

Good morning. My name's Ed Nickoloff and this session's supposed to be Continuous Education Session about Flat Panel Fluoroscopy. I'm going to try to tell you some of the things that we learned and some of the caveats and pitfalls that you should look for when you're doing testing on these systems that I hope will help you in the future. The first thing I want to start off with is that I actually went to college a couple of years out here in Pittsburgh, and when I was out here, it was pretty interesting. The steel mills were running, smoke was pouring out, the steel mills lined up and down the river. This picture is pretty realistic the way it used to look. You could see the smoke rising above the city. Trolley car tracks were all over the city and they were moving everywhere. Old ball stadiums out by Carnegie and now they've really changed the city around considerably, so, it was a big shock for me to come back and see the changes in

Pittsburgh. First thing that I want to say is that many people, especially when consultants come in, they do exactly the same tests that they would do in QC as acceptance tested, and my first point is, they are not the same. They're like night and day. And some of the things that should be done in acceptance testing that would not be done in routine QC, the first thing is that it should be prior to first clinical usage and you need to verify that all the accessories, and all the software, and everything else that was delivered...was supposed to be delivered, was actually delivered. You want to make sure that the architectural design is proper, and the flow is proper, and the things that were supposed to be installed were installed. You need to do a radiation protection survey and shielding, and we actually look for voids in the shielding; if it's a new room, we mark out the scatter levels so the doctors know what kind of scatter levels they're going to get in both

ciné and fluoro. It should be the most comprehensive testing, because you're going to use much of this data to compare during your QC, because doing the QC you're going to look for changes; so you really need to take a look at all the different options, all the different modes it can operate in and establish baseline values. Not only do you need to establish baseline values, on many of these testing, you're actually going to set up the system for your facility and you should have an idea whether you want the doses high or low and just what is reasonable as far as the image quality, and this may include/require you working with the service man; so you may have to do certain adjustments and you may find some of the equipment is not functioning during shipping or installation and that may need to be repaired and replaced and it's your job to make sure that you identify this. The automatic brightness control systems on these systems now, they're so

complicated and they're not something that are controlled by the operator. Something you need to know to...how it operates and under different modes and different thicknesses, exactly what happens. We talked about the baseline values. You also need to do a comparison of the image quality of the manufacturer specs. If the manufacturer provides them to you, you should see what you measure in the field versus what he has for the range. Now, the one thing that we've learned as many of the manufacturers have such a wide range, that almost anything can meet those specs, but we try and make sure we're in the center of whatever that range is. There's a lot of things that are not routinely tested in QC, things like mechanical alignments of the system, is the isocenter correct? Is the table aligned in the right direction with respect to the x-ray tube? Is the x-ray tube focal spot in the center of the central beam in the center of your image receptor? Laser

camera adjustments, not normally done. Archival storage—you may have a great system, but it can't communicate with the PAC system or it can't store properly and retrieve the images. Although we don't do electrical safety, it's very, very important in cardiac cath labs, small currents can be really serious when people are fishing catheters in, so you've got to make sure that there's electrical safety tests done, there's backup power in the room in case the power goes down when the catheter is in the patient, and many other things like that. Certainly regulatory compliance testing has to be done; that's required. We come back with recommendations to the staff. We prefer that you operate in this mode. If you find the image quality not proper, you come back and talk to us and we'll try and improve it for you. We also post radiation dose charts so

that our staff knows exactly what kind of doses they're delivering for different thicknesses of patients, and so forth. Routine QC should really be limited in the number of tests. It should be spot-checks and it should be what you're comparing against the baseline values, and it's intended to identify degradations in the system. Also, when we do this, we look at staff safety and we also see how the staff is using the equipment—are they wearing their aprons? Are they using the shields properly? Where are they standing, and so forth. Are you using the right modes in the image system? If there are major repairs or upgrades to the system, it's important to come back and do this spot-checking to make sure that the system is performing the way it was initially installed and identified as optimum. During QC you do have to do all the regulatory testing. Some tests are similar, but you do fewer measurements and you compare them to the baseline

values. Now the two units that I'm using for the examples of the flat panel systems of the data that I'm going to show you and things that we tested are going to be the GE Innova cardiac system, which is shown here...here's the flat panel unit, the x-ray tube's underneath, you can see it's covered. There's a lot of things in the room including the face shields, and so forth, catheters you can see hanging here. And we had a Siemens biplane flat panel system and AXIOM Artis dBC; it has two flat panel units, here and here. You know, one of the first things we did, we like to measure what the actual field of view is, and the manufacturers had specified GE 20, 17, 15, and 12 cm field of view, and Siemens specifies at 20, 25, 20 and 16 field of view. So, we put a lead ruler directly on the face of the image receptor with the grid removed and we actually measured it, and it turns out that the Siemens 25 cm field of view was almost the same size as the

