**NPTEL**

**NPTEL ONLINE CERTIFICATION COURSE**

**Health, Safety & Environmental Management in Offshore and Petroleum engineering (HSE)**

**Module 2:**
**Accident modeling, Risk assessment & Management**
**Lecture 6:**
**Accident modeling II (continued..)**

Friends welcome to the 6th lecture on module 2 we are talking about accident modeling risk assessment and management under the brace of HSE course in NPETL IIT Madras this lecture is of course a continuation of the 5th lecture I request the viewers the first look at the 5th lecture and understand before we look at the 6th lecture because this is a continuation part if the last lecture. In the last lecture we have been discussing.

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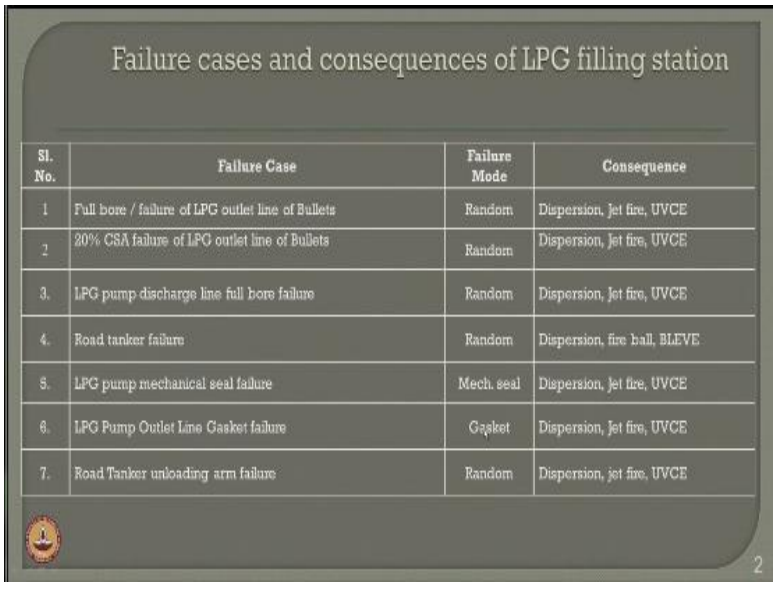


The different failure cases and consequences of a case study of LPG filling station located at two different places geographically different failure cases where identify full mode failure of the

LPG outlet line of bullets 20% gross section area failure LPG bump discharge line full bore failure road tanker failure LPG bump mechanical seal failure LPG bump outlet line gasket failure and road tanker unloading on failure these where the different failure cases for which the consequences could be deposition jet fire cloud exposition BLEVE and fire ball etc..

So we have been discussing partly the disposition in let fire in the last lecture yesterday you please understand that the failure more of all these failure cases are more less random except some of them may be totally dedicated to the mechanical systems which can also be corrected using a detail FMEA analysis.

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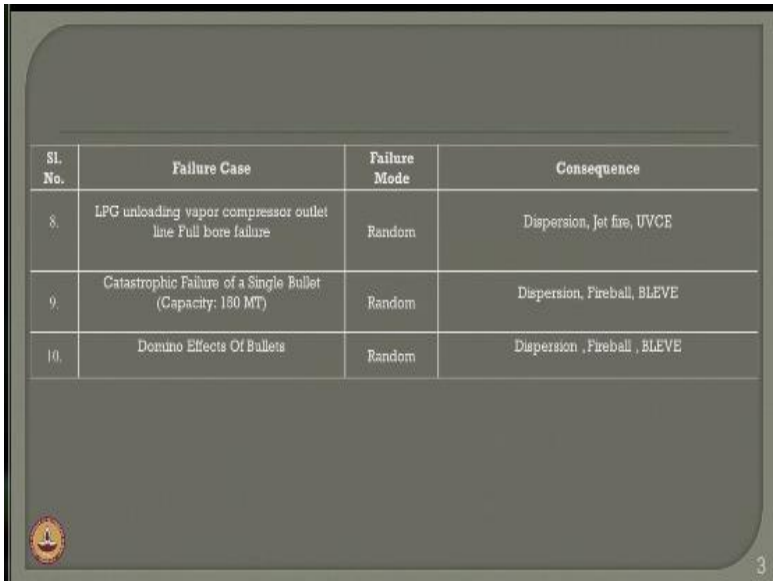


Sub sequently we also said LPG unloading vapor compression out let line full bore failure catastrophic failure of the single bullet and domino effects of bullets sequential gasket getting effect can also be a random mode failure which can result in fire wall BLEVE and dispersion.

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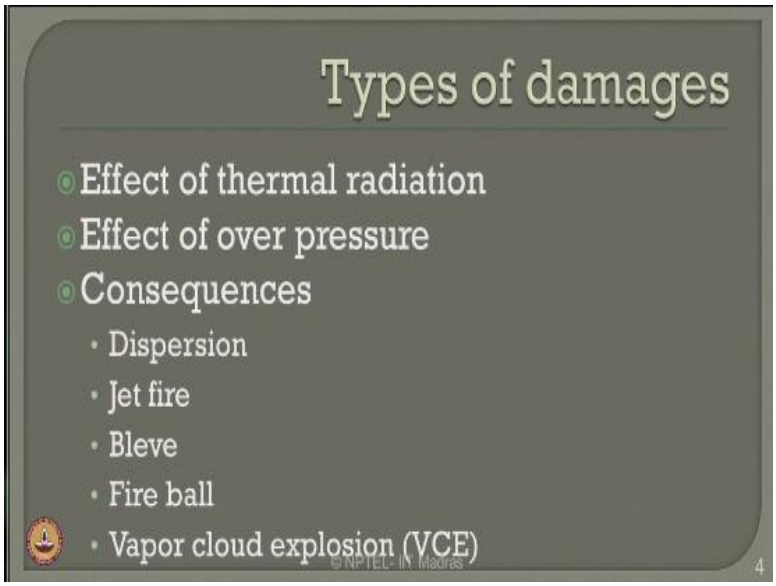


There are different damages we saw effect if thermal radiation effect of over pressure and the consequences derived from this damages could be dispersion jet fire, Bleve, fire ball and VCE in the last lecture we discussed about the consequences of disposition and jet fire on both the plants located ABC and xxx locations respectively

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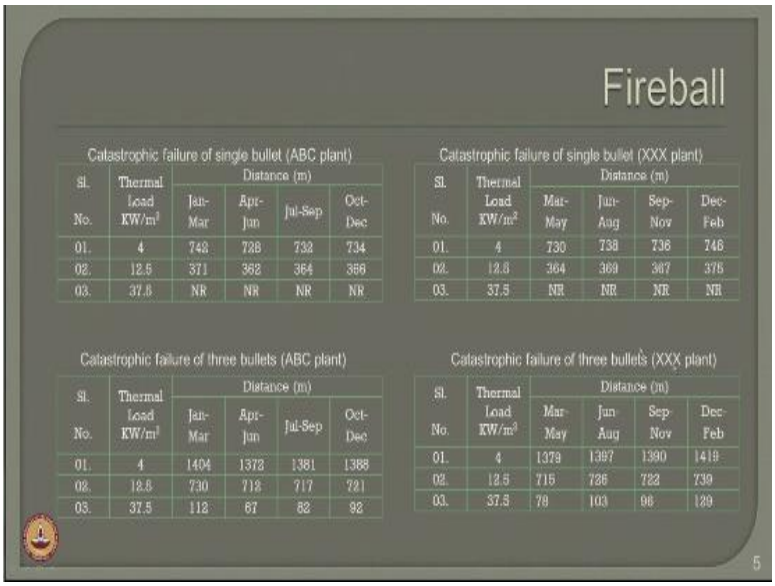


Now we will continue to discuss with this now what will be the consequences of the fire ball on both the plants let us say the left hand side shows the consequences of fire ball on the ABC plant and the right hand side table show the consequences on the XXX plant the catastrophic failure of single bullet catastrophic failure of three bullets and similarly at ABC and xxx I mean discussed here and we all understood that for a given thermal rotation the intensity load varying from 4 to 37.5 kw/$m^2$ for an average period for an year the distances in terms of fire ball is evaluated for different cases for different locations for different kinds of failure may be a single failure may be three gasket failure of three bullets sub sequently.

Now we can understand that the same distances kept on increasing for the whole period of the year when you talk about the thermal load variations from 4 to 37.5 and when the gasket effect of three bullets are happening obviously the hazard distances are the same distances for your fill rising from the fire ball or kept on increasing where as in this case it is not so and the same thing also seen in both the locations ABC as well as to plus plant.

