
Requirements on official electronic dosimetry systems - a concept for the use of official electronic personal dose meter in Germany

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Abstract:

Due to their technical features electronic personal dose meters offer a variety of advantages to their users compared to the use of passive dose meters. Therefore in Germany an initiative was started by the Federal Ministry for Environment, Nature Conservation and Nuclear Safety to promote the use of electronic personal dose meters as official dose meters and as an alternative to the existing passive dose meters. In this presentation the concept of official electronic personal dose meters, which has been developed by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH on behalf of the German Ministry for Environment, Nature Conservation and Nuclear Safety will be explained. Hereby focus will be given also to features of the concept which allow dose estimations in the European context for transient workers.

1 INTRODUCTION AND BACKGROUND

Up to now in Germany according to the German radiation protection ordinance (StrlSchV, see [1]) and according to the X-ray ordinance (RöV, see [2]) passive dose meters (e.g. TLD, film) only are accepted by the competent authorities to measure the official effective dose. The high quality and reliability of these dose meters and their analysis have been proven over several decades so that the determination of the effective dose of occupationally exposed persons is sound.

Nevertheless the demand of task related dosimetry and automation enforced developments in the last few decades of reliable electronic personal dose meters (EPD) which are based on one or more detection probes which can be read out directly without any chemical or physical (like thermal) pre-processing. Typically these dose meters consist of the detection probes and additional electronics and signal processing to allow a direct reading of the dose results. With respect to the passive dose meters EPD offer some advantages which on one hand contribute to a better exposure control and on the other hand foster the development of a sound culture in radiation protection due to direct feedback of dose information. Some of these advantages are:

- lower detection limits and improved resolution
- immediate read out of the measured dose
- no need for chemical or physical pre-processing to get the dose information
- availability of dose and dose rate information as well as threshold alerts for dose and dose rate
- possibility to preset levels and thresholds by the dosimetry system
- further features for internal tests and information storage

Currently the use of EPD, especially of direct reading electronic personal dose meters, is limited to operational dosimetry in Germany. Typically EPD are applied in addition to the official passive dose meters in large nuclear installations and facilities like nuclear power plants, facilities of the nuclear fuel cycle, large research centres or in large hospitals. The reason of this parallel dosimetry may be to the obligation to use these additional dose meters due to license conditions or because the organisation is interested in an on-time knowledge of the current personnel exposures. Many improvements in the reduction of the exposure of personnel for example in German nuclear power plants have been achieved based on task related exposure information which became available due to the use of EPD (see for example [3], [4]). Moreover, for contracted workers in Germany a radiation passport has to be maintained which shall provide up to date information on the current individual dose of the owner of the passport when starting to work in a nuclear facility. This up to date information bases on the results of the official dosimetry with its official passive dose meters. But as due to the processing times the results of the official dosimetry may not be available when changing the work place from one plant to the next. So the passport also documents the results of the operational dosimetry from EPD for the time in between, as this information is available in time when leaving the plant to move to the next work place. Thus even yet EPD contribute to the official system of controlling the exposure of workers in controlled areas.

Due to the advantages mentioned, but also due to additional reasons as e. g. to reduce the costs for the determination of the effective dose by avoiding the use of two or more personal dose meters at a time (but without compromising the requirements of the radiation protection) the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, BMU) initiated a project to introduce EPD as official dose meters forming an alternative to the official passive dose meters. The project is separated into two parts: part one focuses on the development of a general concept on how to design an official dosimetry system with EPD, which shall fulfil the legal requirements for the determination of the effective dose according to the relevant ordinances RöV and StrISchV. In part two as a pilot project the implementation of the concept is addressed and first experiences shall be derived. The later implementation of electronic dosimetry systems as official dosimetry system depends on an approval by the BMU and the authorities of the States ("Länder"). The results of both parts of the project will provide the basis for such an approval.

