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Transcript

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>> All right. Good morning, everyone. Or good afternoon depending where you are in the world. I understand we'll have some folks coming in from UK at least virtually. Want to welcome you if this is your first time here today. I know many of you were here yesterday to Houston. My name is Max Kieba. Director of program development. This morning we're going to start about a discussion of potential impact radius before we do for those in the room emergency rooms out in the hall. Silent your phones, bathrooms outside to the left near the big mirror. Let folks know particularly virtually we have just give a sense of numbers we have roughly well over 800 registered. Probably the bulk of our folks are dialling remotely so thank you to those that are on the webcast. Roughly just over 300 on the webcast. We probably have, give or take, 150 here in the room on any given time. And those on the webcast and many questions we've been asked here in person, the presentations will be available and recordings roughly within a week or two or so so they will be available. Those dialling via webcast, there is a link on the webcast for asking questions and please do. We are intending this to be interactive portion which we had some yesterday. We'll try to balance it out between questions here in the room and also on the webcast. And we'll do our best to answer as many questions as possible. But we also have a pretty hefty agenda overall. So we may need to cut it short at some point. But again we'll try to do as much as we can to answer questions. With that the first session is impact radius. Those here yesterday you heard from Sara at NTSB. This is particular portion, PIR initiated most recently from Danville Kentucky incident. Those that weren't here yesterday 30inch natural gas pipeline rupture August 31st, 2019. Out of that and many things NTSB does looks at a number of other incidents that perhaps has some other issues related with the potential impact radius or PIR. But out of that recommendation or out of that report came a recommendation to revise the calculation methodology used in PHMSA's recommendations to determine the potential impact radius of a pipeline rupture discussed in the report. Feedback is always a gift. Unfortunately, this feedback sometimes does occur when there are fatalities. In this case there was a fatality. 14 others damaged, fire burned, 30 acres of land. We don't always talk about the victims directly. But there is still a people aspect to this. One thing when I read the report was the human response part of it. And we'll talk about it in context of the calculation of PIR at least the baseline of it. But to that end I did want to acknowledge the one individual that did perish, Lisa Denise Derringer was 58. Semi truck driver. She enjoyed dancing. Being outside, working on her home, riding horses, caring for her dogs and donkeys, enjoying home improvements. But perhaps most importantly she was especially loved being with her grandchildren. So if you haven't had a chance to look at that report, please do. There are a lot of aspects and questions we will come up in this panel are the baseline of the PIR is it reasonable for some of the timing aspects. For instance, part of that report talked about aspects and Sara mentioned this yesterday but again if anyone wasn't here yesterday and this is in the report as well, but from NTSB's perspective PHMSA model assumes one percent

chance of mortality with one person finding shelter this mortality rate assumes a individual would take five seconds after fire to analyze the situation, decide to evacuate, run for 25 seconds at 2.5 meters per second and successfully find sufficient shelter from the ongoing natural gas fire. Determining the probability of human errors complicated when faced with a circumstance like a gas pipeline rupture. There's reference to Idaho national laboratory 2005. Also in the report the ability for a member of the public to respond following a gas pipeline rupture may be complicated by, for example, sleeping, being in interior room where one may not be immediately aware of a pipeline emergency or evacuation or eevacuating other household members who cannot self evacuate the speed with which the member is assumed to run is not general population including very young elderly, mobility impaired or those with preexisting medical condition. Two of the evacuees rescued during the incident by sheriff were both elderly mobility impaired I would say this part of the recommendation does also align with if it hasn't been mentioned yet among DOT strategic goals is looking at areas of equity. So hopefully part of this I will say honestly in the beginning we will probably give you a slow death by PowerPoint but part of that is we're hoping to give you at least a baseline discussion of where the PIR came from and kind of how at least PHMSA is implementing it currently. But then the next part we will also talk. So we'll talk natural gas first. There have been questions, it was brought up yesterday some other commodities like hydrogen are of interest, carbon dioxide. We'll talk about impact circle for for some of those. But we hope to go into a lengthy discussion about do we need to reconsider particularly align with the NTSB recommendation but also expand from there. Alan was here yesterday and mentioned part of why we do these public meetings are to help, one, help share some lessons learned which we hope to do that today but also kind of help building a record where we think we'll be going potentially, particularly in this case to help address an NTSB recommendation. So with that, we will get into the presentation portion. The first portion will be a gas PIR development background. It will be by Mark Stephens, senior engineering consulting with MJ Stephens Consulting to CFER technologies and Mark is affectionately called the father of PIR. I'll let Mark introduce himself more but he'll go to the background of potential impact radius PIR. Mark. And to our speakers, there's a clicker up here and also we will have timers in the back that look for signs that go up on different times five minutes to go, et cetera. Mark.

>> You're assuming I can figure out how to use this.

>> Big green button. Good morning. Thanks for the introduction, Max, I think you referred to what I'm going to say as slow death by PowerPoint. I will try to speak quickly and loudly to offset for that. Yes, my background is I've been working in the area of pipeline risk and reliability since the 1990s. And my company focus my previous company, my employer before I retired, CFER Technologies, did a lot of groundbreaking

development work in the area of quantitative failure frequency, prediction and consequence modeling, and the potential impact radius model that I'm going to talk about today was some of the modeling work that we had done back in the late 90s that lent itself to development of this simplified screening model that we're going to talk about in the presentation. I'm going to take you through.

So with that, I'll get started. So just to frame this, the Potential Impact Radius formula was something I developed at CFER technologies around 2000, it was for estimating the hazard zone resulting from a natural gas pipeline rupture and ignition.

Now, the models that I'm going to talk about are trying to idealize something that's pretty complicated. It's a timevarying largescale fire, and we're trying to turn that into a steady state, groundlevel point source heat emitter for the purpose of developing this model. So we're trying to take something very complicated and simplify it.

In the context of simplification I want to point out when the model was developed and the report that was produced, I worked hard to try and develop a model that would appear simple and easy to understand, because the idea was if people can follow it and understand directionally what it's trying to do, they're more inclined to maybe perhaps accept it. But I do want to emphasize that it does incorporate some factors that try to reduce the conservatism inherent in using this really simplified modeling approach to analyze something that's pretty darn complicated. And this is where the slow death by PowerPoint comes in. I'm going to subject you to a few equations. You are not to worry about the details of those. I'm just trying to paint a picture and then highlight certain aspects. So let it wash over you and let's go through it. Really three parts. There's a model that tries to figure out what the release rate. The gas coming out of the pipeline when it ruptures. By rupture, we mean fullline break where both ends every time pipeline are discharging gas into the sphere. And the release releases over time release rate. We want to take that and predict what the power or the heat energy per unit time is that's being released and lastly we want a way to relate the heat intensity to the heat you feel as a function of how far you away you are from the pipeline rupture. Starting with the effective release rate. There's an equation with bunch of factors let's not get too tangled up in it. The simplest way to talk about it within the rectangle is a equation classic formula for the mass flow release rate of gas coming out of an orifice. And that was our starting point. You'll see it depends on D, the diameter and P the pressure, and a bunch of other constants we won't worry too much about. Outside of that basic orifice discharge equation we multiply it by a factor of two because we've got two ends that are feeding gas into the atmosphere. And then there's this lambda factor. It's called release rate decay factor we're trying to take the initial release rate scale it back to a release rate that would be an effective representation of the release rate that feeds the fire over the longer team. Actually feeds the fire in the initial stage. Once we get that release rate we drop it into this other equation to work out the socalled emissive power. We take the release rate, multiply it by the heat of combustion, which says theoretically how much heat gets produced when this stuff burns. And then there's there's factor we tack on the end scales it back accounts for the fact that not all the heat that could theoretically be emitted gets radiated and felt by receptors at distance. We take that emissive power and stick it in a formula you'll get out of an undergraduate physics book predicts heat intensity I as a function of how far away you are from the point of release are.

And all the terms are defined except we've got this efficiency factor that we've attached, which scales back the heat intensity. And we're going to talk about where that comes from. But the idea is if you can get this equation that relates heat intensity and corresponds to the heat intensity threshold you're worried about. If we tick a particular heat intensity threshold to define the zone we get the PIR formula. And because all the terms inside this sign are constant except for science and pressure it collapses to this simple formula.

Now this slide, maybe not that easy to see, but some of the factors are highlighted in red. These are the coefficients or constants that over the past 22 years have received pushback from people saying where did that come from and why is that so low and that seems wrong.

What I want to do is go through first the factors that fiddle the release rate to get an effective release rate. I want to talk about this efficiency factor that scales down the heat energy. And last I want to talk about the heat intensity threshold that forms the basis for how you're supposed to use this equation. If you'll bear with me I'm going to hop through three things that will give you a better feel for how this thing was developed and what it's taking into account and what it's not.

So this plot on the vertical axis has release rate blue is time. Blue line starts high falls quite rapidly the units are seconds. 900 seconds is 15 minutes. So the first quadrant is the first minute. And you can see within the first minute the release rate falls a long way. It falls rapidly then it starts falling at a slower rate and it kind of tails off with a much more slower release rate decay. That blue line is a representation of what the actual release rate would be. It's using the model that's in the original GIR report from 2001, and I won't belabor it. But it is approximation to a numerical model that takes into account the stuff that matters if you're trying to predict a release rate coming out of a long tube. It accounts for the opening, assuming that gas is coming out of both ends without obstruction. It accounts for the density and temperature, the product. It accounts for the friction drag of the gas as it's trying to shoot along the pipeline that comes out. The drag slows it down. It affects the release rate, and it satisfies the equations of state that matter when you're trying to predict this kind of outflow. It's not the only model. I like this one because it's the one I originally referenced. You can look it up you can code it up in a spreadsheet and use it yourself because some of the newer models are really fancy and sometimes fancy just looks confusing.

What I just do now is the effective sustained release rate that the fire model uses. And notice it's not the release rate at the very beginning. It's not the release rate towards the end. It's the release rate within the first minute give or take. If I zoom in on the first two minutes, this is a plot what the release rates would look like over time for pipelines running at 950PSI at different diameters. Top line 36inch, 30, 34, et cetera. The dots are what we assume to be the release rate. The dots are the effective sustained release rate that the model uses. And what we were looking for is a constant that we could multiply the initial release rate by to get an effective release rate that would be equal to 30 seconds because generally these fires, when they ignite, do the most harm to people within the first minute because that's the time when people are trying to find shelter if they're outdoors or that's the time period steady state fire biggest and does the most time. What I'm suggesting here is by multiplying the initial release rate by the decay factor we've got a relays rate for big inch lines it's about the release rate 30 seconds in it conservative for smaller lines we could have come up with a fancier factor but we didn't we tried to keep it simple. Jumping to the thing that figures out how much heat energy gets radiated once we've got a release rate and we know the product. Now the model we used incorporates this thing called an efficiency factor comes out of another study by a company called Technica. That simple model was adopted by CFER, and it tries to address some of the conservatisms inherent in this simplified point source emitter model we built. Where the initial GRI report tries to stay high, talk about things in simple terms, not be labor things with details. The lack of detail has been a problem in terms of the feedback we've got in the model. But we had an opportunity in a report that I coauthored with Michael Baker Jr. company 2005 report with PHMSA looking at PIRs for other gasses. And what that report explains is that the efficiency factor accounts for three things, the fact that a highspeed gas jet doesn't radiate heat the same way that a flare does, and there's a reduction to account for that because most models are based on flaring. It accounts for the fact that the atmosphere, or more specifically, the moisture in the air absorbs some of the heat radiated so people don't feel all the heat because the moisture in the air is absorbing it. And last it accounts for the fact that what you see is what you feel and people do not see the entire fire. Large scale fires are opaque. You can't see the flames all the way through and you see things up in the air geometry effect is the view factor and this accounts for the fact if you modeled this as a fancy multipoint source radiator you would get a different answer than a single point source emitter to the ground. When you chain together all those factors you come up with something that is very close to the efficiency factor that's in the report it wasn't something that we made up. It was something adapted from a model that accounts for these things in a systematic way and it's explained in that 2005 report. If I stop there and say all right that's how we get the fire model, what's it good for in general terms. And we're suggesting that the models that I've talked about so far do form a defensivible basis for estimating the REIT intensity from a crater fire near immediate emission the line ruptures ignites almost right away. And it can be used to estimate the heat intensity as a function of distance. And the thing is I said crater fire, what's a crater fire. A buried pipeline if it ruptures, generally a joiner pipe gets blown out two ends sitting inside a crater discharging gas in opposing directions. So the gas jets impinge upon one another. Chew up some of the momentum and kind of get directed upwards. The crater walls redirecting the gas that's going sideways. So basically you get a vertically oriented fire. And the hazard zone for a vertical fire is a circle which is why the PIR is the radius of a circular hazard zone. But what about fires that don't look quite like that and the reality is that sometimes when you get a pipeline rupture, the ends of the pipeline get misaligned a little bit. Opposing jets do not impinge directly. They bypass each other. They hit the crater walls. They still go up. But you can still get a couple of distinct jets, which is a little bit different from the crater fire which is what the model is all about.

But what happens is if you get misshrinement and you get distinct jets, when you look at the thermal radiation hazard zone, it's more elliptical in shape. The areas about the same because there's the same intensity heat feeding the fire but the lateral extent is often reduced but the axial extent is extended because those jets have length. And in that sense, assuming everything is a crater fire is conservative when you're interested in how far property is away from a pipeline in a perpendicular direction but potentially it's not conservative if you're interested in the length of the hazard zone. But it's worth noting that the way that the PIR formula is used to delineate an HCA, addresses that to a certain extent if you go to HASMEB34AS or the regulations that shows you how to use the PIR to figure out what length of pipeline is in a highconsequence area it says you start from the beginning of the first circle and extends to the end of the last circle. I've drawn a bunch of circles where the assumption enough dwellings within each of those circles to qualify as an HCA. The assumption is the circles to the left or right of those do not have enough houses they would not be HCAs the black shading from the beginning of the first to the last circle is the qualified length of HCA. When you think about it from a theoretical perspective suchling hazard zones are circles and the high consequence is the center of the first circle to the center of the last circle. Not the start to the end of the circles. And that extra length extension effectively accounts for any axial extension you might get from directed jetting that effect is accounted for in how the PIR formula is meant to be used for delineating a highconsequence area pipe. The last thing I want to talk about which is something that Max has already introduced is the heat intensity threshold and where it came from and what it means. And the value adopted is 5,000 BTUs per hour per square foot. I realize that's a pretty abstract quantity. But what it is, based on some recognized models that assess the likelihood of fatalities, function of the thermal radiation dose received, is a 1% leeth a letter meaning one in 100 people exposed to that level of radiation would succumb assuming a 30 second exposure period. Which invites the question where does 30 seconds come from, Max suggested correctly the report says that it assumes five seconds to gauge the situation, figure out what's going on and decide to take action then a decision to move quickly at about five miles per hour two and a half meters per second. And the shelter will be found within about 200 feet. And if you're wondering where did all that come from the literature at the time, which was used for developing quantitative risk assessment models typically in the UK in the Netherlands and other places where people have studied this kind of suggested that two and a half meters per second was defensible escape speed for the average, an average member of the population and in developed areas that shelter would typically be found within 50 to 75 meters. We basically adopted that assumption of travel speed and distance to be traveled again based on national precedent for this modeling. It is not a conservative representation. It's meant to represent typical developments and typical populations. Now in terms of what does that heat intensity mean for property. The idea is that heat intensity means if you're at the edge of a circle a wooden structure is unlikely to ignite and burn and therefore will afford indefinite protection to people that are indoors. In fact, it assumes it will not catch fire for 20 minutes in the presence of a flame. And by 20 minutes, if your house starts to burn and you leave. The fire will be much smaller when you go outside and you'll likely be able to escape the area. Again it's based on a recognized model for how what heat intensity is required to cause wood to ignite and burn as a function of the relevant parameters. The implication is that people indoors are going to be afforded protection by the dwelling variant. If the heat intensity is at or below that. What does that mean in the end that this model is predicting? I'm suggesting it does suggest it's the area within which fatal injury is a significant possibility. And beyond which fatality is not a significant probability for typical members of the population. It's the area within which wood framed structures could be destroyed by fire. It is not the safe distance beyond which people and property are going to be minimally affected. And it is not the perimeter of an emergency response planning zone where you could stand and watch the event. If that's what you wanted it to mean obviously a different heat intensity would be employed. So that's kind of my pitch on what we developed what it's meant to me. People ask how accurate is it? What have you done to validate it? And typically the only information you've got after the fact is the extent of the burn zone. You go to measure it compare it to the radius try to decide whether it's a reasonable characterization. But the burn zone is not necessarily the perimeter of the PIR because some materials will catch fire or burn and discolor and die at heat intensity's lower than the adopted on heat intensity threshold which is meant for people escape and wooden structures. So vegetation might discolor or vegetation might catch fire but as you know if you light a brush fire and you leave it, it can spread. So a problem with using the burn zone is that it delineates the extent of the fire spread not the extent of the zone that was caused to burn by the fire from the pipeline rupture. However it's pretty much the only thing you've got to work with but you've got to keep it in mind when you look at incident results. And the original study we took the incidents that were available at the time, took the hazard areas, turned them into equivalent circular areas with an effective radius and we looked at the maximum perimeter distance to the burn zone and we compared actual to predicted. And without belaboring this plot, there's a unity line, the red diagonal line, if the data points for the real incidents plot to the right of the curve, the model is conservatively overpredicting the area if they plot to the left of the curve they're underpredicting. What it showed is the model consistently overestimated the total impact area or the total burn area but occasionally it underestimated the maximum extent of the burn zone but again keep in mind fire spread is an issue. And we felt that that correlation between actual and predicted suggested we had a defensivible model. It wasn't overly conservative. But we felt it was reasonable for the intended purpose. Now Steve is going to talk about fence's recent experience going out measuring recent experiences and comparing a more recent incident. I'll leave it to Steve. I'll mention one validation effort that I think is important. It's kind of hard to figure out exactly what's going on from looking at incidents after the fact. So what we thought we would also try to do is compare the models I've described in fact slightly modified version of those models that could be used for life safety risk estimation to what you would get out of a really fancy stateoftheart consequence model that accounts for all the things that this simple model doesn't. So we compared results obtained from the models I described which we'll call the variation on the CFER model to the results obtained from a program called Pipe Safe. Pipe safe the pipeline risk software it's now maintained by DMV out of UK. Pipe Safe contains a suite of models developed specifically for natural gas pipeline failure investigation calibrated against largescale tests, including, this is important, two simulated rupture events where they took a 36inch diameter pipeline 50 miles long, set off a shape charge in the middle measured everything how everything varied with time as a function of distance and that model predicted those two release events. So to my way of thinking the Pipe Safe suite is pretty much the gold standard for this kind of prediction. We wanted to compare what that model would predict to what this simple model would predict. Again, without going into a lot of detail we used it to assess two things. One would be the individual fatality risk for someone living very close to a pipeline model using the simple CFER models versus the fancy pipe safe software. It's normalized to account for the fact that, well, failure has to occur let's assume the failure likelihood ignition likelihood is the same for both models. We compared the results for the fancy analysis with pipe safe to the simple analysis with the CFER models. Again without going into painful detail on this plot, that diagonal red line the slope of 45 degrees, if the results plot to the right it means the CFER model was conservatively overestimating the individual fatality risk if it plotted to the left of the line it would be underpredicting. You can see with respect to individual risk, this model, the CFER model approach, was overestimating the individual fatality risk for someone living very close to the pipeline. The other thing we did was measure the total societal risk in expected amount of fatalities in population density. This table shows the results of three diameter pipeline with the pressures and the predicted number of fatalities from the fancy Pipe Safe and the models from CFER. You can see the expected fatality counts are actually very close. So this validation that we did about 2005 led us to think the modeling approach is defensible surprisingly reasonable in comparison to some other fancy other models. So I guess my position on this the models used and the assumptions made that underpin the PIR formula as it currently exists are a defensible basis for generic hazard zone estimation. We don't think there's anything wrong with the models or the approach. It comes down to the assumptions that you make and what you wanted to predict. And we're suggesting as well that the predictive capability of this formula is fit for purpose if your objective is general purpose consequence screening. And again the development focus was to delineate the extent of the fatality and property destruction zone for typically populated and developed areas. It is not to be interpreted to represent the distance beyond which no impact on people or property would occur. And if you want to account for that, you obviously need to change the heat intensity threshold which would impact the PIR. But it depends on what you're using the PIR for. What I want to conclude my slow death by PowerPoint with is to provide some comments on the four incidents that are managed in the NTSB report on the Danville incident, starting with the Danville incident itself and then talking about the other three incidents that are specifically mentioned in the NTSB report. So for the Danville incident, the yellow lines of the gas pipelines the center one is the one that ruptured. The pinkish reddish are PIR, and pinkish cells are occupied buildings and blue circles are nonoccupied buildings. And I guess my takeaway on this is when you look at the dwellings that were destroyed by fire, they all fell within the PIR. And if you look at the residents of the individual who succumbed to the event that person was located at about 300 feet from the pipeline at the start of the rupture event. So they were well inside the circle and unfortunately that, I think, contributed significantly to the fact that they did not survive. There were no fatalities obviously beyond the PIR no property destroyed beyond the PIR but there was property damage and there was injury to animals that were trapped where they were and could not get away. So again the model does not predict no impact beyond. It simply says this is the area within which the impact would be significant and fatality would be a significant concern. The report also talks about the assistantville rupture this figure is hard to interpret focus on the horizontal red line, this is the 20inch line that ruptured. There is in the middle a dashed red circle, that's the PIR for that 20inch line. And the yellow outline is the perimeter of the burn zone that was actually experienced. And from my way of looking at this, the area captured by the

PIR is pretty darn close to the area captured by the footprint of the burn zone. You'll notice it is a little longer than it is high. That's the axial extent due to the fact that there was directional jetting here. But it wasn't all that significant. And I think you'll notice as well it wasn't as wide as it is long, which is what I suggested would be the case for a directed jets as opposed to a crater fire. But on balance, I think the PIR's doing a good job of estimating the area within which significant damage and destruction occurred. The one incident that generates a lot of discussion about the PIR is the San Bruno pipeline rupture that happened in the suburbs of San Francisco in 2010. Eight people died in this event. It was a 30inch line that ruptured in a densely populated residential area. The PIR is the green circle. The white lines outline the property boundaries for all the residences. If they're red, the property was destroyed. If it's yellow, it was damaged. You'll notice destroyed housing extends outside the PIR zone, which raised some eyebrows and led to people to be concerned about whether the model is missing something. But when I looked at this, the key takeaway I found from the information on the incident is that when the pipeline ruptured it took out the water lines. So the fire department, which was within this circle was there within minutes but they could not fight the fire. They had to stand and watch the houses burn got to watch the debris from burning houses be blown by the wind in a northeasterly direction on to the roof of adjacent houses catching them on fire. The extent of the destroying fire by property there was no extent to fire spread because in this situation they couldn't get water on the fire for over an hour. And that is a significant contributor. And of course the model doesn't account for fire spread. It begs the question, should it? And if you wanted to account for that, how would you account for that in a way that's reasonable? Last incident very tragic pipeline rupture incident in Carlsbad, New Mexico, in 2000. 12 people died. The narrative in the report not entirely clear but the assumption is that those 12 people were camping where these vehicles are located. Which is outside the PIR. None of them survived. So this was a red flag that those people died outside the PIR. When you think about what happened, the PIR formula is meant, was originally developed based on generic assumptions about population. If there's houses there and the fire starts when they're inside, the dwellings will afford some protection for at least a certain amount of time. These people were thought to be sleeping outside. And at the time of the rupture they would have had no shelter. So their ability to figure out what's going on, react and move away is perhaps different from the assumptions that were made in the generic screening model. The reality is, if the situation is different, it invites you to revisit the underlying assumptions. But again it depends on what you want this model to do. And again it was set up for generic screening under typical conditions. If you want to set it up to approach things from a conservative perspective, it's going to dictate, perhaps, a desire to have the hazard zone delineated by a bigger circle, but frankly from my perspective if you're within the PIR you're at most risk. If you're worried about affording additional protection, perhaps the most effective way to achieve that is not make the circle bigger but lower the threshold for what's inside the PIR that would trigger the HCA status. And that's exactly what a moderate consequence area that PHMSA has introduced does. It lowers the dwelling count that triggers proactive integrity management. I think that's a more cost effective way to target areas that need higher levels of integrity. I'll now stop. I don't know if I put you to sleep but hopefully not. But if you have any questions or comments, I would appreciate them. I hope we've got some time for that, Max.

>> Yes, we do.

>> We do have a question online. Question comes from Michael Bets how many had spontaneous ignition compared to delayed ignition and how dramatically does the delayed ignition affect the PIR discussion?

>> Good question. I think the working assumption is that if a natural gas pipeline is going to ignite that ignition is almost instantaneous. Within seconds or tens of seconds. The process that causes ignition is not well understood but it's known that pipelines in the middle of nowhere will ignite. So the gas is not encountering an ignition source. It's spontaneous. It's either friction and sparking from debris or it's a buildup of static electrical charge or another phenomenon that's not well understood.

I think the frequency with which a pipeline ruptures has been teased out of the historical data but whether it's immediate or delayed has been very hard to determine because the information at the time is anecdotal. But I think most people would agree that ignition, if it's going to happen, is within the first few seconds or tense of seconds because natural gas goes up into the air unlike propane that might drift downwind encountering ignition sources gas pipelines don't ignite because they find an ignition source, they create their own. And delayed ignition would be associated with a smaller fire, and a smaller hazard zone.

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>> Thank you for the presentation. Linda Daugherty, I'm with PHMSA. I have to tell you that some of the pictures brought back some hard memories. I was at some of the incidence, Carlsbad being one. If you've been to an incident set like that. It has an impact on you. It sticks with you for a long time. My question has to do with one of the core intent as I understand it of the NTSB recommendation is the ability of people to evacuate. And so when you look at I notice your presentation original calculations were based on you said a European standard or a European approach people getting my question is, have we gone back and evaluated the truth of that because demographics change, people change. I'm just wondering, I think you present a very strong case that the radiant heat burn calculations are very have been truthed over time. My question

is, has the people aspect, the ability of people to evacuate has been that truth and more of a comment if I was in a house I saw through my front window a huge fire and shaking the ground would shake, I don't know that I would think, oh, I need to stay inside the protection of this house; I would probably book it, which would put me outside and subject to the heat. Just because your instinct is to run away, not to stay inside of a wooden house. Anyway. Thank you.

>> No, thank you for the comments. It's a very good point. In terms of validating the assumptions of how long it takes people to figure out what to do and what they do. I'm not aware of that being analyzed in a clinical basis for the incidents that have taken place. Just to clarify, the assumption is that if you're outdoors and you're awake, the assumption would be you will spend a few seconds to say there's a fire I'm going to run away. I think the assumption for people outdoors that they're going to start moving away within a few seconds is unreasonable. If you're indoors, your point is that, well, do they know they should stay? It's a fair point. I know that some people I'm familiar with in the UK who have developed the Pipe Safe software, which actually accounts for how long people as people move what dose do they accumulate, how long does it take them to get through doorways get downstairs, they too have thought about that a lot. And I shouldn't speak for them and I'm not sure all the information is in the public domain. But I think the assumption that they are making is that if you're looking out the window at a fire, if it's really close and your curtains are catching fire you're going to leave straightaway. But if you're indoors and it's loud from the rumble, it's getting hot, you're going to think about it for a while and you may or may not stay. I guess the reality, though, is if you think about it for a while, your house, even if it's going to burn, is going to afford protection for probably several minutes before you need to leave or become a fatality within your burning structure. But the assumption is that even if it gives you time to think and if your decision is ultimately to move then you will be experiencing a smaller fire than the fire that we're assuming here. But I don't want to suggest that the assumptions about five seconds two and a half meters per second shelter within seconds a few meters is the only answer. It's a construct that was meant to represent a set of conditions. If you want to acknowledge other scenarios, other exposure durations would be appropriate. But the human reaction component which is obviously important, I just don't have the information to point you to say five seconds is reasonable versus now that seems to be dated information. Although I don't know that Europeans would do things differently than North Americans. They do some things different than North Americans. But as for this I'm not sure. Not wanting to make light of that. But....

>> Wanted to piggyback on Linda's comment and let you know I enjoyed the presentation. Your last comment, when you discuss moderate consequence areas, obviously the code has been adapted to account for five structures versus high consequence areas. I'm not sure we did enough, though, to address outdoor activities. I

mean, we address roadways. We address reducing the structure count but we don't really change what we were previously doing on identified sites. Any thoughts on that? Do we need to go further?

>> Again, if you were going to do a detail risk assessment of an identified site, you would absolutely take that into account because that would be the prudent thing to do. If it's an outside area that doesn't have the shelter density that's assumed, those assumptions wouldn't be applicable. So a detailed locationspecific analysis would warrant taking that sort of thing into account. I guess it comes down to this screening tool uses a certain amount of information. If you want to refine it to account for different kinds of land uses and have different assumptions with respect to exposure period, that's fine. That puts a greater burden on people using this kind of approach to figure out what the PIR should be in that situation. It's simply I guess a tradeoff between the level of effort to collect the additional information and use it all the way along the pipeline versus something that's simpler for again general purpose screening, it all comes down to what you want this to do. Again I'm not standing here saying 30 seconds exposure is appropriate for everything. I think it's reasonable for typical developments, but there are certainly developments where it potentially isn't.

>> Anything else from the webcast. We're good. Thanks Mark for your presentation. It's great to hear from you on PIR again. And I was engaged the whole time so it wasn't death by PowerPoint for me. Couple of questions the first one it sounds like the PIR equation isn't addressing consequential events like damage to water main and fire spread but all are caused by the rupture itself. So when I think about PIR and the definition of PIR and the regulations intended to address significant impact to people or property and hearing from you that it's not considering those consequential factors that could take someone's home or take many people's homes it's a disconnect to me. I wonder how it should be addressed if it's not through the PIR equation.

