Industrial Safety Engineering
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Lecture – 44
Human Reliability Assessment

Hello everybody, today we will discuss Human Reliability Assessment.

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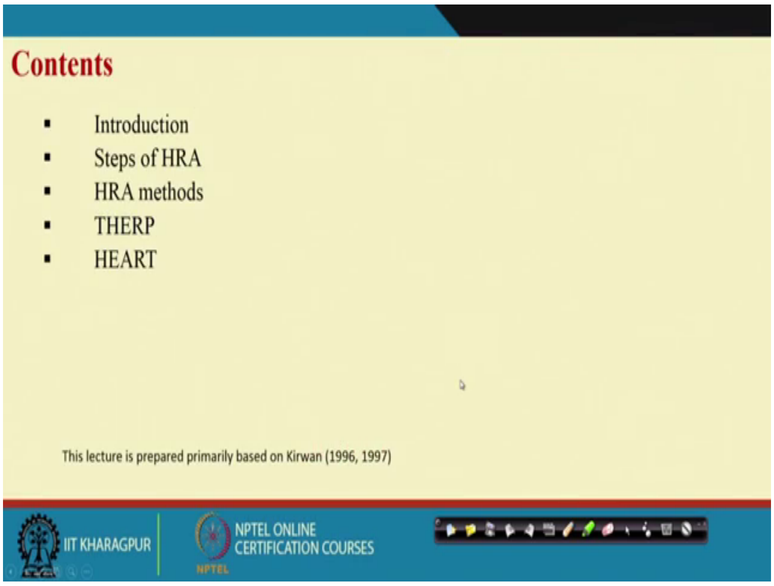

Today's presentation include introduction, steps of human reliability assessment, then different human reliability assessment methods. And we will discuss two important methods one is THERP and another one is HEART. And this lecture is primarily based on the material given by Kirwan 1996 and 1997; also we consulted other books and papers But, most of the materials we have taken from these two papers.

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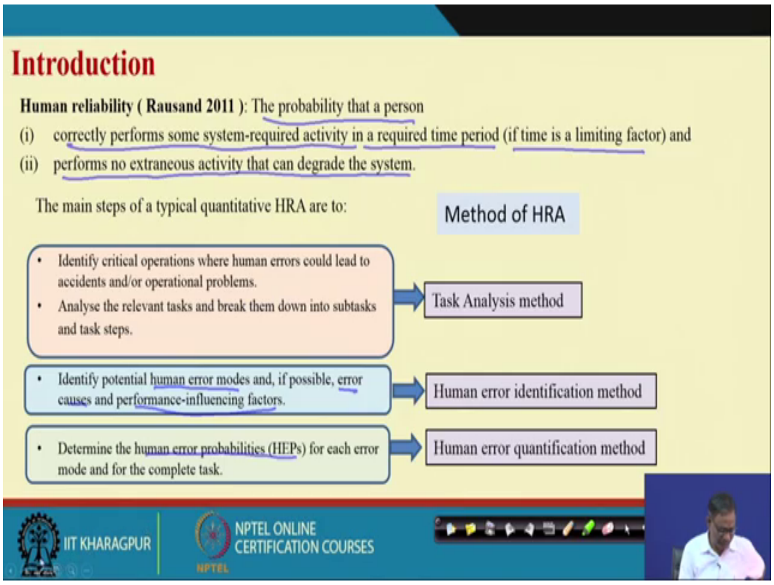

So, human reliability assessment is part of human error analysis and here we will define human reliability as the probability that a person correctly performs some system required activity in a required time period if time is a limiting factor and perform no extraneous activity then that can degrade the system.

So, you all know what is the definition of reliability from the equipment point of view? From equipment point of view we see reliability the probability that the equipment perform its intended function within stipulated period of time given the specified work environment. It is similar here we are saying that instead of equipment, we are talking about person. And as a person the persons correctly perform the activities given to him and at the same time does not perform any activity that will degrade the system and here time is a limiting factor.

And at the same time there are many performance shaping factors which ultimately control the human performance; so, that is what is the given environment. So, it is similar to the definition of reliability from equipment at machine point of view, but context is different; here human perform task and given time and other factors. .

So, in order to quantify the human reliability so, you require to do primarily few things. So, that is given here one is that you must do a task analysis kind of thing and then you must know the what are the relevant task that is the operator or the worker is going to perform. And then you analyze those relevant task and you concentrate on the relevant task what is important for performing the operation or the work.

Then for every you may every task every elemental task you find out the human error modes and also find out the error causes and performance influencing factors or performance shaping factors very important. Because, same person giving two different situation where the performance shaping factors differ so the reliability human reliability will be different.

That means the error causing error probability will be different and then you also require to find quantify the probability of human error. You identify the human error modes then what is the probability of human error human error on that mode which is human error probabilities. So, you required to find due to human error of probabilities.

And then rest of the things are similar to any risk assessment methods; that means, starting with the system description know the system and then what are the jobs and what are the how many people are there, how many people are doing the work and then after assessing the risk then find out where is reduction. So, all those things will be is important as per another reliability any kind of reliability studies ok. So, we will be concentrating more on more on these 3 steps.