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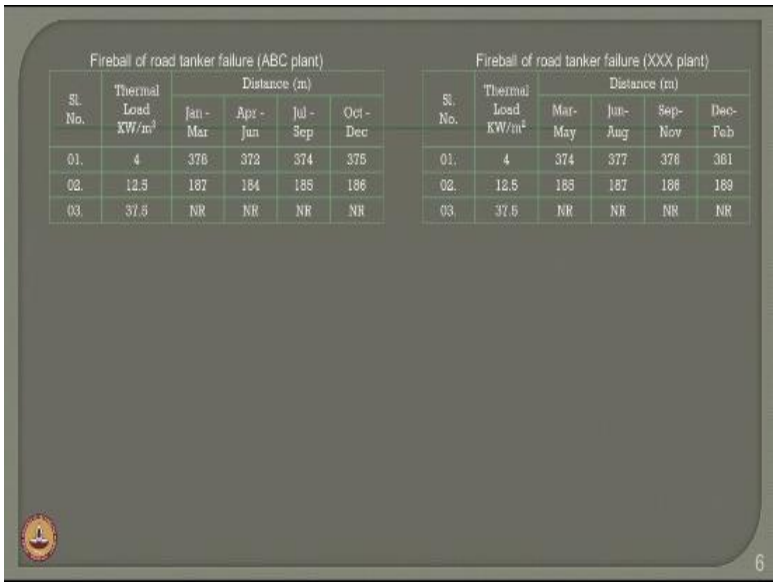


Similarly fireball can arise also from a road tanker failure on both the locations ABC and xxx we can see that the hazard distances or LFL distances arrive for the fireball failure is also shown for three thermal load intensities varying from 4, 12.5 and 37.5 $KW/m^2$

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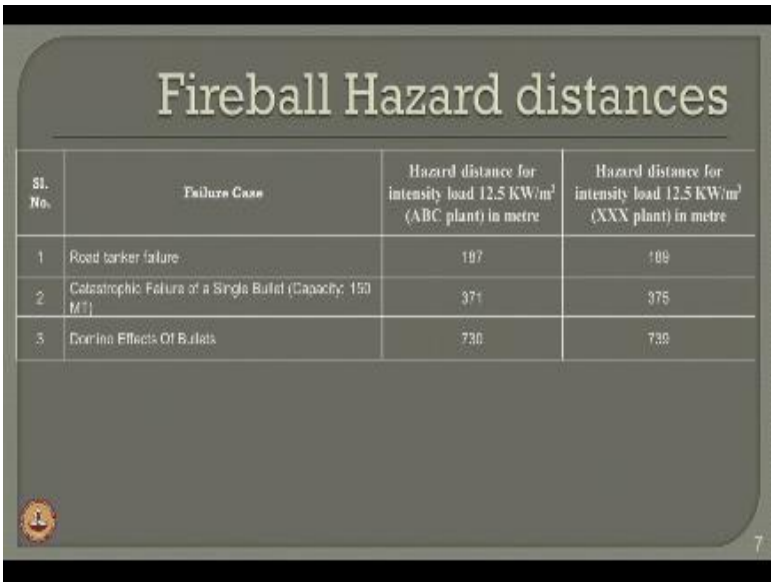


Now based on this we attempted to determine the fireball hazard distances for different kinds of full failures for a road tank failure, catastrophic failure of a single bullet of a capacity 150 metric tank and domino effects of bullets we get hazard distances for intensity of 12.5 which is kept common for both the cases in terms of meters where I see the domino effect generally has the more hazard distance compared to that of a road tanker failure.

This highly local that has a domino is nothing but the cascading effect of C is a failure of bullets which has more hazard distance in both the locations. However you will also see the fireball hazard distance computation is not significantly influenced by the location of the plant because you know the stability class for different plants at A, B, C and XXX are not same even the weather conditions the wind velocity where vary even then the fireball hazard dances is not inflamed by the location of the plant in the geographic manner.

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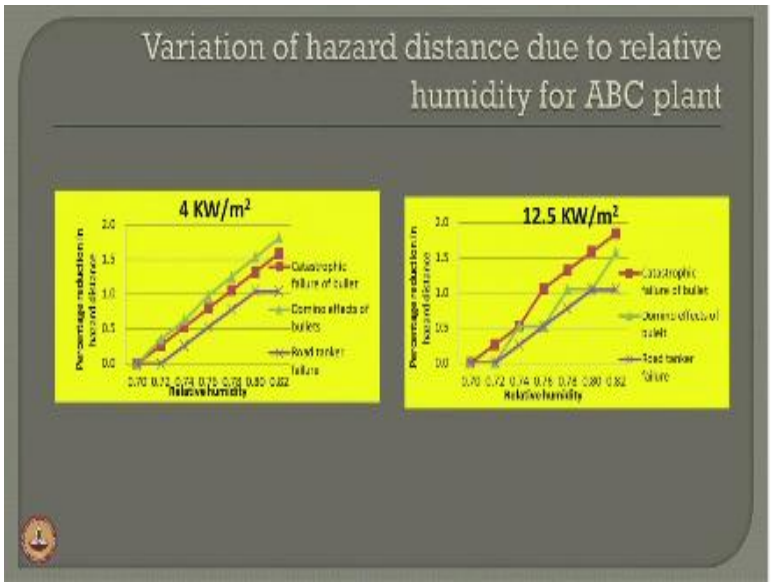


Then we attended to study the various hazard dance due to relative humidity for the A, B, C plant again for the preliminary intensity of 4 and 12.5.

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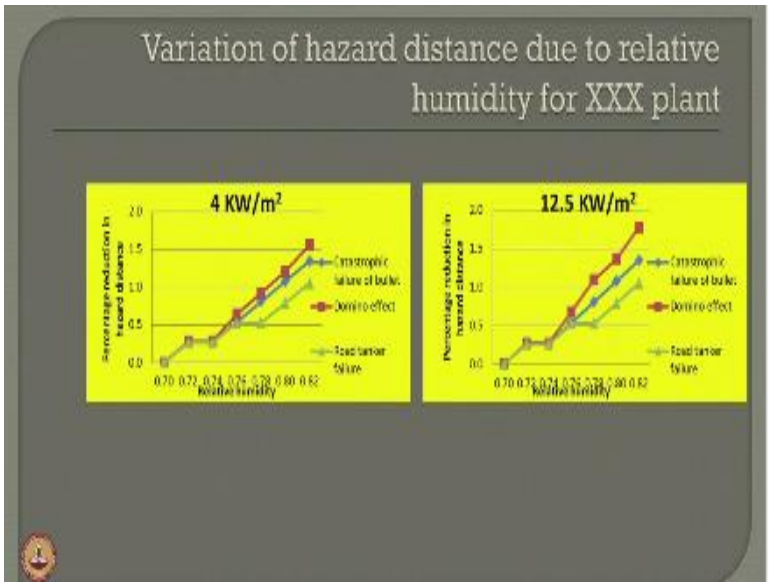


We studied these for both XXX plant and A, B, C plant respectively.

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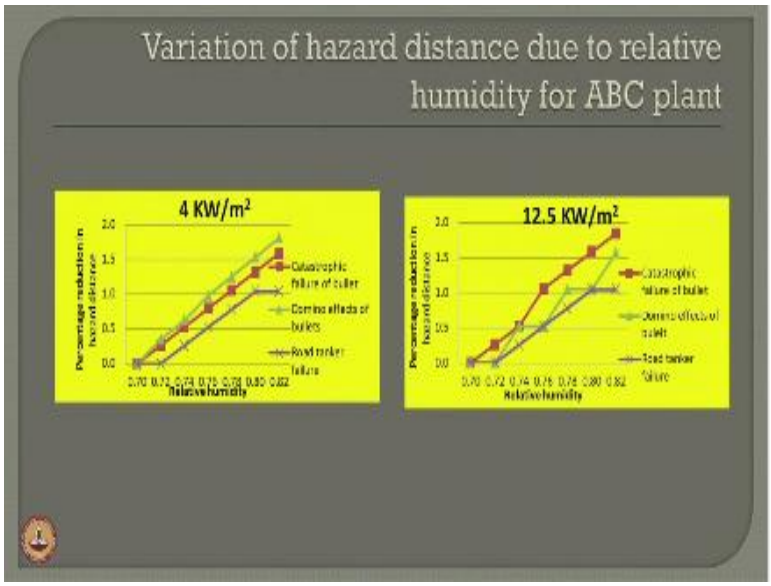


You see that for a different kinds of failure catastrophic failure of the bullet domino effects of the bullet and road tanker failure you will see this more or less increasing that is the percentage hazard reduction in the hazard distance is in the higher side as respect to the relative humidity kept in increasing and this I almost seen for both radiation intensities for 4 and 12.5 respectively.

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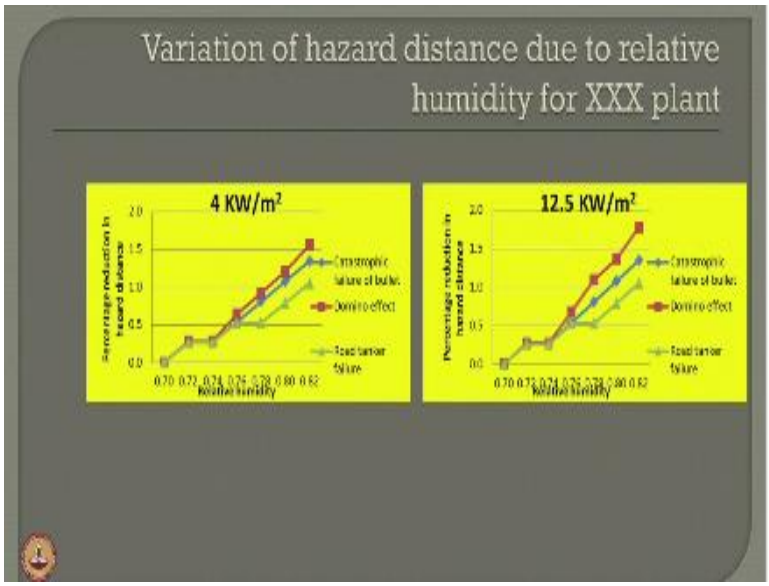


Of course a similar trend is also absorbed in the other location in XXX plant.

