INTERNATIONAL ATOMIC ENERGY AGENCY

Report of the Consultants' Meeting on

DEVELOPMENT OF STANDARDS FOR RADIOTRACER APPLICATIONS

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CONTENTS

1. INTRODUCTION

Nuclear techniques, as radiotracers and sealed sources applications, have been widely used in various industries to optimize and monitor processes, improve product quality, save energy, characterize materials and reduce environmental impact. Their technical, economic and environmental benefits have been well demonstrated and recognized in many industrial sectors. The major radiotracer and sealed sources techniques have been transferred to many developing Member States (MS) through IAEA Technical Cooperation (TC) projects.

The usefulness of nuclear techniques in evaluation or trouble shooting for industrial processes has been proved and it is now widely accepted. There are many instances, where nuclear techniques based on either open or sealed radioactive sources have been used on laboratory and industrial scales to provide solutions to problems which otherwise would have been insoluble. The radiotracer technology developed at earlier stages is now being applied by industrialized countries routinely but often their results are not reported in the literature. Furthermore, many developing countries have also gathered a considerable technical knowledge and experience to apply this useful technology to the benefit of local industry. However, there must still be numerous requests for tracer tests or sealed sources applications which cannot be performed or which provided only limited results because the application group was not able to obtain the best fitted radioisotopes or was not able to obtain the permission for the use of radioisotopes for field experiments in time.

The lack of standards in the area of radiotracers and sealed sources techniques to enhance related nuclear techniques and ensure the sustainability and quality of the technologies in both developing and developed MSs has been recognized. The community involved in radiotracer and sealed sources techniques is expected to solve the standardization issues through various cooperative activities and joint actions. The Agency was requested to organize an experts meeting to address the above mentioned challenges in developing the most relevant standards.

The Consultants' Meeting on “Development of standards for radiotracers applications” convened in Vienna from 10 to 13 November 2015 brought together five participants from Denmark, Finland, Germany, Korea and Albania to discuss and evaluate issues related to international standards on radiotracers and sealed source applications in industry. The list of participants and the agenda of the meeting are attached as Annex 1 and Annex 2, respectively.
The participants of the CM were expected to evaluate the current status of international standards on the above mentioned technology and discuss about future activities for the development of new standards. The topics are:

- Overview of existing valid standards, semi-standards or invalid standards
- Identification of the most important standards to be developed
- Preparation stages and procedures of the most relevant standards
- Strategy to develop them in coordination with ISO, DIN, ASME, etc.
- Setting-up working group in collaboration with ISTRA

2. SUMMARIES OF CONSULTANTS' PRESENTATIONS

The participants of the meeting delivered their presentations on various topics related to the international standards on radiotracer and sealed source applications in industry at the first day of the meeting. The presentations are attached as Annex 3 and summarized as follow:

2.1. PRESENTATION OF JOONHA JIN (KOREA, REPUBLIC OF)

The presentation was mainly focused on ISO standards on radioactive tracer applications. Four series of ISO for flow rate measurement of gas, water and liquid using tracers were introduced:

- ISO 2975: 1974 Measurement of water flow in closed conduits -- Tracer methods
- ISO 4053: 1977 Measurement of gas flow in conduits -- Tracer methods
- ISO 555: 1982 Liquid flow measurement in open channels -- Dilution methods for measurement of steady flow
- ISO 9555: 1992 Measurement of liquid flow in open channels -- Tracer dilution methods for the measurement of steady flow

It was reported that ISO 555 was replaced by ISO 9555 in 1992. The former standard series, ISO 555, was subdivided into parts on the basis of the method of field measurement, i.e. constant-rate injection method and integration (sudden injection) method. The new series of standards, ISO 9555, is divided into parts based on the type of tracer used, i.e. radioactive tracers, chemical tracers and fluorescence tracers, to reduce the unnecessary repetition.

The series ISO 4053, ISO 9555 and ISO 2975 were subdivided into 4 parts, 4 parts and 7 parts, respectively, to measure flow rate of gas, water and liquid in closed conduit and open channel by employing 3 different methods (transit time method, constant rate injection method, and integration method). Only six parts of them are using radioactive tracers. Two of them, however, do not appear in the ISO list due to unknown reason and another two were withdrawn, and therefore only following two parts of ISO 2975 are still active.

- ISO 2975-3 Constant rate injection method using radioactive tracers
- ISO 2975-7 Transit time method using radioactive tracers

The presentation also introduced the ways to find ISO standards. It was demonstrated how to browse the ISO either by ICS (International Classification for Standards) or by TC (technical committees). It is also possible to search the standards catalogue using a key word or the number of the standard. The flow rate measurements using tracers belong to TC 30 / SC (subcommittee) 5 and ICS 17.120.10.

Several technical documents, which may be used in initiation of international standards, were introduced. They are two IAEA documents prepared in 2005 for the submission to the relevant ISO committees and six protocols prepared by RCA member countries. The brief process for the development of ISO standards was also discussed.

2.2. PRESENTATION OF DENNIS RINGKJØBING ELEMA (DENMARK)

DTU Nutech is the national competence center for nuclear technologies at the Technical University of Denmark. The center conducts research in the following scientific areas:

- Medical and industrial dosimetry
- Retrospective dosimetry (dosimetry for geologic and archaeological dating and for radiation protection)
- Radiochemistry and radio-pharmacy (radioactive tracers and drugs)
- Isotope production and accelerator technology
- Radioecology (environmental radioactivity – both natural and manmade)
- Nuclear preparedness (reactor physics, ionizing radiation and radioactive pollution)

The center is divided into three research divisions (Hevesy Laboratory, Radiation physics and Radioecology), all focusing on applications of nuclear technologies.

A large variety of radioactive isotopes for both clinical, research and industrial purposes is produced at the Hevesy Laboratory. The radioisotopes are produced primarily on our own cyclotron (GE PETtrace), which is equipped with high yield targetry for standard liquid irradiations and a powerful beamline for solid target irradiations. The Hevesy Laboratory also has facilities for handling reactor irradiated samples and is a producer of radioactive sealed sources. The Lab has weekly productions of industrial radiotracers (mainly Bromine-82), that are distributed to customers in Denmark.

In addition, the Hevesy Laboratory manufactures several radiopharmaceuticals for diagnostics and therapy for end-users at different hospitals in Denmark and Sweden on a daily basis. The manufacturing is carried out in clean room facilities under Good Manufacturing Practices (GMP) conditions.

Our research focuses on new methods related to radioisotope production, radiotherapy and radiobiology as well as radiolabeling of nanoparticles, peptides and proteins. We are also involved in development of new accelerator technology and automated radiochemistry systems for radioisotope production and synthesis.

2.3. PRESENTATION OF THORSTEN JENTSCH (GERMANY)

The presentation of the German participant of the meeting is titled as “Standards, qualification and continuing education in the field of radiation and radiotracer application in Germany”. It consists of four main parts:

- a survey of existing DIN-standards with regard to radiation application and radiation protection in Germany,
- the German qualification guideline system for appliers of radiation and radioactive material relating to radiation protection,
- the presentation of DIN EN ISO 9712 as a suitable template for developing (a) standard(s) for radiotracer application in the field (in industry) and
- some essential information and boundary conditions for the creation of an International Standard (ISO).

Following conclusions were given:

- There exist no standards for radiation and/or radiotracer application (in the field) in Germany at present but a lot of standards regarding radiation application and radiation protection in medicine and in labs,

- There exist also a well-tried national system of qualification guidelines required for the appliers of radiation and radioactive material relating to radiation protection,
- DIN EN ISO 9712 can be a possible template for developing (a) standard(s) for radiotracer application in the field (in industry),
- Creation of an international standard (ISO-standard) for the qualification of radiotracer personnel or for (some kinds of) radiotracer applications seems to be to complicated and has quite little chances to be successful from the German participant's point of view.

2.4. PRESENTATION OF IIRO AUTERINEN (FINLAND)

Radioactive tracer techniques have been developed at the Finnish research reactor FiR 1. FiR 1 is a TRIGA Mark II reactor with 250 kW thermal power and started operation in 1962. Based on the development and active work in the reactor laboratory a company Indmeas Ltd (www.indmeas.com) was established in 1986, see paragraph 3.4.1.