The general concept was developed in 2004 by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH under the supervision of the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS). The concept is subject of this presentation and will be explained in more detail later. Part two of the project was launched middle of 2005 and is expected to be finished by beginning of 2007.

2 OBJECTIVES OF THE CONCEPT

Emphasis in the concept of the dosimetric system is given to the overall composition of those components, which are necessary to measure the effective dose, to readout the measured date from the dose meter, to transfer the data to a competent evaluating organization and to deduce the effective dose from the measured data. Requirements due to the German regulatory system and the different conditions, under which such a electronical dosimetry system may be operated, have to be taken into account. A rough overview on the requirements will be given below.

The concept does not consider aspects on the quality and on the physical properties of the dose meter probes used in the EPD. It is proposed that dose meters used in the system must have passed a type-test and a type-license of the Physikalisch-Technische Bundesanstalt (PTB), will be compliant with the international standard IEC 61526 (see [5]) and will be

appropriate to the environmental situation in which they are intended to be operated. Nevertheless, as a result of the concept an adaptation of the relevant PTB standards seems necessary, but the related recommendations are not part of this presentation.

Requirements due to the German regulatory system

Requirements to be taken into account due to the German regulatory system are laid down in radiation protection relevant ordinances, i. e. StrlSchV and RöV, in the law and the corresponding ordinance on the type-test and type-license (and related PTB standards) and in radiation protection relevant BMU regulations, which are applied by the German state authorities when transferring general requirements of the ordinances into the practical case. Moreover, several national and international standards and recommendations of the German radiation protection commission (Strahlenschutz-Kommission, SSK) shall be taken into account. Due to the scope of this presentation the requirements can not be discussed in detail but instead the following list may give an overview on the issues treated:

- physical properties of the dose meter probe and the dose meter (incl. avoiding and recognition of malfunctions and failure)
- security against manipulation of the measurement by the wearer of the dose meter
- documentation of the properties of the dose meter and the use of the dose meter
- identification of the dose meter and allocation of the dose meter to its wearer
- operational conditions for the use of the dose meter
- duration of the surveillance period
- quality assurance (for the dose meter as well as for the competent evaluation organization according to StrlSchV and RöV)
- reliability and availability of dosimetry systems (incl. data transfer)

It has to be mentioned, that some of these requirements are currently valid for passive dose meters and their corresponding evaluation systems (e.g. concerning data transfer) so during the elaboration of the concept either corresponding requirements had to be developed or it had to be proven that issues could be skipped.

A basic set of requirement to be fulfilled by an electronic dosimetry system and reflecting the different technologies of EPD and passive dose meters was formulated end of 2003 during the common meeting of the working group on radiation protection of the BMU, the State authorities (Fachausschuss Strahlenschutz des Länderausschusses Atomkernenergie, FAS), the working group on Röntgen of BMU and the corresponding States authorities (Länderausschuss Röntgenverordnung, LARöV). The dosimetric system shall satisfy the demands on

- correctness of the data over the full data chain (starting with the EPD and ending with the validated monthly effective dose, provided by the competent evaluating organization),
- completeness of the data over the full data chain,
- security against any data manipulation over the full chain and
- safety of the data against any unauthorised access.

It should be mentioned, that these basic requirements reflect the “lessons learnt” from international experiences as well as PTB requirements of 1995, which up to now are not implemented in the PTB standards, but are under discussion.

Requirements due to the different conditions of operation

A second group of requirements results from the different circumstances in which an electronic dosimetry system may be operated. Currently the use of such a system is under discussion for a large variety of installations and facilities to be covered. Especially for nuclear power plants, for large hospitals or for research centres the system shall be operational, i.e. the concept shall take into account the similarities but also the differences.