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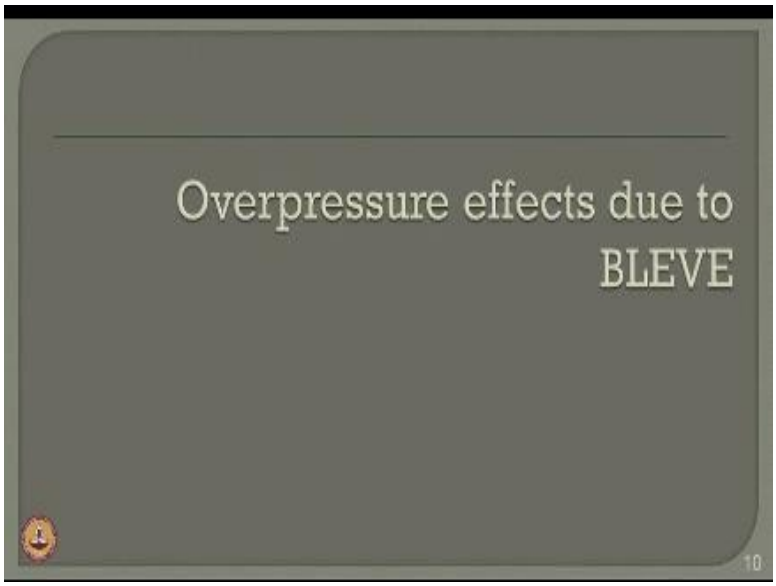


The second focus was subsequently in today's lecture is, what is a consequence of over pressure effect due to BLEVE arising in both the plants.

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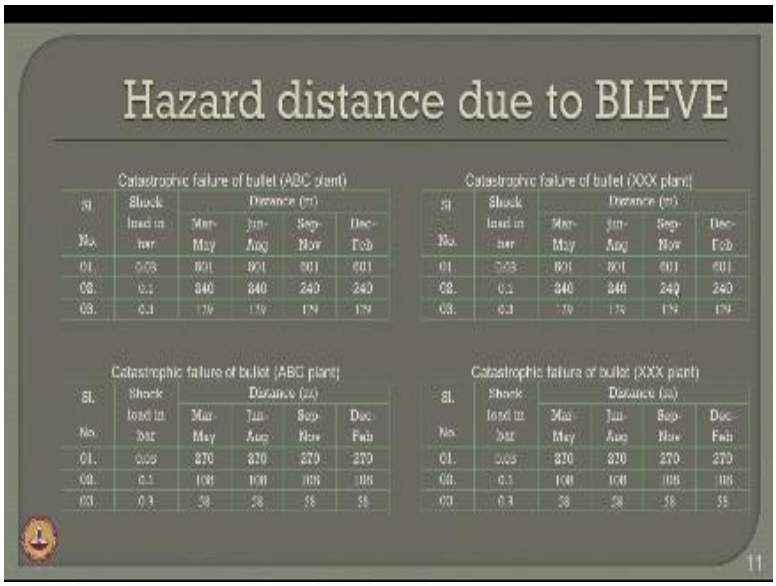


Sp the left hand side table shows the effect of catastrophic failure of the bullet on A, B, C plant and cascade effect of series of bullets on the plant A, B, C whereas the right hand table shows the same effect subsequently on the XXX plant, of course the study is been done for a shock load in terms of bar because shock loads determine what will be the consequence of BLEVE arising because we have already seen explosion is always carried by the shock wave front.

So shock low has been considered for a different intensity in terms of bar and the hazard distances has been worked out as BLEVE consequence arising from the catastrophic failure of the bullet and failure of the bullet separately, this series of bullets is bullets actually is a cascading effect, we will see that the effect of hazard distance due to BLEVE arising is note because this is highly local as far as the single failure bullet is concerned whereas the cascade effect you see that it is not affected much.

Because the distances is getting reduce compared to that of the failure case of bullet in case of in A, B, C a similar trend is also seen in case of XXX plant, you will also notice that the hazard distance arising from BLEVE is not significantly influenced by the location of the plant that be A, B, C having a different weather condition being XXX which has different weather condition

the hazard distance does not vary significantly due to arising from BLEVE in this kind of accidence.

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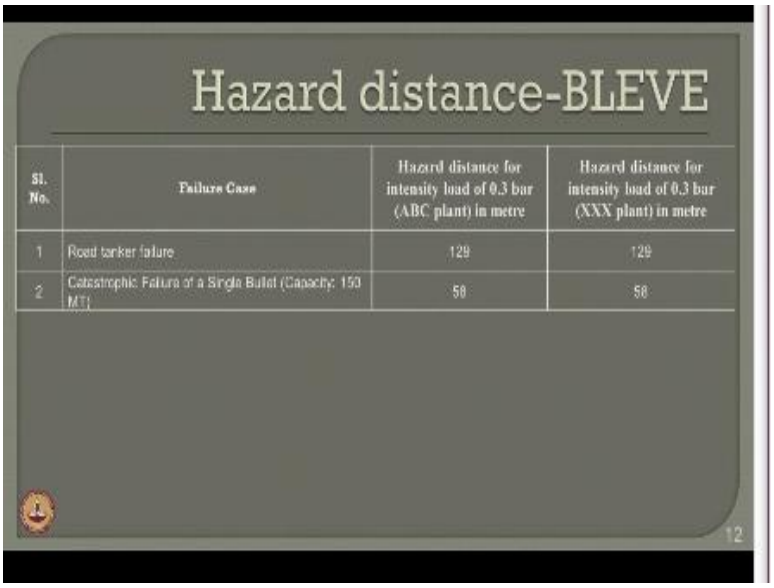


One cannot estimate hazard distance for a different failure case like a road tank failure and catastrophic failure of single bullet you will see that for a single bullet the hazard distance is highly local compared to the road tank failure because BLEVE is an explosion release model which tries to spread over a large area which affords a public population in a larger way.

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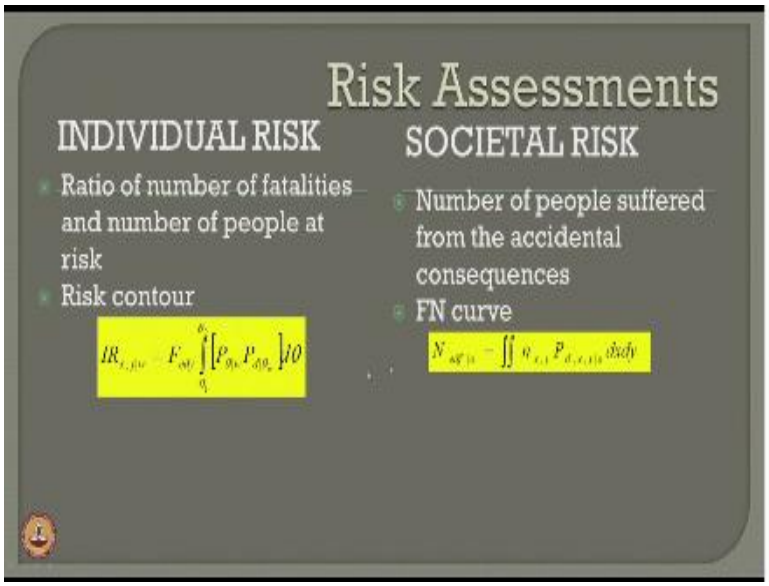


Now based on these studies one is interested to know now the risk assessment, now we want to assess the risk arising from these failure cases and this corresponding consequence. Now the risk assessment can have two parts one is the individual risk, one can be a societal risk. Individual risk we all know is a ratio of number of fatalities and number of people at risk which can be expressed in terms of risk contour. Whereas societal risk is expressed as the number of people suffered from the accidental consequences it is generally expressed in terms of FN curve.

That equations given to you on either side will give you the plot or the equation to calculate the individual risk and the societal risk in the FN curve directly from this equation.

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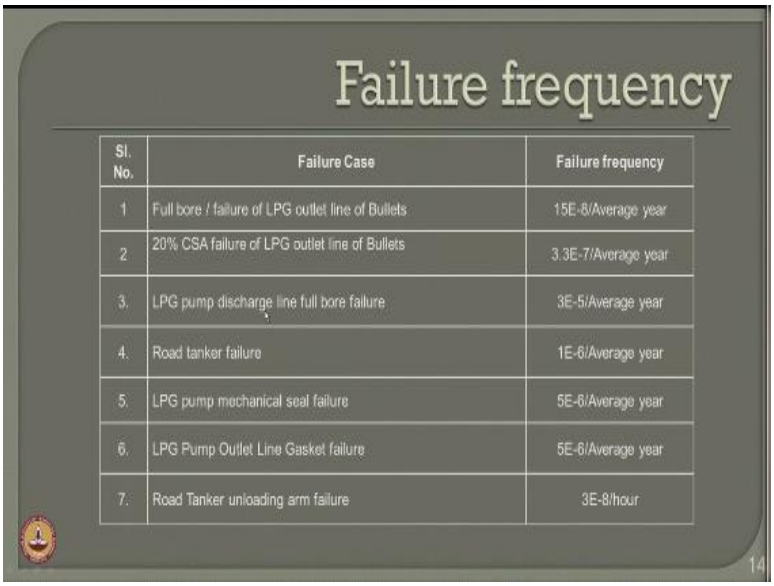


Where is being plotted now, based on the study conducted we arrive at the failure frequency for different failure cases which are envisaged in this specific problem. Let us start looking at each case separately, let us full bore failure of an LPG outlet line of the bullets. Now the failure frequency is about $1510^{-8}$ per an average year. Whereas the failure frequency keeps on increasing for different case of failure except that of road tank failure which is very rare. So the full bore failure has got $15E^{8}$ whereas 20% CSA failure, LPG pumps, road tank failure, road tank unloading arm failure which is having a very large frequency.