Recently, the FiR 1 has had an important international role in Boron Neutron Capture Therapy (BNCT) and regional role in isotope production, education and training. FiR 1 is a member of the IAEA supported Baltic research reactor network. Operation license is currently valid till end of 2023.

VTT Technical Research Centre of Finland as the licensee of the FiR 1 reactor decided in summer 2012 to close down the reactor as soon as it is technically and legislatively possible. VTT considers the reactor as a profit unit without strategic role for VTT. The income from the reactor services had not covered all the costs of the reactor and VTT was not willing to cover this deficit of about 250 000 € annually any more. New significant economic deals were offered for VTT for cancer treatment irradiations but these did not lead to contracts. VTT stopped operating FiR 1 end of June 2015 after decision by VTT management 8th May 2015.

In core irradiations with thermal neutron flux of 10^{13} n/cm^2/s and fast neutron flux of 10^{13} n/cm^2/s were used for isotope production, activation analysis and irradiation testing. Also an irradiation ring with a dominantly thermal flux was used. Main isotopes for tracer studies produced in the reactor were Br-82, Na-24, Ar-41 and La-140; Br-82 in the form of either KBr or ethylene bromide. Typical activity of one irradiated Br-sample was 20-80 GBq. Total activity produced in one year was over 3 TBq, up to 3.5 TBq/year. Radioactive isotopes were produced two days per week (Mondays and Fridays).

3. CONSULTANTS' CONTRIBUTIONS

3.1. CURRENT STATUS OF ISO USING RADIOACTIVE TRACERS

As ISO 555 was replaced by ISO 9555, only the following three series of ISO have part(s) using radioactive tracers.

- ISO 2975: 1974 Measurement of water flow in closed conduits -- Tracer methods
- ISO 4053: 1977 Measurement of gas flow in conduits -- Tracer methods
- ISO 9555: 1992 Measurement of liquid flow in open channels -- Tracer dilution methods for the measurement of steady flow

Some parts of the ISO series were originally planned but not made and some other parts were withdrawn. Current statuses of the ISO series are as follow:

3.1.1. ISO 4053 Measurement of gas flow in conduits - Tracer methods

- Part I General
- Part II Constant rate injection method using non-radioactive tracers
- Part III Constant rate injection method using radioactive tracers
- Part IV Transit time method using radioactive tracers

▪ Part III is a standard using radioactive tracers
▪ Part II and Part III cannot be found in the ISO system (perhaps not yet prepared)
▪ Part I and Part IV were withdrawn in 2003

3.1.2. ISO 2975 Measurement of water flow in closed conduits - Tracer methods

- Part I General
- Part II Constant rate injection method using non-radioactive tracers
- Part III Constant rate injection method using radioactive tracers
- Part IV Integration (sudden injection) method using nonradioactive tracers
- Part V Integration (sudden injection) method using radioactive tracers
- Part VI Transit time method using non-radioactive tracers
- Part VII Transit time method using radioactive tracers

▪ Part III, Part V and Part VII are standards using radioactive tracers
▪ Part IV and Part V cannot be found in the ISO system (perhaps not yet prepared)

3.1.3. ISO 9555 Measurement of liquid flow in open channels - Tracer dilution methods for the measurement of steady flow

- Part 1 General
- Part 2 Radioactive tracers
- Part 3 Chemical tracers
- Part 4 Fluorescent tracers

▪ This new series of ISO is divided into parts based on the type of tracer used.
▪ The series employ new numbering system, Part 1, Part 2, ··· instead of Part I, Part II, ···
▪ Part 2 is a standard using radioactive tracers

- Part 2 was withdrawn in 2011

3.2. STANDARDS, QUALIFICATION AND CONTINUING EDUCATION IN THE FIELD OF RADIATION AND RADIOTRACER APPLICATION IN GERMANY

The presentation of the German participant of the meeting titled as "Standards, qualification and continuing education in the field of radiation and radiotracer application in Germany" gave a survey of

1. existing DIN-standards with regard to radiation application and radiation protection in Germany,
2. the German qualification guideline system for appliers of radiation and radioactive material relating to radiation protection,
3. the content and structure of DIN EN ISO 9712 as a suitable(?) template for developing (a) standard(s) for radiotracer application in the field (in industry) and
4. Some essential information and boundary conditions for the creation of an International Standard (ISO).

3.2.1. The German standardization institute and German standards regarding to radiation application and radiation protection

As a first part of the presentation a short overview of the structure and the organization of German standardization institute (Deutsches Institut für Normung e. V., DIN) were given. Two of the DIN Standardization Committees deal with application of radiation, radiation protection and nuclear technology among others: Standardization Committee NA 080 "Radiology" and NA 062 "Material Testing". The Standardization Committee NA 080 "Radiology" creates and revises standards especially for

- dosimetry
- facilities for nuclear medicine (design, operation and shielding of accelerators, irradiators for therapy, imaging facilities for diagnostic purposes like X-ray-tubes and tomographic devices)
- measuring instruments for radiation protection (design, requirements regarding accuracy/precision, hints for periodic inspections, …).

Standardization Committee NA 062 "Material Testing" is by the department no. 07 "Nuclear technology and radiation protection" among others responsible for national standards of shielding (task force NA 062-07-34 AA), of nondestructive testing in nuclear technology (task force NA 062-07-47 AA) and radioisotope laboratories (task force NA 062-07-63 AA). The German participant of the meeting is active member of the task force NA 062-07-63 AA "Radioisotope laboratories".

A query of DIN database regarding the keyword "radiation protection" in preparation of the meeting delivered a list with more than 800 documents. About 300 documents of them are also related to international standards. No DIN documents could be found with regard to radiation protection at radiotracer applications, qualification of personnel for radiotracer applications or radiotracer applications in industry and environment.

3.2.2. The German qualification guideline system for appliers of radiation and radioactive material relating to radiation protection

Regulations in Germany distinguish between radiation protection against damage and injuries caused by ionizing radiation (Radiation Protection Ordinance) radiation protection and against damage and injuries caused by X-rays (X-Ray Ordinance). Therefore, also the guidelines for the requisite qualification and knowledge in radiation protection are different regarding to these both ordinances. There exist two guidelines with regard to the X-Ray Ordinance

- "Guideline for the requisite qualification and knowledge in radiation protection at handling X-ray units for technical purposes and stray radiation emitters requiring a license" and
- "Guideline for the requisite qualification and knowledge in radiation protection at handling X-ray units in medicine and dentistry"
  and two different guidelines regarding to Radiation Protection Ordinance
- "Guideline for the requisite qualification and knowledge in radiation protection" (Qualification Guideline Technics relating to Radiation Protection Ordinance)
- "Radiation protection in medicine - Guideline relating to Radiation Protection Ordinance (contains among others the requirement for medical physics experts …).

Because the "Guideline for the requisite qualification and knowledge in radiation protection" (Qualification Guideline Technics relating to Radiation Protection Ordinance) covers also the requirements for the qualification and knowledge in radiation protection at the application of radiotracers (in the field) this guideline is presented here in more detail. The Qualification Guideline Technics relating to Radiation Protection Ordinance distinguishes between the following 6 qualification groups:

S1 Handling simple and safe devices with sealed sources,
S2 Handling of sealed sources,
S3 Handling of sealed sources for technical radiography and radioscopy,
S4 Handling of unsealed radioactive substances,
S5 Employment at external facilities or installations requiring a license and
S6 Practices at facilities for the generation of ionizing radiation.

The qualification group S4 essential also for the radiotracer application is subdivided into 3 qualification subgroups:

S4.1 Handling of unsealed radioactive substances with activities which do <u>not exceed</u> the exemption levels by more than 10^5 times,
S4.2 Handling of unsealed radioactive substances with activities which <u>exceed</u> the exemption levels by more than 10^5 times,
S4.3 Storage of nuclear fuels.

