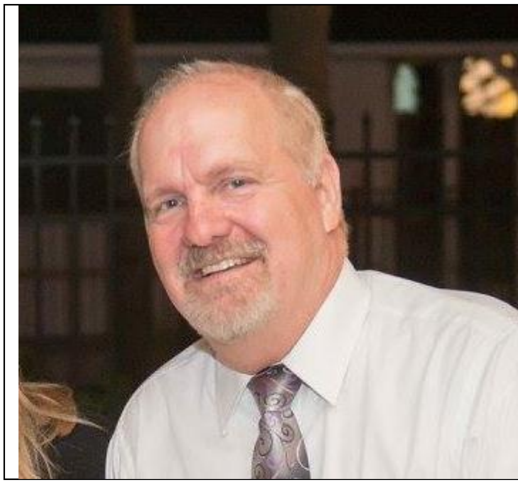
ABOUT THE AUTHOR:



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PURPOSE: The purpose of this document is to describe ECAM and Symbia Detector Uniformity Corrections and Quality Control Procedures in terms that are easily understood. This document covers both HD and Foresight Detectors and describes both manual and automatic QC Procedures. This document does not include CT Quality Control Procedures for Symbia systems that include a CT scanner.

DISCLAIMER: This is not an officially validated and/or approved Siemens Healthineers document. Instead, the following information is based upon the author's personal knowledge, experience and observations with Siemens gamma cameras over the past 30+ years. To the best of the author's knowledge, all of the following information is accurate as of the date it was written. That said, the information is subject to change at any time at Siemens' discretion.

FEEDBACK: Please do not hesitate to provide feedback regarding this document, especially if anything contained within is either erroneous or misleading. Be advised that some of the information within this document has been over-simplified to facilitate a basic understanding without becoming overly technical and precise. In some instances, a small amount of accuracy was sacrificed to simplify an explanation.

For example, this document states, "The ultimate goal when tuning a detector is to have all Tune Values between +/- 007, which indicates all the PMT's are within 1.4% of each other. Tuning will fail unless the aforementioned goal is achieved." Be advised that statement is not 100% accurate, but it does convey the intent of tuning a detector.

Tech-Support Tip: This document includes various Technical Support Tips. These items are intended to help end users avoid issues which commonly occur when performing Quality Assurance procedures.

For example, this document states, "Always ensure there are no injected patients in the scan room or any other sources of background radiation when tuning a detector. Inadvertent radiation striking the crystal causes extraneous counts which adversely affect tuning a detector."

TABLE OF CONTENTS

GAMMA CAMERA UNIFOMITY BASICS

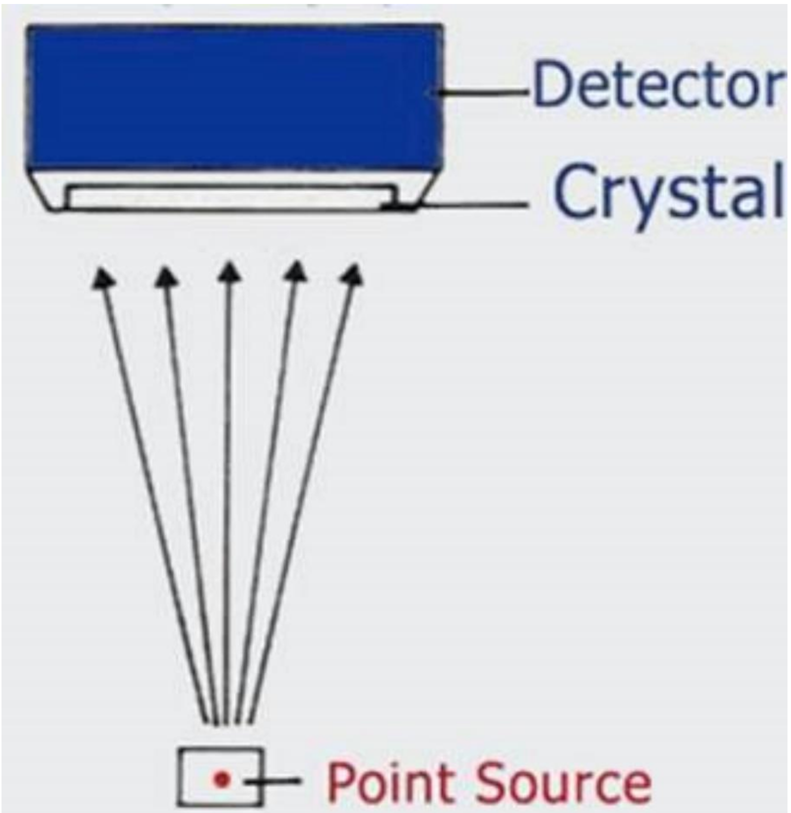
CT and MR scanners use phantoms filled with distilled water to test for homogeneity. In a similar manner, gamma cameras check for uniformity. The difference is gamma cameras use a radioactive isotope for this purpose, rather than the scanner generating x-rays (CT scanners) or magnetic fields & RF signals (MR scanners).

To test **intrinsic uniformity** on a Siemens ECAM or Symbia, collimators are removed and then a cobalt or technetium point source is equally spaced between the detectors. This allows a system to simultaneously acquire QC images from both detectors.

NOTE: In Nuclear Medicine, **intrinsic** refers to images acquired without collimators; whereas, **extrinsic** refers to images acquired with collimators installed on the detectors.

The below pic shows an ECAM with a technetium point source (in the clear plastic vial circled in red) attached to the point source holder (the silver rod that extends from the Rear Bed). On a Symbia-S or a Symbia-T, the point source holder extends from the Front Bed.

With the collimator removed, a point source "floods" a detector with radiation as shown below. This process is analogous to a flashlight "flooding" light on an object. In both cases, the closer the source to the object, the less uniform the distribution. However, the greater the distance from the source to the object, the weaker the radiation or illumination.



For Siemens Dual Head cameras, a technetium point source of 30 to 35 microcuries is needed and the source should be midway between the two detectors when the heads are fully retracted. For systems with AQC (Automated Quality Control) a 50 microcurie cobalt point source in initially installed in the Front Bed and then replaced on an annual basis.

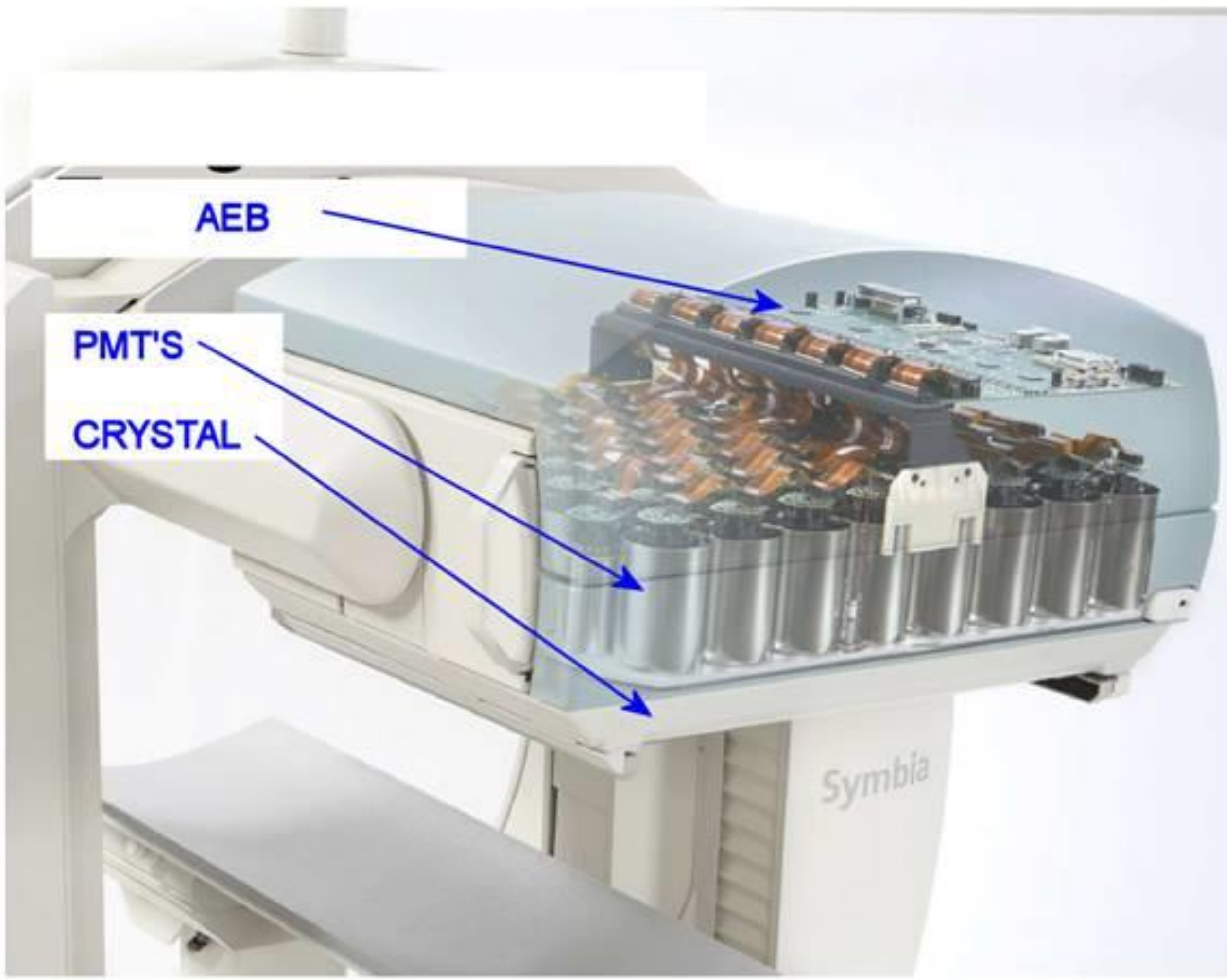
Each time a gamma ray strikes a detector's crystal, one "event" has occurred. Events occurring within the selected analyzer preset are called counts.

For Siemens Dual Head cameras, each month intrinsic calibration floods are acquired for 200 million counts on each detector. On a daily basis, intrinsic or extrinsic verification floods are acquired for 10 to 30 million counts on each detector.

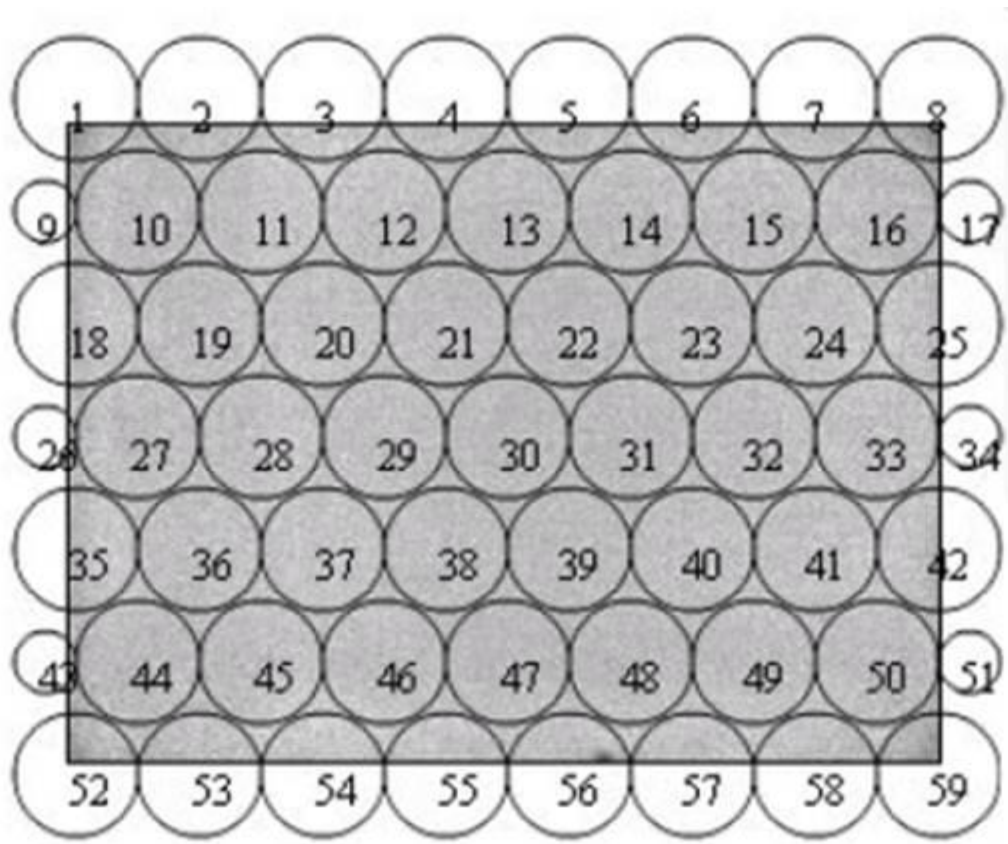
For Siemens Single Head cameras, the same process is followed, except obviously for only one detector.

If you had Superman's x-ray vision, a Siemens detector would appear as shown below. A man-made thallium-doped crystal detects gamma rays from a radioactive source and then emits green light proportional to the energy level of the gamma ray. Those scintillations are then sensed by 59 Photomultiplier Tubes (PMT's) and sent to an Acquisition Electronics Board (AEB) which creates image data. Calibrations and corrections are stored within the AEB to produce a uniform image.

Below is a Symbia-E with a Foresight Detector. FYI, instead of utilizing an AEB, older systems with HD detectors had multiple boards inside the detector (DD, PI, PCALC, DTPS, & AIMD), but the overall functionality is identical.



In Nuclear Medicine, a Quality Control image performed as previously described is called a "flood" since an isotope is "flooding" the crystal with radiation. The below image shows a perfectly uniform flood (the grey part) and an overlay of the corresponding 59 PMT's.



Be advised the above PMT overlay is not shown to users. Also be advised that the orientation in which the image was acquired (e.g., Head First Supine, Feet First Supine, etc.) alters the image to PMT layout correlation. That issue in discussed later in this document.

The remaining sections of this document describe the various procedures needed to produce a uniform flood as shown above. Some procedures are performed by service personal, while others are performed by end users.

In addition to an intrinsic flood, a myriad of the QC tests should be performed by end users, including but not limited to the following:

- Extrinsic Flood
- COR (Singe Head Cameras only)
- MHR (Multi-Head Registration) and NCO (Non-Circular Orbit) (Dual Head ECAM & Symbia-E)
- MHR or Head Alignment (Symbia-S/T)
- NM/CT FOV (Field on View) (Symbia cameras with a CT scanner)

BUILT-IN DETECTOR CORRECTIONS (ZLC)

In Siemens parlance, Z = energy.

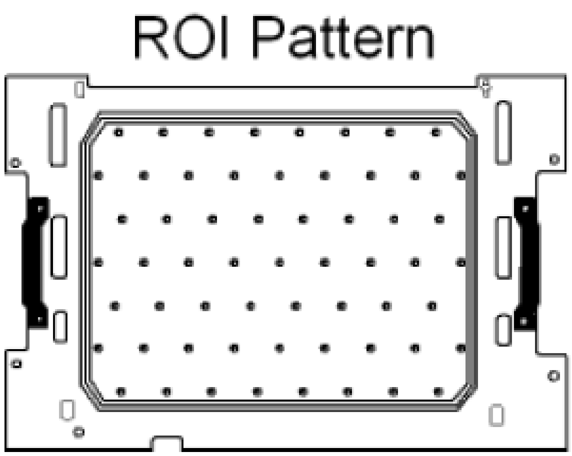
In Siemens parlance, LC = linearity correction.

Therefore, in Siemens parlance, ZLC refers to energy and linearity corrections embedded within a detector.

All Siemens detectors have embedded ZLC corrections.

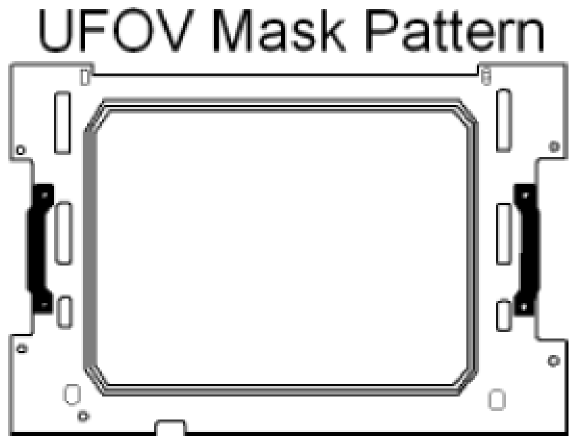
After a HD or Foresight Detector is assembled and calibrated in a Siemens manufacturing facility, a series of images are acquired to produce a uniform and linear intrinsic flood. These images include:

- **ROI MAP** (Region of Interest Map)
  - Used to identify the x/y coordinates for the center of each PMT within a detector's Field of View.
  - Creates a ROI Lookup Table.
  - A ROI Lookup Table is needed to adjust each PMT's output when tuning a detector.
  - Below is a depiction of the **ROI Pattern** which is installed on a detector when acquiring a ROI Map. The black dots shown below represent 59 holes in the pattern, each corresponding to the center location of a PMT, known as its **Tune Mask**.

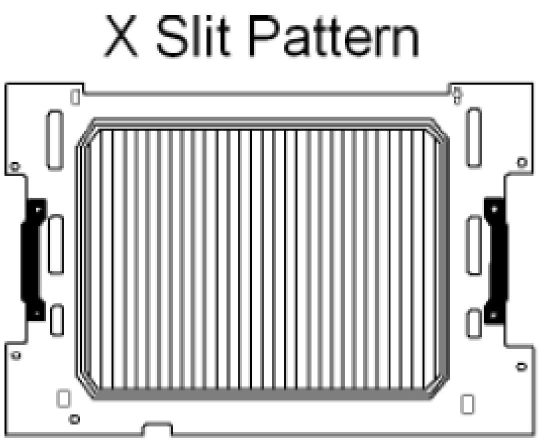


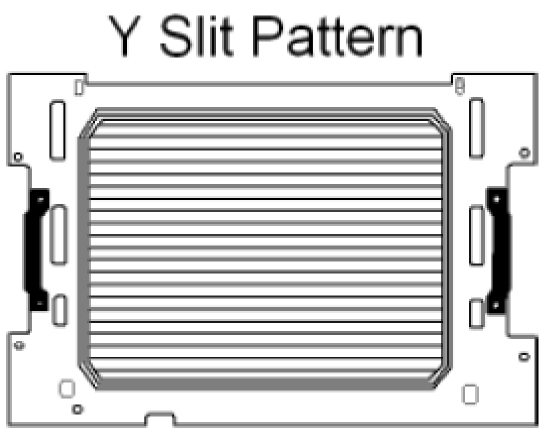
- **ZMAP** (Energy Correction Map)
  - Used to correct non-uniformities caused by the energy response of the crystal.
  - Creates a ZMAP Lookup Table.
  - While tuning adjusts each PMT for the same output level, a ZMAP Lookup Table is needed to correct the crystal's energy response, especially in the areas between PMT's.
  - The ZMAP acquisition is performed without a collimator or pattern installed on the detector. **No pattern** is needed.

- **LC MAP** (Linearity Correction Map)
  - Used to correct any distortions in linearity along both the x and y axis of the detector.
  - Creates LC Lookup Tables.
  - Three separate acquisitions are needed.
  - Below is a depiction of the **UFOV Mask Pattern** which is installed on a detector during the first LC acquisition. The center portion of the pattern is open, while the outer portion masks the detector's Useful Field of View (UFOV).

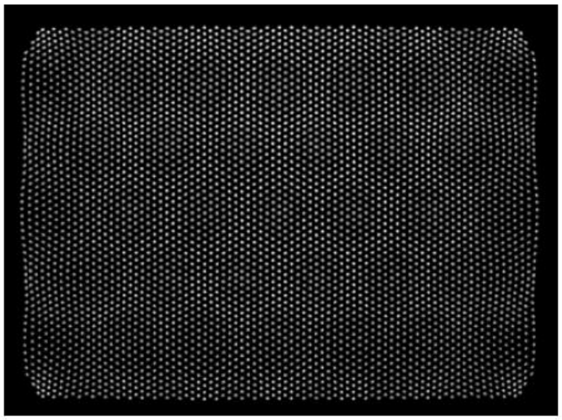


  - Below is a depiction of the **X Slit Pattern** and the **Y Slit Pattern** which are installed on a detector (one at a time) during the second and third LC acquisitions. One pattern is used to correct distortions in the x axis, while the other pattern corrects the y axis.





- Alternatively, rather than performing both a X Slit Pattern and a Y Slit Pattern acquisition, LC Lookup Tables can be generated within a single acquisition using a **Dot Pattern** test fixture. Below is the resultant image when using a Dot Pattern test fixture. This pattern has hundreds of holes, rather than only 59 holes like a ROI pattern.



In Siemens parlance, the aforementioned corrections are known as **ZLC Corrections**.

In Siemens parlance, generating ZLC Corrections using X & Y Slit Patterns is called the **Linear Method.**

In Siemens parlance, generating ZLC Corrections using a Dot Pattern is called the **Iterative Method.**

ZLC Corrections are stored inside the SNAC (the Siemens Nuclear Acquisition Computer) for HD Detectors, but are stored inside the detector for Foresight Detectors. The process of acquiring the aforementioned images, generating Lookup Tables, and then storing that information in a Siemens gamma camera is called a "**generation of coefficients**."

End-users cannot modify or update the aforementioned built-in ZLC corrections. Instead, detector coefficients can only be updated by service personnel. In short, a Siemens Service Representative can reacquire the same images originally generated in the manufacturing facility, and afterwards, store those new corrections in the SNAC or in the detector, depending upon whether the system has HD or Foresight detectors. In Siemens parlance, this onsite updating of ZLC corrections is called a "**regeneration of coefficients**" or more commonly a "**reburn**."

A common question is why would these corrections need to be regenerated? The short answer is because a detector's optics change over time.

The core of any detector is the scintillator, commonly referred to as the crystal. These devices are man-made; and unfortunately, their scintillation characteristics vary slightly over time. Additionally, PMTs (which detect scintillations from the crystal) are held in place with a clear, epoxy-like substance called optical gel. As this gel ages, its optical characteristics change. Over time, both of the aforementioned changes adversely affect a detector's uniformity.

For example, if a PMT in a five year-old detector is replaced, the five year-old optical gel for that PMT is removed and replaced with a new mixture less than 3 months old. As a result, afterwards the new PMT (with the new gel) may appear differently than the other PMTs in subsequent images.

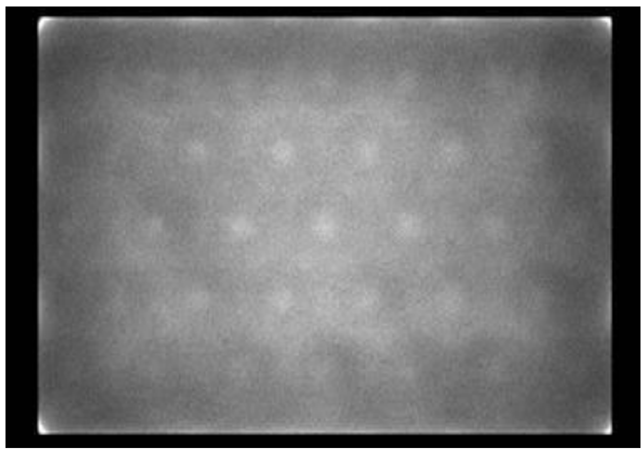
Minor variations in optics are corrected when the end-user acquires an Intrinsic Flood Calibration. But eventually, all detectors degrade to the point where ZLC Corrections need to be regenerated.

With the exception of:

- A cracked or damaged crystal
- Hydration (aka, measles) within a crystal
- Crystal to optical coupler separation

A Siemens Service Representative can reacquire the same images originally generated in the manufacturing facility, and the detector's uniformity should be as flawless as the day it was originally manufactured.

For reference purposes, below is an intrinsic flood without ZLC Corrections. In service parlance, the below image is called an "**uncorrected flood**."



Siemens Service Representatives can also perform a scaled-down regeneration of coefficients, using a process called a **partial or kitless reburn**. As the "kitless" name implies, the aforementioned ZLC test patterns are not needed. Instead, only two acquisitions are performed: a ZMAP and a **LC Gradient**. The former was discussed previously, while the latter is merely an update to the existing Linearity Correction Lookup Tables.

While a partial reburn has obvious advantages over a full reburn (specifically, it takes less time and does not require any patterns), it has one huge disadvantage: the results are only "partially" as good. While a full reburn using ZLC patterns will generate corrections that result in uniformity values in the 1% range, a partial reburn typically only cuts a detector's uniformity values in half. For example, a detector with 6% to 7% uniformity values would have values of approximately 3% to 3.5% after a partial reburn.

Only one partial reburn should be performed between full ZLC reburns; otherwise, the detector's resolution will be adversely affected. This happens because the partial reburn corrections are an additional filter on top of the existing, pattern-generated, full reburn corrections.