17; so we immediately asked the manufacturer, what are you doing here? And it turns out that Siemens measures their distance in the diagonal and the GE measures it along the horizontal and the vertical; so, although I'm going to plot this data according to the manufacturers' specified field size, remember that Siemens 25 is almost the same size as a GE 17. And, by the way, despite the fact that they specified them differently, it turns out that the manufacturers usually specify within 1 cm and they were usually 1 cm less. And this shows you for different field of view what was happening...I don't want that...I want to talk about the detectors. What about the flat panel systems? They're both indirect systems and, basically, the way they work is there are scintillators above photodiode detectors that are then read out with thin film field effect transistors will read out the gates. And this just shows them sitting here. The crystalline structure

is needle-type so that it directs light, when there's an x-ray interaction, more or less, down

towards the photodiodes; however, there is some light spreading and some statements that, you know, there is no reeling glare because of this, is not true; some of the light does go in the horizontal direction. More things about the design... So when the x-rays interact with the caesium iodide, they produce light, the light goes to your photodiode panels, and the transistor rays, which read it out, and then you get the digital data to read. GE gave me this slide, which shows the overlay of the scintillator crystals in the individual cells of the pixels that are measuring it, and they're shown here. One of the key factors to notice, and there's all sorts different terms about the fill factors; there are various fill factors and you should familiarize yourself with it, but the key to this is that not all the area is sensitive, so if the detectors hit this entire area, which is defined as the pitch--which is a different pitch from CT, by the way, it's just the dimension—

only portion of this area is actually the active area; so the sensitive area over the real area of the individual pixel is your fill factor, and they're typically 60-70% with this size of detectors. If you go to mammo, the fill factors are even lower and this changes with the size of your flat panel. Artifacts: Well we know with image intensifiers there's a number of artifacts, such as vignetting, distortion, phosphor burns, you can dirt saturation, you can have grid problems. Well some of these do not occur in flat panel, but that does not mean there are not any non-uniformities with flat panel, so you'll have to take a look at it. For example, I call them bad detectors, but it's bad pixels. You can have non-uniform gain or calibration problems, because the individual pixels may not be exactly the same. If there is dirt inside it, you might have an effect of that. You can still have grid problems, and software problems, and I'm going to try to illustrate this in the next

slide. So we put a screen rash out and it looks pretty uniform, there's no bending of the lines, and so forth. But notice the edge. Do you notice how there's a difference in intensity around the edge? And you may say that that's not much of anything, well if you move in the collimators, it will track the edge of the collimator blades. So, this is a software feature and how it handles the edge of the field versus the image portion of the field. So, that's part of what can happen with looking at uniformities, and you should look at it. Okay. Spatial resolution is the next thing I want to talk about and we usually measure it with a lead line pair pattern, and some places require you to use mesh patterns and we did have that in the City until our regulations changed recently. And we need to take a look at it with different fields of view. Intuitively you would say that we expect flat panels to have almost the same spatial resolution in all fields of view 'cause

the pixel sizes are the same. But before I want to talk about this, I want to talk about some caveats. Some of the things that can go wrong when you're measuring spatial resolution: The first thing is that, if you take a look at it, if these are the individual pixels and you're trying to measure a line pair pattern, you would say the best you can do is, if one of the bars is lined up with the column of the pixels and the spaces in between, so that's probably your best resolution, and, in fact, that could be your best resolution. But one of the problems is that if you pixel-shift your pattern by half a pixel, you will not be able to see it, although intuitively and inherently you should be able to see that because the size of the bars is the size of the pixels, but if you shift it, you run into a problem. So, if you're going to try and measure with a bar pattern, as far as the spatial resolution it is, and you shift it, either in this direction or you orient it in a horizontal

direction you pixel shift, you could get any reading from seeing the best resolution to having not

