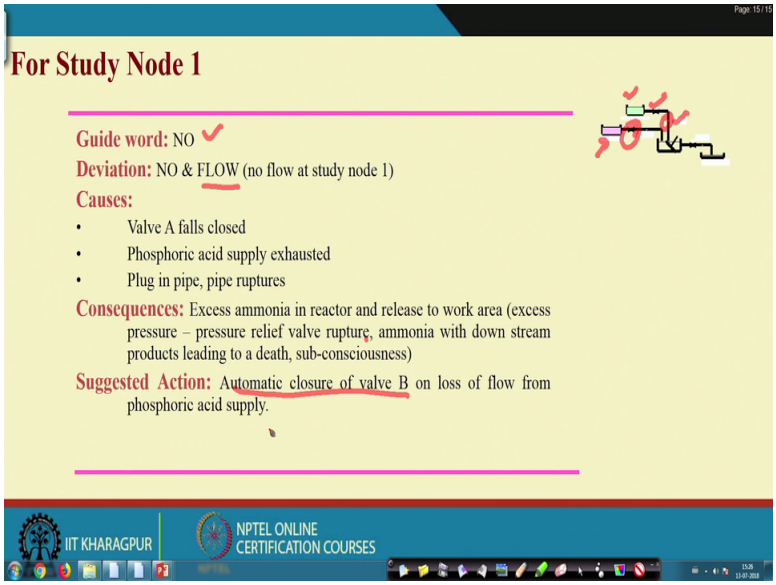

So, study node 1, study none 1 is here what is happening here sulfuric acid is coming through this, now parameter is flow guideword is no what is the hazard no flow. So, no flow why no flow valve a closes phosphoric acid tank no supply or there is jam in the pipe or you can say pipe a ruptures. All those things will be the causes, what is the consequence? If less sulfuric acid comes to the reactor excess ammonia in reactor and release to work area excess pressure, pressure relief valve rupture ammonia with downstream products leading to death sub-consciousness because it is hazardous.

What is the suggested action? If you find out there is no flow we have to control ammonia flow a automatic closure of valve B this valve will be closed. And so that loss

of flow from phosphoric acid, automatic closure of valve B on loss of flow from phosphoric acid supply, let us see the next no flow we have seen.

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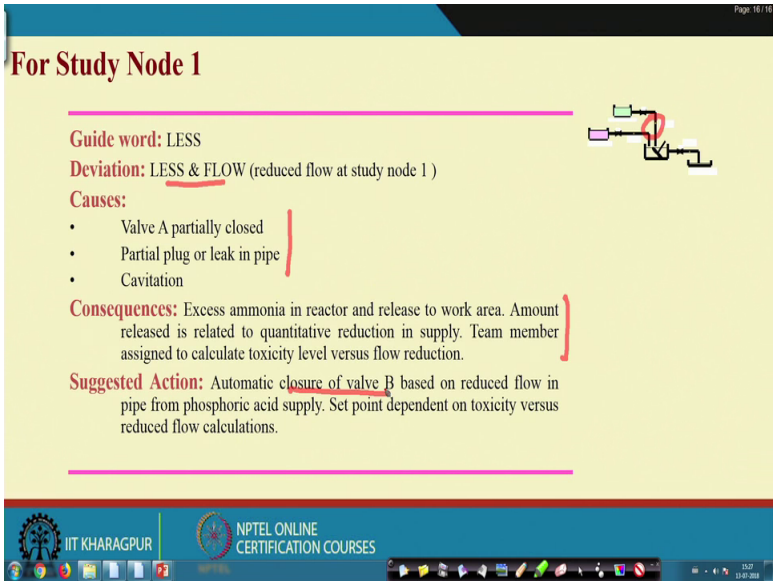

Now, see there may be less flow less flow, so I mean flow is the parameter first one is no flow second one is less flow find out the causes. Find out the consequences you suggest action again automatic closure of valve B.