In *German nuclear power plants* EPD are used by operational dosimetry. The dose meter is taken from a dose meter pool by the wearer just before entering the controlled area and is returned to the pool after leaving the controlled area (so called "pool concept"). When leaving the controlled area the measured dose information is read out from the dose meter and stored in the computer of the central operational dosimetry system. To allow for later processing and analysis of the measured effective dose an allocation of the supervised person, i.e. of the wearer, of the measured dose and of the work permit is performed during the entry; typically an identifier of the wearer is stored in the dose meter when entering the controlled area and is transferred together with the read out measured data, when leaving the controlled area. The "pool concept" benefits from the rigorous access control which is established at all entries to controlled areas of NPP - neither entering nor leaving of a controlled area is possible without passing an access control system.¹ If information is not provided by the wearer (or any malfunction of the dose meter occurs) access or passage is denied and the radiation protection staff can become active.

Typical to the situation in German nuclear power plants is that in general only one (large) controlled area does exist, which has to be supervised and for which a central access to enter and leave does exist. Nevertheless in addition some de-central controlled areas (e.g. for interim storages) may exist, which are not as frequently entered as the central controlled area, but which have to be taken into account, too, in the concept of an electronical dosimetry system.

In research centres or in large hospitals the situation tends to be different compared to the situation in nuclear power plants. Typically no technical access control systems exist to control the entering and leaving of the controlled area. As a consequence it is difficult to ensure that a dose meter is worn by the personal to be supervised,² as there are only limited means to ensure that dose meters (electronic or passive) are worn.

In addition, in these facilities the number of (frequently entered) controlled areas sited at different locations may be much higher than in NPP. On the contrary the number of qualified personal in charge of radiation protection available is much lower than in nuclear power plants. This situation results in the high need of a reliable and centralised radiation protection surveillance system including the issue of official dosimetry. If an access control can not be established (e.g. in case of interventional medical treatment applications) a permanent allocation of an EPD may be the only reliable alternative (compared to the "pool concept" present in the nuclear industry sector).

¹ For the rare cases in which no hardware based access control does exist (e.g. temporarily existing controlled area during preparation of radioactive transports) organizational and administrative procedure ensure the control of access.

² Certainly this problem also is present for the use of passive dose meters. The staff responsible for radiation protection invests a lot of effort to convince the personal to be supervised in wearing the dose meters.

3 CONCEPTUAL APPROACH – THE CONCEPT

3.1 Overview of the concept

Summarizing the different conditions of operation in different institutions, i.e. the different options of access control, the concept shall allow “pool concepts” as well as concepts, in which the EPD permanently are allocated to a wearer. In the following presentation there will be a focus on the “pool concept” with technical access control, which will be the typical concept used in nuclear power plants. Nevertheless some recommendations are given for a concept with permanently allocated dose meter, considered as a good solution if a technical access control is missing.

The data flow in the concept worked out by GRS for an official electronic dosimetry system with “pool concept” layout is sketched in Figure 1. It has to be stressed, that the figure represents the situation for utility personnel; for contracted personnel amendments are necessary to direct the evaluated dose data to those organizations which according to StrlSchV and RöV are responsible for the contracted personnel. For some more details please refer to chapter 3.2 .