being able to see it due to the shift of the pattern. Well, what happens if you put it at 45 degrees to measure it? Well, you think you're getting rid of some of the pixel-shift problems, but the other thing that's happening is there is more than one pixel between the bars, in the case of the smallest, so you're actually improving your resolution. So, remember, you're not measuring the resolution that you would get if it were oriented in a horizontal and vertical direction. It's a different resolution. You're actually giving the system a break that you're able to see better when you orient it in a horizontal direction, and this is without the grid on. The grid can cause a problem, too. So partial pixel shifts, either vertical or horizontal, can alter your resolution and you could get either zero or part of it if you shift. If you go at 45 degrees, you're actually

improving your resolution due to the fact the spacing is bigger along the diagonal by about a factor of 1.4. What else should you know when you measure resolution? Well, you think you're measuring resolution, but you may not be measuring resolution, because each system has numerous software features. On the GE system, there are three factors; and on the Siemens system there are three factors. The GE has contrast and noise and...there's one I'm missing...sharpness; and the Siemens has DDO, K and gamma; and each of those has a range of settings. So, now, you're going to get into numerous combinations and as shown here, depending on how you set the software, you're going to get different measures of resolution, so beware, when you measure resolution, it depends on how your software is set up and maybe the way you're testing it on initial acceptance may not be the way the radiologist are going to have the

system running when they're doing clinical cases. Siemens' system was hard to get into and change and it required intervention of the service person, so I asked them to give us some examples of what can happen to the image as you change the software and here are some examples here. Let's talk about the MTF curve and how that effects our imaging a little bit. In general, when you're using a line pair, you're assuming that it has a 100% contrast and that you're measuring it properly. So, therefore, if you're following the MTF curve, you're expecting your limiting \_\_\_\_\_ spatial resolution with no noise to be somewhere out here; but if you have noise, and the noise level is shown as the dashed orange line, you have to be at least several times above the noise, and that noise level changes depending on what dose setting you have in your system, and you may have numerous dose settings with the flat panel systems. So that

moves your spatial resolution down. And the next thing I'm going to tell you is that maybe the bar pattern that you think is 100% contrast, is not. Okay, so the image noise has an effect; as the model increases it changes your resolution, and the record mode may not be the same as the fluoro mode, and the way you set up your, ABC system will also have an effect, so it depends on how much attenuator you have in your field when you do your line pair measurement what result you will get. Okay, well let's take a look at the filtrations. Most of these modern systems now have a significant amount of filtration. They can have a lot of copper filtration in from zero up to 0.9 mm of copper on the Siemens system, and I calculated the spectrum for you. The energy changes dramatically. Well, how does this effect spatial resolution? Well this is going to effect whether the line pair pattern looks like 100% contrast or not. Well, this is the contrasting we get

with line pairs pattern. This is the 0.05 mm lead thickness and this is the 0.1 mm thickness, and

as you put in the different filters, the contrast of the bar pattern goes down. And, in fact, I would highly recommend not using the 0.05 a line pair pattern because you get a much lower contrast that might affect your results significantly. So, what's the key thing? Note that the filtration is different in the beams. Depending on your ABC system and how much attenuator it is in the beam, you're going to get different kV's and filtration, which could affect the contrast in the bar pattern. Try and use the 0.1 bar pattern. And, also, a key thing to remember here, that I'm not going to say much in this talk about, is that the scatter radiation has a different quality. It's more penetrating, so whatever you have for shields and barriers, and so forth, may be different than what you're used to, so you ought to take a look at your lead aprons, and face shields, and so forth, 'cause they may not be providing the same protection that you used to be provided because you have higher filtration in the x-ray beams. Okay, while we're talking about that, let's talk a

little bit about the half value layer. We used to be thinking of half value layers that were fairly low. The half value layers of the beam now are very high because of these various filtrations that can be in, and, certainly, they depend on what kV and what kind of filters that you have on your beam. Another thing that I will mention to you, the systems are automated, so unless you have the service guy in, you can't keep everything fixed because you can't get into the service software. So how do we used to do the measurements with automated systems? Which seem reasonable. We pile all the aluminum in the beam behind the detector and then we start shifting it in front and hope the system stayed the same. Well the scatter qualities can change as you're moving this around. So, if you want to try this trick, be sure you raise that image intensifier as high as you raise it above the aluminum, so that you don't see the scatter effect, then you have

maybe a chance of doing it this way. Otherwise, you're going to need the service guy in to do it. The other thing I'm going to point out to you that there's an IC standard with the half value layers now and possibly will come into regulations with the CDRH, but they wouldn't commit to it now; and the half value layers are much higher. They actually give you a chart like they usually do. Each kV, what is the minimum allowed half value layer. I put it in a formula for you so you don't have to do that and it's a pretty easy formula— $3.5 \times (kV/100) + 0.08$ —and that'll give it you for each kV. In New York, we usually measure at 80 kV. And when you do that half value measurement, you're going to have to add enough total aluminum so the automatic system goes to 80. And we're finding very high half value layers when we measure them. For example, I have plotted on here for the GE system, which only goes up to 0.2 mm of copper, and the