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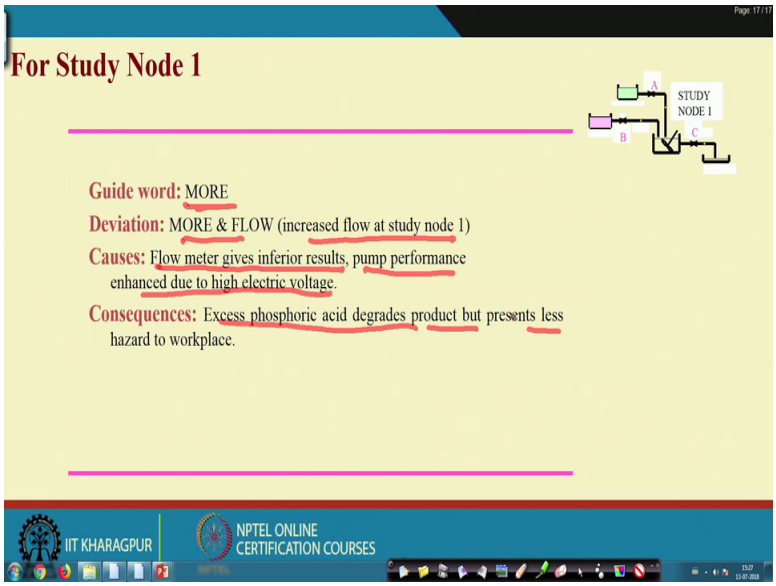

So, if you repeat this what is happening here more flow, now more flow. So, why more flow here more flow increased flow at study node 1. And then causes flow meters gives

inferior results pump performance enhanced due to high electric voltage flow it is not automatic pump is used for this. So, if there is more flow excess phosphoric acid degrades product, but present less hazard at workplace ok.

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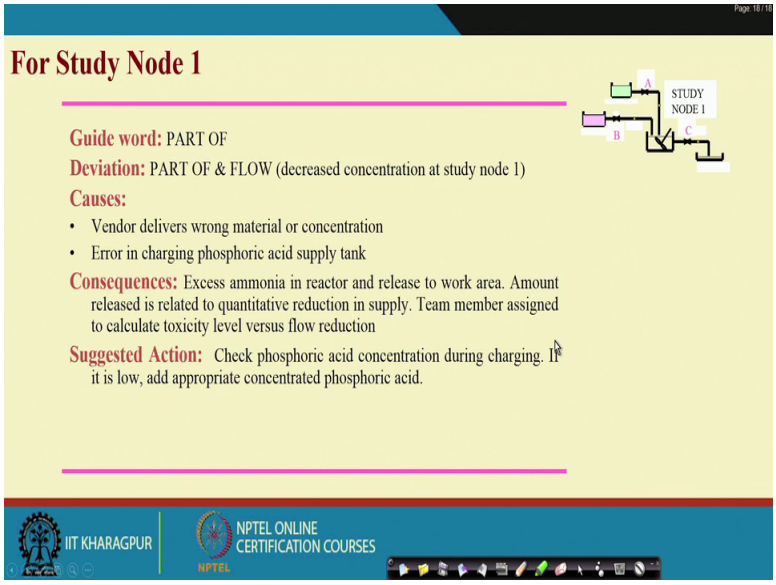

So, this is the way you have to conduct, and then study none 1 flow your writing part of flow concentration is less. Then what are the causes vendor delivers wrong material or concentration error in charging phosphoric acid supply tank, there will be consequences there will be suggested actions.