LPG mechanical seat failure extra. Now looking at this failure cases one can easily observe that a common frequent failure is the discharge pump, so it is important to know that one should pay more attention to this kind of failure discharge pump failure in the LPG stations as we saw from this specific study.

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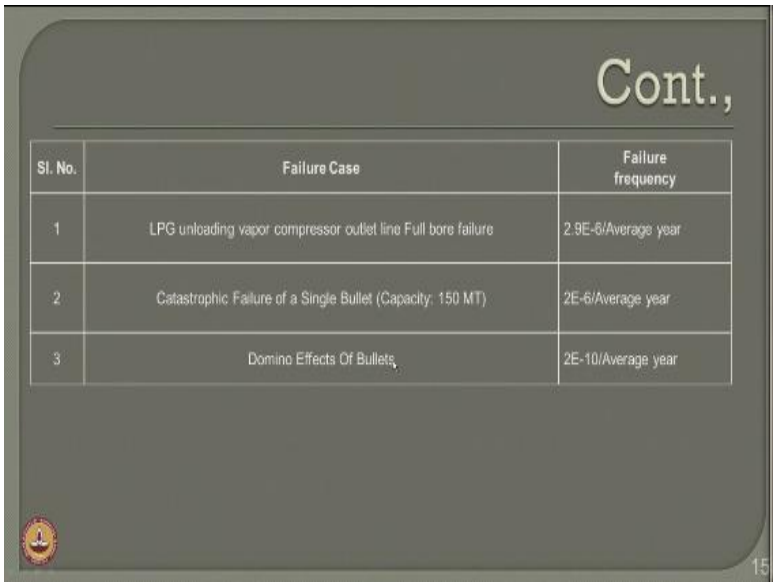


Looking at the LPG unloading vapour compressor outlet, now this is having a very high frequency compared to the earlier case and the maximum frequency what you see in the study of occurrence is domino effects on bullets you generally the cascading effect failure of series a bullets does not frequently happen in LPG stations.

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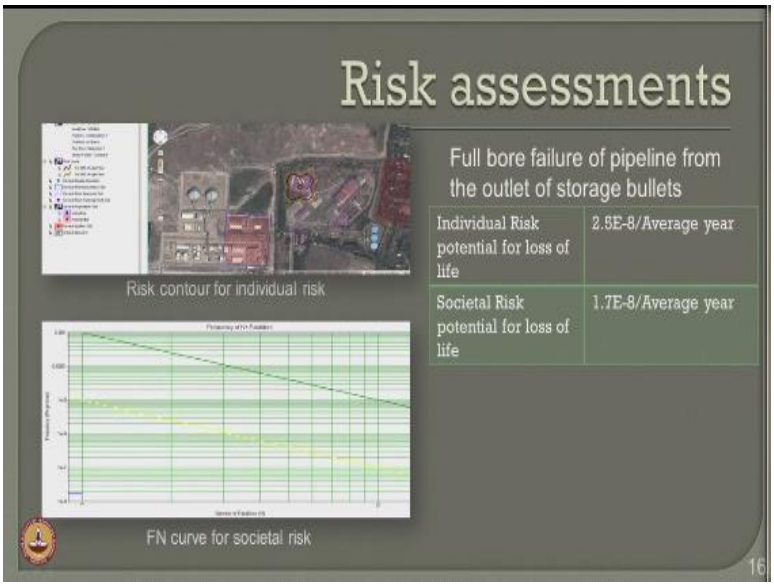


Now as we understand we are now trying to plot the risk contour for individual risk and FN curve for the societal risk. let us take case by case, now first case discussed here is a full bore failure of a pipeline from an outlet of a storage bullet at ABC plant. In the individual risk is arrived as about $2.510^{8}$ average year whereas societal risk is about $1.710^{8}$ average year as you see from this. ladies and gentle men is very interesting and important to know that these plots of risk contour and societal risk plots of FN curve or automatically arrived as an outcome for the software analyzed and used in the study.

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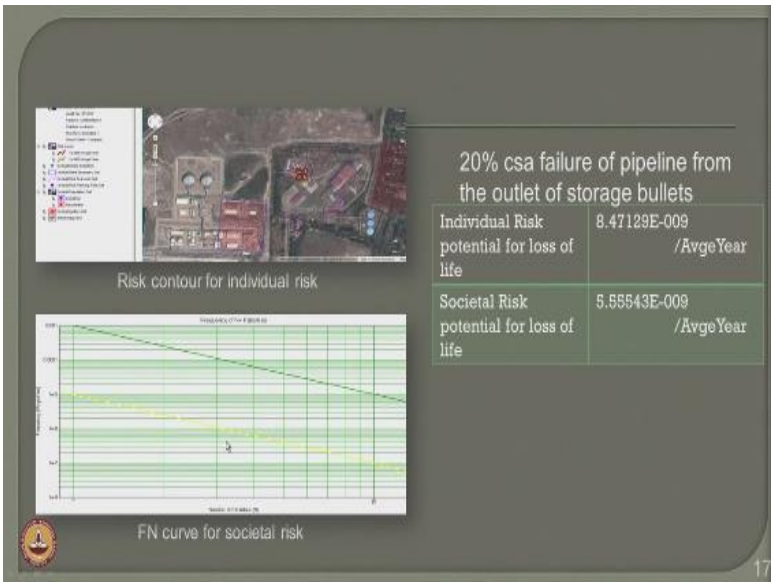


Similarly for a 20% CSA failure with the pipeline from the outlets of the storage bullet individual risk has been seen as about $8.4710^{-9}$ whereas societal risk is about $5.5610^{-9}$ where the plots are shown very clearly here for an individual risk and for the societal risk separately.

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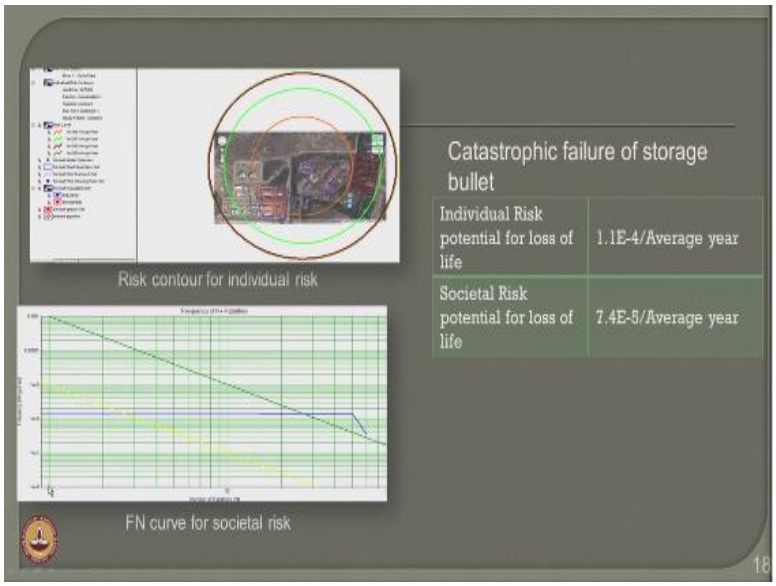


Of course when we look at the catastrophic failure of the storage bullet, now the frequency is higher it has $1.110^{-4}$ now we are contours mean developed and it is been shown that how the safe hazard distance can be extended circum financially from the epicenter of the failure of a catastrophic failure of the storage bullet. Similarly when we look at the societal risk FN curves you will see there are three plots available one is the yellow one should obviously be between the blue and the green one indicating that it is safe. Whereas in this case you will see it is even mush safer for certain number of fatalities when the frequency is lower.