Siemens system, which goes up to 0.9 mm of copper, what are the half value layers? Well the curves overlap in the range where they put in the same kind of filters, but with the higher filtration that's available in the Siemens systems, you can get up to almost 0.9 mm half value layer measured at 80 kV. Okay, well let's talk a little bit about the spatial resolution at the input surface and compare it to image intensifier systems. Well image intensifier systems, what happens is you change the field of view, the limiting resolution is due to the television lines, and as you go to a smaller field of view, you're spreading out the anatomy over a smaller area over the same number of television lines and the resolution always steadily increases with image intensifier systems. What we would expect with flat panel systems is at the surface it remains relatively flat; however, you might see some increase to a flat level, like this, due to the fact of

scatter and possibly the fact that the noise might have an effect because, as you go to smaller

fields of view, most manufacturers increase the radiation levels, which I will show you shortly. Okay, so the spatial resolution of image intensifier T.V.'s improves with small field of view, flat panel does not or does not much, at the image intensifier surface, but that's not the way we operate, so I'm going to talk about that later. The spatial resolution of flat panel systems is less than image intensifier plus T.V. systems in small fields of view, but it's...the spatial resolution of flat panels is better in the large field of view, okay. What you would expect for a flat panel system is if you know the pixel size, one over twice the pixel size should be your resolution. So, for the GE system that we're using, the pixel size is 200 microns and for the Siemens or the Trixell system it's 184 microns, so if you put those in you get a limiting resolution at the surface

of the detectors about 2.5 and 2.7, which is what you would expect and that's approximately what we measured, but these measurements depend on all these factors as we mentioned earlier. Okay, well what's the real thing? Well, if you're measuring spatial resolution in clinic, you're not at the surface of the image receptor, so you really should take a look what happens at different distances away from the image receptor. And, basically, what you would think theoretically is that, because of the geometrical magnification as you move away from the surface, that whatever the limiting resolution, the inherent resolution, of the imaging system is, it improves by the magnification times that resolution. But, on the other hand, because of the focal spot size, the focal spot blur increases and at some point the focal spot blur's going to dominate and the resolution's going to go down; and so that at low magnification the inherent resolution of

the system dominates, but at high magnification geometrically, the focal spot blur down in it. So, if we plot all this out and we look at it for a large field of view, that in this case, let me see, this is the Innova flat panel in yellow, the Siemens in the bluish color, and the...this is a Siemens image intensifier...no wait a minute...purple...this is a flat panel in pink, and the II system is down here. So, in the large field of view the II system has worst resolution and, as you can see, they're starting to go down with further distance from the entrance surface; but if you go the small field of view, the opposite happens. The image intensifier system has the better resolution and here's the two flat panel systems; and, remember, I've expanded the vertical scales, so there's not as big a difference as you might think it is. The two flat panel systems are pretty much in align, giving you the same kind of resolution and the resolution is falling off over here due to focal spot blur,

and the image intensifier system, because they're T.V. line limited, has better resolution in a small field of view. And this shows you another field of view and the same kind of thing is occurring. Okay, so displacing the pattern away from the entrance surface improves the resolution to about 20-25 cm, if the SID's around 100, so that's a mag factor of about 1.3. After that, the focal spot blur starts taking over and the longer distances result in more focal spot blur, which degrades it. Flat panel systems are still better at the large field of view than image intensifier systems, but the image intensifier systems are better at the small fields of view. Okay. How about comparing the record mode versus the fluoro mode? You would inherently expect that, because the record mode, or the cine mode, has higher radiation dose and the noise is lower, that it's going to be better resolution, and, in fact, that occurs here; but as you move away, in this

case they seem to be about the same, and this is for the GE Innova system, and this is for the

