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Dosimetry Standards and Dissemination Systems for Radiation Processing in China

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Organization

Founded in 1955, National Institute of Metrology (NIM) is the national metrology institute of China, subordinate to General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), China. It is the nation's highest technical authority in the field of metrology, and responsible for providing metrology services of the highest accuracy and reliability to customers.

NIM's main tasks

- *Research, establish, maintain and improve national primary standards & national standards*
- *Participate in international comparisons to ensure traceability and international equivalence of national standards;*
- *Disseminate values to its clients through verification and calibration services, ensure all unit values are traceable and reliable within the nation;*
- *Carry out fundamental and frontier research in metrological science, study measurement theory and technique; develop value disseminating and tracing methods, etc.*

Div. of Metrology in Ionizing radiation :

Three section: Radioactivity, Dosimetry, Accelerator and Neutron

- *Primary standards: 18 (1 for radiation processing)*
- *Secondary standards: 15 (4 for radiation processing)*
- *Comparison: 34 (1 for radiation processing)*
- *CMCs:195 (8 for radiation processing)*

Dosimetry system for high-dose

In 1983, a project of high dose standardization was initiated in China.

- To establish the high-dose standards system for γ-rays and EB irradiation.
- To establish the dissemination of high-dose value through intercomparison, calibration and verification.
- Implementation of NDAS using alanine/EPR dosimetry system.
- To Calibrate routing dosimeters and measure radiation field dose mapping of radiation processing facility.
- To train the technical personal in dosimetry for irradiation facilities and to help them to set up their own routine dosimetry system.
- To enact administrative regulation and technical standards concerned absorbed dose for radiation processing.

Dosimetry system for high-dose

In 1986, the high-dsoe standards and dissemination system has been established at NIM.

- ***Primary standard :*** ***Fricke liquid chemical dosimeter***
- ***Transfer standards:*** ***Ceric-cerous sulfate liquid chemical dosimeters***

  Dichromate liquid chemical dosimeters

  Alnine/EPR dosimeter

	Fricke dosimeter	Silver Dichromate dosimeter	Potassium Dichromate dosimeter	Alanine/EPR Dosimeter
Absorbed dose range	40~400 Gy	0.4~5 kGy	5~40 kGy	0.1~40 kGy
Uncertainty at k=2	2.0%	4%	4%	4%

liquid chemical dosimeter Standards at NIM

A type of Cary 4E Uv/vis spectrophotometer has been used for measuring optical absorbance of dosimetric solution, the pre-irradiation absorbance : Ao and the post-irradiation absorbance: Ai.

$$\Delta A = |Ai - Ao|$$

Cary 4E Uv/vis spectrophotometer

Liquid chemical dosimeters

The Fricke dosimetry system

as primary standard to measure the absorbed dose in water of $^{60}Co\gamma$-rays in processing level with uncertainty of less than 2% (k=2)。

- *The absorbed doses are calculated as follows :*

$$D_W = 1.004\, D_F = 1.004\, K_F \cdot \Delta A \qquad (1)$$

$$K_F = 1 / \varepsilon \cdot G \cdot l \cdot \rho = 279 \quad (GyAbs) \qquad (2)$$

---K is the dose-response conversion factor.

---G is radiation chemical yield
(=1.61×10^{-6} mol·J^{-1} , ICRU 34# report)

---ε is molar linear absorption coefficient of Fe^{3+}
(=219.2±0.3 m^2mol)

--- l is optical pathlength of the dosimetric solution in the cuvette
(=10.0mm)

---ρ is density of the dosimetric solution,
(=1.024 g/cm^3)

Dosimetry system for high-dose

Alanine/EPR dosimetry system

It has been developed as a transfer standard used for NDAS program similar to IDAS of IAEA, and used to unify quantity of absorbed dose for irradiation at radiation processing dose level with uncertainty of less than 4% (k=2).