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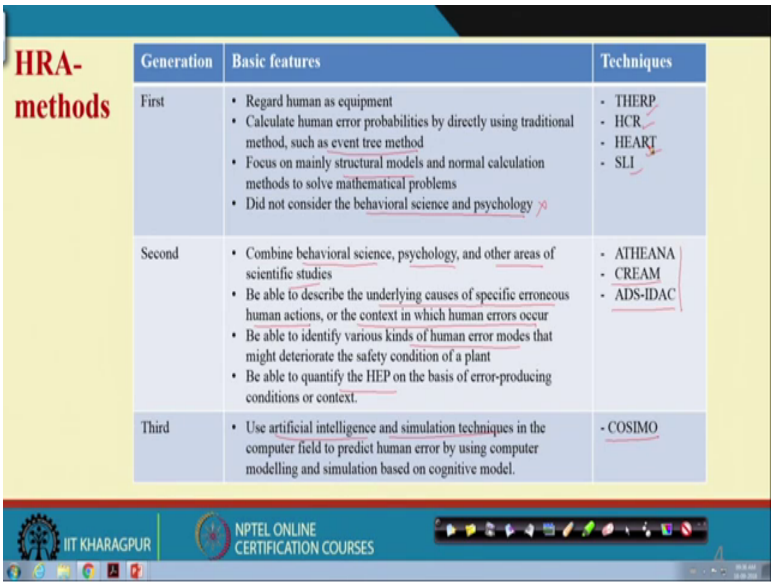

So, there are typically so many human reliability assessment methods developed and HSC in 2009; they have classified these and they found out that there are 72 methods and finally, they found out 17 methods for review final review. And they recommended that this 17 one 17 methods the 17 methods are useful for the high hazard situations. But at the same time we HSC 2009 and as well as other papers that they have give also classify the human error methods into 3 generations first, second and third generations.

Now, the first generations methods are THERP, HCR, HEART, SLI; second generation ATHEANA, CREAM, ADS IDAC and third generation COSIMO. There is also some other like SLIMORD all those things we have not included here. But, if you go for the any review of human reliability methods you will get plenty of good literature and from there you can find out that; what are the basic features of different generation methods?

Obviously, you cannot create clear cut distinction between one generation to another there will be little bit of overlap, but more or less these are the basic features. So, in the first generation they regard human as equipment, calculate human error probabilities by directly using traditional that equipment probability calculation method that is such as event tree. Focus mainly on structural models and normal calculation methods to solve problems mathematically.

Do not consider behavioral science and psychology ok; there will be debate that whether it is true or not for the last point, but more or less most of the techniques do not consider this behavioral science and psychology method or some technique which they have considered that is inadequate (Refer Time: 07:40). Then the second generation combine behavioral science, psychology and other areas of scientific studies that is the advantage.

Be able to describe the underlying causes of specific erroneous human actions and the context in which human error occurs. Be able to identify various kind of human error modes that might deteriorate the safety of the plant. be able to quantify human error probabilities on the basis of error producing conditions or context use and this is basically the second generation.

And third generation basically use of artificial intelligence and simulation technique that is basically the clear distinction ok. So, although these so much of techniques are available, so many techniques are available so, we will not discuss all of them today we will see the THERP and HEART, today and how it is developed and what is the use of it?

These are essentially simple to use, but if you consider the development phase they have they are particularly very laborious things ok.

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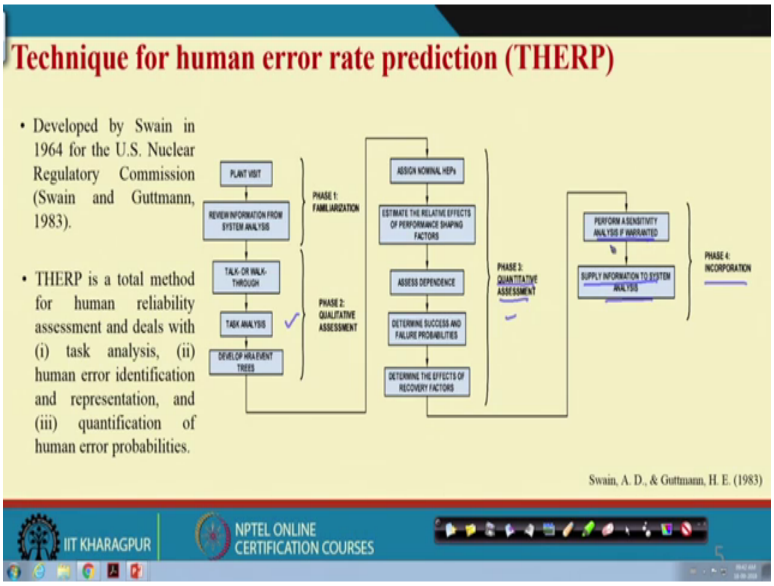

So, now let us discuss that THERP; what is THERP? THERP is Human Error Rate Prediction; Technique for Human Error Rate Prediction. So, this is developed by Swain in 1964 for nuclear plants and it basically comprises of task analysis, human error identification and quantification of human error probabilities. Then Swain and Guttmann in 1983; they had given the complete picture of THERP that how to do? So, there are 4 phases.