Siemens system, and you notice a big change here and it starts dropping off. And this is because the record mode has a larger focal spot, so it starts dropping off faster than it would drop off in fluoro, which uses a smaller focal spot. Why didn't the GE use it, the GE system have the same thing occur? Well, depending on the attenuator you put in the field, you may not always have the large focal spot in record mode. So, flat panel units, at the input surface, the record mode/cine uses more radiation; therefore, should have less quantum modeling and should be a little bit better, but the record mode has a larger focal spot, so as you move away there's more focal spot blur and you're going to start losing spatial resolution. Okay, let's take a look at an image intensifier system alone. In this case, it's the image intensifier with cine film in green...pardon me, the cine film in yellow, the fluoro mode in green, and the record mode with the digitized

T.V. signal over her in pink. Now, what's happening here? Let's take a look. Well, as you would expect the fluoro has a small focal spot and, therefore, the blur doesn't occur soon, so the fluoro spatial resolution stays up with the image intensifier for a while, but cine film is better initially, but because a larger focal spot, it drops off. But, then, what happens with the digitized signal from the T.V. on an image intensifier system? It's much lower, and what's really happening here? Well, typically, in most systems, fluoro operates at 1023 lines and when you digitize it for record mode for the T.V. signal, it drops to 512 lines in this typical system. This doesn't always happen, because there are some that are allowing you 1000, but in general, this is what happens and so you lose resolution and actually you'd be better off if you could record your fluoro, except for the model. Okay, well let's look at patient radiation doses and talk about that a minute.

And the way we did it is illustrated here with this picture where we put the plastic on the table, our detector's underneath, this is the flat panel, we kept the fixed SID--which you may argue maybe you shouldn't do it that way, you should modify it according to patient thickness, but that's what we did and this drawing illustrates it—that we used a constant SID of 100 cm, we used a fixed distance to our detector of 30 cm, and then we just added plastic. Why did we do that? I didn't want too many things occurring at once. I didn't want the SID tracking confuse the issue. Okay, so what did we get? Well, first thing that's kind of a surprise. Here's the fields of view here, the 20, 17 in green, the orange is 15, and the red is 12. What's happening with this GE Innova in fluoro mode is while I'm increasing my acrylic thicknesses from 10 cm to 30 and my dose is going up, the different fields of view are not the same. Now, we thought that because of

the same size pixels that the dose would be the same. Well, the manufacturers boost the dose. At first we thought some of it might be due to binning, that does occur with flat panels that are very large field of view, they sometimes bin; and, therefore, when you go to the smaller field of view they don't bin, and so that might be a reason, but it seems as though, both GE and Siemens do this and it seems as though this effects the noise pattern as you spread it out over a small field of view the noise pattern looks different and to reduce the noise they actually boost approximately one is over the dimension that you're using, they actually boost the dose so the small field of view has more dose. The other thing you're seeing with this is that it's going up almost linearly on semi-log plot, which I like, because from the semi-log plot you figure out what your half value layer is in plastic and convert it to tissue, which I will give it to you later. The other thing

that you can see that at some point it saturates, in this case it goes 10R. The third thing that I'm

going to tell you, and this is the Siemens system in fluoro doing similar thing, and they're going up and reaching about 10R; but with the Siemens system, it actually went up to 10R per minute in two of the modes; in the third mode, it went up to 20; so it actually had a high dose mode, but it wasn't intuitively obvious from looking at the buttons on the controls, so that means you've got to test everything. The other thing I'm going to tell you is that each one has some kind of a mode, a plus, a normal, a minus, or something, and you think you know it all. But there's another thing that you don't know that many of the manufacturers, GE calls it trajectory, have different automatic brightness control programs, and these are selectable in the service software. So, if you measure it in one set of criteria and you measure it for different thicknesses, different fields of view, different modes, someone can go along and change it, which happened in our case. The

applications people told our cardiologist to change the mode, and they changed it and all our measurements were invalid. So you find out you have many, many measurements to do if you're going to try and take a look at the different modes. Okay, what happens in the cine mode, and again this is showing you the dose as a function of acrylic thickness in record or cine mode and this case it's for the GE system, and, again, each field of view as you go to a smaller field of view the dose goes up, and, in fact, it goes from very low doses for thin amounts, which would be equivalent to a small child, up to a large patient, up to about 100 roentgens per minute of...in record mode. And it's pretty similar for the Siemens system, if you take a look at it going up the same, but again, you have plus and minus buttons and different trajectories, so you can get much higher or much lower doses. So, because of this...and I point out these trajectories or ABC