>> Thank you, Sara. It's a difficult question. Thank you very much for that one. The fact that the PIR narrowly looks at what the pipeline rupture incident and what its heat does and doesn't account for what knockon effects might be or what other things might contribute I think stems from the fact that there's all kinds of things that could develop that would impact what the extent of the impact zone is. And I'm not smart enough to figure out what one could do to that to make it bigger by a certain amount to account for other stuff because it depends on what the other stuff is. The fire spread thing if you're talking about the spread of the grass fire if you capture the extent of the grass fire. And if you have fires in San Bruno, that's obviously a concern but to be in an urban setting where firefighting doesn't work, I would say is the exception rather than the rule. Do you want to revise the model to account for the exception or not. If you account for the exception, you are conservative. If you have the luxury of making conservative

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assumptions and you can live with what the implications are of making that set of conservative assumptions then fine. But unfortunately because of cost and benefit associated with everything. So I don't want to suggest that nothing could make it worse because knockon effects can happen. But the situations that could precipitate various things that would make the impact a significant impact zone bigger are kind of hard to capture.

You'd either have to wing it and say we're going to make it such and such an amount bigger, and that's fine. I'm not sure how you justify the amount by which you make it bigger.

>> We have time for one more question I think on the webcast. Or give Sara a chance to

>> The other question, so a lot of the accidents that we've seen including well Danville and some of the recent accidents, they look like they were occurring near bends in the pipeline and in your earlier, the earlier part of your presentation, you talked about assuming linear structures which they're mostly linear but there are many bends. How do you reconcile that piece?

>> I guess the short answer is I don't. We assume that the majority of pipelines are linear. There are bends. And at those bend locations if you're unfortunate enough to be at a bend location, the potential for the directed jet to have a larger offset distance for impact, it could very well be. The model just is not that sophisticated or at least the way it was developed and what its intended use was wasn't to flag bends of areas that need additional protection. For the reasons you're alluding to, I think the argument could be made is yes, maybe more protection could or should be afforded there. But again, if you're going to say and we need extra bends and we need extras if the land use is this and that, it's going to get complicated. If you guys I'm not sure who the guys I'm talking, girls are, if that's the decision taken, then there's going to be a lot more work required to keep track of all this stuff.

>> A question online from Adele Dbiaso are your conclusions the same for hydrogen and hydrogen blends?

>> No. I think we're going to talk about hydrogen versus natural gas a little bit later. So if we could table that one, if that's okay.

>> Okay. Our next question is from Danyo Nivson in the Danville incident where does it occur in relation to the PIR?

>> Another good question. My understanding is that all the people that died were in or or around the rupture point. Sara might have more specific information but I think the NTSB indicated in some information I heard that everybody was well inside the circle.

>> Sara is shaking her head yes, so yes.

>> Thank you. Question from Carlos. Does the PIR model consider ambient conditions? Were the incidents discussed conditions of the day of the incident compared to the model assumed ambient conditions?

>> Right. So for jet and crater fires the ambient weather conditions are secondary. The air temperature doesn't have the big effect. The wind will tilt the flame a little bit but those are secondorder effects, kind of in the five or 10% one or the other. It assumes the typical set of assumption doesn't take into account location or doesn't take into account it could be windy cold or hot, those are secondary. If you look at vapor cloud dispersion and cloudy conditions then the wind speed and the wind direction and temperature matter but it's secondary for these fires which is why it's not part of the mix.

>> Last question I have, Nicole from Nicole Tebow. Yesterday we saw two incidents where ignition of the gas cloud was one or two hours after the initial release. Have we evaluated data on how soon the emission of a gas cloud usually occurs?

>> Right. So if the gas that is flammable is heavier than air, and that's when it drifts downwind and finds ignition sources and it can take time to ignite. But natural gas is buoyant, and it's being driven upwards by high momentum from the initial conditions. So the vapor that is flammable does not collect near the ground. It's up in the air. And so delayed ignition generally doesn't happen because the ignition sources that you're worried about would be in and around the ground but the flammable reach of the cloud is in the air. So again if you're talking about dense vapors that are flammable then delayed ignition is a significant concern. But for buoyant vapor like natural gas it's not something that's a concern. The biggest concern is ignition within seconds or is it delayed by tens of seconds or a minute or two. At least that's my understanding of where that's at. Am I dismissed?

>> For now. Thank you very much, Mark.
[APPLAUSE]
I do appreciate, I did die slowly a little bit there but I was reinvigorated by great questions and good discussion. And I appreciate Mark trying to convey what the PIR does and does not cover. We will have time definitely for more questions in the panel discussion. But the next presentation right now will be Steve Nanney, senior technical advisor with the Engineering Research Division is going to be talking about regulatory development and current implementation of gas PIR. If I didn't mention it earlier, too,

particularly folks on the webcast you might see some slight delays as we're transitioning. Now we have the new slides. I do want to say thanks to all the folks in the back supporting between the camera folks and the folks running the slides. I do appreciate it. Steve.

>> I'm glad you asked all the hard questions to Mark. And thank you Mark. One thing, just to say, Mark is from Edmonton, Canada. He had a long trip to come down here. I just want to say from PHMSA we're appreciating taking the effort to come. When I left here last night, I had something I had to do with my wife. That's go to a Houston Rockets basketball game. And I know we're talking about risk and all of that type stuff. And the Rockets haven't had a very good record over the past several seasons. But here lately they've been beating the top teams. So we've been talking about risk and reward and all of that type stuff. And I've been wondering, well, I was hoping for them to get the No. 1 draft choice. No you I guess I'm hoping for them to get into the playoffs since they've been winning. Last night they played the Phoenix Suns, one of the top teams in the NBA, and they beat them. The last time we went they played the Philadelphia 76ers and beat them. And then the game before that, they played the Milwaukee Bucks and beat them. After seeing so many losses over the past three years it's nice to see them win.

But with that, just to get to the more serious stuff, I'm going to be going over, as Mark and Max and some of the others have said, is just to give everybody an idea of what PHMSA's looking at on PIR. Just talking about a PIR and having a potential impact radius without having anything behind it, you don't really have anything. You just have a distance. It's like what Linda and Allen and others yesterday said where you've got a threelegged stool. You've got to have the public. You've got to have industry and regulators and in identifying anomaly or threat whatever you want to call it, you've got to have it in your program to go look for it, to indirectly assess it. What PHMSA has elected to do in the code as you go and look is to use inline inspection as the number one choice. That's also what NTSB and some of their recommendations has given to PHMSA. The other part is to assess it. You have to have criteria to go out and assess it. Whether that's a potential impact radius high consequence area, which is a higher bar, whether it's a moderate consequence area, or where it's criteria just if you're doing a dig and it's not any of those. You've got to have criteria of what you do when you go out. That you have a certain level for all three of those areas that when someone goes out and looks at it, they've got to meet that bar. And as you've heard others say, there's been recent rulemaking that we've done that we think from a PHMSA standpoint has raised that bar. We've also done things such as the valve rule that's come out, is when I hear Mark, I hear Sara from NTSB, and others, and we talk about how far it spread. Well, if you've got a fuel source and it just keeps being a fuel source, then you're going to have a fire that spreads. Isn't that correct, Mark? Fuel source. And so we've put regulations in place as far as having valves in place whether remote controlled, whether automatic shutoff valves that close in a certain timeframe. So PHMSA through rulemaking has tried to do things to address the issues on this topic. It may not be perfect, but it's a step process of getting there.

So what I'll be going through today is giving you have an overview of I think we've got a helicopter coming over [helicopter noise]

But giving you an overview of some of the ruptures that we've seen, what our accident investigation group has gone out, what they've measured as far as being the impact area where the pipe has actually gone. And how long it's taken to shut off this area, which we think are all of those are factors in assessing. So with that, I'm going to start and go through the presentation. It works. Good.

The first thing is I'm going to talk about is gas transmission ruptures. 2017 to present. The reason we started at 2017 is that's when the PHMSA A group was put together and they've started going out on accident investigations. I didn't try to change it because I was trying to not put something in there. The next item I will talk about is identifying high consequence areas. And the definition of a high consequence area and the methods, whether it's method one or method two. Then I'll talk a little bit about the potential impact radius, how you calculate it. The PIR versus pressure and diameter, and then gas transmission mileage. How much mileage is on HCA, how much in a moderate consequence area, versus all the other pipeline mileage, then we'll go back to the PIR and just do a summary of it. I hope everyone can see this slide. This slide sheer is sort of to show you from 2017 to present, as far as all the various accidents that PHMSA has gone out and evaluated, I do not have an operator associated with it. I mean, we have that information. But that's not the intent. Also I haven't listed whether it's a high consequence area moderate or no consequence area or it's out in the middle of nowhere with nobody around it. But here's the things I want you to see. I've heard a lot of various things. But let's just look at the line here that's got PIR. You see right here in green, I put it in a different color for the intent so you could see that. Well that's PIR based on what Mark and others have been talking about. Doing the calculation of pressure versus diameter, which in the code pressure means MAOP. The maximum allowable operating pressure of the pipeline. Then you come over and you can see the various PIRs. And then I also put in a PIR based upon the pressure at the time of the failure. And what I did is I went back to our aid group, and I said tell me where this is located. Tell me if you have a compressor station, it's a point A and it's going to point B as the next compressor station or the ending of the pipeline, where, between that, did you have the rupture? And so what we did is we estimated what the pipe pressure if we didn't have it at that point we estimated it based upon that length and the discharge pressure versus the pressure at the section site of the pressure station. So these

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numbers here are actually what we think the pressure at the failure point is. So there's also a PIR associated with that. And I've heard a lot today as far as Danville Kentucky. And let's just show Danville Kentucky. It had a PIR I think Mark said it was 633. I rounded it up said it was 634. That's very immaterial in it. But if you look at the pressure drop going out of the Danville compressor station, I think it was about just a few miles outside the station. I forget how far it was. You can see that it had an impact based on where it was located of 630. We're showing the impact area based upon measurements that our group took was 704 feet. That's about 10% greater than the 634, the 630. Also had a width of 645. And here's another key point. It ejected pipe about 600 feet away. And then you come on over. My point here would be the oscillation time was an hour and 52 minutes. And I just picked that one out because I've heard everyone talking about Danville yesterday and this morning to show you. But what I tried to do also is show you others where it's exceeded the PIR. If you look down, we've had two in 2022. One was Union Town Alabama one in Pennsylvania, and you can see they were slightly over. But less than 5% over for both of them. You can also see the pipe ejected on one 72 feet, the other 304 feet. So sometimes the pipe goes right, very close to what the PIR is. Most of the time it's a lot less. And the same thing of what Mark was talking about earlier, was on fire duration, oscillation time. If you look, the points here where we just got a dash, there was no fire. And you can see there's one, two, three, four, five, six six of these seven teams there's no fire associated with it. The others there was a fire and you can see what the fire duration was.

And I've looked at these to see if there was any correlation between oscillation time and fire duration. Sometimes it seems to be. Sometimes it seems not to be. Like here's one that the oscillation time was two minutes. But the fire duration was over two hours. So I just wanted to put this up to give everybody an idea of what PHMSA is seeing. If you look, about over 80% of these, the PIR estimated based upon the present calculation in the code, it was under it.

There was, like I said earlier, three of these that it was over, and just slightly. The Danville was the most. And it was about 11% over. The other thing is the potential impact radius was developed for high consequence areas. We're also now using for moderate consequence areas too as we've discussed. And again it was put in in late with 2003. And it's in part 192903 in the code. And also the PIR calculations were based upon the CFER model as we talked about earlier. And again, just going back to the others, if you look, I know Mark talked about the 5,000 BTU per foot intensity threshold. And also if you're looking at wooden structures, the 5,000 would either go down to 4,000 or 3500, something in that type neighborhood.

All right. The next item is Potential Impact Radius. I just want to talk for a minute as far as what a Potential Impact Radius is. If you look here, again, it's in subpart o, and it's used for high consequence areas. And it's the radius of a circle within which the failure of the pipeline could have significant impact on people. And the Potential Impact Radius area uses the PIR. As far as identified site, I know I heard people talking about it. What is identified site. If you look, it's an area open structure that is occupied by 20 or more persons on at least 50 days in any 12month period. And again it's also a building that is occupied 20 or more persons on at least five days a week for ten weeks in any 12month period. And then it's a facility occupied by persons who are confined or of empowered mobility or would be difficult to evacuate. In other words, hospitals, prisons, schools, day care facilities, retirement facilities, places like that.

And I know I heard earlier someone asking, should we have an increased PIR for those areas because people probably cannot get out in 30 seconds. I think we've heard that comment. And it's a fair comment. And as far as the next item as far as potential impact circle or PIC, PIR, whatever term you want to use for it. For lead natural gas the radius is calculated by .69 times the pressure times the square root of the pressure times the diameter squared of the pipeline. With R being the radius of the circular area in feet. P being the maximum allowable operating pressure of the pipeline. The reason I'm pointing that out is as a natural gas pipeline moves from point A to B the pressure drops. The only way it would not drop would be if you had it closed in on both ends of the pipeline. But as it moves and it flows gas, the pressure's going to drop. Normally you're probably going to see about five pounds per mile pressure drop. That's why you'll see compressor stations on transmission lines being about 50 to 60 to 70 miles apart. They're looking at somewhere around a 300 or so pressure drop before you compress it back. So five pounds may be if you're feeding a city it may be ten pounds. But the point is you're going to have pressure drop as you go. And the diameter is the normal diameter of the pipeline in inches. As far as what does this use, there are other areas that are used as far as defining a high consequence area. If you look here you can see a class one, class two, class three, class four location. A class one location, which is here, and here at this area is 10 or fewer dwellings within a mile. In other words, a very rural area like what we're showing here. A class two location is 11 to 45 dwellings. And again it would be as shown here you would have subdivisions being built around it but more spacing than a class three or four. And then a class three would be 46 or more dwellings or occupied sites. And a class three would be an area where you may have schools. As you can see here and homes built around the pipeline. And then a class four is where you're in a downtown type area with buildings with four or more stories around it. This picture here is in Manhattan where there's a pipeline, transmission line that goes into Manhattan. That's what it's illustrating. So there are pipelines in class four. Not as much mileage but there are some. As far as identifying high consequence areas operators can choose from two methods. Method one is based on class locations and it includes all class three and four locations. Also any area in a class one or two location where the impact radius is greater than 660 feet and the area within the potential impact circle contains 20 or more buildings intended for human occupancy, or any area in a class one or two location where the potential impact circle contains an identified site. So an identified site would make a pipeline an HCA whether it's in a class one, two, three, four, area. Some other items to consider, this is just giving you an overview of examples of method one. Again, if you look here, where you've got more buildings, highrises and things built around, it would be a class three or four. In other words, 46 or more dwellings for human occupancy. A class one or two would be areas where again you would have 20 or more homes buildings around it. PIR and you can see identified sites around it. And three and four if you're using method one would be an HCA. If it's a class one or two you'd have to look to see if it's an identified site. Our method two is based upon using the PIR. And it's any location on the pipeline with a potential impact circle containing 20 or more buildings intended for human occupancy. Or identified site. And you can see, whoops... you can see here 20 or more buildings intended for human occupancy or identified site. And just an illustration of this is on the next slide. This shows you an identified site here. And how, as Mark had shown earlier, how the PIR for the HCA actually projects out. Also, for method two, when you're looking at the PIR and you're looking at 20 or more dwellings, this is an example here where, if you look at the top here, it's got the MAOP of 1200. The pipe diameter is 36 inches. We've calculated the PIR here is 861 feet. And again these circles slide as long as you've got 20 dwellings in this circle, then you just keep moving the circle out and it becomes the HCA. Another item to consider as far as PIR and the methods would be what would be the PIR for various pressures and diameters and also the class location unit. And I'll just start with the class location unit. If you look here, you'll see the red line. Again, that's the six hundred 60foot foot from the pipeline. You class homes for class one, two, three, four location based upon distance on either side of the pipeline for sliding mile going down the pipeline. So you're looking at that's what you're looking at when you're looking at class one, two, three, or four. But to give you an idea of what the PIR gives you, is what this is showing and let's just start with the 42inch. If you had a 42inch operating at a thousand pounds, you can see you would have here's the pressure, a thousand pounds. And here would be the PIR.

It would be about a thousand feet. Maybe a little bit under a thousand feet. Again, now then let's go down to 8inch. An 8inch at a thousand pounds would be somewhere under 200 feet. For these different sizes, we made this chart just to give you an idea of how the PIR changes based upon pressure and based upon diameter. And then going to talk about moderate consequence area. Moderate consequence area or MCA, again, it uses the potential impact radius. And it's five or more buildings intended for human occupancy. Right here. And then any portion of a paved surface including shoulders of a designated interstate, other freeway or expressway as well as any principal roadway with three or more lanes. And another item one 97210 if you look there requires applicable gas transmission MCA with maximum allowable operating pressure of over 30% specified minimum yield strength to be periodically reassessed every 10 years. So it does have in the code where you have an MCA you do have to reassess it every 10 years if it's FGL. As far as the mileage, as far as being in an MCA, HCA or in neither, this is a breakdown. If you look let's start, first of all, with the HCA mileage. You can see here we've got about 21,000 miles of HCA mileage. In the new rulemaking that's come out in the past two years, you can see MCA, whether it's allowable not allowable or RLI able here. There's about 19,000 miles of MCAs that you can run an LI tool through. So when you add these up, we're at about 40,000 miles of transmission pipe that would be evaluated on a periodic basis. Whether that was every seven years or every 10 years for threats. And you can see all the other that's outside of those, as you can see here it's about 257,000 miles of 301,000. But again the definition of MCA would be five dwellings or more. And HCAs, if you're using method two, would be 20. Just in summary, potential impact radius is used to determine high consequence areas. PIR is used to determine the mileage and moderate consequence areas. Again, there's two methods for determining HCAs for gas transmission. Either using class locations or using PIR. I know earlier we were having a discussion on various locations that had ruptures and fires. But the key part is how much was around them. I know like Danville that we were talking about, when it happened, I think HCAs was all that was in the code. Now we have MCAs, which is five dwellings or more. So areas that we were not picking up before, we will be picking up with this addition to the code. As far as again what I had gone through earlier, some of the other items you have to look at is just because you run an ILI tool, you've got to have a bar that's consistent for everyone. What PHMSA did, we went in, if you look here, seven 12 and 714, we strengthened the repair criteria for nonHCAs, if you look at the code previous before we strengthen 710 and 712 there wasn't a defined requirement of when and how to repair or remediate whatever term you want to use anomaly outside of an HCA. So what we've done is we've added requirements for MCA similar to HCA requirements were a couple years ago. The only thing we did we gave operators up to two years to do the repairs. Also we've added for MCAs to do assessments, if it's ILI applicable, every 10 years. After initial timeframe in the code. The other thing that we've done is on anomalies outside of HCAs and MCAs, we've got criteria there for remediation, which I think that's raised the bar for everyone. And then again if you look at the impact, as I've stated earlier, the impact for the HCAs and MCAs is about 40,000 miles. Again, just going back to what we talked about before, and I tried to highlight areas where we've seen, where it was from the potential impact radius based upon the MAOP, whether it was the length, versus the length of the impact area versus pipe ejected, and all of the ones that I've highlighted on the length of the foot, the pipe ejected on the impact area and the pipe, where it's been exceeded you can see again as I've stated earlier, three locations out of 17 and here where the pipe went

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further was two locations out of 17. And again this is going from 2017 to 2022 has been the case that PHMSA has evaluated. As far as fire duration, I know here we've got that. We have got the valve rule that has a 30minute or less timing as far as shutting off anomalies on new pipelines. You can see here some of the fire durations were quite long and also as far as oscillation times for some of the sections. If you look here here's an hour and 21 minutes an hour and 35 minutes an hour and 12 minutes, two hours and 12 minutes. An hour and 52 minutes. Three hours and 23 minutes. Two hours and 25 minutes an hour and 26 minutes. So we've got a lot of them that were over an hour to oscillate. The reason I was pointing that out is I know yesterday we were hearing about SMS. I think tomorrow Allen Mayberry will be talking about SMS. Operators that participate in SMS should be looking at items such as this and making where they've got areas such as this and looking at the oscillation times. They should not take the code to require you to do it where we have to put exact language. Operators should be doing that on their own accord when they do a risk profile of their pipeline. The reason I was pointing that out is again part of the three legged stool is everyone doing their part. So PHMSA expectation is for operators to be doing that. Again, thank you for listening to me. And if you have any questions, I guess I'll turn it over to Max and others. We have a question from online from Charlie Child's, what parameter are the impact area length and width burn area structures damaged?

>> Say that one more time. What parameters for the impact area length and width burn areas structures damaged?
>> First after all, the areas I have on impacted is actually what we measured in the field. When our inspectors went out it's actually the impact area that I'm showing on length and width is actually what we measured when we went out on the field and looked at it.
>> Thank you.
>> Can I sort of echo the question. When you guys were measuring those businesses did you measure to the edge of the burn zone or did you measure to anything that was damaged? Like what were those distances to?
>> I think it was to the edge of the burn zone.
>> Burn zone. Thanks.
>> Yes?
>> Thanks, Steve. Garrett. Just for wanting to make sure that we have all the right facts, the Danville incident, just right out of the NTSB report is actually 56 minutes for time to isolate on that section. So I wanted to point that out. Maybe there was an error on your slides.
>> Thank you.
>> Thanks. Okay.
>> Thanks for your presentation, Steve. It's really interesting to hear how the regulations apply and what role PIR plays there. You know, thinking back on the

Carlsbad accident that Mark mentioned earlier and the 12 people that died outside of the PIR, six found dead and six that survived initially, later circuming to their injuries. The PIR and regulations it seems to me there might be room for relooking at that definition but from your presentation I wasn't sure if that was your view as well or if you think MCAs cover the concerns with PIR there.

>> Well, first of all, if you look at HCA areas where it's 20 or more, what the five in the MCA does will extend out the evaluation area that you're looking at. So let's say if normally you had 20 and it would stop at some point, as it goes down that whole area that you'll evaluate and assess will be larger. So from a standpoint of what you'll be assessing, it will be increased and should get a larger area in the areas that Sarah that you've been talking about. So I think part of it, yes, will cover that. Whether PHMSA wants to go further with it, we'll have to go back and look at that and we'll be coming back to the public and everyone when we decide what we're doing there. So that will be something we'll be letting everyone know as we go forward.

>> This is Allen from PHMSA. One of the reasons we're talking about this today is, you know, certainly we not the least of which we recently received an NTSB recommendation related to PIR but, you know, here we're gathering information from you all having a conversation and it's fair to say while we don't have I guess an active rule making docket that includes this, you know, it's up for consideration. We're exploring options right now. So we're open is what I'm trying to say.

>> Thanks.

>> I have a couple of questions online. One is from Jason Lambert. But I believe his question is covered by Bill Norton's question. That is, Steve, on your slide showing PIR in impact area you note three areas with an impact length longer than the PIR. What do you mean by impact area or length? Is this the area where structures were destroyed by the direct influence of the failure or does this area include secondary damage such as fire spread?

>> It would be in the ones that I have here I don't think there was fire spread anywhere. It would be the burn area. You're talking about fire spread such as San Bruno. San Bruno was not included here.

>> Again. So, Steve, a question. I know that you've worked a lot with our European colleagues on a variety of topics and also our Canadian colleagues. I'm curious do we see similar types of regulatory approaches related to PIR in Canada and in Europe? Or maybe Steve or Mark or Max or anybody. I'm just curious what others are doing in this area.

>> Do you want to answer it?

>> I do have some perspective on what the Brits do. They have a concept of a building proximity distance, a BPD. They use that to determine development exclusion zones and there's another distance that's sort of what the Americans are doing with the PIR. It's not based on PD squared but it's very similar relationship and when you overlay the

number of BPDs that trigger the kind of attention that the PIR does here, there are strong similarities. I'm not aware of other European jurisdictions that use that which is not to suggest that quantitative risk and explicit consequence analysis doesn't get used because it does certainly in Britain and The Netherlands there's an established precedence for rule making and decision making based on risk. So they are obviously looking at a consequence analysis that would be a fancier version of what the PIR does. More like what that pipe safe model does. But, again, it's not distilled down into this simple formula to side a circle. The closest analog is the distance in the UK.
>> A question online I believe was directed towards Mark. Could depth of cover be considered in revising one's PIR. For example pipelines and depths greater than 10 feet or HDD pipe.
>> That's a good question because the operating assumption is that pipelines are at a typical depth about a meter, yard below the ground. If they're deeper the tendency for the crater to redirect everything straight up goes up. And of course if it's a directional drill way down below the ground it's kind of hard to imagine how that rupture manifests at the surface. But we don't or people do not typically take into account the impact of deep burial depths on how the hazard zone looks. But, again, I think you would be more inclined to get a vertically oriented flame as the crater gets deeper. Which is what the crater model assumes anyway.
>> How is it going to burn with no oxygen. That was just a comment that was made.
>> Of course when it reaches the surface it makes it so the fire may not actually start until it comes above the ground.
>> I had a maybe Steve can help too. Maybe to educate the public a little bit too. A lot of what we learned this morning was definitely at a technical basis behind PIR and others. Steve can you touch on at the end of the day they become a negotiated rule making. Maybe Steve can talk about some of the aspects that might go into a rule making or maybe when PIR was first put into the rule but other considerations.
>> Well, as far as any rule making and when we put in the MCA we have to go back and look at what Max was saying, negotiated or cost benefit analysis and any time we put in rule making the valve rule, any of the repair rules, MCA, others, we go and look at a cost benefit as far as whatever standard we're trying to put in, whatever repair, remediation conditions, what that cost will be over a time period and what benefit it will be. So what he's asking is anything we do here whether we're increasing the PIR, whether it's 10%, 20% or some number, yes, we would do a cost benefit. It would have to go through a regulatory process where it would go through the office of management and budget. They would do an overview if it was cost beneficial and we would not be able to get anything through that did not pass that. So that's how we do on all our rule making unless Congress and the authorization makes it authorized in the rule making that we get from the law we get from congress.
>> Any other questions from the webcast? Or one here from the room.

>> Good morning. Alan with AGA. This is a question for Mark, possibly. Within the model what's the relationship between that exposure time that we talked about at the heat intensity threshold and PIR? I think you talked about it being like a 30 second. So for sake of argument if that was to be doubled to 60 second I presume that would not double the PIR. What's the relationship there?
>> Yeah. It's not proportional so doubling one doesn't double the other. I'm probably not in a position to do the arithmetic on the fly but if you go to the GIR report there's a table that gives you what the dosages or the heat intensities would be for the assumed exposure time. So you can actually work that out from the table directly. But I guess obviously if one's contemplating a different heat intensity threshold tied to a different exposure period one would want to know what that translates to in terms of distances. It's raised to a power less than one I would think is what the answer is. So it's going to be attenuated somewhat just by virtue of how the equation is structured.
>> And just to add to that, if you go to the PHMSA website and how I get to it, I normally Google or one of the search engines put PHMSA pipeline technical resources, and I go to gas integrity management and to the technical page of that and it will have the paper that Mark is talking about. It will have the calculations and show you that if you're wanting to look to see what the variation would be. I know a while back ago I had looked at it. What Mark is saying is what I had come up with too. It wouldn't be one to one. It would be less than that. And normally if you're looking at doing that there's a table in there that has like whether it's 5,000 that you're looking at BTU or 4,000 for like a wooden structure. It has a listing of times as you go down the list. So there is a table that would answer your question.
>> I'm seeing no other questions. So we'll go into break. It will be slightly more than 15 minutes. We'll go to 10:00 central. Thanks to Steve very much for the presentation and questions.
>> [Applause]

>> If you're on a panelist for the next portion right after break just come ahead on the table and we'll talk about CO_2 and hydrogen from Mark and then go into panel discussion right away.
>> [Break being taken until 10:00 a.m. central time]

>> Ladies and gentlemen, we begin in about two minutes. Could I ask you to please move back towards your seats. Thank you.
>> Just a reminder, panelists if you're on the next session please come up. We'll go into panel after Mark's presentation.
>> All right.
We have 10:00 central on the dot. Thanks everyone for coming back and the great questions in the first part. I want to let you know in the webcast if we're looking at the

floor there's a monitor here is we're not looking at Alan's shoes. We have a monitor so just so you know. There was a question about hydrogen and carbon dioxide pipelines, what we regulate with gases and other liquid phases. So we asked Mark to give perspectives on potential impact radius or potential impact area for both hydrogen and carbon dioxide pipelines and then we'll go right into a panel session with both covering additional topics from the morning and also more on this. So, Mark.