Over the lifespan of a detector, the typical process is:

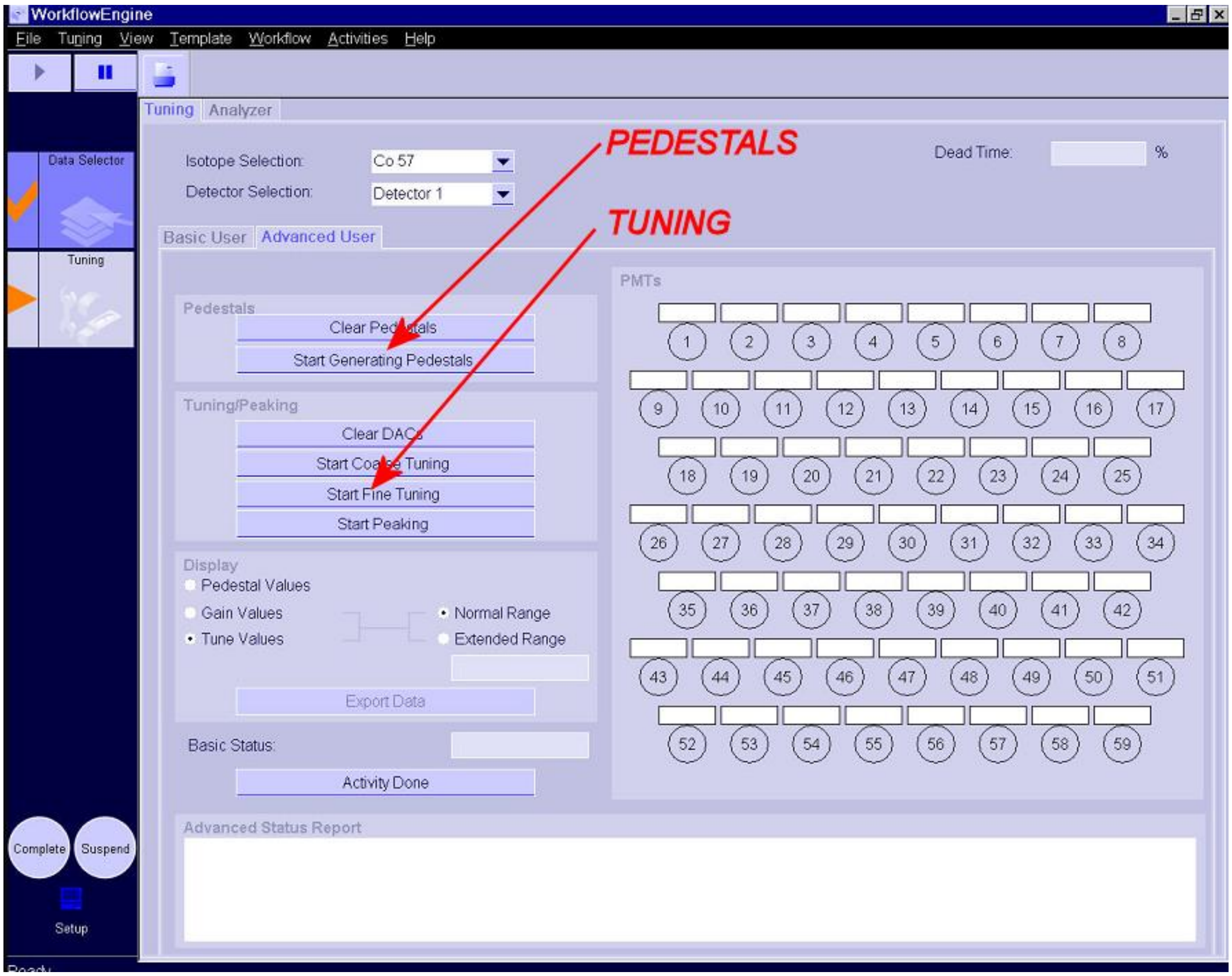
- A full reburn is performed at the Siemens manufacturing facility.
- A partial reburn is performed onsite.
- After a partial reburn has been performed, at some future date, another full reburn is performed.

Be advised that partial reburns are optional. It not uncommon for only full reburns to be performed, since the end results are superior as previously described.

CUSTOMER GENERATED INTRINSIC CORRECTIONS

After a HD or Foresight detector is installed into an ECAM or a Symbia and that system is installed at a customer facility, each time the customer acquires an **Intrinsic Flood Calibration** the system creates an additional correction table to compensate for minor changes in the detector optics; as well as, for minor drift within the detector electronics.

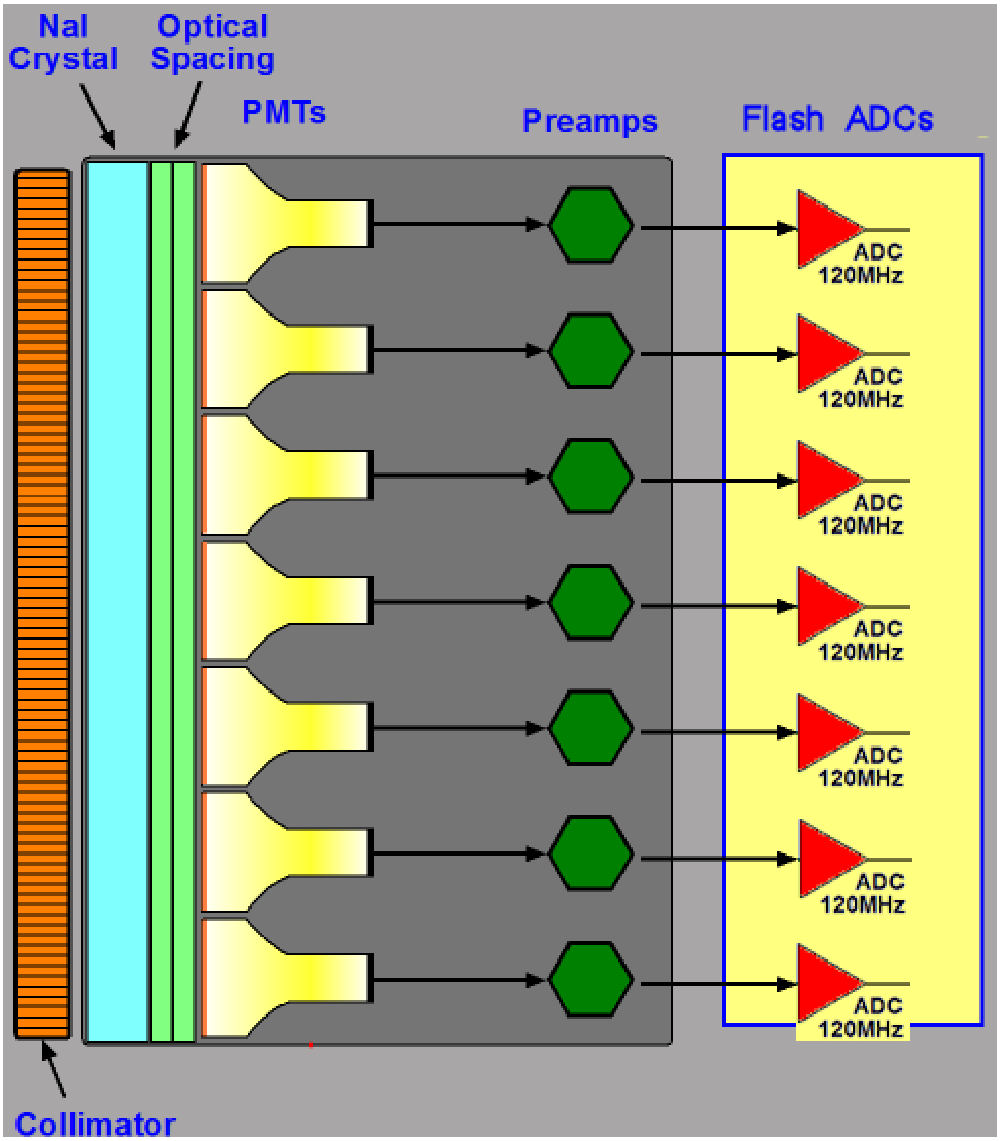
Before acquiring an Intrinsic Flood Calibration, the customer has the ability to **Generate Pedestals** and **Start Fine Tuning** via the Advanced User tab of the Tuning Workflow. See screenshot below.



Tech-Support Tip: Never click on “Clear Pedestals” or “Clear DACS” unless someone from Siemens Service has advised you to perform either function. In some circumstances, clearing pedestals or clearing DACS can change a detector’s uniformity from marginally acceptable to significantly unacceptable.

Tech-Support Tip: Most detector uniformity problems are corrected by generating pedestals and then performing Fine Tuning. Therefore, please take the time to read and understand the following descriptions of these two important detector functions.

PEDESTALS: Inside each detector, the output of each PMT is digitized by an ADC (Analog to Digital Convertor). See the below drawing. In a Siemens gamma camera, ADC's operate at much higher speeds than typical ADC's; and therefore, they are called Flash ADCs. These devices are calibrated when the end user selects Start Generating Pedestals in the Tuning workflow.



Be advised this calibration assumes no radiation is striking the detector's crystal, therefore, prior to starting pedestal generation, collimators must be installed and all sources of radiation (patients, Sharps Containers, point sources, sheet sources, etc.) must be removed from the scan room.

Conceptually, think of generating pedestals as nulling the detector. In other words, zero in = zero out. Therefore, it is absolutely imperative there is no radiation striking the crystal when generating pedestals. There are 60 Flash ADC's in each detector; one for each of the 59 PMT's and one for the **Energy Sum (ESUM)**, which is the combined output from all the PMT's. Generating pedestals simultaneously calibrates all 60 Flash ADC's in one detector.

TUNING: While generating pedestals calibrates a detector for zero in = zero out, tuning adjusts a detector for the same output from each PMT when the same radiation level (KEV) is striking the crystal under each PMT.

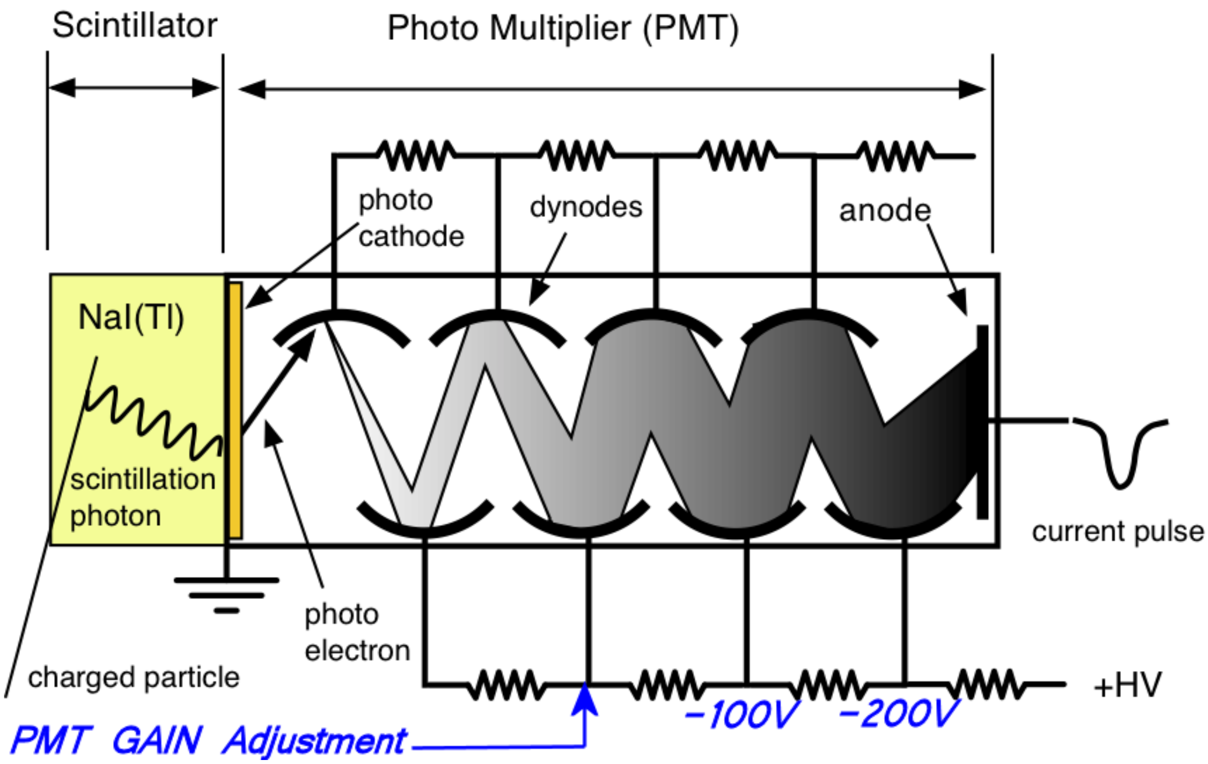
HD and Foresight detectors have the ability to adjust the output of each PMT by:

- Varying the detector's High Voltage.
  - The same High Voltage is applied to every PMT.
  - The greater the High Voltage, the larger the output from all PMT's.

- Varying one of the dynode voltages on each individual PMT.
  - Each PMT's output can be increased or decreased by varying one of its dynode voltages.
  - Varying a PMT's dynode voltage adjusts the "PMT Gain."

The process of adjusting a detector's High Voltage and each PMT's Gain is called "tuning the detector." The ultimate goal is for each and every PMT's have an identical current pulse when tuning with either a technetium point source or a cobalt point source.

Below is a drawing indicating various voltages to a PMT in a HD or Foresight Detector. Each and every PMT has the same -100 & - 200 volts applied, as well as, the same High Voltage. However, each individual PMT has a different voltage applied as it PMT Gain Adjustment.



Be advised that tuning can only be performed:

- Using a technetium or cobalt point source.
- With collimators removed.
- On one detector at a time.

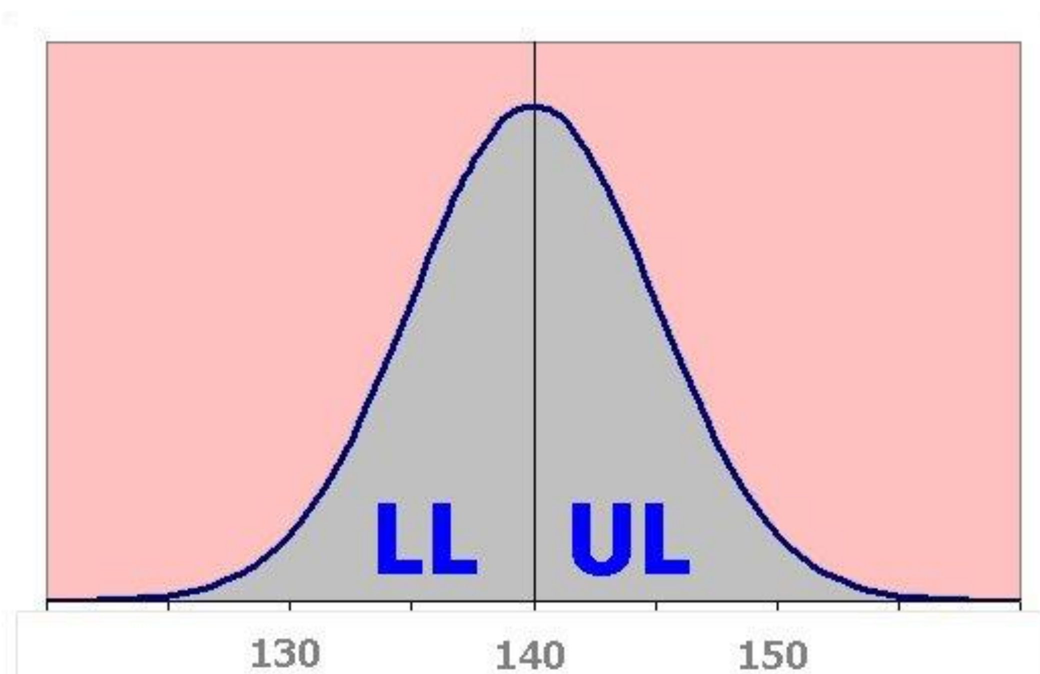
During Tuning, there are four items to monitor: **Gain Values**, **Tune Values**, **ZMAP Value and HV DAC Value (HD) or High Voltage Value (Foresight).**

GAIN VALUES: Gain Values indicate the amount of dynode bias adjustment sent to each PMT via its Gain DAC (Digital to Analog Convertor). The Gain Value displayed to the end user indicates the amount of PMT Gain Adjustment applied to each PMT.

A DAC is the opposite of an ADC. The former converts a digital value to an analog voltage, while the latter converts an analog voltage to a digital number. Each PMT Gain DAC converts a number in the range of -512 to +511 to a voltage that is applied to one of a PMT's dynodes. Consequently, increasing or decreasing a PMT's Gain Value alters one of the dynode voltages applied to a PMT, and that alters the amplitude of that PMT's current pulse. Increasing or decreasing each PMT's Gain Value is intended to center the output from each PMT within the selected analyzer's energy window.

In the Tuning workflow, Gain Values can range from -512 to +511. Tuning will fail if any Gain Value reaches -512 or +511. It sounds counterintuitive, but -512 will apply maximum gain; whereas, +511 will apply minimum gain. Consequently, a PMT with a Gain Value of -512 is operating at its maximum output.

TUNE VALUES: During each tune pass, the detector begins accepting events that occur within each PMT's Tune Mask as determined by the detector's ROI Lookup Table. The selected cobalt or technetium analyzer is split into equal halves, called the Lower Level (LL) and the Upper Level (UL). See below for technetium. The LL is 140 KEV and below, while UL is 140 KEV and above.



When a predetermined number of counts have been acquired in either the LL or UL within each PMT's Tune Mask, the system momentarily stops acquiring and analyzes the data. That's called a Tune Pass. The counts in each PMT's LL and UL are compared, and the result is the PMT's Tune Value.

Tuning will fail if the number of counts in the LL and UL cannot be equalized for each PMT.

Tune Values are displayed as three digits, indicating XX.X percent. For example, -009 indicates -00.9%.

The following formula is utilized to determine a Tune Value:

$$\frac{(\text{Counts in LL}) - (\text{Counts in UL})}{(\text{Counts in LL}) + (\text{Counts in UL})}$$

As example, suppose PMT #12 has 6000 counts in the LL and 6500 counts in the UL.

6000 – 6500 = -500
6000 + 6500 = 12500
- 500 / 12500 = - .04
As a percentage, that is -4.0%
Consequently, a Tune Value of -040 is displayed for PMT #12.

As example, suppose PMT #38 has 6600 counts in the LL and 6400 counts in the UL.

6600 – 6400 = 200
6600 + 6400 = 13000
200 / 13000 = .015
As a percentage, that is 1.5%
Consequently, a Tune Value of 015 is displayed.

As you can see, a negative Tune Value indicates more counts in the upper half of the tune analyzer (UL), while a positive Tune Value indicates more counts in the lower half of the tune analyzer (LL).

The ultimate goal when tuning a detector is to have the same number of counts in each PMT's LL and UL; therefore, the tuning algorithm adjusts PMT Gain Values until all Tune Values are between +/- 007, which indicates all the PMT's are within 1.4% of each other. Tuning will fail unless the aforementioned goal is achieved. Be advised, the lower the Tune Values, the more uniform the flood.

Tech-Support Tip: Always ensure there are no injected patients in the scan room or any other sources of background radiation when tuning a detector. Inadvertent radiation striking the crystal may cause extraneous counts in either the LL or UL, and that adversely affects each PMT's Tune Value.

During Fine Tuning:

- HD Detectors
    - The same number of counts are acquired during each Tune Pass; and therefore, each Tune Pass takes the same amount of time.
    - As soon as all Tune Values are within +/- 007, Fine Tuning stops and a tuning was successful message is displayed to the end user.
- Foresight Detectors
    - Each Tune Pass attempts to produce more accurate results than the previous Tune Pass; therefore, each subsequent pass acquires more counts and takes a longer period to compete.
    - As soon as all Tune Values are within +/- 007, tuning is considered successful. However, tuning will continue until all Tune Values are as low as can be obtained. After that process has completed, a tuning was successful message is displayed to the end user.

Tech-Support Tip: The lower the Tune Values, the more uniform the flood. Therefore, on HD Detectors, run Fine Tuning again and again while monitoring the Tune Values. Stop when the Tune Values are at their lowest. Be advised that Foresight Detectors perform that process automatically.

To improve a detector's energy resolution, a detector performs tuning twice; once in **Normal Range** and once in **Extended Range.** The former is 324 KEV and below, while the latter is 324 KEV and above. Each range has its own Gain Values, Tune Values, ZMAP Value and HV DAC Value (HD Detector) or High Voltage Value (Foresight Detector).

HV DAC Value (HD Detector) or **High Voltage Value (Foresight Detector):** During Tuning, the tuning algorithm adjusts each PMT's output (as indicated by Gain Values) in an attempt to center all the PMT's output with the selected analyzer (as indicated by Tune Values). The algorithm can also increase or decrease the detector's High Voltage applied to every PMT to assist in this endeavor.

The algorithm for determining whether a High Voltage adjustment is needed varies by software version and the type of detector, and that discussion is far beyond the scope of this document. However, be advised of the following:

- HD Detectors
    - HV DAC Values can range from -127 to +128.
    - When the HV DAC is set to -127, all the PMT's are provided with minimum High Voltage.
    - When the HV DAC is set to +128, all the PMT's are provided with maximum High Voltage.
    - If the end user clicks on Clear DACS within the Tuning workflow, in software versions 2.5 and above, the HV is set to -127 (minimum high voltage). In earlier software versions, the HV DAC is set to 000 (midrange).

- Foresight Detectors
    - The High Voltage is displayed to the end user in volts.
    - The voltage range is from -600 to approximately -735 volts.
    - If the end user clicks on Clear DACS within the Tuning workflow, the High Voltage is set to -675 volts (midrange).

ZMAP VALUE: A ZMAP Value is the Tune Value for a sampling of areas between the PMT's. While the Tune Value for each PMT can be changed by increasing or decreasing a PMT's Gain Value, a similar adjustment for the areas between the PMT's does not exist. Instead, the ZMAP LUT (which was created during a generation of coefficients) is the only correction for the areas between PMT's.

Immediately after a generation of coefficients, a detector's ZMAP Value is 000 or 001. However, since optics unavoidably change over time, the ZMAP Value will slowly and steadily increase. Once a ZMAP Value reaches 010 or greater, tuning fails due to a ZMAP error.

A ZMAP Value of 010 indicates there is +1.0% deviation between:

[a] The average energy level of the 59 PMT's and
[b] A sampling of areas between the PMT's.

Be advised, the lower the ZMAP Value, the more uniform the flood.

PEAKING: While tuning centers the output of each PMT within either a technetium or cobalt analyzer, peaking centers the combined output of all the PMT's (called the ESUM) within an analyzer. Rather than adjusting the PMTs, peaking shifts the analyzer.

- ✓ Tuning: Centers the output of each PMT within a Tc-99 or Co-57 analyzer.
- ✓ Peaking: Centers the analyzer around ESUM (the combined output of the PMT's).

Peaking is needed for each isotope the end user utilizes for quality control and/or patient imaging.

Be advised that peaking should only be performed after a detector has been successfully tuned.

A negative off-peak shift indicates ESUM had more counts in the UL, whereas a positive off-peak shift indicates more counts in the LL. Peaking will fail if the off-peak shift is more than +/- 12%.

Be advised that it is never a good idea to peak analyzers using an injected patient or with collimators installed. Instead, the proper method of peaking an isotope requires removing the collimator from each detector and using a 35 micro-curie point source in a plastic vial. This process will be discussed in detail later in this document.

One of the Golden Rules when peaking or tuning is to check the detector's **dead time** immediately after removing collimators. The reason for this precaution is to ensure there is no background radiation or other unintended sources of radiation that will adversely affect peaking or tuning.

According to Siemens MI-SPECT, "Dead time is the relation between counts that fall in the energy window versus all the counts processed by the detector electronics; in other words, the time the detector is "paralyzed" and cannot process a new event."

To an end user, the dead time percentage (displayed on the Analyzer tab of an acquisition workflow) indicates the amount of radiation striking the crystal, regardless of the energy level of the radiation and regardless of the analyzer settings.

To elaborate, when radiation strikes a scintillation crystal, that crystal emits green light. The radiation could be from a technetium point source, a gallium-injected patient, or a CT scanner in an adjacent room. PMT's affixed to the opposite side of the crystal detect those "scintillations." In a HD or Foresight Detector, the output from each of the 59 PMTs is fed into extremely complex electronic assemblies and analyzed using highly sophisticated algorithms to determine both:

[1] The precise energy level of each gamma event.

[2] The exact x/y coordinates where each gamma event struck the crystal.

Gamma events that fall within the energy range of the selected analyzer and within the selected Field of View will be "counted" and appear on the system's persistence scope in the corresponding x/y position. Gamma events that fall outside the energy level of the selected analyzer or outside the selected Field of View will be discarded. Both sets of events contribute to the detector's dead time percentage, since both sets of events were digitized and analyzed.

Be advised that HD3 and Foresight Detectors have multiple integrator circuits working simultaneously in parallel with the intent to digitize and analyze each and every gamma event. While this process only takes a fraction of a second per gamma event, a detectors can only analyze up to 300,000 events per second. Additionally, before the maximum count rate is reached, as more and more gamma events strike the crystal, a larger and larger percentage of events are not analyzed because all the integrator circuits were busy.

Tech-Support Tip: It is a common mistake to remove collimators and then check the count rate of each detector. Counts are the gamma events within the currently selected window; whereas, dead time indicates how much radiation is striking the crystal, regardless of the energy level of the radiation and regardless of the selected analyzer. End users should always follow the Golden Rule and check the detector's dead time immediately after removing collimators, rather than simply checking the detector's count rate.

Tech-Support Tip: End users may encounter an error when either Coarse or Fine Tuning that states, "Source too strong" and be perplexed because the count rate appears normal. This error occurs because the dead time is 10% or greater. If the count rate is normal, then this error usually indicates there is excessive background radiation in the scan room, and that background radiation has increased the dead time to 10% or above, while not increasing the count rate.

Tech-Support Tip: End users may encounter an error when Fine Tuning that states, "No count or low count in energy window" and be perplexed because the count rate appears normal. This error occurs because the count rate is too low for the percentage of dead time, yet the dead time is still less than 10%. This error usually indicates there is excessive background radiation in the scan room, and that background radiation has increased the dead time while not increasing the count rate.

While the percentage of dead time varies slightly according to a detector's internal components, as a general guideline, HD and Foresight Detector should indicate 6,000 to 7,000 counts per second for each one percent of dead time. For example, if 5% dead time is displayed on the acquisition workstation, then the PPM should indicate 30,000 to 35,000 counts per second if the correct analyzer has been selected and the background radiation is less than 200 counts per second.

Tech-Support Tip: End users may also encounter the "No count or low count in energy window" error if any portion of ESUM is outside the selected tuning analyzer. The most common cause of this scenario is selecting the Co-57 analyzer while tuning with a Tc-99 point source. The Co-57 analyzer has a 20% window, so a portion of the technetium photopeak falls within that window. Consequently, during tuning, the output from each PMT will be misadjusted to 122 KEV. Once the end user realizes their mistake, they will attempt to tune the detector using the Tc-99 analyzer. However, that analyzer only has a 15% window, so the output from the PMTs (which were inadvertently misadjusted to 122 KEV) do not fall inside that window. Course Tuning is needed to re-center ESUM in the correct tuning analyzer. Coarse Tuning uses a 75% window; and therefore, the count rate within that larger analyzer window will match the reported dead time.