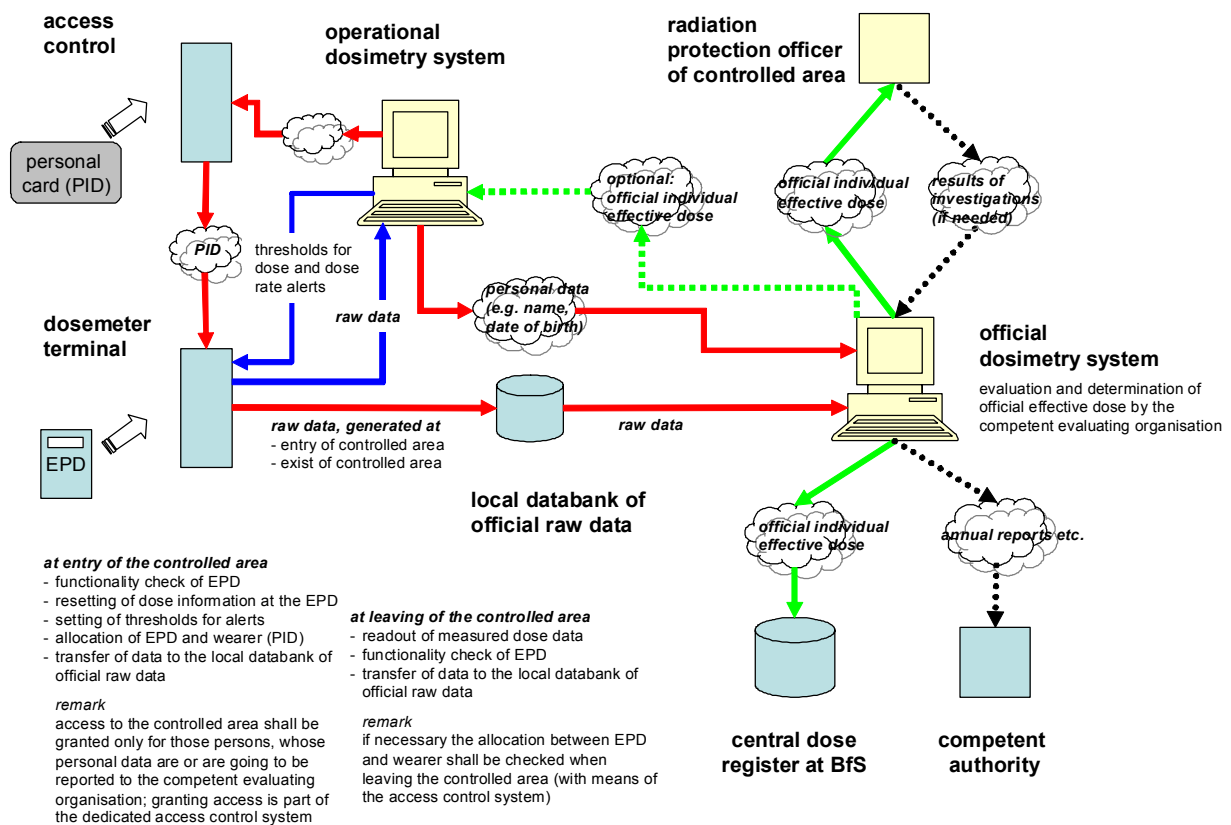


Figure 1 Data flow in the GRS concept for an official electronic dosimetry system with use of pooled EPD. The data flow is sketched for facility personnel; for outside personnel some amendments are necessary (for further details please refer to chapter 3.2)

Some remarks on the conventions in the figure will help to understand the figure more easily: those data transfer lines which correspond to the transfer of data of the **official dosimetry** system are marked in **red colour**. Those data transfer lines, which are part of the **operational dosimetry** system are **coloured blue**. These lines in principle are out of the focus of the official dosimetry system, except that they must not influence the official dosimetry system in any way. Further data transfer lines in green or blue correspond to the transfer of data from the competent evaluation organization to the responsible person of the controlled area or to the competent authorities. Finally clouds in the data links symbolise that these data links are needed from a functionality point of view but the concept does not define any technological aspects. I.e. the technical layout of the functionality indicated by a cloud is completely subject to the implementer's decision.

In case of the "pool concept" in a nuclear power plant EPDs shall be used, which in Germany have passed a type-test and a type license of the Physikalisch-Technische Bundesanstalt (PTB). These devices will be provided from a pool of dose meters at the entrance of the controlled area. Active EPD will be used, if due to operational needs features as e. g. direct readability of the dose, preset of alarm levels for dose respectively dose rate or additional data (dose rate sequences, maximum of dose rate) are necessary in addition to the pure determination of the individual exposure. The application of passive EPD seems possible, if only simple demand, e. g. supervision of routine activities, rests on the measuring task.