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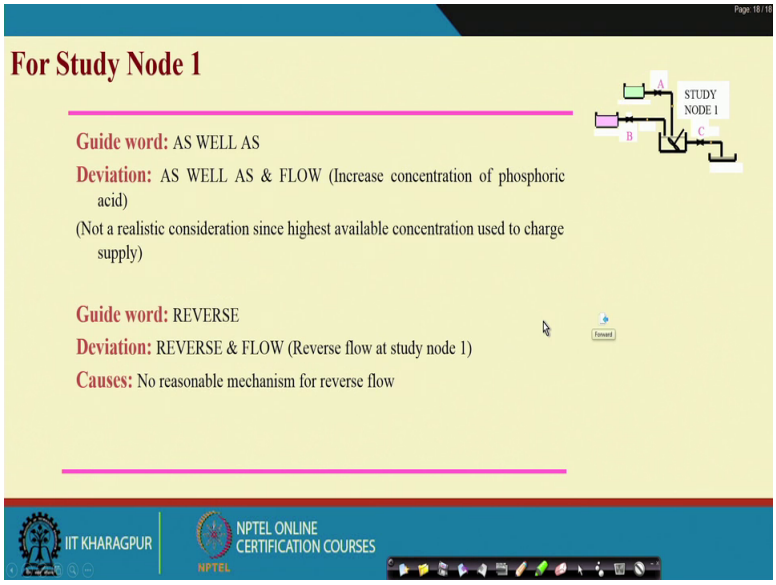

Now, what happened again as well as mean means qualitative increase, increase concentration why increase concentration find out the reasons no not a realistic consideration since highest available concentration used to charge supply. So that means, this is not possible forget about this.

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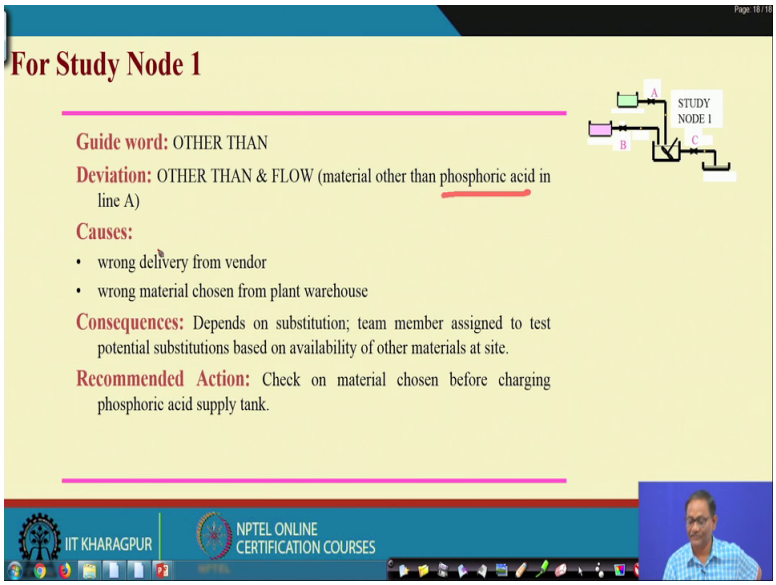

Next other than what is in design intention supply of supply of sulfuric acid. So, you are supplying other than sulfuric acid sorry other than phosphoric acid I am sorry. It is phosphoric acid other than phosphoric acid now phosphoric acid why other than flow means material other than phosphoric acid in line probably varied in sulfuric acid let it be like this then wrong delivery from vendor wrong material chosen. So, these are the causes and consequences you have to find out.

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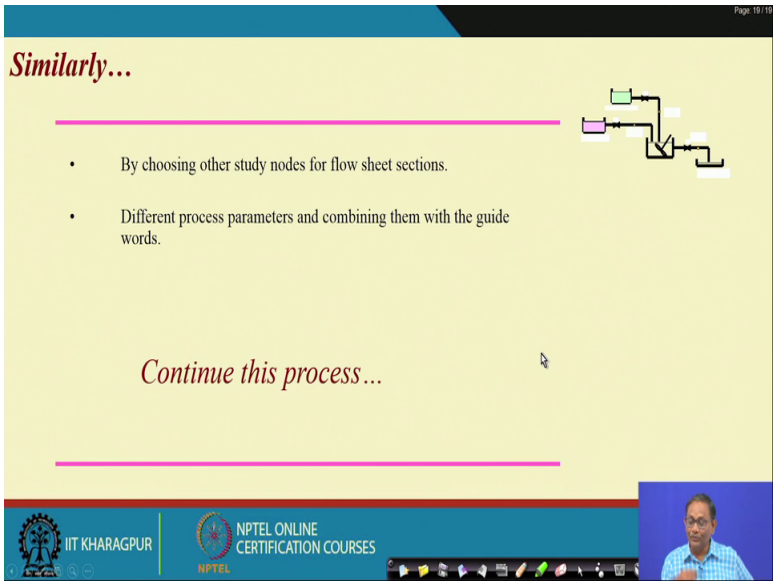

