

WHAT IS IT AND WHY WE NEED A FIT™ INDICATOR?

FIT is an acronym for **F**alse Positive/Negative, **I**nactivation and **T**ampering. As explained below, it is essential for the reliable monitoring of radiation exposure with SIRADs.

What is a FIT™ indicator and what does it do?: We introduced the FIT indicator so a user and/or an issuing organization can detect/monitor: (1) service life and expiration of service life, (2) overexposure to high temperatures for a prolonged period, e.g., 60°C/140°F for a month, (3) overexposure to UV/sunlight, (4) exposure to uncommon high temperatures e.g., above 90°C/195°F (or boiling water), thereby altering reactivity or making it inactive, (5) passed through laundry cycles and/or (6) if somebody tampered with it. SIRADs equipped with FIT indicators (e.g., RADTriage-FIT) are smart dosimeters, not only does it monitor exposure to radiation but it also gives you **peace-of-mind** that you are not exposed to radiation and in the case you are exposed to radiation, the dose is reliable. We take great pride in developing such a unique, but simple to use and interpret indicator for false positives, false negatives, archiving and service life.

RADTriage-FIT, a dosimeter in the SIRAD family, would not give false positive/negative indications if used as per instructions. However, someone can tamper with it or inadvertently expose to UV/sunlight or excessive temperatures. The false positive, false negative and tampering can create problems for the users, vendors and issuing agency/organization.

How does the FIT indicator work?: The central blue dot of the FIT indicator (if it has it) is a temperature indicator. It changes color when heated above 90°C. This is important because the sensor's service life and ability to monitor radiation may change if it gets heated above 90°C. This will be indicated by the color change (blue-to-red) of the central blue dot of the FIT Indicator or the FIT indicator itself.

The area surrounding the blue dot has very little sensitivity to X-/Gamma ray. However, it is significantly more sensitive to UV light. It has been designed this way because the sensors are also more sensitive to UV light. The sensor develops color very slowly with annealing at higher temperatures and hence the area surrounding the blue dot of the FIT Indicator also develops blue color slowly with annealing at higher temperatures. Though the color development of the sensors upon exposure to UV light and annealing to higher temperatures is quantitatively not the same as that of the area surrounding the blue dot of the FIT indicator and also does not quantitatively match the color reference bar of the FIT indicator, it gives an indication with about 30% uncertainty.

No malfunctioning: SIRAD does not have any electronic or any moving parts. The sensors are made by coating radiation sensitive formulations on polyester films. There is essentially nothing in SIRAD that can malfunction.

Sensing Materials: The radiation sensitive chemicals used to make the sensors are diacetylenes (R-C≡C-C≡C-R, where R is a substituent group). However, diacetylenes are also sensitive to UV light, temperature and integral value of time and temperature of storage (i.e., limited service life). These undesired effects can create serious problems including liability, worry and confusion for vendors, issuing organizations and users.

Effect of High Temperature: Diacetylene based sensors (e.g., those of SIRAD) could undergo a significant change in sensitivity to radiation and/or service-life if heated near or above melting point of the

diacetylene. The sensors will not monitor radiation above their melting points (e.g., above 90°C/194°F for SIRADs). If heated above its melting point and cooled to room temperature, depending upon the rate of cooling, the sensors could (1) remain insensitive to radiation or (2) could have different radiation sensitivity and service life. Under these conditions, the sensors could provide false positive or negative readings and/or lower service-life - thereby making estimation of dose and service life potentially meaningless and creating a variety of problems for vendors, issuing organizations and/or users. Under direct sunlight, the temperature inside of a truck could exceed 55°C/130°F during shipping and 80°C/176°F near the dashboard of a car. Hence, one needs to make sure that diacetylene based dosimeters are not exposed to high temperatures (90°C/194°F for SIRADs) during shipment and normal use. It is less likely that during normal use temperatures would exceed 90°C. However, under abnormal use (e.g., high temperature laundry cycle) and uncommon use (e.g., during fire fighting) if a SIRAD is exposed to a temperature above 90°C, the central dot of FIT indicator will indicate so, i.e., change from blue-to-red.

Question: *How do I know my dosimeter is active (i.e., capable for monitoring radiation) or not?*

Answer: If the central blue dot of the FIT indicator has not changed to purple or red color, your SIRAD is active to radiation, i.e., it will monitor radiation.