In the 1st phase is plant familiarization, in the 2nd phase is qualitative assessment, 3rd phase is quantitative assessment and 4th phase is incorporation. So, for any kind of reliability studies or re studies you know that the first part is obvious; so unless you are not familiar with the plant and the operations and the jobs performed by the people there so, you will not be able to find out the performance shaping factors and other things.

So, this is basically the prerequisite to this, then when you are doing the qualitative assessment means you are basically identifying the task and then breaking down into the relevant elemental task. And then from there you are basically developing the trees these are the things what you are basically doing in the qualitative assessment. So, you will be developing event tree that is where the qualitative event tree.

So, talk or walk through, task analysis and development of trees these are the 3 steps which is to be done in the qualitative assessment. And qualitative assessment very important after qualitative assessment that assigned nominal human error probabilities, it is very difficult to find out human error probabilities. So, given an elemental task and knowing the different error modes what is the probability of doing the error or making the error for that elemental task?

It is nominal human error probabilities by nominal we are means this is probably the minimum one and but if the context changes or the performance shaping factors changes that probability will be will be arguemented or will be adjusted with the things so, nominal this is the base probabilities. So, mostly these are based on either expert opinion or based on some simulation studies or based on some experiment where particularly may be the arogonamic experiment.

What we have seen in the last class I said that from some generic error modes, some arogonamic experimental based error modes and then simulation based error modes. And when you are doing all those things you are also finding out the what is the nominal probability of or probability of commuting that that kind of error.

So, this is the first step, then estimate the relative effects of performance shaping factors very important. Then assess dependence, then determine success and failure probabilities determine the effect of recover effectors. So, you committed error at the same time that error recovery is important so, what are the recovery factors of there all those things are discussed under qualitative assessment, quantitative assessment.

So, qualitative assessment then quantity then finally, here incorporation perform sensitivity analysis and supply information to system analysis; the person who is designing the system which designing for intervention for them this information is very important.

Perform sensitivity analysis is also important because, there are so much of performance shaping facto so, changes with the factor condition. So, ultimately it may change to the resultant reliability resultant human reliability and if there is some cases significant changes for small change in shaping factors, there may be significant change. So, all those things you have to understand and accordingly proper action must be taken.

So, this is what is our THERP; now we will see little bit of quantification of THERP.

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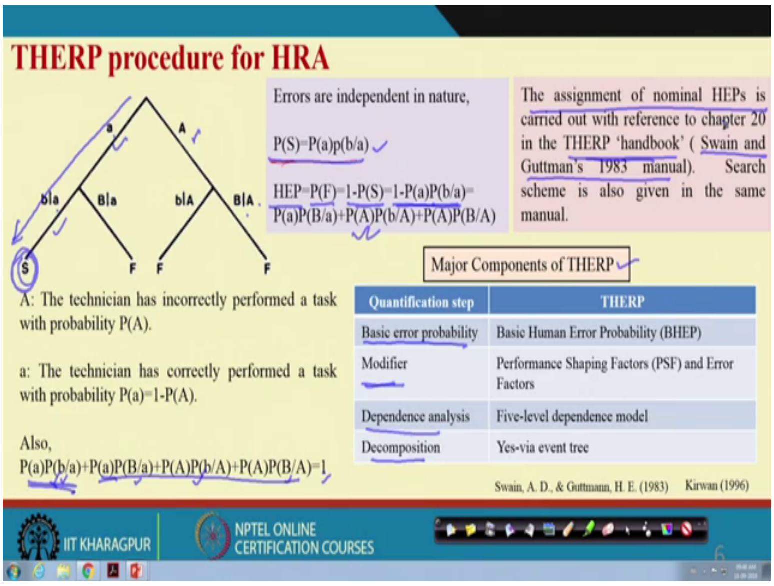

So, as I told you that the starting point in the task analysis and then you make the tree. So, there are two issues that means, you are doing it correctly or doing it wrongly. So, here we are this particular tree; you see that first one is A, which is this the technician has incorrectly performed the task. Then technician has correctly performed the task so; that means, given a task the operator, the technician, the worker there are two outcomes either he does it correctly or incorrectly. So, that is this one is incorrect this is correct so that means, there will be probability of correctly doing, probability of incorrectly doing it. So, then this is P A is incorrectly doing P small a is correctly doing the some of the two will be 1 ok.

Now, then come to this condition; suppose it is correctly doing the first element task. Then here probability b given a; what is probability of b give a? B given a means you see this small b it is again correctly and capital B wrongly. So, in this manner you if can see that what is the probability of S; probability of S is probability of a probability of b given a; probability of S is probability of a probability of b given a.

So, it is a is correctly doing; so correctly doing fast a and then again correctly doing. So, that because the you if you see the action tree so elemental action tree so, one after another it will come; first task followed by second task followed by third task like this.

So, first one is done correctly, second one is done correctly, third one elemental step is done correctly then total things will be done correctly ok.