alanine/EPR dosimetry system at NIM

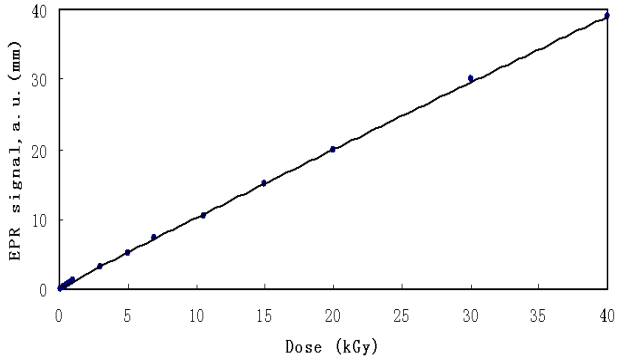


Fig. 2 The dose response curve of the alanine/EPR dosimter

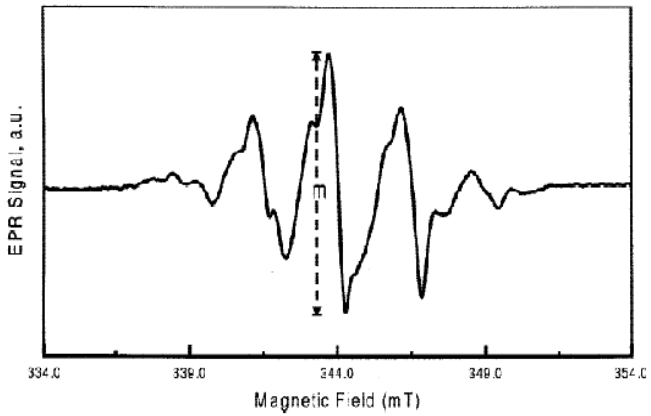


Fig1. EPR spectrum of an alanine dosimeter irradiated to an absorbed dose of 1 kGy; the amplitude, m, of the central peak is used for dose evaluation

Dosimetry system for high-dose

Routine (working) dosimeters

The Fricke, potassium/silver dichromate, several kinds of radiochromic films (RCD), cellulose triacetate (CTA) and PMMA dosimeters have been recommended as routine dosimeters for radiation processing in China.

Dosimetry system for high-dose

The schema of dosimetry tractability to national standards for radiation processing in china

