Progress report on radiation dosimetry at NIM

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1. Introduction

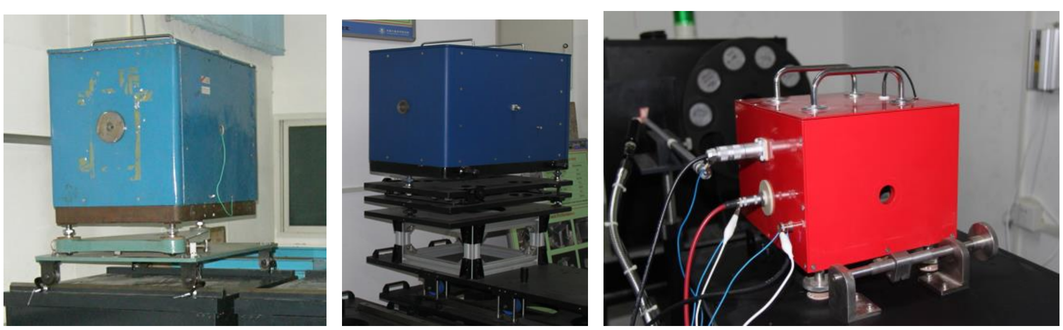
This report is a brief overview of radiation dosimetry activities carried out at NIM during the last 2 years, for the CCRI (I), March 25-28, 2013, Paris. More detailed scientific information can be found in the publications listed in Section 5.

2. AIR-KERMA STANDARDS

2.1 Kilovoltage X-rays

2.1.1 Primary standards

NIM maintains three free-air chambers (FAC) which is used in the range 10 to 300 kV (shown in Figure 1a, b, c). All three free-air chambers are parallel plate type. Figure1a. shows the free air chamber for medium energy x-rays which is made in 1980s. The free air chamber (shown in figure 1b) was established in 2010 to measure air kerma in the range from 60kV to 300kV. The red one (figure 1c) is a low energy x-rays free air chamber, which is designed in 2008 to realize air kerma of x-rays from 10kV to 100kV.



a b c

Figure1. Photograph of the NIM FAC used for realizing air-kerma in the range of (10-300) kV X-rays.
a. FAC for medium energy x-rays made in 1980s;
b. FAC for medium energy x-rays established in 2010;
c. FAC for low energy x-rays established in 2010;

2.1.2 Irradiation facilities and beam qualities

The x-rays irradiation facility is used to establish beam qualities for air kerma realization and calibration. The x-rays tube and generator is listed in table 1. It covers low and medium energy range with tungsten and molybdenum target. For beam qualities, the CCRI qualities for comparison, IEC 61267 RQR series, ISO 4037 narrow spectrum series were established for survey meter calibration. Figure 2 shows the irradiation facilities the lab developed.