Question: *How do I know that the radiation sensitivity and calibration of the SIRAD is not altered during shipping and/or use?*

Answer: If the central blue dot of the FIT indicator has not changed to purple or red color, the sensitivity of your SIRAD sensors should be normal.

Question: *How do I know that no color development of the sensors of my SIRAD is not due to a false negative, i.e., I am exposed to radiation yet the sensors do not show it?*

Answer: If the central blue dot of the FIT indicator is not purple or red, the sensors of your SIRAD are active, i.e., it has the ability to monitor radiation and you/SIRAD are not exposed to radiation. You have peace of mind.

Effect of UV light: Diacetylenes are extremely sensitive to ultraviolet light, especially to short wavelength UV light. The unprotected coating of the diacetylenes is usually so sensitive that it would develop blue color equivalent to about ten minutes if exposed to direct intense summer sunlight. Diacetylenes used for SIRAD have very low sensitivity to UV light. Additionally, we have added (1) UV absorbers in the formulation, (2) protected with films which are UV absorbing and (3) a red colored film which protects the badge from UV from sunlight for days. Fluorescent light also emits both long and short wavelength UV light. Exposure to UV light can provide a false positive. The sensor can get exposed to UV light during reading the dosimeters. If the sensor of SIRAD is exposed to UV light, inadvertently or intentionally, the area surrounding the central blue dot of the FIT indicator will develop blue color

proportional to UV exposure. Thus, the degree of UV exposure can also be monitored with uncertainty of ~30%.

Thermal annealing and service life: Diacetylenes also develop color during storage (thermal annealing). The higher the temperature and the longer the time of storage, the darker the colors of the sensors and FIT indicator become. The color development depends upon the integral value of time and temperature, creating limited service life. We have added so called service life extenders to extend the service life of SIRAD. However, the service life of SIRAD is about one year at 25°C. The service life is defined as time required for the sensor to develop color at room temperature equivalent to ~2% of the upper limit listed on the color reference bars for wide dose range SIRADs. For example, the sensor of RADTriage would develop color equivalent to about 1-2 rad when stored for one year at room temperature in absence of all radiation. The service life will be reduced to six months at 38°C/100°F and to about one month at 60°C/140°F. Hence, there is a need for the service life indicator. If used at temperatures higher than 25°C, the reduced service life can be indicated by color of the area surrounding the central blue dot of the FIT indicator. If it develops color darker than the color reference bar, the service life has expired. The service life could be extended to almost ten years if kept frozen (e.g., -10°C/14°F). This allows SIRAD (without expiration date printed) to be stockpiled at a lower temperature and used in emergencies.

Sensitive to both UV light and annealing: The area surrounding the central blue dot of the FIT indicator is sensitive to both integral value of time and temperature of storage (service life) and exposure to UV light. Prolong exposure to UV light and/or high temperature could provide false positive. The FIT indicator will monitor both thermal annealing and exposure to UV light.

Question: How do I know that the color of my sensors is due to a genuine exposure to X-/gamma ray and not due to a false positive?

Answer: If the area surrounding the central blue dot of the FIT indicator is not bluer than the adjacent color reference bar, it is likely that you have a genuine exposure to radiation.

Question: How do I know that color development of the sensors of my SIRAD is a false positive?

Answer: If the area surrounding the central blue dot of the FIT indicator is bluer than the adjacent color reference bar, it is likely that you have a false positive signal. There are also other false positive indicators, e.g., internal indicators.

Question: How accurate is FIT indicator?

Answer: The central blue dot of the FIT indicator is fairly accurate ($95 \pm 3^\circ\text{C}$) in monitoring temperature depending upon the heating rate. However, the uncertainty in matching effects of UV light and/or service is about 30%. The uncertainty in any color matching device is usually at least about 10-15%. For example, the uncertainty in visual estimation of dose of SIRAD is about 20%. In case of FIT indicator is

higher because it monitors too many parameters at one time, e.g., temperature, UV light over wide range (400nm to 150nm) and it also monitors effect of integral value time and temperature and still remain un-affected by X-ray. The color matching of the area surrounding the central blue dot of the FIT indicator with its adjacent color reference bar should be in fluorescence light.

X-/gamma ray sensitivity of the FIT indicator: The area surrounding the central blue dot of the FIT indicator is almost 500 times less sensitive to X-/gamma ray compared to that of the sensor. And it is still significantly more sensitive to UV light and thermal annealing.