The guideline fixes the requisite modules of the qualification courses are necessary for each qualification (sub)group and the minimum number of lesson units for each module (1 unit = 45 minutes):

S4.1: GH - Basics for qualification groups with advanced requirements (26 teaching units)
OG - Handling of unsealed radioactive substances: low level (13 teaching units)

S4.2: GH - Basics for qualification groups with advanced requirements (26 teaching units)
OH - Handling of unsealed radioactive substances: high level (28 teaching units)

The teaching modules deal with

- legal foundations, recommendations and guidelines,
- tasks and duties of radiation protection supervisor and radiation protection officer,
- natural scientific basics,
- radiation protection measuring techniques,
- radiation protection methods and technologies,
- radiation protection safety and security,
- practical training,
- demonstration exercises,
- (calculation) exercises,
- examination.

The advantage of this national qualification system is that the update of qualification is required every five years. A disadvantage of this system is seen in the requirement for the necessity of (repeating) the qualification only for the radiation protection officer and not for the “normally” working persons who (also) handle radioactive substances.

3.2.3. DIN EN ISO 9712 - a suitable template for developing standards for radiotracer application in the field?

DIN EN ISO 9712 is titled as “Qualification and certification of NDT (Non-Destructive Testing) personnel”. It is a German standard as well as a European and an international one. This standard specifies requirements for principles for the qualification and certification of personnel who perform industrial non-destructive testing (NDT). It is mentioned here because it could be a suitable template for developing (a) standard(s) for radiotracer application in the field (in industry).

The second sentence of the scope written in this international standard is the following: “The system specified in this International Standard can also apply to other NDT methods or to new techniques within an established NDT method, provided a comprehensive scheme of certification exists and the method or technique is covered by International, regional or national standards or the new NDT method or technique has been demonstrated to be effective to the satisfaction of the certification body”. The following methods are covered by ISO 9712 at present:

- Acoustic emission testing (AT),
- Eddy current testing (ET),
- Infrared thermographic testing (TT),
- Leak testing (LT),
- Magnetic testing (MT),
- Penetrant testing (PT),
- Radiographic testing (RT),
- Strain gauge testing (ST),
- Ultrasonic testing (UT) and
- Visual testing (VT).

Based on the second sentence of the scope the ISO 9712 could be (easily) extended for radiotracer applications. Indeed, radiotracer application is a non-destructive method but it is not a testing method in the sense of the standard ISO 9712. Therefore, if it is intended to create a standard for the qualification and certification of radiotracer personnel, it is recommended to create a separate standard which is (only) geared to this international standard. The new separate standard could or should be based on the structure and content of the ISO 9712 and could adopt proper and reliable parts or ideas from this standard.

Related to the list of NDT-methods in ISO 9712 the new separate standard for qualification and certification of radiotracer personnel could cover the following kinds of radiotracer applications:

- RTD studies,
- Mixing studies,
- Flow rate measurements,
- Sediment transport studies,
- Leak detection (opt. also extension of ISO 9712 thinkable),
- Gamma column scanning (opt. also extension of ISO 9712 thinkable),
- Gamma densitometry (opt. also extension of ISO 9712 thinkable),
- Gamma tomography (opt. also extension of ISO 9712 thinkable),
- etc.

For all listed radiotracer applications above sufficient knowledge/experience in the following fields should be required in the new separate standard at least:

- calculation/estimation of necessary activity,
- calculation/estimation of necessary shielding/collimation,
- handling of detectors and data acquisition system,
- calculation/manipulation/evaluation of acquired data
  (e. g. background subtraction, half-life correction, expected value, variance),
- derivation of required information from (manipulated) data
  (e. g. knowledge of simple and advanced flow models, dead volume, bypass flow)

The given list above raises no claim to completeness and can or should be completed at any time.

3.2.4. Some essential information and boundary conditions for the creation of an International Standard (ISO)

As last part of the presentation some essential information and boundary conditions for the creation of an International Standard (ISO) were given. The creation process of a national standard as well as a European and an international standard is clearly defined and occurs by the same well-defined stages. Normally, the creation process starting with applying a proposal by a member state and ending by publication of the approved standard takes 36 months. The creation process is subdivided into six stages:

10 Proposal Stage,
20 Preparation Stage,
30 Committee Stage,
40 Enquiry Stage,

50 Approval Stage,
60 Publication Stage.

Each of these stages contains several sub stages and special decision sub stages. The creation process can be broken off on each stage. For the approval of a New Work Item Proposal (NWIP) the single majority of participating members (P-members) in Technical Committee (TC) is necessary and an active (!) contribution of 5 P-members at least is required. In the case that not more than 16 P-members attend the TC an active contribution of only 4 P-members is necessary. For the approval of a Committee Draft (CD) the dissenting vote of only one (!) P-member is allowed. For the acceptance of a Draft International Standard (DIS) (40 - Enquiry Stage) and a Final Draft International Standard (FDIS) (50 - Approval Stage) approval of 2/3 of P-members in TC is necessary. Not more than ¼ of the votes cast (incl. the votes O-members!) are allowed to be negative. The following votes are not evaluated: abstention from voting and refusals without any technical reason.

The presentation was finished by the following summary/conclusions:

- No standards for radiation and/or radiotracer application (in the field) but a lot of standards regarding to radiation application and radiation protection in medicine and in labs in Germany exist at present.
- A well-tried system of qualification guidelines required for the appliers of radiation and radioactive material relating to radiation protection exists in Germany, too.
- DIN EN ISO 9712 could be used as a possible template for developing (a) standard(s) for radiotracer application in the field (in industry).
- The creation of an international standard (ISO-standard) for the qualification of radiotracer personnel or for (some kinds of) radiotracer applications is a complicated and time consuming process and seems to be little successful from the German participant's point of view.

3.3. CURRENT STATUS OF RADIOTRACERS IN DENMARK

In Denmark radiotracers and sealed sources are commonly used for medical, industrial, research and educational purposes. Currently, there are about 900 registered users (license holders) in Denmark. In industry most applications are based on the use of sealed sources. However an important industrial application is the use of Bromine-82 (^{82}Br) as an open source for leak detection in closed hot-water heating installations.

3.3.1. Leak detection in closed hot-water installations using Br-82

^{82}Br has a half-life of 35 hours and emits high energy gamma radiation. The isotope is therefore ideal for leak detection in different types of pipelines typically located deep inside thick concrete constructions. The Hevesy Laboratory at DTU Nutech, Technical University of Denmark, has weekly productions of this radiotracer, which is distributed to 14 different highly specialized leak detection companies in Denmark. Instructions related to the use of ^{82}Br can be found in Annex 4 published by the Danish National Institute for Radiation Safety.

3.3.1.1. Production of ^{82}Br, quality control and distribution to end-users

The ^{82}Br radiotracer is produced by neutron irradiation of 0.8 g of NH_4Br (ammonium bromide) powder contained in a water soluble PVA bag.

FIG.1. PVA bag containing ammonium bromide.

The neutron irradiations are mainly carried out at the JEEP II reactor at IFE in Norway and each bag is activated to approximately 1.5 GBq of ^{82}Br.

The ^{82}Br is, after the irradiation, transported by car from Norway to the Hevesy Lab in Denmark, where a quality control is performed before shipping the ^{82}Br to the different customers. The quality control includes measurement of the activity and a visual inspection of the bags to check that the bags have not been damaged. Regularly, the radionuclidic purity of the ^{82}Br is determined either by decay methods or Germanium detector spectroscopy. The individual ^{82}Br samples are packed in smaller transport containers and transferred to the end-users the following day. Each user will receive one sample containing a maximum of 1 GBq ^{82}Br. At the end-user the ammonium bromide will be dissolved in approximately 100 ml of water.

3.3.1.2. Leak detection method

In Denmark many buildings (including private homes) are heated by a local closed hot-water system distributing warm water through pipes often deeply located under the floor. In case a leak occurs in such a system, the ^{82}Br radiotracer can be used to trace the leak. The isotope can be injected into the system (typically 5-10 MBq) and circulated for some time depending on the size of the leak. After flushing the water system with clean water the leak can be located precisely using a radioactivity detector by measuring the floor in the room, where the leak is expected to be. The method is extremely accurate and provides a more precise localization of especially small leaks compared to other detection methods. The radiotracer can also be applied in larger industrial setups.