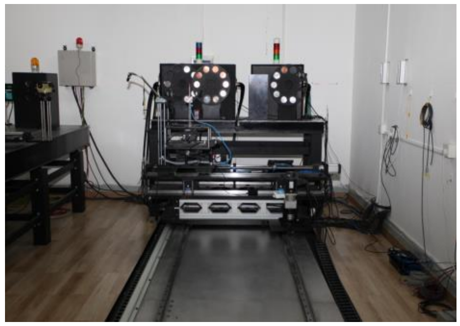


Figure 2. Low energy and medium energy x-rays facilities

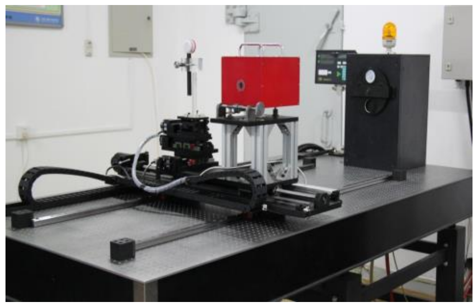


Figure 3. Mammography x-rays Facility

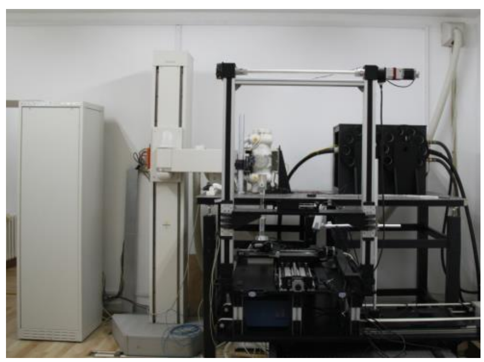


Figure 4. Secondary standard in Diagnostic x-rays

Figure 5. Control, monitor and current measurement system

Table 1. X-rays tube and type

Tube	Type	Anode	Tube voltage	Notes
MCN321	Phillips	W	15 kV - 320 kV	For Radiation protection
SRO3310	Phillips	W	50kV-150kV	For diagnosis x-rays
YCLON.TU 320-D01	YXLON	W	15 kV - 320 kV	For medium-energy x-rays
YCLON.TU 160-D02	YXLON	W	8kV - 160 kV	For low energy x-rays
MCB100	RTW	Mo	10 kV - 100 kV	For mammography x-rays
M-152	Varian	Mo/Rh	22 kV - 39 kV	For mammography ,it will be installed in 2013
M-113T	Varian	W	22 kV - 39 kV	For mammography ,it will be installed in 2013,
X-view X5000	NSI	W	25 kV - 225 kV -450kV	This Industrial CT will be installed in 2013

2.1.3 kV measurement system

We have established the measurement system for the calibration of kV meter(kVp, exposure time), and are extending our services: radiograph, computed tomography, mammography. Two high voltage divider were purchased to measure high voltage of x-rays generator, one is used for diagnostic x-rays machine, another is for industrial x-rays generator.

Figure 6. High voltage divider for diagnostic x-rays machine

Figure 7. High voltage divider for industrial x-rays generator

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2.2. Gamma Radiation Air-kerma Standard

2.2.1 Primary Standard Graphite Cavity Chamber

The NIM primary standard of air-kerma for ^{60}Co radiation is a 9.5 cm^3 cylindrical graphite walled spherically-ended cavity chamber. It continues to be maintained. No further upgrades to report since April 2011.

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2.2.2 ^{137}Cs Gamma-ray Calibration Facility and Standard Cavity Chamber for Radiation Protection

A new facility for the dissemination of the air kerma standard from ^{137}Cs with activity about 2.2 TBq was developed in 2012, which could extend the current range of air kerma values available at NIM. The facility includes a new self-shielded ^{137}Cs irradiator, and a track positioning system to enable irradiations of various types of radiation measuring instruments.

The facility can give an air kerma rate of 200mGy/h at 1 m, which meet the needs of the testing and calibration of radiation-detection instruments in radiation protection and homeland-security applications.

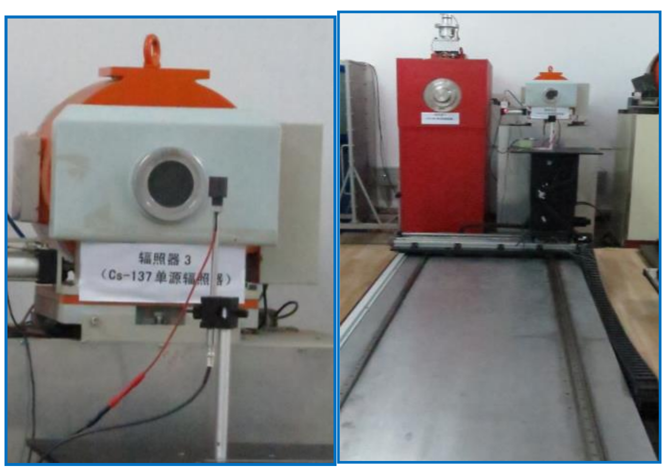

Figure 8. Photograph of the New ^{137}Cs Gamma-ray Calibration Facility and Track Positioning System

In 2012, a new cylindrical graphite walled cavity chamber to measure air-kerma of ^{137}Cs radiation has been designed and manufactured according to the definition of air-kerma at NIM. The characteristics of the cavity chamber are shown in Table 2 and illustrated in Figure 9.