So, this is the that is why we are interested to know that what is the probability that things are done correctly ok? So, this probability will be along this line, you will end and then this is the issue; where probability of a correctly doing first one, now first is correctly doing then second one so, like this.

So, this is the end probability is this end state is this success this one. Then because there will be success in one way only and now if you think of the failure there will be many ways that failure will be there. So, that mean that then what is the error probability failure probability or human error probability? That probability of F which is 1 minus success 1 minus probability of success; so, 1 minus P a into P b by a if I consider this action tree. Then 1 minus this is nothing, but this the reason is this. So, P a into P b by a P a into P b by a; then P a into B; capital B by a; P capital A into P capital B by A and p capital A into small probabilities small bi; b by capital A.

So, all those things all those outcomes probability sum will be 1, now you got this. So, this one is 1 minus this is P a into P b by a, then 1 minus P S 1 cancel out. So, ultimately 1 minus this equal to this that is what we were writing here.

So, the assign now, issue is that what are the major component of THERP? First is basic error probability, then you require to have modifier, then dependence analysis and decomposition that is what earlier also we have said. Another thing you please understand the assignment of nominal human error probability given by Swain and Guttmann in THERP handbook.

And it has been proven later on also may be based on experimental and simulation study also this what the probability given in this book more or less they are right for all practical purposes. So, that is why this handbook is very important and there are lot of that error descriptions are given. And they are nominal probability the which is which is human error probability that is given there. And now you take that the human nominal HEP and then depending on the performance shaping factors you add on ok.

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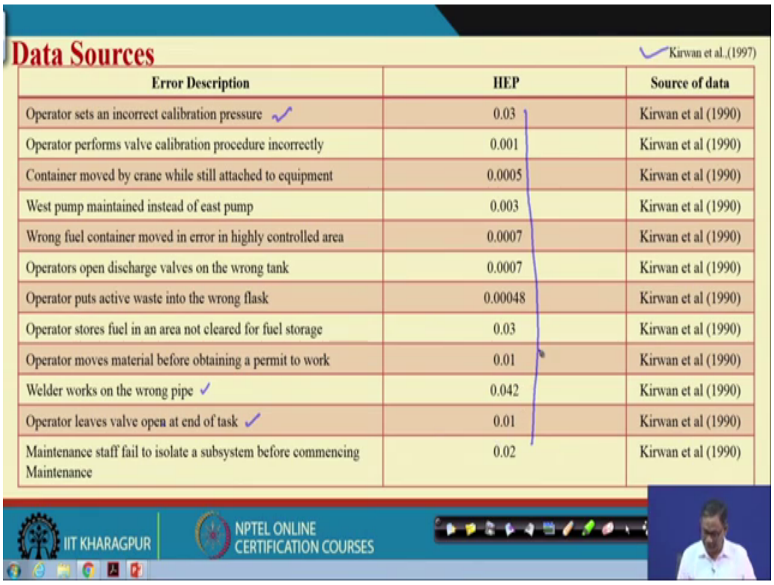

Data Sources

Kirwan et al.(1997)

Error Description	HEP	Source of data
Operator sets an incorrect calibration pressure	0.03	Kirwan et al (1990)
Operator performs valve calibration procedure incorrectly	0.001	Kirwan et al (1990)
Container moved by crane while still attached to equipment	0.0005	Kirwan et al (1990)
West pump maintained instead of east pump	0.003	Kirwan et al (1990)
Wrong fuel container moved in error in highly controlled area	0.0007	Kirwan et al (1990)
Operators open discharge valves on the wrong tank	0.0007	Kirwan et al (1990)
Operator puts active waste into the wrong flask	0.00048	Kirwan et al (1990)
Operator stores fuel in an area not cleared for fuel storage	0.03	Kirwan et al (1990)
Operator moves material before obtaining a permit to work	0.01	Kirwan et al (1990)
Welder works on the wrong pipe	0.042	Kirwan et al (1990)
Operator leaves valve open at end of task	0.01	Kirwan et al (1990)
Maintenance staff fail to isolate a subsystem before commencing Maintenance	0.02	Kirwan et al (1990)

So, let us see that how we can use it. So, we have relied on Kirwan publication in 1997; I think it is in it is published in applied ergonomics. So, there are different kinds of errors that may happen is given with their nominal probabilities.

For example, operator sets and incorrect calibration pressure; so, these are the list of that errors particularly from plant operation point of view. Operator leaves valve open at the end of task, welder walks on the wrong pipe; so like this a huge list is given by Kirwan and the human error probabilities nominal probability is also given.