Tech-Support Tip: Another common mistake is checking for the source of background radiation using a Geiger Counter. Often times an end user will remove collimators and notice one of the detectors has 2 or 3% dead time without any known sources of radiation present. Generally speaking, most Geiger Counters lack the sensitivity to detect radiation in very small amounts. Instead of using a Geiger Counter, use the detectors as a pair of ultra-sensitive Geiger Counters to ascertain the origin of the unknown dead time and/or the unknown counts.

Specifically:

[1] Remove collimators.

[2] Position Detector 1 in the 12 o'clock position and Detector 2 (if applicable) in the 6 o'clock position.

[3] Remove all known sources of radiation from the scan room. Close the Hot Lab door (if applicable).

[4] Launch the Tuning workflow.

[5] Select the Co-57-NMG preset on the Analyzer tab. Using the Co-57 analyzer includes portions of both the cobalt and technetium photopeaks.

Note: Often times, running the spectrum tool on the Analyzer tab will identify the KEV of the background radiation. In that scenario, select an analyzer present to match the KEV of the background radiation, and then continue this procedure.

[6] Check the PPM (Patient Positioning Monitor) for the same count rate on each detector. The count rates should be within 5% on both detectors. Also, check the deadtime on both detectors using the Tuning workflow. The dead time should be within 0.5% on both detectors.

Note: While searching for the source of the stray background radiation, do not forget that counts are the gamma events within the currently selected window; whereas, dead time indicates how much radiation is striking the crystal, regardless of the energy level of the radiation and regardless of the selected.

For example, if there is unventilated Xenon gas from a lung scan, the resultant gamma events generate dead time, but will not generate counts on the PPM if a Co-57 or Tc-99 analyzer is selected.

[7] If count rates are different on the detectors, then rotate the detectors 180 degrees while observing the PPM. If the higher count rate moves from one detector to the other after swapping their positions, there is too much background radiation. Use the detectors to locate the source.

[8] If count rates are the same on both detectors, but the dead times are different, the then rotate the detectors 180 degrees while observing the dead times. If the higher dead time moves from one detector to the other after swapping their positions, there is too much background radiation. Use the detectors to locate the source.

Earlier in this document, it stated that the proper method of peaking an isotope requires removing the collimator from each detector and using a 35 micro-curie point source in a plastic vial.

According to the Operating Instructions e.cam Signature Series Systems:

> Prepare the point source as directed below.
>
> Use as little liquid as possible and ensure that the point source's activity is correct.
>
> [1] Place a small piece of cotton (approximately 3 mm in diameter) into the vial. The piece of cotton should not be too large, and should not fill the entire vial.
>
> [2] Place drops of Technetium on the cotton. Try not to exceed the cotton's saturation capacity.
>
> The source is now prepared for the desired calibration.

After preparing the source, remove collimators from the detectors. Launch the Tuning workflow and then select the Tc-99m-NMG preset on the Analyzer tab. Ensure the dead time is less than 0.5% on each detector. Extend the point source holder until it is centered in each detector's short axis field-of-view. Raise the patient bed until the point source is an equal distance from both detectors. Place the vial containing the point source in the tip of the source holder rod. The goal of this setup is for all the PMTs in both detectors to detect the same amount of radiation from the point source. See image below. Be advised, collimators should not be installed as shown below. Peak the Tc-99m-NMG analyzer.

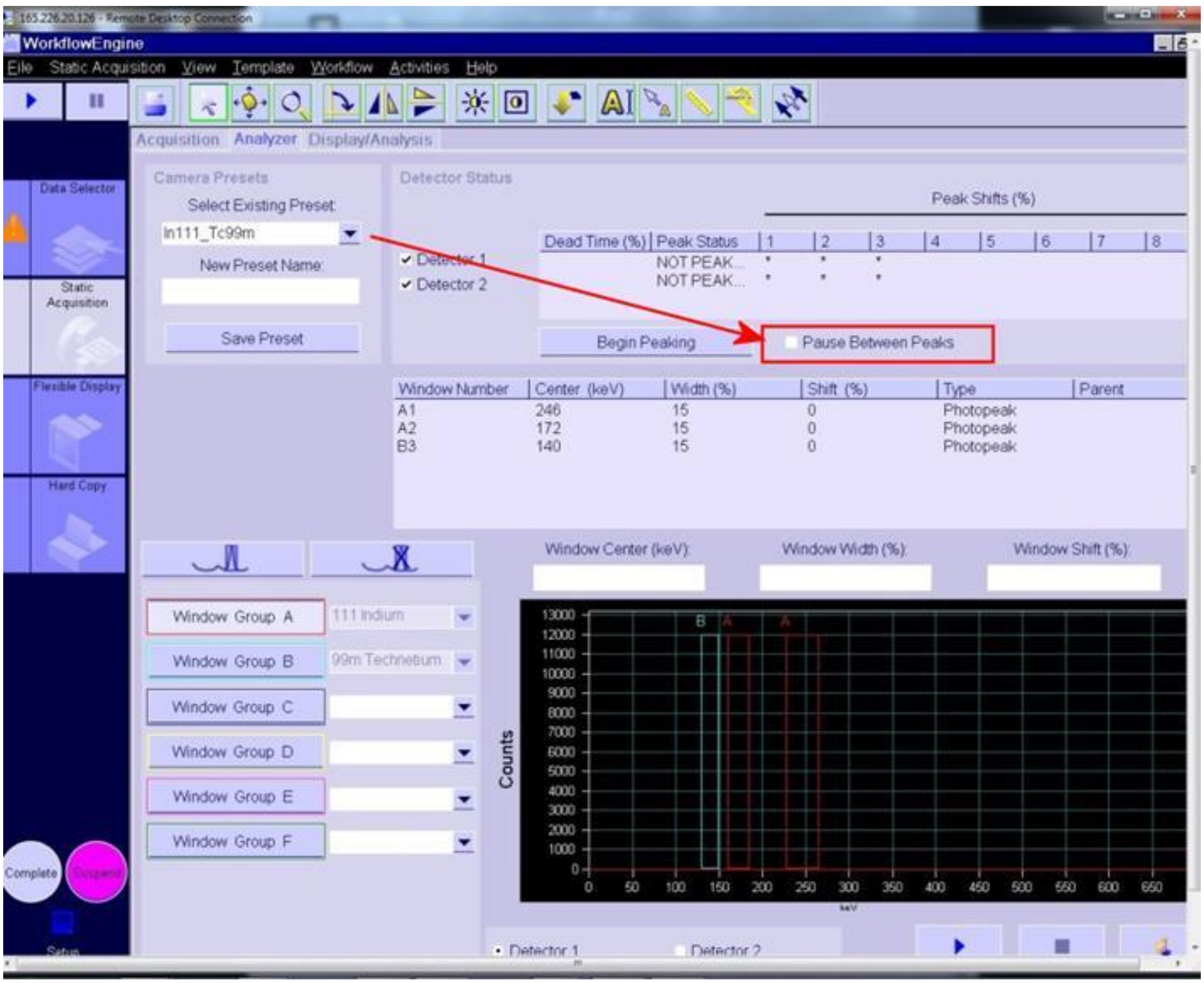
Analyzer peaking is stored on the acquisition workstation (rather than in the SNAC or in the detector) in a database named GDS.mdb. The GDS will be discussed later in this document.

Tech-Support Tip: One important reason to never click on "Clear DACs" (unless someone from Siemens Service has advised you to perform that function) is because clearing the PMT Gain DACS will require Coarse Tuning afterwards, and those actions also clear all the peaking values stored in the GDS.

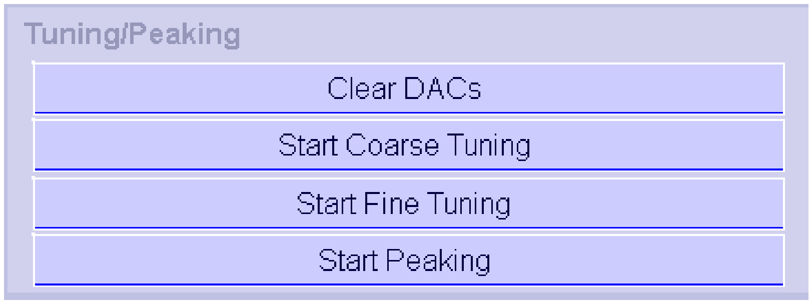
When creating and **peaking a dual isotope** (e.g. In111 & Tc99m), a separate vial is needed for each isotope, and then the user will utilize 'Pause Between Peaks" (see screenshot below). The user will start with the isotope configured as A1 in the system's point source holder, and then select "Begin Peaking."

In the example below, A1 & A2 are set to In111, which has both a 246 15% and 172 KEV 15% window. In this example, the detectors will peak A1 and A2; and afterwards, the system will prompt the user to change sources, and click OK. After the user has swapped vials in the point source holder and then clicked OK, the system will peak B3, which is setup for Tc99m, which has a 140 KEV 15% window.

Tech-Support Tip: When peaking two separate isotopes, keep the vial containing one isotope in the Hot Lab while peaking using the vial containing the other isotope. Otherwise, the second isotope may interfere with peaking the first isotope and vice versa.



When running the Tuning workflow, the user has four Tuning/Peaking options:



Clear DACs causes the High Voltage and each of the 59 PMT Gain Values to be reset to a default value.

Start Coarse Tuning is needed after the PMT Gain DACs have been cleared. During Fine Tuning, either a cobalt or technetium analyzer is selected, and then a predetermined number of counts are acquired in either the Lower Level (LL) or the Upper Level (UL) for each PMT. However, when a PMT is reset to its default Gain Value, the output of that PMT might be outside the energy range of the selected analyzer. Therefore, a wider energy window is needed.

When a user selects Coarse Tuning, rather than using a 15% analyzer window for technetium or a 20% analyzer window for cobalt, the tuning algorithm automatically switches to a 75% window. After all the PMT's have been adjusted for an output within the aforementioned 15 or 20% window, the algorithm automatically narrows the energy window to the analyzer's default values.

Specifically, the Coarse Tuning algorithm uses a 75% analyzer window until the Tune Values are less than +/- 029 for the inner PMT's and less than +/- 039 for the edge PMT's. Once those Tune Values are obtained, the analyzer automatically narrows to 15% or 20% according to the selected analyzer. Afterwards, the tuning algorithm continues until the Tune Value of the inner PMT's are less than +/- 021 and the Tune Value for the edge PMT's is less than +/- 014. That's why this is called "coarse" tuning.

After Coarse Tuning has successfully completed, then the user should **Start Fine Tuning**. As previously noted, the ultimate goal when tuning a detector is to have all Tune Values between +/- 007, which indicates all the PMT's are within 1.4% of each other. Fine Tuning will fail unless the aforementioned goal is achieved.

Note: HD Detectors can perform both Coarse Tuning and Fine Tuning; whereas, Foresight Detectors only perform Fine Turing. Foresight Detectors use a different tuning algorithm than HD Detectors.

Tech-Support Tip: Whenever there is a circular hole in a flood which is the size and shape of a PMT, a quick test is to remove the collimators and flood the crystal with a cobalt or technetium point source. Launch the Tuning workflow and select the Analyzer tab. At the bottom of the window is the spectrum display section. Select the appropriate detector, and then start the spectrum display.

While running the spectrum display, the system opens an extremely wide analyzer. Therefore, if there are no holes in the flood on the PPM while the spectrum display is running, the detector will probably tune. Conversely, if any holes are still on the PPM present during the spectrum display, then the detector will definitely not tune.

Be advised that a Coarse Tune is needed to recover from a hole in the flood problem; a Fine Tune will not correct a hole in the flood problem because the output of one or more PMT's is outside the normal cobalt or technetium analyzer window.

An **Intrinsic Flood Calibration** is acquired using the same setup as peaking or Fine Tuning. A technetium or cobalt point source is placed midway between the two detectors, and then 200 million counts are acquired simultaneously from each detector. To a physicist, the image displayed as the intrinsic calibration flood is called an "**uncorrected flood**."

NOTE: An Intrinsic Flood Calibration should not be confused with a NEMA test of intrinsic uniformity. The former is a calibration, whereas the latter is a test. A NEMA test of intrinsic uniformity requires extremely precise positioning of a point source, contained within a shielded point source holder, and placed at least five Field of Views from the detector. Consequently, physicists and end-users should not expect an Intrinsic Calibration Flood to produce NEMA results.

An Intrinsic Calibration Flood creates an intrinsic correction table for each detector. That table is stored on the acquisition workstation (rather than in the SNAC or in the detector) in a database named GDS.mdb with the images in a BINARY DATA folder. Since QC is stored in the aforementioned locations, deleting the corresponding QC images from the patient database has no effect on the system. For example, deleting APRIL MONTHLY FLOODS via the Patient Browser has no effect whatsoever on the QC stored in GDS.mdb and the BINARY DATA folder.

For systems with Automatic QC, the end-user can acquire an Intrinsic Calibration Flood using either technetium or cobalt. Afterwards, technetium intrinsic verification floods and all patient images will have technetium corrections applied, if an intrinsic calibration was acquired with technetium; whereas, cobalt intrinsic verification floods and all patient images will have cobalt corrections applied, if an intrinsic calibration was acquired with cobalt.

Technetium and cobalt floods are considered "master corrections" since they are applied to all isotopes. If both a technetium and a cobalt intrinsic calibration are performed, all isotopes will have either the technetium or cobalt corrections applied, depending upon which correction is most recent.

End-users also have the option to acquire **isotope-specific corrections** if they desire. For example, in addition to the technetium or cobalt calibration flood, an end-user can acquire an Intrinsic Flood Calibration using thallium or gallium. Afterwards:

- Thallium verification floods and thallium patient images will have thallium corrections applied.
- Gallium verification floods and gallium patient images will have gallium corrections applied.
- All other isotopes will still have technetium or cobalt corrections applied, depending upon which correction is most recent.

However, since technetium and cobalt Intrinsic Calibration Floods are considered "master corrections," the next time a technetium or cobalt Intrinsic Calibration Flood is acquired; it will take precedence over any and all isotope-specific floods. In other words, the thallium and gallium corrections will no longer be applied.

Therefore, the proper QC sequence is:

[1] Acquire a technetium or cobalt Intrinsic Flood Calibration.
[2] If needed, acquire isotope-specific Intrinsic Flood Calibrations.

If the above sequence is reversed, the isotope-specific corrections will not be applied. Instead, the master calibration would take precedence, since it was acquired most recently.

A new Intrinsic Flood Calibration should be acquired once a month. This is the reason the workflow is named, "Monthly Intrinsic Flood Calibration."

CUSTOMER GENERATED EXTRINSIC CORRECTIONS

During system installation, an Intrinsic Flood Calibration is performed, followed by an **Extrinsic Flood Calibration** for each collimator. An Extrinsic Flood Calibration is usually performed with a cobalt sheet source, although end users have the option of using a technetium/saline filled sheet source.

Be advised that a separate Extrinsic Calibration is needed for each collimator, with the exception of a Pinhole Collimator.

Collimator-specific correction tables are stored on the acquisition workstation (rather than in the SNAC or in the detector) in a database named GDS.mdb with the images in a BINARY DATA folder.

Mathematically, the system subtracts the intrinsic calibration from the extrinsic calibration, and the difference is the **Collimator Correction**. After acquiring an Extrinsic Flood Calibration, a Collimator Correction is stored in GDS.mdb and the BINARY DATA folder for that specific collimator. The next paragraph will explain how that Collimator Correction is utilized.

HOW AN INTRINSIC CALIBRATION UPDATES ALL FLOOD CORRECTIONS

As previously discussed, detector optics unavoidably change over time. Likewise, electronic components drift over time. For these reasons, end-users should acquire an **Intrinsic Flood Calibration** once a month. Conversely, the imaging sections of collimators are merely honeycomb-shaped pieces of lead; and therefore, collimators typically they do not change over time unless physically altered or damaged.

Mathematically, the system adds a new Intrinsic Flood Calibration to an existing Collimator Correction, and then the result is a new extrinsic **Flood Correction** that can be applied to all subsequent images for the applicable collimator. Consequently, this means that (in theory) end-users do not have to repeat Extrinsic Flood Calibrations unless either:

[A] A collimator has been altered, damaged, or replaced.
[B] A detector has been reburned or replaced.

Instead, simply acquiring an **Intrinsic Flood Calibration** will automatically update the **Flood Correction** for every collimator and every isotope.

To summarize:

Extrinsic Flood Calibration - Intrinsic Flood Calibration = Collimator Correction

Afterwards:

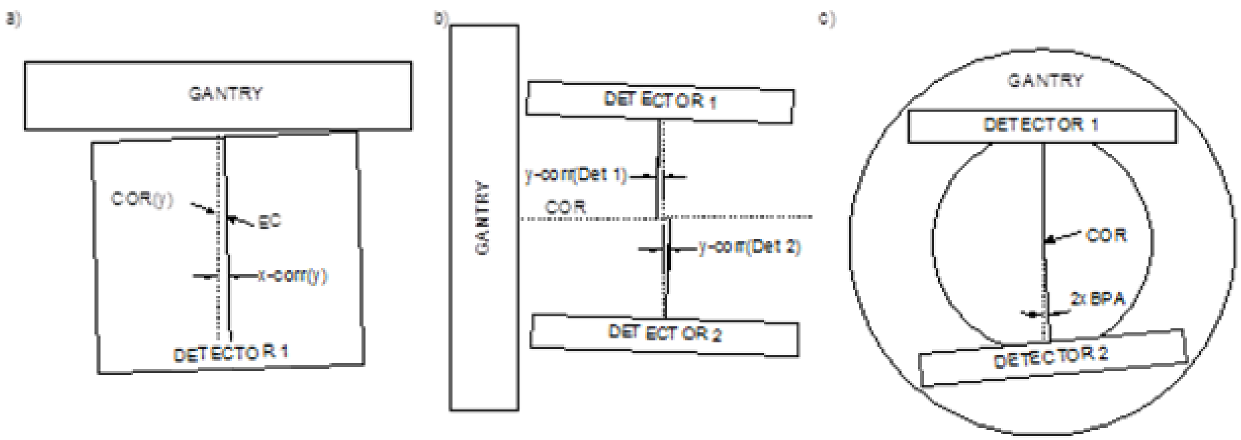
Intrinsic Flood Calibration + Collimator Correction = Flood Correction

The above calculations save customers from acquiring Extrinsic Flood Calibrations every month.

Tech-Support Tip: Not needing to repeat Extrinsic Flood Calibrations is true in theory. However, over the life of a system, some detector components (PMT's, power supplies, and other electronic assemblies) that were used to originally acquire Intrinsic and Extrinsic Flood Calibrations might be replaced. Due to manufacturing tolerances, when replacing any electronic part, no two components have 100% identical operating characteristics. Therefore, in some instances, replacing a detector component may necessitate acquiring an updated Extrinsic Flood Calibration.

CUSTOMER GENERATED HEAD ALIGNMENT CALIBRATIONS

Single Head SPECT cameras require a COR (Center of Rotation) Calibration. This procedure corrects any deviations in a system's circular orbit. Dual Head SPECT cameras not only need to have their orbit corrected, they also require corrections for any misalignment between the two detectors. See examples below.



Originally, Siemens called the procedure to acquire these corrections on Dual Head cameras a **Multi Head Registration**. Nowadays, it's commonly known as a **Head Alignment Calibration.**

Be advised that a separate Head Alignment Calibration is needed for each "collimator set /configuration angle" that will be used for TOMO acquisitions. For example:

- Smart Zoom Collimators with detectors configured 76 degrees apart.
- Low Energy High Resolution Collimators with detectors configured 76 degrees apart.
- Low Energy High Resolution Collimators with detectors configured 90 degrees apart.
- Low Energy High Resolution Collimators with detectors configured 180 degrees apart.
- Medium Energy Collimators with detectors configured 180 degrees apart.
- High Energy Collimators with detectors configured 180 degrees apart.

Head Alignment Calibrations are performed by acquiring a TOMO acquisition using multiple point sources. Upon completion, collimator / detector configuration specific correction tables are stored on the acquisition workstation (rather than in the SNAC or in the detector) in a database named GDS.mdb with the images in a BINARY DATA folder. After a Head Alignment Calibration is stored in the GDS.mdb, a Head Alignment correction table is applied to all isotopes when using the specific collimator / detector configuration for TOMO imaging.

CUSTOMER GENERATED COR AND NCO CALIBRATIONS

Single Head camera system (such as an ECAM Single Head or a Symbia-E Single Head) obviously do not need a Multi Head Registration Calibration. Instead, Single Head Cameras require a **COR (Center of Rotation) Calibration** to correct any deviations in a system's circular orbit.

On a Dual Head ECAM or a Dual Head Symbia-E, the entire gantry shifts left/right during TOMO acquisitions. Therefore, in addition to needing an MHR or Head Alignment Calibration, these systems require an **NCO (Non Circular Orbit) Calibration**. An NCO Calibration corrects any deviations caused by the left/right movement of the gantry.

QC APPLIED TO PATIENT SCANS

All images have **ZLC Corrections** applied to them. These corrections as embedded in the gamma camera; and therefore, customers cannot alter or disable them. In short, all image data sent from the detectors to the acquisition workstation has ZLC Corrections automatically applied. Once image data is received on the acquisition workstation, additional corrections are applied based upon QC stored in the GDS.mdb and the BINARY DATA folder.

As previously described, ECAM and Symbia systems have both Intrinsic Flood Calibrations and Extrinsic Flood Calibrations. Unlike some systems (e.g., a Siemens CCAM) that allow a user to select which calibration to apply, Siemens ECAM and Symbia system create a **Flood Correction** which is applied to all patient scans. Customers cannot disable Flood Correction from being applied.

Additionally, all TOMO acquisitions have a **Head Alignment Calibration** applied. Unlike Siemens ICON workstations, customers cannot disable this calibration from being applied.

Every Siemens collimator has a circuit board affixed to it called a **Collimator Identification Board (CID)**. Among other things, a CID is programmed with the Collimator Type and Serial Number. For example, a Dual Head system might have the following:

Low Energy High Resolution Collimator Serial Number 23517
Low Energy High Resolution Collimator Serial Number 23518

Medium Energy Low Penetration Collimator Serial Number 2811
Medium Energy Low Penetration Collimator Serial Number 2812

When preparing or starting an acquisition, the CID for both collimators is read, and then the GDS.mdb and BINARY DATA folder are searched for a corresponding collimator specific Flood Correction for each detector. If a Flood Correction is not found, a **QC Alert** will be displayed to the user.

When preparing or starting a TOMO acquisition, in addition to checking each detector's CID, the detector configuration angle is read from the gantry. For example, 76, 90 or 180. Afterwards, the GDS.mdb and BINARY DATA folder are searched for a corresponding combination of the installed collimator set and the detector configuration angle. If not found, a **QC Alert** will be displayed to the user.

Users may also see a **QC Alert** if either of the aforementioned calibrations is more the 30 days old.

Be advised that:

- A QC Alert that a calibration is "missing" always indicates a problem.

- A QC Alert that a calibration is "out of date" does not always indicate a problem, with the exception of an out of date Intrinsic Flood Calibration and/or an out of date Sensitivity Calibration (to be discussed later in this document).

A common question from end users is why would a QC Alert appear indicating QC is out of date when each of the QC requirements has been completed? The following section will answer that question.

SIEMENS RECOMMENDED QC

After the installation of an ECAM or Symbia system has been completed, the end user is responsible for performing Quality Control and Assurance. In most cases, the diagnostic facility will obtain a license to use radioactive materials from their state's regulatory agency, and that license states the local facility will adhere to the OEM (Original Equipment Manufacturer) Guidelines for Quality Control.

Important Note: End users should always perform each and every test listed in their license to use radioactive materials from their state's regulatory agency. Their license may include tests other than the ones recommended by the Original Equipment Manufacturer.

For ECAM and Symbia gamma cameras, the OEM Guidelines for Quality Control are listed in the System's User's Manual, Operating Instructions or Operator Manual that was supplied with the system upon its delivery. Each manual contains a chapter entitled, Quality Control and Assurance, and that chapter contains a System Calibration Schedule.

As an example, the **System Calibration Schedule** for a Symbia-T16 with syngo MI Applications software version VB10 is shown in the Operators Manual as shown on the following page:

Performed	Quality Control Procedure	Source
Daily for NM	Intrinsic Verification, or Extrinsic Verification or Extrinsic Sweep	35 µCi of Tc99m, or Co-57 sheet source AutoQC source
Daily for CT	CT Checkup - every 12 hours CT Quality - daily CT Calibration - after 1 hour or if ring artifacts occur	
Weekly for NM	Intrinsic Verification with Tune	35 µCi of Tc99m AutoQC source
Monthly for NM	Intrinsic Calibration with Tune	35 µCi of Tc99m AutoQC source

Performed	Quality Control Procedure	Source
Monthly for NM	Multiple Head Registration (MHR) 180° Head Alignment Verification	1-2 mCi of Tc99m per source (Match sources within 20% of each other for Tc99m only) AutoQC source
Monthly for users performing quantitative studies	Sensitivity Calibration	1-5 mCi of Tc99m, or Precision Co-57 point source
Monthly for CT	CT Constancy Test	
Every 6 months or per Regulatory/License requirements	Perform a leak test of the automated quality control device sources.	Gd-153 line source and Co-57 point source
If the collimator is damaged or replaced.	Intrinsic Calibration, and Extrinsic Calibration for collimator MHR for collimator Head Alignment Calibration for collimator	See source strengths above.
Significant change to Head Alignment values for the reference of Low Energy Parallel Hole collimator	Multiple Head Registration (MHR) 180° Head Alignment Calibration	1-2 mCi of Tc99m per source (Match sources within 20% of each other for Tc99m only) AutoQC source

As shown above, a Head Alignment Verification is required on a monthly basis for a Symbia-T16 with VB10 software, whereas a Multiple Head Registration (MHR) Calibration or Head Alignment Calibration is not. As of this writing, whether a Monthly Head Alignment Calibration is required depends upon the System Type and Software Version (see below).