>> Thanks, Max. Hello again. Welcome to death by PowerPoint part two. Yeah, I'm going to give you sort of my perspective on things to think about when trying to develop or update PIRs for hydrogen and carbon dioxide. It reflects a lot of the work that I was involved in when I was with CFER technologies because we have been looking at quantitative consequence modelling for project. There was a project looking at building simplified models for fancy analysis for a wide range of carbon products for a new design approach going into the 2023 edition of the Canadian pipeline code. So that is going to inform the remarks I'd like to make today as well. To jump in, I'd like to paint a picture of hydrogen the product in contrast to natural gas and then I'd like to talk about carbon dioxide in comparison to natural gas and hydrogen. So starting with hydrogen, hydrogen like natural gas is lighter than air, so it goes up, doesn't want to stay in the ground. The hazards that you're worried that has simply implications for hydrogen like natural gas would be fires and explosion. The concentration range of hydrogen gas in the air that's of concern, between 4 and 75% hydrogen is a mixture that will burn in the presence of an ignition source. That's a wider range of concentrations than would burn for the case of natural gas. It's also important to note that hydrogen is classified as a high reactivity fuel in comparison to natural gas which is actually classified as low reactivity. The energy required to ignite hydrogen is way lower than the energy required to ignite natural gas which means it's going to be more susceptible to spontaneous ignition. And another important consideration is when you ignite a hydrogen flame the rate at which the flame speed runs through the flammable cloud is way higher than it is for natural gas and that has implications for over pressure. Turning my attention to carbon dioxide unlike the other two products it's heavier than air. So when it comes out of the pipeline it hugs the ground. It's not flammable which means what you're left with is an asphyxiation hazard and a toxicity hazard. The concentrations defends if you're talking about asphyxiation or toxicity. You have to cut it in half before the fatality risk becomes significant. Which means that you've got to have more than half of the mixture that you're breathing made up of carbon dioxide for it to pose a fatality risk. However, there's a body of literature that would suggest that in addition to being that it has to be a hazard. It's something we exhale, it's in the air but concentrations above the typical concentrations although way below the concentrations required to asphyxiate it has a physiological impact on the body. It will lead to unconsciousness and stop breathing. Which means the toxicity hazard is generally perceived to be the governing hazard. If you look at the Internet you can find sources to suggest that carbon dioxide is an

asphyxiant. There's other things on the Internet. It's a toxicity hazard is important. I believe the debate is not settled as to what concentration thresholds can lead to fatality due to the toxic effects to the asphyxiating. It's not flammable so the other parameters that I talked about for hydrogen don't apply. What I would like to do now is sort of compare and contrast the hazards that can develop when you get a rupture of a pipeline transporting natural gas versus hydrogen versus carbon dioxide. I want to do that using what's known as an event tree. But if I'm going to subject you to that I better tell you what an event tree. So an event tree is a graphical representation of a sequence of events that has to occur to lead to an outcome. If events do or don't happen the outcomes are different. You have an initiating event and other possible events that constitute branch points. If this happens then that. They call it a tree because if you look sideways it looks like a tree because the events downstream are branch points and hence the reference to an event tree. So if we talk about pipelines transporting flammable gases, natural gas and hydrogen the initiating event we'll say it's a pipeline rupture and the subsequent events that are of interest is does ignition occur and when does it occur. So in the event of pipeline rupture, if you have immediate ignition you have one set of outcomes, if it's not immediate ignition and you get delayed out come or delayed ignition then it's another outcome and if delayed ignition it's another outcome. Regardless of whether you're dealing with natural gas or hydrogen, in the event of a pipeline rupture you're going to get what's known as a rupture pressure pulse. It has nothing to do with ignition. It's simply the fact that this highly compressed gas is no longer confined by the pipeline. It comes exploding out of the pipeline and expands rapidly and that high speed release and expansion pushes the air out of the way and it effectively creates a pressure pulse that you can hear and you can feel. If you're really close it's going to knock you over or do even more harm but that pressure pulse tends to die out pretty quickly with distance. In the event of immediate ignition when the flame starts to burn and then runs through the flammable region of the crowd or cloud you're going to get an ignition pressure pulse. And if the immediate if the ignition is immediate you typically get this expanding ball of flame that rises into the atmosphere, that would be the fire ball which rapidly transitions to what's known as the crater or jet fire that you typically associate with this type of incident. If you don't get immediate ignition but delayed ignition there's now an established flammable vapor cloud up in the air which when it ignites and the flame runs through that vapor you're going to get an ignition pulse and a very short lived flash fire that collapses into the jet, the crater fire. And in the event of no ignition you get an elevated vapor cloud. If we're talking about natural gas, history has shown that that pressure pulse is not negligible but not a governing hazard. It's overwhelmed by the radiation from the jet fire or the crater fire and that's the hazard that's being addressed by the PIR formula that you'll find in federal regulations and in ASMBE318. In the case of hydrogen, the same stuff happens but if we skip straight to the end and ignore pressure for a moment, the fire ball decaying into the sustained crater fire or short lived flash turns into a crater fire. That's what people think you need a PIR formula for, and you do. I'm note sure if all of you are familiar with the fact that there is a PIR formula for hydrogen. It's in the ASME hydrogen pipeline design standard B3112. Now it's presented and called the PIR although the way they use it is slightly differently from the way it's currently used in the integrity management rules. They don't cite the source for that model but I am familiar with it because it's sort of my fault. Back in 2005 when I partnered with Michael Bacon, junior on a project to develop PIR formulas for other gases, that report included a model for hydrogen releases. And the hydrogen formula in the Baker report from 2005 is what's made it into the ASME B standard. That work was done on evidence that flame that was prior to 2000. The reality is that information is out of date. There were no large scale hydrogen fires, no attempts to simulate hydrogen releases from buried pipelines until the past 10 years. And that information paints a somewhat different picture of hydrogen in the event of high speed release in complete combustion, et cetera. The formula in ASME B31.12 is out of date and needs to be updated as it relates to crater and jet fire hazard. However I put question marks on the pressure pulse due to rupture and ignition. Shock tube tests have shown that the pressure pulse from the gas release because the velocity of the hydrogen coming out of the end is so fast, that pressure is bigger than it is for a comparable pipeline transporting natural gas and the ignition pressure pulse that you get is also going to be higher because, again, hydrogen is a highly reactive fuel and the flame runs through the flammable cloud way faster, the pressure pulse is going to be higher. That needs to be looked at. I'm not saying that it's going to govern. In fact I doubt that the rupture pressure pulse is going to be that big of an issue but the potential ignition pressure pulse might be big enough to have an impact on what the potential impact radius is. And I'm not saying that that will be the case, it's just I have not seen information in the public domain that clearly lets you dismiss the over head pressure for hydrogen ignition. When you get to carbon dioxide, you still get that rupture pressure pulse but it's going to be comparable to natural gas or less because typically the CO2 is being transported in a dense phase. It's the flashing from this dense phase fluid to vapor that is going to generate that pressure pulse and that pressure is going to be lower than it would be for natural gas. Because it doesn't ignite what you're left with is a vapor cloud but because CO2 is heavier than air that is going to hug the ground. You have a ground level vapor cloud where the concern is asphyxiation and toxicity. If we look at and compare the hazard zones you get from a sustained or crater jet fire, which is what you have for hydrogen and natural gas and compare that to the hazard zone you get from CO2 the cartoon is meant to highlight a few things. For thermal radiation hazard the release rate designs the size. The gas composition and the flame that results in the density of the fluid is going to effect things and your heat intensity threshold. One of the things we've been talking about this morning is going to be on the table. You have to have all that stuff to be able to work that out. If you're

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looking at carbon dioxide, the release rate matters to diameter and pressure matters. The concentration threshold that you design as hazardous be it for lethality you have to look at is it toxic and what levels might lead to fatality as what might be the result from concentration to cause asphyxiation. You need to know where the cloud is because where the cloud is where the hazard zone is. That's very much influenced by wind speed and direction, very much influenced by the atmosphere stability class which is how the atmosphere mix the gas with air as it spreads downwind. You care about the terrain, in particular how rough it is. If you release this dense vapor on a Tarmac the downwind extent will be greater than if you release it into a field with tall grass because the tall grass acts as a friction drag thing to hold up the spread some the rougher spread. So the rougher the suffer face the less the vapor cloud spreads and the shorter the downwind distance is. Last but not least dense vapors seek low points. So the elevation profile is potentially a consideration. So there's unfortunately more stuff to think about if you're doing a hazard zone analysis for dense vapor clouds. Now with respect to wind speed and direction, atmosphere stability class and terrain roughness you can do a fancy site specific analysis but there is precedent for doing this at a relatively high level in a generic sense with typical assumptions about wind speeds, typical assumptions about atmosphere stability class and typical assumptions for terrain roughness. So you can do a fairly generic type of analysis for CO2 using representative values for those parameters. That would probably be the way you would carry out an analysis for, quote, screening purposes. I put an asterisks on there because we were involved in a study that looked at dense gas dispersion in the context of a consequence screening analysis for the development of the safety class system and I've referenced the paper that came out quite recently that talks about and compares and contrasts the hazard zones for CO2 pipeline dispersion and the hazard areas compared to the fire hazard zones. Even though fancy models, numerical models are run to do the analysis regression analysis was used to turn them into PIR type formulas so it might be of interest to look at. Dense gas dispersion models are complicated. If you try and take elevation profile into the mix it gets even more complicated. You have to use computational fluid dynamics to be able to count for the terrain elevation profile. So if you want to do the full meal deal there's lots of fancy analysis required and the terrain or elevation profile consideration really does complicate things and it's going to make it very location specific. Last comment I'm going to make before I turn things over to the panel is if you use the thermal radiation hazard zone models like the ones we talked about you get this, quote, radial distance. The assumption is the radius defines maybe a circle in which the bad things happen. If you look at the downwind extent to these vapor cloud hazard zones and you call that a radius, and if you then treat that as a circle, you're over estimating the impact area because it's not a circle, it's the pedal of a flower. So the actual hazard zone area is not figured out by using that distance as the radius of the circle. It's the downwind extent of this shape that looks more like a football. If you use it as if it means the same thing as

the PIR for thermal radiation it's apples and oranges. So when you're working out how you're going to use that information to build a, quote, PIR you got to think about flower pedals versus donuts. So I will leave you with that as a background. I'll turn it back over to Max and we'll go from there.
>> Thank you, Mark.
>> I stole that. Sorry.
>> If anyone does have questions we'll first do intros of our panelists that joined us but if you have a burning question, use a different term, about hydrogen or carbon dioxide Mark will definitely field it. With that we're going to into our panel portion. It do want to is introduce some additional panelists that have joined us on stage left, house right. Bill Caram, executive director of pipeline safety trust. We have John Wolfgram and then Andy Drake vice president of integrity for gas transmission and midstream. I want to give them five minutes to introduce themselves, their perspective on PIR for both natural gas specific but also potentially CO2 and hydrogen. So, Bill.
>> Okay. Is this on? Working now? Delay. How about now? The green light is on. There we go. Okay. Yeah. Thanks, Max. Thanks, Steve and thanks Mark for a great discussion. I introduced myself yesterday so I'll skip that introduction and the introduction of the pipeline safety trust. I want to, you know I do really appreciate the NTSB's recommendation on this by looking at PIR on this nonconservative nature and the human factors that play into it. I really appreciated that walk through from Mark this morning. It really is remarkable how such a complicated concept was distilled down to such a simple formula. It's really impressive. I would say from the public's perspective, you know, rather than the of course the math behind the calculation, the public's concerned about the definition that's in the regulations, the area where a pipeline's potential failure could have a significant impact on people or property. And I think the public's perception of what a significant impact could be is probably different than what the calculation is calculating. I think they would be surprised to learn of what would be expected of them in the event of a failure in the time it would take to recognize and how fast they would need to run and things like that. So I think there is room to look at those assumptions and the calculation from the public's perspective. And I think there's the potential for the to find a calculation that more accurately reflects that qualitative description in the regulations of significant impact. We're also realistic about the outcome of anything like that. We saw the mileage on HCAs and MCAs that are subject to those extra safety standards and integrity management and I think any adjustment to that calculation is probably going to have a pretty modest impact on that mileage that's under integrity management. So I think what it really comes down to from the public's perspective is really about public awareness and public engagement. I think both of those programs from an operator are probably going to look different to a member of the public who is within that potential impact radius versus outside of it. As far as CO2, I think, you know, there are much more dramatic effects possible with new

calculations on CO2 as Mark just outlined because it can move so far, so much further than what any kind of current calculation measures as we saw in Mississippi that I think we are talking about some more dramatic potential effects on mileage of pipeline that would be subject to integrity management and other safety factors. But it's also really important on public awareness and public engagement and then I think extremely importantly is emergency response and making sure that communities that would maybe otherwise be considered too far away from a pipeline to be potentially impacted are prepared for an emergency response. Yeah. So I think looking at PIR for gas is probably a relatively simple questioning of the assumptions. CO2 obviously much more complicated. So looking forward to the discussion.
>> Thank, Bill. John.
>> Good morning again everyone. John Wolfgram with the national association of pipeline safety representatives. Like any good conference you have some ideas when you show up and then you maybe come up with new questions as you continue the discussion. I think through the kind of the lens at least from the state perspective looking at obviously we're talking about PIR potential impact radius and that really kind of lands on the transmission pipelines as I kind of went through yesterday we do regulate those. Lots of those are often negotiated with distribution piping that we have in our states. I did a quick dive into data. Since 2010 states have experienced about 500 gas transmission related incidents. Around 12 of those are incidents where, you know, damages were seen outside the PIR area. So just a little perspective on where that is. You know, then that is certainly not minimizing the impact that all 500 of those can have on people, property and the environment. You know, one thing I took away this morning was we have that calculation, you know, that was based on data based on evidence, based on practice and I think maybe some of the questions I have as we kind of discuss this further is do you change the calculation, do you change kind of the basis on for how the PIR is defined or do you utilize the current definition or calculation and maybe change where you apply that. You know, do you change counts, do you broaden the area in which that definition gets applied to. We talked a little bit about that with the MCA, you know, definition that we have in the regulation. Thinking about accidents and incidents primarily we have integrity management, we have PIR calculations and all that good stuff but the end of the day we you know, we have gas distribution accidents that happen where it's a totally different side of the house but I think we can really have some equal comparisons there that, you know, go back to emergency response. So if you do have a release, you do have an accident, the amount of time you can minimize where you have glow blowing gas, where you have that product being released I think that's where you see a lot of impact as well. Certainly we see that in the gas distribution world with what we see in states. Certainly in the areas of CO2, I think a lot of the pipelines that states are going to be familiar with are going to be interstate pipelines. I still think at the end of the day there's a lot more questions, there's a lot more we need to look at

there as far as the impact that these can have on folks. Thank you.
>> Thanks, John. Thanks, Max. A little bit of background on me, why am I up here. I was the ASME chairman of the standards at the time with B document was developed. That was the document that actually drove the development of the PIR and Mark and I met each other 20some years ago when we were much younger trying to think through how to provide consequence guidance to operators. Inside if you you know, I think really from a standpoint of the ASME document, that document was written on how to manage integrity management, how to do integrity management everywhere. It doesn't differentiate between high areas. That became codified later. The document was developed in the context of trying to provide guidance to operators of how to do integrity management everywhere. It gave a PIR to help people quantify assessments so they could do assessments at some point. I sit on the advisory committee for rule making and have sat on that committee for quite a long time including at the time this was adjudicated back in 2000 when we were vetting about the section O document which the B31.8S became a heavy information base for what later became section O of the code. So those two are very closely related. So ASME was generated and used to fuel the conversation that became section O of the code. So I sat on the advisory committee to PHMSA about creating section O of the regulations. So those two are heavily interconnected. I think that the really interesting thing I appreciated Mark's conversation and Steve, I think you really get a sense of how deliberate the effort was to try to provide a credible consequence model that was practice and conservative. A lot of data was as Mark eluded to a lot of data was used to look at the fire patterns we had, litmus test the model. Steve indicated since then we've been doing kind of an on going check model, you know, so our PDCA model is working and I think this is a part of the PDCA model. Here we are again, we have more data. It's prudent for us to come back together and again and check it, check this data, do we need to act and make some adjustment to what we're doing. I think the thing that may help, it provides some context in this discussion is kind of back to B31.8S. The purpose of the PIR was really to help operators get a sense of consequence to try to provide some credible model of what impact might look like in the interest of working progressively through their whole system. So we've done ACAs and people said, okay, we're done. We're not done. There's MCAs. People go, oh, we're done now. No we have LCAs. It's just a series of tranches that we're going to go through to get to the whole system. The question that I think has to happen is how long will it be until we get to the next tranche, so 12 years ago when HCAs and MCAs and maybe take another 10 to get to the rest. So what's the value proposition, you know. Okay. We're going to get there. You know, is there a certain fingerprint that we're learning that we need to get to that's urgent I think is relevant in this conversation. I appreciate the effort to center on facts. Getting centered on what is the basis of the model, what is happening inside and outside, how it was designed to work. It was never intended as an exclusion zone. And I think that's really

important. I appreciated Mark's wrestling with the effect. At the time there was fires in California. We could burn down a county that starts a fire that keeps knocking, knocking, knocking. How do we model that? We can't because it would be chaotic and unhelpful to everybody. So we tried really to look very deliberately at the immediate impact and tried to make some conservative assumptions about radial damage and things like that. But I think that the sense that I have out of it is inside the PIR is a high consequence, high risk event in the face of a failure. There that's why we call them high areas. That's why we call it an area of concern is if you're in that zone that is a high risk event. So we need to be very focused on that. Outside that area is not a no risk environment. It is a different risk level where structures and time can give you some opportunity to, you know, prevent or mitigate lethality. But I think the real key in that conversation is heat intensity threshold. Okay. If we want to change heat intensity threshold what you're saying is how far outside the HCA do we want to look to get them in that higher consequence area, that higher lethality consideration. So it's really I think the delta that we're talking about here is in what I would say call LCAs if we say ACAs, MCAs, LCAs, the next, if we want to pass a revised PIR through the LCA we would just be saying how much further out do you want to look of I think the thing we want to lay out is is the juice worth the squeeze. We're going to get to LCAs next. It's just when and is that interim time not acceptable risk that we're carrying until, you know, we can get there with this revised criteria. So that to me is how I see this conversation sort of boxing out. But it's a great conversation. I do think hydrogen is a different animal on many fronts. Not just mylergically. We should be thoughtful in how we put hydrogen in steel structures and should be thoughtful how to model that impact or that consequence. Thanks.

>> Thanks, Andy. I'll start off. Any questions? I have a whole bunch. John has one.

>> Hi. Thanks. John Study with liquid energy pipeline association. Picking up on Mark's presentation as a foundational question is how to label this zone or area for CO2 pipeline. Potential impact radius is not only the wrong term but a bad word. If you had a radius of 100 yards picking up a number you would leave out the town down the road. No CO2 is going to flow a mile uphill. How do you when we're picking up on recommendations of encouraging people to do more and better modelling or to do more and better out reach how do you get the correct zone or area and you're not sending them to the wrong places or taking money from the right places to give to the wrong places if we're going to misapply the PIR term to CO2? What would you suggest we call a potential impact zone or potential impact area or how would you have us do this?

>> I don't have the acronym in mind but I'm certainly cognizant like I brought that point up and you amplified it. The maximum extend for a downwind vapor cloud is not the same reach for a fire hazard zone. When one does work out a PIR type of formula to get you to the maximum downwind extent there needs to be another later on top of that to figure out how to use it in the context that's consistent. I don't have the answer at this

point in time but I'm just concerned that it shouldn't be treated the same way. And I'm equally concerned about the fact that to the extent the elevation profile factors into it, and you eluded to that, it makes it even more complicated and location specific. And currently the standards try very hard not to impose too big of a burden on the pipeline designer or the operator at certain stages in the design and management process for fancy out flow modelling and consequence analysis whereas we're kind of getting into an area that suggests, well, if we want to change that it's really going to have implications. So I think care has to be taken in how you define that distance and how you use it to figure out what the area is and how you actually count houses in proximity because it's not a straightforward process. At this stage I'm simply saying that needs to be sorted out along with the modelling of the dispersion characteristics as well. So, yeah, very different for CO2. And I don't have the answer yet but we and others are working on it.
>> Yeah. I might just add in the next session this afternoon we'll have our colleagues from engineering research talk more about CO2 including one project we have on looking at PIR. So Lynda.
>> So thank you. This meeting but also a lot of policy decisions, discussions have just like opened up Pandora's box in my mind. I keep thinking, oh, what about this or oh, what about that. Mark one of your diagrams just kind of put a light on it. I don't know if we can go back but the slide in which you showed the PIR with the circle, the donut versus the pedal leafs.
>> Yeah.
>> So I immediately thought, oh, natural gas pipelines donuts and CO2 pedal leaf. Then I thought what about ammonia? What about CO2? What about propane? Propane has the if you have a rupture of propane you have a vapor cloud and it can move like CO2 does, you know. The whole setting off the flame to set off the vapor cloud. So then you've got PIRs, the whole question of what about PIRs for propane. So right now we're looking at what about PIR or PIR requirements that we currently have in place for natural gas, what about propane, CO2 and hydro's ammonia. Do we need to take a bigger picture look at all these different aspects?
>> Maybe I'll try and answer that first. It's a very good question. You brought forth an issue that we had to wrestle with in the joint industry research project. Remember I said we did consequence modelling to support the development of this new alternative design approach to go in the Canadian pipeline code. The idea was it was going to involve explicit consequence modelling everything covered by the code. Natural gas, propane, butane, sour gas, multiphased pipeline CO2. Natural gas has hazards that are circled on the break point. CO2 has flower pedals with the center of the flower centered on the break point. Propane is a mix. You can get a jet fire from propane. You can get a flash fire from propane. So one is the circle, one is the power pedal. So our approach is we need a weighted average of those that reflects the likelihood of having the vapor cloud fire or the vapor cloud explosion or the jet fire. And then what you end up with is

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this weighted average hazard zone because the alternative is the outside worst extent. And if you have the luxury of doing this worst extent analysis, fine. But in practical terms, given the implications for managing the assets and correctly estimating how likely it is the weighted average for all the different shapes and hazards is what we ended up with which becomes a bit abstract because it's not the worst of the bunch, it's the average of the bunch based on how likely they are. Explaining that and selling it gets more complicated. But I mean that's the road we went down. So in the upcoming Canadian edition these zone area estimates are weighted averages of the hazard zones from all the hazards that could develop given the release and the distances for figuring out the house counts are also weighted averages. I guess devil's advocate some people are going to say isn't there a hazard that could be bigger. Yes. But in the context of how we're using this analysis, we're using this weighted average approach. So, yeah, HVPs, propane and butane are nasty because it's a mixed bag of what can happen and the hazard zones have very different shapes. It gets complicated.

>> From the general perspective we have lessons learned. For CO2 it's a different animal. It's not liquid, it's liquid like in transportation if you're talking super critical. If the public doesn't know super critical is a different pressure and temperature, above 1070 PSI and above 88. When you play with those numbers you would get into a gas state, you could get into a liquid state and solid state. So that point I might transition a question to Steve on plume modelling has come up. Can you talk about the regulations looking at modelling for HCAs in a liquid context that might be applied to CO2?

>> If I can get this to is this working?

>> Yeah, you're on.

>> I'm on. Okay. As far as in the liquid code which would be part 195, you have to look is it on?

>> It's off.

>> There it is. It's on now. You've got to look at the dispersion modelling. No matter what type liquid it is, whether it's CO2 or even in HVLs and things like that. I know some of the models that have been used and some that are probably being used for CO2 would be the aloha model would be one and DNB PHSAT model. There are other models being used for dispersion and everything. When you look at an HCA you have to look at the could effect area. So you may have an HCA and then you've got to go down and look at the whole area that the product can go to. So that's why if you look at the mileage and the liquid side about half of the pipeline mileage that's under part 195 would be an HCA based upon how the modelling is in part 195.

>> I got something.

>> If I could just point something out there too. On those models fast and I believe aloha2 do not take terrain into account which as we know is very important in modelling CO2. So it's a simple and inexpensive model but it does have some big draw backs.

>> And just to add to that, there are other models that can be used. I just there is

canary. I could list a whole bunch of them. There's more than just those two models.
>> I think Mark touched on, there are models available. It's technically possible but it gets really time intensive to then also expense. But, yeah, there are models out there.
>> If I can jump on that band wagon. I realize it's a topic to come up but there are lots of commercial dispersion models, some more accurate than others, I'm not aware of any commercial tools that handle elevation profile changes for dense cloud dispersion. They handle surface roughness which is really important but the up and down bit is where the computational fluid dynamic stuff comes in. That I would call more research than practical application. So the reality is it may be easier said than done to account for all of that with the technology that's currently available to most operators.
>> We have several questions online. Going back to Mark. It is a follow onto Lynda's earlier question. Mark, can you further expand on your thoughts about the hazard area for thermal versus vapor cloud being apples and oranges due to one being a circle and a flower pedal. Thinking about a vapor cloud's potential impact area as a circle defined by hazard distance radius seems to make sense from an individual risk standpoint. The area of the hazard only becomes important when we start thinking about societal risks. Where the number of people impacted are influenced by the area involved and all wind directions are possible. They don't occur with the same frequency. How can we address the differing possibilities for each pedal when we have nonuniformed structures around the pipeline?
>> Right. So the issues at play for dense cloud is the downwind extent depends on the wind direction and the wind direction isn't actually random, there's preference directions that depend on where you are. There are other issues around the terrain and similarly if the property density varies within the area the only way to do that strictly correctly that you would have to take do an analysis of at least 16 different wind directions, do the analysis for that wind direction, see which properties it engages and then pick another direction and another and then for societal risk you do a weighted average and for individual risk I guess you could do it for each wind direction and for each house. So it's doable that way but as you can appreciate if you're trying to generify it you have to make smearing type assumptions. So there's no easy way to get around the issues that the question invites. And I guess the people who are trying to implement this approach have to decide what level of rigor to employ to dumb this analysis down to something that will be practical in the context of what we're trying to use it for because you cannot do a site specific consequence analysis for every mile of pipeline I don't think in any practical way given the technology and the tools and the information that's current floating around.
>> Thank you. We have a comment more than a question from Kevin Ricks. PIRs for pipeline carrying pipelines other than natural gas may more resemble thermal than vapor at LNG facilities. The next question I have. Max, I'll direct it towards you as you kind of touched on this topic. It's from Cindy. What is a dense phase fluid, is this the

same as a super critical liquid or the pure CO2 that is proposed to be transported from ethenol plants to be sequestered? Thus think natural gas is so much more dangerous than the proposed CO2 pipelines. Where is easy to understand information I can share with them of the dangers we may be facing.
>> Yeah. So anything on Iowa I defer to the public record there. There's siting meeting going on now. We don't do siting. So the phases, so first super critical what's in regulations, typically it's above 1070 PSI, 88. But my understanding as part of part of that process, sequestration of getting out there's a production that wouldn't fall directly under us. My understanding, there may be different phases that differ from the out take to the injection portion to the intake. I have heard there might be cases where they will be just below the super critical point but Lynda is here and I think it's fair to say PHMSA won't play games if it's just below the critical point. We're going to treat it as regulations through super critical. I don't know if Lynda wants to add on that. Things are getting pretty darn close. There's some perception out there, is an operator doing it to try to get out of the regulations. Some might be super critical. I don't know if Lynda wants to talk more about that.
>> If there is any possibility that there's super critical in that pipe we will regulate it. So if you have mixed phase and let's say you see this sometimes on the gas line, natural gas where you may have some liquid entrained you're covered. On CO2 if you have let's say even if you're at a point where you're in a gaseous phase it's covered, we will be out there. The other thing I want to be very clear on, congress has given PHMSA statutory safety authority over gaseous CO2. We already had it for super critical CO2. We have regulations that apply to super critical CO2. But we also have safety authority over gaseous CO2. So if we see a concern we can move to act. We have to know that there is an issue and we're going to keep our eyes on all these new projects being proposed. So it would be unwise for a company to say oh, we're going to keep it in the gaseous state and think that PHMSA won't be out to see them because we will. So I hope that helps.
>> Thanks, Lynda. We have another comment. It is from Jen. Just a comment on elevation and roughness. Out puts from models like Aloha can be over laid in products to account for elevation and roughness. We can take a question from the audience.
>> So CO2 in gaseous, what part would that fall under?
>> [Inaudible]

>> It's a question was CO2 for gaseous where would that fall in the regulations? Lynda said probably 195. I will say our rule making folks are looking at those contexts of do they all fall under 195, should they be broken up, 192, 195.
>> Russ Morris with air products.
>> Yeah.
>> Has anybody talked to CGA about how to build and operate hydrogen pipelines? Compressed gas association. I just wonder because it doesn't sound like it. Because

we've been operating hydrogen pipelines since probably the 60s with almost zero incidents. Other than small leaks. So I suggest somebody get in touch with CGA.
>> Yeah, I think we have experience with them in the past. I want to say even some of our former I want to say some of our former administrators had some experience with CGA in the past, yeah.
>> Yeah.
>> If I could add, I think some of the context that you're talking about is hydrogen specific pipelines. Some of the context that society is dealing with now is blended hydrogen into natural gas streams using the existing pipelines. That's a different animal. That's where you're getting some of the pensive response about we really need
>> True. But I think that there's been some studies that show that as small as 10% hydrogen in a natural gas mix is going to act like a hydrogen pipeline in operations. So, you know, I
>> I agree.
>> That's a small so it would take the hydrogen would take over in operations.
>> Yeah. I think a bigger concern and someone correct me if I'm wrong, it's not necessarily if you're building a brand new dedicated hydrogen pipeline, it's when we have questions are you going to repurpose an existing line that maybe wasn't intentionally built for hydrogen in the first place what happens when you start building with natural gas more and more. Those are the questions that get concerned. I don't know if Bill mentioned it but there's a public report out through TST that talks about some of those concerns. I think it's fair to say if anyone has not seen it the pipeline safety trust conference recently all the discussions are recorded now and publicly available. So good to hear some of the questions, concerns that are coming up in that context. Bill, do you want to?
>> Yeah. I encourage everyone to we have a white paper both on CO2 pipeline safety and now on hydrogen safety that just came out. There are also as Max mentioned was a really great discussion at our conference a couple of weeks ago and that's on our website as well. Under programs go to our hydrogen page to see the paper. You can also go to the conference page and you can watch the replay of that discussion which I thought brought up some great issues. We've seen I think we're getting beyond the PIR discussion here but we have seen, you know, integrity issues with blends as low as 1%. And I thought Mark's chart there of all the different physical characteristics between gas, hydrogen and CO2 was excellent and we have a lot of those features in our paper and it was really great to see it laid out that way. So I think issues like flammability range and yeah. All of those physical properties that Mark pointed out I think are really important. I was curious you said the PIR for hydrogen needs to be revisited. How would a PIR for a hydrogen blend be approached?
>> Right. I did want to make a couple of comments on the topic of blending because I didn't say anything about it at all, I talked about natural gas and hydrogen. And there is

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frankly more interest in blends than hydrogen pipelines. And if the hydrogen concentration if the proportion of hydrogen in the mixture is relatively low like you see numbers like 10 or 20%, I don't think the over pressure hazards that might be an issue for a pure hydrogen pipeline are on the table. It's more like how does the blend effect the crater fire hazard. And there's a process that you can go through if you treat hydrogen as a mixture component to work out what the release rates would be and what the theoretical heat energy would be and there's now more information on better information on the hydrogen. I think doing the jet crater fire analysis for a blend is not something that requires a whole bunch of research. It just has to be based on an agreed approach and followed. The issue is when does the hydrogen content get sufficiently high that some of the other hazards might become an issue. I don't think that transition happens at 10 or 20% I think it's happening at a higher concentration level. And there is a cook book of sorts in that Baker report from 2005 that talks about how you would treat a mixture with some adjustment it would I think work well for hydrogen blends as well.