3.3.1.3. Legislation

In Denmark the use of ^{82}Br is regulated by the National Board of Health (National Institute of Radiation Protection). In the special case of ^{82}Br the National Institute of Radiation Protection has published a guideline (Reference “Bromine-82 instruction”) that describes how this area is regulated. The main topics of this document are presented in the following.

3.3.1.3.1. Justification

The Danish National Institute of Radiation Protection has recently (2012) evaluated the use of ^{82}Br as a radiotracer for leak detection and concluded that the use of this method can fully be justified, taking both economical and health related considerations into account. It is also clearly stated that the use of ^{82}Br may only be used if other non-radioactive techniques cannot be applied. In each specific case the license holder may decide if the use of ^{82}Br can be justified.

3.3.1.3.2. Obtaining a license

A company can obtain a license to use ^{82}Br for leak detection by applying to the Danish National Institute of Radiation Protection. The company must appoint a “responsible person”, who will be the license holder. This person has to ensure that the company fulfills all the requirements of the regulations within this area.

3.3.1.4. Education and training

The responsible person must have passed an examination in the course “Fundamental radiation protection” provided by the Danish National Institute for Radiation Protection. All employees of the company must also have passed the same course, and must prove that they have obtained practical skills concerning the handling of open radioactive sources, and that they have hands-on experience with leak detection methods. The examination must be repeated and passed every 5 years.

3.3.1.5. Limitation regarding activity levels

The company can use up to 100 MBq of ^{82}Br per injection in a given heating system, if the system can be connected to the public sewers afterward in order to discard radioactive water. Otherwise only up to 10 MBq can be used. A special license can be obtained if higher activity is needed and if the purpose can be justified.

3.3.1.6. Handling of radioactive waste

Radioactive water can be pumped away through the public sewers. The company must remove contaminated equipment and used utensils before leaving the place. Repair of the leak (sometimes performed by another company) cannot be initiated before the activity level is below 10 MBq at the location of the detected leak. Concrete waste can be discarded as normal waste if the radioactivity content is below 10 kBq/kg.

3.3.1.7. Transport

The companies can transport ^{82}Br by road transport according to the ADR regulation in Europe. It is not required that the company/driver has an ADR “dangerous goods” certificate.

3.3.1.7.1. Personal dosimetry

All workers should carry personal dosimeters according to the general rules for radiation workers.

3.3.1.7.2. Reporting

The company must maintain a protocol describing all the investigations that are performed (date, address, amount of activity, description of the system) and send a report once a year to the Danish National Institute of Radiation Protection.

3.4. CURRENT STATUS OF RADIOACTIVE TRACERS IN FINLAND

Finland is the home of Indmeas Inc. (www.indmeas.com) the only accredited field flow meter calibration service company in the world using radioactive tracers. In addition to Finland Indmeas, with its technical staff of some 20 people, operates in Sweden, Norway and Denmark and in some other European countries like Estonia and Slovenia. Also some other domestic and foreign companies perform occasionally radiotracer measurements in Finland, including the VTT Technical Research Centre of Finland Ltd.

According to the statistics published by STUK Radiation and Nuclear Safety Authority (www.stuk.fi) [Säteilyn käyttö ja muu säteilylle altistava toiminta, Vuosiraportti 2014, Riikka Pastila (ed.) STUK-B 189, June 2015.] in 2014 there were 24 workers performing radiotracer experiments in Finland.

Radiotracer measurements in the industry and environment are performed by licensed organizations with skills and capabilities to work with the radioisotopes and the detection systems. The foundations for the safety and acceptability of radiation practices are set forth in the Radiation Act (592/1991). STUK – Radiation and Nuclear Safety Authority (Finland) issues general instructions, known as Radiation Safety Guides (ST Guides), concerning the use of radiation and operations involving radiation. The relevant guides for radiotracer applications are explained more in detail in section **Error! Reference source not found.**.

3.4.1. Radiotracer measurements performed by Indmeas and the supporting industrial standards

Indmeas performs flow measurement calibrations that are internationally accredited and follow the standard EN ISO/IEC 17025 (General requirements for the competence of testing and calibration laboratories). The onsite calibrations assure a traceable accuracy for flow and energy measurements in the industry. With their method typical calibration uncertainty for flow measurements is 0.5-1%. The tracer based calibration methods cover all kinds of flows, from pipe to open channel flows. In the process industry the calibrations include measurements in e.g. paper plants (fiber flows), water purification plants (waste water flows) and petrochemical plants (gas flows). Totally Indmeas has carried out over 15 000 onsite calibrations in the energy and process industry; each year there are about 600 more done.

Indmeas is accredited by FINAS, the Finnish national accreditation body, as an accredited calibration laboratory against the requirements by the standard SFS-EN ISO/IEC 17025:2005 for fluid quantities; on-site calibration of volume flowmeters for gases and liquids. They are also accredited for determination of carbon dioxide concentration in the stack gas based on carbon balance of the boiler.

The referred standard for on-site calibration of flow meters with the transit time method is ISO 2975-7:1977 (Measurement of water flow in closed conduits -- Tracer methods -- Part 7: Transit time method using radioactive tracers). In addition they also refer to the Nordtest standard NT VVS082 (Liquid flow metering installations: radioactive tracer transit time method, in situ calibration) and British standard BS 5857-2.4. For inter-comparison measurement for stack gas flow using transit time method they refer to the Swedish guideline NFS 2004:6 17§ (Naturvårdsverkets författningssamling).

On-site calibration of liquid flow meters with the tracer dilution method is done based on the ISO 9555-1 (Measurement of liquid flow in open channels -- Tracer dilution methods for the measurement of steady flow -- Part 1: General), ISO 9555-2 (Measurement of liquid flow in open channels -- Tracer dilution methods for the measurement of steady flow -- Part 2: Radioactive tracers), ISO 2975-3 (Measurement of water flow in closed conduits -- Tracer methods -- Part 3: Constant rate injection method using radioactive tracers) and ISO TR 11656 (Measurement of liquid flow in open channels -- Mixing length of a tracer). It should be noticed that the ISO 9555-2 has been withdrawn in 2011 and ISO TR 11656 in 2013.

Residence time distribution measurements are used to study process flow patterns, such as possible bypass flows, dead volumes and mixing. For measurement in pipes typically Ba-137m with half-life of 2.5 minutes is used. It is produced using $^{137}Cs/^{137m}Ba$ generator. Other generators used are Mo/Tc and Ge/Ga generators. In the dilution and residence time methods isotopes with longer half-life, like Br-82 with 35.3 h, are used.

Up to 3.5 TBq of Br-82 was produced yearly at the FiR 1 research reactor in Espoo, Finland for Indmeas until VTT decided to stop this service in summer 2015. Indmeas is still able to receive Br-82 from some other European research reactors, notably from the JEEP II in Kjeller, Norway.

4. TECHNICAL DISCUSSIONS

4.1. DISCUSSION ON DISAPPEARED AND WITHDRAWN ISO STANDARDS USING RADIOACTIVE TRACERS

The participants of the meeting realized that there are three important international standards which have parts for radiotracer applications in the field. These are

- ISO 2975 Measurement of water flow in closed conduits - Tracer methods
- ISO 4053 Measurement of gas flow in conduits - Tracer methods
- ISO 9555 Measurement of liquid flow in open channels - Tracer dilution methods for the measurement of steady flow

4.1.1. ISO 2975 Measurement of water flow in closed conduits - Tracer methods

The international standard ISO 2975 consists of five parts at present:

- Part 1: General
- Part 2: Constant rate injection method using non-radioactive tracers
- Part 3: Constant rate injection method using radioactive tracers
- Part 6: Transit time method using non-radioactive tracers
- Part 7: Transit time method using radioactive tracers

Part 4 [Integration (sudden injection) method using nonradioactive tracers] and part 5 [Integration (sudden injection) method using radioactive tracers] are absent. There is no information about publishing or withdrawal available.