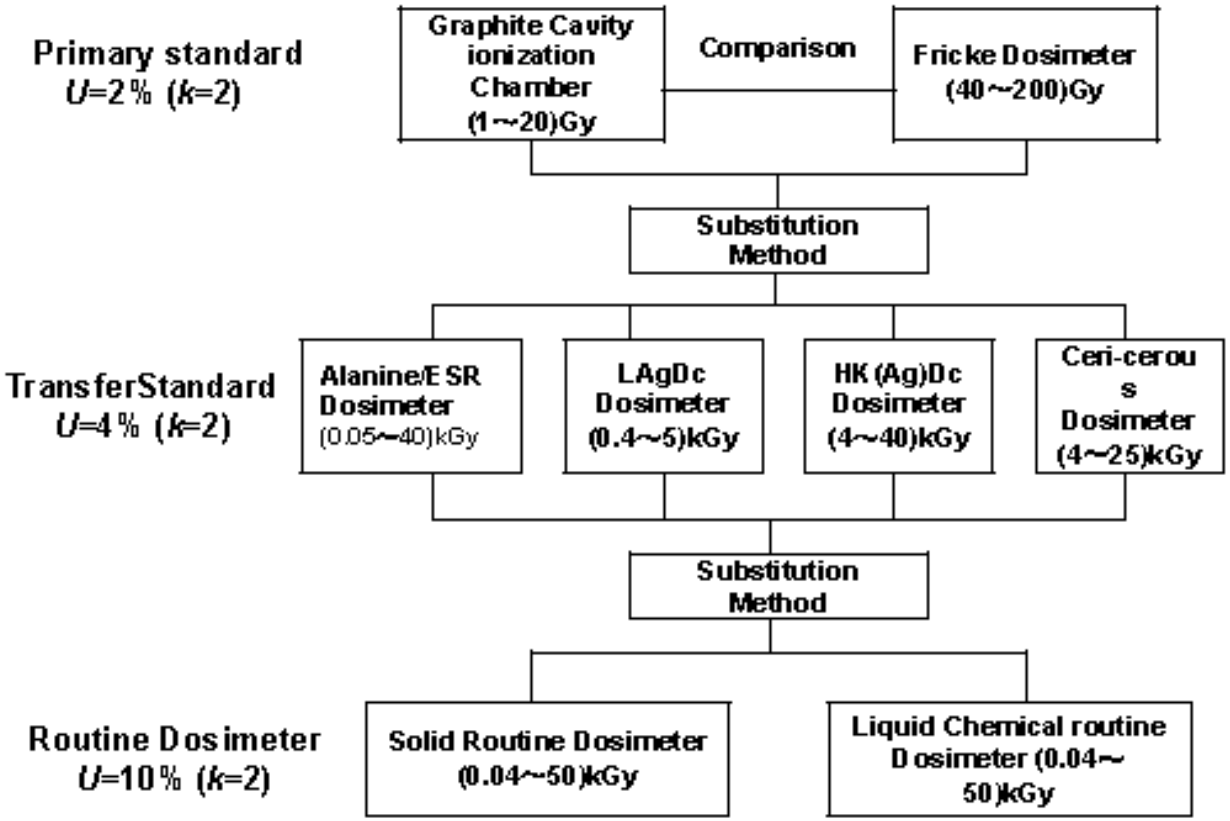
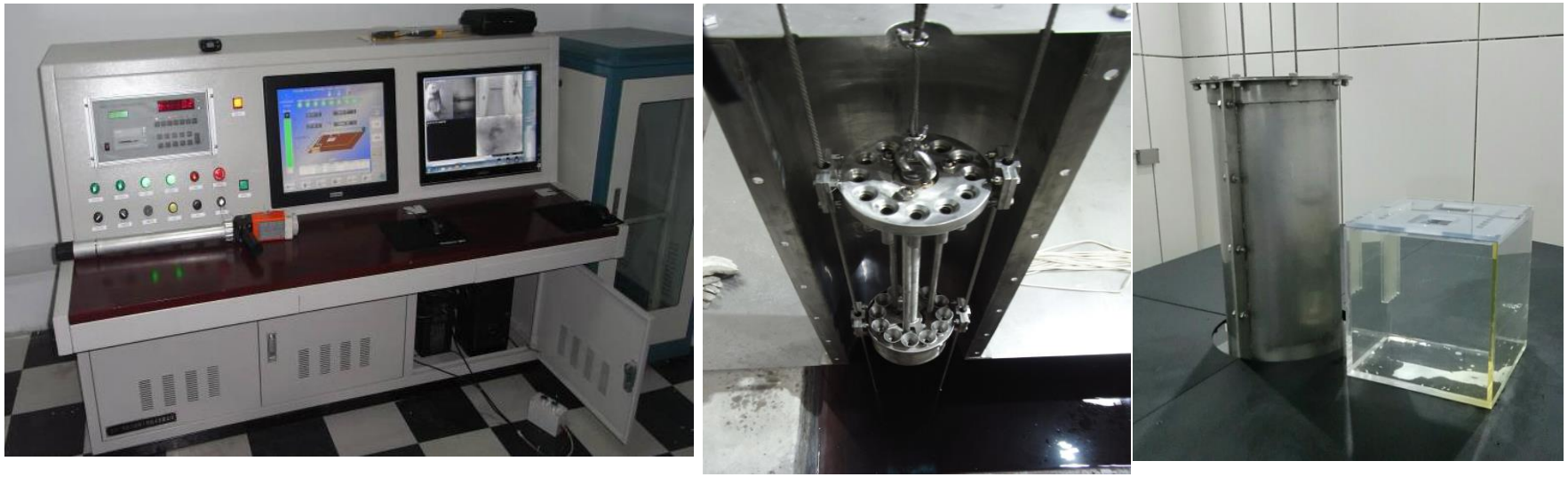


FIG1. The schema of dosimetry tractability to national primary standards for γ-rays

Dosimetry system for high-dose

γ-rays reference irradiated facility

- *The pool ^{60}Co source with an activity of 770 TBq on Oct 1st, 2016 opened beam and barrel source*
- *The source was calibrated in terms of absorbed dose to water by a set of Fricke dosimeter. The K of transfer standard and routing dosimeter are calibrated through the Fricke dosimeter standard at the dose rate of about 2 kGyh^{-1} in this irradiation filed, respectively.*