So, you continue this ok, so let me go little back again just to you just see phosphoric acid and ammonia are mixed keep in mind not sulfuric acid, phosphoric acid and ammonia are mixed. And then that fertilizer is produced and I have shown you that ee each a how that that parameters and guidewords are used. And how deviations are determined and then once deviation is significant then what are the causes consequences and suggested actions are identified the team will do it.

Then finally, what you will do you once you finished none 1 go to node 2. So, all the study node will be completed for particular section next section like the entire system all study node will be completed and you will be having a having a existive leads of list of deviations.

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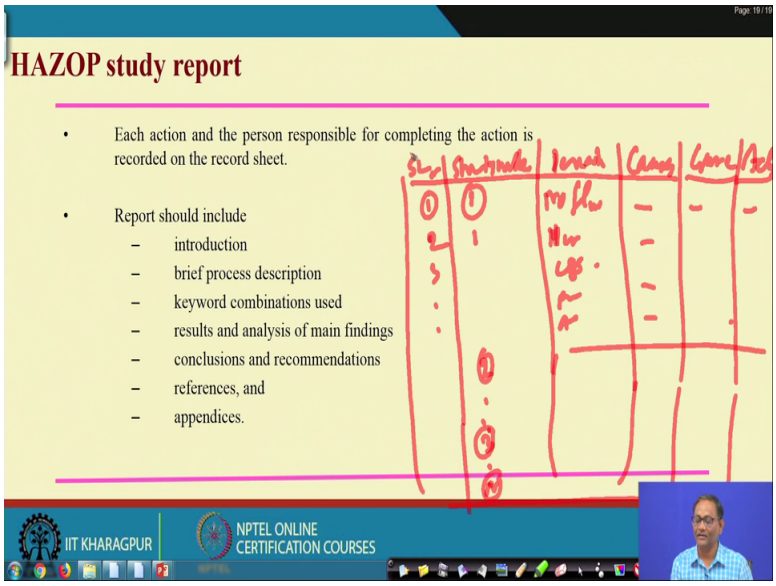

And then it is the documentation once you have all those things you require to document. I think it will be better if we say that serial number 1 and study node, then how many deviations you are getting, then what are the causes what are the consequences, and then what are the actions at least this much you must get. So, if I say study node; a serial number 1 study node may be your that one study none 1 that pipeline. Then your deviation if you say this is no flow then you have seen the causes you have seen the consequences see the six in the action required.

Again study none 1 that is more flow less flow part of flow as well as to all those things you use and finally, for study none 1 we have disused all those things what are the causes consequences and their actions. Now then serial number this is again 1 this is 2, 3, 4 like this. So, like this what will happen your study none 2 will start in this way study node 3, like study node n number of nodes will be there. And against every node there will be many deviations or every deviation find out the causes consequences and actions taken.

And obviously, the team should work together and develop a existing HAZOP list. Here if they if any deviation is not possible do not include, if you think that a deviation is trivial one you may not include or even if you include you can write down in terms in co under comments that is it is a trivial one ok.

Another one is that you can put under remark also you can put if any of the actions are implemented that will be your closed if not implemented it is opened ok. So, I hope that you got brief idea about hazard study.