System Type	Software Version	Monthly Head Alignment Calibration Required
Symbia-S	VA60	No (see Operating Instructions page 233)
Symbia-S	VB10	No (see Operator Manual page 211)
Symbia-S	VB20	No (see Operator Manual page 223)
Symbia-S	VB21	No (see Operator Manual page 223)
Symbia-S	VB22	No (see Operator Manual page 239)
Symbia-T	VA60	No (see Operating Instructions page 255)
Symbia-T	VB10	No (see Operator Manual page 246)
Symbia-T	VB20	Yes (see Operator Manual page 257)
Symbia-T	VB21	Yes (see Operator Manual page 257)
Symbia-T	VB22	Yes (see Operator Manual page 253)
Symbia Evo	VB20	No (see Operator Manual page 225)
Symbia Evo	VB21	No (see Operator Manual page 225)
Symbia Evo	VB22	No (see Operator Manual page 239)
Symbia Evo Excel	VB10	No (see Operator Manual page 187)
Symbia Evo Excel	VB20	No (see Operator Manual page 193)
Symbia Evo Excel	VB21	No (see Operator Manual page 193)
Symbia Evo Exce	VB22	No (see Operator Manual page 201)
Symbia Intevo	VA70	No (see Operating Instructions page 260)
Symbia Intevo	VB10	Yes (see Operator Manual page 246)
Symbia Invevo	VB20	Yes (see Operator Manual page 259)
Symbia Intevo	VB21	Yes (see Operator Manual page 257)
Symbia Intevo	VB22	Yes (see Operator Manual page 253)
Symbia Invevo Bold	VB20	Yes (see Operator Manual page 259)
Symbia Intevo Bold	VB21	Yes (see Operator Manual page 259)
Symbia Intevo Bold	VB22	Yes (see Operator Manual page 251)

You may recall it was previously stated that users may see a **QC Alert** if the MHR or Head Alignment Calibration is more the 30 days old. Whether that's a problem depends upon the table listed above. Some systems require a monthly calibration, while many others do not.

Please note that Siemens Guidelines for Quality Control do not include resolution tests using a Bar Pattern or a Jaszczak Phantom. An end user may perform these tests, but Siemens does not require them.

Many Siemens Symbia cameras have **ACC (Automatic Collimator Change)** and **AQC (Automatic Quality Control)**. These camera systems can perform quality control automatically. Specifically, these systems can automatically remove and reinstall collimators as needed, and these systems contain radioactive sources stored in the Front Bed that can automatically extend and retract to perform various Quality Control procedures.

There are three basic QC groups:

- **Daily QC**
  - Perform uniformity verification for each detector.
  - The flood can be intrinsic, extrinsic, or an extrinsic sweep (AQC systems only).

- **Weekly QC**
  - Tune each detector.
  - Perform intrinsic uniformity verification for each detector.

- **Monthly QC**
  - Tune each detector.
  - Perform an intrinsic uniformity calibration for each detector.
  - Perform a Head Alignment verification on one collimator set at 180 configuration.
  - Perform Sensitivity Calibration on systems using licensed Quantitative SPECT features.

In Siemens parlance, **Calibrations** create **Corrections**.

After a calibration is performed, it becomes a correction for all subsequent images. The only three "calibrations" Siemens recommends on a regular basis are Tuning, an Intrinsic Flood Calibration, and a Sensitivity Calibration (if applicable).

In Siemens parlance, **Verifications** prove **Validity**.

Verifications ensure the corrections (from the most recent calibrations) are being applied and are valid.

While a system may have multiple Extrinsic Flood Calibrations and multiple Head Alignment Calibrations, end users do not have to perform those calibrations on a daily, weekly or monthly basis. For this reason, users may see an occasional QC Alert if either of the aforementioned calibrations is more the 30 days old. This alert is merely informing the end user of the number of days since the last calibration was performed. The alert usually does not indicate a problem.

Please note the Monthly QC recommends a lone Head Alignment 180 Verification rather than a Head Alignment calibration on every collimator set at every detector configuration angle. During Monthly QC, the system performs a TOMO acquisition on one set of collimators with the detectors configured 180 degrees apart; and if that TOMO matches the stored Head Alignment 180 Calibration for that collimator set at that detector configuration, then there is no reason to perform any other Head Alignment QC.

If a customer wishes to perform Head Alignment calibrations rather than verifications, they should run the **Head Alignment Calibration All** workflow. It will acquire a Head Alignment Calibration at "all" configuration angles for the collimator set currently installed on the detectors.

A common question from end users is, "What **uniformity values** are acceptable for floods?" The answer depends upon the type of flood.

A Siemens workstation will indicate four uniformity values to an end user.

- ✓ Integral Uniformity: Center Field of View (CFOV)
- ✓ Differential Uniformity: Center Field of View (CFOV)

- ✓ Integral Uniformity: Useful Field of View (UFOV)
- ✓ Differential Uniformity: Useful Field of View (UFOV)

Integral Uniformity indicates the maximum deviation within a specified area, while differential uniformity indicates the maximum rate of change over a specified distance (typically 5 adjacent pixels). For more information, refer to the NEMA Standards at the end of this document.

- ✓ UFOV (Useful Field of View) is 95% of a detector's entire Field of View.
- ✓ CFOV (Center Field of View) is 75% of the UFOV.

Intrinsic Flood Calibration Uniformity Values: Uniformity specifications for an Intrinsic Flood Calibration are not listed in the ECAM or Symbia Operating Instructions chapter on Quality Control and Assurance. Instead, the manual states, "The Intrinsic Calibration flood should be reviewed for major uniformity defects consistent with crystal damage, defects, or detector malfunction. Mild variations in uniformity may occur with a properly functioning detector and will be improved by the uniformity correction. In general, uniformity calibrations can compensate for values up to 10%; however, if the integral uniformity exceeds 7%, contact your Siemens Customer Service Representative."

Be advised that according to Siemens MI-SPECT Headquarters:

> The operator's manual reads: 'If Calibration Integral Uniformity exceeds 7% call service, system can be used with values up to 10%'. The 10% number is based on our clinical experience and supports the fact that non-uniformities up to 10% may be corrected for without impacting clinical image quality. It is recommended that service be notified of potential problems when the integral uniformity exceeds 6% and a ZLC regeneration be scheduled when it exceeds 7%.

When the Intrinsic Flood Calibration Integral Uniformity UFOV exceeds 7%, the first step is for the end user to check for background radiation, and then generate pedestals, perform Fine Tuning, and acquire another Intrinsic Flood Calibration. These are the "user calibrations."

Afterwards, if the aforementioned uniformity value still exceeds 7%, then a Siemens Service Representative should be dispatched to test and fully calibrate the detector, and to replace parts if needed. If there are no failed parts and all tests and calibrations complete successfully, but the Integral Uniformity UFOV uniformity still exceeds 7%, then a regeneration of coefficients is needed.

Extrinsic Flood Calibration Uniformity Values: There are no published specs for Extrinsic Flood Calibrations, because extrinsic uniformity is based not only upon the detector; but also, upon the sheet source and the collimator. Consequently, when running an Extrinsic Calibration workflow, no uniformity values are displayed. That said, each Extrinsic Flood Calibration should be visually inspected for any uniformity defects consistent with collimator damage, defects, or detector malfunction. An Extrinsic Flood tests both the detector and the collimator.

Intrinsic Flood Verification Uniformity Values: According to the ECAM or Symbia Operating Instructions chapter on Quality Control and Assurance, the specs for an Intrinsic Flood Verification are:

- ✓ Integral: 5% CFOV and 6% UFOV
- ✓ Differential: 2.5% CFOV and 3% CFOV

Extrinsic Flood Verification Uniformity Values: According to the ECAM or Symbia Operating Instructions chapter on Quality Control and Assurance, the specs for an Extrinsic Flood Verification are:

- ✓ Integral: 5% CFOV and 6% UFOV
- ✓ Differential: 3.5% CFOV and 4% CFOV

Extrinsic Sweep Verification Uniformity Values: According to the Symbia Operating Instructions chapter on Quality Control and Assurance, the specs for an Extrinsic Sweep Verification are:

- ✓ Integral: 5% CFOV and 6% UFOV
- ✓ Differential: 3.5% CFOV and 4% CFOV

Tuning is performed using either a 30 to 35 microcurie technetium point source or a 50 microcurie cobalt point source stored inside the Front Bed for systems with AQC.

Intrinsic Floods are acquired using either a 30 to 35 microcurie technetium point source or (for systems with AQC) a 50 microcurie cobalt point source stored inside the Front Bed.

Extrinsic Floods are acquired using either a 5 or 10 millicuries cobalt or technetium sheet source.

Extrinsic Sweep Verification Floods are acquired using a 10 millicurie gadolinium rod source which is stored inside the Front Bed. Extrinsic Sweep Floods are only acquired on systems with AQC. After the rod source is extended from the bed, each detector “sweeps” across the rod to create a full flood.

Multi Head Registration or **Head Alignment** TOMO acquisitions are acquired using 3 to 5 technetium point sources of 1.0 millicurie each or (for systems with AQC) the 10 millicurie gadolinium rod is extended and then a MHR Sleeve is extended encircling the rod. This sleeve has a series of small holes to simulate multiple point sources.

Sensitivity Calibration is required for a Symbia Intevo if the system is used to perform quantification analysis. This test compares the count rates of the two detectors; and therefore, a 3.15 millicurie Co-57 bullet source is shipped with the system for this purpose. The source attaches to the end of the Front Bed source holder, and the test takes about 10 minutes. First, the detectors must be tuned using the same isotope as used for the sensitivity calibration, and then an acquisition is performed using the aforementioned bullet source with collimators installed. The count rate of the detectors must be within 8%. A QC Alert will appear if 30 days have passed since the last Sensitivity Calibration. This alert should not be ignored.

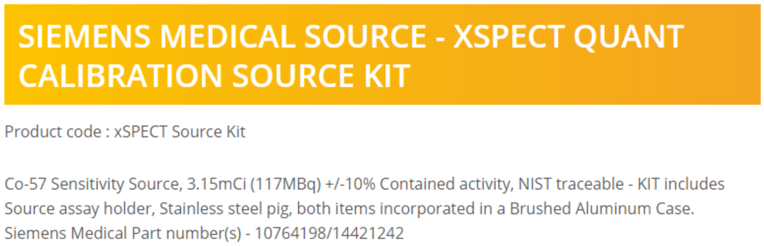
AQC Point Source: This device is a 50 microcurie Co-57 point source. Replenishment is recommended every 12 months. The source is manufactured by Eckert & Ziegler Isotope Products and its part number is **PHI-0124**.

AQC Line Source: This device is a 10 millicurie Gd-153 rod source. Replenishment is recommended every 24 months. The source is manufactured by Eckert & Ziegler Isotope Products and its part number is **HEGL-0133**.

Sensitivity Bullet Source & Button Source

If the system has AQC, then the AQC Point Source is used to tune the detectors with Co-57. Afterwards, a 3.15 millicurie Co-57 bullet source is needed to perform Sensitivity Testing. Replenishment is recommended every 24 months. The source is manufactured by Eckert & Ziegler Isotope Products and its product code is **xSPECT Source Kit**. It's called a kit because it includes the source (**PHI-0129**) along with a stainless steel pig, and both items are stored within a brushed aluminum case.

The below screenshot is from the Eckert & Ziegler Isotope Products website (http://www.ezag.com).


SIEMENS MEDICAL SOURCE - XSPECT QUANT CALIBRATION SOURCE KIT

Product code : xSPECT Source Kit

Co-57 Sensitivity Source, 3.15mCi (117MBq) +/-10% Contained activity, NIST traceable - KIT includes Source assay holder, Stainless steel pig, both items incorporated in a Brushed Aluminum Case.
Siemens Medical Part number(s) - 10764198/14421242

If the system does not have AQC but requires Sensitivity Calibration, then a 50 microcurie Co-57 button source is needed to tune the detectors prior to Sensitivity Calibration. Be advised that both the aforementioned bullet source (**PHI-0129**) and the button source for Tuning shown below (**GF0093**) are available in a single kit containing both sources. Replenishment is recommended 24 months. The kit is manufactured by Eckert & Ziegler Isotope Products, and its product code is **xSPECT Source Kit w/Peaking**."

Below is the contact information for the manufacturer of the AQC sources:

Eckert & Ziegler Isotope Products Inc. (http://www.ezag.com)
24937 Avenue Tibbitts
Valencia, CA 91355
USA
Tel. +1 661-309-1010
Fax +1 661-257-8303

When ordering sealed, medical sources from Eckert & Ziegler Isotope Products, each order includes a one-for-one, like-for-like exchange.

MONTHLY AQC

For systems with ACC and AQC, the **Monthly QC Suite** workflow automatically performs each of the following:

- Remove collimators
- Tune Detector 1
- Tune Detector 2
- Acquire an Intrinsic Flood Calibration for both detectors.
    - Simultaneously acquire 200 million counts on each detector.
    - Each image is 1024 x 1024.
- Acquire an Intrinsic Flood Verification for both detectors.
    - Simultaneously acquire 10 million counts on each detector.
    - Each image is 1024 x 1024.
- Install collimators.
- Acquire a Head Alignment TOMO Verification
    - Simultaneously acquire 60 views from each detector.
    - 120 total views / 256 x 256 matrix.
    - Acquires 25k counts on Detector 1; afterwards, acquires each of the remaining 119 views for that same amount of time it initially took to acquire 160k counts.
- Acquire Extrinsic Sweep Verification Flood.
    - 66 views on Detector 1, and upon completion, 66 views on Detector 2.
    - 132 total views / 256 x 256 matrix
    - Acquires 160k counts on Detector 1; afterwards, acquires each of the remaining views for the same amount of time it initially took to acquire 160k counts.
    - On each detector, 66 views at 160k counts per view = 10 million counts total.

Be advised that the Monthly QC Suite performs an Intrinsic Flood Calibration, but it does not perform a Head Alignment Calibration or an Extrinsic Flood Calibration. Instead, verifications are performed. Consequently, customer utilizing the Monthly QC Suite may occasionally see a QC Alert which indicates the number of days since the last MHR Calibration and/or the last Extrinsic Calibration was performed. This alert is merely for informational purposes; it usually does not indicate a problem.

WEEKLY AQC

For systems with ACC and AQC, the **Weekly Intrinsic QC Suite** workflow automatically performs each of the following:

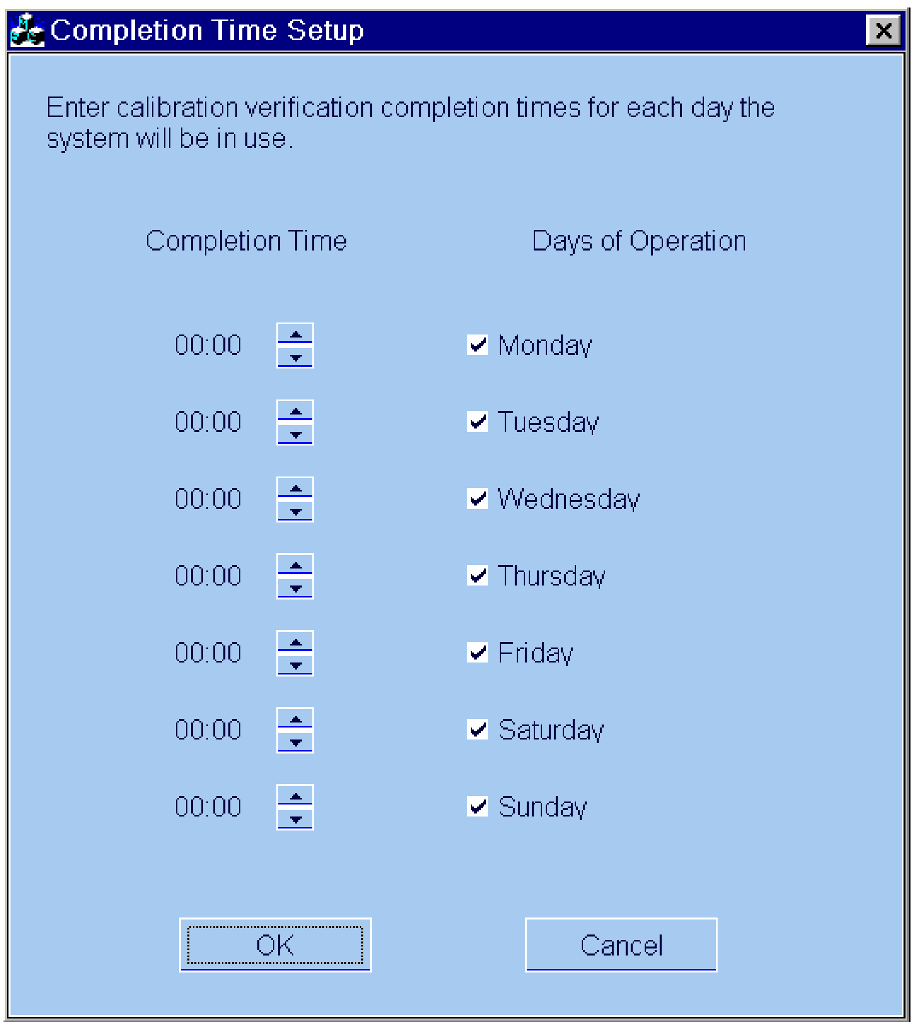
- Remove collimators
- Tune Detector 1
- Tune Detector 2
- Acquire an Intrinsic Flood Verification for both detectors.
    - Simultaneously acquire 10 million counts on each detector.
    - Each image is 1024 x 1024.
- Install collimators.
- Acquire Extrinsic Sweep Verification Flood.
    - 66 views on Detector 1, and upon completion, 66 views on Detector 2.
    - 132 total views / 256 x 256 matrix
    - Acquires 160k counts on Detector 1; afterwards, acquires each of the remaining views for the same amount of time it initially took to acquire 160k counts.
    - On each detector, 66 views at 160k counts per view = 10 million counts total.

DAILY AQC

For systems with ACC and AQC, the **Extrinsic Sweep Verification Auto** workflow automatically performs the following:

- Acquire Extrinsic Sweep Verification Flood.
  - 66 views on Detector 1, and upon completion, 66 views on Detector 2.
  - 132 total views / 256 x 256 matrix
  - Acquire 160k counts on Detector 1 and 160k count on Detector 2.
  - Afterwards, acquire each view on Detector1 for the same amount of time it initially took to acquire 160k counts on Detector 1.
  - And then acquire each view on Detector 2 for the same amount of time it initially took to acquire 160k counts on Detector 2.
  - 66 views at 160k counts per view = ~ 10 million counts total.

For systems with AQC, the end user will setup a scheduled time for the aforementioned workflow to complete on each day of the week by selecting **Options > Configuration > syngo MI Acquisition Settings** on menu bar along the top of the acquisition computer screen. Below is the default Completion Time Setup window.

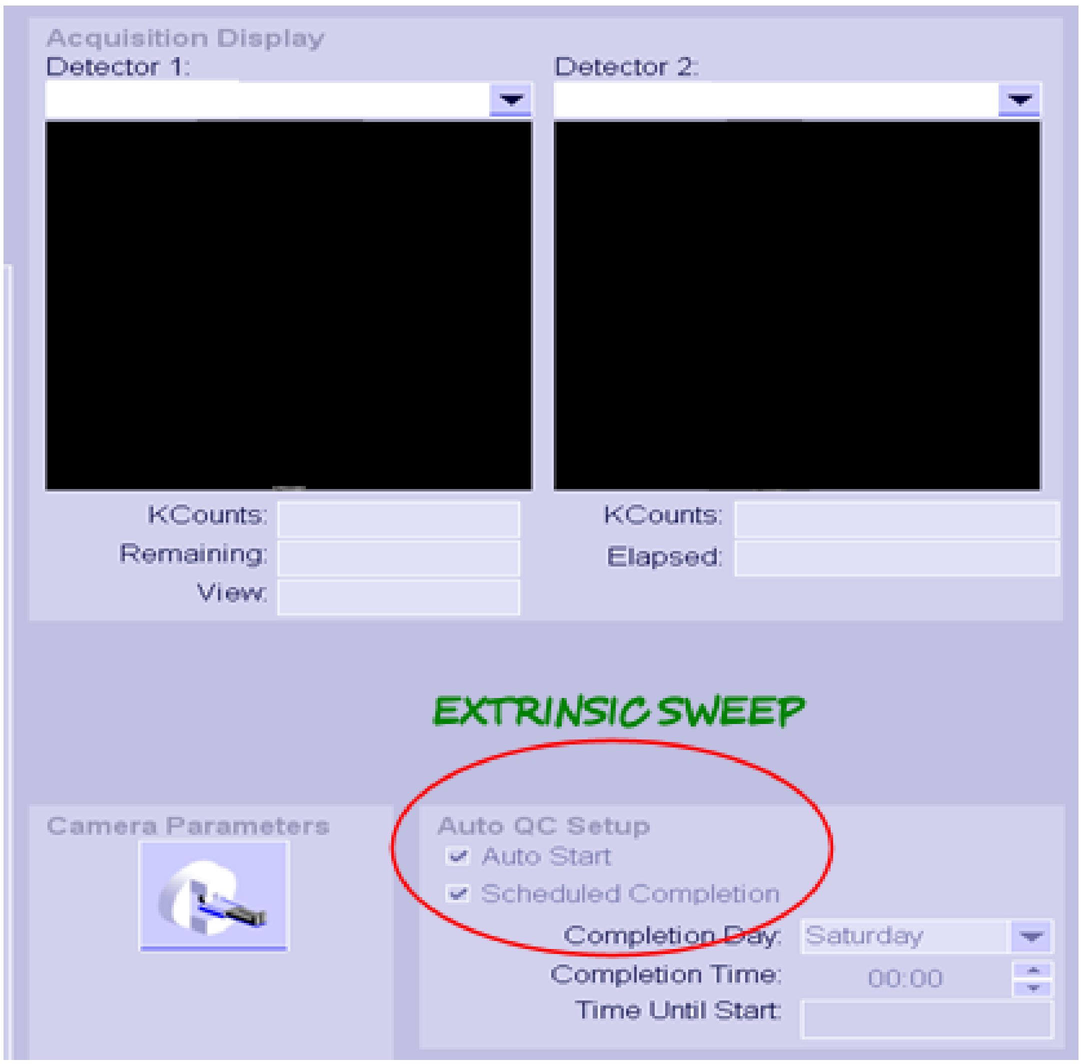


Tech-Support Tip: A common mistake is incorrectly configuring the individual AQC workflows. Specifically:

Auto Start must be enabled for each acquisition "activity" within the AQC workflow. Otherwise, the AQC workflow will stop at that activity and await user intervention.

Conversely, **Scheduled Completion** should only be enabled and setup for last acquisition "activity" within an AQC workflow. Additionally, the Completion Time within the AQC workflow should match the aforementioned **Options > Configuration > syngo MI Acquisition Settings**.

See example below from the Extrinsic Sweep Verification Auto workflow.



When the aforementioned Extrinsic Sweep Verification Auto workflow is initially launched, Detector 1 is rotated to the 12 o'clock position, the AQC Line Source is extended from the Front Bed, and the system acquires 160k counts on each detector with collimators installed. This process is merely sampling the count rate of the gadolinium line source. Afterwards, the source retracts.

The goal is to acquire a 10 million count extrinsic flood on each detector, and that's accomplished by summing 66 TOMO images of 160k counts per image as a detector "sweeps" across a gadolinium line source. Since there are two detectors and only one extrinsic flood is acquired at a time, the acquisition computer computes the time needed to acquire a total of 20 million counts, based upon the aforementioned count rate sampling.

For example, let's say acquiring 160k counts on each detector takes 30 seconds. Since the count rate is 5333/cps, acquiring 20 million counts will take approximately 60 minutes. If the workflow and **Options > Configuration > syngo MI Acquisition Settings** is setup to complete this workflow at 6 AM every day, then at approximately 5 AM, the line source will automatically extend and Detector 1 will sweep across it. After Detector 1 finishes acquiring 66 images, Detector 2 will rotate above the line source and then it will acquire 66 images while sweeping across the line source. At 6 AM, the workflow completes, and a 10 million count extrinsic flood for each detector is displayed, along with each detector's uniformity values.

Please note that as the gadolinium line source decays, the time needed to complete QC will steadily increase. Gd-153 has a half-life of 8 months; therefore, the time to complete QC doubles every 8 months. This rarely causes an issue with the Weekly QC or Daily QC because:

[A] Those workflows do not include a Head Alignment Verification, and
[B] Those workflows have all night to complete.

However, the increased time needed to complete the Monthly QC usually does not go unnoticed. Specifically, once the gadolinium line source is 18 months past its assay date (i.e., the date the source was created), end users notice the Monthly QC Suite takes 12 hours or more to complete. The typical scenario is for an end user to start the Monthly QC Suite at the end of their workday, and then they are surprised to see that workflow is still running upon their arrival the following morning. In most cases, that never happened in the first 18 months since the line source was installed.

The Monthly QC includes a Head Alignment Verification. During this TOMO acquisition, a MHR Sleeve covers 95% of the line source; and therefore, 18 months after its assay date, the line source is causing very little radiation to strike the detectors.

Below are a few personal observations regarding the time needed to complete a Head Alignment Verification as the line source decays.

Months Past Assay Date	Time to Complete Head Alignment Verification
19	9 hours
21	11.5 hours
25	14 hours

In the Monthly QC Suite, the Head Alignment Verification is preceded by Tuning each detector and by an Intrinsic Calibration Flood and an Intrinsic Verification Flood. Performing these procedures usually takes an hour or longer to complete. Additionally, the Head Alignment Verification is immediately followed by an Extrinsic Sweep Verification. The sweep usually takes four hours or longer, once the line source is 18 months past its assay date.

Long story short, once the line source is 18 months past its assay data, completing the Monthly QC Suite takes 12 hours or longer. For this reason, many end users perform Monthly QC on the weekend, rather than during the week.