^{60}Coγrays high-dose irradiation facility at NIM

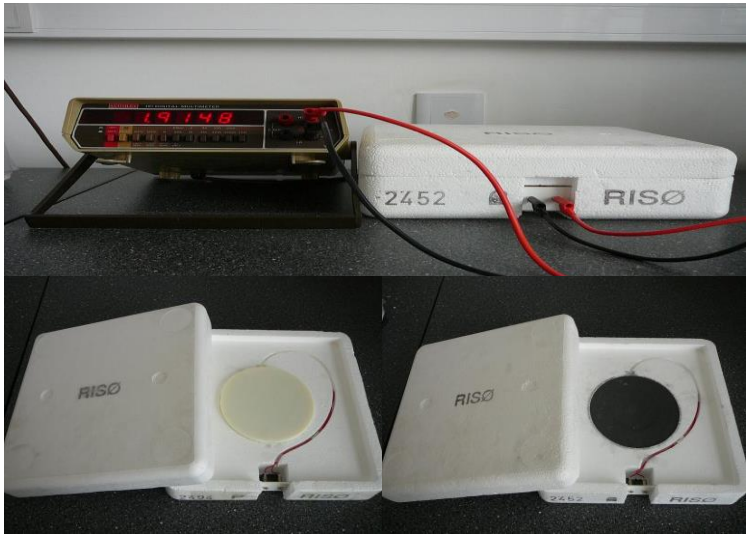
Dosimetry system for high-dose

EB reference irradiated facility

- *Nominal energy of EB:* *9、 10、11、12 MeV*
- *Maximum power of electron beam:* *10 kW*
- *Repetition rate of EB current pulses:* *50, 100, 150, 300 1/s*
- *Scanning length in 100 cm from extraction window :* *60cm*
- *Speed of conveyor system:* *10- 200mm/s*
- *Minimum absorbed dose (50 Hz, 200mm/s):* *40 Gy*

linear electron accelerator

conveyor system



Graphite and polystyrene calorimeter

The CCRI(I)-S2 comparison

In 1998 and 2008, NIM's Fricke dosimeter participated in CCRI (I)-S2 comparisons of standards for absorbed dose to water in ^{60}Co γ-rays at radiation processing dose levels using alanine/EPR dosimeters of the NIST and the NPL as the transfer dosimetrs.

Results in 1998

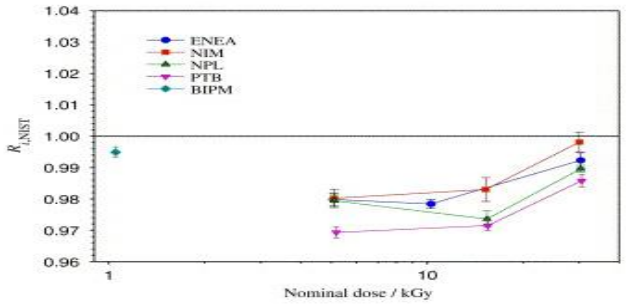


Fig. 3. Results for the comparison ratios *Ri*,NIST using the alanine transfer dosimeter of the NIST. The uncertainty bars represent the statistical standard uncertainty *si*,NIST

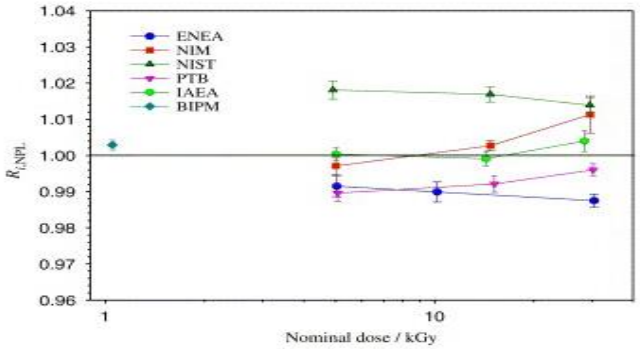
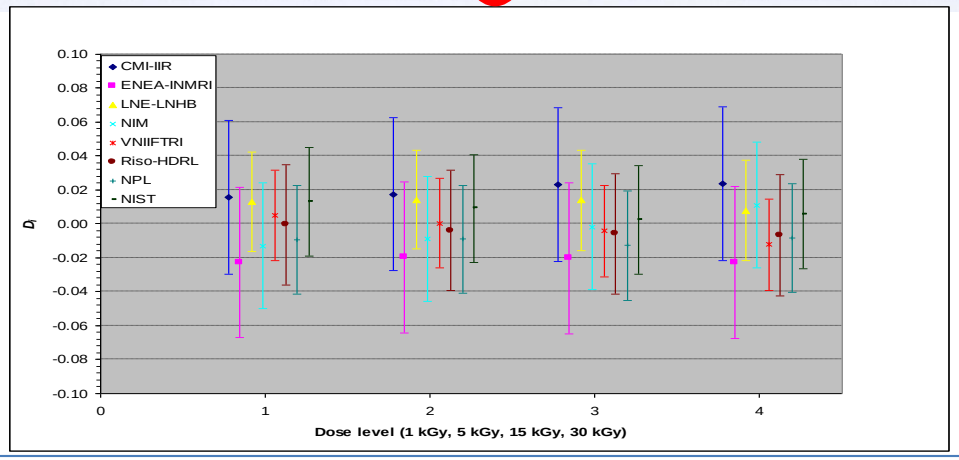