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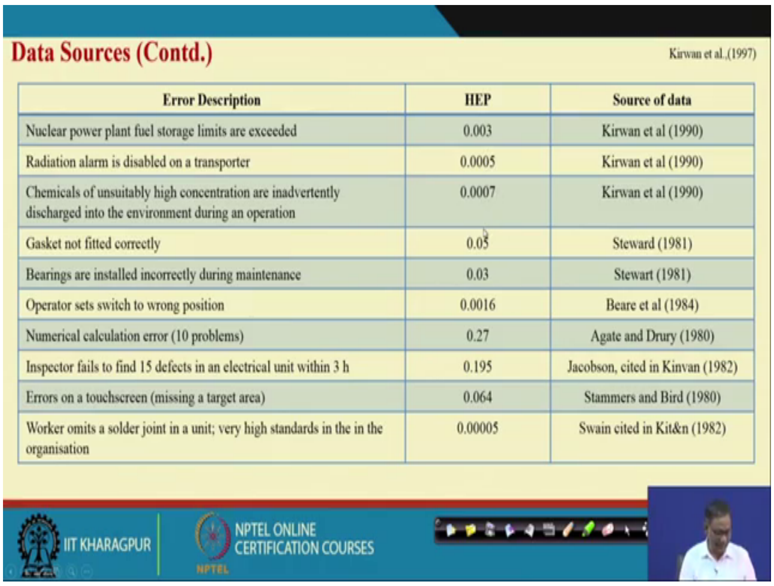

Data Sources (Contd.)

Kirwan et al.(1997)

Error Description	HEP	Source of data
Nuclear power plant fuel storage limits are exceeded	0.003	Kirwan et al (1990)
Radiation alarm is disabled on a transporter	0.0005	Kirwan et al (1990)
Chemicals of unsuitably high concentration are inadvertently discharged into the environment during an operation	0.0007	Kirwan et al (1990)
Gasket not fitted correctly	0.03	Steward (1981)
Bearings are installed incorrectly during maintenance	0.03	Stewart (1981)
Operator sets switch to wrong position	0.0016	Beare et al (1984)
Numerical calculation error (10 problems)	0.27	Agate and Drury (1980)
Inspector fails to find 15 defects in an electrical unit within 3 h	0.195	Jacobson, cited in Kirwan (1982)
Errors on a touchscreen (missing a target area)	0.064	Stammers and Bird (1980)
Worker omits a solder joint in a unit; very high standards in the in the organisation	0.00005	Swain cited in Kit&n (1982)

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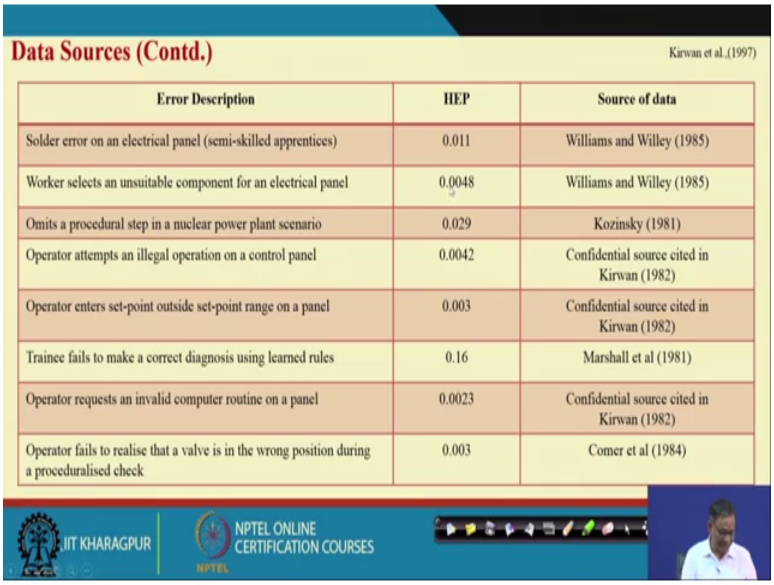

Data Sources (Contd.)

Kirwan et al.(1997)

Error Description	HEP	Source of data
Solder error on an electrical panel (semi-skilled apprentices)	0.011	Williams and Willey (1985)
Worker selects an unsuitable component for an electrical panel	0.0048	Williams and Willey (1985)
Omits a procedural step in a nuclear power plant scenario	0.029	Kozinsky (1981)
Operator attempts an illegal operation on a control panel	0.0042	Confidential source cited in Kirwan (1982)
Operator enters set-point outside set-point range on a panel	0.003	Confidential source cited in Kirwan (1982)
Trainee fails to make a correct diagnosis using learned rules	0.16	Marshall et al (1981)
Operator requests an invalid computer routine on a panel	0.0023	Confidential source cited in Kirwan (1982)
Operator fails to realise that a valve is in the wrong position during a proceduralised check	0.003	Comer et al (1984)

Second one the probabilities, third error description probabilities ok. So, you can now once you are you are finding out the human error probability. So, either means what I mean to say by showing this Kirwan this so many table is that that this issue is a complicated issue for practicing engineers.

And so as a result it is better you should rely on the handbook or the authority whatever they have developed like Kirwan is considered authority in human reliability assessment. So, whatever he has given; so you can use this probabilities human error probabilities in computing human reliability.

