Improved Safety in Gamma radiography –
New Equipment Design, New Isotopes

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Gamma radiography is an important tool in non-destructive testing on construction sites and remote locations. Main applications are weld inspection on oil and gas pipelines, power plants as well as in chemical and petrochemical production sites. Gamma radiography is a very economical and at the same time safe process to ensure operational safety of inspected assemblies resulting in better protection of human health and environment. Gamma radiography completes the full range of a modern NDT business. Where other methods are inapplicable, e.g. due to lack of electricity out in the field in pipeline building, gamma radiography is fulfilling the lack of electrical applications. Easy positioning of the very small focus spot and short preparation time are also advantages of the use of isotopes in NDT.

The mainly used isotopes in industrial radiography are ^{60}Co, ^{192}Ir, ^{75}Se and ^{169}Yt. On account of the hard energy range the use of ^{60}Cobalt is limited to big wall thickness of steel and concrete (up to 150 mm). This fact leads to focus on the other mentioned isotopes more particular only. The main technical specifications of the isotope sources ^{169}Ytterbium, ^{75}Selenium and ^{192}Iridium are shown in table 1.

Isotope	Yb-169	**Se-75**	Ir-192
Energy Range /keV	63-308	**66-401**	206-612
Average Energy /keV	145	**217**	353
Typical. Steel Thickness /mm	2-10	**2-30**	10-60
Half-life / d	32	**120**	74
R/(h*Ci) at 1m dist.	0.125	**0.203**	0.48

Table 1: Characteristics of the isotopes used in gamma radiography

The short half-life of 32 days and the very high costs for ^{169}Ytterbium sources as well as the resulting long exposure time have been the main factors for the rather low importance of ^{169}Ytterbium in the full range of gamma radiography. With introduction of the isotope ^{75}Selenium in 1996 it is replacing ^{169}Ytterbium in the modern gamma radiography.

As visualized by the different radiation constants of 0.48 (^{192}Iridium) and 0.203 (^{75}Selenium) exposure times differ by an approximate factor of 2.5 with slight variations depending on the actual material thickness under inspection. X-ray comparable image quality and the longer half-life makes gamma radiography with ^{75}Selenium also commercial interesting.

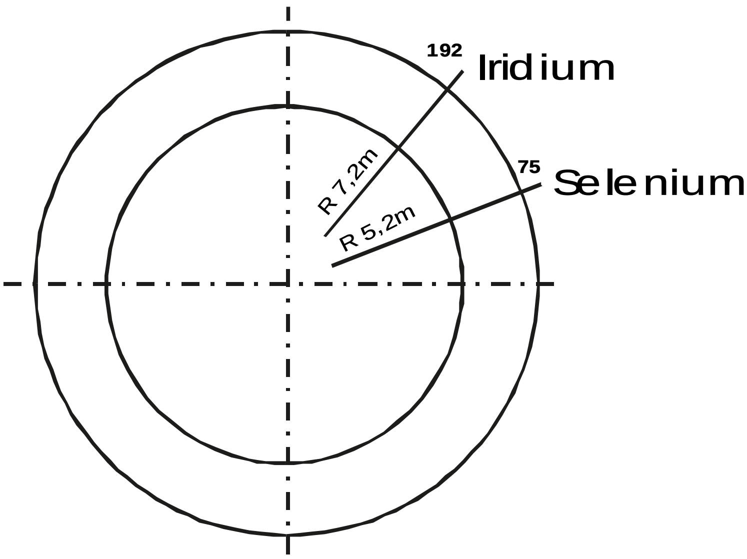

Table 2: Radiation isodose radius obtained with 10 Ci ^{75}Selenium and ^{192}Iridium

The physical properties of the ^{75}Selenium also offer big advantages with respect to radiation shielding and beam collimation. Within the comparison of radiation isodose areas the required area-radius for a survey of 40µSv/h result in a shut off area that is for ^{75}Selenium only half the size as for ^{192}Iridium. Sources of similar activity and collimators of same absorption value (95%) have been used to obtain values as mentioned in Table 2 above.