>> Yeah and I think again this afternoon we'll get into a lot more technical thoughts and research beyond hydrogen and CO2. I did want to shift gears a little bit. I did appreciate Bill saying we're getting out of PIR. I want to put Andy on the spot just a little bit. To help well, let folks know too when these incidents happen it's not just NTSB coming out and you're hit with a report. I want to talk about the incidents at Danville, what the industry does, the info sharing. There's a lot of discussion on the need for info sharing, transparency sharing, things like that. I want to give Andy a chance to talk about lessons learned from the incident and where they went with it.

>> Thanks, Max. I thought there was really good presentations yesterday. Really good discussions around it. I think the key, again, facts on the table. These are things that, you know, investigation identified, opportunities to learn. We did a lot of work with pull through labs are known samples of hard spots and pulled every tool we could find on this planet in the testing schema to get a sense of what was their testing capabilities and try to better define technologies to go in the ditch. We also really looked hard at what we think drives certainty. We're moving over to quantitative risk management, what drives certainty in this threat. I think there was some really good points about reevaluating the data. When we look at facts, when we took the old tools and passed it through the algorithm it identified a lot of hard spots but did not characterize them as actionable. Including the one that failed were well below any actionable criteria. They were below 240. That's not going to cue anything for anybody to do. That's not helping raise the confidence that you will find the critical flaws. The tool capabilities of the old tools is particularly susceptible. It's not mature. We're looking at I think the question is the thing that we learned is the new technology that are out there.

We also really looked hard at what we think drives certainty. Moving over to quantitative risk and managing the threats. I think there were good points brought up about reevaluating the data. I think when we look at the facts, the facts are when we took the old tools data and passed it through the new algorithm, it did identify a lot of hard spots. It just did not characterize them as actionable. Almost virtually all of them, including the one that failed, were well below any actionable criteria. They were well below 240. That's not going to cue anything for anybody to do that's not helping raise the confidence you're going to find the critical flaws, the tool capabilities of the old tools is particularly susceptible. It's not mature. And we're looking at I think the question is the thing that we learned is the new technologies out there, particularly Rose and Tool, I'll give them credit, I think they have a good tool. The ability for that tool to characterize is significantly better than the old tools even with modern algorithms.

So the question becomes, do you spend your time reevaluating the old data with a low certainty of finding the outcome or do you run the new technology. And I think that's a really important pause for everybody is simple solutions to hard problems don't usually lead out. They lead back in. And I think that's really an important lesson that we learned. I think the other thing we talked a lot about CP system. I mean, hydrogen is a product of the CP system. Okay. So we don't want to be overvoltage. I think that is really prudent because it damages the coding system, which is bad. I mean, you're starting to disbond the hydro coding system but dialling in the CP system will not mitigate the risk of hydrogeninduced cracking due to hard spots in my opinion very seemingly. The work that Kevin Garrity has done recently that identified the environment is a huge player in creating is yous he thoughtibility that with the right or wrong environment, you can create absolutely enough hydrogen at .850 to drive failure that's been documented. Our CPC system was not overvoltage by any stretch. Trying to mitigate or someone asked the question, you asked the question, Linda, should we go after managing hard spots or should we go after finding them. I think when you introduce the uncertainty around the environment influence and the fact that you can have a failure well below overvoltage criteria, and have, managing them is very scary. Below certainty event. Finding them is better outcome on certainty. I think that's a really important thought to pass on. The other things are good but it's not yielding the certainty level that we're looking for to manage threat. I think the tool, driving the confidence around the tool is really important. And I think edified tool that was developed in particular in the ditch really helps validate or confirm the IRI finding. So if you go in the ditch and you have a new tool but you have old technology in a ditch you may never find it. Equitip is not going to help you narrow that down effectively. So I think using those in concert with one another is also important. I think finally, we talked this morning, someone here pulled me aside was asking about the comment we made yesterday about the pipe. There's all kind of distributions about susceptible pipe.

Well, susceptible pipe is interesting but the question is where did the pipe come from that's what's happening there's not enough happening in the pipe melt thermal temperature to create a hard spot. It's happening in the plate mill. So the real relevant question is where did the plate come from? And I think what you'll find is that very large majority of the pipe is affected particularly the pipe came from Sheffield, Baytown Mill. Right over here. The interesting thing was AO Smith tube mill 30inch pipe mill was right next door. So shipped the point from one to here. There's also AO pipe made not in bay town. If that pipe is not made in pay town doesn't have Sheffield pipe it implies low risk but there's other manufacturers buying Sheffield pipe, too. So I think that's a real centering data, really centering facts in your analysis. Don't look for the answers it's AO Smith. Not really. It's Sheffield plate. And the other plate could be at risk, too, but predominant lid we're finding that Sheffield pipe was important. I appreciate the opportunity putting me on the spot there I hope I answered the question or provided insights there.

>> Yes, sir.

>> I had a question for Andy as well as pipeline operator representative on the panel today. So I know my understanding, correct me if I'm wrong, Embridge you include not just those portion of your assets in HCAs integrity management program but you include other assets as well. But just for natural gas systems and Embridge specifically, if the PIR definition was changed and it was larger, say, how much of an impact or burden would that be for a company like yours?

>> Well, specifically for Embridge I can't speak for everybody but we manage our system in an integrity program regardless of HCA, MCA or LCA, we treat the whole system as under the same integrity program. And we do the same with facilities like storage and program facilities like compressor stations. I think the big impact would actually be can appreciate this from an audit standpoint, it's the paperwork. How much paper do we need to prove that we did this becomes quite significant, become quite the challenge, actually. When we convert it to a legal requirement. A regulatory requirement, it has to be demonstrable outside. And I think that becomes, can become significant. But physically not to us, not significant. And our pipeline integrity program director is back there waiting for him to jump up straighten out if I said anything out of bounds. But we're good. Curt says it's good so we're good.

>> So with the PIR, it's a good question because what is extending a PIR on it? Because the current PIR that we have didn't save those peoples' lives. So extending the PIR is just going to bring in more pipe that we're probably already assessing anyway because you're not just putting pig traps at the end of HCAs, right? You're doing miles and miles of pipe covered in the ILR or even in a well pressure test obviously. So the question is,

why are those, why are we having incidents in PIRs? It's something is wrong with the system that we keep having incidents of PIR. So that's what you've got to find out. You don't need to keep expanding the PIR because we're capturing that stuff anyway. So your question is, it's not going to be that much more of a burden. It could be for some people that their pipelines are unpickable if they would have to go do direct assessment on, obviously. But I don't know if the answer is more regulation. I think it's more being better operators than facing the problem that you have. And looking for the QRA's a very good tool to tell you in what spots out those threats and go after those threats. So I think more people utilize the QRE the way it's intended I think we could reduce a lot of incidents in my opinion.

>> Great comment. I think it's Andy do you want to

>> I think it's a great series of questions. I've heard about three, I think. I'm glad to opine on them or if you want to max. The thing that I think may be on the table here, we talked a little yesterday, as we're in the PVCA cycle we're looking at we have new data saying that the PIR could be changed, okay, I think we revisit that in earnest, look at that. Maybe that creates an interim tranche between MCAs and LCAs this little group we want to change it and look at that. So we get more attention there. I do think you're right. When we look at interior programs, typically run trap to trap. Or at least tools run trap to trap. So you're getting a large percent of the population, which is really the goal. You want to drive these programs to the whole system. And I think slowly over time we're getting there. But it's the slowly over time and the piece you missed that's the one you worry about it's the snake that bites you it's the one you didn't see. So I think continuing to push that is a good challenge for people. You comment, I do want to kind of opine on the thought of why are we having incidents in PIRs? It's a great question. I think that was the question we've wrestled yesterday. Seen the statistics aren't driving down. Well, I think we're casting broader nets. We're learning things. We're also starting to see where we have confidence interval issues on tools. We need to get more sophisticated how we talk and frankly how we even think. Sevenyear interval for inspection that applies to external corrosion it doesn't apply to cracks. It doesn't apply to hard spots. It doesn't apply to geo hazards. And as we start deploying these newer tools, they're not as mature as MFL tools. Okay. So we're learning in the case of some of these tools vertically. That tool's confidence interval isn't the same conclusions we draw are not as certain we may be technology limited quite frankly I'm not making excuses I think we're driving like crazy to places like PRCI and figuring out a better way to crack this nut we're seeing those things and some aren't regulated it's industry discretion, it's not a requirement and not everybody is doing it. I think it's growing pains. I thought what I would try to hit was three different thoughts and they're good thoughts.

>> It's a good comment, too. To what extent do we need regulations to move this forward, I think Steven made a comment but sometimes you hear operators say we can't go too far above them because if anyone does our code is the minimum safety regulations it is the floor nothing precludes an operator from going above and beyond. But there are some operators that make statements that we can't go too far above and beyond unless the floor is raised a little bit. So I think we heard yesterday PHMSA doesn't determine what the HCAs are, it's the operator determining. So what's the balance between PHMSA setting up the minimum and the flexibility the operator seeing what the aspect is. It's a comment. I don't know if we have answers. But any questions from the webcast? A few questions. This is from Ming. PAR used AOD for calculating but actual PIR the explosion fire ball from MOP and OD if it's much lower than OAD may we use MOP instead of MAOP?

>> No. The code says that you have to use MAOP.

>> Sorry. Steve can you repeat that.

>> Can you hear me?

>> Can you hear me?

>> The code if you go to part 192, the definition says you have to use maximum allowable operating pressure, MAOP you can't use a lower.

>> I know there were a lot of acronyms.

>> MOP maximum operating pressures. MAOP allowable operating pressure. Did we hit them all?

>> MAR.

>> Another couple of questions from Robin first question are there any efforts to support further development of models that include terrain for dense gas hazard modeling CL2 or other dense gasses?

>> We'll start with the marker at least what you're aware of. I think this afternoon you guys are going to be talking about a research initiative to explore just that kind of going beyond the state of the art in the current models. It's just that I'm not aware of commercial models that handle the elevation profile. But I understand that that's obviously something that's being explored.

>> Just add to that, this afternoon they will be going through a couple of R&D programs that PHMSA has. One was with Texas A&M for CO2 pipelines machine

learning. And another is within BMT fleet as far as welding on CO_2 pipelines. I think Bob Smith will be going over that. Some of them in our group this afternoon.

>> Maybe over to Bill. A lot of statements made today about we have the MCA new part of the new gas rule that came out. Do you feel like that's a step in the right direction? Do we need to go further? Are there other aspects PHMSA to consider processes to help address any kind of aspects that aren't included in the underlying assumptions with PIR?

>> Yes. I do think the MCA establishment of the MCA and the programs under those is a great step. And as Andy mentioned I think that's just the next of more steps ahead of us. Expanding integrity management programs to more and more mileage of pipeline I think is just the direction we should be continuing to go. And that MCA is a good step in that direction. I do think that the gentleman's question earlier, some of the discussion we had yesterday, of not seeing the trend move in the right direction on HCAs versus outside of HCAs is a bigger question. And one we need to work on at the same time. So it's great to expand these areas that we're doing the higher safety standards. But at the same time we also need to be finding ways for those extra safety standards to start translating into lower trends.

>> One more on the webcast.

>> Question again from Robin. For HDD, natural gas pipelines, the PIR doesn't account for the potential migration of subsurface gas similar to migration from distribution releases into buildings. Has there been any discussion of addressing this threat pathway beyond PIR used for HDDs in developed areas?

>> What was the term used?

>> HDD.

>> HDD, horizontal directional drilling?

>> Yes.

>> So I'm assuming I'm assuming the question relates to the fact that if you get a line break deep under the ground in an HDD, the gas is necessarily going to come straight to surface of crater it's going to go along the direction of the drill. What's the PIR for that? And I don't have the answer for that beyond the fact that if the gas has to worm its way along the interface between the pipe and the ground, there's a whole lot of flow throttling going on and the behavior of the gas when it finds surface is going to be a lot different than would be currently modeled by a crater or a jet fire. So to the extent that

that refinement is deemed appropriate, then that would have to be looked at separately, I think.

>> I think you have the possibility with migration to gather in basements and structures as well.

>> Well, I guess the PIR to my mind was meant for transmission type pipelines which is sufficiently removed from places of business or residences. So it's the distribution network where you're worried about gas migration in, but if you've got a directional drill under a river on a 36inch line and that lets go, all the gas comes how we fail is one question but how it comes to surface would be another.

>> Another qualifying comment there is you're talking ruptures, not leaks. It's a full blown rupture of a transmission pipe migrating down the pipe is not likely the outcome.

>> I guess fair point. It probably does, is going to find a weaker path to surface.

>> Can I just add something? Normally HDDs are going to be less than 100 feet deep where it's going under. So whether it's soil or rock, it's not going to have much resistance to 500 pounds of gas coming out. So you would expect the rupture to be very close to where it is. If you've got an HDD and normally an HDD is going to be a couple of inches bigger in diameter of the pipe. You might get some migration that way if that bore hole hasn't completely collapsed in. But I would expect it to be minor. But we haven't had any ruptures or anything to actually see this phenomenon. But again if you just look at the soil pressure, unless it's in solid rock, where it would migrate, it's going to come up in the soil. And just one other thing on what Mark was talking about earlier. Is on the Baker study, on the PHMSA website, it has the actual PIRs as far as how to calculate it for hydrogen for rich natural gas, lean natural gas SIM gas it has criteria there if anybody wants to see what those figures are. Good to go there and look it will give you something to look at even if those numbers adjusted overall you'll see they're lower than rich natural gas.

>> That's the track we need. We need the dialogue and discussions back and forth. And this discussion will continue into next year. So we are started down the road to evaluate PIRs. Are they adequate? Do they need to be changed? We are down that road. What I'm struggling with based on the dialogue here where we are on the risk equation. Are we focused on prevention by changing the PIR and expanding the segments of pipe which I heard from a gentleman over here. I don't know where he went. Or as I heard from I heard people allude to is consequence side the impact on people and whether the change in PIR will have a significant impact on people. We're definitely going down the road on PIR but then we've initiated we have rulemaking out

there on valve rupture detection, valve response, all those. But the question is is there something we need to track on the side.

>> Are you tracking quizzical thoughts. Not to start a fight or anything, but one immediately the PIR was designed to prompt an intense effort to assess and mitigate. Lowering the consequence side. We're obviously looking at it to queue up valve automation things like that. What I heard was beyond that. Here's where the challenge match is if the issue is beyond the PIR that you're really talking about the heat intentionality, finding shelter, evacuate, whatever number you pick, the people in that zone outside need to be evacuated and find shelter. I think that's where I think potential discussions would come into play about zoning and public awareness. I think that if things build up around the pipeline, then people outside that area may be benefited by an explicit evacuation plan in the design of those facilities or the structures and I think that you would even perhaps want to have some sort of advisory if you want to talk about people that are not in structures, just gathering is there egress for them? Is there an awareness of the pipeline's presence. I think you start getting into other things that start managing consequence. That's the thought that jumped into my mind.

>> I know you're not the reason I don't want to start a fight, is some of those things are agencies beyond PHMSA. And I don't want to start a fight with them. Awareness for a longer discussion I absolutely agree. What triggered that thought was something that Bill Caram said you said it's right for public engagement or engagement and discussion so people know. You were talking about would people know to evacuate. What about engagement, what about understanding if you live in the vicinity of a pipeline, yeah, you get the flyers but do you understand that means go quickly, that kind of thing. The other thing I'll toss it out there. Deputy administrator Tristan Brown who we heard from although we did not see on Monday but we heard from him, he actually asked a question he didn't have an answer for I was stunned good idea for, he said it wasn't about this type of scenario in relation to another event he said if we know, if a pipeline has an emergency, why don't we have a system or why doesn't somebody have a system where they can send a text to landowner saying evacuate? So many systems to do it. How many get the amber alerts. Maybe get a notice I'm reaching out there. That's coming from somebody thinking outside of the box I'm thinking on the consequence side. And I think some can argue, I think time for one more question we have to transition to the 11:30 panel. But our existing regulations for public awareness one can argue, it's partly in that. I mean CO2 for 1950440 looks at identifying HCAs but maybe that helps you figure out who are your audiences you have to give regular intervals. Emergency response happens, who are the individuals you need to make sure you look out for that might be impaired. And you have the new RPA1185 in the works could potentially take that to another level. Mark, did you have if I could pile on to this discussion. As I heard the discussion in and around what should the PIR capture,

maybe it should capture more because people aren't aware beyond the PIR damage can occur. Maybe it's not death and maybe it's not destruction but it's damage. That's fine but what are you going to use that for? What I was thinking of was what you're really talking about is the emergency response planning zone. And there are jurisdictions that have those. And there are jurisdictions that have taken the PIR formula and modified it to lower the heat intensity threshold so that that would define the perimeter not that you could stand and watch the fire but almost that's a bigger zone. To the extent it's framed as an emergency response planning zone and those conversations happen. That might be a way to have your cake and eat it too. Insofar as you can make it hall the way out to where you could set up facilities for responding and define the area within which people ought to be aware of the area it could happen and plan accordingly. PIR the way it's being used is a little different from what that entails. That might be a way to approach things.

>> One more question webcast.

>> Question is from Michelle Slider has PHMSA evaluated what they can do to assist industry in getting local planning departments to enact development exclusion zones?

>> Good question. We have colleagues pipeline emergency security support division they are looking at things certainly drills and exercises. They do a lot on the oil spill response side for sure there's talks about to what extent do we look at trainings exercises particularly in these areas as well. I believe the answer is, yes, we're discussing it, but I would defer to the PES group for answering more on that. I don't know if Linda wants anything else. She's nodding heads. But if anyone doesn't know Tim Gaither is director. Chris Gerard helps lead some of the exercises there, either Tim or Chris could be good ones to reach out to.

>> I think with that, I'm getting the sign to wrap up. So thank you to the panelists, we're going to have some transition time between the panelists leaving and Bryan is going to come on to talk about Freeport. Thank you.
[APPLAUSE]
Is.

>> Good morning my name is Bryan Lethcoe regional director for the Southwest Region. And I'll present the review. Due to PHMSA's ongoing investigation, the information on in this presentation is all publicly available and my comments will be limited to publicly available information. I cannot comment on the ongoing investigation. On June 8, 2022, at 11:28 central time the Freeport LNG facility experienced a loss of primary canement and boiling liquid expanding vapor explosion resulting in catastrophic failure of the vacuum insulated piping. The explosion that took place was the result of the overvaporization of the piping causing it to fail and cascading

of series of multiple piping fail ierswhere it was located and the initial piping fail year and sploesh together with the damage to other process piping instrumentation, wiring, and pipe rack structures resulted caused severe damage to additional process equipment and associated piping P in adjacent areas within and near the pipe rack. The initial loss of primary containment event continued for nine seconds atmospheric result of a flammable videotape for with methane trace materials making up the balance. The initial release of methane and gas phase was released along with a smaller release of approximately two barrels equivalent of LNG into the pipe rack containment. The dispersion of this flammable vapor open atmosphere served as a fuel for the secondary vapor cloud explosion. And as it progressed release of mixed phase methane gas dispersed into the pipe rack in the area directly above the pipe rapidly rising into the air with dispersal aided by wind from the south southeast at 13 miles per hour and ambient air temperature 85 degrees Celsius the release of methane was not fwr a single point along the pipe but was unevenly released from various sections of the line as the piping failed. As a result, the full 10,500 pounds of methane was not available to fuel the vapor cloud explosion that occurred above the pipe rack. Given the large number of pipe section failures and their displacement from the pipe rack, propelled by escaping gas is believed no more than 50% or 5,300 pounds of methane was ultimately consumed in the visible fire ball with a balance of the fuel escaping into the atmosphere or consumed in a flash fry that was not observable on the available security cameras. The vapor cloud explosion in this event was fueled by the vaporized LNG escaping from the rupture generated minimal overpressure. The initial release of vaporized LNG was very buoyant and was ignited with visible fire ball. The vapor ball explosion was an event that failed to transition to detonation lack of fuel lack of confinement and lack of fuel availability to sustain combustion within the fire ball. The initial piping failure and explosion and subsequent displacement of piping and other structural and nitrogen. And observed secondary loss of primary containment involving vaporizing LNG escaping from pipe occurred until approximately 5:25 p.m. until it was terminated. Secondary LNG release did not ignite caused by a large failed section of pipe flying south from the pipe rack striking other piping in the area. On June 30th, PHMSA issued a notice of proposed safety order proposing that Freeport LNG take certain measures to ensure that the public property and the environment are protected from the integrity risk of the facility. The proposed corrective actions include requirements for written approval from the director of the Southwest Region prior to return to normal al operations. Selection of a qualified independent thirdparty to perform evaluations and assessments approved by the director. Completion of a root cause failure analysis by the thirdparty consultant. Submission of a complete plan of and schedule of inspection and assessment to determine the full extent of the damage caused by the explosion and subsequent fire. Submission of evaluation of operating procedures, control system procedures and assessment of personnel qualification and training performed by the independent third party. Submission of remedial work plan for director review and approval and delivery of monthly reports.

AAugust 3rd PHMSA issued a consent order and consent agreement to resolve the alleged integrity risks raised in the NOPSO. The agreed corrective measures included requirements for written approval from the director of the Southwest Region prior to return to normal al operations, selections of qualified independent third party to perform evaluations and assessments approved by the director. Completion of a root cause analysis by the consultant provided by the Freeport and director concurrently. Submission to the director review and approval complete plan of assessment to determine the full extent of the damage caused by explosion subsequent fire. In addition, Freeport was to implement the approved plan according to the schedule and provide weekly written reports. Submission of an evaluation of operating procedures, control system procedures and assessment of personnel qualification and training performed by the independent third party. Submission of a remedial work plan for direct review and approval. Delivery of monthly reports and written requests for any extensions of time, timely submitted demonstrating good cause for extension. On October 30th, the IFO group the independent thirdparty issued the root cause failure analysis report. By November 15th, PHMSA posted the root cause analysis report to the PHMSA FOIA library reading room. They identified the direct cause of the incident as the overpressure of vacuum insulated piping with no protection from overpressure. Removal from overpressure protection is believed to have occurred during annual testing of the connected pressure safety valve or PSV on April 26, 2022. The vacuum insulated piping line was heated by surrounding environment causing overpressure to happy the Bevy and loss of containment. Immediately following the loss of containment the group identified the cause of the fire to be contact between flammable vapor the methane and ignition source likely open and damaged electrical conduits and circuitry in the pipe rack following the loss of primary containment which resulted there the videotape for cloud explosion a small secondary pool fire on the northeast end of the pipe rack in the elevated LNG drainage trench. There was also the shortterm release of the vaporizing LNG from the 3inch piping that failed to ignite and was suppressed by fire water master streams deployed by emergency responders.

IFO group identified the root cause of the incident as a lack of PSV testing procedure and a lack of CARCIO program. Freeport LNG lacked formal written testing procedure to ensure they were put back into service without testing with CARCIO in open position in addition there was no formal car seal procedure or car seal training or no car seal checklist inventory process and no formal requirement to audit car seals in use throughout the units.

IFO group recommended that Freeport LNG develop a PSV testing procedure to also include the use of car seals. IFO group also recommended that Freeport LNG consider providing formal classroom field training in the use of procedures. IFO group also recommended that Freeport LNG consider developing a car seal program to include procedures for their use, a checklist to be maintained, evergreens, showing the status of all car seals. Formal classroom procedures used in the checklist and internal audits of all car seals upon agreed upon special. IFO group identified another root cause incident lack of safeguards to warn operators of vacuum insulated piping pressure. There are various leak detection temperature points installed in the piping but they offered no safeguard even if they had alarmed. The IFO group recommended that the group perform vacuum to identify audible alarms can alarm. And Freeport LNG analyze temperature data and perform repairs on temperature indicators to maintain effectiveness of the outer skin temperature measurements. IFO group recommended Freeport LNG revise to warn of vacuum insulated lines due to loss of flow. Another root cause IFO group identified is a lack of operating integrity of certain operating procedures. IFO group recommended that Freeport LNG consider a complete review of operating procedures for their tank farm area and the IFO group also recommended that Freeport LNG remove the designation of operator choice valves and these valves be temporarily changed to supervisory control valves until a solution could be agreed upon. IFO group also recognized a number of contributing causes. One contributing cause of the incident was the 2016 hazard operability analysis to not evaluate all the operating modes for the facility. The HAZOP study documented in the applicable report dated July 22nd, 2016 failed to evaluate the impact of operating modes and potential consequences caused by the intentional or accidental actions by operators that result in the overpressure of certain LNG lines caused by LNG heating and vaporization. As a result, the HAZOP study did not identify any current or potential safeguards against the consequences of this scenario and the current likelihood of success or failure in preventing the overpressurization of this line. In addition, the design change was made after the HAZOP that resulted in the line being designed as a vacuum insulated piping line. There's no record of management of change was signed off or as subsequent process hazard analysis was reconvened to consider this change. IFO group recommended that Freeport LNG consider performing a revalidation process hazards analysis for all vacuum insulated piping systems ensure the necessary safeguards are provided in their design based on severity of consequence including in particular identifying and avoiding or mitigating scenarios of this incident. IFO group also identified a contributing cause of the incident as failure to follow the Freeport management of change process for modifications to procedure, unit 18 tank management. Freeport LNG does have a written management of change policy intended to comply with 29CFR 1910119. IFO group reviewed a list provided by MCOs performed since 2020. There were no MOCs related to the changes in the operating procedures between the joint venture for Freeport and Freeport LNG for various valve settings for loads of evaluations. The completion of a compliant management of change would have provided an opportunity for the facility personnel to identify operational conflicts and risks within the operating procedures and prevent this incident. IFO group recommended that Freeport LNG consider using the MOC procedure for all changes in the unit as defined in the procedure. IFO group also identified a contributing cause of the incident as facility personnel failing to recognize an abnormal operating condition and related hazard. On the morning of June 6, 2022 a Freeport LNG operator noticed that piping had been moved. He reported this to a supervisor who in turn notified Freeport LNG operations and engineering personnel. The mechanical engineer sent out to the unit by supervisor to evaluate the pipe movement reported the issue as a possible failed spring can attached to the bottom of a pipeline on the side of a tank and the lack of a pipe support that was indicated in the design drawings. This engineer had very little experience with piping as his expertise was primarily rotating equipment pumps and pressures. However, he prepared a detail report which was distributed amongst senior Freeport LNG operations management team at the site on June 7, 2022. With none of these more experienced personnel went to the tank farm to evaluate the issue for themselves. Regardless, no one went to the site to recognize the cause for the cause movement for expansion increasing in pipe pressure applying forces to the expansion joints and other components of the line and the events continued unabated until the mechanical explosion and subsequent loss of primary containment. IFO group recommended that Freeport LNG engineering operations maintenance personnel should be trained to recognize abnormal operating conditions including those related to pipe movement and the recognition of pipe movement stresses as a result of the cause of the incident. Finally, IFO group identified the final contributing cause of the incident as operator fatigue. Operator fatigue is believed to have served as a cause of the incident probable design of the Freeport operator to restore to the connected PSV or pressure safety valve after it was tested on April 26, 2022. The facility had a long standing practice of calling in operators on overtime to provide staffing for PSV inspections and other related activities. The IFO group reviewed hours worked by operations staff for the first half of 2022 and some clear patterns of concern emerged. The following observation is a summary of the patterns of hours worked by operators at the plant in 2022 and the days and weeks before the incident. 23% of the staff worked between 110 percent and 119% of their scheduled hours. 54% of the staff worked over 120% of their scheduled hours. 20% of the staff worked over 130% of their scheduled hours. And there have been over 900 occurrences identified in the first half of 2022 in which operators worked overtime shift on one or more of their scheduled days off. During the assessment period of the first half of 2022, each shift averaged 12 hours plus on shift and operators generally worked 84 hours per pay period excluding unscheduled overtime. Operators and supervisors made numerous comments in interviews during the investigation and about operators feeling fatigued due to the number of hours work and routing scheduling. So as a result, the IFO group recommended that Freeport LNG consider a review of operator staffing and hours worked. So this concludes the main part of my presentation. Like I mentioned, due to our ongoing investigation, the information presented this morning is all publicly available and my comments have been limited to what's in that publicly available information. So I cannot comment on the ongoing investigation. But I would like to thank our team here at PHMSA including especially Mary McDaniel, Chad Hall LNG officer and entire Southwest Region LNG team and headquarters LNG engineering team for providing great support as we continue to work through the consent order and consent agreement and our followup activities that we have to continue to execute in order to ensure that Freeport LNG is a fit for purpose facility and safe to restart. Also like to recognize the efforts of our regulatory partners at FERC and US Coast Guard for efforts to return to facility activities and couple of the FERC engineers working tirelessly with our staff to assure that the facility is fit for purpose and safe to return to normal operation. Subject to your questions, that's all I have this morning. Thanks.

>> Yes, my name is Tony Marion. And you stated on October 30th PHMSA released a redacted version of the RCFA that redacted version was actually an approved redacted version submitted by Freeport LNG. My question is, do you or will PHMSA release a different version of the RCFA, a less redacted version or nonredacted version of the RCFA?