ATTENUATION CORRECTION

Attenuation correction is performed on a Symbia-T and similar systems using a CT scanner affixed to the SPECT gantry. Therefore, these systems require a **NM/CT FOV Calibration**. This calibration aligns NM images from the gamma camera with CT images from the CT scanner.

A NM/CT FOV Calibration is required during system installation and whenever the CT scanner and the gamma camera are separated during a service procedure. A separate NM/CT FOV Calibration is needed for each "collimator set / detector configuration angle" that will be used for combined NM/CT imaging.

According to Siemens documentation:

> Talk with the Technologist and determine the applications that each collimator set will be used for.
>
> 1. If certain collimator sets will not be used in conjunction with a CT acquisition, then it is unnecessary to perform the NM CT FOV calibration for those collimator sets.
>
> 2. If certain configuration angles will not be used in conjunction with a CT acquisition with a particular collimator set, then it is unnecessary to perform the NM CT FOV calibration for those angles.
>
> 3. It is not necessary to perform the NM CT FOV calibration for High Energy or Fanbeam collimator sets

While NM/CT FOV Calibration procedures are not listed in a system's Users Guide or Operators Manual, end users often perform these important calibrations, especially if any "**image registration**" problems are observed between NM and CT images.

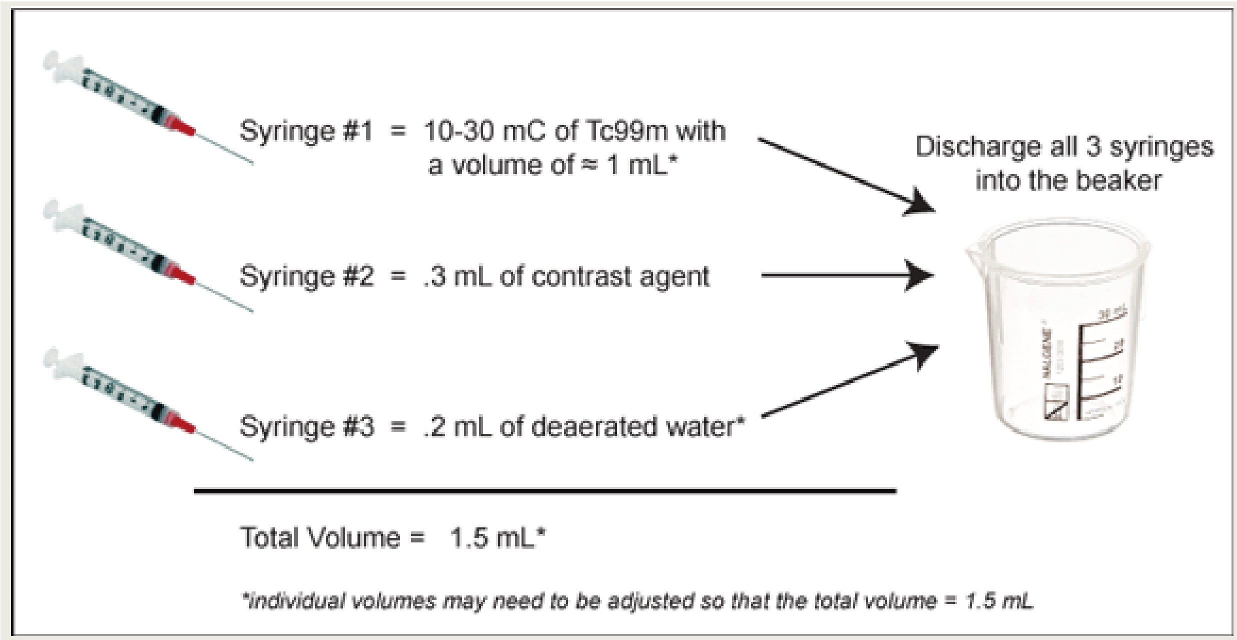
Prior to performing any NM/CT FOV Calibrations, the CT scanner must successfully complete CT Checkup.

Prior to performing NM/CT FOV Calibration calibrations, a valid MHR or Head Alignment Calibration must exist for the "collimator set / detector configuration angle."

NM/CT FOV Calibration uses the following workflows:

- **NM CT FOV Calibration 76**
- **NM CT FOV Calibration 90**
- **NM CT FOV Calibration 180**

Be advised that AQC sources cannot be used for NM/CT FOV Calibrations. Instead, the end user mixes 10 to 30 millicuries of technetium (in a volume of 1.0 mL) with 0.3 mL of contrast agent and 0.2 mL of deaerated water. The resultant 1.5 mL of liquid will be dispensed into 10 separate point source vials.

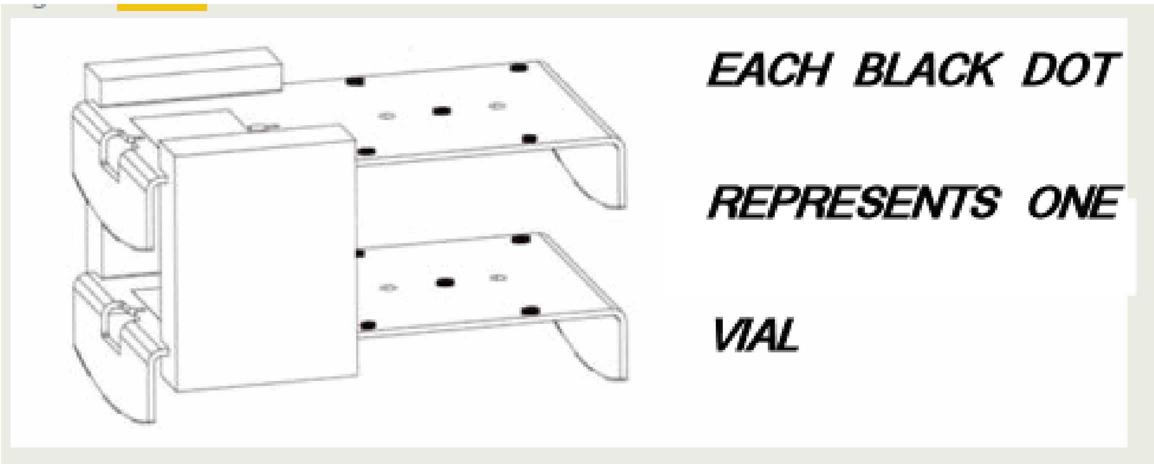


Only ¾ of the conical portion of each vial should contain the aforementioned mixture of technetium and contrast agent. See image below.

To be precise, each vial should only contain 0.15 mL or less of solution in a 4 to 1 water to contrast ratio. No cotton or other material should be placed in the vial.

The objective is for both the gamma camera and the CT scanner to see 10 distinct and very small points. Therefore, it is imperative no technetium or contrast agent is spilled on the any part of the vial other than the conical portion.

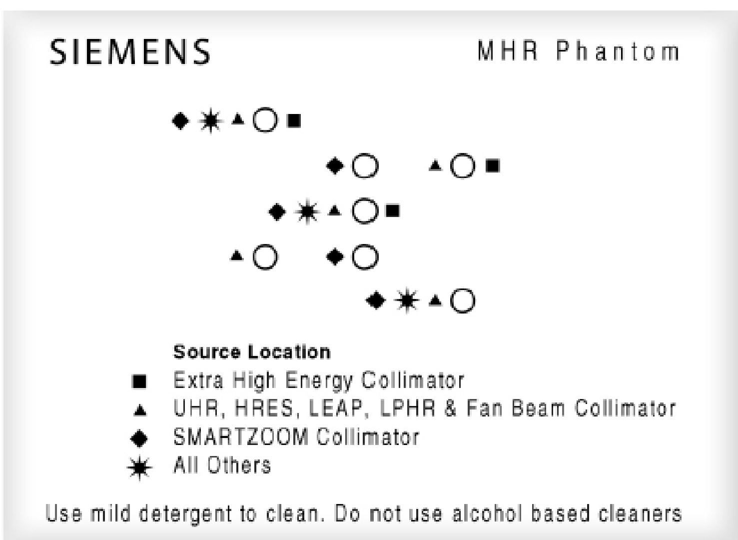
Next the 10 vials are placed into two MHR point source holders, which are then stacked upon each other (as shown below) and placed on the system's patient pallet.



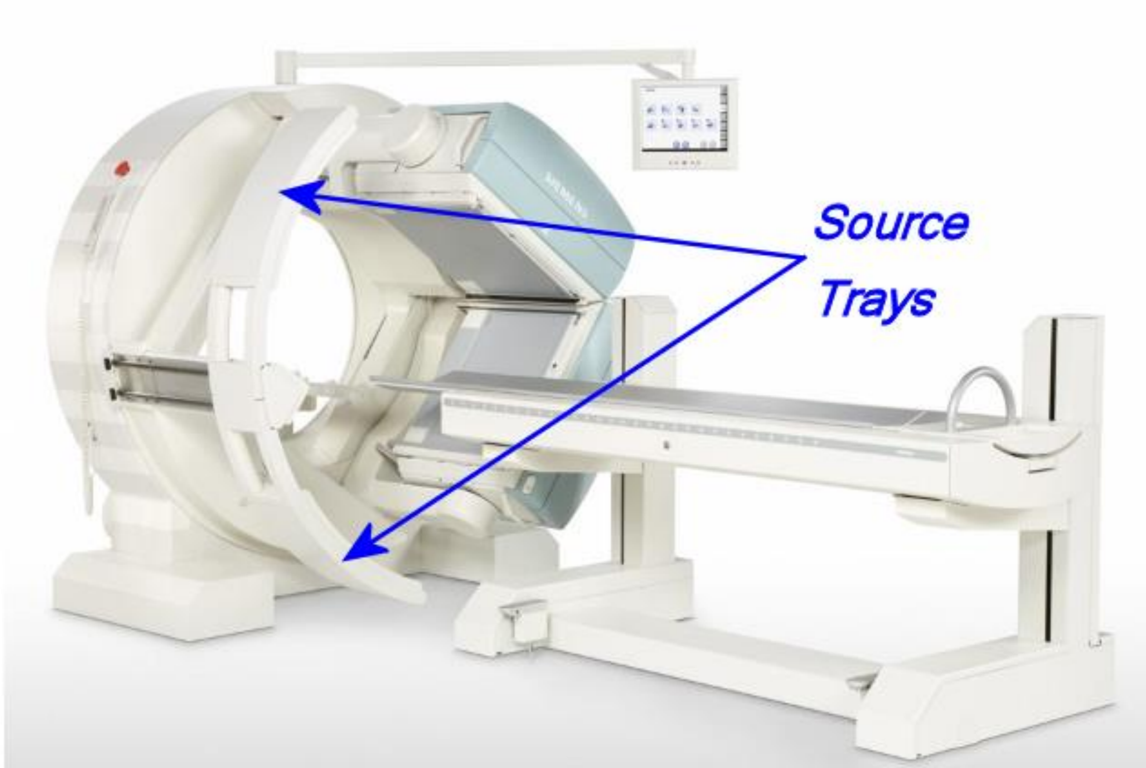
Afterwards, a SPECT/CT acquisition is preformed, and the resultant corrections align the 10 technetium points in the nuclear scan with the 10 contrast points in the CT exam.   NM/CT FOC Calibrations are stored on the acquisition workstation (rather than in the SNAC or in the detector) in the GDS.mdb and BINARY DATA folder.

Tech-Support Tip: Upon completion of each workflow, display the CT images of the vials using the syngo Viewing tab. Place the cursor inside each vial to get a HU reading (Hounsfield Units) of the mixture. The contrast agent should indicate between 600 - 900 HU for each vial. If the HU values are less than 600, then the vials did not contain enough contrast.

Tech-Support Tip: The MHR source holders indicates the number of sources and their locations according to the collimator set. See below. This information is for MHR or Head Alignment Calibrations only. When performing NM/CT FOV Calibrations always use 10 vials positioned as shown above.



On an **ECAM with Profile** option or a **Symbia-E with C.Clear** option, attenuation correction is performed using a pair of "wings" affixed to the gantry. Each wing contains a source tray of 14 gadolinium line sources.



Each source tray contains 7 pairs of gadolinium sources varying from 0.9 millicuries to 20.0 millicuries as shown below. Each source tray has two of each slot number listed below. For example, each tray has two positions labeled as Slot 1, each containing a 0.9 millicurie source.

Slot Number	Activity (mCi)	Activity (MBq)
Slot 1	20.0 mCi	740 MBq
Slot 2	11.9 mCi	440 MBq
Slot 3	7.0 mCi	259 MBq
Slot 4	4.2 mCi	155 MBq
Slot 5	2.5 mCi	93 MBq
Slot 6	1.5 mCi	56 MBq
Slot 7	0.9 mCi	33 MBq

Since gadolinium decays at a known rate, every six months:

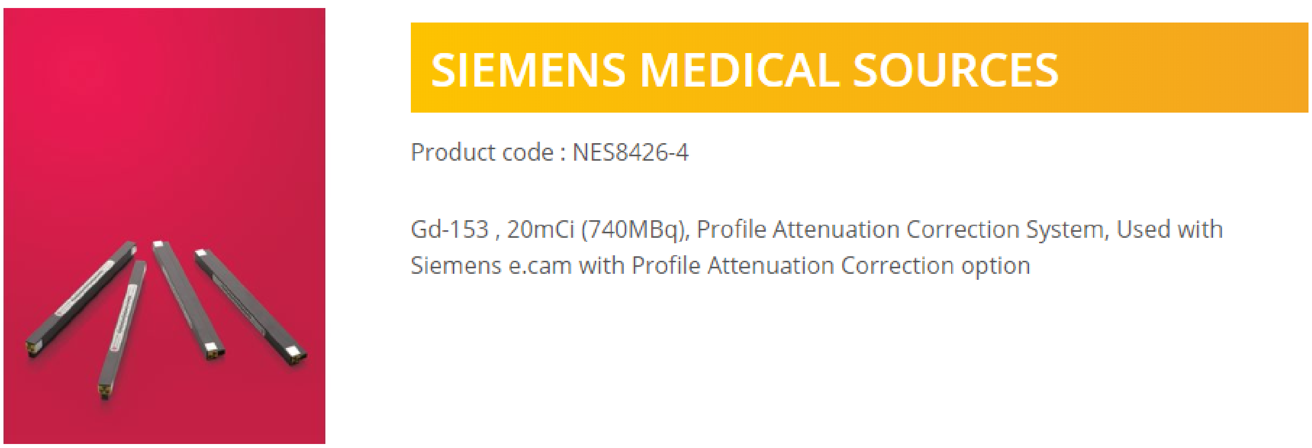
- The sources in Slot 7 are removed.
- The sources in Slot 6 are moved to Slot 7.
- The sources in Slot 5 are moved to Slot 6.
- The sources in Slot 4 are moved to Slot 5.
- The sources in Slot 3 are moved to Slot 4.
- The sources in Slot 2 are moved to Slot 3.
- The sources in Slot 1 are moved to Slot 2.
- New 20.0 millicurie sources are Slot 1.

Since there are two source trays and each tray contains two positions labeled Slot 1, four sources are replaced every six months.

Siemens manuals state, "Replacement of the sources per the six month scheduled interval is critical for correct system operation. Any deviation from this schedule will distort the shape of the source profile and may lead to poor performance of the system, especially on heavier patient."

The gadolinium sources are manufactured by Eckert & Ziegler Isotope Products and the product code for four replacement sources is **NES8426-4**.

The below screenshot is from the Eckert & Ziegler Isotope Products website (http://www.ezag.com).



Below is the contact information for the manufacturer of the Profile or C.Clear sources:

Eckert & Ziegler Isotope Products Inc. (http://www.ezag.com)
24937 Avenue Tibbitts
Valencia, CA 91355
USA
Tel. +1 661-309-1010
Fax +1 661-257-8303

When ordering sealed, medical sources from Eckert & Ziegler Isotope Products, each order includes a one-for-one, like-for-like exchange.

C.CLEAR CALIBRATIONS: SYMBIA-E DUAL HEAD

Performing attenuation correction with a Symbia-E requires a **Near Scan**, a **Shutter Leakage Test** and a **Far Scan**. These QC procedures are performed during system installation and are repeated every six months, immediately after replacement sources are installed.

Prior to performing C.Clear calibrations, the following prerequisites must be met:

- ✓ A valid MHR or Head Alignment Calibration must exist for the collimator set (usually LEHR collimators).
- ✓ A valid Monthly Intrinsic Flood Calibration must exist.

Near Scan Calibration

- ✓ Workflow is entitled, "**Near Blank Scan Calibration**". It takes 2 minutes to complete.
- ✓ Requires a calibration fixture, which is set directly on the collimators, and then the source trays are set directly on the fixture. The reason it's called a Near Scan is because the sources are near the detectors.
- ✓ Requires the gantry to be configured to 90.
- ✓ Requires Detector 1 at -135 degrees and Detector 2 at +135 degrees..
- ✓ Requires LEHR collimators.

Shutter Leakage Test

- ✓ Workflow is entitled, "**Shutter Leakage Test**". Three two-minute acquisitions are performed with the camera at three different rotational positions. This tests whether gravity has any effect on the source shutter mechanisms. The fourth two-minute acquisition is acquired with the wing assembly in the "Parked Position" to measure the background rate.
- ✓ Requires the source trays to be installed in the wings.
- ✓ Requires the gantry to be configured to 90.
- ✓ Requires the wings to be extended for 3 of the 4 acquisitions.
- ✓ Requires LEHR collimators.

Far Scan Calibration

- ✓ Workflow is either "**Tc99 Blank Scan Calibration**" or "**Tl201 Blank Scan Calibration**". It takes 6 minutes to complete.
- ✓ Requires the source trays to be installed in the wings. The reason it's often called a Far Scan is because the sources are far from the detectors.
- ✓ Requires the gantry to be configured to 90.
- ✓ Requires the wings to be extended.
- ✓ Requires LEHR collimators.

PROFILE CALIBRATIONS: ECAM DUAL HEAD

Performing attenuation correction with an ECAM a **Blank Scan** and a **Shutter leakage Test**. These QC procedures are performed during system installation and are repeated every six months, immediately after replacement sources are installed.

Prior to performing C.Clear calibrations, the following prerequisites must be met:

- ✓ A valid MHR or Head Alignment Calibration must exist for the collimator set (usually LEHR collimators).
- ✓ A valid Monthly Intrinsic Flood Calibration must exist.

Blank Scan Calibration

- Workflow is either **"Tc99 Blank Scan Calibration**" or "**Tl201 Blank Scan Calibration**". It takes 6 minutes to complete.
- Requires the source trays to be installed in the wings.
- Requires the gantry to be configured to 90.
- Requires the wings to be extended.
- Requires LEHR collimators.

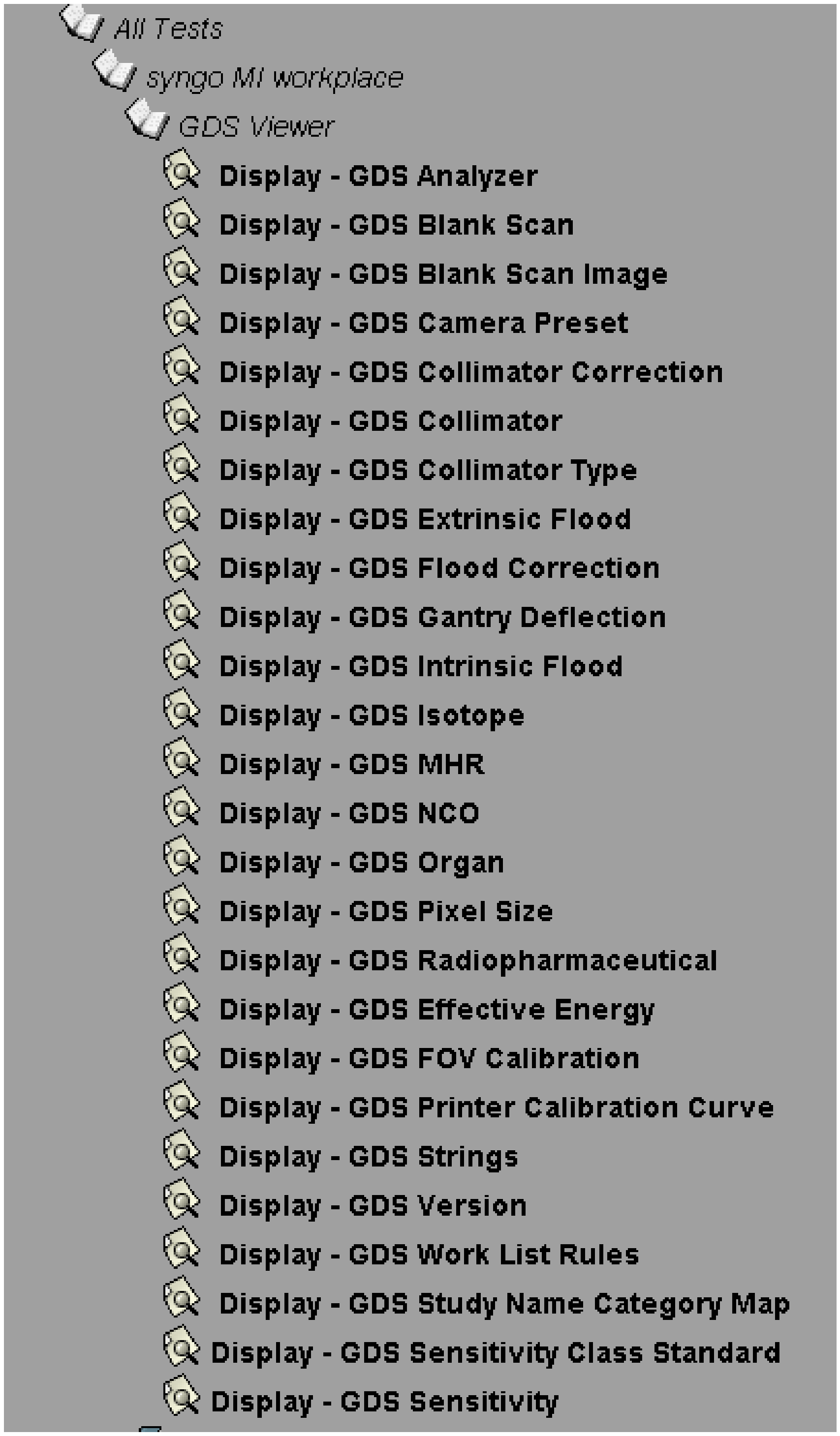
Shutter Leakage Test

- ✓ Workflow is "**Shutter Leakage Test**". Three two-minute acquisitions are performed with the camera at three different rotational positions. This tests whether gravity has any effect on the source shutter mechanisms. The fourth two-minute acquisition is acquired with the wing assembly in the "Parked Position" to measure the background rate.
- Requires the source trays to be installed in the wings.
- Requires the gantry to be configured to 90.
- Requires the wings to be extended.
- Requires LEHR collimators.

Note: On ECAM systems, there is only one Blank Scan, and it is often called a Far Scan. ECAM systems do not require a Near Scan.

GDS.MDB & BINARY DATA

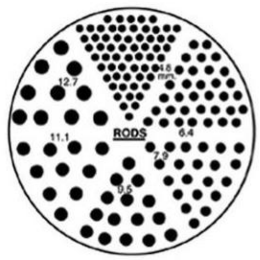
As previously mentioned, QC is stored in a GDS.mdb and BINARY DATA folder. The contents of the GDS and the corresponding BINARY DATA folder are accessible via NM Diagnostics with a Level 5 or higher service password. Below is the a screenshot of the GDS Viewer menu.

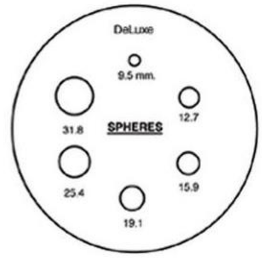


ACR ACCREDITATION / JASZCZAK PHANTOM

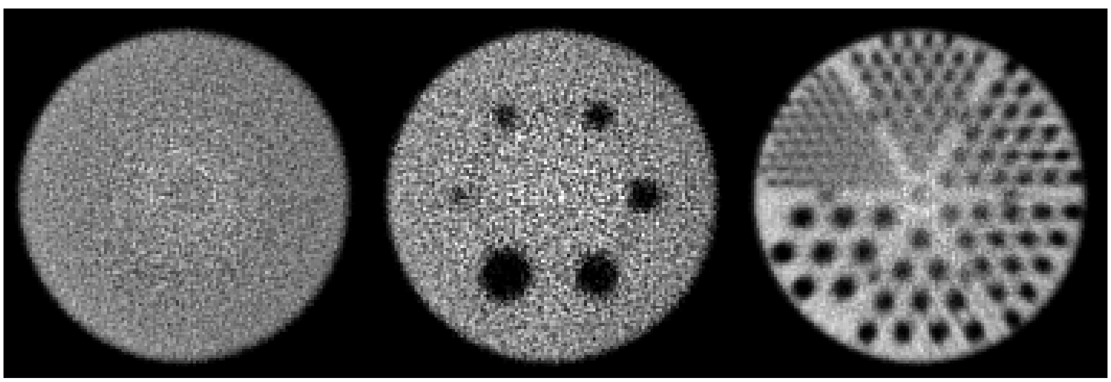
While acquiring bar pattern images and/or Jaszczak images are not listed on a Siemens System Calibration Schedule, end users often acquire these images for ACR Accreditation or Annual Testing.

Jaszczak Phantom is shown below:

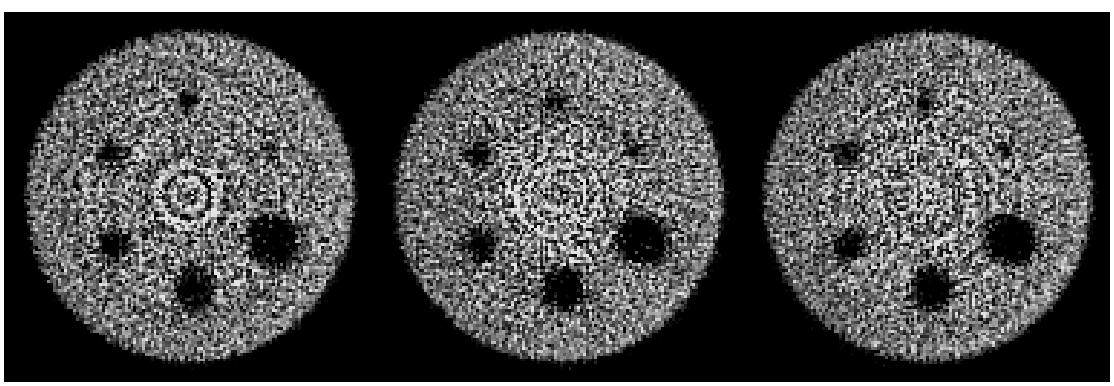




Below are “normal” transverse slices from a Jaszczak Phantom.