Test	Sealed source	Sources to be used in device
Temperature	-40 °C (20 min), +800 °C (1h), and thermal shock to about 20 °	-40 °C (20 min), +800 °C (1h), and thermal shock to about 20 °
Pressure	25 kPa absolute to 2 Mpa absolute	25 kPa absolute to 2 Mpa absolute
Impact	5 kg from 1m	20 g from 1 m
Puncture	300 g from 1 m or equivalent imparted energy	10 g from 1 m or equivalent imparted energy

Table 3: Source tests performed

Through lower energies of the emitted gamma radiation and a lower specific dose rate (only 40% of ^{192}Ir) ^{75}Se allows for largely decreased levels of leakage irradiation at otherwise comparable operational conditions, which result in drastically reduced radiation exposure to the environment.

In general sealed sources have to pass several tests before releasing into the market. Sealed sources are capsuled radiated isotopes in one or two housings, depending on the isotope and the capsule. For the approval of such a sealed source several tests as listed in table 6 have to be passed. Additional to the bubble and inversion test each source is wiped before leaving the MDS Nordion facilities to ensure that no source is contaminated.

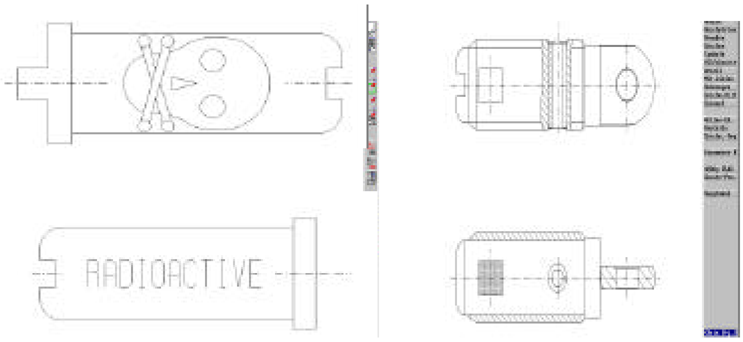

Table 4: Sealed source capsule, different views

Radiation safety during the inspection process strongly depends on the operational safety of the equipment and the isotopes used, as well as the application of appropriate radiation protection and the general awareness of the human operators. A significant improvement of radiation safety during operation and a reduction of potential radiation incidents will result from the new ISO 3999 standard. This implements a variety of requirements on apparatus for industrial gamma radiography, so called projectors and their operational accessories., Table 5 shows the main safety mechanisms of the **GAMMAMAT®** SE devices. This projector is the result of most sensitive research to fulfil all the requirements of the ISO 3999:2000. It is developed for the use with the isotope ^{75}Selenium which is described more particular above and is designed under modern safety standard aspects. This new design and tests in cooperation with the German institute BAM (Bundesanstalt für Materialprüfung; Institute for Material Testing) results in best safety for operator and environment. Tests simulating much higher requirements than ever will appear with the unit under real working conditions are passed without any restriction. Table 5 shows the most important test results of GAMMAMAT® SE and TSI devices. Also standard accessories like remote control, source holder with the connection with the drive cable are tested under different circumstances. These test results also show that the different components of the equipment passed the tests without any restriction.