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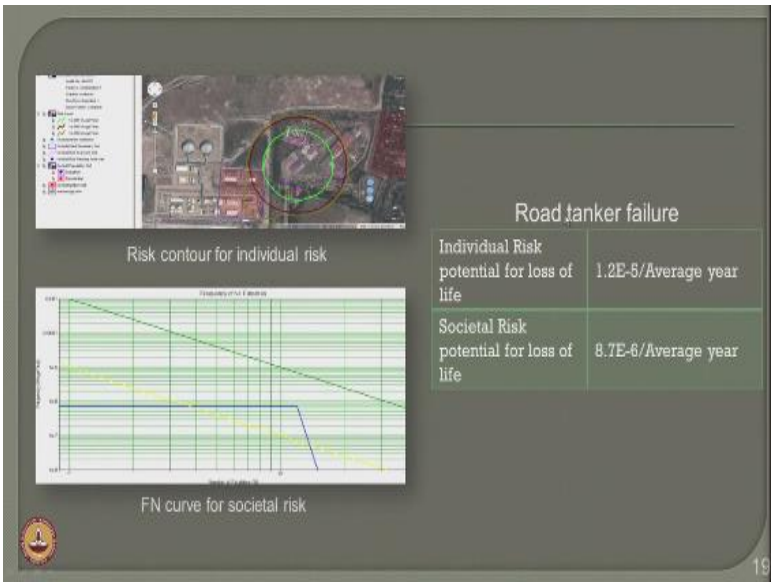


Talking at the road tanker failure this also one of the local failure road the frequency arrived is about $1.2E^{-5}$ for the individual risk where as for societal risk in this as I as $8.7\ 10^{-6}$ for the plot shows very well that it is between the band of acceptable limits on the societal risk and this curves very clearly show from the periphery of the center of the road tank failure the hazard distances which we discuss in the last slides have in plotted graphically from the software directly.

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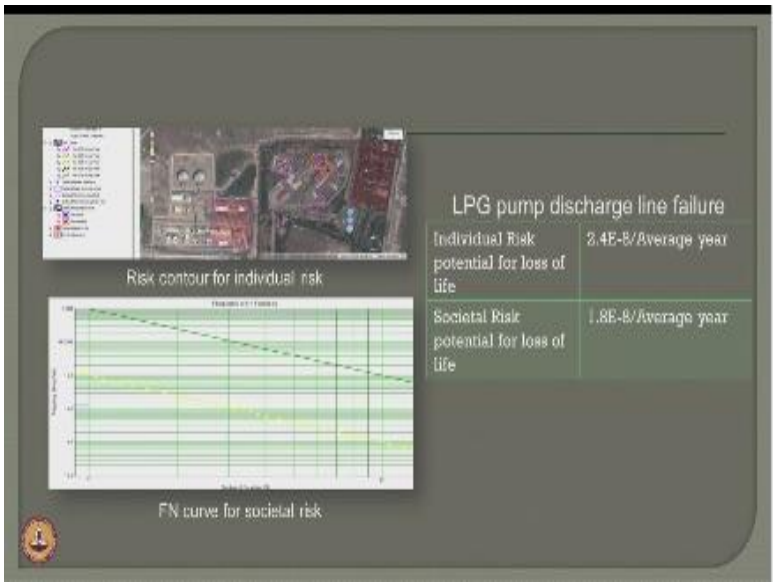


Looking at the LPG pump discharge line failure for ABC plant the individual risk is shown as $2.4\ 10^{-8}$ where as the societal risk is about $1.8\ 10^{-8}$ is slightly larger compared that or be individual risk in LPG pump discharge line failure.

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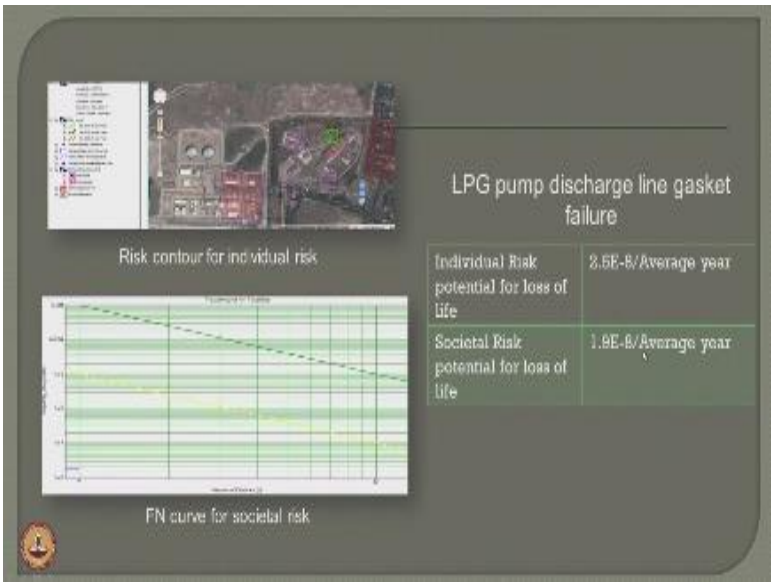


The LPG pump discharge line gasket failure shows an individual risk of about 2.5 $10^{-8}$ it is only send only in this area and where is the place where the LPG pump discharge is being located in the plant and societal risk is very much within the band down acceptable limits which is 1.910 $^{-8}$ for average here.

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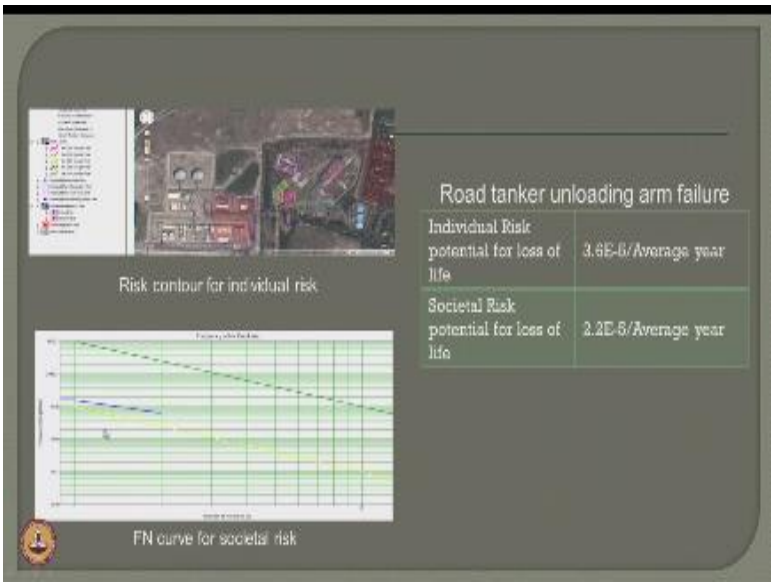


As I told you the road tanker unloading on failure for tanker unloading on is a specific geography glucosion the given plant this is about 3.6 $10^{-5}$ average here there is a societal risk is slightly higher compared to this which is 2.2 $10^{-5}$ it is beyond the boundary of acceptable limits of the risk can flow.

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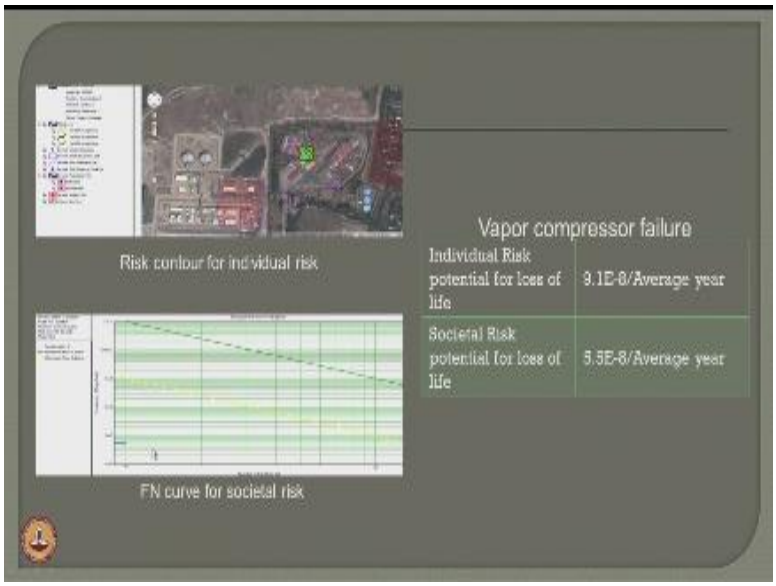


Vapor compression failure which is gain local in a specific point where the fatal has been discharged the frequencies found to be 9.1 $10^{-8}$ compared to the certain risk which is around 5.5 $10^{-8}$ and you can see that the societal risk is again it is in the bands on the acceptable values.

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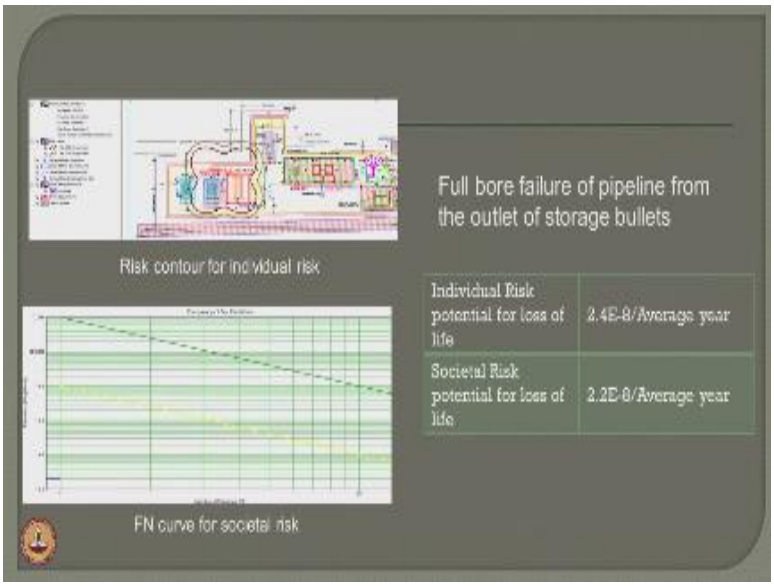


Talk about the full bore failure of the pipeline from the outlet of storage bullets individual risk is focused to get about 2.4 $10^{-8}$ there are societal risk is about 2.2 $10^{-8}$ which is again the acceptable limits of the.