If the dose meters are supplied from a pool, the dose meter will be assigned to the wearer in a reader station (EPD-reader, dose meter terminal) when the person enters the controlled area. A unique personal ID will be used to identify the wearer; this ID will be stored in the EPD. If an exchange of the EPD cannot be excluded due to the way how the wearers use the EPD, the personal ID can be used to identify the assignment to the wearer either by displaying the ID or by implementing special readers for identification in the controlled area. The EPD fulfils special demand regarding safety against loss or manipulation of data. In addition it will store the information on battery changes and can not be switched off by the wearer. These demands have to be proven as part of an extended type-test.

During the set up of the dose meter in the dose meter terminal for the entrance of the controlled area a functional test will be carried out. To store the wearer's ID to the EPD the personal-ID has to be delivered to the EPD reader by appropriate means.

The data sets retrieved when entering and leaving the controlled area which both are needed to evaluate the contribution to the wearer's official effective dose, both in addition to the dose information contain the identification number of the EPD, the personal ID, the time of access of the controlled area, and the positive result of the functional test of the dose meter performed. If passive EPD should be used in a pooled system, the dose actually stored in the dose meter (if not reset) needs to be transferred to a data base, too, to allow for the later calculation of the dose received.

The design assures that the official branch of the data and the data stream cannot be interfered with by the operational dosimetry system. The de-coupling of the operational and the official dosimetry system takes place at the dose meter terminal.³ From there, the data – if necessary after a short interim storage – are transferred to a local intermediate storage system, which acquires the data, stores them for intermediate storage, archives the data for a certain time period and makes the data available for transfer to the competent evaluating organization. This local station will be called the "local databank of official raw data" and is

³ If a de-coupling is not possible at the dose meter terminal the data flow from the dose meter terminal shall be devoted to the official dosimetry system in which a split of the data flow for the operational dosimetry system shall be performed. The requirements related to the data flow of the official dosimetry system (see later) completely hold for that data flow emerging from the dose meter terminal.

represented by a local IT-component in the responsibility of the competent evaluating organization. Including its interfaces with the dose meter terminal, it may have a type license but at least must be certified according to international technical rules. The interfaces to the dose meter terminal and to the competent evaluating organization including the data transfer via these interfaces will be surveyed and protected against data losses and data manipulation by adequate transfer lines and protocols.

If in case of de-centralized controlled areas the dose data have to be retrieved from different places, data sampling may be performed by a sufficiently secured local area network (LAN) including a router, which supplies the data to the local data base. This solution certainly has to meet the high demand regarding data losses and data manipulation.

The IT-system of the local data base addressed above shall be safe against loss of electrical power (e.g. by a battery driven emergency power) and shall consist of mirrored processor/disk-systems to increase the safety against data losses. The system stores each data set of entrance and leaving the controlled area to assure the possibility to combine the data sets but also to be able to identify missing data sets.

During the stay in the controlled area the EPD stores the dose received and furthermore additional data as e. g. the results of permanently executed internal self-testing procedures of the EPD, dose rate data and data of additional probes installed inside the EPD.

When leaving the controlled area with a pool-type dose meter (or with a dose meter which needs to be read out each time when leaving the controlled area⁴), all data are read out and transferred to the operational dosimetric system. In parallel and de-coupled from the operational dosimetric system all data necessary for the official dosimetric system (for data analysis same as for validation) will be supplied to the local data base of official raw data. The transfer will be secured against loss of data. The data supplied especially cover the personal ID, the ID of the dose meter, the flags representing the results of the internal self-testing, the time of leaving the controlled area and certainly the measured dose data and relevant information that may be important to validate the data. The personal ID and the ID of the dose meter are important to be able to combine the data set of access and exit as well as to correlate the personal data of the dose meter's wearer during analysis. The data addressed will be stored in the local data base and will be made available for later transfer to the competent evaluating organization. In addition these raw data are stored for some time locally. This storage aims at the possibility to have access to the raw data for some time. It does not cover the demand to archive the data by the evaluating organization according to the German regulations, which will be done at the premises of the competent evaluating organization.