Table 2. Characteristics of the NIM standard of air kerma

Type NIM-CC10		Nominal values
Chamber	Outer height/mm	30
	Outer diameter/mm	30
	Cavity height/mm	24
	Cavity diameter/mm	24
	Wall thickness/mm	3
Electrode	Diameter/mm	2
	Height/mm	20
Volume	Air cavity/cm3	10.8
Wall	graphite	graphite
	Densuity/g·cm-3	1.836
Insulator	Kel-F	C_2ClF_3
Applied tension	Voltage/V	800

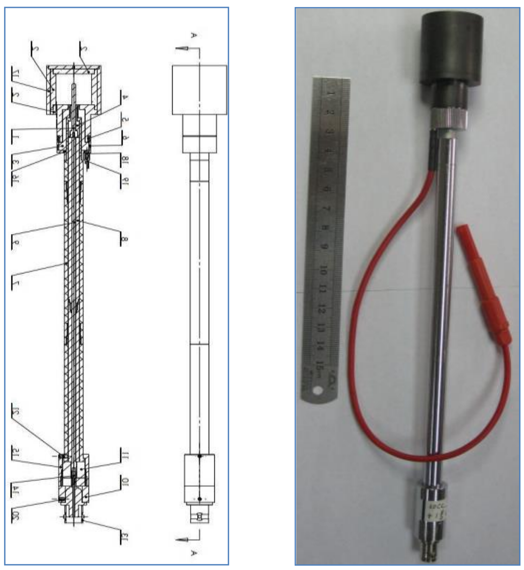

Figure 9. Schematic drawing and photograph of the cylindrical graphite cavity chamber used for realizing air kerma for ^{137}Cs beam

The characteristics including leakage current, the correction factor are obtained by physical experiment or the EGSnrc Monte Carlo system. This chamber will be established as a primary standard for realizing the unit Gy for air kerma for ^{137}Cs γ-rays.

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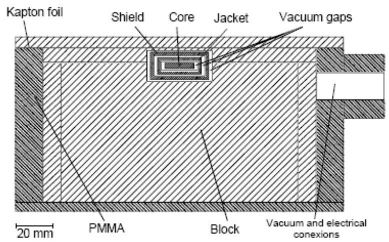
3. ABSORBED DOSE STANDARDS

3.1. Absorbed Dose Primary Standard for Cobalt-60 beam for radiotherapy

To meet the measurement of the absorbed dose for cobalt-60 beam, NIM started to develop the graphite calorimeter and ionization chambers for radiotherapy since 1980s.

The graphite calorimeter (GR7, which is developed by Mr. A. Ostrowsky, LNHB 1983-1984) will be used as the NIM absorbed dose primary standard for cobalt-60 beam. After the design and construction of the electronic control and measuring system, the main of performance test and dosimetry work are now being carried out.



(a)

(b)

Figure 10. Schematic drawing of GR7 graphite calorimeter (a) and photograph of the electronic controlling and measuring system of graphite calorimeter.

This graphite calorimeter (GR7) operates in two modes, i.e., quasi-adiabatic and constant-temperature operating mode.

The vacuum in the calorimeter is ～5×10^{-5} torr. The variance of the thermostat resistance in calorimeter with temperature is measured. The relative sensitivity is 0.0382 K^{-1} in the range of 15℃ to 26℃, which was about 0.038 K^{-1} in 1983.

The PID controllers based on NI-LabView PC operated for the thermal regulation for core (A), jacket (E), shield (M) and block (B). The temperature of absorber was measured using DC Wheatstone-bridge, and the temperature of absorber and the electrical heater power are recorded as a function of time.

During the beam shutter is closed, the temperature of absorber is stable, and has a standard deviation of below 17 μK from the set value (the voltage at output of the bridge is below 100 nV).