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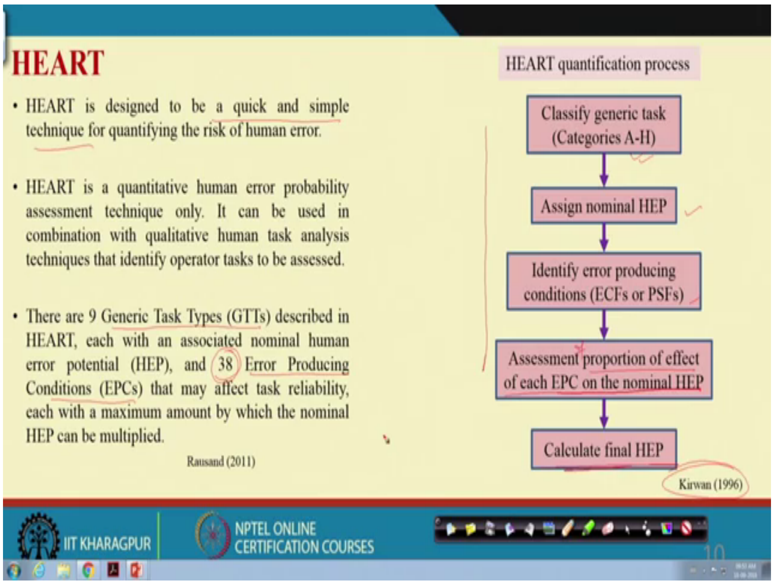

Then we will discuss now HEART; HEART is designed at for quick study, quick and simple technique for quantifying the human error. Actually what happen a HEART is given some generic task and different error producing conditions and under such conditions what are the how the error will be effected probability of the error will be effected that is also given by in HEART.

So, and if you go by the quantification process; you see that classify generic task categories A to H; this one we have taken from Kirwan 1996, where he has given this steps. You see that classify generic task from A to H, then assign nominal human error probabilities, identify error producing conditions which are basically either error producing conditions or performance shaping factors.

Then assessment of proportion of effect of each EPC on the nominal HEP, then calculate the final HEP. So, that means, you have two fittings on hand; one that you know that what are the different categories of task A to H and you also have nominal probability that is what is basically computed by Swain and also from other studies.

Then you have error producing conditions; so there are I think these in HEART I think there are 38 error producing conditions are given. So, how those error producing condition or performance shaping factors will ultimately affect the human error probability that numerical values are given or the scheme is given. So, you have to just see take one job, find out the task, find out the errors and then use the data given in HEART and then finally, you calculate, I will show you that how we have done this one .

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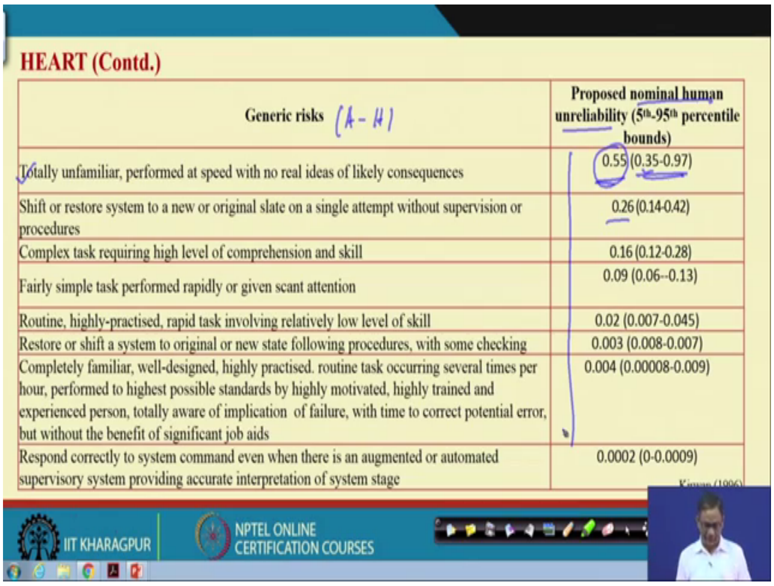

These are the A B C D E F G H; A to H; the generic task A to H and then the nominal human unreliability human error probability given; this one is the mean value and this one is the 90 percent bound 5th to 95th percentile. So, that means, on an average the value will be 0.55 for this particular that situation. Totally unfamiliar, performed at speed with no real ideas or likely consequences under this situation the human error probability will be 0. 55.

And this is on an average it will happen, but depending on situation it may vary from 0. 35 to 0.97 So, we have to choose 0. 55 or in between any value so this manner the A to H, the generics risk, so the generic risk categories are given some nominal probabilities ok; so you straight away use this nominal probabilities.