The official raw data will be encoded and sent to the competent evaluating organization in regular time intervals defined by this organization. The data transfer will be secured against data loss and manipulation by dedicated transfer protocols. The competent evaluating organization addressed within this concept is a certified organization which is approved by the competent authority for this task. This organization provides competent, qualified and experienced staff, which is responsible for the data retrieval and transfer, the check and evaluation of the partial (raw) data received. It accumulates the partial data (entrance and exit data set of each access of the controlled area) to the official dose for the surveillance interval prescribed. The organization is responsible for the full chain of data retrieval and transfer from the dose meter terminal (reader) via the system of the local data base to the final destination in the data evaluation system at the site of the competent evaluation organization. This organization will not necessarily be responsible for the EPD, as these may be a part of the operational dosimetric system of the organization operating the controlled area. In this case responsibility for the EPD devices will rest with this organization. It is, however, considered possible that the organization responsible may charge a qualified organization/company with the operation of this (operational) part of the system to provide for maintenance, tests and calibration according to the national regulation. In any way it has to

⁴ This may or may not be necessary for a passive electronic dose meter, especially if it is assigned permanently.

be assured that all necessary information (tests, calibration, ..) will be available to the competent evaluating organization.

The competent evaluating organization transfers the official doses derived to the competent radiation protection officer of the facility, to the competent authorities and to the radiation protection register of the Federal Office for Radiation Protection (BfS). If necessary, evaluations by the radiation protection officer of the controlled area will be initiated in case of erroneous or missing data.

To fulfil its duties, the competent evaluating organization will need additional data from the organization operating the controlled area. This for example affects personal data for each supervised person. The data may be delivered by channels agreed upon between the evaluating organization and the organization operating the controlled area.

It has to be kept in mind and remembered that plants and institutions may differ in layout and number of their controlled areas and especially in the access control conditions for that areas: For nuclear power plants the access to the controlled areas is quite formalized and technically secured – the previously explained “pool concept” strongly takes credit from this.

In contrary to this in hospitals and research organizations a large number of access locations and controlled areas may needed to be operated, which only in rare cases are technically secured e. g. by turn stiles - thus usually no real access control is established. Considering data retrieval being performed by several reader terminals linked by a secured LAN, it has to be pointed out that in case of missing technical access control additional organizational and administrative measures and personnel responsibility have to be taken credit of to ensure a proper allocation of EPD and their regular readout. With respect to the degree of effort related to these administrative and organizational measures in case of a pool concept, it is more likely to permanently allocate an EPD to a wearer and to establish processes to ensure a readout of the dose meter at the end of a surveillance period. It has to be noted that the processing of the EPD data shall be the same as in case of the “pool concept”.

3.2 Dosimetry of outside workers in the European context – an approach within the concept

In Germany for contracted personnel the responsibility not to violate dose limits is with the radiation protection officer of the company sending contracted personnel (dispatching company) into the controlled area of the hiring company. As a consequence and, moreover, as clearly stated in the relevant ordinances the responsibility to determine the individual effective dose is with the dispatching company too. Therefore actually all contracted workers - in addition to the dose meters of the contracting company - wear dose meters supplied by the dispatching company to measure the official effective dose for the full evaluation period of e.g. one month (It has to be kept in mind that contracted workers may be active in several facilities during one month).

In the previous chapter the concept focused on the application of EPD for utility personnel. With slight amendments in the field of the competent evaluation organization the concept can be adapted also to the application of official EPD to contracted personnel to the benefit of contracting companies. This means that the concept is able to cover the full measuring tasks of official dosimetry.