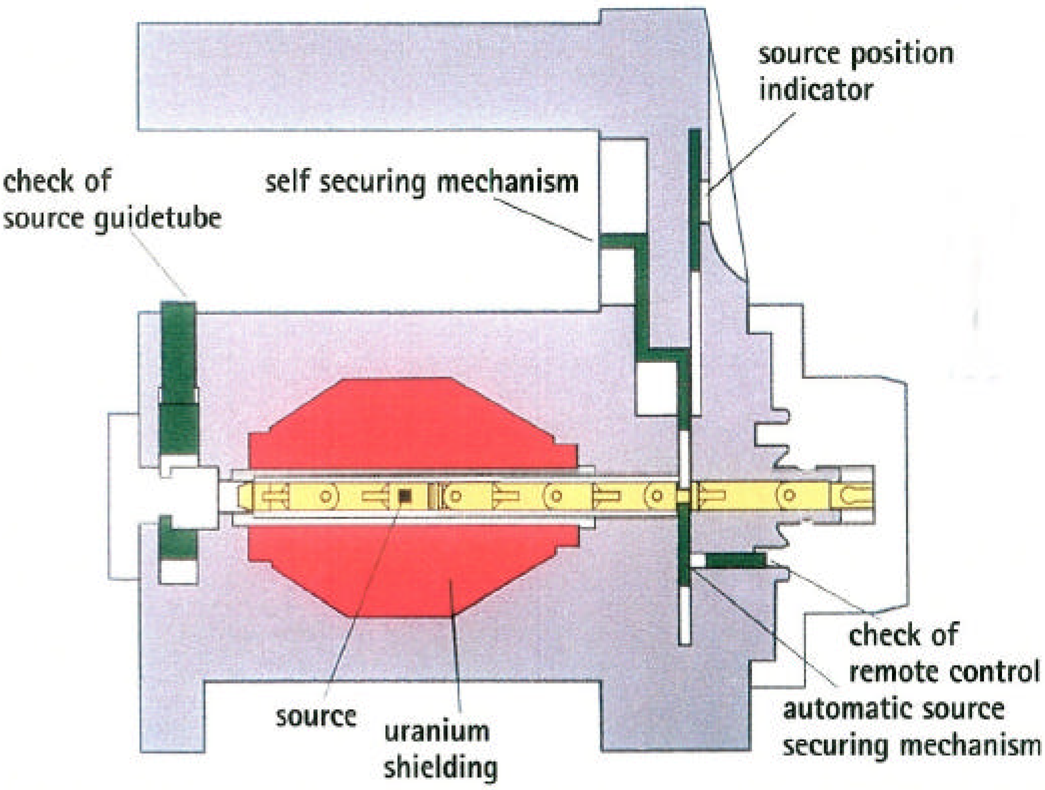

Table 5: Sketch of GAMMAMAT® SE, with safety mechanisms required by ISO 3999

Before extracting the radioactive isotope into working position with the remote control three steps have to be absolved. It is impossible to open the device without connecting the remote control and the guide tube, which is leading the isotope in the source holder into working position. The remote control cannot be connected when the drive cable of the remote control is not fixed with the source holder. This avoids the loss of the isotope by moving out the source without connection. The connection is necessary for retracting the source into the container. After connecting all necessary items a safety lock avoids opening the closing mechanism. Only the operator with the correct key is able to unlock the device. A final source securing mechanism gives the source holder free to extract the isotope. After retracting the source back into the apparatus the source securing mechanism blocks the isotope to avoid that the radioactive material fells out of the device. The operator has to open this locking mechanism before doing a new exposure. Easy handling and lowest possible weight with 7 kg only allows safe, comfortable and easy work for the operator.

This new safety mechanism are also installed into the new GAMMAMAT® TSI series which is replacing the older series GAMMAMAT® TI, including GAMMAMAT® TI-F and TI-FF. With the new design moving Uranium parts are no longer built inside the device. This results in no potential contamination by Uranium dust getting free caused by wear and tear. As the device has no self closing mechanism unaware extracting could easier appear.