Conversely, below are “abnormal” transverse slices from a Jaszczak Phantom.



End users unfamiliar with acquiring images using a Jaszczak Phantom should refer to the videos shown below, courtesy of YouTuber TechNucMed.

Part 1 > https://www.youtube.com/watch?v=50jACfCmg4o

Part 2 > https://www.youtube.com/watch?v=aDmntzOCu5M

NOTE: Unlike the YouTube videos listed above, Siemens recommends placing the phantom directly on the pallet and not on the patient pallet pad. Siemens also recommend taping the phantom to the pallet to inhibit any unintended motion of the phantom during the TOMO acquisition.

Below are the Jaszczak Phantom Image Quality recommendations according to the Siemens MI-SPECT Headquarters Support Center:

> Before acquiring phantom images:
>
> [1] Acquire an Intrinsic Flood Calibration within 10 days of acquiring phantom images. The flood should have 200 million counts.
>
> [2] Acquire an Extrinsic Flood Calibration within 10 days of acquiring phantom images. The floods should have 120 million counts for each Low Energy High Resolution Collimator.
>
> [3] Generate Pedestals the same day phantom images will be acquired.
>
> [4] Run Fine Tuning the same day phantom images will be acquired. The ZMAP Value for each detector must be less than 005. If the ZMAP Value is 005 or greater, a regeneration of coefficients may be needed.
>
> NOTES:
>
> Use a 15 millicurie dose in the phantom. In the past, a 30 millicurie dose was recommended.
>
> The total number of counts in the projections when summed together should be no more than 25% of the counts in the applicable Extrinsic Flood Calibration. In the past, the recommendation was no more the 25% of the Intrinsic Calibration Flood.

Possible ACR issues and their solutions are shown below.

Rings in background (aka, ring artifacts in transverse slices) indicate a uniformity problem. Both the Intrinsic Verification Flood and the Extrinsic Verification Flood on each detector must be visually perfect. Acquiring a new Intrinsic Flood Calibration immediately followed by a new Extrinsic Flood Calibration is a common remedy for ring artifact problems. However, a full regeneration of coefficients might be needed.

Blurred pies or poor resolution indicate a COR (Single Head Camera) or MHR/NCO/Head Alignment (Dual Head Camera) problem. Perform COR, MHR, NCO or Head Alignment calibrations rather than verifications.

Blank spots or spots of low Intensity indicate a poor phantom mixture. Ensure there are no air bubbles in the phantom. Also, ensure the radioactivity is well mixed with saline within the phantom.

BAR PATTERNS

End users unfamiliar with acquiring images using a Bar Pattern should refer to the video shown below, courtesy of YouTuber TechNucMed.

https://www.youtube.com/watch?v=XsHt85kzdnY

When using a four-quadrant bar pattern, most states require an image to be acquired for each of the pattern's four possible orientations. After the first acquisition, the bar pattern is rotated 90 degrees. This process is repeated after the second and third acquisitions.

On a Single Head Camera, four separate images are needed. On a Dual Head Camera, eight separate images are needed (four images from each detector).

According to, "Site Scanning Instructions for the ACR Nuclear Medicine," the American College of Radiology recommends the following:

> Spatial Resolution (four-quadrant bar phantom) Tc-99m (preferred) or Co-57.
>
> Set the appropriate energy and acquire an intrinsic or system (whichever type is routinely used for quality control) resolution pattern image using a 512 x 512 matrix (or the finest matrix that is available). For large rectangular field cameras (longest dimension > 32 cm), acquire 5 million counts. For large and small circular detectors and small rectangular field cameras (longest dimension < 32 cm), 3 million counts are satisfactory.

Let's discuss the following recommendation:

- using a 512 x 512 matrix (or the finest matrix that is available)

The minimum number of counts to acquire bar pattern images depends upon:

- The collimator type
- The width of the smallest bars in the pattern
- The acquisition matrix

The physical dimensions of a Siemens HD or Foresight Detector are 21" x 15.25" (533.4 mm x 387.35 mm). Therefore, the pixel sizes when using a Zoom Factor of 1.0 are approximately:

- 512 x 512 = 533.4 / 512 = 1.04 mm
- 1024 x 1024 = 533.4 / 1024 = 0.52 mm

Obviously, 1024 x 1024 provides the best resolution, but it comes with a very steep price.

- 512 x 512 = 256k pixels, so 5 million counts / 256k pixels = 19.53 counts per pixel
- 1024 x 1024 = 1024k pixels, so 5 million counts / 1024k pixels = 4.88 counts per pixel

As shown above, a 5 million count acquisition in a 1024 x 1024 matrix has very few counts in each pixel; and therefore, the resultant image will have very little contrast. Conversely, acquiring using a 512 x 512 matrix has four times the contrast of a 1024 x 1024 image. Therefore, with HD and Foresight Detectors, bar patterns should be acquired using a 512 x 512 matrix rather than "the finest matrix that is available." When viewing bar pattern images, contrast is essential.

If you wondering why not use a 1024 x 1024 matrix, that would necessitate acquiring four times more counts to obtain the same contrast as a 512 x 512 image. Most end users acquire 5 million counts for each 512 x 512 image and they acquire 8 separate images (4 from each detector), rotating the bar pattern 90 degrees for each image. Using a 1024 x 1024 matrix would require 20 million counts per image to obtain the same contrast as a 5 million counts in a 512 x 512 image. On a Dual Head Camera, that would necessitate acquiring a total of 160 million counts.

Be advised that when acquiring images on an ECAM or Symbia using a Zoom Factor of 1.0, the image does not fill the entire 512 x 512 or 1024 x 1024 matrix. Therefore, the aforementioned calculations were merely approximations.

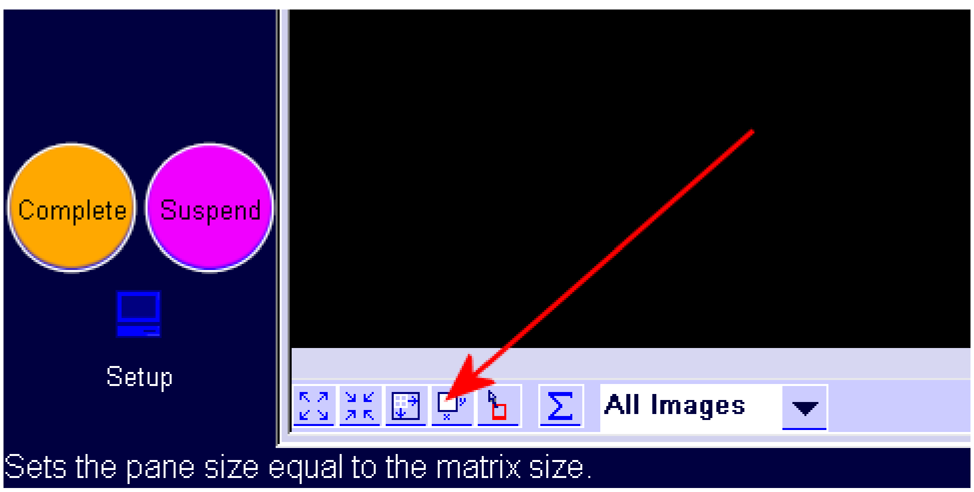
Tech-Support Tip: When displaying a bar pattern on a Siemens workstation, ensure the image is displayed in its native resolution; otherwise, the resolution will be smoothed via pixel interpolation.

- If the bar pattern images were acquired in a 512 x 512 matrix; then afterwards, those images should be displayed using 512 x 512 pixels on the monitor.

- If the bar pattern images were acquired in a 1024 x 1024 matrix; then afterwards, those images should be displayed using 1024 x 1024 pixels on the monitor.

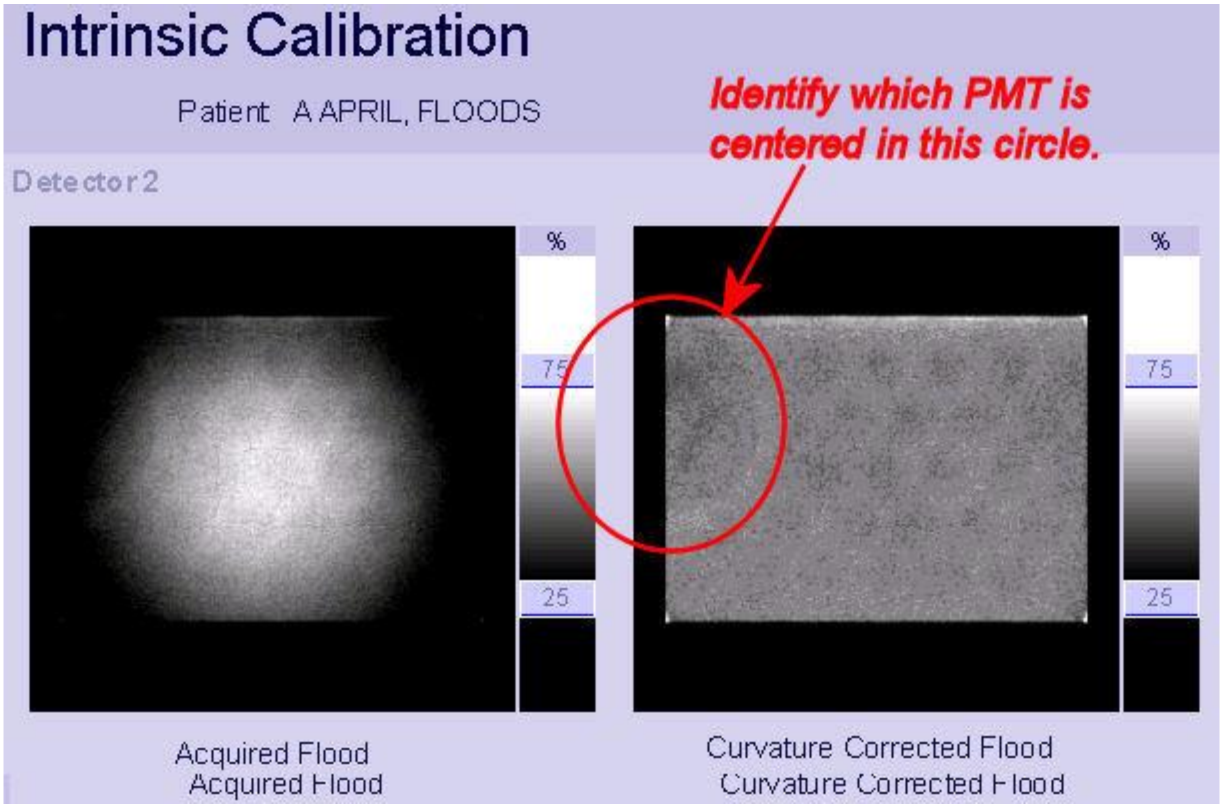
On a Siemens MI-SPECT workstation, the monitor resolution is 1280 x 1024. Therefore, a 512 x 512 image should fill approximately half the screen, while a 1024 x 1024 image should fill nearly the entire screen.

On a Siemens MI-SPECT workstation, to display an image in its native resolution, after the image is displayed in the Flex Display activity, click on the image and then click on the icon at the bottom of the screen (shown below) that, "Sets the pane size equal to the matrix size."



PMT ARTIFACTS

Below is an example of a PMT artifact in an Intrinsic Flood Calibration. The obvious question is, "Which PMT is causing this artifact?"



The following is an aid to help identify the location of PMT artifacts in images.

The first step in identifying the location of a PMT artifact is ascertaining the patient orientation used to acquire the image. All Siemens MI-SPECT images are stored as DICOM files, and according to the DICOM Standard, **DICOM tag (0018,5100)** is designated as the "**Patient Position**."

For Siemens MI-SPECT raw images not acquired on a stretcher, the Patient Position DICOM tag should contain one of the following Patient Orientations:

- HFS (Head First Supine)
- FFS (Feet First Supine)
- FFP (Feet First Prone)
- HFP (Head First Prone)

To view the DICOM tag for Patient Position on a Siemens MI-SPECT workstation:

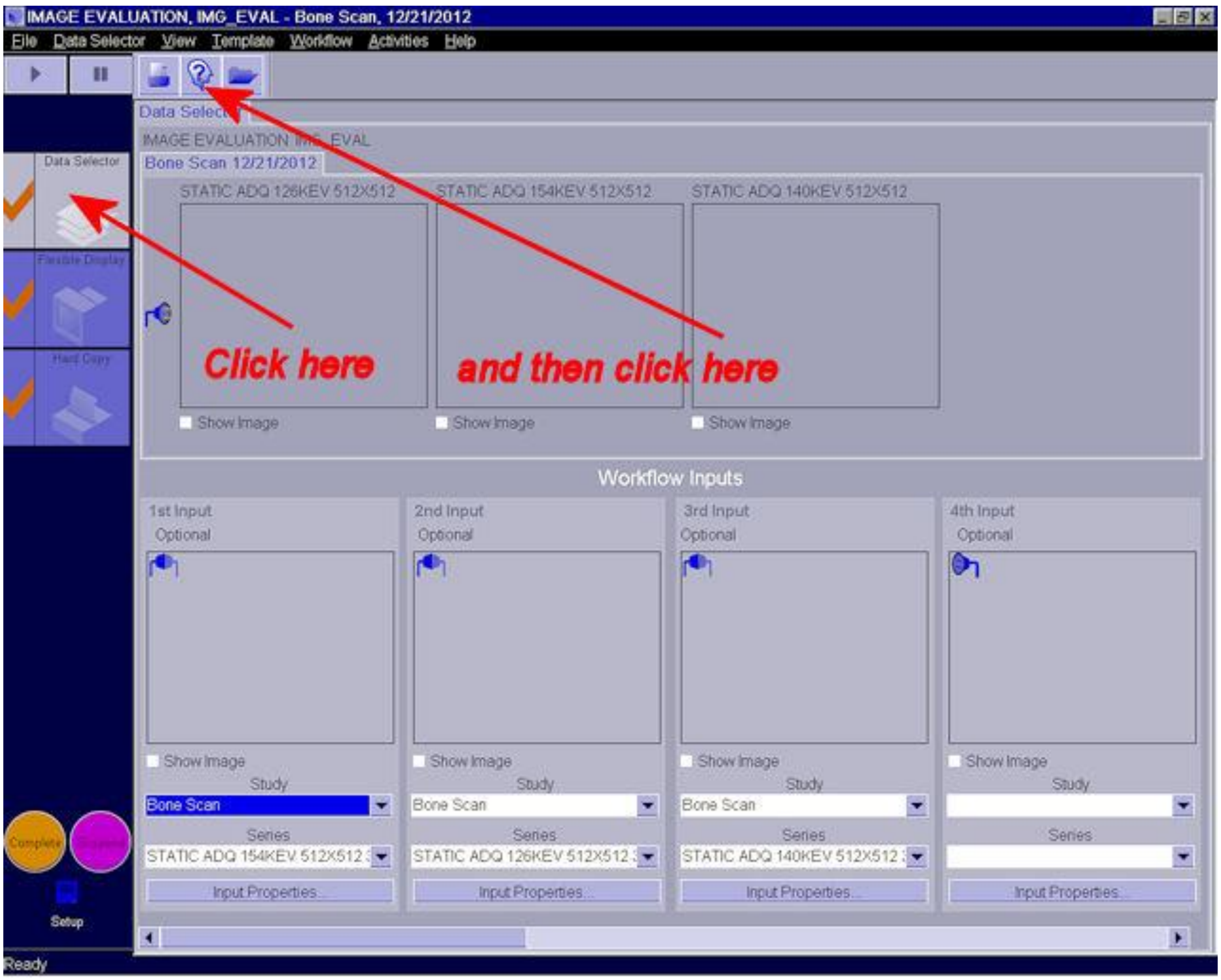
[1] Select the series containing the image and then launch the "Display" workflow.

[2] Click on the "Data Selector" activity (see below).

[3] In the Data Selector activity, select the "Get Series Information" button, which looks like the profile of a human head with a question mark (see below). A "Series Information" window will appear.

[4] In the "Series Information" window, use the drop-down located at the top, right side of the window labeled "Series" to select the desired image.

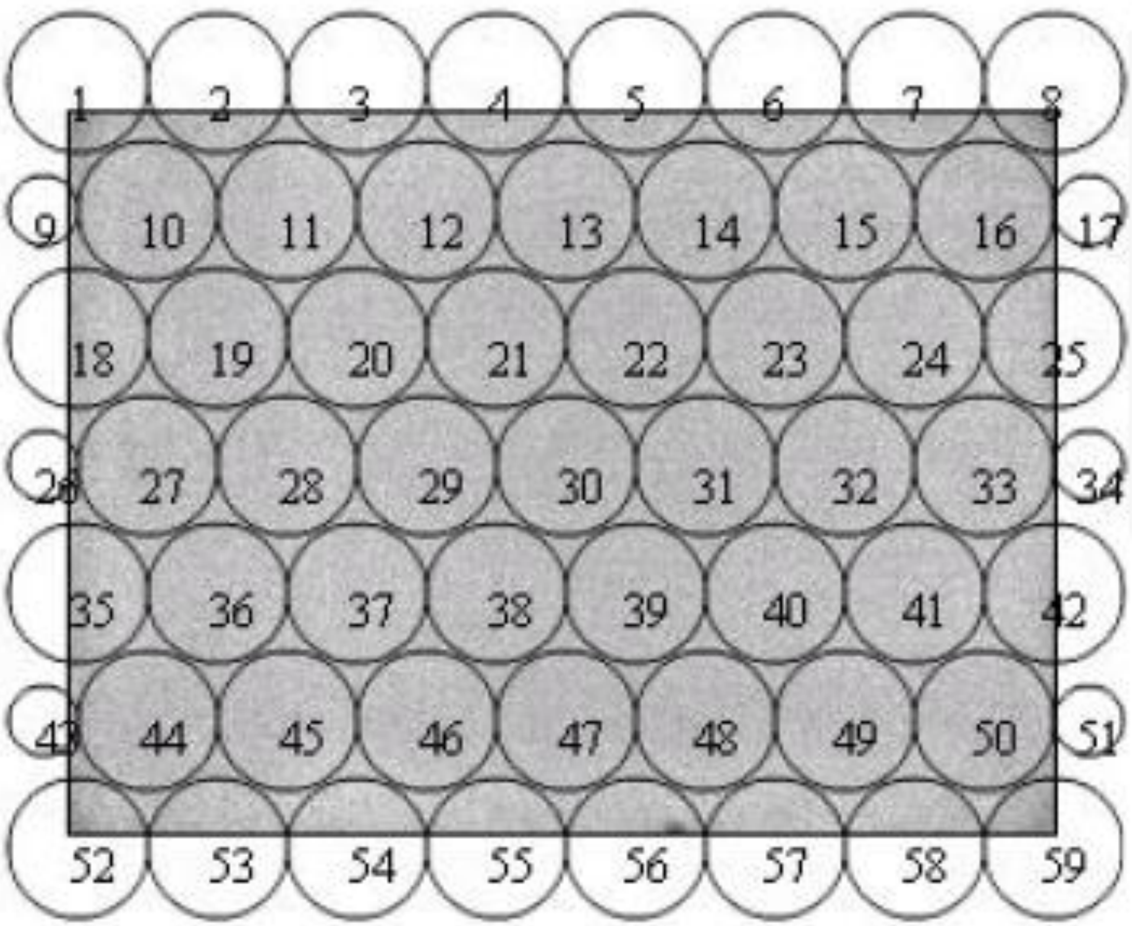
[5] "Patient Orientation" will be displayed in the middle of the "Series Information" window.



After the Patient Position or Patient Orientation has been determined, the next step will be comparing the acquired image to the corresponding PMT layout. The following pages show each of the four possible patient orientations and the corresponding PMT layout.

But first, be advised that PMT's along the outer edge of a detector extend past the imaging Field of View displayed to an end user. The below drawing depicts the PMT layout in HD and Foresight detectors compared to the imaging Field of View when utilizing a Zoom Factor of 1.0. Consequently, when a PMT located along the outer edge of the Field of View creates an artifact, that anomaly will not appear as a full circle in subsequent images.

For example, a failed PMT #42 would appear as half of a circle artifact, rather than a full circle artifact. Additionally, PMT numbers 9, 17, 26, 34, 43 and 51 are only two inches in diameter, while all other PMT's are three inches in diameter. Obviously, a 2" PMT will cause a smaller artifact than a 3" PMT. As shown below, a 2" PMT will cause a very, very, very small artifact.



Now that you understand the Patient Position or Patient Orientation for the image; as well as, the relationship between PMT's and the Field of View, continue to the following four pages. There is a separate page for each possible orientation.

Take a business card (to simulate a rectangular detector's field-of-view) and draw a stick person along the short axis on the blank side of the card. Add two eyeballs to the stick person to aid in determining supine and prone. See below.

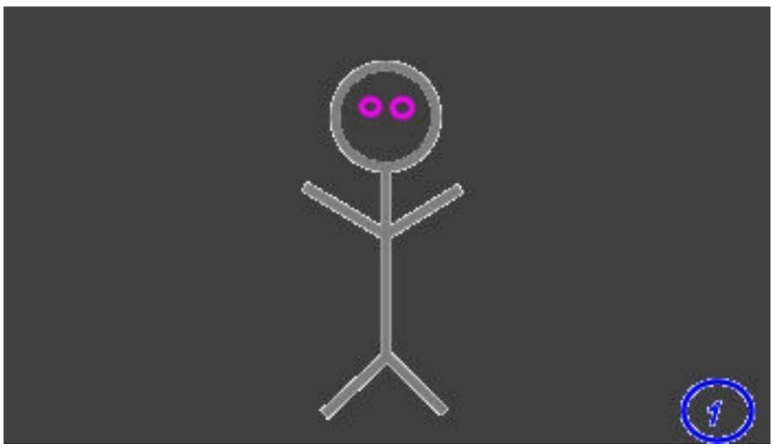
Draw a small circle in the lower right corner of the card and put a "1" inside the circle to simulate the location of PMT #1. See below.

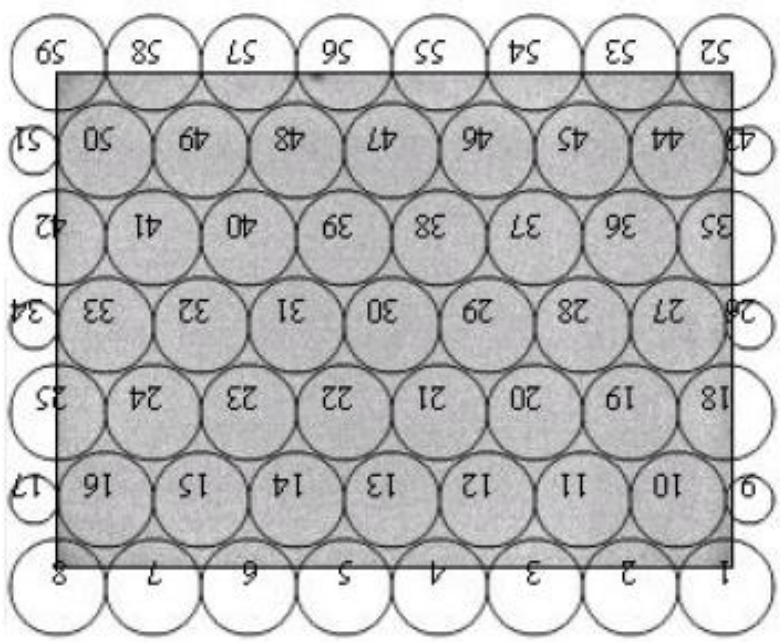
This is **HFS (Head First Supine)** orientation.

In HFS orientation, PMT #1 is located in the lower right corner of the image.

HFS orientation is used for Intrinsic and Extrinsic Flood Calibrations, Intrinsic and Extrinsic Flood Verifications, and Extrinsic Sweep Verification Floods.

The corresponding PMT layout is shown below.





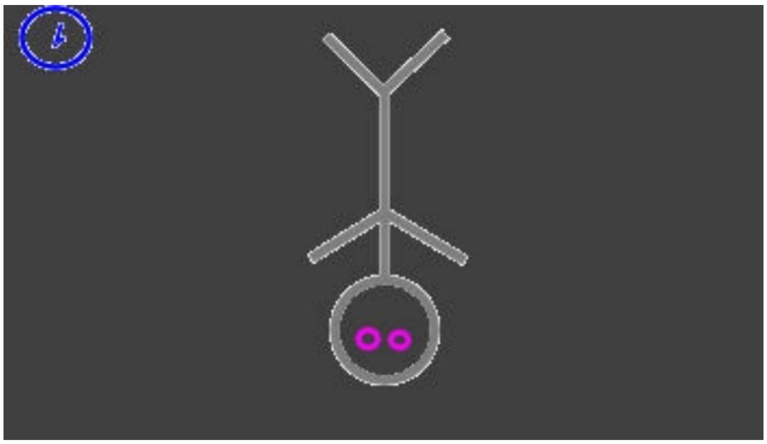
Rotate the business card clockwise 180 degrees. See below.