If contracted personnel will only be detached to plants using EPD as official dose meters, with the agreement of the competent authorities of the worker's company it is possible to use the official EPD of the organization of the controlled area instead of passive official dose meters of the dispatching company. It has, however, to be assured that the summing of all exposure data from different controlled areas for the period of survey can be performed by the competent evaluating organization assigned to the dispatching company. This for example can be implemented by forwarding the partial data acquired in each controlled area also to the competent evaluating organization of the dispatching company, as is shown in the

sketch of the related data flow in fig. 2. It has to be noted, that certainly all relevant personnel data (including information on the competent evaluating organization of the dispatching company) is available at the competent evaluating organization of the controlled area to be able to forward the data to the correct receiver.

For staff of dispatching companies, which becomes active in companies with official EPD and also in companies with official passive dose meters, it will not be as easy to use EPDs as official dose meters. In this case special agreements will be necessary to be fixed. E. g. – as current standard in Germany - passive dose meters supplied by the dispatching company to its staff will have to be used and it will be necessary to flag the electronic data of the EPD which in this case only will be used for operational dosimetry reasons.

Although up to now only discussed in the German context it is obvious, that evaluation of doses auf workers – and especially of contracted workers - is not only a German, but even more a European issue. From that point of view the discussion in Europe is an important task to assure harmonisation of dose retrieval and implementation of an effective data exchange of doses of transient workers. The concept presented hopefully will contribute in a supporting way to this discussion.

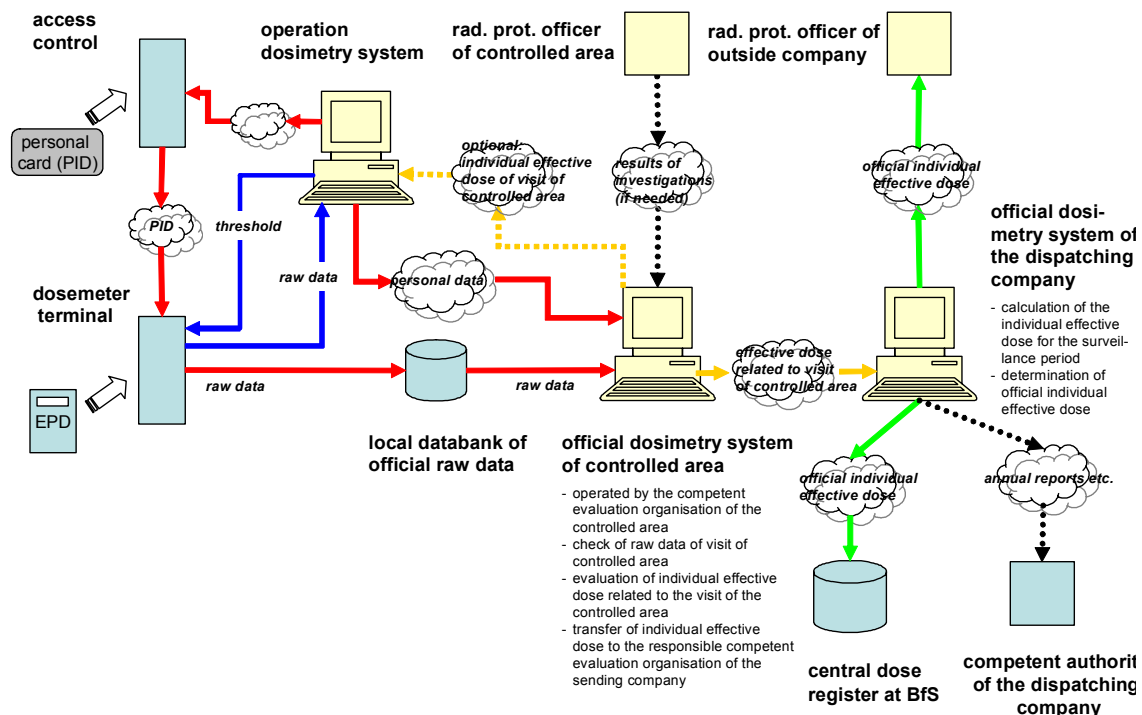


Figure 2 Data flow in the concept for an official electronic dosimetry system with use of pooled EPD for dose measurements for outside workers.