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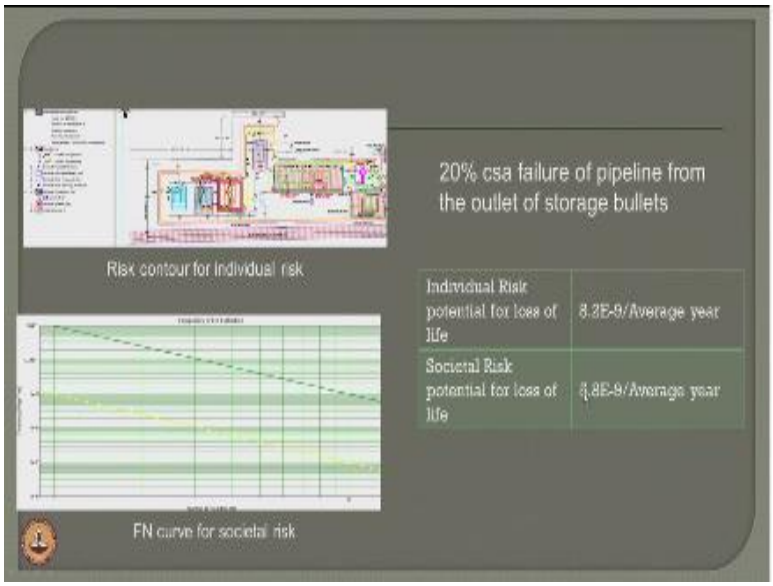


Oil gas industry when we talk about 20% cost in a failure with the pipeline for the entire layout of the plant individual risk feels to be very high frequency of $8.2\ 10^{-9}$ but a societal risk is in the lower frequency how about $5.8\ 10^{-9}$ however both of them are within acceptable limits has per the --

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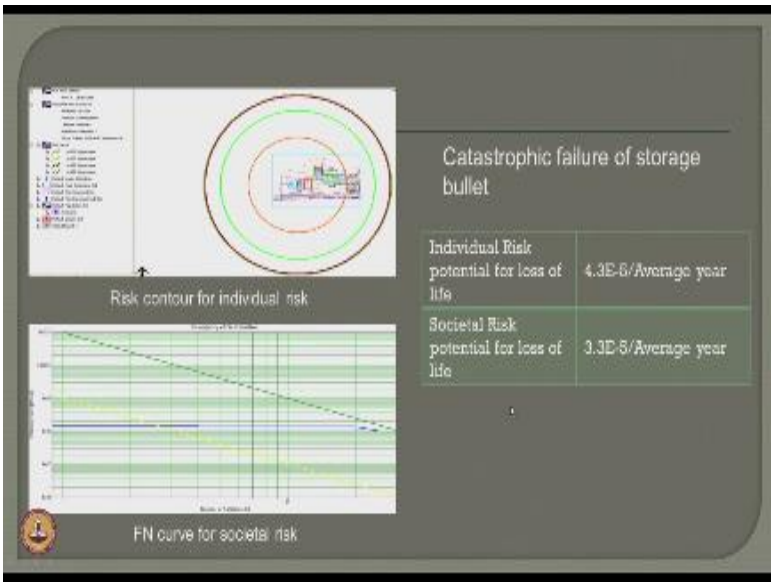


Oh yes 80 standards similarly look at the catastrophic failure in the storage bullet the contrast spherically show that what it is average of about 4.3 10 – way average here the hazard distance are computed just on the verify or the center of the catastrophic failure gather storage bullet is being parked.

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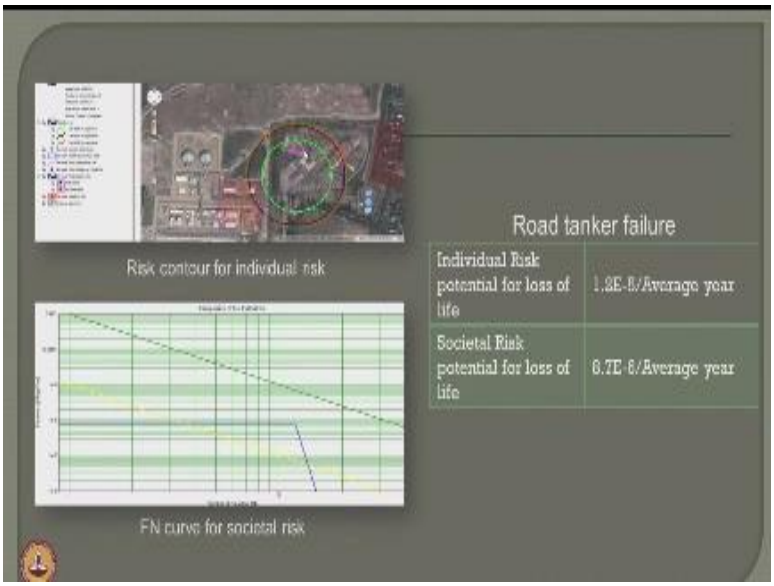


When you talk about road tank failure of XXX model it shows 9.1 $10^{-6}$ and 8.5 $10^{-6}$ respectively for individual and societal risk for the plant.

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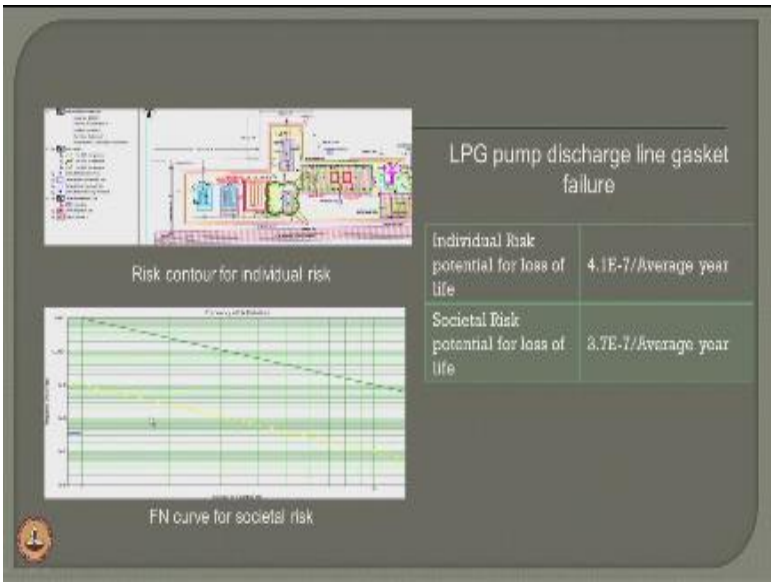


If you talk about LPG pump discharge line failure for xxx plant then again the AP center is shown in different contacts which gives me a value of $5.4\ 10^{-7}$ compared that of $4.9\ 10^{-7}$ across societal risk we talk about the gasket failure in LPG pump discharge line the frequency that shown in the table and they are much within the acceptable limits of oil stand gas industry standards.

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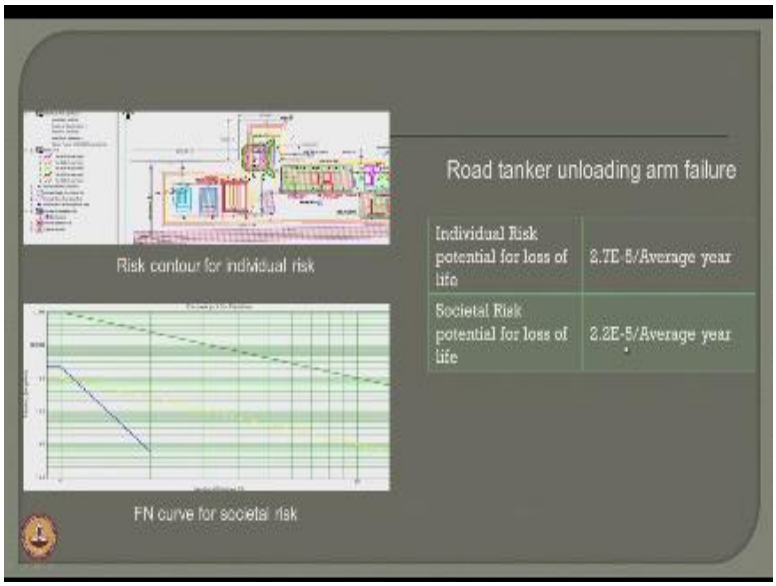


The road tanker unloading arm failure is a different location compared that ABC plant as got where individual risk of 2.7 $10^{-5}$ which is slide to higher compared the ABC plant where a societal risk is again within the acceptable plants which is around 2.2 $10^{-5}$.