>> What I can say is there have been numerous FOIA requestses for the information to the incident and we're going through the process to understand what can be released what needs to be withheld at this point. That said, there are numerous FOIA requests for the information you're receiving. At some point likely information will be put out there through the FOIA process. Any questions from the chat? All right. No other questions, thank you, and turn it over to Max.

>> I think we I think we might go on to give you a little bit more of a lunch break, is that okay, Bill, I got a thumbs up. We still need to be back at 1:00 central time. Correct? 1:00 central, back in this room. Thank you, everyone.
[APPLAUSE]
[Lunch break]

[Lunch break]

>> We'll be starting in about one minute.
>> All right.
Well good afternoon, everybody and welcome back to our afternoon session. I hope

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everybody enjoyed lunch. I'm Sentho White, the director of engineering and research at the PHMSA office of pipeline safety. We have a really full and exciting agenda this afternoon. It's going to cover some of our research program and the recent R&D Awards as well as some discussion on our success stories from our research investment as well as some discussion on successes and challenges related to technology development. And of course we're going to also follow on on our CO2 and hydrogen discussions with presentations from some of PHMSA's staff as well as our research partners and also stakeholders. And so with that I'll move into our overview. So I'll be providing some background on our research program, its vision as well as providing a summary of the recent R&D Awards that were funded in September of this past year and then also give you guys a few helpful links about how you can engage in our R&D program. So I'll first provide you with a bit of background on our research program and its mission. So PHMSA's pipeline safety research program sponsors R&D projects that are focused on providing near term solutions for the nations 3.3 million miles of pipeline systems and 400 underground gas storage facilities. The program's research results and solutions comprehensively address the mission as well as priorities through research that promotes safety and environmental protection, and equity for all communities. So our R&D program as I mentioned is very comprehensive in its research strategy and we partner with a very diverse group of stakeholders as shown here. So these partnerships are going to include our colleges and universities through our competitive academic agreement program, pipeline research organizations and technology providers through our core program, small businesses as well as with the national labs and federal partners and also international government bodies. And this diverse collaboration ensures the research is non duplicative and produce safety and environmental protection. We want to invite you to collaborate with our colleges and universities, Hispanic serving institutions. These partnerships are vital to ensuring the research objectives and the solutions are relevant to pipeline integrity challenges and it also provides the under graduate and graduate students with an opportunity and exposure to pipeline experts and also subject matter related to pipeline engineers to really encourage career placement within the pipeline sector. So we've had a really great track record since 2002 focusing on technology with over 120 technology projects. And as you can see our program has had a lot of success with 77 technology demonstrations as well as frequent patent activity. We've had over 35 commercialized technologies that provide solutions available for industry adoption that better meet our exceed regulatory requirements. So most of our areas in pipeline research solutions involve threat prevention, leak detection and anomaly detection. We're hoping to see some investments in the future with alternative energy, LNG and also underground gas storage facility challenges. So this slide just highlights a few of our performance metrics such as the number of website hits that we've had and downloaded reports. And we also provide all of these reports electronically for all of the projects that we funded and there's also a keyword search that's available for you on our electronic library. So now just to cover a few of our recent Awards starting with our CAAP program. Really all of the Awards that we've funded in September of 2022 are available and they have dedicated website pages. So you can go to each of those and definitely follow on on the research as it progresses. Starting with our CAAP projects for this past fiscal year we've awarded $4.8 and funded universities. These projects are focused on investments covering hydrogen. As well as material research on structural liners to rehabilitate damaged pipelines. Moving onto our core projects. Within our core program we've funded 15 projects and about roughly $7.54 million. Many of these are to investigate advanced solutions that support prevention and mitigation of climate change impacts through research focused on hydrogen and pipeline integrity challenges associated with that as well as CO2 pipelines and also projects that address methane detection and geo hazard risks. Just to follow on a bit more about our core projects, we are also looking at validating leak detection technology through field demonstrations to pinpoint leak location and for the first time ever we are actually awarded a project on corrosion challenges with respect to break out tanks. So through our core program we historically fund a research related to field demonstrations. Moving onto our small businesses funding. We collaborate with the department small business innovative research program and here we awarded two phase one projects. Phase one projects really focus on lab demonstrations. So this past year we worked with intelesense and oceanic laboratories. They are working to test out additional functionality of fiberoptic technology sensors. Oceanic are developing sensors using nano particles to plug gas well leaks. So very interesting projects. And last but not least we also have interagency agreement projects and these are projects that we fund with our national labs and also with NIST. This project actually I'm highlighting here is a follow on project that's focused on welding procedures for hydrogen pipelines and it's actually built upon some prior work that was done by NIST. We are also collaborating with the high blend initiative as part of DOE's program. And so this slide just really highlights the importance of our research outputs, their outcomes and impacts. And so I just wanted to convey how our program achieves these areas but our outputs really result in informative research through research reports. Again, all of our reports are available online and really they give stakeholders, the public the opportunity to find out about a lot of research solutions that will help to inform standards and policy development and future, you know, potential rule making that could come about. There's also opportunities here to look at, you know, technology adoption as well as commercialization into the marketplace of these technologies that we fund. And I will leave you all with a few links to our R&D web page. Again, as we mentioned earlier, all of our presentations are going to be available online and what I want to highlight here is the last link where you can actually sign up for alerts so you'll never be able to miss an opportunity about our R&D program as well as any webinars or report outs that come out. And so with that I am going to turn it over to Kandi Barakat,

our operations research supervisor and thank you.
>> [Applause]
>> Thank you, Sentho. My that I mean is Kandi Barakat, I'm operations supervisor of the R&D team. I'll be providing an overview of PHMSA's most recent technology transfers and some of the success stories that we've had. But before I do that, I would like to give an overview, just a visual of PHMSA's R&D program and some of the collaborative process we have. We identify research gaps through stakeholder engagement and public forums. We develop research topics, offer research solicitation which occur around the beginning of the calendar year typically. After the comment period on the resource solicitation closes the merit row view panel reviews those proposals. Then we award state of the art research projects to help the environment. Research projects typically take around two to three years to complete and then we issue a final report. Some of the research projects advance the commercialization and that's the part I'm going to be highlighting right now. Since 2002 as Sentho mentioned 77 technology demonstrations have occurred as part of research projects scope, execution involving technology development and only 35 have commercialized to technologies that are being used in the industry. Our hope is to help this number grow more. Technology demonstration as part of the research and development activities at PHMSA play a key role from our program's success. I will present the last five technology transfer success stories in the following slides. These technology transfers were possible through the partnership of public, private entities in the research that utilize a combination of private facilities, academia and government laboratories. These research enterprises have enabled technology development to be conducted in the public domain and operating natural gas and liquid pipelines right of ways. For this first project this project succeeded in developing an electro magnetic transducer. The research project scope involves testing improvement capabilities into our robotic inspection platform and significant field testing and demonstration to validate its performance. PHMSA registered this technology in June of '22 and this tool is available to the industry through Baker Huggies and QI2 elements. This project succeeded in further developing and demonstrating a probe that can be inverted into an active natural gas pipeline and map from the surface. Once in an active operating pipeline the probe can be deployed in either direction up to 1,000 feet and capture accurate geographic. PHMSA register in '22 and it's available in the industry through reduct company. This project succeeded in further developing and demonstrating a laser sensor that can be very accurately measure mechanical damage effect in an active natural gas pipeline that cannot be detected. It was integrated into our robotic inspection platform. PHMSA registered this technology in February of '21 and it's available through the industry by technologies. This project yes, this project succeeded in developing and demonstrating advanced in ultrasonic technology. This sensor was applied to pipeline cracking threats for the first time as part of this project. This new sensor technology can be applied through tools

and ditch or through a deployed in line inspection or robotic inspection platform. PHMSA registered this technology in April of 2020 and this tool is available to the industry through Applus company. And last but certainly not least, this project succeeded in further developing and thoroughly demonstrating a methane leak sensor. It can identify a methane like from an automated mobile unit. The field demonstrations were primarily conducted in urban areas. PHMSA transferred this project in December of 2018 and this tool is available to the industry through heath consulting. So we've worked diligently over time to test out ideas and work with anyone with mutual interest to draft technology development and commercialization but what else can we do, what are the next steps. We will continue stakeholder engagement, conduct public meetings to highlight the program, work with field operators for feedback on some of the technologies and track the research results and commercialization technologies. We're also looking into conducting our out reach and maybe working with other DOT modes on their research programs and commercialization. You've seen this slide before for the R&D links. I highly encourage you to join the distribution list so you will never miss any announcement that's related to R&D. And this is the R&D team. We also have Colin who joined our team, his name is not listed here. We have four additional R&D team that joined that will start in January. Thank you.

>> [Applause]

>> All right. Thank you, Kandi. And now we're going to move to our technology panel in this next session. We are going to hear from a few of our research partners on their perspectives and their organizations research challenges in developing and deploying the best technology into the market. So I'm of course going to be moderating this panel. A few housekeeping instructions, we're going to go through three panelists and our third panelist is going to be joining us virtually and then after that we'll take Q&A. So with that I'm pleased to introduce our first presenter, Cliff Johnson who is the president of pipeline research council international. Cliff.

>> Well good afternoon. Sorry about that technology, pushed the wrong button. So what we want to spend some time on this afternoon is really kind of talking about technology, the way advances our future and maybe some challenge to putting it into practice. Some of the things we've talked about so far are really looking at the opportunities for what is next in our technology suite. Where do we go, how do we do more, how do we learn better to build a stronger, better mouse trap so to speak. Here is where we are today. PRCI is an organization that's founded to do just that. We started in 1952 to create the research that's needed by our industry to look to the next generation of technologies, tools, how to improve people and practices. We're very fortunate to have members from around the world that bridges in knowledge from all parts of the industry. Looking at the natural gas, the hazardous liquids, hydrogen, CO_2, work that we've been doing for many, many years now, looking at the facilities associated with it. As we continue to push though one of the things is how do we move

this technology into practice. Many of the operators who are involved with PRCI are ready to pick it up. However there's impediments from a regulatory or process point of view of how do you put technology into practice and where do you go. We want to spend some time talking about that today. As I mentioned the mission for PRCI is to look for that innovative applied research. Make sure it's utilized as soon as we can through direct adoptions, regular standards or industry regulations. As was shown yesterday this is kind of the make up of our slides that Zoe shared with you on what we look like an as organization proud to say the international aspect. We were able to learn from our members in Europe, Australia and around the globe on how we move key challenges. What I want to do today is give you two success stories and one story still in process. One where we're slowly evolving and still trying to make it happen. The first shows some nice wins. The first one is a maritime story, one of our corner stone research results and the next one on the integrity and service of our systems. The first one is a story about onbottom stability. It's pipe that's in the water and what we need to think about. This looks at the environmental impact and how to ensure the integrity and is safety. That was an industry standard globally to ensure the aspect and integrity of the sub sea assets. The next is an evolution, we've been talking about the safety and integrity there on B31S. The next revolution is the R string technology. This is a system how do we do fitness for system. PHMSA referenced it actually as a way for us to identify the fitness for service of our systems. These are examples of how we can move together as we work together as a collaboration bringing in that public and the industry together as a joint approach. This needs to be a partnership between all three legs that we saw on the triangle to further advance these opportunities. These great technology advances that we've had at PRCI that you saw in the previous slides at PHMSA really only work if we have people using the research. It's good to do research but if no one uses it what's the value of where we're trying to go. The next one I want to talk about is something that we've developed now that we've talked about R string as an advance, the next step beyond that now is to a claim called P square. A continued refinement of the opportunity for fitness for service, how do we know more about our systems to make more productive decisions. This is based off the data that we're able to pull together from our various tool runs and information to provide a wider, better sense of what we need to be doing. Right now this is completed back in 2019. We're still working through the regulatory and association adoption of this technology. This is something that can really help with more understand of our fitness for service around corrosion and the cracks. The process now from completed research to adoption is three years in. How do we shorten that window, how do we more productively move through this process. Through what we've been able to do at PRCI we're able to get a collaboration of a number of operators from around the world together to see how to test and verify these ideas. We need to look at and partner with our industry partners and the government and the public in showing how these technologies work so we can have a greater adoption of the technology we need to continue to advance our industry. When we looked at how do we begin to shift that story in PRCI, we built the technology center here in Houston. This actually came out of a recommendation from NTSB many years ago after marshall, Michigan. Part of that recommendation is aligning inspection tools as strong as they say they are. They asked PRCI to help validate that statement. To do that in partnership with PHMSA we actually built a pool test facility in Houston, Texas. The first one of its kind. To be able to allow the tools to get up to full speed, be able to test real performance. This was a collaboration between government and industry that really helped us say, yes, the tools are as good as we say they are but there's more to be done to improve them further. Through this investment we were able to test in line inspection tools in hydrogen, CO2 and the other opportunities we're going to be addressing for the next fuels of our feature. So this facility if you have the chance is here in town. We've one of the largest pipe sample repositories currently both of manufactured and real world defects from around the globe that really allow us to begin testing these tools and training the next generation of professionals on how to do this work. Right now we're able to put spools together of 6 inch and up to 40 inch to run the tools of various lengths. This is this way we help technology to move. As we complete research now we're able to get collective members together to show how these tools perform and move into industry adoption. This is the kind of activities we continue to push and think about. PHMSA pushed in Colorado to build a research development and technology center. Initially it was kind of following the same steps we just developed here at the TDC but on a larger scale. We're talking about hundreds of acres of facility, probably much more than we can think about. But really what they needed to begin focusing on from my point of view at least is how do we transfer into hydrogen and CO2. One of the largest needs is full scale testing. To begin looking at how do we push the boundaries on these pipes that we have in the ground, these assets that we've had in the ground for 75 years. How do we transition. To do that a full scale test facility similar to what they were considering in Pueblo is needed in the United States. This could be the next step for how our industry moves for safety, moves into the next really understanding of what these systems can abstain. Again, the current infrastructure we built never envisioned putting hydrogen in it. Not built with that in mind. Never having built the idea of super critical CO2 into it. We can do it, we just need the opportunity to invest and verify. It could be part of this solution. Unfortunately we can't have that facility at the TDC, I would love to do it here in Houston, I like to blow up stuff. Can't quite do it there. Not big enough of a facility to do that safely and efficiently. In a large scale situation where many of us can come together both government and industry together to partner begins to show the way how we can do this. Again, give us the facility that then leverages the public asset to it to see what are we talking about, where do we do. Bill mentioned on his website they have picture from what the CO2 looks like. Let's do that here in the test environment so we can see how that works in the possess.

It's how we transfer the knowledge we need to continue pushing for those zero failures we all want to get to to have that opportunity. The other thing that PRCI is embarked on is data. We've been talking about how do you use the data, how do we do that. As an industry globally we're not very advanced in this. Individual companies are doing really good with the data and are very short with it. As an industry we didn't developed a repository similar to the federal aviation administration to learn from our data systemically. There's an effort probably about five years ago, I believe Allen it was five years ago, the volunteering share information begin to be explored. That was on congressional direction on how to share knowledge and look at this more. PHMSA was not able to complete that activity. PRCI has begun down this path to begin pulling data together to help us become better, smarter in what we're doing. I'll close with safety is not something that we want to compete on. However, safety needs to be our number one priority for everything that we do. Safety is going to be the number one priority. To do that we have to get together as a group and it can't be us versus them, the public versus the industry, we all have to be in this together to push that. So with that, Sentho and Kandi thank you so much. If there's any questions I look forward to answering it during the panel. Thank you.

>> [Applause]

>> Thank you, Cliff. Next up is Dr. Samuel Ariartnam and he is the professor and chair of heavy construction at Arizona state university.

>> Great. Thank you. All right.

Does this oh. All right. Well it's a pleasure to be here and I'm going to give you kind of a perspective of technology and technology transfer from an academic perspective. As someone who has been involved in a couple of PHMSA projects that resulted in technologies that are being currently used in industry as well. So to talk about what technology is, what are the drivers of technology transfer, you know, why do we do this type of thing. It's really looking at discovering new knowledge and taking that knowledge, protecting the intellectual knowledge through copyrights and patents. It was mentioned before some of the patents that came out of some of the projects in the past. Developing that commercialized strategy to you can license for companies or create startups. A lot of startups do come out of academic institutions. Why does an academic institution in general end up looking at technology transfer? Well, there's a couple of reasons. You know, what we do is we provide learning discovery research and public service and economic development. That's what coming out of academic institutions from a research perspective. What technology transfer does is it provides a easier way to support this mission through commercialization of this knowledge that was discovered or done through university research avenues and that. What it does and it enhances, it helps us to attract better researchers or more world class faculty to come to your institution if you're really engaging in research. It improves the local economy. A lot of those offshoots that come out of research end up being local companies that are driven by academic personnel. We attract the industry sponsors for research. That's really important that industry engagement or stakeholder engagement is critical and I'll talk more about that as I continue on. And then obtaining licensing and technology transfers and things like that can end up in economic gains too as well. Like, for example, at Arizona state university we have a technology office and if you develop something that's patented through the university then there's a third, third, third split. So the professor would get a third, the research group would get a third and the university keeps a third after expenses. So we have to keep those expenses down I guess in that office. That's how they sort of try to incentivize academia to file patent processes and go through those. I want to point to something. I was going some research. This bayhdole act. I don't know if you're familiar with it. It was instrumental because it provided this legislation in 1980 that basically enabled academia or small businesses or research institutions to maintain the patents from federally funded research. That opened the doors to a lot of innovation. That's where a lot comes out with industry or federally funded type research. Some of the inventions that can come from academia, I just want to put things that you heard of, blackberry, bar code, Google, that's what came out of academia. A lot of these have been from a societal perspective very, very important aspects of it. Talking about some of the challenges, you know, I'll let you in on a little secret. Academia is pretty good at doing research but we're not really that good at business. So when you're looking at any of this type of thing understanding real world versus theory, we can develop these technologies in that but we don't know that whether they will be applicable to industry. Will industry like those things. That's why I'm a really big proponent of stakeholder engagement. You have to have the end user from an academic perspective. Even partnership with technology providers in developing the technology which I'll show you in the next slide is very, very critical but we don't really typically know how to market things in that. The time between disclosure and patents can take too long.

I know cases where you go to the office, technology office, you say, here, I have an idea, and maybe two years later you'll get a result -- an answer back that says, yeah, actually, this is good, let's pursue the patent.

And in the meantime, somebody developed something new, right?

And so that's part of the problem.

And making that business case, right?

We don't understand -- most academics don't understand valuations and marketing and those types of things, and oftentimes a new and better tool comes along, along the way.

But one of the things that we do very well in academia is that we do a lot of presentations, and when we take our research that we've done, a lot of the PHMSA research and that, we're presenting that, so we're marketing that in a way that maybe industry doesn't have that opportunity to do as well.

We're going to different conferences, talking about the successes, talking about the projects, and that is a really important benefit that comes out of working with academia on these types of research projects and that.

Tying into a couple of projects that I was involved with here, the one on the top is the innovative free swimming acoustic tool for leak detection, that's about 10 years ago with a company called pure HM, now they're required by, and leak detection obviously is a really big issue and doing that.

We helped develop this technology, pure had already had patents that were done, they just brought in Arizona State, we worked together on this and had partners, and that was really important.

In this particular project, Enbridge, trans-Canada pipelines were major partners of ours, we were using their systems, demonstrating it.

Our program manager from PHMSA had it pretty good because when we did the demonstration for the project, it was in Puerto Rico, so he got a nice trip down to Puerto Rico, and it wasn't Bob, he wanted to go but -- it was good.

And it really demonstrated the real life applications.

So today this technology is being used all over the world, actually, and it's commercialized and that.

The second one just finished a year ago, in August.

And that was looking at river scour monitoring.

And a lot of that came out of, back in 2011, the ExxonMobil, the 63,000 gallons of product in the Yellowstone River and a break that happened.

Then in 2015, the pipelines, the oil spill that had 40,000 gallons.

So with this type of project, and once again, we had Enbridge and we had -- Pipelines as partners so we actually were installing, working with their teams, installing these sensors in there, and what it does is it looks at river scour over time, and it helps to -- in preventing these spills into rivers, right?

And I think we just had one last week, which was about 500,000 gallons or something like that, in Kansas?

That happened.

So these are kind of applications that we did and we utilized that, and through academia, industry and government, these are kind of the success stories that we can bring.

But academia alone can't do it.

We have to have the industry stakeholder and partners to be able to be successful in our R&D mission and that.

So thank you.

[applause]

>> All right, thank you, Dr. Sam.

Next up, our third panelist from the technology panel, she is joining us virtually.

Please welcome Sonal Patni, and she is Vice President of operations technology development.

>> Thank you.

I just want to check that everyone can see and hear me.

Yes?

Okay.

Thank you for the introduction.

Happy to be here virtually.

Thank you for helping set this up.

A lot of great conversation, a lot of different topics touched on.

I'll be walking us through a few commercialized projects from OTD and then just some general considerations for R&D.

If we could go to the next slide.

OTD is a not-for-profit corporation led by 28 member utility companies who serve over 70 million natural gas consumers in the United States, Canada -- yes.

>> Can you give us a few minutes and we'll have your slides up.

>> Okay.

It's kind of tough to just be doing it blind.

>> Okay, and we're up.

>> Okay.

Are you on the second slide?

>> We are, yes.

>> Okay.

Great.

So I'll just start again.

So, again, we are a not-for-profit corporation, made up of 28 member utility companies in the United States, Canada, as well as France.

We focus on continuous improvement and developing solutions through innovation and research.

Next slide, please.

Here you'll see that there's the different GTI member companies.

One thing I want to touch on, sorry that I didn't cover on the last slide, was, at the bottom there's a few different branches of GTI that focus on end use technologies, end use technologies with new products, and a low carbon initiative that we also have.

OTD is primarily focused on pipeline and pipeline infrastructure that's owned and operated by local distribution companies.

Next slide, please.

Hopefully you can see on the screen OTD's missions and goals, which really answers the question of why do we need R&D and why does the industry need to continue on focus on R&D.

A phrase that was threaded throughout the discussion yesterday was continuous improvement, and that's what OTD aims to do.

Through our work, we work on enhancing processes and practices to enhance safety, finding efficiencies which can result in a cost savings to our customers -- to the customers that our members serve, discovering new technologies that tell our members more about their system -- you're sick of hearing us say this, but you don't know what you don't know.

Number four, enabling the deployment of cleaner energy within the pipeline infrastructure that maintains the same level of energy and reliability natural gas companies are used to.

I heard Linda during the morning session yesterday emphasize the synergy that PHMSA as well as deputy administrator Brown see with pipeline safety and the environment.

Providing solutions for deploying alternate fuels and decarbonization is of high interest to OTD members.

Next slide.

So hopefully you can see on the screen a few examples of how we've leveraged technology to move the industry forward.

We're going to be going through a few recently commercialized projects.

I'm going to touch on some of these projects, I'm still pretty new in my role at OTD, so if you do have any follow-up questions, my email address is on the last slide of this presentation.

Feel free to shoot me a note and I can definitely connect you with the right people that know more about these projects than I do.

The first project is the HALOVALVE, a breakaway fitting attached to a meter set that stops the flow of gas.

There's a lot of incidents, if you've reviewed incident data, that relate to either cars running into a meter set or snow pile-up.

When we're thinking about, for example, the snow pile-up, it's really important that we look at this event because in some cases, even if operators are sending field personnel out to report, sometimes they don't even have access to those roads and it could take them hours, so this is really a way to quickly and safely turn off the gas and keep that house and customer safe.

The next technology I want to talk about are remote methane monitoring sensors which can help operators better quantify concentrations of natural gas.

And also if these are installed in the field after a pipeline repair is made, it can also supplement the -- of the leak.

In the top right you'll see a technology, the Kleiss flow stopping system.

This technology was actually developed initially internationally.

We worked to retrofit, and I'm sure several people at GTI and OTD would say further improve this technology for the United States and our pipeline infrastructure.

And this is also another important point that I heard brought up as well, it's really important for us to try to leverage technologies, lessons learned, and studies, to see what their applicability is here in the United States.

This is something that OTD members are also very supportive of.

There's been a lot of discussions that we've been having about understanding how gas utilities internationally are actually integrating alternative fuels.

So just a little more about this technology.

The fitting within this technology really is useful for, for example, for performing larger excavations, so instead of having to excavate a larger area, this technology reduces the size of that excavation and helps operators isolate the flow of gas.

And then in the bottom right-hand corner, you have the virtual reality training.

Now, this is really intended to help supplement both training -- obviously when I first came on board and saw this or even in my prior role when I saw this, this was really very useful during something like Covid.

I'm sure several operators experienced the same situation where it wasn't always safe to go in and get training, and this provides that additional supplemental reminder if you need it.

Another great use for this technology is, and unfortunately we're seeing more of these, is those larger weather events where you are having to call for mutual aid.

And so as other operators are coming to your service territory, it's a great way to refresh them with how you do things in your service territory.

Next slide, please.

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And these are some projects that OTD has partnered with PHMSA on.

I do want to say we really appreciate working with PHMSA to help develop new ideas and solutions, so thank you.

On the top left you'll see the small diameter electromagnetic acoustic transducer, that is a mouthful to say, so again it's just using a different tool, it's a little different than your typical MFL tool, to gain more data.

You don't know what you don't know, right?

And specifically this really helps identify more details about potential cracks in welds and helps operators just learn more about their system.

In the bottom left corner you'll see the orifice project.

This is not fully deployed yet.

The pilots were delayed due to Covid.

But this is a really important technology, and I know we're really excited to further the research here.

This is a radar system that identifies obstacles, horizontal directional drilling.

And this can actually be more broadly applied than just for gas utilities, so anybody that's using this technology to install, whether it's fiberoptics or a water pipeline, can use this to just be made aware of what else is in the ground.

And I do want to remind everyone that excavation damage is still the leading cause of incidents.

So really important technology for us to understand more and identify and leverage.

Lastly, there's the 3M locatable plastic pipe, which is an alternative to tracer wire which can also be damaged through weather and just normal wear and tear.

Next slide, please.

So let's talk about some factors to consider to develop and deploy successful R&D work.

First, you just have to understand that technology development can take a long time.

We need to walk before we run, and we have to do this safely.

Number two, understanding your constraints and understanding your variables.

You're not going to be able to create a solution every time for every variable, and sometimes that's okay.

For example, the mobile methane leak detection technology, which has been out for a few years, was at the time more accurate than a hand-held detector, but it doesn't work in every system, and that's okay.

That doesn't make it an ineffective technology or that that innovation should not be promoted where it makes sense to deploy.

Number three, work to identify commercial partners early in the process and get them involved in the deployment.

We need support from regulators to build the confidence and funding and supporting innovation.

I really like that a few moments ago Sam distinguished the difference between the need for both R&D in academia and the marketing of that end product.

There was a comment earlier this morning and somebody said that nothing precludes operators from going above and beyond code, but in fact business decisions -- that in fact business decisions and changes to work, including if you're trying to implement new technologies or R&D, need to be approved by the commission.

Providing regulatory support and this isn't always through a formal rulemaking or regulation, it can be through an advisory bulletin or just having conversations with -- to say we really support this technology or focus -- for operators to focus in these specific arenas, really provides some of that support that we need for deployment R&D.

More simply stated, you just need to develop a solid business case that can bring your product to market.

Lastly, you just have to understand the impact of implementing new technologies.

Like I said at the start of this slide, implementation is always going to have unknown challenges.

And you also need to understand how this affects your specific system as you're looking to deploy new R&D or a new technology.

And then I just want to point out, it's also really important that you communicate with your external stakeholders, whether it's your customers, whether it's your policymakers, just so you all understand the benefit and the potential changes that are coming your way.

Next slide.

Also as PHMSA and other governing agencies look to develop new regulations, regulations should allow for alternative or new technologies, that spurs innovation, and also new technologies may provide more system knowledge, helping how operators can leverage R&D and be more proactive in their risk management.

New technologies may also provide a solution for different types of pipeline systems.

Again, one size does not fit all.

And then ultimately, this just enhances safety to the public and the environment.

And then the last that I want to leave you with is this: The success of an R&D program cannot be represented solely patents or technology in the market.

White Papers, updates or new codes and standards, even failures and lessons that you learn when you're trying to deploy a pilot, are incredibly valuable to the industry.

So how you measure success is key.

Thank you, and you will turn it over to Sentho for what I think is the final.

>> All right, thank you, Sonal.

>> You're welcome.

>> Am I on?

And now we'll go ahead and open it up to the participants in the audience first for any Q&A they have for the technology panel.

>> We do have one question online.

That question comes from Terrence Peterson.

Can PHMSA provide an update on its implementation of the technology pilot program in the 2020 Pipes Act?

>> The question is related to section 104 of the pipes act of 2020 where we were required to establish safety enhancement testing programs to evaluate innovative technologies.

As of now, we have not received any applications for that program, but we are -- there is a report that was issued that provides information about how you can file your application with PHMSA, and so definitely please reach out to contact us if you have any questions or any interest in the program.

>> I can yell.

It's on, okay.

>> We can hear you.

>> Good afternoon.

Rick, ExxonMobil, technology and engineering.

Really appreciate y'all being here and talking about one of my favorite topics, which is technology.

One of the concerns I have is siloing.

As we develop technology, particularly with relationship to CO_2 and hydrogen infrastructure, how do we avoid siloing our technology development efforts?

Specifically I'd like to address this to the federal agents, but what role might DOT and DOE play in coordinating with largely a federal effort of how do we capture, transport, and sequester CO_2, and how do he effectively transition to alternate lower carbon intensive energy sources like hydrogen?

What do DOT or the federal agencies see as their role in helping to effectively coordinate those efforts and avoid siloing of technology development?

>> I can probably take that one.

It's a great question, and as I mentioned earlier, our efforts with our R&D are definitely collaborative.