4 SUMMARY AND OUTLOOK

In the presentation the German concept on the use of electronic personal dose meters as official dose meter according to the German radiation protection ordinance and of the X-ray ordinance was presented. The concept was developed to cope with the situation in nuclear power plants as well as in large hospitals or research centres. Up to now electronic personal dose meters were used as operational dose meters, but it could be shown that the

use of EPD is possible as an alternative to official passive dose meters thus introducing the state of the art of technology into the official dosimetry in Germany, which will give benefits in dosimetry as well as regarding cost reduction and efficiency.

The concept is flexible to cover application of official EPD by contracted workers. Thus the benefits are not limited to the operator of a facility but to the dispatching company. This will improve the radiation protection for contracted workers in Germany and may trigger implementation of such dosimetric systems in other European countries. With the concept of official EPD a first step has been made to introduce new IT technologies into the official dosimetry in Germany.

Currently the implementation of the concept is under progress. In the frame of project consisting of several pilot projects the technical realisation of the concept will be performed. As a result the project under way shall provide a sound basis to approve the implementation of official EPD by BMU and the state authorities. In addition "lessons learnt" shall be drawn from the experiences made, including, if necessary, amendments or technical modifications of the concept presented here.

A next major step to further improve radiation protection for outside workers on a European level, will be the development of a German and preferably of a European radiation protection passport. In Germany, same as in other European countries, this passport is a paperback which requires a lot of effort to maintain, esp. by manual none-automated transfer of measured dose data and by transfer of personal data to the dosimetry systems at the operating organizations. To reduce the risk of failures in data transfer and to reduce the associated effort and to improve the processing times to get up to date data via the radiation passport an electronic – and preferably a European - radiation protection passport should be discussed and focused on. Concepts may vary from

- radiation passports, which contain all information including the dose information, which are loaded to the passport, when the owner is leaving the organization of the controlled area, to
- radiation passports, which only contain an identifier unique in Europe, which allows to get all relevant information from a national or European central radiation data base, which contains all dose information including those of the last visit of a controlled area (it is obvious, that this concept requires the use of EPD for all outside workers)

It's the vision and hope of the authors that further effort will be made to develop electronic dosimetry and radiation protection passports on a European level and thus to set the individual dosimetry onto a modern and effective system.

5 REFERENCES

- [1] „Radiological Protection Ordinance“
Verordnung über den Schutz vor Schäden durch ionisierende Strahlen (Strahlenschutzverordnung – StrlSchV) vom 20. Juli 2001 geändert durch Verordnung zur Änderung der RöV und anderer atomrechtlicher Verordnungen vom 18. Juni 2002, BGBl. I S. 1869, 1903
- [2] „X-ray Ordinance“
Verordnung über den Schutz vor Schäden durch Röntgenstrahlung (Röntgenverordnung – RöV) in der Fassung der Bekanntmachung vom 30. April 2003, BGBl. I S. 604

- [3] J. Kaulard, W. Pfeffer
„Task related exposure in German Nuclear Power Plants“
Proceedings of the EUROSAFE 2003 conference, November 25th and 26th 2003 at Paris
- [4] J. Kaulard, W. Pfeffer
„Progress in the Occupational Exposure in German Nuclear Power Plants due to the Influence of Experience Feedback and of the German Rules and Regulations“
Proceedings of the EUROSAFE 2004 conference, November 8th and 9th 2004 at Berlin
- [5] International Electro Technical Commission (IEC)
Radiation protection instrumentation – Measurement of personal dose equivalents $H_p(10)$ and $H_p(0,07)$ for X, gamma, neutron and beta radiations – Direct reading personal dose equivalent meters and monitors
DIN IEC 61526 Ed. 2.0,
February 2005