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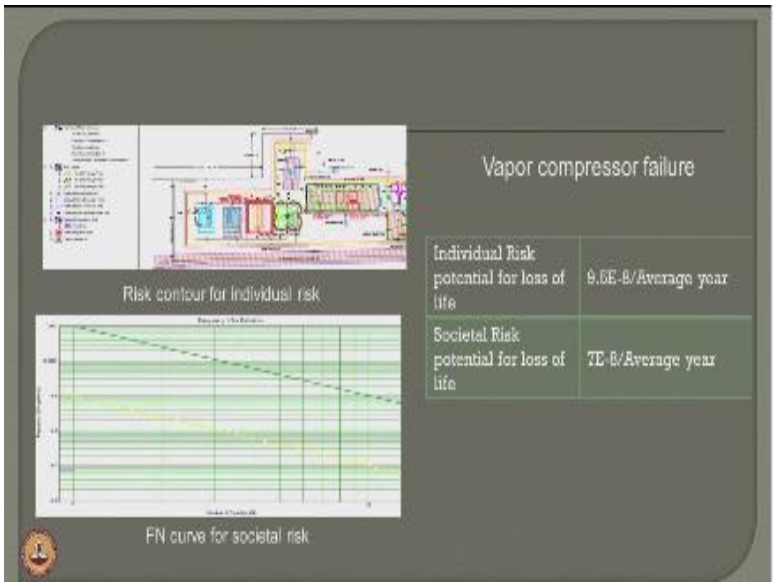


The vapor compression failure xxx plan is our high frequency of 9 point fit and 4-8 located on a specific plant were the ferry bullets are parked.

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| Sl. No. | Failure Case | ABC plant | | XXX plant | |
|---|---|---|---|---|---|
| | | Individual risk (per average year) | Societal risk (per average year) | Individual risk (per average year) | Societal risk (per average year) |
| 1. | Full bore failure of LPG outlet line of Bullets | 2.8E-006 | 1.7E-006 | 2.4E-006 | 2.2E-006 |
| 2. | 20% CSA failure of LPG outlet line of Bullets | 8.5E-008 | 5.6E-008 | 9.2E-009 | 5.8E-009 |
| 3. | Catastrophic failure of storage bullets | 1.1E-004 | 7.4E-005 | 4.4E-006 | 3.3E-005 |
| 4. | Road tanker failure | 1.3E-005 | 8.7E-006 | 9.1E-006 | 8.5E-006 |
| 5. | LPG pump discharge line full bore failure | 1.7E-006 | 1.2E-006 | 5.4E-007 | 4.9E-007 |
| 6. | LPG Pump Outlet Line Gasket failure | 2.5E-006 | 1.9E-006 | 4.1E-007 | 3.7E-007 |
| 8. | Road Tanker unloading arm failure | 3.6E-005 | 2.3E-005 | 3.7E-005 | 3.2E-005 |
| 7. | Vapor compressor line failure | 9.1E-008 | 5.5E-008 | 9.5E-008 | 7E-008 |

Now let us compare the risk obtain our different failure cases for different plants ABC and XXX as I told you one cannot directly compare the risk constitutively obtain for different plants because the stability class the weather condition the relative humanity etc for or not saying for the two geographical locations of the plants. However for a compared study let us see both of the values simultaneously on the screen for full board failure of an LPG out left line which come from out of the bullets.

You will see that ABC plan shows an individual risk about 2 point fit and 4 – 8 that is societal risk is much higher compare to that of this on the contrary if we look at the triple explants the values are almost comparable and we can drivel inference from here saying that what about the geographic location maybe stability class relative humanity the full more failure is not influence by this conditions in terms of in duel risk as well as for settle risk.

The other comparison we can make is in both the cases the societal risk frequency is much higher compare that of in duel risk in both the locations, similarly for 20% per sections here failure capacity to be failure of the storage bullets road tanker failure LPG pump discharge line failure LPG gas get failure road tank and unknowable non failure and vapor compression line

failure one can prepare and compare the frequencies of individual risk and societal risk as we have spend as an out come from the study from the software.

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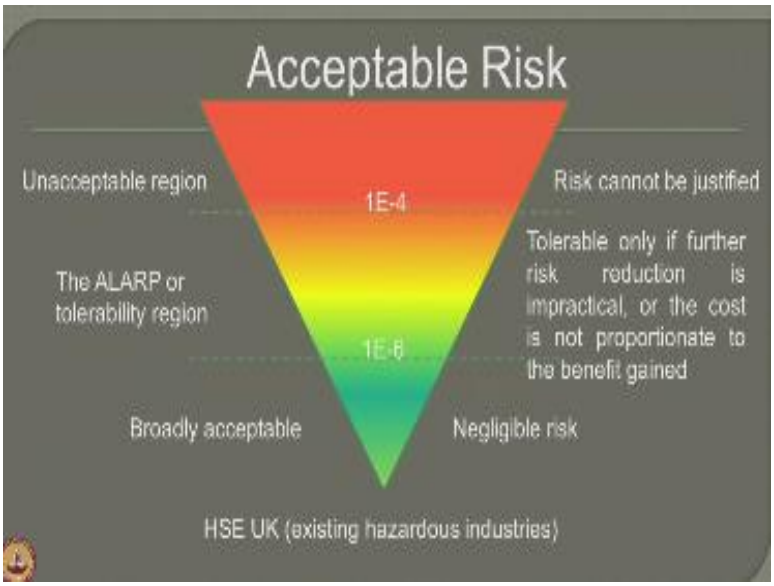


Now we take the plan this acceptable risk level in terms of ALARP triangle now ALARP triangle in this example as been used by the Government is given by a HSE UK because based upon existing hazard is industries in UK ALARP triangle is in suggested by HSE UK which is being use for comparison in this present study. Or the values of $10^{-6}$ and $10^{-4}$ clearly show the border line of unacceptable and ALARP region. However the values of frequency or below $10^{-6}$ let us say in most of the cases they are broadly acceptable for oil gas industries.

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So now super imposing the values based upon ALARP acceptance level of HSE UK we see very clearly that the value shown in red and yellow are unacceptable and in ALARP regions respectively however this s border case therefore we put them in red so we clearly understand for an ABC location of the plant the capacity failure for storage a bullets in unacceptable failure however the same failure for a different geographic location becomes an ALARP region.

So friends please understand the failure cases and the consequences and the frequency which arrive and ALARP distances are influence by the location and geographic layout of the plant obviously however it is interesting for all of to understand that since this industries have been built maintain properly by OS id standards. You will see most of the cases the frequency of failure are within acceptable limits try ALARP conditions of HSE UK. Accept for a campest to be failure of the storage bullets so based on this study.

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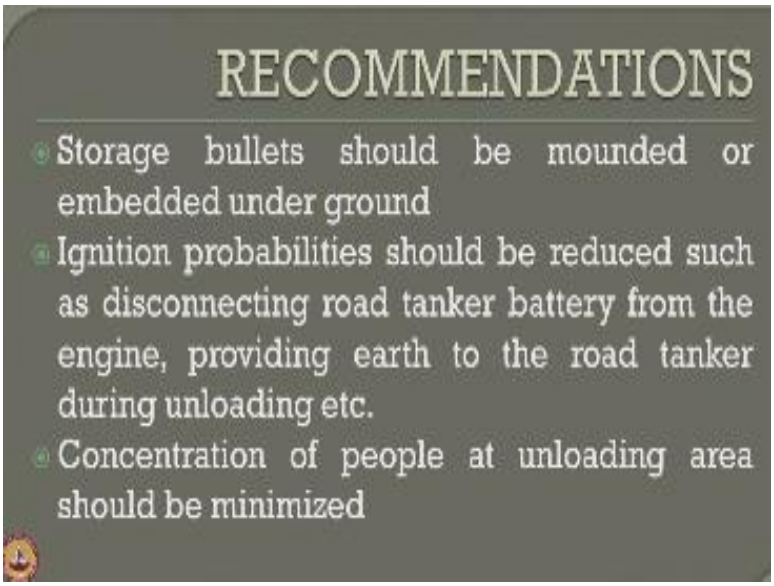


A few recommendations were made to both this plants with a list now the storage bullets should be either mounded or embedded underground, ignition probabilities should be reduce such as disconnecting road tanker battery from the engine providing proper earth in to the road tanker during unloading etc. they should also recommend and we have recommended concentration of people at unloading area to minimize the concentration, so the recommendation implemented.

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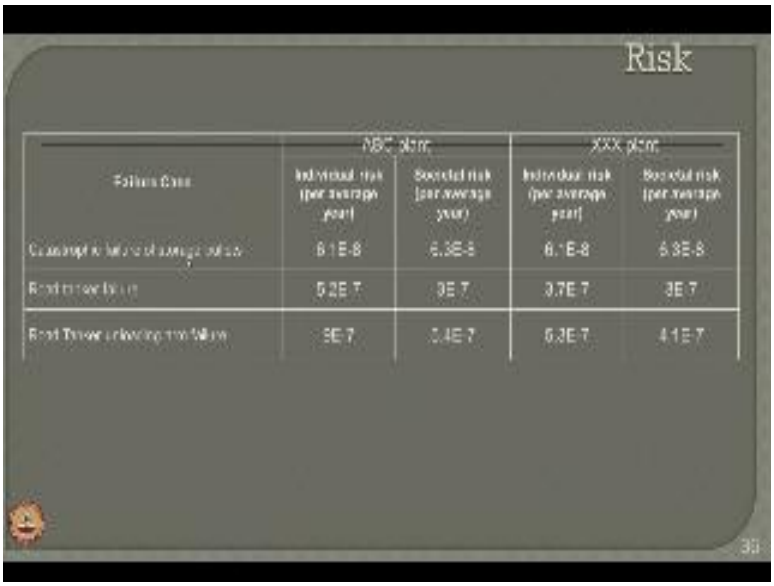


The studies again reconducted an ABC plant an access plant only on those regions where the study was showing alarm and un acceptable for example look at this table.