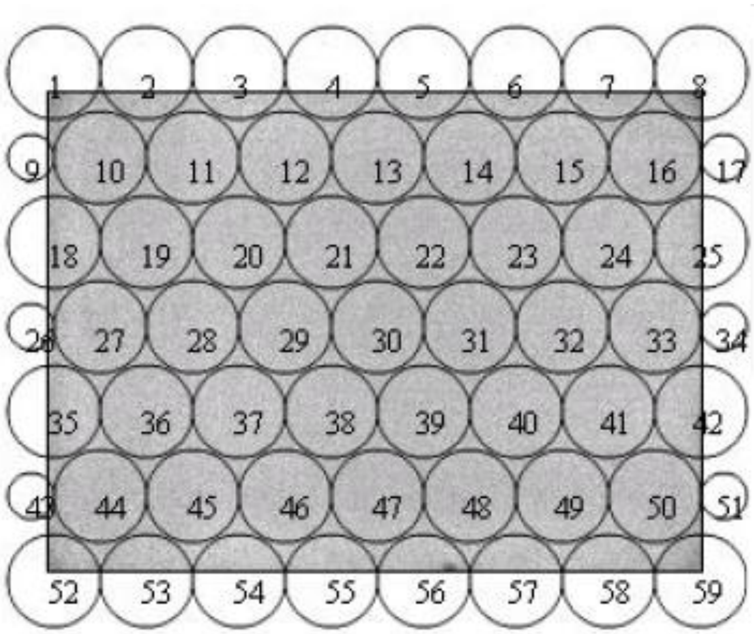
This is **FFS (Feet First Supine)** orientation.

In FFS orientation, PMT #1 is now located in the upper left corner of the image.

FFS is is the most common orientation for patient acquisitions.

The corresponding PMT layout is shown below.



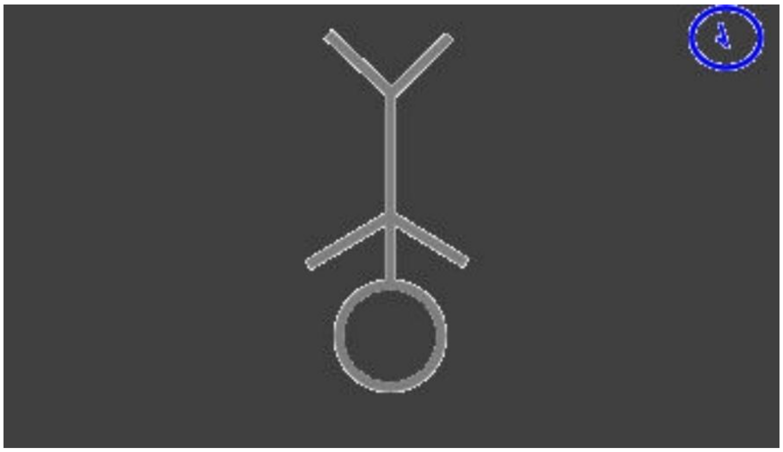


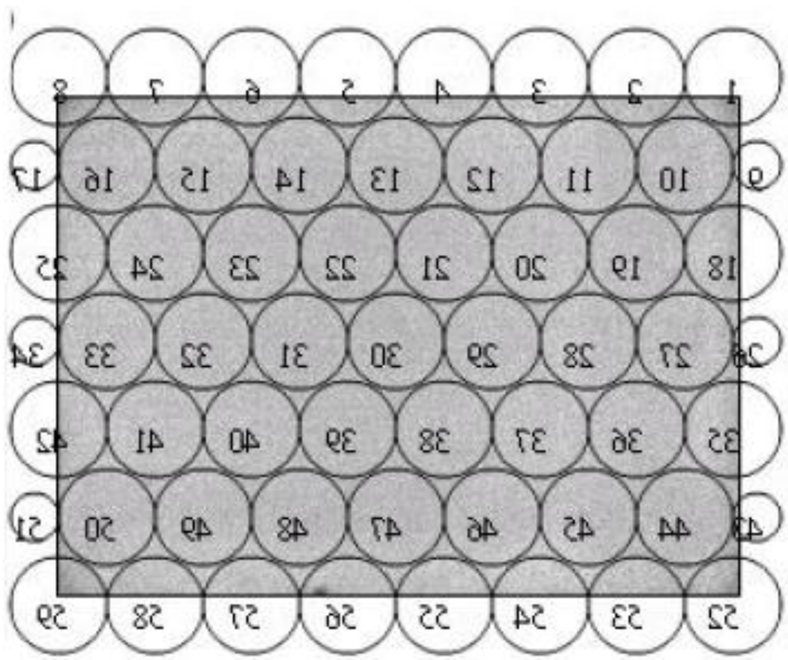
Flip over the business card from left to right. While you can no longer see the stick person on the card, that stick person is now facing downward.

This is **FFP (Feet First Prone)** orientation.

In FFP orientation, PMT #1 is now located in the upper right corner of the image.

The corresponding PMT layout is shown below.



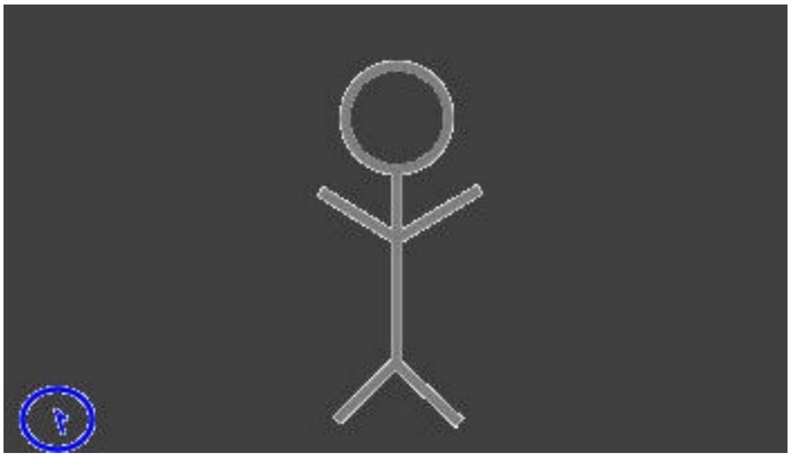


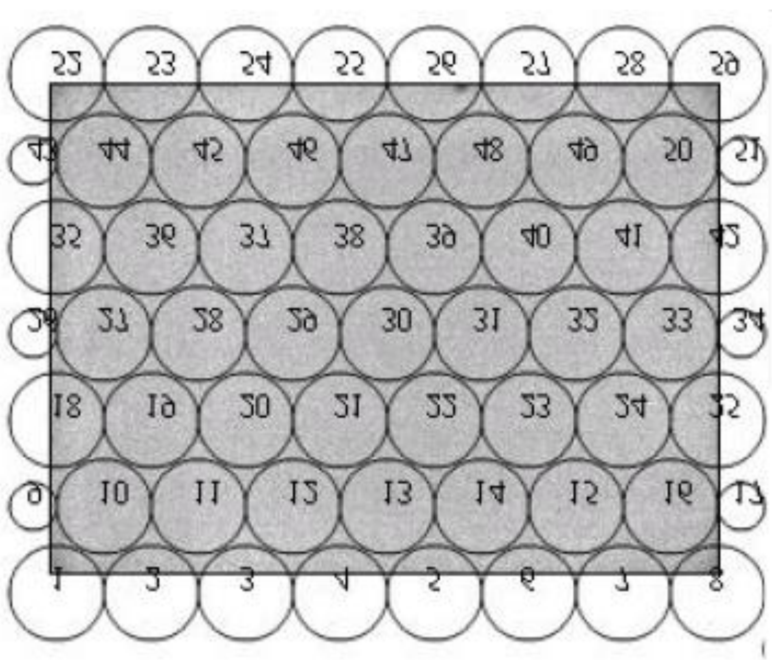
With the business card still facing down, rotate it clockwise 180 degrees.

This is **HFP (Head First Prone)** orientation.

In HFP orientation, PMT #1 is now located in the lower left corner of the image.

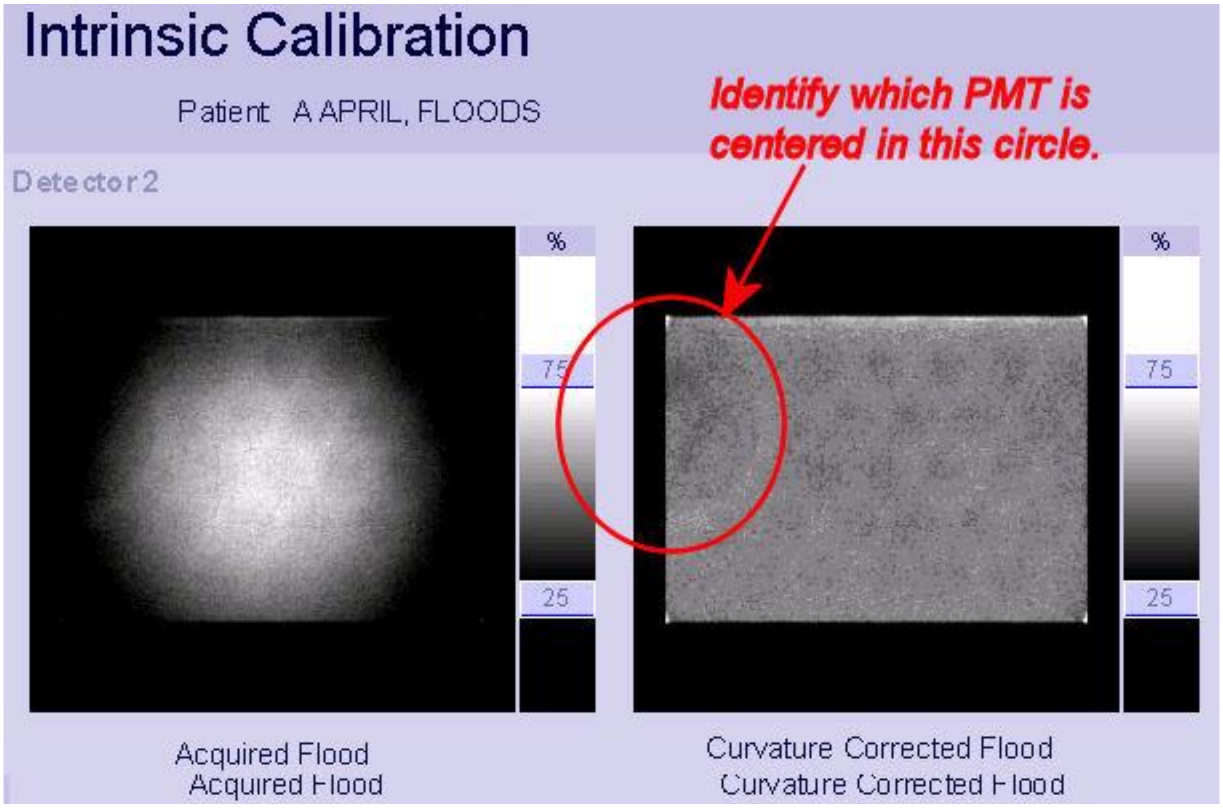
Corresponding PMT layout is shown on the below.





Now let's put this information to use.

Which PMT is causing the artifact shown below?



Analysis:

- ✓ An Intrinsic Flood Calibration is acquired HFS.
- ✓ The artifact arrears to be a half-circle, which probably indicates an edge PMT.
- ✓ The center of the artifact is located one row of PMT's above the center row of PMT's.
- ✓ According to the HFS PMT layout, the artifact is centered at PMT #42.

In this example, a Siemens Service Representative replaced PMT #42 and the artifact was eliminated, along with the other non-uniformities in the image. Since the output of all 59 PMT's are summed together to create ESUM, be advised that a problem with one PMT may cause the entire Field of View to be non-uniform.

If you believe you now understand how Patient Orientation works, the bad news is that for a Dual Head camera system, it's actually more complicated than described here.

On a Dual Head system, when acquiring a patient who is face-up with Detector 1 in the 12 o'clock position and Detector 2 in the six o'clock position, Detector 1 is acquiring **Supine**, while Detector 2 is acquiring **Prone**. But when the images from each detector are displayed side by side, a radiologist doesn't want the images displayed as left/right on Detector 1 and as right/left on Detector 2. Therefore, additional DICOM tags are needed, and different tags for this function are available in various versions of Siemens MI Applications software. To elaborate would only confuse an end user at this point, so this dissertation shall come to an end. For most images, the explanation previously described should suffice.

NEMA STANDARDS AND IAEA QUALITY CONTROL ATLAS

NEMA is the National Electrical Manufacturers Association. According to www.nema.org …

> It is NEMA's belief that standards play a vital part in the design, production, and distribution of products destined for both national and international commerce. Sound technical standards benefit the user, as well as the manufacturer, by improving safety, bringing about economies in product, eliminating misunderstandings between manufacturer and purchaser, and assisting the purchaser in selecting and obtaining the proper product for his particular need.

A personal story from the author: Three decades ago, I began working as a Field Service Engineer with Siemens Medical Systems in Miami, Florida. Prior to my first day on the job, I had never heard of Nuclear Medicine or a gamma camera. Fortunately, during my training, I was provided the following eight-page NEMA document entitled…

Standards for Performance Measurements of Scintillation Cameras…
And What They Can Mean For You

While written in 1980 when gamma cameras only had a single head and a circular Field of View, that document explained NEMA Tests and Procedures in terms that even someone new to Nuclear Medicine could easily comprehend. Therefore, 30 years later, I still cherish that document. I scanned and attached it here.

If you need the current NEMA Standard (NU 1-2012), it is available for $151 from the link shown below.

https://www.nema.org/Standards/Pages/Performance-Measurements-of-Gamma-Cameras.aspx

Another excellent reference is the International Atomic Energy Agency's document entitled…

IAEA Quality Control Atlas for Scintillation Camera Systems

It's 299 pages, so refer to the link shown below.

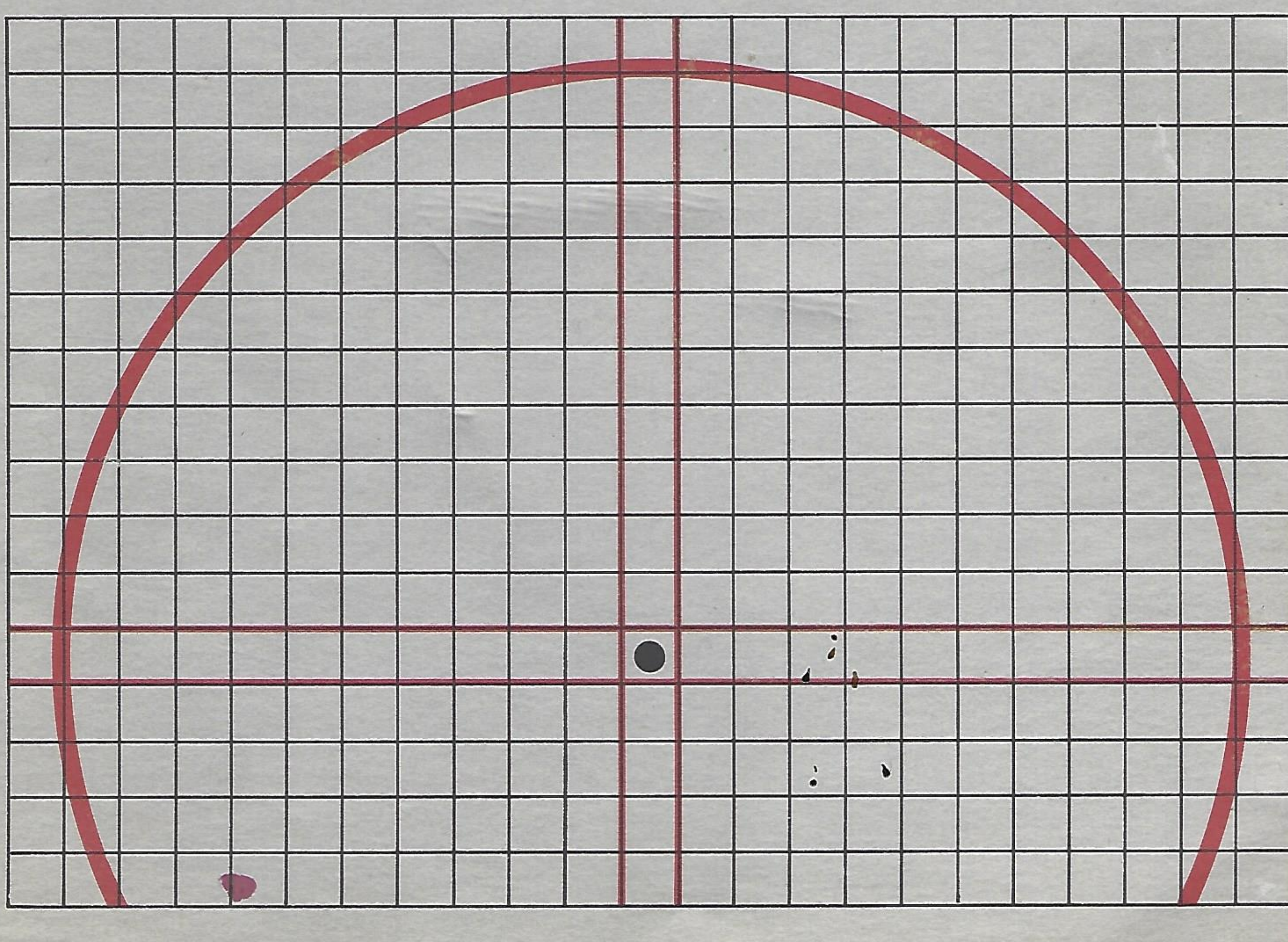
http://www-pub.iaea.org/MTCD/publications/PDF/Pub1141_web.pdf

- Section 2.2.6.1 — No Linearity or Energy Correction
- Section 2.2.7.1B — Loss of optical coupling
- Section 2.2.7.2A — Cracked Crystal
- Section 2.2.7.4 — Crystal Hydration

NEMA

Standards for Performance Measurements of Scintillation Cameras......

And What They Can Mean For You



What is NEMA?

The National Electrical Manufacturers Association—the largest trade association in the United States for manufacturers of electrical products. Formed by merger of several groups of electrical manufacturers in 1926, it now has approximately 550 company members nationwide, small and giant, producing component and end-use electrical equipment.

What is the Diagnostic Imaging and Therapy Systems Division of NEMA?

One of NEMA's eight product Divisions. It grew from industry concern about:

—The economic impact of government regulations and legislation.

—The need for public understanding of how medical technology can reduce costs and improve patient care.

Its sections comprise: nuclear imaging, X-ray, ultrasound imaging, computed tomography, radiation therapy...all part of the rapidly expanding medical instrumentation industry, thus part of this NEMA division.

What is the Nuclear Section's role?

It represents manufacturers of nuclear medicine equipment, including all major suppliers of scintillation cameras. It represents its members in addressing legislative issues, such as nuclear medicine equipment standards to be promulgated under the Medical Device Amendments of 1976. It provides a forum for addressing problems and issues facing the entire nuclear medicine equipment industry. The Section devotes much effort to assuring effective communications between the industry and user groups...a basic objective of its standards program.

Other interests that the Section and professional groups have in common besides nuclear medicine equipment standardization include: exchanging information on pertinent technological developments, improving the image of nuclear medicine to the general public, better informing referring physicians concerning nuclear medicine, explaining nuclear medicine benefits, and developing methods to discuss financial advantages of capital equipment with administrators.

What are the NEMA standards?

"A standard...defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, quality, rating, testing, and the service for which designed." The standards are living documents, kept up to date. A mandatory review and revision process ensures that none are more than five years old. Any standard proposal submitted for approval must show sound evidence of safety considerations.

How are the NEMA Standards developed?

By a carefully organized, concensus process. Manufacturers write them, and participation in their development is, like the standards themselves, strictly voluntary. Within a NEMA product section, technical committees develop the text for a standard, which is next discussed at a section meeting. Revision or approval of a standard is voted on by member companies of the section, each having one vote. The proposed standard is checked by the Codes and Standards Committee for whether it conforms to NEMA procedures, considers the interests of all affected sections, is technically sound and accurate, and shows evidence that both safety and user needs have been considered. A mandatory statement indicating the degree of user input during the development process is submitted with each proposal. User representatives may participate in the writing of a standard or evidence concurrence later. Drafts of NEMA Standards for "Performance Measurements of Scintillation Cameras" were circulated to committees within the

Society of Nuclear Medicine, the American College of Nuclear Physicians, the American Association of Physicists in Medicine and the International Electrotechnical Commission for comments. It was also publicly presented and discussed in panels at the Society of Nuclear Medicine Instrumentation Section and the American Association of Physicists in Medicine.

Why have the NEMA standards for performance measurements of scintillation cameras been developed?

To provide a uniform criterion for the measurement and reporting of scintillation camera performance parameters by which a manufacturer may specify his device and, when doing so, reference NEMA Standards Publication for Performance Measurements of Scintillation Cameras. These standards do not establish minimum performance levels.

Only elaborate measurement equipment can provide the uniform and accurate specification of performance characteristics required for standards. Thus these standards are not primarily intended for acceptance testing at installations, user quality assurance or for use as a quality control procedure.

What do these new standards encompass?

The new Standards Publication establishes:

A. Definitions

B. Procedures for quantitative measurement and reporting of performance parameters
   - —Measurement techniques are chosen to be reproducible, quantitative and accurate.
   - —Standards address single and multiple crystal scintillation cameras; exclude scanning and tomographic devices.
   - —All parameters are measured over the Useful Field of View (UFOV) of the camera (the collimated field of view) and Central Field of View (CFOV). The CFOV is 75% of the diameter of the UFOV.
   - —Recommended instrumentation includes a computer based two parameter multi-channel analyzer system with a 1024 x 16 measurement resolution.
   - —Additionally, several phantoms and radionuclides are required.

C. Multiple crystal scintillation camera test methods are included in the standard. The specific tests are slightly different from the single crystal tests due to differences in technology, however effort was made to be as consistent as possible between instrument standards.

How shall manufacturers specify performance by NEMA standards?

In stating specifications, all reported values shall be labeled as "worst case", "better than", "not to exceed", and UFOV or CFOV indicated, except where otherwise defined in these standards.

How can the nuclear medicine community benefit by these new NEMA standards?

The voluntary standard provides a common link between the various manufacturers and the user community. By means of the NEMA standard, users now have a way to intercompare specifications from different manufacturers and on different models of cameras. Such intercomparison has previously been very difficult.

The following are tests to be performed on all scintillation cameras in accordance with the recommended NEMA Standards:

1. Intrinsic spatial resolution

DEFINITION

Intrinsic means the basic scintillation camera without variables such as collimators which may change its inherent characteristics.

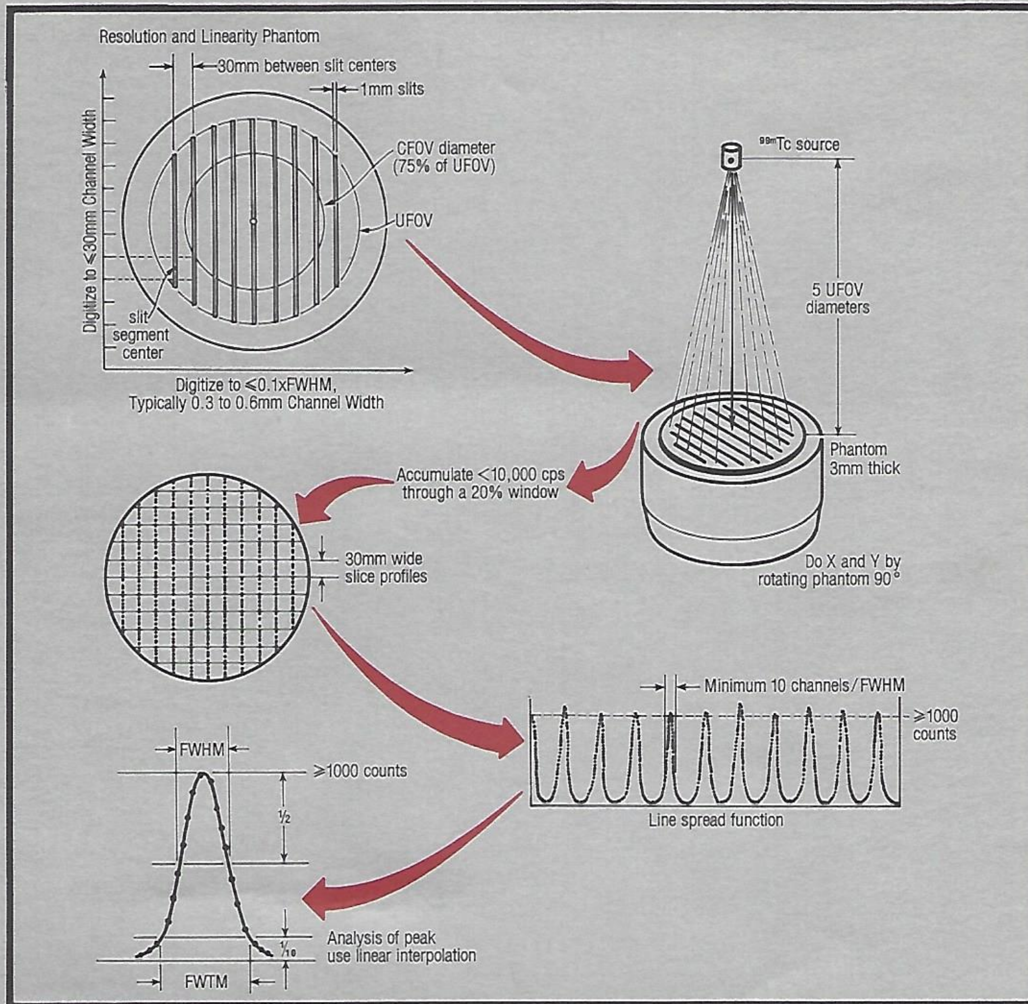
Spatial resolution is a parameter of a scintillation camera which characterizes its ability to accurately determine the original location of a gamma ray on an X-Y plane.

STANDARD

Intrinsic spatial resolution shall be measured in both the X and Y directions and expressed as full width at half maximum (FWHM) and full width at tenth maximum (FWTM) of the line spread function measured in millimeters.