		ISO 3999 required	Test performed	Test result
Accidental drop test	TSI Unit	Not required	4x9 m drops performed by BAM / Germany on the same unit	No loss of shielding integrity
	SE Unit	1 drop from 1.2 m	1 drop from 9 m	No loss of shielding integrity, unit operates correctly
			1 drop from 1 m on a steel billet	
			2 drops from 1 m with 90 ° angle	External plastics damaged, unit operates correctly
Endurance test	TSI Unit	50.000 cycles	Over 100.000 cycles	Unit and components (remote control and guide tube) operate correctly
	SE Unit	50.000 cycles	Over 70.000 cycles	Unit and components (remote control and guide tube) operate correctly
Horizontal shock test	TSI Unit	20 shocks on every critical part of the unit	20 shock tests on the front side of the unit, 20 shock tests on the back side of the unit	Unit operates correctly
	SE Unit	20 shocks on every critical part of the unit	20 shock tests on the front side of the unit, 20 shock tests on the back side of the unit	Unit operates correctly
Tensile test	TSI holder	10 tensile tests of 10 s at 1000 N	10 tensile tests of 10 s at 1000 N	The source holder assembly maintained ist integrity
	SE holder	10 tensile tests of 10 s at 1000 N	10 tensile tests of 10 s at 1000 N	The source holder assembly maintained ist integrity
	Remote cable	10 tensile tests of 30 s at 500 N	10 tensile tests of 30 s at 500 N	The remote control assembly remained operational
	Remote sheath	10 tensile tests of 30 s at 500 N	10 tensile tests of 30 s at 500 N	
	Guide tube	10 tensile tests of 30 s at 500 N	10 tensile tests of 30 s at 500 N	The exposure tube remained operational
Shielding test (No change of dose rate when the device is opened as long as the source is in shielded position)	TSI 3/1 Unit	2 mS/h contact	Dose rate with 3 TBq Ir-192 source	Max. 1.03 mS/h contact
		20 µSv/h at 1 m		Max. 8 µS/h at 1m
	TSI 5/1 Unit	2 mS/h contact	Dose rate with 5 TBq Ir-192 source	Max. 0.99 mS/h contact
		20 µSv/h at 1 m		Max. 9.1 µS/h at 1m
	SE Unit	2 mS/h contact	Dose rate with 2.7 TBq Se-75 source, containing Sc-46 (calculated for 3 TBq)	Max. 1.93 mS/h contact
		20 µSv/h at 1 m		Max. 5 µS/h at 1m
Temperature test	TSI Unit, SE Unit	-10°C +45°C	-40°C +50°C	Unit and components (remote control and guide tube) operate correctly

Table 6: Test results of some tests performed with GAMMAMAT® SE and TSI devices and accessories.

Always being on the actual status of the stand of technique and convenience for the operator, the MDS Nordion research department is testing new ideas and aspects regularly. One of the newest result is the “easy click connector” as shown in table 7.

For the time being in a prototype status this new connector will be released soon in the market. With the elder model the operator was forced to connect the cable with the source holder by touching the cable. By incorrect handling or just difficult environmental conditions where the operator is working with gloves the drive cable is bent and threatened to break. With the new connector it is not needed to touch the cable. This avoids the bending of the cable and the potential possibility of breaking is no longer given. Further it is easier for the operator to work with gloves.

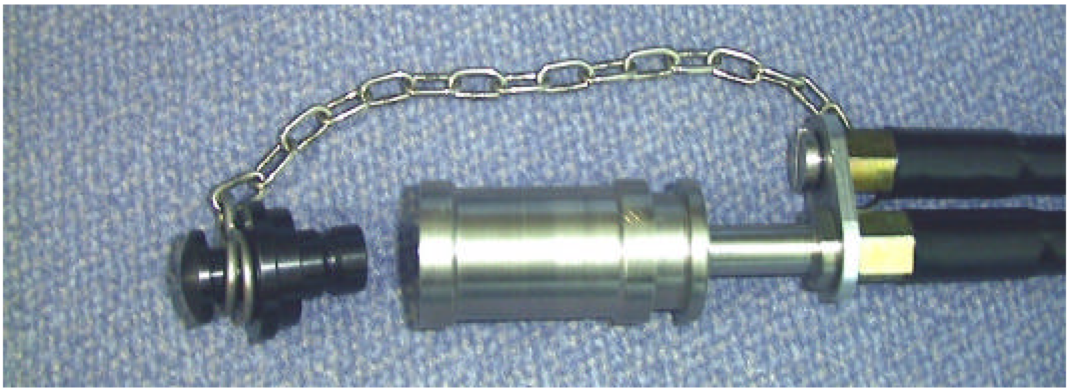

Table 7: Easy click connector

Summary:

The new isotope ^{75}Selenium with its typical characteristics allows a smaller shut off area around the exposure working place. Several safety mechanisms on GammaMat® equipment allows no accidents due to inattentive operation with gamma radiography apparatuses. Tests simulating worst cases of different accidents show that GammaMat® equipment is resistant against any potential accident which could appear during operators work. No increasing radiation safes the operator as well as the environment conforming the actual status of the stand of technique and still allows safe transport of isotope and unit without increased radiation level. Although having the most possible safety on equipment, improvements are developed on device, accessories to conform the actual stand of technique in manner of safety and convenience.