We partner with DOE and specifically fossil, energy carbon management office, and we have a DOE representative, actually, several representatives that will be presenting later on about their efforts related to hydrogen and CO_2, but, again, I will say, in terms of siloing, we definitely have a broad stakeholder base.

And we really try to encourage partnerships and encourage really a diverse set of input.

We have forums that we put on and they're very collaborative, we have working groups, but we also have an open solicitation, really, to hear about input about how research can really help to inform our agenda.

In terms of a federal effort, we have been working, again, with the Department of Energy, FECM, as well as the office of hydrogen, and internationally as well, we have joining us U.K. health and safety executives, so there has been definitely a broader effort to make sure there isn't any duplication with research.

>> Another thing that PRCI is doing that we had embarked on is creating the online community for research, we call it the research clearinghouse, which will be available in the first half of next year.

And the idea is to reach out to other organizations and provide a transparent place for everybody to go to find knowledge.

And so we're looking to other industry partners, look to the OTDs, European members research groups and others to be able to putting out information that's available.

It may be the titles and abstraction extracts of the work that links back to the organization so we can find because this environment we're in, the pace of change is rapid.

We have to keep up with it.

And everybody is doing something, and we need to make sure that we can strategically allow everything to flourish and provide the solutions in the right time and the right place.

Ideally, with the clearinghouse coming online in the first half of next year, we'll be able to provide a community space where anybody, whatever role you play, can find what's going on in the industry and hopefully can be able to do that, like I said, on a very wide basis.

To complement what PHMSA is doing with their outreach but from the industry point of view as well to create this visual of what is being done because there is so much happening at this current time.

>> Hi, Jon with liquid energy pipeline association, following up on the tech pilot question.

Do you have any ideas or thoughts on how PHMSA -- what PHMSA could do more to facilitate the demonstration of technology we saw in the case of the tech pilot, the legal and regulatory Congress requires effectively preventing operators from -- considering that a viable program and thus we've got no application?

Do you have any thoughts on what PHMSA could do assuming that it wants to leverage technology for the benefit of pipeline safety, what we could do to make it easier to use technology, not harder?

>> Well, I definitely would encourage a lot of dialogue with staff, with PHMSA, and I would also, you know, really highlight, a lot of our program is based on technology demonstration.

And so definitely having that confidence, that today, really having confidence in the data to be able to actually promote out and adopt technology is really key for us.

>> One thing, actually, I want to add to that one is, yes, have those discussions among the industry and stakeholders.

If one company is utilizing one technology, share that success, share some of maybe the concerns that you have with another company, so feedback can be provided.

While we cannot endorse certain technologies, I think the feedback among the industries might be very helpful.

>> And with that, we're going to have to move to our next panel, which is on hydrogen, and Kandi Barakat will be moderating.

Thank you, and thank you to all the technology panelists.

[applause]

>> Thank you, Sentho.

So I will be the moderator for this next discussion, and the Q&A following this panel.

As a reminder, please hold all your questions until the very end, after all presenters have had an opportunity to speak.

The objective of this panel is to discuss opportunities and challenges on hydrogen and hydrogen blending.

It's now my pleasure to introduce Vincent Holohan, senior engineer for the engineering and research division at PHMSA, who will discuss what PHMSA regulates, safety challenges, expectations, and will foreshadow future possibilities on hydrogen research awards.

The floor is yours.

>> Thank you, Kandi, appreciate it.

Let's see if I can get the technology moving.

Well, you guys are all in for a real treat here.

My name is Vinny Holohan, as Kandi said, I work in the engineering and research group for -- I want to make brief comments about PHMSA's involvement with hydrogen gas.

A couple things about past performance of the pipelines we have in our repertoire, and then a little bit about what the research and development program is doing in that space currently.

I'll be moving pretty quickly, but we'll have the Q&A afterwards.

As a quick aside, any time I have family or friends coming, visiting the DC area, they want to see the national treasures or natural mall, monuments, museums, each time I come here to Houston, I come to the Galleria mall.

I'm not sure if that's a parody.

You've heard enough about who PHMSA is.

By now you know our function.

I'll remind you that between us and our state partners, we regulate about 3.3 million miles of gas and hydrogen liquid -- I'm sorry, hazardous liquid pipelines, the majority transporting natural gas.

We regulate underground natural gas storage and certain liquefied natural gas facilities.

Of those 3.3 million miles, right now there is a little bit more than 1500 miles of hydrogen gas transmission pipelines.

Since 2010, we haven't seen a market increase in that mileage, but we expect that to be changing in coming years.

This is a map of the hydrogen pipelines as of the 2021 data.

The 1500 miles of hydrogen transmission pipelines are operated by about 36 different operators in the U.S.

So far there is no regulated gas distribution systems carrying hydrogen that we're aware of, and these pipelines are generally more of a local fractured nature, maybe that's not the right term for it, but shorter nature than most of our other infrastructure on liquids and gas and they concentrate around the gulf, Louisiana, and Texas areas.

So hydrogen pipelines are currently regulated under part 192, transportation of natural and other gases, and they have been since 1970.

As it stands today, the regulations are largely the same for natural gas and they are for hydrogen gas, the differences being mostly in performance language, that requires the operator to design and operate the pipeline for the commodity that's being transported.

Performance based requirements include considerations of materials compatibility for the components, differences in the PIR, which we talked about quite a bit today, for integrity management, and the hydrogen, if it's used as feedstock in certain cases can -- doesn't have the requirement for odorization.

It should be noted that currently PHMSA is not capturing information having to do with blends, there's not a choice for that -- or annual data, so more than likely if you had a small amount of hydrogen blended into gas, natural gas would probably be listed as natural gas in that data, or as other, but from what we know, communicating with stakeholders, we're not currently aware of any regulated pipelines operating with blends.

And if you know different, I'm here, please come talk to me.

So a little bit about past performance.

Since 2010, there have been a total of five incidents on hydrogen-carrying transmission pipelines, all five were transmission -- because there are no distribution currently.

None involved injuries or fatalities, and none of them appeared to involve hydrogen, assisted cracking -- meaning the transportation of hydrogen was not a contributing factor to the failure itself.

Taken overall, that's not a lot of data, doesn't seem to provide significant evidence to support or to refute any integrity concerns with those pipelines.

Out of order here.

This is a slide that highlights our research investments in the space of hydrogen gas, supporting the administration's clean energy initiatives and outlines the past research we've done on hydrogen pipelines.

Previously the projects began in the lay 2000s, 2007, 2008, and led to some early successes supporting the development of ASME standards for those pipelines, which was talked about a little bit today.

Those projects mainly focused on integrity management and materials properties issues.

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Go back here.

There we go.

More recently, the end of 2021, the R&D program hosted this event which has been talked about.

Some of you were in attendance there.

Basically it was talking about hydrogen and emerging fuels and going through and prioritizing research that is in campus tense, these were used for the recent solicitations which went out and we have a total of seven projects that are starting in the space this year.

I'm going to very briefly highlight these.

This information has been noted on the website.

There's a lot of depth there.

This is too much to read through in the two or three minutes that I have here.

Essentially, MC Squared, they'll be researching integrity threats and threat assessment of pipelines transporting hydrogen gas and blends as one of their projects.

And another, the same company, MC Squared is also going to be considering how existing pipelines can safely be repurposed for hydrogen and hydrogen blends.

I apologize, I know I'm going a little fast here.

GTI is studying the impacts of leakage and how current leak detection could be affected by the presence of hydrogen and what's needed to go forward.

GTI will also be looking at underground storage facilities for suitability of storage of hydrogen gas.

University of Oklahoma, they have a project they'll be developing an assessment model, and then a tool looking at the compatibility of existing pipelines to transport hydrogen and hydrogen blends.

And North Dakota State University will be developing AI based software tool that may aid in decision making when considering the repurposing of natural gas pipelines for hydrogen gas service.

Finally, the national institute of standards and technology will be considering steel weld qualifications for new hydrogen pipelines as well as performance of modern steel welds and the assessment of vintage steel welds for hydrogen service.

You've seen this a few times today, some links in the presentation for anyone that's just tuned in to get a little more in-depth in the program.

With that, I thank you for your time.

Appreciate it.

[applause]

>> Thank you, Vinny.

Now I would like to well R welcome Evan Frye, physical scientist with the division of methane mitigation technologies at the Department of Energy, and mark Richards, technology manager with the hydrogen and fuel cell technologies office, also the Department of Energy.

They will be presenting on hydrogen production, transport, storage, and research, and development opportunities and challenges.

And they are presenting virtually.

Mark and Evan?

>> Thanks, Kandi.

I'm a technology manager with the hydrogen and fuel cell technologies office.

My primary focus in that office is on hydrogen infrastructure.

I would like to cover a little bit of why hydrogen first and then get into things related to hydrogen infrastructure.

Next slide.

On the left of this slide, you can see that renewables only represent about 15% of U.S. primary energy consumption.

The Biden administration has set goals to decarbonize the electric sector by 2035, and to reach net zero economy-wide by 2050.

The administration also has concurrent objectives to address domestic jobs in environmental justice.

Next slide.

DOE sees hydrogen as one component of a multi-office effort, as indicated on the right, to reduce carbon emissions.

Recent documents outlining the hydrogen aspects of the effort include the 2020 hydrogen program plan, and the 2022 draft clean hydrogen strategy and roadmap.

Next slide.

Looking at overall CO2 emissions, some end use sectors can be addressed by electrification such as heat pumps and battery electric vehicles.

Others are difficult to electrify, such as heavy duty vehicles and industrial processes.

Hydrogen can help address these end uses.

Next, please.

Two recent pieces of legislation included hydrogen-related support.

The bipartisan infrastructure bill provides nearly $10 million of funding for hydrogen research development and deployment, with 8 billion of that for hydrogen hubs.

DOE has solicited concept papers for these hubs already, and these papers are currently under review.

The second item is the Inflation Reduction Act, and that includes provisions for a clean hydrogen production tax credit of up to $3 per kilogram.

Next slide.

One challenge DOE is trying to address is the cost of hydrogen.

This graphic shows the market clearing prices need for hydrogen to be competitive across several end use sectors.

For hydrogen to help address the decarbonization of industrial usage, costs need to be reduced to around $2 per kilogram at the point of use.

DOE's hydrogen shot goal is to reduce the cost of clean hydrogen production at the point of production, $2 by 2026, and $1 by 2031.

Next slide.

To help guide RD&D funding, the DOE develops targets for various cost components across the production and delivery chains.

The middle two boxes on this graphic outline current costs, estimated high volume production costs based on current technology, and 2030 targets for clean hydrogen production and distribution.

Next, please.

I'm going to touch on hydrogen production pathways briefly here.

We break down hydrogen production into three groups, electrolysis, thermal conversion, which includes reforming and -- and advanced pathways such as thermochemical, photo electrochemical and others.

We're working to identify RD&D pathways to reach the $1 per kilogram target but it should be noted that advanced pathways are lower TRL at this time and these pathways can be more challenging to identify.

Next slide, please.

Aside from adjusting costs, DOE is working to ensure that materials and components needed for hydrogen production and distribution are developed and suitable for use.

Hydrogen is known to affect the properties of many materials, such as strength, ductility, et cetera.

Hydrogen effects do not necessarily pre-conclude the use of a particular material.

Design and operation conditions for a material in hydrogen service play a role in determining suitability.

A multi-lab consortium is performing cross-cutting R&D on the effects of hydrogen on metals and polymers.

The green highlighted items on the right are work areas that may be of interest to the pipeline community.

These include improving the fracture toughness of high strength steels, developing master curves for pipeline codes to simplify new material adoption under those codes, and examining pipeline materials relative to blends of hydrogen in the natural gas network.

Next, please.

To help assess the potential to blend hydrogen in the natural gas network, DOE established a multi-office initiative called Hugh blend.

The first effort in the initiative is a cooperative R&D project consisting of six national labs and over 30 industry partners, and that effort is to investigate various aspects of hydrogen blending, the effort is undertaking material testing in various blends, developing integrity models to help identify operating conditions and establishing analysis and lifecycle analysis models that will be publicly released for economic assessments of blending.

Next, please.

Finally, the hydrogen fuel cell technologies office maintains the safety codes and standards subprogram that supports the development of codes and standards to enable the use of hydrogen.

The subprogram focuses on developing the scientific data needed to establish requirements for hydrogen deployment and use and to disseminate this information as well as safety practices to the broader community.

Thanks for your attention, and I'll hand it over at this point to my DOE colleague, Evan Frye.

>> Many thanks.

Apologies, this is my first slide showing.

Hey, everyone, appreciate you coming virtually and thanks to PHMSA for organizing this.

My name is Evan Frye, program manager for the natural gas decarbonization and hydrotechnologies program.

Second slide, please.

Here I present FECM division of methane mitigation technologies.

We support administration goals including a 50% emissions reduction by 2030, a CO2 emissions repower system by 2035 and net zero emissions economy no later than 2050.

Our division is organized into four primary program areas, methane emission mitigation is focused on eliminating future emissions.

Quantification works to measure and quantify methane emissions across in natural gas value chain.

My program, the natural gas decarbonization and hydrogen technologies program, functions to decarbonize the natural gas supply chain and support a clean hydrogen-enabled economy.

Finally, our newly established undocumented orphaned well program is tasked with locating undocumented orphaned wells.

This presents DOE's H2 scale framework which highlights an energy economy.

When we think of hydrogen as a carbonless fuel, at FECM we explore how fossil resources and infrastructure assets can be leveraged to provide clean hydrogen at scales necessary in meeting administration goals.

Thus the NDGHC program focuses on three areas of interest around transformative hydrogen production, transport and storage.

Fourth slide, please.

In thinking of a net zero economy by 2050, FECM's program mission falls cause challenges and opportunities.

With respect to current R&D for production, activities include developing processes that produce clean hydrogen and hydrogen carriers from fossil feedstocks in support of the hydrogen energy.

Specifically, we are assessing processes that convert methane to clean hydrogen while capturing and converting carbon in marketable, solid carbon products.

With respect to transportation R&D, we are characterizing the long-term impact of hydrogen on piping and pipeline materials within natural gas infrastructure.

We are also developing advanced sensors for hydrogen leakage detection and blend monitoring in real-time.

To further validated the carbon-free proposition, we need to conduct lifecycle analyses from equipment transporting natural gas and hydrogen blends.

Finally, we conduct technoeconomic analysis to understand lower, more reliable hydrogen and blended national gas transport pathways.

With respect to storage needs, FECM will determine the viability, safety and reliability in storing pure hydrogen or hydrogen natural gas blends in subsurface environments.

I'll speak to this subsurface storage portfolio in later slides.

Next slide, please.

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This slide provides a high level overview of potential, near, mid and long term R&D opportunities for FECM.

In the near term we continue to work across DOE offices to understand market opportunities in various regions of the United States to best deploy federal resources.

In the mid-term, scaling of subsurface storage of hydrogen is of specific interest and we welcome your inputs on this subject.

I'll identify a way to connect with us in later slides.

In the long term, understanding FECM's role is critical towards maintaining and achieving administration goals and providing safe, reliable and secure resources to the American public.

Next slide, please.

So a major component of our storage portfolio is our subsurface hydrogen storage and technologies acceleration program, known as SHASTA.

Subsurface hydrogen is limited to storage facilities.

SHASTA is composed of four national labs.

SHASTA works towards expanding the footprint for subsurface storage, which is crucial to enabling the widespread utilization of hydrogen via bulk storage.

This team will identify and address key technological hurdles and develop tools and technologies to enable broad acceptance for storage with natural gas or pure hydrogen storage in the subsurface.

As we've established in the update, this data knowledge, SHASTA and our stakeholder working groups will determine the viability, safety and reliability of pure hydrogen or blended gas storage by conducting field demonstrations.

Next slide, please.

So I'm going to present some preliminary workout of the SHASTA group.

Underground hydrogen storage has the potential as a long duration energy storage option for low carbon economy.

Using PHMSA's underground natural gas storage facility reports, our investigators assessed 399 underground gas storage facilities in their working gas volumes.

They considered blended, hydrogen methane storage scenarios and estimated the working gas energy of these mixtures in domestic facilities.

If these facilities could be converted to 100% hydrogen storage, the total working gas energy of underground gas storage facilities in the United States is estimated to be 327 terawatt hours.

We estimate the transitioning domestic facilities from natural gas to pure hydrogen storage would reduce the collective gas energy by 75% from 1,282 terawatt hours to that 327 terawatt hours.

Because of hydrogen's volumetric density compared to methane, approximately 73% of the 399 underground gas storage facilities can store hydrogen blends up to 20% and continue to reliably meet their current energy withdrawal demands.

Presented here are facilities by storage reservoir type, their working gas energy capacities, and then the cumulative storage potential organized into regions.

Hydrogen demand projections suggest that hundreds of new storage facilities may be needed to meet reliability demands.

Next slide, please.

Other work within the SHASTA portfolio.

The previous analysis will improve on our principal -- the previous analysis will improve as our investigators integrate higher fidelity inputs into meteorologist which consider biological, geological to assess domestic storage facility.

Because there are only a few hydrogen storage data points and limited examples of blended natural gas and hydrogen stored at scale, the SHASTA team is continuously updating our analyses to inform infrastructure planning.

Ultimately it is the team's goal to describe components of the hydrogen natural gas storage chain as a function of storage facility type capacity and end use demand.

We hope to develop tools using existing DOE analyses and national labs, delivery scenario analysis model, HDSM, to inform policymakers of existing and future storage potentials by providing metrics on costs of stored hydrogen.

Next slide, please.

As mentioned, SHASTA can leverage assets and expertise to clarify operational risks, develop enabling tools and technologies, and demonstrate a collaborative test plan in partnership with a network of stakeholders.

This last point is especially critical as I encourage those interested to reach out to our team via our SHASTA page on the NETL energy data exchange to join our stakeholder working group.

Next slide, please.

2400, fossil energy based production storage transport and utilization of hydrogen approaching net zero or net negative carbon emissions.

Thanks for everyone that submitted applications for this funding opportunity.

It was highly competitive.

Applications are currently under review, four AOI's, two within the area of 14 one respectively to each AOI 15 and 16.

We hope to make selections and announcements next spring, but for future areas of interest, please seek out our FECM solicitations page for ways or opportunities of doing business with DOE.

Next slide, please.

Finally I present the NGDHT, the natural gas decarbonization hydrogen technologies programmatic timeline.

The program was established within the FY22 omnibus, however, we've leveraged insight from our programs, but ultimately the NGDHT program collaborates with the larger system as we work together to transition energy infrastructure and systems into a more decarbonized energy economy.

I think that's my last slide and thank you for your time today.

Please reach out to FECM and our research partners.

Take care, everyone.

Thanks.

>> Thank you, Mark, and Evan, for your presentation.

[applause]

>> Now I would like to welcome Dr. Simon Gant, he is with the health and safety executive science and research center based in the U.K.

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Dr. Gant will be presenting on H2O research initiatives, challenges and opportunities, and also joining us virtually.

>> Thanks very much, Kandi.

It's been a great meeting so far and thanks for the opportunity to come and present here.

Slide 2, please.

Yeah, I'll give a quick introduction to HSE and talk about our net zero strategy, talk about ongoing activities and some recent publications that I thought might be of interest and end with some knowledge gaps.

Slide 3, please.

HSE is the U.K. regulator for health and safety, which includes all onshore and offshore pipelines as well as other bits of infrastructure.

Our activities cover -- some of the things awesome as PHMSA, consultation, regulation, incident investigation and enforcement.

Regulatory regime is slightly different in that it's a bit more risk based than based on codes and standards.

I work in the science and research center, about 400 staff, and we've got test facilities to support the agency and other government departments as well as joining in projects in consultancy.

Slide 4, please.

Net zero plans in U.K. these are centered around two main areas at the moment.

We've got regional hydrogen and CCUS industrial clusters, there's two of them.

I'll talk about them on the next slide.

And we've also got a big program of work on hydrogen for heating, looking at using 100% hydrogen for domestic, commercial and industrial heating.

And there's a lot of work going on at the moment that's in support of a cross-government policy decision on hydrogen heating that will take place in 2026.

And in the run-up to that, there's various trials ongoing.

So in the next year or two, there will be a neighborhood trial with 300 properties in Scotland, running, and cooking on hydrogen, using a new distribution network, and after that, there will be a village trial with up to 2,000 properties, including a school and hospital, running 100% hydrogen using a repurposed gas distribution network, and then after that, there will be a town pilot probably -- 2026 and going on into rollout.

Next slide, please.

So like I mentioned, one of the areas of work is the industrial hydrogen and CCUS clusters, there's two of them.

HYNET and the East Coast cluster, both of them involving new or repurposed hydrogen and CO2 pipelines.

They received funding last year, and there's a second phase of funding being announced next year, related to those two industrial clusters.

These are projects that are looking at incorporating CCS so there's a number of projects, some hydrogen production plants and industrial installations like refineries and cement factories.

Next slide, please.

The second part of the work is a hydrogen heating program.

This is an area of work funded by BEIS funding industry consultants and regulators, to deliver a range of research projects and testing work looking at putting 100% hydrogen into the domestic heating and commercial and industrial heating.

So within HSE, we've convened 11, what we call evidence review groups, they're listed on this slide.

And each of them have got about a dozen scientists, regulatory and policy specialists.

What's happening is that we're receiving various documents from industry and consultants that we're reviewing and you'll go into some examples in the next few slides.

Next slide, please.

Slide 7.

This is just covering the areas of work that we're reviewing.

It covers everything from materials performance to risk assessment, different types of equipment and procedures and training.

Next slide, please.

So for an example, a bit of work we've been looking at, this is work run by the gas company SGN, looking at using the polyethylene distribution pipe systems for 100% hydrogen, the scope of that work, the standards, looking at failure modes, fracture toughness, crack proper a graduation, leak tightness and various different squeeze-off welding and repair technologies.

They also funded some experiments looking at accelerated lifetime testing, so that was one large report that we reviewed and gave some feedback on.

Next slide, please.

Second example here, this is some work in support of using hydrogen in the gas transmission network, which in the U.K. is operated by the national grid.

And they've given us various bits of work to review, so they've done a fair amount of working looking at potential impacts on materials, also looking at due points, barrier coatings, looking into deblending, this is mixing hydrogen within natural gas at different points in the network.

Looking at what information is required if you're going to repurpose pipelines, so the design standard of that pipeline and its history, also looking at in-line inspection and repurposing.

Reviewed some of that.

Next slide, please.

The third example is, there are a number of studies that have been done at various facilities, industrial sites looking at the implication of switching from natural gas to hydrogen.

So issues around area -- some materials issues, things like that, so we'll review reports on that.

Next slide, please.

Slide 11.

So we've been very busy over the last few years, looking at qualified risk assessment methodology for hydrogen distribution platform that works, so this includes pipeline distribution network and also within domestic buildings, the internal pipeline system, and the modeling work includes the whole gamut of things from the pipeline release frequency, hole sizes, how the gas tracks through the ground, ingress into buildings, gas cumulation, and explosion, fire, consequences, and various experimental studies to support that modeling work.

And this is aimed at looking at what are the relative risks between 100% hydrogen and the current system of natural gas, and also looking at different mitigation measures to reduce the risk with 100% hydrogen, things like excess flow valves, gas detection, and so on.

And barriers to see what mitigation measures are needed in order to make the risks equivalent to hydrogen as they are for natural gas currently.

Okay.

So, the next few slides, slide 12, sorry, talk about some of the previous slides work that we're reviewing.

Agencies also carried out some research of its own that Adam banister has headed.

I thought this was relevant to what Vinny was mentioning, was it Iowa, looking at material compatibility for 100% hydrogen and developing methodology there.

Next slide, please.

This is looking at assets on the gas network and their suitability for hydrogen, and the work looks at assets, the component -- if you're looking at a valve, looking into educator use different component parts of the valve, and the quantitative methodology is looking at the individual component sensitivity to hydrogen degradation, how that component is loaded, and the consequences of failure of that component.

And then it gives a ranking system or score for the threshold assigned to it.

And the idea is that if the component fails in some way, this work also looks at mitigation options for how you can deal with that.

And it's also codified into a spreadsheet tool.

Next slide.

Slide 14, please.

And there are examples here, I won't go into the details, but this is what single band repair clamp on the distribution network -- the top part of it is looking at its current risk situation for natural gas and the bottom part of the spreadsheet that is shown is the various scores that are given for different component parts of it for hydrogen and it's given a green mark at the end as a pass.

Next slide, please.

And this is the same thing but for a different asset, so building entry tee.

You can see it's got more components there.

This one is in process.

Next slide, slide 16.

That methodology was tested by the gas network company on a range of assets on their network, and you can see the chart here is showing -- passes or fails, it highlighted them -- pressure regulating devices and slam shut valves were areas they needed to look at in a bit more detail.

Next slide.

Slide 17.

Cast iron is a bit of an issue we're looking into at the moment.

A number of U.K. gas network companies are doing further work on material testing of cast iron for 100% hydrogen and we'd be very interested to learn about any work that's ongoing in the U.S. or elsewhere on cast iron hydrogen surface.

There is a replacement program that's ongoing in the U.K.

Next slide, please.

I didn't know to what extent the energy institute is visible in the U.S., but they're coordinating a number of studies in the U.K.

I don't know whether it's just the U.K.

I think a number of international organizations are involved.

They've published a couple of interesting reports looking at repurposing of natural gas infrastructure for hydrogen, and something else on energy efficiency, and there's a number of ongoing projects that -- they've got a number much industry stakeholders and the agency often participants in their working groups.

It's just a highlight that that work is going on.

Next slide, please.

And there are a couple of other interesting publications that came out this year, not on the safety side as such but on the emissions side, so the one on the left there about atmospheric implications of increased hydrogen use, has something on the global warming potential of hydrogen, and the publication on the right on fugitive hydrogen emissions, emissions is a big area of interest, so this was looking at what it would be for hydrogen in the future.

Those are freely available reports.

And then slide 20, please.

To conclude then, I've got a couple of slides here on knowledge gaps and technological innovation needs.

I had a chat with colleagues to pull this list together.

These are things we're looking for some work on in the future.

Development of procedures and remote repair technologies for gas escapes on the distribution network.

Flow stopping equipment for hydrogen distribution pipelines.

There's been a fair amount of work going on on hydrogen pipeline purging, tests, but there's more needed there.

Gas detection for homes and smart excess flow valves for homes.

Two experiment points that I've got on this slide, one on ignition of hydrogen pipeline releases and one on response of buildings to internal hydrogen explosions.

So work that I'm aware -- projects are being put together on those two areas in the U.K., and if people are interested, I can put them in touch with the project leads for those.

There's also a need for work on explosion relief systems, governor kiosks.

Next slide, please.

And a need for work on -- further work, I guess I should say, on compatibility of gas network assets for hydrogen service, and also the performance of network assets, and finally erosion of pipeline systems for blends and 100% hydrogen.

So if you know of any work that's going on in that area, we'd be really interested to know more about it, the agency.

And the final slide, slide 22, is just my contact details.

Thanks very much for listening and thanks again to PHMSA for organizing this meeting.

Thank you.

[applause]

>> Thank you, Simon.

We appreciate you joining after business hours.

We realize the time in the U.K. right now.

Thank you so much.

>> Okay.

>> Now you'd like to welcome Dr. SIARA so a, technology development manager, research, development and demonstration clean energy innovations.

They will be presenting on hydrogen composition, supply customer, design operations, locations, and safety considerations.

.

>> Thanks so much for the introductions.

And hi, thank you for having me today.

I've been work for SOCAL gas in 20 years, different capacities in the engineering area, materials testing, evaluations, failure natural circumstances, all kinds of interesting things.

And now I manage the low carbon research system on their project for research and development.

Basically our projects range from hydrogen production and renewable gas production, all the way to carbon capture utilization and sequestration.

Very interesting and exciting for me.

A great change after so many years.

While we wait for that Powerpoint to come up, I'm going to explain today specifically about our strategy at SoCal gas for hydrogen and hydrogen blending.

Basically we are focused on decarbonizing our system and reach carbon zero goals or zero -- okay, there we go.

I guess now it's on me to do this.

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Yes, okay.

Going back to SoCal gas and their strategy, we're looking forward to becoming zero greenhouse gas emissions by 2045, a very ambitious goal, and we need to set up a clear strategy on how to achieve those lofty goals.

We are the largest gas distribution utility in the country, and we have over 22 million customers being served by an infrastructure that's relatively old, since our company's been serving the public for over 20 years.

Basically we're taking a serious look at all of the different options in terms of clean fuels and how are we able to have different strategies to decarbonize our system.

So with that, we defined specific goals on how we were going to approach this, and regarding hydrogen, we had defined two specific strategies.

One of these is what we call -- I'm going to go over this.

Angeles link is our proposal to the public utilities commission to let us have 100% hydrogen pipeline infrastructure.

This would be new construction, if you will.

There's many different phases to this proposal, and currently we have a decision by the CPUC to allow us to go forward and plug this effort in with the -- submitted by the state of California for the -- one of the hydrogen hubs that is opened by the Department of Energy.

How could this make sense?

Basically what we're trying to combine is the source of hydrogen with the end user, and for this to work, we need to use basically the renewable electricity from solar and wind that can be curtailed from time to time every day.

So based on that availability, we can use an electrolyzer to split water from hydrogen and sides where we have availability, transfer that to our end users that are hard to decarbonize and that could use the hydrogen, for example, for heavy duty trucks and the like or other industries like cement, for instance.

One of the key advantages of this process is that by using electrolyzers our hydrogen product will have a pure composition.

Different type of trace elements, maybe a little bit of moisture or oxygen, depending on the technology, working with very pure hydrogen.

Basically our customers, as we're planning at a high level, could be the LADWP electric plants that use electric generation facilities, in addition to those heavy duty fleets that I was talking about before.

The heavy duty fleets are very large in Southern California and that would be a significant impact in terms of the pollution reduction and emissions reductions.