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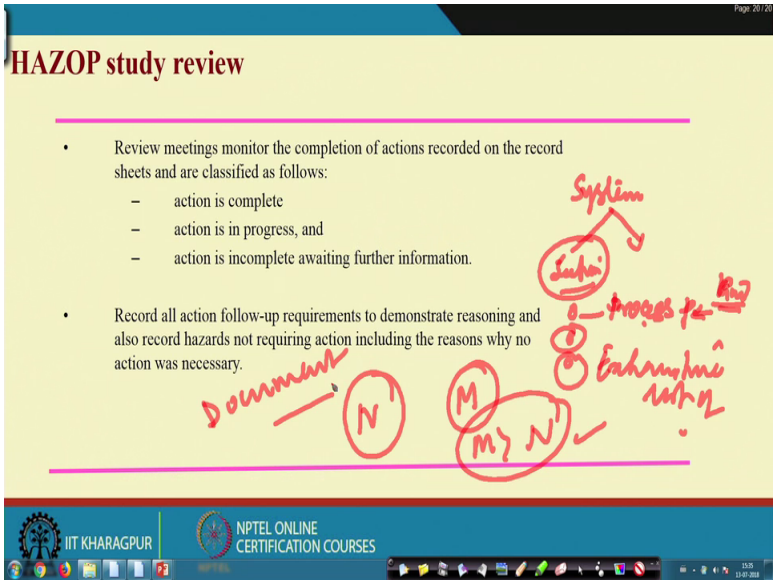

And it is a really a scientific study and it is a difficult study my sole purpose here is to tell you the process of conducting hazards analysis or hazard identification using HAZOP and I am sure that you have understood it ok. So, to repeat the thing let me tell you what you have to do. A system will be given to you or you will be sued then system will be finally broken down up to section level. A section can be a simple equipment or can be a combination of equipment or you may not require to go to this level the system I given is so small that it is one section

Now, in this particular every section you find out this couple of study nodes. Then for every study node find out the applicable process parameters; process parameters. Then for once you for take one parameter find out how many guidewords are applicable for example, in case of flow we have shown five guidewords it can be more guidewords can be also. So, using this guideword to the process parameter find out the deviation an existive list of deviation will be found out, existive list of deviation. So, similarly then go for the second study node go for the third study node find out the list of deviations.

Then go for section two like this, so that means, there will be may be your big N number of study nodes. So, on and average may be for every study node there will be different.

So, um different deviations, so there will be capital M number of total deviation where M is definitely more than N.

So, this is what is our; and final one is the documentation you document the process documentation. Documentation I told you study node, then every study node guidewords and deviations and causes, consequences, action, status all those things.

So, thank you very much and I hope that you have enjoyed this lecture also.

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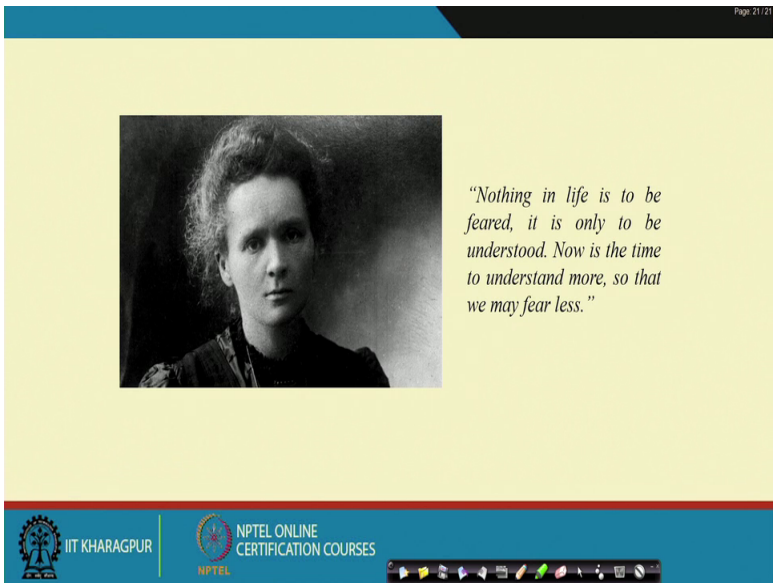

And be sure that you will apply this, unless you apply to a real life situation or in case if you not develop you will not learn this.

Thanks a lot.