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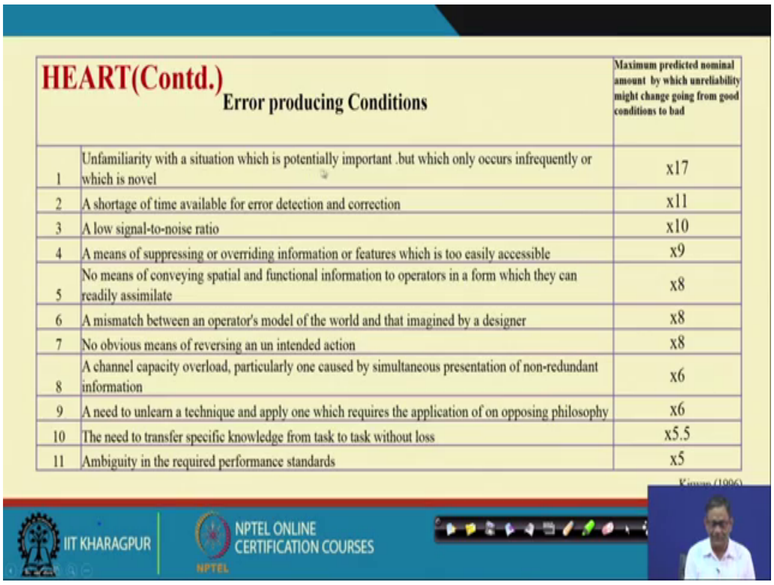
HEART(Contd.)

Error producing Conditions		Maximum predicted nominal amount by which unreliability might change going from good conditions to bad
1	Unfamiliarity with a situation which is potentially important .but which only occurs infrequently or which is novel	x17
2	A shortage of time available for error detection and correction	x11
3	A low signal-to-noise ratio	x10
4	A means of suppressing or overriding information or features which is too easily accessible	x9
5	No means of conveying spatial and functional information to operators in a form which they can readily assimilate	x8
6	A mismatch between an operator's model of the world and that imagined by a designer	x8
7	No obvious means of reversing an un intended action	x8
8	A channel capacity overload, particularly one caused by simultaneous presentation of non-redundant information	x6
9	A need to unlearn a technique and apply one which requires the application of on opposing philosophy	x6
10	The need to transfer specific knowledge from task to task without loss	x5.5
11	Ambiguity in the required performance standards	x5

Then as in Roshan book; it they have say it is written that 38 error producing conditions are there or performance shaping factors are there, but in Kirwan they have listed 26 error producing conditions so, that means, ten another error producing conditions are not listed. So, here we have taken from Kirwan and we are showing those error producing conditions.

So, what happened basically unfamiliarity with a situation which is potentially important, but potentially important ok, which is potentially important comma, but which only occurs infrequently or which is novel. So if this is this case then this will be multiplied so, maximum predicted nominal amount by which unreliability might change going from good condition to bad.

So, you have nominal HEP; so, for this condition it will multiplied by 7. So, that is why under different error producing conditions; so there are different multipliers that is also given ok; so it is available in HEART so like 26.

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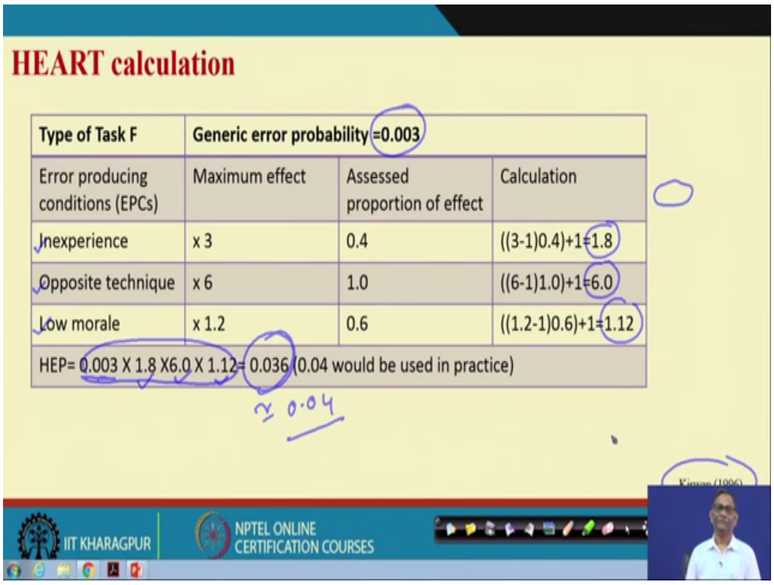

So, now what we will show? That how the calculation is done for example, let the task type is F. If the task type is F; what is the generic error probability or a nominal error probability HEP that one A B C D F; A B C D E F this one; so A B C D E and F so, this is our task type. So, that mean restore or shift a system to original or new state following procedures with some checking so, that is what is the task the type of task is this.

Then what is the average HEP, nominal HEP? 0. 003. So, you have written this 0.003, then suppose the what are the error producing condition one is inexperience opposite technique low morale. So, if it is inexperience what is the maximum effect ok? Then assessed proportion of effect and then you are basically calculating what will happen with the money because of this what is the ultimate multiplier?

So, if it is inexperience so from the error producing condition you have to find out what is the multiplier? So, what you will do. So, if you see what is happening here ok so, these are the I am sorry so, these are the probability values per different A to task; type of task and these are the error producing conditions.