The Sub Committee 5 of Technical Committee ISO/TC 30 is responsible for maintenance of the international standard ISO 2975. Responsible secretariat is British Standards Institution (BSI, 389 Chiswick High Road, London W4 4AL, Great Britain, Tel: +44 208 996 90 00, Fax: +44 208 996 74 00, E-mail: standards.international@bsigroup.com). The mirror committee at the German institute for standardization (DIN) is the standardization committee DIN NA 119 with Lutz Wrede (Burggrafenstr. 6, 10787 Berlin, Germany, Tel.: +49 30 2601-2092, Fax: +49 30 2601-42092, E-mail lutz.wrede@din.de) as responsible person.

Inquiries regarding the status of the more important part 5 at German institute for standardization during the meeting yielded that it could be that both parts (4 and 5) were planned to be created indeed but they were never really created. Experts of the Technical Committee were contacted but no answer was received during the meeting.

The participants of the meeting agreed that Part 5 of ISO 2975 is urgently needed.

4.1.2. ISO 4053 Measurement of gas flow in conduits - Tracer methods

Following parts of the international standard ISO 4053 are known:

- Part 1: General
- Part 2: Constant rate injection method using non-radioactive tracers
- Part 3: Constant rate injection method using radioactive tracers
- Part 4: Transit time method using radioactive tracers

Part 1 published in 1977 and part 4 published in 1978 were withdrawn on 2003-03-25. Part 2 and part 3 of the standard are absent. There is no information about publishing or withdrawal available.

The Sub Committee 5 of Technical Committee ISO/TC 30 is responsible for maintenance of the international standard ISO 4053. Responsible secretariat is British Standards Institution (BSI, 389 Chiswick High Road, London W4 4AL, Great Britain, Tel: +44 208 996 90 00, Fax: +44 208 996 74 00, E-mail: standards.international@bsigroup.com). The mirror committee at the German institute for standardization (DIN) is the standardization committee DIN NA 119 with Lutz Wrede (Burggrafenstr. 6, 10787 Berlin, Germany, Tel.: +49 30 2601-2092, Fax: +49 30 2601-42092, E-mail lutz.wrede@din.de) as responsible person.

Inquiries regarding the status of the more important part 3 at German institute for standardization during the meeting yielded that it could be that both parts (2 and 3) were planned to be created indeed but they were never really created. Experts of the Technical Committee were contacted but no answer was received during the meeting.

The participants of the meeting agreed that a reactivation of part 4 of ISO 4053 is urgently necessary. They also agreed that Part 3 of ISO 4053 is urgently needed.

4.1.3. ISO 9555 Measurement of liquid flow in open channels - Tracer dilution methods for the measurement of steady flow

The international standard ISO 9555 consist of three parts at present:

- Part 1: General
- Part 3: Chemical tracers
- Part 4: Fluorescent tracers

Part 2 dealing with radioactive tracers is absent. The part 2 was published on 1992-11-12 but withdrawn on 2011-05-10.

For maintenance of the international standard ISO 9555 the Technical Committee ISO/TC 113 is responsible. Responsible secretariat is Bureau of Indian Standards (BIS, 9 Bahadur Shah Zafar Marg, New Delhi 110002, India, Tel: +91 11 23 23 79 91, Fax: +91 11 23 23 93 99, E-mail: ird@bis.org.in). The mirror committee at the German institute for standardization (DIN) is the standardization committee DIN NA 119 with Ralph Dominik (Burggrafenstr. 6, 10787 Berlin, Germany, Tel.: +49 30 2601-2134, Fax: +49 30 2601-42134, E-mail ralph.domink@din.de) as responsible person.

In document ISO/TC113 N651 "Report of voting on CIB (ISO/TC 113 N 649) Continuation/withdrawal of ISO 9555-2:1992 Measurement of liquid flow in open channels – Tracer dilution methods for the measurement of steady flow – Part 2: Radioactive tracers" details of the voting are evident (Annex 4). 11 participating members (P-members) of ISO/TC 113 casted their vote. One of them (Czech Republic – UNMZ) voted for an unrestricted continuance of the document. Two P-members [India (BIS) and Sweden (SIS)] voted for continuance with corrections. Five P-members recommended the withdrawal of the standard: Egypt (EOS), Republic of Korea (KATS), Norway (SN), UK (BIS) and USA (ANSI). Environmental aspects were one reason for recommendation of withdrawal e. g. (Norway).

Three P-members abstained from voting [Mexico (DGN), Netherlands (NEN), Switzerland (SNV)]. 4 P-members did not cast their vote. 2 observing members (O-members) which are not allowed to vote submitted comments: Italy (UNI) and Jamaica (BSJ).

The participants of the meeting agree that a reactivation of part 2 of ISO 9555 is urgently necessary.

4.2. DISCUSSION ON EXISTING INTERNATIONAL AND NATIONAL STANDARDS USING RADIOACTIVE TRACERS (ALL PARTICIPANTS)

4.2.1. Korean National Standard

KS (Korean Industrial Standards) are Korean national standards developed, reviewed and notified under the Korean Industrial Standardization Act. KS may be divided into 21 sectors ranging from the Basic standards (A) to the Information (X), as well as it may be classified into 3 types of standards as follows:

- Product Standards: Specifying improvement, measurement and quality of product
- Procedure Standards: Specifying testing, analysis, inspection, measurement method and process standard, etc.
- Horizontal Standards: Specifying terminology, technical characteristics, unit and numerical progression, etc.

Flow rate measurement is belong to sector B (Mechanical Engineering), which includes General, Machine elements, Tools, Machine tools, Measuring instrument · physical apparatus, General machinery, Industrial machinery, Agricultural machinery, Thermal apparatus · gas apparatus, Metrology · measurement, Industrial automation, etc.

It was found that there is only one series of ISO for flow rate measurement, which is composed of two parts, Part 1 and Part 4 as follow:

- KS B ISO 4053-1 Measurement of gas flow in conduits - Tracer methods – Part 1 : General
- KS B ISO 4053-4 Measurement of gas flow in conduits - Tracer methods – Part 4 : Transit time method using radioactive tracers

They were made in 2001-12-28 by the translation of ISO 4053-1 and ISO 4053-4 to Korean language. Though the original standards (ISO 4053) were withdrawn in 2003-03-25, the Korean standards were reconfirmed two times in 2006-12-14 and 2011-12-30. The ICS code is 17.120.10 (Flow in closed conduits).

4.2.2. German National Standards

A survey over the existing German National Standards was already given in chapter 3.2. A query of DIN database regarding the keyword “radiation protection” in preparation of the meeting delivered a list with more than 800 documents. About 300 documents of them are also related to international standards. The most of them are dealing with the handling of radioactive substances in medicine and in laboratories. No national standards could be found with regard to radiation protection at radiotracer applications, qualification of personnel for radiotracer applications or radiotracer applications in industry and environment.

Nevertheless, some DIN standards regarding the application of non-radioactive tracers exist. These are for instance:

- DIN EN 13185:2001 - Non-destructive testing - Leak testing - Tracer gas method
- DIN EN ISO 12569: 2013 - Thermal performance of buildings and materials - Determination of specific airflow rate in buildings - Tracer gas dilution method

4.2.3. Nordic countries

NT VVS082: **Liquid flow metering installations: Radioactive tracer transit time method, in situ calibration**

This document specifies the method for in situ calibration of liquid flow metering installations using the radioactive tracer transit time method. The method specified is an application of the flow measurement method described in ISO 2975/Vll for the calibration of permanent flow meter installations. The aim of the method differs clearly in principle from that of the calibration of flow meters in calibration laboratories, where the flow meters are calibrated under ideal flow conditions. The in situ calibration result obtained by the method specified here involves the total error of the installation position, i.e. both the error component due to the flow meter itself and those caused by a non-ideal installation position. The latter components are due to a distorted flow velocity profile, fluid properties, environmental effects etc. They are in practice always present in permanent flow measuring installations and are generally responsible for the major part of the total error.

http://www.nordtest.info/index.php/methods/item/liquid-flow-metering-installations-radioactive-tracer-transit-time-method-in-situ-calibration-nt-vvs-082.html

4.3. DISCUSSION ON CANDIDATE RADIOACTIVE TRACER TECHNIQUES FOR PROPOSAL OF NEW ISO STANDARDS

As mentioned in section 4.1, the participants of the meeting agreed that reactivation of part 4 of ISO 4053 and part 2 of ISO 9555 is urgently necessary. It was also agreed that part 3 of ISO 4053 and part 5 of ISO 2975 is urgently needed. The meeting recommended establishing two new ISO standards for most frequently used techniques, gamma column scanning and leak detection.