This is an example of how we envision our industrial hub for hydrogen in terms of what would be our customers, basically by bringing that hydrogen from the areas where we have wind and solar that are in the desert, outside of our Los Angeles basin area.

So that's, when you make that connection, the transportation via pipeline makes sense.

Ideally, you will have a collocation, electrolyzer next to the end user, but for that to work, to have an impact, the renewable piece needs to be brought together.

It's definitely not an easy analysis, and that's part of why we're requesting the state to allow us to move forward to do all the evaluations in order to demonstrate a specific plan that will make sense.

Our second aspect of our hydrogen initiative to decarbonize our system is on blending.

We don't have a specific level of hydrogen to blend, but we're working on a significant amount of research, we're part of so many different consortiums with PHMSA, with the Department of Energy, with Europeans, if aliens would be doing hydrogen blend go, we would partner with them, too.

It's important for us to come together and make sure we can substantiate together, make sure we raise a flag to any other constraints that we need to consider.

This is a very important issue because hydrogen can have certain impacts on old infrastructure.

This is the basic idea that we have with our blending proposal and electrolyzer to split the water, using electricity, and going through our blending skid, inject that into our system.

And at a high level, these are the specific areas of focus that we're working on in terms of our studies.

Definitely that plastic and steel compatibility are critical.

We've heard today many people are already working on those type of projects.

Integrity of our pipeline is the number one concern, and we've all gotten into safety again because of the safety piece.

In addition to that, we're also part of the center for hydrogen safety.

I highly encourage anyone that has either safety concerns or safety questions about hydrogen or curiosity in terms of how to deal with it, is it safe or not and how will it impact me as a customer regardless if you're industrial or at home, go to the website, this is from the American Institute of Chemical Engineers.

I don't have a link there but I promise I will add it when I share the presentation.

These people are doing a fantastic job of making sure we're touching all the pieces and they're also reaching out to standards and codes organizations to ensure that everything that needs updated is updated.

They had a very large conference in Anaheim this past September, and they will be having another next year.

I'm not sure where.

But, again, they're a very, very large and reliable source of information.

I encourage anyone with that curiosity to go and reach out to them.

They also accept memberships.

We, of course, are members as well.

Again, I encourage anyone that's interested to reach out to them.

And I also wanted to put a few examples of some of the projects that we are collaborating with.

Definitely running those tests are a large period of time to substantiate that it works in the real life environment, modified demonstration type projects is something important for us.

So we have several efforts here, explaining we have this higher pressure or let's say medium pressure, not necessarily transmission but not -- this project with UC Irvine.

We also have another project with UC San Diego, I believe these are lower pressures.

I said we because SDG and SOCAL gas are sister entities.

Bodies from southwest gas are developing another plastic demonstration project.

Then these are more examples of what we're actually doing at SOCAL gas.

We have this training facility that we use for our employees that go into customer service.

And in one of their sites, one of their little homes that you see there, we developed a closed loop system with materials used by the residential system and the distribution system, and tested several blends of hydrogen and natural gas at different levels, over relatively long term.

This test was several years long.

And we wanted to see what could be potential impacts on these materials as well as also monitoring equipment, and we figured out with small leaks, trying to figure out how our monitoring equipment will work.

That's why it's indicated there by liquids.

We have a second version of this project that is called the living lab that is collaborative with a team and it's a two-year demonstration still in the plans.

So no pictures yet.

And this is yet another demonstration project.

This is a very large project, we just finished construction this year.

And we typically call this a hydrogen home, hydrogen innovation experience.

Over here we wanted to have another closed loop system to run appliances at a residential level for a long term, and running blends up to 20% of natural gas.

So the home is fully equipped, is very pretty if you ever are in Los Angeles and want to go take a look.

And it has its own system to produce their own hydrogen, which we'll see in the next slide.

It has some solar panels, and electrolyzer, so it's a closed loop system.

And it's aimed to demonstrate that all of this can work together in a home, like anybody's home.

This is the second project that we have on my R&D team, and this is a demonstration of technology that can separate and compress hydrogen from an initial blend.

So this is meant to demonstrate in case we want to retrieve the hydrogen after blending to use it for another customer that might need specifically only hydrogen, that is something that can be potentially and easily done.

This first project was made at a relatively low pressure, so I want to say under 6 PSI, but we have a second phase coming up that will be higher pressures, and this is European technology.

And last but not least, this is one of my favorite projects in hydrogen.

We are working with a company, a start-up that was funded by the Department of Energy.

They invested already, I want to say $12 million on this technology.

And this technology developed small, compact 3D-printed reactor to produce hydrogen from renewable gas.

So we're basically having these larger demonstrations installed in the sun line bus transit agency.

They have their buses all running hydrogen and they have an SMR but we're plugging in this reactor in order to test out their ability to scale up for larger volumes.

And with that said, thank you very much.

If you have any questions, we can discuss either at our Q&A or if you want to reach out to me either via LinkedInor at the end of this presentation, thank you so much.

[applause]

>> Thank you, Dr. Sosa.

I'd like to introduce Jay Meyers, vice president for engineering and technical services at Tallgrass Energy.

He will be presenting on hydrogen composition, supply customer, design operations, and safety considerations.

All yours.

>> Thank you, I appreciate the presentations.

It's nice seeing some of the real world applications that people are working on for hydrogen production.

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All right.

So today I'm going to be talking a little bit about some of the hydrogen initiative projects that we're working on.

below is a list of projects.

And I do have a couple other more detailed slides associated with each of these projects so I'll just touch on these briefly.

First project is up near Douglas, Wyoming, the initial engineering of CO2 capture on a unit, 220 million standard cubic feet today standard hydrogen production facility, in partnership with BASF, universities of Wyoming and others.

Second project is something that I think is very interesting and that's in northwest New Mexico, and that's the conversion of an existing 265-megawatt coal fired power plant to 100% hydrogen fired, which includes new hydrogen production with 95% of the CO2 capture in sequestration.

Then we have the Black Hills Cheyenne project, which is a demonstration of hydrogen combustion in a commercial natural gas combined cycle unit with the Wyoming Energy Authority, Black Hills, and others.

I do think that it's important to say that, you know, with a lot of these blue hydrogen projects, you're not going to have blue hydrogen without the capture and the sequestration of CO2 so they inevitably require CO2 projects.

We do have a project potentially our existing Trailblazer pipeline which runs from Cheyenne out to Beatrice, Nebraska, but it's an existing 36-inch pipeline and we're looking at converting approximately 390 miles of it from natural gas to CO2 with access to approximately 10 million tons per year of CO2 within 50 miles of the pipe.

That's not really related to the blue hydrogen.

There are ethanol plans where we plan to gather the CO2 from.

We're looking at the Eastern Wyoming CO2 sequestration hub which is the development of a 5 to 10 million ton per year sequestration hub, and also including characterization well drilling in a Class 6 permit application.

All right.

So first project, is DOE project up near Douglas, Wyoming, but it's the initial design of a commercial scale carbon capture system that would be installed and fully integrated

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with a 220 million standard cubic feet per day blue hydrogen facility, which will utilize ATR technology or auto thermal reforming.

Also the identification of potential pathways for CO_2 and hydrogen, and it will also help us determine the levelized cost of hydrogen in cost-to-carbon capture.

As far as success criteria, we are, you know -- it's the development of the initial engineering study for the commercial scale of the carbon capture and underground sequestration system that separates and stores more than 100,000 tons per year of CO_2 with 95% purity.

Then the carbon capture efficiency will be 90 plus percent.

Then there are other purification requirements and then the CO_2 delivery pressure at 2215 pounds absolute.

ESCALANTE, an existing 265-megawatt power plant, coal fired power plant, that was originally commissioned in 1984.

It was retired on August 31stof 2020.

So this project involves the evaluation of large scale clean energy production facility in northwest New Mexico and the repurposing of the ESCALANTE power plant to use, you know, the clean hydrogen as fuel.

Greater than 95% of the CO_2 from the hydrogen production facility will be captured and permanently sequestered, which means that we will now be using the CO_2 for enhanced oil recovery, we will be permanently sequestering the CO_2.

From a clean power standpoint, approximately 265 megawatts, very low greenhouse gas dispatchable power.

We do expect 60 plus per minute jobs to be created in the local community as well as 500 plus construction jobs.

We also believe that this will serve as the foundation for further development of clean hydrogen in the area.

Talking a little bit about the conversion of the power plant to hydrogen fuel, it's really not that much different than the conversions of, you know, coal fired power plants to natural gas, with the exception of you have to create the hydrogen, but you've got the coal handling that feeds the boiler, produces the steam and drives the steam turbine and you have your off sides for ash pond, et cetera.

You'll remove the coal handling, the off-sites, but you will bring in natural gas, produce the hydrogen, the hydrogen in turn will feed the boiler, produce the steam, drive the existing steam turbine which produces the power, but you do need to capture the CO2 as well as sequester the CO2.

From a reliability standpoint, you know, we believe that -- ESCALANTE will be capable of dispatching power at any time and provide decarbonized power, you know, when renewables are producing.

You know, the reliability will be very similar to what we have for natural gas generation except it will have very low CO2 emissions. From an affordability standpoint, we also believe that this will be a less expensive source of power capacity than solar or renewable growth as renewable growth continues. Then a lower cost than green hydrogen. From a decarbonization standpoint, 95% of the carbon capture from the production of the hydrogen will be permanently sequestered. Next project is with is black hill Cheyenne. This is a demonstration of a hydrogen combustion of hydrogen combustion in a commercial natural gas combined cycle unit with Wyoming energy authority, black hills energy, GE and black and beach. Black hills energy is the lead on this project and will be providing the technical expertise for the blue hydrogen production. The initial phase of the project is the front end engineering design for a blue hydrogen gas production for the facility with carbon capture. There's also conceptual engineering assessment of the equipment modifications for a GE LM600 combustion to combine the blend. I should have mentioned this, this is a blend of hydrogen and natural gas. And then, you know, finally there will be the demonstration of using that as a fuel but for the demonstration testing, the hydrogen will be supplied from tanker trucks. So it's going to be a testtype project. I will touch briefly on the trail blazer conversion project. This is the conversion of an existing 36 inch natural gas pipeline to gas CO2 services. So it will not be super critical. The MAOP of the pipeline is not such that we can move out in the super critical site. The pipeline hard to see runs from Cheyenne out to Beatrice. It over lays part of the trail blazer pipeline. You can see the converted piece of trail blazer in blue and then there are inner connects with recs to maintain the supply of natural gas to the customers. But the blue area is where it will be converted. Then, you know, we'll also be able to of course leverage the office and field personnel that we already have in the area. I do want to touch a little bit on hydrogen pipelines since I though this is a PHMSA conference and that's what I think everybody is interested in. But hydrogen pipelines, these are kind of our thoughts and what we see here. But hydrogen pipelines of course are regulated under part 192. Hydrogen is a flammable gas as defined in 192.3. It includes natural gas pipelines with hydrogen blends as well as pure hydrogen pipelines. Part 192 really doesn't say a lot on hydrogen. There's not a lot of specific guidance. You know, in fact the gas factor that's used for hydrogen in the PIR calculation for HEA determinations not mentioned of course .69 is typical for natural gas. I know there was discussion around that this morning. .69 is typical for natural gas. It references ASME B for gas. It doesn't have much guidance on hydrogen either. You know, it was mentioned earlier this morning ASME B 31.12, 31.12 does include a reference for the gas factor to use for hydrogen and that's .47. You know, as we as I think Mark brought up this morning, you know, he believes that that is out of date and really needs to be refreshed. I'll be interested to see where that goes. But then there's also ASME B31.12 for hydrogen piping and pipelines. I'm not sure how many people are familiar with it but it is a good standard. Very similar to B34.8 and 31.8 but t specific to hydrogen pipelines. It's not incorporated for reference within part 192 but applicable for pipelines containing more than 10% hydrogen. It does address a design construction and operation and then there are a couple of things that I think are interesting in there because it does include guidance on design factors which are typically lower than they are for natural gas service. You know, they include an option A which is a prescriptive design method. There you use a .5 design factor for class 1 through 3 and then a .4 for class 4 areas. They do have an option B which is more of a performancebased design factor and in there you get your more typical design factors for class locations like you do with natural gas or of course you can go with a .72 for class 1, .6 for class 2, .5 for class 3. There is also a separate material performance factor that can further decrease the design pressure as your, you know, pipe grade exceeds. The higher yield pipe there's a recommendation for a further D rate for the pipeline itself. And then last slide I do want to address a little bit on at least my thoughts on, you know, pipeline conversions, you know, whether I guess building new versus converting. So, you know, there of course have been a lot of conversion projects and a lot that have looked at that people have looked at. I think it was mentioned yesterday what was it 400something pipeline conversions, whether it's a conversion of service or, you know, change in product. So there are quite a few out there. New pipelines of course give the operator complete control over all aspects of the design and construction of the asset. You know, that's nice to have. Pipeline conversions, the repurposing of existing pipelines does make sense in some cases. You know, new pipelines are challenging to permit and the process can be lengthy. It does provide opportunities for underutilized pipelines and there's typically less environmental impact. You know, as far as steps for conversion, you know, we discussed quite a bit the PHMSA guidance for pipeline flow reversals, product changes or conversion to service. Great document if you're not familiar with it. But it does, you know, walk you through different scenarios, what you need to pay attention to and how to go about the conversion. Then I do want to mention that ASME B31.12 does address pipeline conversions in section PL3.21 for its steel pipeline service conversions. So what makes a good candidate for conversion? Every pipeline is unique and needs to be evaluated based on its unique characteristics. That really comes down to operators need to understand their pipeline, need to understand their assets and the specific risks associated with it. I do want to point out that a

pressure that I guess I believe a pressure D rate will probably be required if you're following B31.12 to operate at no more than 50% SMICE. This is largely because of the prescriptive design factor where you have the .5 limitation for class 1, 2 and 3 areas. Then also, you know, potentially because of the material performance factor. Vintage pipelines, you know, pre1970 pipe, the good thing is a lot of times those are lower yield pipe that may not require that material performance factor for the further D rate. But we need to be aware of the historical issues associated with vintage pipe. Weld seams, load toughness, hard spots, poor coding, SCC, you know, we had quite a lengthy discussion yesterday morning on hard spots. You know, cathotic production providing a source of hydrogen that could further brittle the material. Same thing with putting hydrogen in service. You need to understand your assets and how to address it. Then you also need to you know, so really just understanding the abrittlement and the impact on these potential issues. As far as modern pipelines it voids some of the historical issues associated with vintage pipe which is a real plus and typically operators have much better records what they have on their newer assets. You know, half our modern pipe is typically a higher yield that might require further D rate due to the material performance factor. So a lot of times the pipes are X70 or so. So, you know that could require a further D rate. I guess thank you for your time. I appreciate you letting me speak. I look forward to the panel discussion.
>> [Applause]
>> We'll move on to the Q&A session right now.
>> We do have a couple of questions online. This question is from drew Gomer. Does PHMSA plan to incorporate ASME B31.12 in reference to part 192?
>> Currently we are evaluating and that's why we're having this PHMSA public meeting today. So I definitely encourage comments to the public meetings docket for consideration for potential future rule making.
>> I'll add to that that B31.12 is currently going through the revision process and look forward to reviewing the next version of that when it comes out.
>> Thank you. Next question is from Justin. Is there any estimate of when there will be comprehensive hydrogen regulations in place? It appears that some of the research mentioned here that would support that effort won't be done until late 2025.
>> I can take part of that at least. I think in some spaces there's already coverage for hydrogen. We did publish through San Diego national lab I believe it was earlier this year, it was called federal regulatory map I guess for hydrogen infrastructure that walked all the way through all of the different federal agencies that cover different aspects of putting hydrogen distribution systems in service. If I can dig up a link shortly I will I guess I'm not sure exactly where to send it but it's out there.
>> Okay.
>> Looks like now we have a question here.
>> Hi this is Bill Caram the pipeline safety trust. So I guess my question is mostly for

DOE. Given the known integrity issues with introducing hydrogen into pipelines, the safety issues that have been talked about of the flame ability range and the fact that hydrogen is a gene house gas with potential warming potential and leaks from infrastructure with the money that DOE has, how are you going to prioritize projects that don't put the public at added risk and meet our climate goals?

>> Well, I mean obviously safety is always a primary concern in any project we do we require safety plans from all of the projects that involve any kind of like beyond the lab or even beyond very small scale lab activities. In terms of addressing things like greenhouse gas effects or indirect greenhouse gas effects there is some work being planned in conjunction with folks like MIST that are going to examine and try and get better information because some of the information that's out there regarding this is not terribly refined. So we're going to try and get better numbers and better handle on that situation. We also currently got a solicitation that's that proposals have been submitted to that are going to be reviewed soon to develop sensors that can quantify PPB levels of hydrogen at facilities also to get a handle on how much is actually being released because just comparing hydrogen leaks to current methane leaks isn't necessarily fair if you're not careful about it. I don't know if I answered every bit of your question but I got pieces of it.

>> Okay. Thank you. We have another online question. This one from Shawn Wallace. Bear with me. As the speakers have discussed today the feasibility of hydrogen and hydrogen blending transportation from storage to gas transmission and gas distribution needs to be researched, modelled and tested to ensure public safety and system reliability. On site hydrogen production instead of hydrogen transportation for large volume customers like power generation appears to provide many benefits with less risks EG it's not typically transported through public space and it is maintained and operated by qualified industry professionals. However, I want to ask the question about in use feasibility and safety risks behind the residential meter. These piping systems are typically addressed by a variety of building, fire, fuel gas codes as adopted within each state and the piping systems contain a great variety of materials, components and the related that's span over many decades. Can one or more of the speakers discuss the concern of this weak link in the transportation network behind the meter and how we have a responsibility to work with our behind the meter jurisdictional partners to ensure public safety with these proposed increase blends of hydrogen in the gas blends that can increase leak rates and exposure limits? I will repeat the question.

>> That's fine. Let me answer from the standpoint of what I have seen over many years of many studies. You remember from our last panelist we had the someone representing the OTT group and that same token there's also a similar parallel group called UTD, that's for utilization technological development. They have over the years dedicated themselves to make sure they do a lot of testing in different not only equipment but also appliances. They are large programs in residential appliance

testing. One of the projects I showed is the hydrogen home. There's a lot going on in how the different codes are impacted by the use of hydrogen or hydrogen blend in the residential aspect. And the idea is to make sure that we do reach out an agreement with all subject matter experts and all different people from all the industry and the regulators in terms of what is it that we need to update in our codes in order to make this happen if this is doable at all. So all of that is still part of the conversations we're having as feasibility studies go further. Hope that answers the question. Not sure if you want to add anything.
>> I agree. I think there's a lot of joint efforts going around researching the issues as far as bringing hydrogen into the homes for power and all. I think there's a lot of studies taking place over seas as well in Europe. So maybe good coordination between the different entities I think will be beneficial.
>> Right. If I could add, certifying and standards and code organizations are all either already involved or getting involved folks like ICC and CSA and NFPA. This is all on their radar. Obviously we don't necessarily have all the answers yet but we're going to get at them.
>> Thank you. So this concludes our Q&A session this afternoon. I would like to thank all the presenters, both virtual and in person. We have a break I believe until 3:30. Thank you, everyone.
>> [Applause]
>> Thank you.
>> [Break being taken until 3:30 p.m. CT]

>> Ladies and gentlemen, we will begin again in one minute. May I ask you to please return to your seats.
>> All right everybody we're going to go ahead and get started. Good day everyone. I'm Robert Smith, bob Smith, I'm going to be the moderator for our final panel for today. On this panel we're going to talk about CO2 pipelines, carbon dioxide pipelines just like we did for the hydrogen panel earlier. We're going to have three speakers, three presenters for this panel. After the presentations we're going to go through a short Q&A session and entertain any questions from the floor and on line. I will announce a couple of corrections through the agendas. Without further adieu let's go to our first speaker. We will talk about the PHMSA regulation and what we regular visit. Vinny Holohan is going to talk about some of the safety challenges, some of the possible rule making that might be Afoot as well as some of the research that we recently awarded. With that Vinny.
>> Thank you, Bob. You're going to get a second helping. All right. Good afternoon again, working in the engineering and research group. Going to talk a little bit today about PHMSA's involvement with carbon dioxide pipelines including what regulations pertain to them, to the pipelines carrying soup critical fluid CO2. A few points regarding

pest performance and talk about what PHMSA is doing with R&D and projects in that space and regulatory development going on. I'll move quickly through this to keep with time. I like maps. This is a map of PHMSA's regulated CO2 pipelines, a little over 5,000 miles of super critical fluid, carbon dioxide pipelines represents about two and a quarter percent of the liquids pipelines that we regulate. Since 2010 the CO2 mileage just like hydrogen hasn't really increased marketably but we're feeling that an acceleration is coming. I know 15 to 20 years ago we thought the same thing but this seems to be maturing at a much faster rate. Most of these pipelines were originally built for enhanced oil recovery but different market forces are acting today. As far as regulations go, since 1992 when it was added to the code, CO2 pipelines have been regulated in part 195 transportation of liquid by pipeline regulations. Alongside other liquids, petroleum and products. They cover pipelines to move at the critical temperature in the super critical state. It's treated as a hazardous liquid but there's considerations that are a little bit different. These are a few highlights from the regulations that are specific to carbon dioxide. First the CO2 has to be 90% or more the fluid being transported. Has to be moved in super critical state to be regulated by part 195. There are compatibility requirements for the pipe in the facilities and your only material choice is seal. Let's see if I get to there. Pipeline materials and their design must take into account the potential low temperatures during operations. Design must also consider fracture propagation and valves must be considered for compatibility with the fluid being moved. As far as performance, these 21 years from 2001 to 2021 there were a total of 105 accidents reported to PHMSA on these slides. Zero fatalities resulted and one injury. Although that is one injury for in patient hospitalization. It was a contractor involved in the excavation damage. I'll note that injuries does not include out patient or people that were not staying in the hospital for treatment. Mississippi's incident that was discussed in more detail the last couple of days did have 45 injuries that did not result in patient hospitalization. I spoke earlier about this event. This generated some topics on carbon dioxide along with hydrogen pipelines to be looked at online. All right. A little bit of a shorter list. BMT commercial USA was awarded a project that is in progress. They will be looking at the design in weld requirements for new and existing pipelines for carbon dioxide. Texas A&M engineering experimentation will be looking at PIR. And finally carbon dioxide rule making. PHMSA's initiated rule thinking to update the requirements for CO2 pipelines including those related to emergency preparedness and response. Since the rule making started I'm not at liberty to discuss the areas that will or will not be included in the rule or considered for the rule. In my opinion we have a pretty good idea of what the gaps are out there and anything will be considered that can improve regulations down the road. These are the links that are in most of the presentations which I can skip over. And I think that's it. Thanks very much.

>> [Applause]

>> All right thanks for that. Once again we're going to hold questions until after the full

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panel has presented. So our second presenter is Sarah Leung. She's the carbon transport program manager for the U.S. department of energy and correction to the agenda she's specifically going to talk about the CO_2 transport, not production and storage research development and demonstration activities. Sarah.
>> Good afternoon. Thank you Bob. Thank you PHMSA for the invitation. I'm really glad to be a part of this forum alongside my DOE counter parts that presented earlier. I'll talk through what is carbon dioxide removal just to give some context for those who may not be as familiar and then talk into the RDND, to research, development and demonstration at the department of energy that we're supportive of as well as go into the provisions listed in the bipartisan infrastructure law, which is the other arm which is the funding opportunities that we have. So I find this interactive diagram really helpful to level set and give a sense of what the ecosystem for carbon management is. This is available on our website and it's meant to be an interactive helpful tool for stakeholders and, you know, if you were to go to the website and it's hyper linked here for this page when it's posted as part of this forum, but if you go to that website each of the ten blue dots you can find information on our research programs as well as fact sheets that we put out at DOE related tot aspects. CCUS and carbon dioxide removal, all of that is the umbrella term is carbon management. So essentially we're taking CO_2 captured at point sources or captured and moving that from point A to point B being an end use of CO_2 whether that be utilizing that for carbonbased materials like low carbon concrete, turning that into carbonbased chemicals like sustainable aviation fuels, turning that into other synthetic chemicals through fisher trops processes. It's in the permanent and safe geologic storage of safe CO_2 in the under basically in the sub surface. And what you can see on the right of this diagram is what a class 6 weld would look like, which is regulated by EPA. So this is just a really helpful hint to show that CO_2 transport is the intermediary that connects CO_2 sources with CO_2 end uses and permanent geological storage as a climate mitigation solution either on shore or offshore. So you heard from my counter parts earlier but fossil energy and carbon management, we added carbon management to our name. We've also been the name of fossil energy since the 1970s but this represents the new vision, you know, with the executive order 14008 when the U.S. rejoined the Paris agreement. Really what I want to take away from this slide if you look at the greenhouse gas emission pi chart you can see that industry and electricity represented by power plants of which fossil fuels is, you know, 60% today in the U.S. represents a huge opportunity for carbon management. It is going to be renewable energy and it's going to be carbon management on top of that. So it's not or but it's rather an and conversation. That's supported by the international energy agency, you know, the inner governmental panel on climate change AR6 working group 3. So all of that is, you know, if you take a look at that it's supportive of carbon management that's needed to meet net zero goals. Another thing too you should be aware of is our strategic vision that was put out earlier this year. That really represents the priority areas across

our office of fossil energy and carbon management. Of note, I want to point out, you've heard from the hydrogen and carbon management aspect but we also have domestic critical minerals within our office and what I'll be talking about mostly though is, you know, on CO2 conversion, CO2 removal and then CO2 transport that underpins, you know, being able to move CO2 capture to these end uses. So this is available online. There's a hyper link there too. Another important aspect that we put out, a road map for industrial decarbonization recently actually it's September of 2022 and really just underpins how CCUS is one of the strategic pathways for decarbonizing industry. It's one of four. These are the industries too that are the hard to abate sectors. So really just underpins that slide earlier that I showed which is the pi chart. So to get to the meat, to meet decarbonization goals CCUS and CDR is needed. We publicly have a goal, a target of catalyzing this growth for carbon storage. You can see these stage gate goals every five years, you know, right now we're in the validation phase and we do that through our flag ship program called carbon safe. But, you know, we have public targets that we want to get to one billion metric tons of CO2 injection by mid century. That's supporting the decarbonization goals. It's in the national climate strategy of the United States. It's a very, you know, universally acknowledged across multiple sources whether it be the national petroleum council, as you mentioned the IPPC, the national climate strategy, Princeton's net zero study. All these sources helped inform these targets for us. But I really want to point your attention towards the bottom of this slide which is the CO2 transport modelling that is shown. So as Vinny pointed out today we have 5300 miles of pipelines today. Mostly servicing enhanced oil recovery end uses and by the end of this decade what are we looking and projecting, it's 1100. So basically doubling CO2 pipelines. What I should note too is that this is not showing any offshore pipelines and so, you know, gulf of Mexico we've done a lot of storage characterization work as well as depleting gas reservoirs as well as saline formation. That represents another key opportunity of prolific storage resource in the United States. That's something that we work closely with the department of interiors BESI on who is doing regulations alongside BOEM for the continental shelf. Moderning for mid century showing looking at 2500 miles of pipelines. We are also looking at other modes of support in concert with pipelines. Talking about research, development and demonstration, you know, we have in this strategic vision our goal in the 5, 10, 15 for CO2 transport but what I relaxing wanted to dig into is, you know, what does that need to look like in the next five years and how do we do our DND at DOE. It's a complimentary arms looking at it from an early TRL to maturing that technology and demonstration and then deployment and we do that really heavily in an iterative process with our national labs, with academia, with industry and what we can see, you know, as we go to these first of a kind demonstrations to an endth of a kind we are proving and scaling up this technology. This technology existed since 1970, right. We've been doing this commercially, carbon capture and natural gas processing for decades. So we're building off that knowledge and taking it in different, you know, CO_2 capture sources now that we're capturing an iron and steel, cement, ethanol, different sources. The learning curve associated with these different sources so that you can collect the CO_2 and safely store it. So just wanted to point out here that offshore CCUS is definitely an area of research as well as transition of oil and gas infrastructure. Largely speaking, you know, at the 30,000 foot level what are we interested in. Interested in like I said transport is the intermediary but we're also very interested in understanding opportunities for other modes of connecting rail, barge, ship, truck and also in the repurpose of infrastructure as was mentioned earlier in conversation as well with hydrogen. So how do we do that? You know, as you mentioned that iterative approach between earlier stage TRL at the lab level and then demonstration projects funded by our funding opportunities. So this is the slide I want to focus a little bit of time on. Near term our RND. The near term next five years, these are three pillars in which I see a lot of potential in building something similar that mirrors the high blend initiative in hydrogen bringing together consortia of industry, academia, agencies bringing together public stakeholders as well as community is a huge demonstration. These three pillars are highlighted in origin. CO_2 and specifications and impact in integrity. How that differs today the CO_2 moved is typically from naturally occurring CO_2 and now we're talking about CO_2. So talking about how impurities that come from different sources impacts corrosion rate, how it impacts brittleness, two phase flow. Coming back to the principles thermal modelling that DOE can do is a integral piece of how DOE can contribute. Also on low temperature testing, what we do need to do to show brittleness and how we can impact operational procedures or guidance in operational procedures. Second one is CO_2 specific leak detection and emergency response protocols. So that was mentioned a bit in the PIR conversation. Completely agree. Thought that was a really great dialogue and we'll continue on with that work that was discussed. We are also very interested in how we can develop sensors that are sensitive to, you know, if there's an odor and additive added that is part of the OND that Bob shared earlier or Vinny shared looking at odor and additives and what that looks like and how a sensor at the PPB, part per billion, could detect this odorant and warrant a response in the span of seconds. The other component is cross cutting. So as I eluded to the other modes of transportation looking at how we can leverage other existing repurposing work that's done internationally and better understand the opportunity to repurpose infrastructure where it makes sense on a case by case basis in addition to natural gas pipelines but also product lines so ethaline and others. We do demonstration. I know I seem like I'm going quite past but we are under a limited amount of time. All these slides will be available after this as well. I just wanted to highlight a large view of the funding that was available in the bipartisan infrastructure law. The ones highlighted in green are the ones that CO_2 transport is integral too. Actually the regional direct air capture hubs recently dropped yesterday. So that's hot off the press. This is how we are going to