REPORT

(X.X)mm FWHM, FWHT for CFOV and UFOV



2. Intrinsic energy resolution

DEFINITION

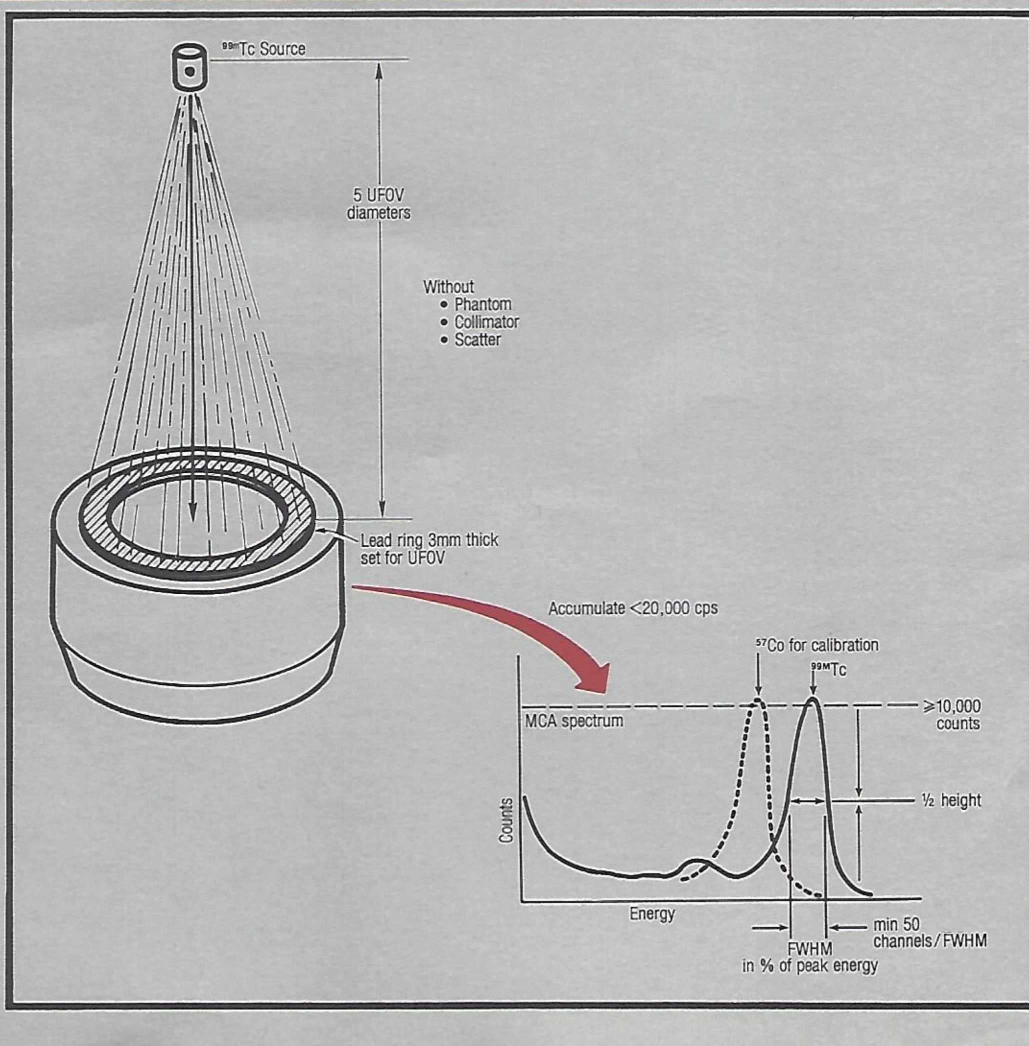
Intrinsic energy resolution is a parameter of a scintillation camera which characterizes its ability to accurately identify the photopeak events. This parameter in a scintillation camera determines its ability to distinguish between primary gamma events and scattered events. This test is intrinsic and done without a collimator.

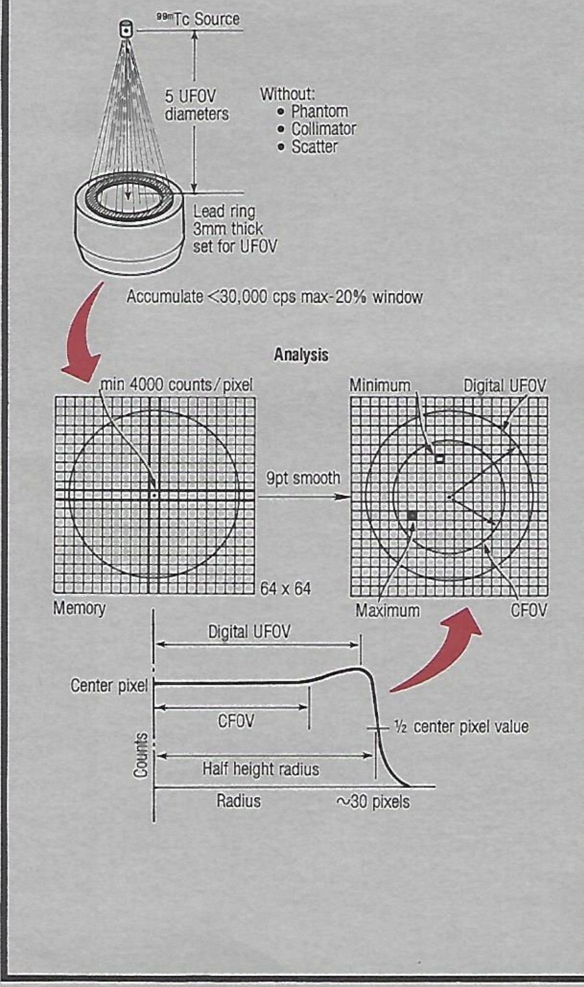
STANDARD

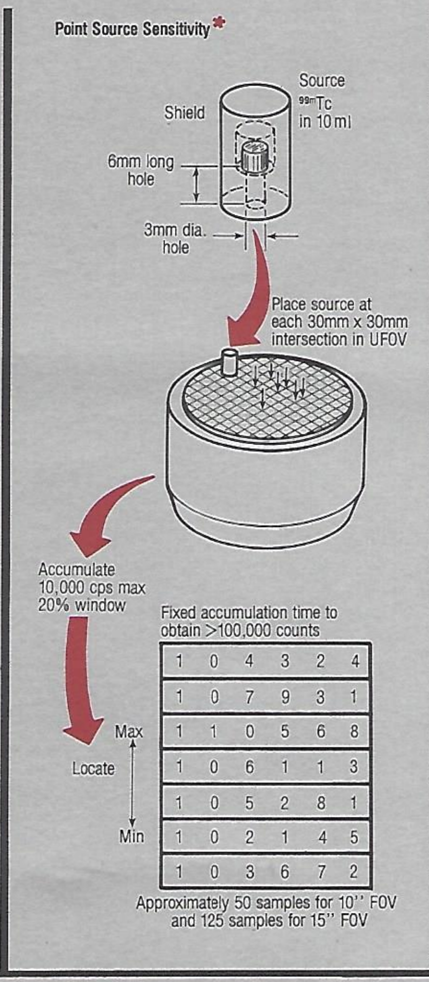
Intrinsic energy resolution shall be expressed as the ratio of photopeak full width at half maximum to photopeak energy expressed as a percentage.

REPORT

(XX.X)% FWHM for UFOV







3. Intrinsic flood field uniformity

DEFINITION

Intrinsic flood field uniformity is a parameter of a scintillation camera which characterizes the variability of observed count density with a homogeneous flux.

STANDARD

Intrinsic flood field uniformity shall be expressed as "integral uniformity" (a maximum deviation) and a "differential uniformity" (a maximum rate of change over a specified distance, roughly slope). Both shall be measured for the UFOV, and the CFOV.

In addition, as a class standard*, point source sensitivity variations shall be expressed as percentage variation.

If field uniformity correction devices are employed all measurements shall be consistently performed with these devices on or off and the results so indicated.

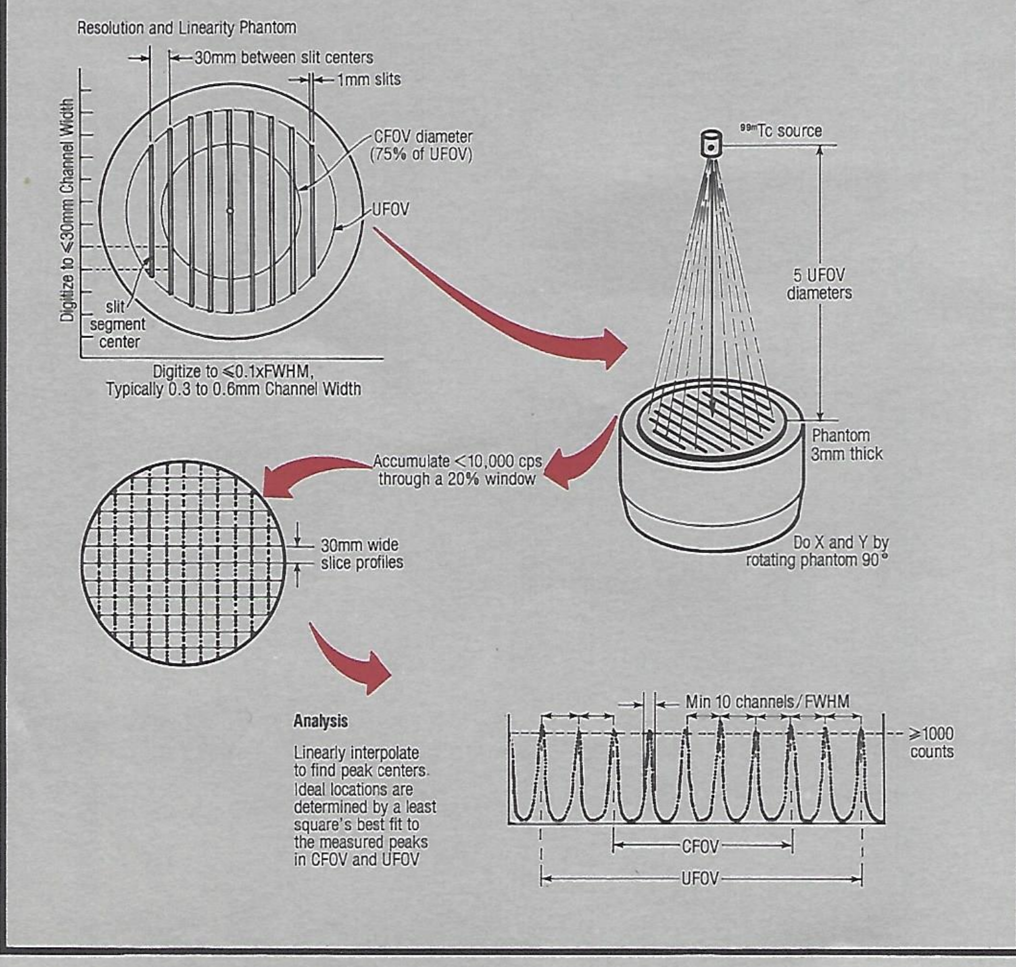
REPORT

Integral uniformity $= \pm 100 \dfrac{(\text{Max} - \text{Min})}{(\text{Max} + \text{Min})}$

for UFOV and CFOV

Differential uniformity (Determine for maximum change of count density over a range of 5 pixels in all rows and columns) =

$$\pm 100 \left(\frac{\text{Largest slice deviation (Hi-Low)}}{\text{Hi} + \text{Low}} \right)$$



4. Intrinsic spatial linearity

DEFINITION

Spatial linearity is a parameter of a scintillation camera which characterizes the amount of positional distortion caused by the camera with respect to incident gamma events entering the detector.

STANDARD

Intrinsic spatial differential linearity and absolute spatial linearity in both X and Y directions shall be measured. Differential linearity (expressed in millimeters) is the standard deviation of line spread function peak separations in the CFOV and UFOV using the intrinsic spatial resolution test pattern. Absolute linearity shall be measured from the same test pattern data and shall be expressed as the maximum amount of spatial displacement measured in the CFOV and UFOV.

REPORT

Absolute linearity: Maximum displacement of peak locations from ideal grid (X and Y) for CFOV and UFOV, expressed in millimeters.

Differential linearity: Standard deviation (X and Y) of peak separations for CFOV and UFOV, expressed in millimeters.

5. Intrinsic count rate performance

DEFINITION

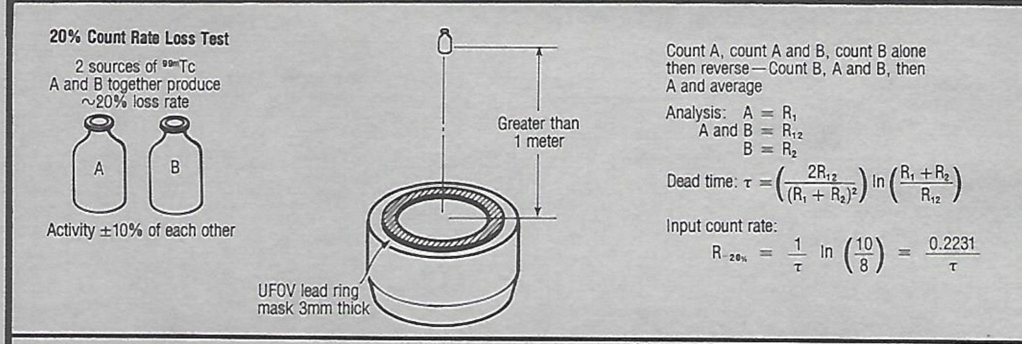
Count rate performance characterizes a scintillation camera's ability to accurately function at count rates which are near the maximum rate of camera operation.

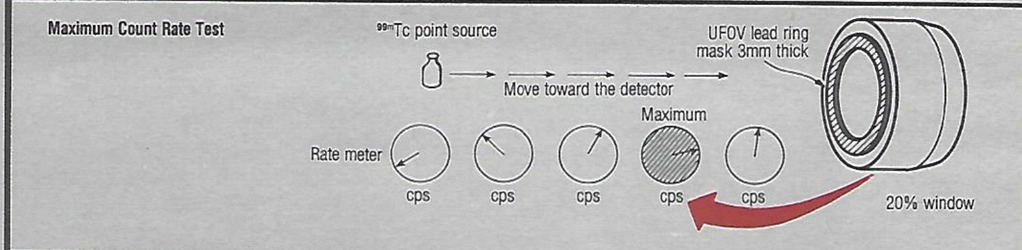
STANDARD

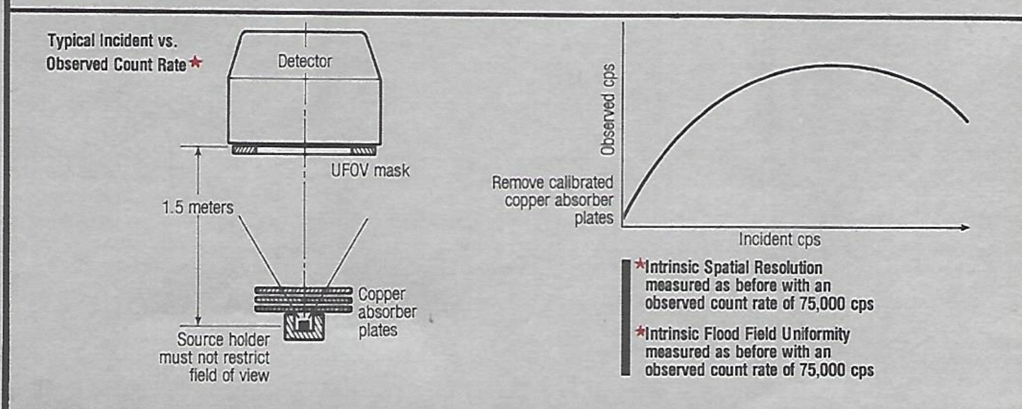
Five parameters shall be measured and reported:

REPORT

Input count rate for a 20 percent count loss, maximum count rate; and, as class standards, typical incident versus observed count rate curve, intrinsic spatial resolution at 75000 cps (observed), and intrinsic flood field uniformity at 75000 cps (observed).







6. Multiple window spatial registration

DEFINITION

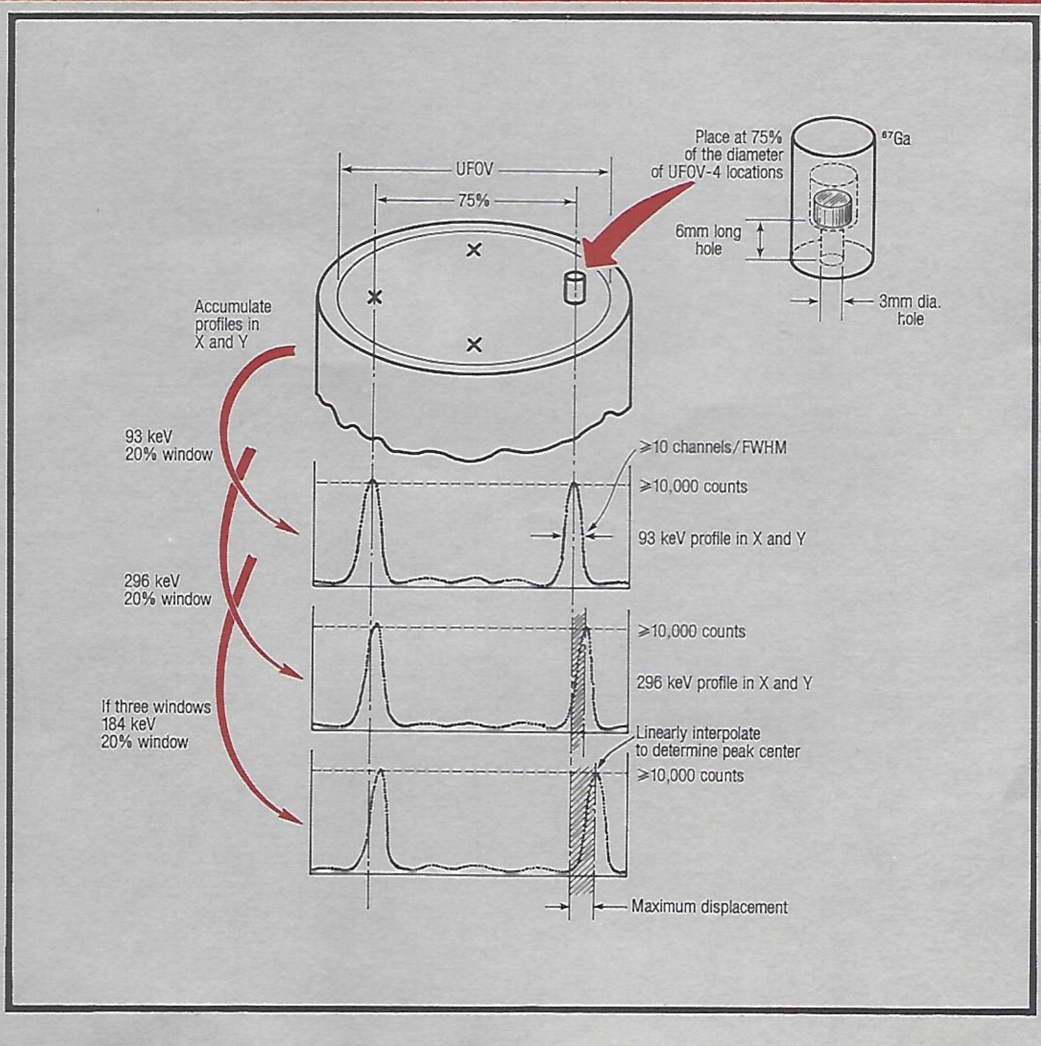
Multiple window spatial registration is a parameter of cameras which characterizes positional deviations in the image at different energies.

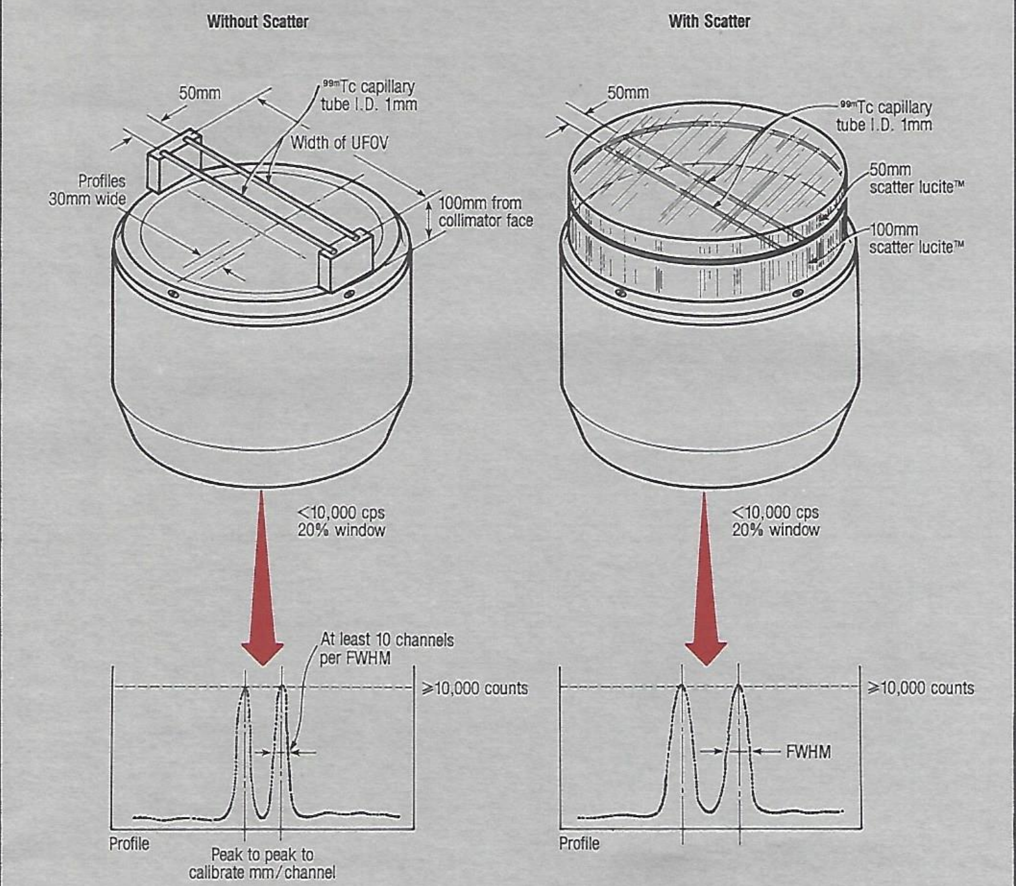
STANDARD

The spatial registration of the images from each of the camera's windows shall be measured and the deviation between the images for a collimated point source reported as the larger of the X and Y measurements, in millimeters.

REPORT

Maximum displacement in millimeters.





7. Systems spatial resolution with and without scatter*

DEFINITION

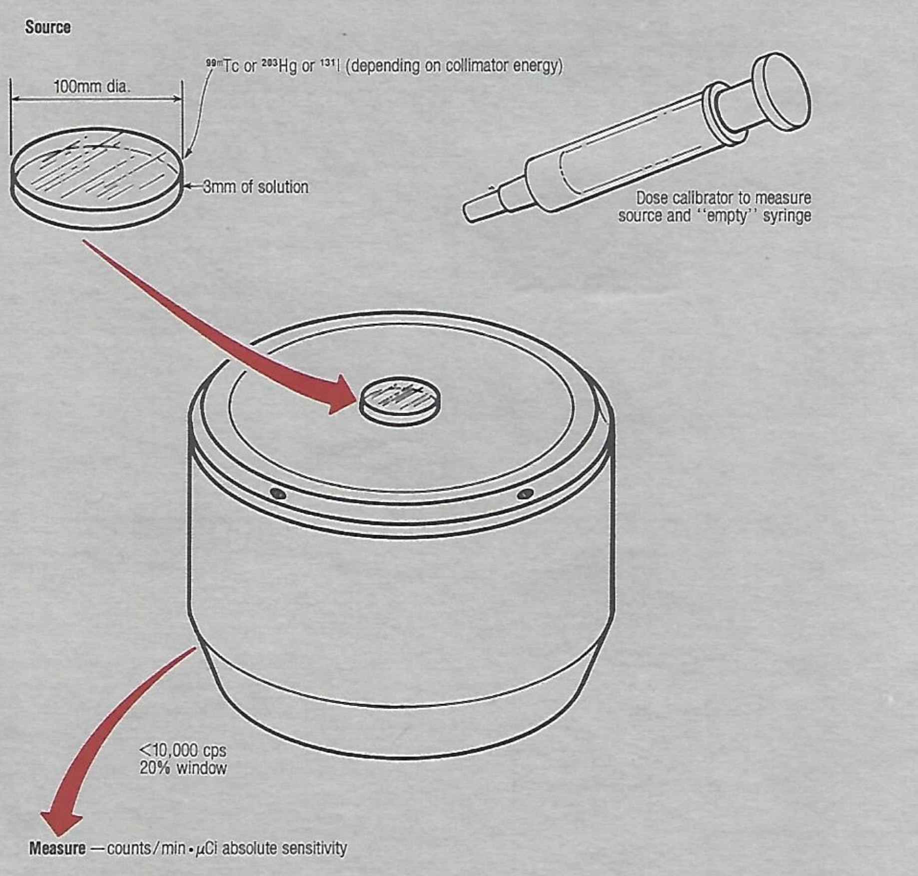
System spatial resolution with and without scatter is a parameter of a scintillation camera and collimator which characterizes its ability to accurately determine the original location of a gamma ray on an X-Y plane.

STANDARD

As a class standard, system spatial resolution with and without scatter shall be measured in both the X and Y directions and expressed as full width at half maximum (FWHM) and full width at tenth maximum (FWTM) of the line spread function expressed in millimeters, with the collimator specified.

REPORT

FWHM and FWTM average in CFOV



8. System sensitivity*

DEFINITION

System sensitivity is a parameter of a scintillation camera with its collimator in place, which characterizes its ability to efficiently detect incident gamma rays.

STANDARD

As a class standard, the system sensitivity shall be measured for each collimator and reported in counts/(minute • μCi). Counts are defined as interactions in the crystal that fall within the analyzer window; therefore field uniformity correction devices which alter the number of counts must be disabled.

REPORT

System sensitivity counts/(minute • μCi) with a specific collimator and relative sensitivity for each collimator.

*A class standard is a value(s) which characterizes a specific performance parameter typical of the given model number or series of scintillation cameras for which it applies. Usually the parameter is of auxiliary interest and is a subset of a measured standard.

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Toshiba Medical Systems Div.
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