modes, GE has five that we know of, IQ+, IQ standard, IQ smart, RDL+, and RDL standard, and the range from the maximum doses to the minimum doses is about a factor of 4, so that's pretty high, and that's true both in fluoro and record mode. They have a low and high button and the low is about 50% of normal. Siemens has three modes, a minus, a normal, and a plus; the plus is about 50% higher, the minus is about 50% lower, but again you can change everything. The other thing I'm going to point out when you look at doses is that for both systems about one cine frame is equal to about 4-10 fluoro frames. Well, what does this really mean to you, especially if you're in a cath lab? In a cath lab, you typically do one minute of cine for diagnostic case and about 5-10 minutes of fluoro; so it means the cine and fluoro doses are almost equivalent. We also tried to take a look, and we picked identical systems, these are Siemens systems, and blue is

the flat panel and...pardon me, pink is the flat panel and blue is the image intensifier system—identical systems other than the detectors. Now, we here, again, how flat panels are lower doses and, of course, you have this range where you can set it; but in this case we notice that the flat panels are higher in radiation dose than the image intensifier systems, and I show it to you again for the Siemens, comparing those two systems so they are higher. We think it's useful to plot the log of exposure versus thickness and we're finding the half value of the system, regardless of which ABC mode you're operating at, around 3.7-4.4 cm, just to get an idea, and this is converted to tissue not acrylic. And, if you're comparing the 17 field of view with 15-25 mm of acrylic thickness, the Siemens flat panel systems were about 2.5 times...2 times the dose of the image intensifier systems with digitized T.V. for record. The GE flat panels, it depends on what

you're using, but with RDL normal, it's about the same exposure rates as the Siemens flat panel,

but you have a range where you can set it. The other thing I want to show you is something...we were lugging all this plastic around, all this acrylic to do it, it's very difficult to do these measurements. A number of physicists in New York worked with New York State and we tried to get some standards of what you should measure in the field to get some dose charts up, and we decided the acrylic was just too much and the state agreed and so the new regulations say that you should measure approximately the following: Pediatrics should be one of those blocks in the penetrometer or .75" of aluminum. A small adult should be like 1.5 or the full penetrometer. And this was not your typical patient, although most of us for years were using this as our standard patient, the average adult should be 1.5 mm of aluminum, the entire penetrometer, plus 0.5 mm of copper. And a large adult should be the entire penetrometer plus 2.1 mm of copper for the patient. And I plotted this against what we measured in acrylic so you could see exactly where

you would stand, and here's the pediatric patient standing at, like, 7-8 cm of acrylic; here's your small adult of, like, 15 cm of acrylic; here's your typical adult close to 19 cm of acrylic—and remember acrylic has 1.19 density versus tissue of 1.04—and here's the large adult getting close to 30 cm. So, if you're going to do these measurements in the field, these four points give you nice setting and you don't have to carry all that acrylic around, so just throwing that out. You should know the ABC controls, so we did this. We put in different acrylic and we picked one of the trajectories that I'm showing you here in one of the modes, and I'm plotting it up. The GE system, it's hard to tell what filter is in without going into the service mode, so I didn't show it. But with the Siemens system, I not only showed the kV but I also show what filter's in the beam by the colors, which are shown below; and so, with the Siemens system when it uses the highest

thickness of copper, it's in green. So for the smaller thicknesses of acrylic, we have the high amount of copper, which reduces the dose to small patients, then when we get to large patients, there is less copper in the beam. In general, for the thicknesses that we used and the settings that we used, the Siemens system went from about 55 kV for the smaller sized patients up to about 80 for the larger sized patients in fluoro; and the GE system went just below 70 to up in the 100 kV range for the large patients. We also did it in the record mode, or cine, and this is the graph the two systems, the GE and the Siemens look pretty similar and, of course, they kept the kV's lower because you want to preserve the iodine contrast during the record mode. Okay, well it's important to know the input radiation into your detector and we looked at that. You will find that your old criteria you used will still apply to flat panel systems, although you have changes of

different ways you can set up the ABC system. Generally, in fluoro, on the 23 cm field of view, you should be below 100 microroentgens per second and then cine per frame should be less than 20 microroentgens per second. And this just shows the plot of the data that we measured and you can see it's for no grid and it's in the fluoro mode here, the Siemens II system's in yellow, the flat panel Siemens system is red, and the green is the GE flat panel in fluoro; and, in general, the GE system was lower in fluoro dose and, I think, it flipped the other way around for cine. And this is the cine dose. And also remember these fields of view are designated fields of view; they're not the actual size that we have because of the different ways that the fields of view are expressed. So all systems met the old criteria that we talked about before. GE has about the same...this is another thing that we found surprising, and I think GE's looking at it. Mr.