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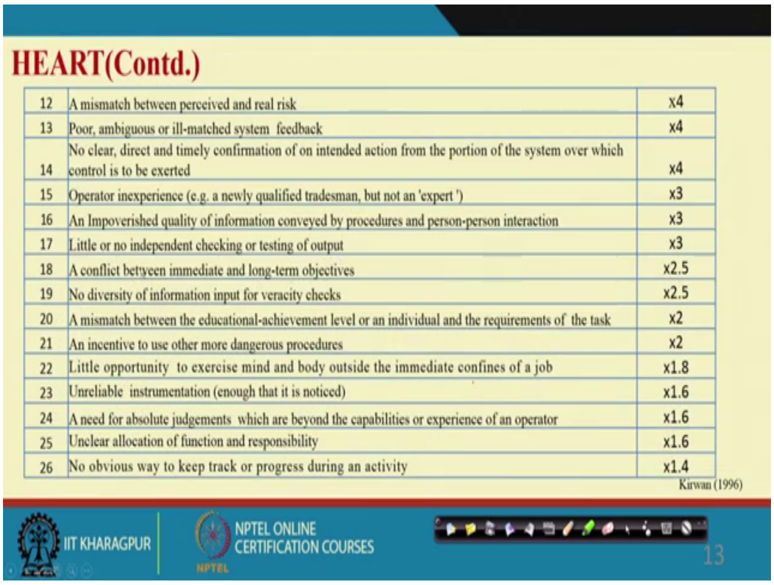

So, what we have found out that inexperience; inexperience case is like little a 1 minute; operator inexperience number 15, then you have to multiply it by 3. So, operators this case; this operator multiplied by 3, operator experience this one multiplied by 3.

So, accordingly you just so multiplied by 3 and you are getting this one ok so, anyhow let us complete this one. So, inexperience will give you this multiplayer, opposite technique gives give you this one and low morale give you this value.

You have 0.003 that generic error probability; so, generic error probability and then multiplied by the inexperienced factor, multiplied by the opposite technique factor, multiplied by 1.12 that is basically low morale factor. So, all those small things ultimately leading to this value 0. 036 so, on an average you can say that this is basically that job on 0.04 that is what is the human error probability.

So, that means human error probability first you find out the nominal probability, then multiply the error producing condition effect. So how it is calculated? It is calculated in this manner, if the maximum rate is 3 this will be subtracted by 1 and then you must know what is the proportion of effect that will be multiplied and everywhere you are adding 1. So, this is the calculation it is given in Kirwan 1996.

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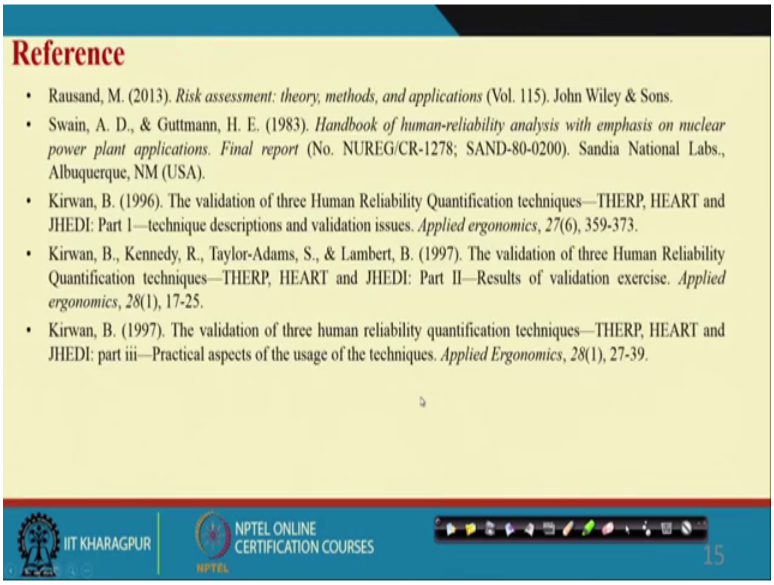

So, then I hope that you got the two techniques; one is THERP, another one is HEART. In both the techniques it is basically the task is very important in the first technique; you do the find out the elemental task and then find out that the all that task if it is done correctly then it is a successful task operation. And then the probability of successful operation can be carried out and given the unsuccessful cases.

That will basically lead to the human error calculation. So, it will be 1 minus success that is the concept part, but again if you will find out that the scientist and the engineers; they worked and ultimately they found out almost all possible situations and conditions and then also come given you the probability human error probability values.

So, you can rely on those probability values because they are more or less working. And in case of HEART what happened so, HEART it is basically a technique which is easy to do for a quick human reliability assessment. And they are several situation that tough situation is task types are created when under an accordingly some probability values or nominal probability values are also given.

And then there are many that performance shaping factors which ultimately effect and a scheme is shown here that how to compute the multiplicative effect of each of the performance shaping factors or error producing conditions. Then all those things will be multiplied with the nominal human error probability to get the final human error probability.

Never the less the plant familiarization that job what is performed and how to break the job down to the elemental task level. And what are the different performance shaping factors that is basically leading to the probability of errors committing or influencing the probability of errors committing. So, all those things is very essential and you must make a team and do a thorough study on it and then use the handbook data and accordingly you take your reduction error reduction interventions similar things. These are all complex things, but simplified by our experts and hope you will be able to use it.

Thank you very much.