The output of heater power source has a standard deviation of below 1nW. Owing to the controller action, the heater power of the absorber (core A) shows a standard deviation of 1 μW about its mean bias value of (50～300)μW.

For constant-temperature operating mode， the dose rate was（11.911±0.18%）mGy/s for 69 measurements during two months and 10min～20min of irradiation time. For quasi-adiabatic mode, the dose rate was（12.025±0.28%）mGy/s for 24 measurements during one month and 300s～1400s of irradiation time. The consistency of 0.07% for two modes is reasonably satisfied.

The final evaluation of uncertainties for primary standard of absorbed dose to graphite is progress. The conversion between absorbed dose to graphite and absorbed dose to water has been further investigated for cobalt-60 beam. International comparison will be planed to carry out.

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3.2. Absorbed Dose transfer Standard for Cobalt-60 beam for radiotherapy

In the end of 2010, NIM's three transfer standards (NE 2571-708, PTW 30012-163, PTW 30010-2369) , which were calibrated by BIPM in Feb 2010, participated in the APMP.RI(I)-K4 key comparison of absorbed dose to water from ^{60}Co gamma-ray beams. There were 15 participating laboratory, the comparison was completed in the winter of 2011. Figure 11 shows the results of this comparison. The results showed that the difference between the NIM and the BIPM, evaluated using the comparison data of the linking laboratories, was less than 0.5% within the expanded uncertainty of the reference value. The report for this APMP.RI (I)-K4 key comparison is in preparation.

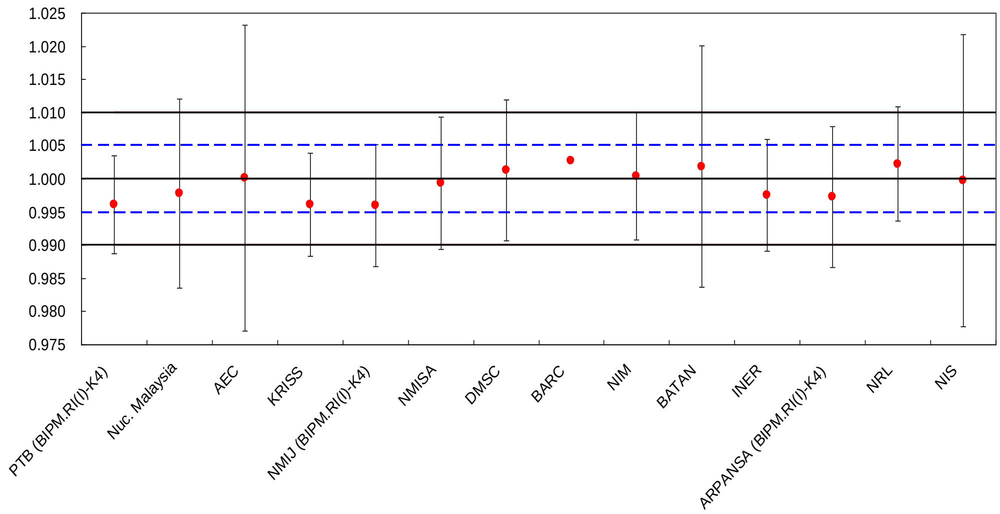

Figure 11. Ratios $R_{\mathrm{NMI,mean}}$ of transfer chamber calibration coefficients relative to the mean value for all laboratories

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3.3 Absorbed Dose Reference Standard to Water for Radiation Processing

No changes to report for NIM absorbed dose reference standard to water for radiation processing since April 2011.

In 2011, NIM Fricke reference dosimetry standard and other seven national standards participated in APMP.RI (I)-S1 comparison of high-dose dosimetry. The comparison covered the range from the 0.1kGy to 50kGy and used OAP (Thailand) alanine dosimeters as the transfer dosimeters. There are 5 participating laboratories. OAP provided the analine dosimeters to NIM for measurement in end Oct, 2010, and these measurements were completed and equipment were returned to OAP in January 2011.

The comparison was completed in the spring of 2011. The Figure 12 shows the results of this comparison. The report for this APMP.RI (I)-S1comparison is in preparation.