**Ballinger** from GE is here with us and you can talk to him later. But a number of physicists have expressed a concern that in fluoro mode, both for 15 and 30 pulse, the doses are almost identical, and most of us are used to seeing that go down, so that's an unusual feature. Okay, there are other things we've talked about. Okay, let's talk about the contrast ratio. We like to look at contrast ratios. It's become more difficult with flat panel. So, you put the lead disc in and you get a picture like this. We now look at the light output on the display monitor and we look at the light output under the lead disc versus outside the lead disc to get some kind of contrast ratio, since we can't do it any other way; and we look for contrast ratio greater than 60. However, let me show you something. I don't know how clearly it shows up in the back, but if you look in the lead disc, you'll see a bright area inside the disc and we think this is a software feature in the

way that it's set up and this actually reduced the contrast ratio, and this is for Siemens system, and we actually don't think it's set properly. Okay, low contrast imaging: many use the penetrometer with the insert to look at the low contrast imaging, and, typically, there's five different sized holes, and I'll tell you right off the bat, this is absolutely worthless, even though it's in our New York regulation. You will never see any change and all these cardiac systems, whether they're flat panel or image intensifier, and all the angio systems can see everything and it won't change with time even when the system degrades. We like to use a contrast detail phantom, which is shown here, and, basically, it looks like this. There's a series of holes, different depths drilled into it; it's aluminum block, and then they have different diameters at each different depth so that you get a contrast detail of display, and then we like to count the total

number of targets that we see, and we feel that that's a better way of approaching the problem so that we can see degradations. And the contrast that you'll see of these holes depends on the depth of the holes; they range...and the kV and the filtration...they range, typically, from 1% to around 20% contrast. The holes diameters are shown here. Now the thing I want to point out, we did say earlier is there are all kinds of settings, so depending on what result depends on how you set it. With GE, you can actually go in and change these in the applications mode, and contrast can go from +2 to -2 and the same for the noise and the sharpness, and this will effect what you're going to see in the images. Siemens has three factors: K factor, which would be similar to the noise factor over here where they're doing something like recurred filtering, where they're adding several images in a row with different weighting factors; gamma, which is like contrast

over here; and this is a density optimization...dynamic density optimization (DDO), which they're changing the darkness display with respect to their radiation measure. Well, if you change these factors, you can see it changes the image quality, so which one are you going to measure? Are you going to measure them all? You have various combinations, so there are five settings, three different parameters you can adjust, you're going to have 15 measurements to make, and you probably should do it initially to give some guidance to the cardiologist, and then the applications person will come in and change it for you. This is just to show you an example of Siemens image so that we're fair to both manufacturers. Siemens also gave us an example of how density optimization can change the image quality, because I couldn't get in there to change it to show you with the same C-D phantom that I had. Okay, well, the weighting factor can have

an affect, especially on dynamic things, and it can affect the noise background shown here. So,

since it's averaging out the noise, do you change this weighting factor so you can affect the noise? Well, what did we get for the results? It was pretty interesting to me in several aspects. One of them is it does not change much with the different fields of view, even the dose is changing, and the size is changing, and everything else, we're getting similar results; and, also, I expected the cine to do extremely better than the fluoro mode. There's a little difference, but there's not a big difference; and there's not a big difference between the manufacturers, especially if you shift this down so you're matching the right field sizes. Another thing that's very, very important when you do this testing is look at dynamic things, and we like to use the rotating spoke phantom. And it depends on how much water you put in there--we typically do not do this with water; we do it with copper, aluminum, and acrylic, just so we're not sloshing water all over—but it depends on what you put in there, because that's going to adjust your