4.3.1. Withdrawn standards

- ISO 4053-4:1978 Measurement of gas flow in conduits -- Tracer methods – Part 4: Transit time method using radioactive tracers [2003-03-25]
- ISO 9555-2:1992 Measurement of liquid flow in open channels -- Tracer dilution methods for the measurement of steady flow – Part 2: Radioactive tracers [2011-05-10]

4.3.2. Standards planned to create but not created

- ISO 2975-5 Measurement of water flow in closed conduits -- Tracer methods – Part 5: Integration (sudden injection) method using radioactive tracers
- ISO 4053-3 Measurement of gas flow in conduits -- Tracer methods – Part 3: Constant rate injection method using radioactive tracers

4.3.3. New candidate standards

- Procedures of radioisotope techniques for gamma scanning of columns in industrial process plants: [submit to ISO/TC 135 / SC 5]
- Procedure of radiotracer techniques for leak test in industrial process plants (heat exchangers): [submit to ISO/TC 135 / SC 6]

4.4. DISCUSSION ON PROCESS FOR THE INITIATION OF NEW ISO DEVELOPMENT

As mentioned in section 4.1, the two ISO standards for radiotracer techniques were withdrawn by the voting of P-members of ISO technical committee (TC 113). However, there were no members from nuclear institutions in the technical committee even though the committee made decisions on the radiotracer techniques, which are frequently used in many countries. This means that there was no input from radiotracer society to the ISO technical committee. Having international standards on the radioisotope technology is very important for the consolidation and propagation of the technology for the benefits of many industries. Therefore, it is important for the radiotracer people to make close contact with the members of the TC 113 for the reactivation of withdrawn ISO standards and creation of new ISO standards. It is recommended to contact ISO officially through the IAEA and/or the International Society of Tracers and Radiation Applications (ISTRA), which will be established soon.

Among the 3 groups of standards mentioned in section 4.3, the first priority could be the creation of ISO standards for the two techniques mentioned in 4.3.3, column scanning and leak detection. Actually, New Work Item Proposals for gamma column scanning technique and radiotracer leak detection technique had been submitted to ISO/TC 135/SC 5 (Radiation method) and ISO/TC 135/SC 6 (Leak detection method), respectively, and received very positive replies, especially from ISO/TC 135/SC 5. The SC 5 suggested followings;

- An expert of IAEA should participate in the development of the proposed project or even act as project leader.
- The IAEA should ask to become a liaison member, Category A, of ISO/TC 135/SC 5 according to the ISO/IEC Directive Part 1, clause 1.17.2.

Unfortunately the processes could not be continued, because the situation in IAEA at that time did not allow meeting the suggestion of ISO. However, now, the problems can be solved through ISTRA.

It was found that ISO/NP 20485 'Non-destructive testing – Leak testing – Tracer gas method' is under development as a new project by ISO/TC 135/SC 6. It was suggested to contact the subcommittee the check the possibility to include radiotracer method in the new project.

The second priority is the reactivation of two withdrawn standards, ISO 4053-4 and ISO 9555-2. I will be more efficient if the reactivation could be processed together with the creation of ISO 2975-5 and ISO 4053-3. In this case ISO 4053 series and ISO 2975 series can be restructured. The series are subdivided into parts on the basis of the method of field measurement, i.e. constant rate injection method and transit method. The new series of standards could be subdivided into parts based on the type of tracer used, i.e. radioactive tracers, chemical tracers and fluorescence tracers, to reduce the unnecessary repetition.

To facilitate these processes it is very important to show the ISO subcommittee members that the radioisotope techniques are being used in many countries and the ISO standards will be useful for the accredited calibration of flow meters installed in various industries.

5. NATIONAL REGULATION RELATED TO RADIOTRACERS

5.1. GERMANY

Some information about German national regulations were already given in chapter 3.2. The legal basis of all nuclear activities in Germany is the Atomic Energy Act. The subordinated regulations in Germany (ordinances) distinguish between radiation protection against damage and injuries caused by ionizing radiation (Radiation Protection Ordinance) radiation protection and against damage and injuries caused by X-rays (X-Ray Ordinance).
Therefore, also the guidelines for the requisite qualification and knowledge in radiation protection are different regarding to these both ordinances. There exist two guidelines with regard to the X-Ray Ordinance

- “Guideline for the requisite qualification and knowledge in radiation protection at handling X-ray units for technical purposes and stray radiation emitters requiring a license” and
- “Guideline for the requisite qualification and knowledge in radiation protection at handling X-ray units in medicine and dentistry”
  and two different guidelines regarding to Radiation Protection Ordinance
- “Guideline for the requisite qualification and knowledge in radiation protection” (Qualification Guideline Technics relating to Radiation Protection Ordinance)
- “Radiation protection in medicine - Guideline relating to Radiation Protection Ordinance (contains among others the requirement for medical physics experts …).

The application of radiotracers outside of special labs became and becomes in Germany more and more complicated. From practical point of view it is quite impossible to apply radiotracers in industry and environment. By amendment to the Radiation Protection Ordinance in 2011 a new appendix XIV was inserted. This appendix XIV contains a list of unjustified types of activities. Part A of this appendix contains a list of unjustified applications of radioactive substances or ionizing radiation to examine or treat persons (medicine) and part B contains the unjustified applications of radioactive substances or ionizing radiation outside medicine. The second application listed in part B of the appendix prohibits the utilization of unsealed radioactive substances to detect leakages (water, heating, ventilation) or dwell period spectroscopy (e.g. RTD measurements), insofar as these substances are not collected afterwards.

5.2. FINLAND

In Finland radioactive tracer measurements in the industry and environment are performed by licensed organizations with skills and capabilities to work with the radioisotopes and the detection systems. Unlike in some countries in Finland the plant where the measurements are performed does not need any license, like addition to environmental license, for this.

The foundations for the safety and acceptability of radiation practices are set forth in the Radiation Act (592/1991). Under section 70, paragraph 2, of the Radiation Act, STUK – Radiation and Nuclear Safety Authority (Finland) issues general instructions, known as Radiation Safety Guides (ST Guides), concerning the use of radiation and operations involving radiation. The relevant guides for using radioactive tracers in the industry or environment are listed in **Error! Reference source not found.**.

TABLE 1. FINNISH RADIATION PROTECTION REGULATIONS MOST RELEVANT FOR USE OF RADIOACTIVE TRACERS IN INDUSTRY AND ENVIRONMENT

Field	Guide	Title	Issued
General guides	ST 1.1	Safety in radiation practices	23 May 2013
	ST 1.4	Radiation user´s organization	2 Nov 2011
	ST 1.6	Operational radiation safety	10 Dec 2009
	ST 1.8	Qualifications and radiation protection training of persons working in a radiation user´s organization	17 Feb 2012
	ST 1.11	Security arrangements for radiation sources	9 Dec 2013
Industry, research, education and commerce	ST 5.4	Trade in radiation sources	19 Dec 2008
	ST 5.6	Radiation safety in industrial radiography	9 Mar 2012
Unsealed sources and radioactive wastes	ST 6.1	Radiation safety when using unsealed sources	17 Mar 2008
	ST 6.2	Radioactive waste and emissions from the use of unsealed sources	3 Oct 2014
Radiation doses and health surveillance	ST 7.1	Monitoring of radiation exposure	14 Aug 2014
	ST 7.2	Application of maximum values for radiation exposure and principles for the calculation of radiation doses	8 Aug 2014

Most relevant guide is ST 6.1 ‘Radiation safety when using unsealed sources’, which states the requirements for tracer tests carried out outside the laboratory. The section 8 of the ST 6.1 describes the guidance on ‘Tracer tests outside the laboratory’ as follow;

Radioactive substances are used as unsealed sources in tracer tests also outside the laboratory. Radioactive substances can, for example, assist with the measurement of flow rates and lag times of industrial and sewage processes, or of the mixing of substances in such processes. The radionuclides used for measurements are normally short-lived gamma emitters, the movement of which can be traced from the outside of pipes, or by taking samples. Tracer tests using radioactive substances are prohibited in those water systems, the water of which is used as drinking water.