Fig. 4. Results for the comparison ratios *Ri*,NPL using the alanine transfer dosimeter of the NPL. The uncertainty bars represent the statistical standard uncertainty *si*,NPL

Results in 2008

Table 2. Results for D_i and U_i for each laboratory and each dose level.

	CMI- IIR	ENEA-INMRI	LNE-LNHB	NIM	VNIIFTRI	Risø-HDRL	NPL	NIST
D_i (1 kGy)	0.016	-0.023	0.013	-0.013	0.005	0.000	-0.009	0.013
D_i (5 kGy)	0.018	-0.020	0.014	-0.009	0.000	-0.004	-0.009	0.009
D_i (15 kGy)	0.023	-0.020	0.014	-0.002	-0.004	-0.006	-0.013	0.002
D_i (30 kGy)	0.024	-0.023	0.008	0.011	-0.012	-0.007	-0.008	0.006
U_i	0.045	0.044	0.029	0.037	0.027	0.036	0.032	0.032



NDAS Program in China

- *From 1988, the project of NDAS was initiated by using NIM alanine/EPR and dichromate dosimeters transfer standards in China, which is used to unify value of absorbed dose for ^{60}Coγ-rays radiation processing all over China.*
- *a set of 3～5 dosimeters with information sheet every six months by mail.*
- *Irradiation dose in the range of 0.5 to 40 kGy.*
- *Up to now, more then 70% γ-rays or EB radiation facilities used for food processing and sterilization participated in the NDAS program in China.*
- *From 2007 to 2016, altogether 988 dose checks have been carried out. 929 of 988 dose checks fall on the deviation range less than ±5%.*

Dosimetric Process of Control

- ***Characterization of the irradiation facility and Validation process***
- ***Dose Mapping in simulated product units: to determine location of D_{min} and D_{max}, and timer setting for achieving the desired D_{min} for actual product.***
- ***For EB: to measure beam and depth profiles, and to determine conveyor speed, beam current, electron energy, scan width for D_{min} and maximise the beam penetration capability.***
- ***Routine product processing***
- ***To Control, monitor and document the operating parameters to ensure that each process load that passes through the irradiator is processed in accordance with specifications.***
- ***To place dosimeters either within or on the selected process load at predetermined locations of D_{min} (and D_{max} if a prescribed limit) or at the reference positions to provide an independent check that absorbed dose is still within the desired D_{min} and D_{max} during the processing.***