filters and everything else; and it depends on your software. Well, we looked at in fluoro, stationary, you can see a large number of spokes; then, when you're moving—I don't know how clearly it shows up in the back, because it's pulse fluoro, you don't see the blurring, but you see several different images here at reduced density, and you should count how many of these spokes you see, and it shouldn't be more than about three or four, otherwise they're averaging too many frames together and it's a real problem. So, this is what happens with fluoro. And this is record mode. So record mode does not show those multiple images; and, because of the higher doses and because of the way they erase, it looks much cleaner when you look at the moving object and compare it to the stationary object. Well, I don't have one to show you of the fluoro mode, but I have the record or cine mode to show you with the Siemens...look it still appears. There's

something mis-set for the cine mode, or the record mode, with the averaging of frames, and you can still see multiple images of those spokes as it's moving. This was an electrophysiology cardiac lab, so they did mostly fluoro; they hardly ever used the record mode. If they did, they would be complaining about this. Okay, the other thing with flat panels, and since we've gotten away from cine film, is you should look at your monitors, and it's important to set your monitors properly--that you have the right brightness, density, contrast, and so forth; and we find one of the most useful things, of course, is to use the SMPTE patterns, and we look at several things. We look to see the bars in each corner and also the low contrast and high contrast bars. We actually measure the light output of each of these steps and we compare one monitor against the other; so, if we have right and left monitor, we compare them, and we take a look at the density

settings that it has. Here are the low contrast objects, I don't think it displays real well where you sit, but you have to see the 5% and the 95% low contrast objects in there as well. And we look at the black and the bright levels, and we actually measure those. So the monitors must be balanced, have similar grayscales, within a reasonable comparison, the 5% contrast objects must be visible, and the black level should be really low, like one to two lux; and the maximum brightness should be high, like 400-500 lux. This is a little different than your cine projectors, so the light levels does have an affect. And you don't want to look at any distortions in the monitor, or tint or color differences, and if you'd been looking at the images, you will see that one of the manufacturers used a CRT display and the other one used a flat panel display and one looked like a black and white image or grayscale image, and the other one had a blue tint to it. And this

does affect the way that the physicians interpret things. There are also other differences in the flat panel and the CRT's and the noise and the way that it looks; there seems to be more low frequency noise with flat panel. There are a lot of tests that should be performed when you do acceptance testing and some of those should be repeated in QC. I only talked about those that were more interesting from an aspect of the flat panel display, but you should be checking things like the kV, and now you're going to run into problems because some of the detectors are sensitive to filtration and, unless you have a detector that either compensates for it or you have a correction table, you may not measure the kV, not because it's wrong, but because of the filtration that's in the beam. You need to look at the waveforms, so we bring in an oscilloscope and we hook it up a radiation detector. Half value layer, we did talk about. We look at mA

linearity, make sure that that works. We actually measure our focal spots sizes. We have to look at all the regulatory things, like the maximum dose rate, and I told you about the surprise that in several of the modes it goes to 10R; but in some of the modes, and it may not be obvious, it goes to 20R. Safety checks of various kinds to make sure that everything's there. We look at the grid to make sure that it's the right ratio and is properly installed, and so forth. We also do a lot of mechanical checks. We look at the isocenter. We look at the central beam alignment. We look at the motion of the table, up and down, rotating, tilts, and so forth. We look at collision sensors and make sure that they're working so that no patient gets injured. And we do a complete radiation protection survey. We also, if there's a DAP meter there, we check the accuracy of the DAP meter. And, by the way, we're working on a new kind of device that'll be applicable for

fluoro and CT with no calibration. It's about the size of a pack of cigarettes and it has three MOSFET detectors you can place directly on a patient, and without any correction factors, instantaneously you get the doses that you're delivering to the patients; and this is really a great thing that if you want to find out what the real patient doses are in CT...or in cardiac, or any kind of angio, versus trying to calculate it from some phantom. And this should be available at the RSNA; unfortunately, the RSNA rejected our abstract, which I don't understand because it's the only one of its kind in the country without any fancy calibration and small. Archiving and PAC system transmission: That's part of the acceptance tests; you've got to make sure it works, so even though you get the images at your station, you've got to make sure they're not lost or somewhere in the network not transmitted. Electrical safety: Not only grounding and polarity,

emergency power for the room and all our cardiac rooms and angio rooms where they're fishing catheters, and it could be dangerous if the power went off and you couldn't remove the catheter properly, that it has emergency backup power, and cutoff switches, and so forth. Look at the grid and the SID tracking. And with that, I'll end with these images and say thank you very much for your attention. I'll be available for questions.