The following radiation safety requirements apply to tracer tests:

- *The requirements stated in Guide ST 6.2 for discharges of radioactive wastes into the environment also apply to tracer tests carried out outside the laboratory. When necessary, the fulfilment of these requirements shall be demonstrated by calculations (evaluation of the radiation exposure caused by the tracer tests to the member of the critical group) or by monitoring the discharges.*
- *A person who independently carries out tracer tests outside the laboratory must be a radiation safety officer qualified to use unsealed sources in the industry, research and education (see Guide ST 1.8).*

- *When shipping radioactive substances, the transport regulations of radioactive substances must be followed.*
- *When tracer tests are carried out outside the laboratory, the controlled area shall be separated by barricade tape or a clearly visible equivalent warning line, and furnished with a sign indicating a danger of radiation.*
- *Access of unauthorised persons into the controlled area must be prevented.*
- *There must be written instructions for the tracer tests, including instructions for radiation protection and the event of abnormal incidents.*
- *After finishing the tracer test, measurements shall be carried out to ensure that the area is not contaminated.*

In addition to requirements stated above, STUK may set out further requirements for a single tracer test. Other requirements shall be considered case by case.

An advance notification of tracer tests shall be made to STUK at least two weeks prior to the date of the tracer test. The advance notification shall be in a written form and must contain at least the following information:

- *the holder and number of the safety license, and the radiation safety officer*
- *the place and time of the tracer test*
- *the purpose of the tracer test*
- *the radionuclide used, including its chemical and physical form*
- *the total activity used in the tracer test, the number of measurements to be taken, the activity used in a single measurement, and the expected time of the tracer test*
- *risk assessment (a description of the amounts of radioactive substances discharged into the environment and an evaluation of the radiation exposure to the member of the critical group).*

The other relevant guide is ST 6.2 'Radioactive waste and emissions from the use of unsealed sources'. The section 3 of the ST 6.2 describes the guidance on 'Radiation and Nuclear Safety Authority has set limits for emissions'. As the official English translation is currently not available, the relevant part of the section 3 is unofficial translated as follow;

If small emissions derived from the use of unsealed sources into the air, into sewers or the environment can not be avoided, the operator shall in particular ensure that the quantities of substances discharged are kept as low as possible and below the thresholds set by the Radiation and Nuclear Safety Authority. The effective dose from processing of radioactive waste to a representative person shall not exceed 10 μSv per year. This condition is deemed to be met by compliance with the limit values set in STUK decision 4/3020/2014. Radiation and Nuclear Safety Authority can in individual cases, through application by the operator, or on its own initiative set limits different from the above-mentioned decision. ...

Limit values for radioactive substance discharges into the sewer system are as follows:

From one place of radiation use single discharge activity may not exceed the limit for each radionuclide set exemption limit, but not greater than 100 MBq. From one place of radiation use discharge into the sewer during one month shall not exceed 10 times the exemption limit set for each radionuclide. Discharge into the sewer during one year must not exceed 100 GBq.

When radioactive substances are released into atmosphere, emissions must be limited in such a way that the effective dose to a representative person due to emissions shall not exceed 10 μSv per year.

In practical situations the radioactive tracer remains in the closed circulation of the process (like boilers + steam network/district heating system) or is finally emitted to the waterways or atmosphere. Calculation models have been established for different cases. The dose limit from one measurement to the other personnel at the factory is set to 0,3 mSv per measurement session. Effective yearly dose to outside public is limited to 10 μSv /year. In practice this has meant that maximum 37 GBq (1 Curie) of Br or Tc can be used in one measurement session [Indmeas, private communication].

Guide ST 1.4 'Radiation user's organization' requires that the responsible organization having the safety licence shall nominate a radiation safety officer. For the industrial use of radioactive tracers also a deputy radiation safety officer has to be nominated.

Guide ST 1.8 'Qualifications and radiation protection training of persons working in a radiation user's organization' sets out the requirements concerning the qualifications and competence of persons working in radiation user's organizations as well as the requirements concerning the radiation protection training required for their qualifications and competence.

Radiation safety officers are required to take radiation protection training, the content and extent of which are set out in the STUK guide. The command of the contents of the training is demonstrated in exams. Such exams are arranged by training organizations approved by STUK. A person serving as deputy to a radiation safety officer must also possess the qualifications specified for radiation safety officer. Radiation safety officers' competence training shall provide the trainees with the skills required for working as radiation safety officers in their particular competence areas.

5.3. DENMARK

In Denmark Order no. 954 of 23 October 2000 on the use of unsealed radioactive sources in hospitals, laboratories etc. contains a description of the requirements any company should fulfill in order to handle radioactive sources for medical and non-medical purposes:

- Any person or company handling radioactivity must apply for a license at the National Board of Health (the Danish National Institute for Radiation Protection).
- A license describes the intended use of the radioactive isotopes applicable. Furthermore, a license is often restricted to the use of only one radioisotope for one specific purpose. In other cases a person or company can obtain a general standard license to receipt, use, storage and transfer all radionuclides from radionuclide groups 2, 3 and 4. There are three levels (S1, S2 and S3) specifying the maximum activity that can be handled. A special license can also be obtained for radionuclide group 1.
- A license will always be issued to person (called "the responsible person"). This person is not necessarily the owner or manager of the company. The responsible person must be approved by the National Board of Health based upon an evaluation of the experience and education of the person. The responsible person must have passed at least one course offered at university level focusing at ionizing radiation, radiation protection and biological effects (two different courses are at present approved by the National Board of Health). Besides hands-on experience with radioactive sources, the person must as a minimum be familiar with the following:

  - Radioactivity and radiation

- Measurement of radioactivity and radiation
- Biological effects of radiation
- Principles of radiation protection
- Practical experience with radiation protection
- Laws and rules regarding radiation protection

The responsibilities of this person are:

- Maintenance of equipment used for measurements related to radiation protection
- Personal dosimetry of the personnel
- Safety and emergency instructions
- Ensure that the requirements for the isotope laboratory are fulfilled
- Radioactive waste management
- Decontamination and regular control measurements of the lab
- Instructions for handling radioactive material
- Training of personnel
- Reporting to authorities

In Denmark the responsible person (license holder) is responsibility for the training of the personnel. The responsible person must ensure that the personnel is properly instructed in the work with radioactive material and informed about the potential danger related to handling radioactivity. The personnel must be informed about all safety precautions, radiation protection and must have obtained proper practical skills and training before being allowed to work with radioactive sources. It is not required for the personnel to have passed any of the officially approved courses.

5.4. KOREA

Followings are the laws and regulations related to the use of radiotracers in the Republic of Korea:

- Nuclear Safety Act
- Enforcement Decree of the Nuclear Safety Act
- Enforcement Regulation of the Nuclear Safety Act
- Regulations on Technical Standards for Radiation Safety Control, Etc.

The responsible organization for the implementation of the laws and regulations is the Nuclear Safety and Security Commission (NSSC).

The purpose of Nuclear Safety Act is to promote public safety and prevent radiation hazards by establishing regulations on safety management of research, development and the use of atomic energy. According to the Article 53 of the Act, a person who intends to use (including the possessing and handling; hereinafter the same shall apply) or make a mobile-use of radioisotope, shall obtain permit from the NSSC as prescribed by the Presidential Decree. The same shall also apply to the case where he wishes to change any permitted matters. Provided, that if he intends to change minor matters such as temporary change of place of use as prescribed by the Ordinance of the Prime minister, he shall file a report thereon.

Any person who intends to obtain the permit shall submit an application for permit for the use of radioisotopes, attached with radiation safety report, safety control regulation, documents evidencing the purchase of equipment (radiation survey meter), documents evidencing the employment of the radiation safety officer and compensation standards, to the Commission. For permission for radiotracer applications in industry, ‘the mobile use of radioisotopes’ should be declared at the application form.