Standard and technical norm

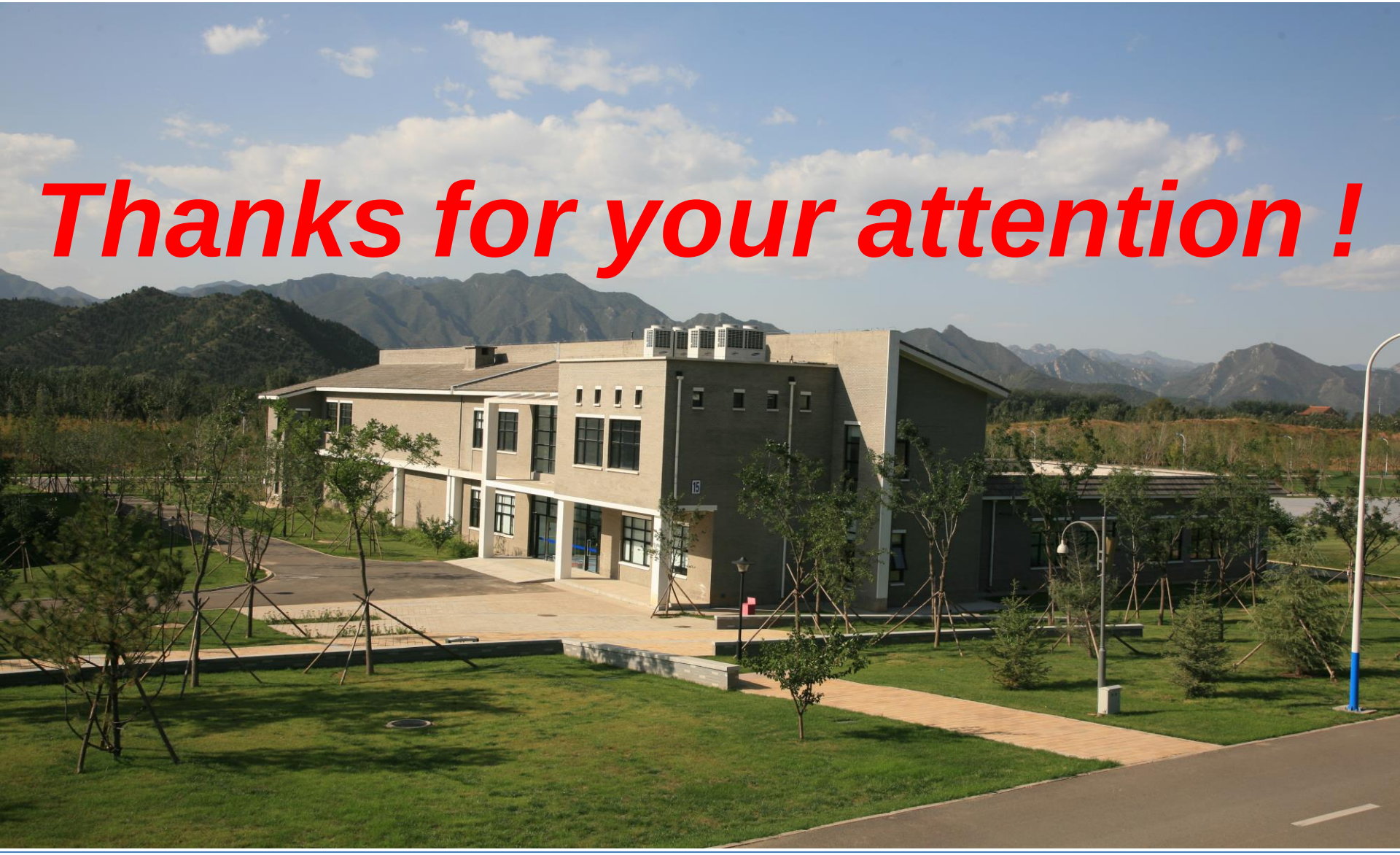
In order to guaranteeing the product quality of radiation processing, General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) has issued 20 national standards or technical norms concerned to the field of radiation processing with reference to ISO /ASTM Standards since 1990'.

Include as follows:

- ***GB 139-2008 Standard method for using the ferrous sulfate (Fricke) dosimeter to measure absorbed dose in water.***
- ***JJG 1018-90 Standard Method for Using the Potassium (Silver) Dichromate Dosimeter to Measure γ-rays Absorbed Dose in Water.***
- ***GB/T 16639-2008 Alanine-ESR dosimetry system for radiation processing.***
- ***GB/T 15053-2008 Standard method for using the radiochromic film and PMMA dosimeters to measure absorbed dose***
- ***GB/T 16640-2008 Standard guides for selection and calibration of dosimetry systems for radiation processing.***
- ***GB/T 16334-2008 Practical guide of dosimetry in a gamma irradiation facility for food processing.***
- ***GB/T 16841-2008 Guide for dosimetry in an electron beam facility for radiation processing at energies between 300kev and 25 Mev***
- ***GB/T 16509-2008 Standard guides for estimating uncertainties in dosimetry for radiation processing.***

Conclusion

The *Dosimetry Standards and Dissemination Systems for Radiation Processing* has already provide a useful method to ensure the routine dosimeters tracing to the national standard and take an important role to control quality of radiation processing in China.


Thanks for your attention !