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| Sl. No. | Failure Case | ABC plant | | XYZ plant | |
|---|---|---|---|---|---|
| | | Individual risk (per average year) | Societal risk (per average year) | Individual risk (per average year) | Societal risk (per average year) |
| 1 | Full bore failure of LPG outlet line of bullets | 8.0E-006 | 1.7E-028 | 8.4E-006 | 8.8E-006 |
| 2 | [illegible] | 8.8E-007 | 8.8E-029 | 8.2E-007 | 5.8E-009 |
| 3 | Catastrophic failure of storage bullets | 1.1E-005 | 1.6E-028 | 4.4E-005 | 5.3E-006 |
| 4 | Road tanker failure | 1.2E-006 | 6.7E-029 | 9.1E-006 | 8.9E-006 |
| 5 | LPG pump delivering line full bore failure | 8.4E-006 | 1.8E-028 | 8.4E-007 | 4.9E-007 |
| 6 | LPG Pump Outlet line Gasket failure | 3.5E-006 | 1.2E-028 | 4.1E-007 | 3.7E-007 |
| 7 | Road Tanker refueling area failure | 8.0E-006 | 2.8E-028 | 8.7E-006 | 8.8E-006 |
| 8 | Vapour dispersion due to failure | 8.1E-006 | 8.3E-026 | 8.0E-006 | 7E-006 |

Only in this three locations that is catastrophic failure of storage bullets or tanker failure and o tanker un harm failure has indicated an acceptable and unacceptable regions are failure so they have been revised again after recommend is implemented and now they see all of them are coming within acceptable levels so recommendations are implemented and the plant safety has been accenting in terms of its risk to the society as well as individual working in the plant.

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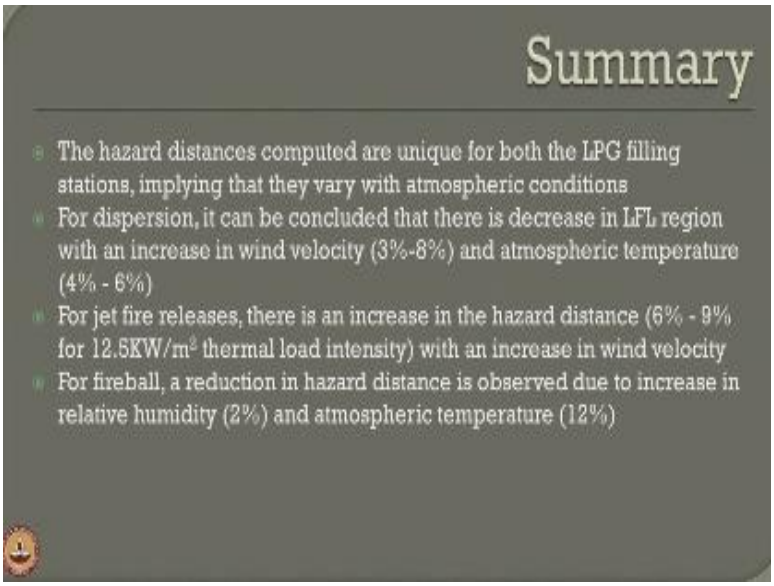


Let us look at the summary of the both the lecture quickly the hazard distances computed are unique for the both the LPG stations implying that the vary with atmospheric conditions for dispersion one can conclude that there is a decrease in LFL region with an increase in wind velocity and this variation is about (3-8%) and decrease LFL region with increase in atmospheric temperature which varies above (4-6%)

For jet fire releases there is increase in hazard distance about 10% for a 12.5Kw /$m^2$ thermal load intensity with an increase in wind velocity ,we will also see the fire ball a reduction in hazard distance is observed with increase in relative humidity ,and this reduction is 2% quantified and for atmosphere temperature variation as high as 12%.

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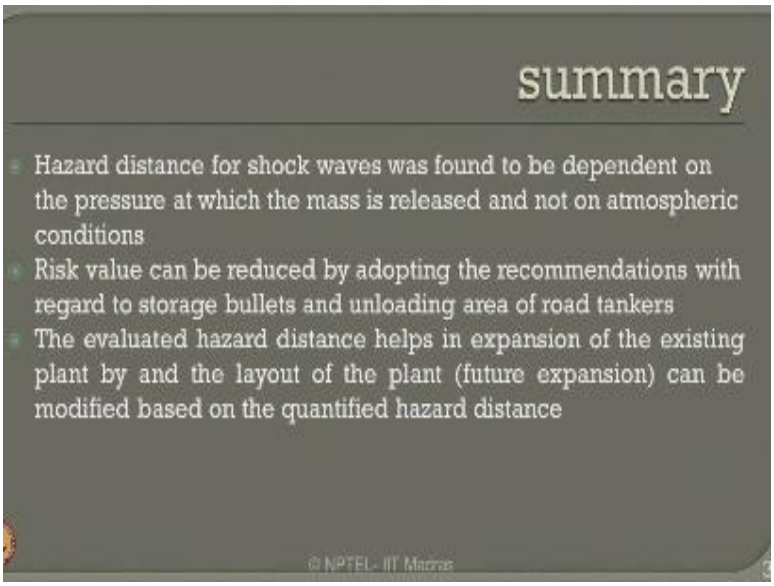


Hazard distances verified for shock waves was found to be dependent on the pressure at which the mass is released and off course they are not dependent on atmospheric conditions at all ,risk value therefore can be reduced by adopting the recommendation with regards to storage bullets and unloading area of road tankers ,the evaluated hazard distance helps in the expansions of the existing plant and the layout of the plant for future expansion therefore modified based on the quantified hazard distances.

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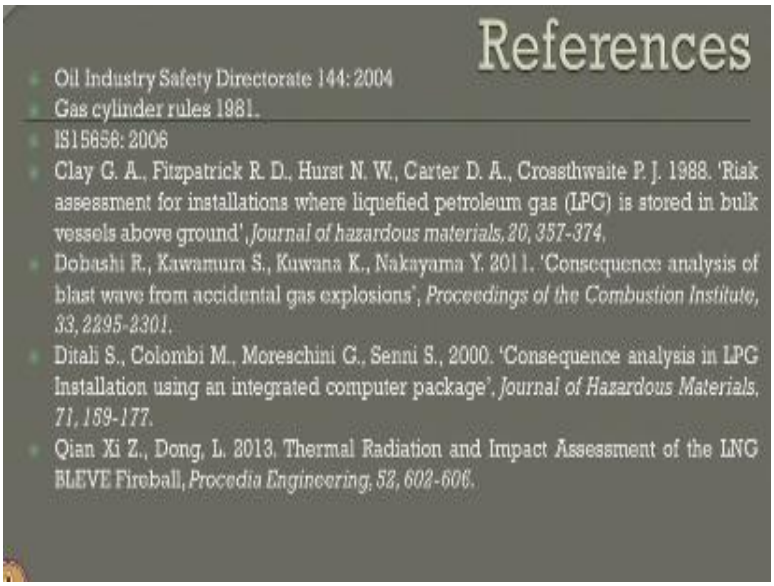


So ladies and gentlemen the study presented is very interesting and it gives a very well risk picture of two locations LPG stations and off course the study supported by different references which showing now on the screen.

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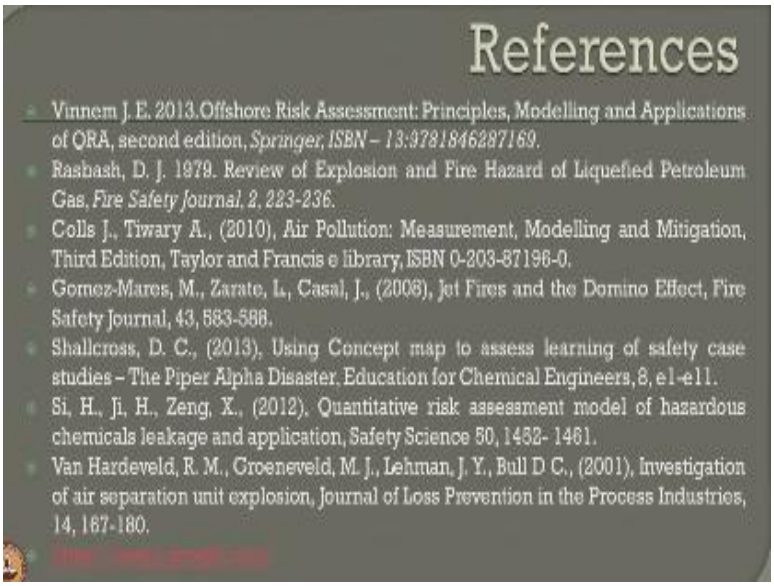

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And I request that you please go through the lecturesone second simutaniously togather so that you understand the serious of failures addressed inboth the cases of LPG plants located at ABC and XXX you will then understand with easily how intesting infrernsis of risk contour socital and individual can derived from studies which can easily done using a software in the next lecture I will try to show you an hands of experience on the software so that you can also use the software readily in input data available to you in input industry  thank you very much.

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