A radiation safety report shall contain each of the following. Provided that said provision shall not apply in those cases where any of the following is not related to the subject of the permit:

- Overview of the facilities;
- Environment surrounding the facilities;
- Overview of an operation plan;
- Features, location and specifications of radiation sources;
- Overview of the safety facilities;
- Radiation handling method and radiation safety control plan;
- Procedures, methods and results of estimated personal dose assessment;
- Impact of radiation on the surrounding environment;
- Accident risks and relevant measures;
- Plan regarding generation and processing of radioactive wastes; and
- Personal records and qualifications of a person who shall produce radiation safety reports.

Detailed guidelines for the production of radiation safety reports shall be determined and publicly notified by the Nuclear Safety and Security Commission.

The safety control regulations shall include each of the following. Provided that said provision shall not apply to cases where any of the following is not related to the subject of the permit:

- Matters related to the organization that handles radioisotopes or materials contaminated by radioisotopes and the functions thereof;
- Matters related to the purchase, use and sale of radioisotopes;
- Matters related to distribution, conservation, transport, processing, discharge, storage, self-disposal and delivery of radioisotopes or materials contaminated by radioisotopes;
- Matters related to radiation dose rate, personal dose, measuring of contamination by radioactive materials or materials contaminated thereby and the recording and safekeeping of such measuring results;
- Matters related to the safekeeping, control and calibration of radiation safety control equipment;
- Matters related to personal dose assessment and personal dosimeter control regarding radiation workers;
- Matters related to education and training necessary to prevent radiation hazards from occurring in respect to radiation workers or persons with frequent access;
- Matters related to measures necessary to detect occurrence of any radiation hazards;
- Matters related to necessary measures to be taken for the purpose of providing health services to those who have been or are feared to have been subjected to radiation hazards;
- Matters related to the records as provided in Article 69 of the Act and the keeping thereof;
- Matters related to measures to be taken in the event of an occurrence of a risk;
- Matters related to measures to be taken in the event of an accident including loss or theft of radioisotopes and the prevention of accidents;

- Matters related to the authority, responsibilities and performance of duties of a radiation safety officer; and
- Other matters necessary for protection against radiation hazards.

Detailed guidelines for the formulation of safety control regulations shall be determined and publicly notified by the Nuclear Safety and Security Commission.

In the case of a temporary change in the place of use for radiotracer field experiments, a report of temporary change in the place of use shall be submitted at least five (5) days prior to the commencement of the mobile use. The same shall apply in cases where any reported matter is to be changed. Each of the following documents shall be attached to such report:

- Explanatory statement on the place of use and the surrounding area thereof;
- Detailed structure description of storage facilities;
- Layout of storage facilities and the radiation control area;
- Explanatory statement on work methods;
- Explanatory statement on transportation methods; and
- Documents related to change of reported matters (only in those cases where any reported matter is to be changed).

6. CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

The use of radiotracers and radioisotope sealed sources for diagnosing and troubleshooting in various industrial processes and the need for international standards were discussed at the meeting. The main conclusions from the discussions are:

- The benefits of industrial use of radiotracers for troubleshooting, process control and optimization, plant safety enhancement and industrial pollution reduction are very high and already proved and recognized by the end users.

- Quality control and assurance of radiotracer and sealed source services are highly needed. The service providers have to follow certain prescribed procedures and protocols to provide quality services to clients. National/international standards contribute to making the services more accurate, efficient, safe and competitive.

- Accreditation to ISO standards improves the quality of services and helps the relation between service providers and clients. There are several mature techniques that are already used today and can directly be converted into ISO standards. In particular, radiotracer techniques for flowrate calibrations and leak detections, as well as radioisotope sealed source techniques for column scanning.

<u>Overview of existing ISO-standards</u>

From the presentations and the discussions at the meeting it was found that several parts of the ISO series on radiotracer techniques for flow rate measurement in industry had either been withdrawn or could not be found through searches on the ISO webpage.

During the meeting it was investigated the reasons why these parts had been withdrawn and why some of them were missing. An overview of the explanations found is presented in chapter 4 of this report.

<u>Identification of the most important standards to be developed</u>

At the meeting a list of ISO standards related to the use of radiotracers in industry was established as well as an overview of the withdrawn and missing ISO parts. This is presented in chapter 3 of this report. It was agreed that establishment/re-activation of the following ISO parts is highly needed:

- ISO 4053 part III and IV
- ISO 9555 part 2
- ISO 2975 part V

During the meeting it was also found that some countries like Germany, UK, Korea, USA and the Nordic countries have developed their national standards related to the use of radiotracers in industry. The countries have developed most of the standards by adopting the ISO standards in their national standardization system. This is described in chapter 4.

The use of radiotracers in the Nordic countries

The consultants from Finland and Denmark presented how radiotracers are used for industrial purposes in the Nordic countries. It was concluded that the authorities in Denmark and Finland in general have acknowledged that the use of radiotracers in industry is eligible taking both health and economical perspectives into account.

Legislation

Regarding legislation it seems that the authorities in some countries are more accepting of the use of radiotracers in industry than in others. The differences between the different countries regarding legislation were discussed. In Denmark and Finland companies specialized in radiotracer techniques can relatively easy obtain a license, where as in Germany and France for example this appears to be much more difficult.

Education and training

Education and training of license holders and personnel in the different countries were also discussed.

Based on the discussions at the meeting the consultants recommend:

- Accreditation of some of the mature techniques and applications already existing and used in industry should be considered. This includes radiotracer techniques for flow rate measurement and leak detection, as well as gamma scanning.

- ISO TC135, SC6 is working on a new ISO standard on NDT/leak testing/tracer gas method. (ISO/NP20485, stage number 10.99 April 19 2015). The meeting recommended IAEA to contact the SC to check the possibility to include radiotracer methods in the new ISO standard.

- Preparation stages for new standards and re-activation of withdrawn ISO standards should be initiated. A working group for promoting and finalizing the ISO standards has to be created. A working group could be established in collaboration with ISTRA.

- The positive experience of flow rate calibration in Finland and of leak detection in Denmark should be largely recognized and promulgated; the further approach has to be investigated.

- The training of radioisotope practitioners was recognized as being vital to the provision of quality services. To facilitate training and to ensure harmonization of training standards, it was proposed that the Agency should compile a comprehensive, modular training package, which would be made available to the Member States.

- The new series of ISO standards should be divided into parts based on the type of tracer used instead parts based on the method of field measurement.

- It should be investigated how the different European countries interpret the EURATOM regulations, and how this is implemented in the national legislation of each country.

ANNEX 1. AGENDA

Consultants Meeting on "Development of standards for radiotracers applications''
10-13 November 2015, Vienna, Austria

Tuesday, 10 November

09:30 - 10:00	**OPENING** o Opening remarks *Mr. Patrick BRISSET – IAEA-NAPC* o Election of the chairman and reporter o Adoption of the agenda o Scope and objectives of the CM *Mr. Patrick Brisset (Scientific Secretary, IAEA)* o Administrative arrangements
10:00 - 10:30	Coffee break
10:30 - 12:00	**SESSION I: Participants' presentations (30 min)** 3 participants
12:00 – 14:00	Lunch
14:00 – 15:30	**SESSION I: (continue)** 3 participants
15:30 – 16:00	Coffee break
16:30 - 17:30	**SESSION I: Continue or change to Session II**

Wednesday, 11 November

09:00 – 12:00	**SESSION II: Technical discussions** o Discussions on the presentations o Strategy for the efficient meeting organization
12:00 – 14:00	Lunch
14:00 – 17:30	**SESSION II: Technical discussions**

Thursday, 12 November

09:00 – 12:00	**SESSION III: Technical discussions**
12:00 – 14:00	Lunch
14:00 – 17:30	**SESSION IV: Preparation of Draft Meeting Report**

Friday, 13 November

9:00 – 12:00	**SESSION V: Discussion on Meeting Report** o Finalization of the meeting report
12:00 – 14:00	Lunch
14:00 – 17:30	**SESSION VI: Approval and Closing** o Approval of the meeting report o Closing of the Meeting

ANNEX 2. PARTICIPANTS' LIST

Consultants Meeting on "Development of standards for radiotracers applications''
10-13 November 2015, Vienna, Austria

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