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catalyze the demonstration and such that it goes to commercialization and deployment. Over all some key facts is that $12 billion supportive of carbon management is part of the bipartisan infrastructure law. For those not generally aware cost share is 20% government, 20% industry or applicant and as how you get to higher levels demonstration is 50/50. That's typically how our cooperative agreements work in partnering with the department of energy. So zooming in particularly into the studies that's one of the provisions that we have. $100 million to support front end engineering design studies. This recently closed actually and it's supportive of new build out and repurposing. It's really to identify areas in which we are supportive of studies and we worked on this in concert with the department of transportation, FMSA. So we are aligned with specific provisions as well in there that are deliverables that are looking at pipeline set back, looking at odor and additives. Things that are critical for the delivery. It's going to be an interesting one. It's under review, expected probably in spring of next year. Another key component as well is in the build out of CO2 infrastructure we have what's called SIFIA, that is supported. That acts as the commercial arm. It helps with to bridge to bankability. They offer loan and loan guarantees on CO2 infrastructure ranging from pipelines to all other modes of transportation. So that one is live and the website to access that for those who are interested is listed there. And then the other part is actually on you know, the twoprong approach. We're anticipated future use of direct air capture and other sources come online, how do we develop infrastructure today with future sources in mind such that we aren't redigging. We dig once, we think about the capacity for the future today. So a bit of strategic planning there. The request for information is open right now and seeking input from all stakeholders. Another thing here that we're doing in concert with the department of transportation is on the CO2 transportation report and that's looking at the state of the art of where we are with moving CO2 today by rail, by truck, by barge, by ship and where are the efforts globally as well as the near term and the long term to provide cost effective service. So this was in our Congressional language in house report and Senate report. So this is something that we're working on right now and offered an opportunity to work not just with PHMSA but also with the railroad administration, office of the secretary federal high administration. So really working in concert with the department of transportation as we think about connecting CO2 transport networks on a regional and national scale. Just want to offer here the repurposing infrastructure, R&D priorities report is available on our website actually. It brought together 170 participants earlier this year virtually. We looked at regulatory and opportunities on repurposes not just pipelines but also wells for injection or monitoring for CO2. So this is my last slide. Really as we look towards building out infrastructure I think we need to be very thoughtful about infrastructure in the consideration of, you know, how the future uses are going to be, how do we colocate with renewable energy sources with hydrogen pipelines, you know, void stranded assets but also keep in mind centering environmental justice

considerations. We are working all of government in doing this in R&D and in deployment, you know, as seen as working very closely with the department of transportation, PHMSA in our fee studies and the roll out of that. A huge potential for intermodal pipeline transportation. A lot of activity is happening in ship transportation globally. Expect to see similarly in the United States especially around the gulf of Mexico. It's underpinned by not only the bipartisan infrastructure law that gives $12 billion for carbon management but the 45Q which raises credits for CO2 projects. Lastly we're seeing a lot of continued collaboration on R&D. We also have the college competition that we kicked off for workforce development. Anyone who knows anyone who is an undergrad or graduate students we have a challenge for students that can compete on proposing a CO2 regional network. That's how we're getting students to work on real world modelling and providing a feed study. The other thing I'll say is we're building up this network of infrastructure and storage is that there is some on going, you know, CCUS task force permitting task force that's being put together by the executive office of the president council of environmental quality. So I think that's another key aspect that's going to help streamline inner agency work, help support with R&D and help support with general permitting for CO2 infrastructure. So I think with that I'll open it up for questions at the end and thank you very much.
>> [Applause]
>> Sarah, thank you very much for the comprehensive presentation. There's a lot of important work going on in DOE. Excellent summary. Our third and final speaker Steve Lee, executive vice president for engineering and construction for the navigator CO2 project. He's going to give a summary of the project.
>> Thank you, Bob. That's kind of loud. First I'd like to thank PHMSA and the audience for giving me the opportunity to sit up and talk about the heartland greenway and some of the things that we're doing as a project team that's going to take a lot of the complex situations and processes we've seen throughout today and turn them into practical midstream development of CO2 transportation networks. First I'd like to go over just I've got a few slides here that I'd like to get through the first few slides pretty quick to leave a lot of time on the back end as we go to some of the practical aspects how we're implementing these design models, et cetera. So from high level standpoint, the heartland greenway started back in 2020 with around 5 million metric tons of, you know, capacity to support the ethanol plants in the Midwest. As the initiative of decarbonization and energy transmission the system has grown in the past 18 months to over 15 metric million tons per year equating to a 1300 mile system throughout the Midwest. We cover five states. We have permanent sequestration storage and formation in south central Illinois. Sequestration welds are class EPA6. We had 5 million metric tons. Looking at the future development, making sure there's enough storage the mount Simon formation was the ideal location. It's over a $3.2 billion capital investment and we are partnering with some of the leading ethanol producers

throughout the U.S. Some of the things I want to go through real quick is the economic benefits. We have a lot of the traditional pipeline infrastructure benefits of property tax, jobs, you know, the standard, you know, indirect aspects of economic development of large midstream asset installation. One of the things I would like to highlight here is the unique business model that navigator is using when it comes to the economics of our system. We are utilizing the common carrier tariffbased system when it's pretty much a dollar rate for the various metric tons that goes from point A to point B on our system. Coupled with some of the economic benefits very seldom are we able to talk about the environmental benefits of pipeline infrastructure. With the 15 million metric tons once the system is fully built out is equivalent to around 3.2 million vehicles annually off the roads or 18 million acres of reforestation throughout the country. One of the things that I did want to get into because there's been a lot of questions about, you know, details, data of the system as well as the CO_2 transportation networks these days, you know, I like to use this timeline because one of the things that we're going through is there's no federal Nexis when it comes to the process. There's a lot of ambiguity. The state doesn't have the aspects for permitting, state by state, community by community, county by county. We started in 2020. What we did in order to help promote county and community engagement was mimic a process, get out in the community, talk to stakeholders, elected officials, landowners, energy responders of all things, on all their concerns. For the first two years we were in data acquisition mode talking to anybody that wanted to talk to us about some of their passions, fears, as well as some of the existing precedents of the 5300 miles of pipe that's already in service today. Right now as we've already submitted three out of the four PUC permits we're kind of rounding third base when comes to the front end cycle of the development where we're looking at the core permits. Wanted to make sure we're still early in the process.

We're not looking at going into construction until at least the middle of 2024 and that would be -- and in service somewhere in mid to late 2025.

So here's where I wanted to spend a little bit more time as we go through details of the system because there is a lot of ambiguity, a lot of passion out there that we're trying to do the right thing and be proactive in everything we do.

First of all, when it comes to the composition of our CO_2, it is 98% pure CO_2.

The remaining 2% is a makeup of nitrogen and oxygen.

The biggest thing is taking all the water out of CO_2 and water creates carbonic acid.

As we take CO_2 from ethanol in fertilizer plants, it's almost pure, it's just taking the water out and pushing -- compressing it and sending it down the pipeline.

One of the things, we talked about a lot with super critical, that's a defined term that is 88 degrees Fahrenheit as well as above 1,070 pounds per square inch.

Some of the other things we learned about was lined pipe.

Ductile fracture propagation, brittle fractures, you know, we're looking at starting with the current top industry standard of API5 Psl2 plus some additional aspects on the wall thickness and some of the toughness to mitigate fracture propagation just by using the certain line pipe characteristics.

Some of the things we also did when it comes to 195 is, we heard a lot of things about are there gaps, are there continued enhancements.

We looked at several different industry standards, regulations, but also reached out to the international community.

The biggest one that we started talking with is DNV, when there's 195 or additional guidance, looking at RPF 104, which is DNV's CO2 design and operation standard for recommended practice, I'm sorry.

The other thing is, as we talked PIRs this morning, there's things in 192 that might be applicable to CO2 as a best practice or that would promote public safety.

Some of the technical aspects of the system is, our normal operating pressure is between 1300 and 2100 pounds with a final MOP of 2200 pounds.

The pipe depth, as we talked about, reducing risks, we agreed and committed to being a lot deeper than most conventional oil and gas infrastructure.

Being below five feet means more protection from third-party damage.

Up in the ag fields and a lot of things going on, so as we get deeper, less third-party impacts plus in the event of a release, you have more overburden to help protect the flow of that.

The diameter of the system is between six and 20 inches, about half the system is eight and six, the other half is 12, 16 and 20.

But the operating temperature here, we changed lately, it was -- used to be 40 to 80.

That was more of the pipeline.

As we look at some of the characteristics of the capture locations, the compression and the pumps, we do have a range of 40 to 110 degrees Fahrenheit.

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We've also already implemented our main line valves per the recent rule that came out in March, when it comes to looking at, you know, 20-mile spacing and non-HCAs, 15-mile within -- that's an environmental HC A's and seven and a half mile maximum spacing when it comes to populous areas from OPAsand HPAs.

We looked at the other thing we really took time, took us two and a half years just to develop our route, where a lot of the 195 pipelines, we look at minimizing the collective impact, and a lot of times that's routing that next to an existing utility to enhance public awareness as well as damage prevention.

However, when you take some of the other parameters of modeling, sometimes you have to deviate from those existing utilities in order to have a comprehensive route that does minimize that collective impact.

I think Vinny went through some of this stuff, but one of the things I did want to key in on, because there's a lot of people out there that are either saying that CO2 pipelines aren't regulated by PHMSA, I did put the definition back up, a fluid consisting of more than 90% carbon today dioxide models cools compressed to a super critical state, to kind of drive home the point, here are some of the carrots that we put up where we know we're rated by PHMSA and here are our interpretations that run that home.

When it comes to wear at 98% CO2.

The receipt points, the 21 capture sites, we will be above the 88 degrees Fahrenheit and the 1070 critical pressure.

As you start checking all the boxes, it is under PHMSA's jurisdiction from a navigator standpoint.

One of the things, maintaining the fluid state, you know, a minimum of 1200 pounds, again, when you look at the phase diagrams, it will always be a fluid or dense phase or super critical phase.

One of the things -- and this is where a lot of the opposition or the uncertainty comes into is the critical temperature, where any pipeline, unless it's insulated or heat traced, it will revert down to ground temperature a certain distance away from the pressure source.

And so we're coming out between 90 and 110 degrees, but eventually it will normalize to ground temperature, which would be below the 88-degree critical temperature.

We spent a lot of time this morning going over high consequence areas.

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Don't want to regurgitate some of the definitions, but when it comes to HCAs, we as an operator have to take measures to mitigate all the consequences of the pipeline.

Not just within HCAs, could they affect HCAs, as well as they're growing, not just looking at the HCA maps that are generated.

It's getting out in the community and finding out from zoning individuals where these municipalities are growing, where are the developments moving as we develop this pipeline system.

I have listed some of the things here that we're doing when it comes to damage prevention, you know, cathodic protection, as well as leak protection.

We talked about absolutes.

There is no one size fits all to mitigate all risks.

Sometimes there's overlapping since that have to work together in order to have the proactive safety culture and public safety.

Okay.

Plume modeling.

Thanks to Mark for going through a lot of details.

It's very complex.

There's a lot of research going on.

Navigator ended up using two models to date, one, we used ALOHA, that is a recognized system, not only for modeling techniques but these are the ones that emergency responders use.

As we reach out and talk to some of these emergency response districts, this is the model that they're going to go to right off the bat.

As we used that for the first area to see these plume models and where they're going to affect, how they're going to affect, what's that concentration, et cetera.

After we did some initial routing, we did also use the DNV PHAST model, I think you may have heard about that earlier this morning, but this is the model that's proprietary, that, not only do they have the algorithms but this is also the reason for that -- the eight-inch plant rupture, to have instruments out there to validate their models that it can adequately predict the plume size and air dispersion of a CO_2 release.

How did we use these models?

I think Mark did a great job where it's not just a localized PIR, it's a -- one of the things with CO_2 as he explained, it's toxic.

When it comes to the toxicity, it's mildly toxic by definition so you have to take concentration and exposure time to see the true effects of that CO_2 plume upon humans and animals.

And so what we did at Navigator was, we took some of these models and brought them all the way up into the early stages of routing, and so to use this analogy of these petals, we had four different concentration levels and exposure times to have these different bands where we have initial routing where we're trying to avoid the risk altogether, instead of that being a reactive aspect under the 195 code, why not route the pipeline to avoid the risk.

What we get into, we have customers or ethanol plants that you can't always maintain that buffer and route around everything.

That's where we have the additional design and operation mitigation aspects, associated, to help maintain that same level of safety throughout the system.

The lessons learned from Satartia, was response, notifying the various responders, down in the Gulf Coast or in west Texas a lot of CO_2 infrastructure, not much up in the Midwest so it's new to them, so training them and knowing who they call on.

We're reaching out to the counties as well as the mutual aid counties in order to have a comprehensive engagement with emergency response.

The last one here is the public awareness.

Again, you know, engagement, engagement, education, education, and it's tell them, tell them again.

We have a larger buffer to help reach out to the communities and educate them on what is CO_2, what does it look like, how does it react, what are some of the risks attached with the CO_2 pipeline, but what I would say from our different plume models, you know, we took one of those leaves and drew a complete circle all the way around to have a larger I'd say potential impact area on each one of these, and they grow in size.

The first one for routing was smaller, the second one was concentric circles getting out getting larger and larger as we go along.

So here is -- I want to go through -- basically when it comes to the initial routing buffer, this is what we used a lot of it for, is to identify direct HCA impacts.

And that's other populous areas, trying to wiggle around and avoid as much as possible.

When it comes to including the significant parameter to minimize, a lot of people aren't using plume models.

If you look back at the 5300 miles, they might not have used plume model.

When it looks at repurposing existing infrastructure, this is one of those parameters you might need to look at as you go through on the rehabilitation of existing infrastructure for CO2.

Additional design and operational mitigation buffers, this is where we looked at some of the things in 192 for guidance.

And 195, there is not a difference of design factors.

And so we look at as we encroach on some high population areas or HCAshaving different wall thicknesses, having more conservative design factors, also looking at the EFRD analysis to maybe put additional valves within the seven and a half miles from the new rule.

Also there we have enhanced leak detection, what we're seeing right now from leak detection is, you have a compressible fluid, and so you have computational mass balance, you have fiber, negative pressure waves, all those can work together to have a comprehensive leak detection system which would also help assist in response time and identifying a leak.

Some of the other -- we're talking about soil movements and surveillance.

This is what we look at, the areas that we would increase these inspections to make sure That we know what's going on, you know, along the pipeline route as well as some of the areas of impact and growth.

As we're getting into some of the emergency response aspects of it, this was the third buffer, this is where we looked at for indirect HCAs, when it comes to high population areas, so we think of a much larger potential impact area and band that goes language to do to make sure the people who live within that band and emergency responders know what's going on.

One of the things that we are doing already is CO_2 training, as we said earlier, about emergency responders in the Midwest don't know CO_2, and Q1 of 2023, we're having a comprehensive tour of every county we touch plus regional aid counties.

There's a lot of questions that we have.

Talking too fast.

Basically, you know, when we went -- what do we need as emergency responders.

We don't have the resources.

Help us understand what we need.

We don't know what they need.

We think we know but it's getting county by county, you know -- there you go.

And collaborative -- got it.

And so once we have the initial training, they can start thinking about their local communities, what resources do they have, what do they think they need.

And then also get some of the HAZOP districts to have that comprehensive engagement because it's not what Navigator thinks, it's what everybody thinks when it comes to not only emergency responders, police, fire, et cetera, you know, and one of the things that we did promote, it's our job to make sure those emergency responders are equipped that have the resources, so a lot of these communities, they're volunteer firefighters so sometimes we have to find strategic resources, third-party resources to place in order to address a potential CO_2 release in the community.

And so currently, you know, we are doing the training.

The next thing is developing a collaborative plan.

Next after we do the plan together, the resources to execute that plan.

Then we go back and we drill well before this pipeline goes into service to see the effectiveness of the plan and have that continual enhancement of these plans to ensure public safety.

One of the things I don't say -- probably run out of time but I want to get to some of the other things, one of the things on the public awareness that we're looking at is, you know, what we call the NAV 9-1-1 system.

There would be a polygon, similar to the A 11 polygons, when it comes to signing up landowners and emergency responders where in the unlikely event of a release they will be notified by text message, by phone, similar to how the Amber alerts work in Texas.

How much time do I have left?

I got a minute.

I'm going to jump all the way to this slide.

As we -- we've been hearing a lot about odorant.

One of the things from Satartia, they were confused for the first 30, 45 minutes on what was the product released.

Traditionally the gas industry uses the mercaptans that have

a rotten egg smell.

We're looking at developing in conjunction with the academic world as well as industry partners on a garlic smell, so basically enhancing the public awareness and the identification of that product because it does, it acts different.

It's not going to go up in the air.

It's going to basically follow the plume models and elevation.

As you look at some of the enhanced response to these events.

The last thing that I'd like to talk about is, you know, the leak detection.

In the past decade there's been phenomenal progress in quantitative leak detection systems, both from a real-time transient model, computational mass balance, the negative pressure wave, but one of the things that we're finding out is the fiber, you know, optics, is going to be a redundant system that can serve two purposes.

One, to have the acoustics for a leak, but you can also use it for intrusions to your right-of-way, as they have the quantitative aspects, finding out, is somebody digging on your pipeline that you weren't aware of.

All of these are proactive systems that have to work together to promote that public safety aspect of the Heartland Greenway.

That's all I've got.

Thank you for your time.

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[applause]

>> Steve, thank you very much for that marathon.

I know you don't work for Marathon, but for that marathon effort there.

That's a great summary and it looks like you have a plan in place for just about everything we can think of.

It was great to see that effort.

With that, that concludes the presentation portion of the panel, and now we're going to go into a 10 mustn't Q&A.

It looks like we already have a question from online.

>> Sure.

Questions from online.

For PHMSA.

Several individuals were hospitalized per PHMSA's definition after the Satartia incident, with some victims in the hospital for several addition.

Deny berry new this and it's in our communication two days after the incident, it said two people are still at the hospital.

Shouldn't Denbury be required to revise its incident report to reflect the actual circumstances?

It seems important that injuries be reported accurately given the fact that these CO_2 pipelines are touted to be safe.

>> I won't be able to answer that question, so I'm looking to punt to Max or Alan.

>> This came up at Pipeline Safety Trust where there was -- that statement came up where they believed there was multiple individuals that were hospitalized overnight, multiple weeks.

We're having our data folks look into that, whether it's true or not, and if the operator needs to submit a supplemental report, but we are check on that.

>> Thanks, Max.

Another question?

>> Jon from Liquid energy pipeline association, thanks, everyone, for coming including Sarah from DOE.

One thing that struck me when I saw the lab opportunities slide, is, it looks like there's a potential for a lot of duplication between what DOE is thinking about, what PHMSA is doing, what PRCI is doing, even industry right now is working on best practices for emergency response, and I don't say that to be critical but to say that it's an opportunity, and we should all get together, especially given the different timelines, the research has their own timeline, industry standards will probably come out quicker, Congress is going to be there in the middle next year, so different stakeholders have an opportunity to deliver different products at different points.

So if we all sat down and I'm not saying divvy up but at least avoid duplication and know who's doing what and when things will come out, I think that would be great to coordinate because there is a lot going on by all the parties, whether it's addressing specific incidents in the past or proposed projects in the future.

It would be great if we could all get together and I'll certainly talk to you after the meeting.

>> I think I speak for the panel that we all agree but it looks like Sarah wants to add to the point.

>> Definitely thank you for the comment and we seek to be complementary, not to duplicative, so completely agree and look forward to chatting more.

>> Another question?

I'm sorry.

>> Go ahead.

>> Bill Caram, Pipeline Safety Trust.

There are a lot of regulatory gaps but also a lot of knowledge gaps that remain on CO_2 pipelines as evidenced by the R&D program and the projects that have been approved recently that we won't have the results from for a couple of years.

In your plans, do you -- will you be incorporating what's learned from those -- it seems like you're pretty far along in the knowledge process so how will you incorporate what's found in those R&D projects?

>> I think I'll take that one first, for PHMSA, at least.

Bill, as you know in your participation in the program, where we started the pre-award process to try to bring everyone to design a project with the right kind of components of participation so we're just not creating a coffeetable book at the end of the project.

We want to be able to reach out and connect the knowledge to standards, if it's knowledge transfer, or if it's technology development project, bring in the right type of maybe technology service providers early into the process, demonstrate it thoroughly and hopefully be able to remove barriers for tech transfer.

So duly noted.

And it's really one of the hallmarks of our program, is to bring that collaboration, so we are successful, create the highest likelihood of success at the end.

Thanks for the question.

>> I'll add to it.

I echo what Bob just said.

Additionally, DOE hosts annual project review meetings that are open to the public, every August, and any of the funded projects will be reported out on there so I think that's a great forum to communicate to everyone, anyone who's interested on the knowledge gained from these funded projects.

I think the other component, too, for DOE-specific projects, we have a segment that's called societal considerations and impacts, and as part of that, projects going forward are having to consider and implement programs that look at how we can have two-way engagements with communities and community benefits plans such that communities have access to data at certain times of the project, but this is a forward look, and something that hasn't been done, you know, so much in the past, and we're living and learning at DOE but that's one of the integral ways in which I see that information just doesn't get siloed in research projects but is available and putting these procedures and structures in place such that data is accessible to communities is one of the key roles I see of our funded projects.

>> We have time for one more question.

Rick, ExxonMobil to respond to Jon's excellent question on the CO2 task force lead within PRCI.

We all work collaboratively with multiple agencies.

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Happy to talk to you more about that afterwards but to my previous comment about siloing, we want to make sure that we try to prevent silo, particularly in the CO2 space and hydrogen space.

My question has to do with the odorization in future pipelines, and the one thing I haven't heard is whether they have any adverse impact on things like corrosion control, namely, through change in dewpoint and whether there's any impact --

>>

[inaudible audience comment]

>> You've been cut off.

[laughter]

[inaudible audience comment]

>> Steve, I guess I might want to start with you on that one.

>> Sure.

The answer is yes to all those.

One of the things that we look at with the impurities of CO2, especially in the dense phase, a small imputer makes it react very differently.

So we're utilizing the Binnel two methods as we look at the composition of the Heartland Greenway and the present of some of these odorant, but how does it deal in sequestration in the formations.

And so that's why we are working with Penn State and some of the industry odorants to do all this testing, we've been testing for almost nine months, but it's a process, as we find we had several we were reviewing, rear probably down to two or three, and we don't have the full answer yet but yes, it does impact several things, so it's not an easy yes or no at this point on what's the perfect one.

>> Everyone, thank you very much for your questions.

That concludes the Q&A.

Let's give a round of applause for this fantastic panel.

[applause]

All right.

And with that, we're going to move to the final presentation, I'm going to be giving it.

So convenient to be up on stage.

I think I introduced myself fully before, the research program manager for PHMSA's pipeline safety program.

And I'm going to talk to you a little bit about -- a short presentation.

We're going to look at some of the research topics that you all helped us derive, develop, and try to understand if they're still important enough as something we should look into, solicit and fund.

Take these off.

Just kind of in review, when we have these R&D forums, regardless if it's for other subjects outside of pipeline, gas storage or LNG, like the one we just held, this is an opportunity to bring everyone together to talk about developing -- identifying real gaps, gaps that are not duplicating something else that's going on by another federal agency, that's been noted, PRCI or others.

We want them to complement where possible and leverage opportunities from existing and ongoing research.

They're definitely intended to be a priority need that we should try to fund some research, solicit and fund.

But they are a snapshot in time and that's why we want to revisit some of these topics.

They're a form of peer review from the standpoint of a pre-solicitation review, to develop some of the subject matter experts that are in the room, and it really creates a wonderful opportunity for cross cutting, collaboration, all the goals that we really have in the program to make sure we create the highest likelihood of success.

So you can see the data over on the right.

We took a look at the 2020 and 2021 R&D forums.

The last two full pipeline ones that we did that had other subjects like LNG and gas storage.

From the output of these forums, we did solicit multiple topics.

We did actually combine some topics.

We had topics that weren't taken at that time that other federal agencies like RPE did in their repair forum, and the remaining topics you see there, five from 2020 and five from 2021, fall into some of these programmatic areas that we have, threat prevention, underground natural gas storage, anomaly detection/characterization, methane abatement and breakout tank corrosion.

So I'm not going to go through each one of those 10 topics, I'm going to leave you all with some homework.

If you're interested in participating, it's voluntary.

If you go back to the website that you registered, and also for the virtual attendees where your got the link to participate in the webcast, there's a file listed there entitled list of unfunded research topics from prior forums.

Take a look at that.

It has the 10 topics that I mentioned before that we haven't, you know, done anything with.

And we want to be able to see what the interest level still is, so we urge you to take a look at leaving a comment on the docket that was established for this public event, it's listed on the meeting page that you registered, it's listed right there in the presentation, you just have to go to regulations.gov type in the docket and it allows you the opportunity to leave a comment.

Review those topics.

We want to understand the remaining importance for our program to solicit.

Leave us a comment.

The docket is going to be open for at least another 30 days.

At some point we do have to take a look at what was submitted, make a call, pull together a full solicitation, and solicit for these research projects.

So next step is basically what I said.

We're going to look at pulling that together sometime early in January and look to hear from comments that are left.

And with that, thank you very much.

[applause]

With that, I want to reintroduce Alan Mayberry, associate administrator for pipeline safety.

He'll give the final remarks and close of day two.

Alan.

>> Thanks, Bob, and thanks to everyone who stayed.

I think we have about, what, 50 people in the room, maybe a tad shy.

And then today on the webcast, and thank you all on the webcast, we had about 285, so good participation.

A little bit less than yesterday, but, you know, the topics drive the attendance, and certainly today was a shift from yesterday where we talked about, you know, accidents and lessons learned from accidents, was the big focus.

But, yeah, we'll wrap up quickly here.

We started off the day talking about PIR for gas.

We brought in the father of PIR, Mark Stephens, who was on the original team who developed that, and it was great to hear his perspective on, you know, the background to PIR and give us some things to ponder related to what it considered, what it didn't consider.

And then of course we had the panel discussion that brought up, you know, the various issues related to that.

I will tell you one thing, from our perspective, and like I said yesterday, you know, from PHMSA's perspective, you know, we're doing this meeting here to learn and to establish a public record and be transparent in the deliberations.

We will address the NTSB recommendation related to PIR.

I think I mentioned that earlier, but I just wanted to reiterate that.

And we're open.

I think it's probably a good opportunity, a good time in the spirit of pipeline safety management systems to take a look and see where we may need to go on that, perhaps there are changes that need to be made.

Certainly we're serious about looking at and addressing the NTSB recommendation.

And getting better, it's all about getting better.

Then we had a great discussion after lunch -- by the way, we also talked about the PIR for CO_2 and hydrogen.

I know we use PIR and CO_2 in the same breath.

It's probably less about being a radius or a circle and more about maybe a blob or a shape that is less of a circle and more of a -- determined by topography of the area we're dealing with.

But nonetheless, it's a convenient term to use, PIR, which tends to be, you know, a circle that we calculate for gas pipelines.

But nonetheless, obviously there's a lot of work to do there, and the session we had in the afternoon, we heard a bit about some of the research projects we have and certainly learning more about how we need to determine the PIR, concept for CO_2 pipelines is a topic of discussion -- or one project related to R&D.

We also talked about a lot of the success stories in R&D.

I think that's a great story and that's just our program, and then we heard from our partners, various research partners on success stories that they were mentioning.

We talked about hydrogen and hydrogen blending.

Vinny did a great job of just talking about our current framework, what we currently regulate related to that and I will tell you, related to -- I'll mention CO_2 in a minute, but, you know, our usual -- the way we evolve the regulations, the federal standard for pipeline safety is, we address what we can address, we develop rule making, policy for what we can address.

With hydrogen, there are a lot of things we don't know, and a lot of research going on as evidenced by the great discussion we just had.

So I think we're going to need to see the outcome of that and apply the lessons from that to policy making as we go forward.

You know, kind of scratching our head on the next step, but, you know, it may be some sort of advisory to just recognize related to the -- you know, the difference in the properties of hydrogen and things you need to consider for emergency response, things that could be tightened up in that area.

So that's one area we're looking at.

Obviously, you know, we're considering possibly rulemaking in that area as well.

Just wanted to give a special thanks.

We had a kind of understated international component here but I appreciate the involvement of HSC, our counterparts in the U.K., and Dr. Simon Gant.

I thought his input and the advances they've made over in the old country were quite informative.

As you know, over there, they're a bit ahead of us related to the -- looking at hydrogen.

And then related to CO2 and similarly like Vinny mentioned, we are in rulemaking right now, we can't really talk about the particulars there, but in our usual model for developing national policy making, we're addressing what we can address now, I think it's fair to say.

I'm see that in the form of a proposed rule in the coming months.

I would hope it would be sometime by next year, but we'll see how that progresses, as you know, as many of you know, we have a very busy regulatory docket but it is a high priority for us and we do realize that there's some gaps we need to address, which are also being addressed with technology.

And just a bit on that, related to technology, you know, as we get the learnings from research, we'll apply them, you know, as needed to the oversight program that we have, and obviously in a very transparent way to make sure that we get the information out.

Two other things I wanted to mention related to CO2 is, our intent here this week was really to whet your appetite on CO2.

We recognize that probably not all the stakeholders that are out there that have a vested interest in CO2 were able to make it, so this is really to whet your appetite.

And we anticipate having a -- [no audio]