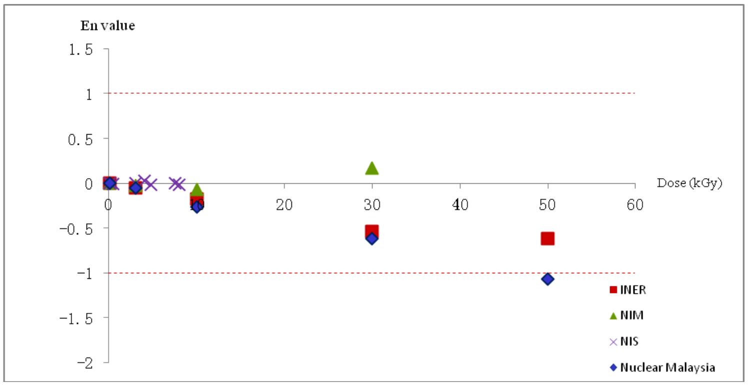

Figure 12. The En value from participants in absorbed dose range 0.1-50 kGy

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3.4 Resourced of the NIM radiation processing level ^{60}Co source

The pool-type Co-60 irradiation facility at NIM was characterized in terms of absorbed dose rate and has been re-furbished for the high dose calibration service since 2009 and resourced in May 2012. The overall activity of the source is about 1200 TBq in March 2013.

The source was calibrated in terms of absorbed dose to water by a set of Fricke dosimeter. The *K* of Ceric-Cerous sulfate, potassium dichromate dosimeter is calibrated through the Fricke dosimeter standard at the dose rate of ～70Gy/min in this irradiation filed, respectively.

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3.5 Mega-voltage X-ray and electron beams

3.5.1 Linear Electron Accelerator Facility

No changes to report for NIM 10 MeV 10kW Linear Electron Accelerator Facility since April 2011

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3.5.2 **Clinical** LINAC.

In 2012, NIM signed purchasing contract of the Elekta Synergy medical standards linear accelerator for megavoltage dosimetry and the direct calibration of hospital reference dosimeters. The clinical LINAC building is planed to be built this month, and hand over to NIM in the end of 2013. The manufacturer for the LINAC will be delivered and carried out preliminary installation of the clinical LINAC as soon as possible after the building completion.

The clinical LINAC provides X-ray energies of 4, 6, 8, 10, 15, 18 and 25MV respectively. The available electron energies are 4, 6, 8, 10, 12, 15, 18, 20 and 22MeV.

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3.6 Alanine/EPR Dosimetry

No changes to report for the NIM the alanine/EPR dosimetry since April 2011.

A study has been carried out to reduce the minimum dose of alanine dosimeter to 1Gy for radiotherapy applications.

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4. APPLICATIONS OF DOSIMETRY STANDARDS

4.1. TLD Dosimetry System

TLDs were used for monitoring the exposure of personnel working programs by the Centers for Disease Control and Prevention of China (CDC) and environment radiation measurement programs by Ministry of Environment Protection in China (MEP). NIM provides calibration services for the TLD readers to the CDC and the MEP to supporting the programs.

The TLD Dosimetry System allows dissemination of the national standard and is available to existing as well as customers including CDC and MEP， hospitals, nuclear power plants, and manufacturers of instruments.

NIM participated in the IAEA TLD POSTAL QUALITY AUDIT for ^{137}Cs radiation protection calibrations in Dec 2012. the results have not been published yet. NIM is planning to carry out the comparison for protection-level TLD comparison in the APMP regional as the pilot laboratory.

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4.2 Measuring Instruments Calibration and Verification

NIM establishes and maintains the standards at the accredited dosimetry calibration laboratories providing the state metrological control for the secondary and working standards calibration and comparisons, type approval, products certification for radiation safety.

For the last 2 years, NIM performs more than ten thousand calibrations, verifications and comparisons of working standards and measuring instruments for X-ray, gamma-ray and electron beam, including personal dosimetry control systems.

5. PUBLICATIONS AND REPORTS

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