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ISBN 1-85893-025-1

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This report describes the selection process adopted in identifying personal dosimeters suitable for fire service operations. Although none of the products originally tested completely met the specification, three have received appropriate modifications. All three now meet the minimum requirements and two of these offer additional capabilities.

INTRODUCTION

One of the recommendations of the Joint Working Group on Chernobyl was that "research be undertaken to identify or develop an electronic integrated device, preferably one which incorporates facilities for both personal and dose rate monitoring, suitable for use by the fire service." The National Radiological Protection Board (NRPB) subsequently reported that it would not be practical to produce a dosimeter combined with an electronic integrated dose rate survey meter, as the dose rate elements of the meter would not be sufficiently sensitive or accurate to be used as a survey meter.

A draft specification for a personal dosimeter for fire service use was prepared by the Home Office Emergency Planning Research Group (EPRG) in consultation with the Fire Service Inspectorate. The contract for assessing the various products available was awarded to the Dosimetry and Instrumentation Division of NRPB. A preliminary survey of the market was undertaken, and the possibilities were reduced to two currently available dosimeters and two prototypes which manufacturers offered to submit to meet the specification (Figure 1).

NRPB's final tests were therefore conducted on:

Merlin Gerin DM90
Stephens Gammacom 4200M
Siemens Plessey NRPB EPD Prototype
Appleford Prototype

The Home Office Fire Experimental Unit (FEU) was subsequently asked to conduct further tests on the dosimeters to assess their suitability for fire service use.

NRPB TESTING

The NRPB tests showed that both currently available dosimeters came close to meeting the requirements, and both prototypes had more serious shortcomings. All the meters would have to be modified to some extent, but this would depend on the willingness of the manufacturers.

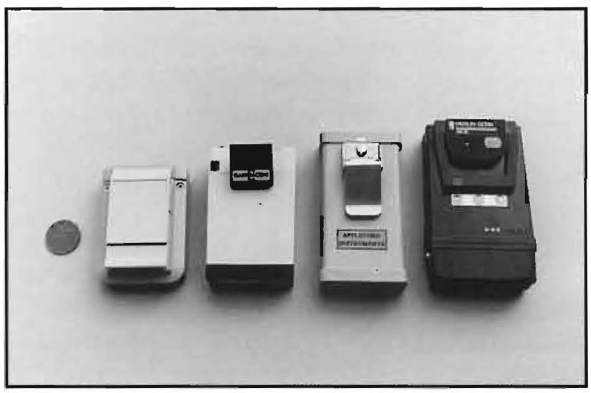

Fig 1 The four dosimeters tested

One important point NRPB made about dosimeters was that they can be directional in operation. If they are designed to be placed in outside pockets, the clip will be on the same side as the detector, and an incorrect reading would be measured if such a dosimeter were clipped to a BA harness. It is important that the manufacturer knows where and how the dosimeter is to be mounted.

In addition to their performance measurements, NRPB also subjected the four dosimeters to high fields of electromagnetic radiation, in the vicinity of an airport 3GHz search radar. The Gammacom and Appleford dosimeters were unaffected, the Merlin

recorded the occasional random count which had no significant effect on its reading, and the Siemens Plessey ceased to function entirely.

FEU TESTING

The NRPB tests compared the dosimeters with the specification issued by EPRG. The FEU tests assessed their suitability for fire service use. The tests consisted of measurements of the audibility of the alarms, the visibility of the displays, ease of operation, and operational considerations of where they should be worn.

Audibility

All dosimeter alarm sound level measurements were made with the help of a firefighter using a Draeger breathing apparatus, because it is generally regarded as the noisiest of the sets in use in the United Kingdom fire service. The firefighter wearing it commented that he had to control his breathing to be able to hear anyone speaking to him.

All the dosimeter alarms could be heard by the firefighter when wearing BA and no gas-tight suit. When used inside a gas-tight suit, the firefighter was still able to hear the dosimeter alarms, but the measurements showed that the sound levels were similar to those produced by the BA when the firefighter was breathing normally, so there might be difficulties in hearing the alarms under some conditions.

In these circumstances, FRDG concluded that it was the frequency of the sounder tone which was most important. The firefighter commented that it was easiest to hear the Merlin sounder (6000 Hz), and most difficult to hear the Siemens sounder (2000 Hz). The Gammacon sounder gave a combined two frequency alarm (2000 Hz and 4000 Hz) which was almost as easy to hear as the Merlin.

The dosimeters could not be heard by the wearer when they were used mounted on the outside of a gas-tight suit. It was clear from the firefighter's comments that the only dosimeter alarm he could hear was the Gammacon, when they were mounted in this way. Even that was very faint and unlikely to be noticed when the firefighter was breathing heavily and concentrating on other aspects of the job.

If the dosimeter audible sounder were to be used as the principal way of drawing the firefighter's attention to alarms, as opposed to relying on the display, the dosimeter would have to be carried inside a gas-tight suit when one is used.

Reading the Displays

When wearing BA and a gas-tight suit, a firefighter was asked to try to read the instrument at different lighting levels. None of the dosimeter displays could be read at a level of 1 Lux without backlighting. (At this lighting level it is perfectly safe to move around a room without the need for artificial illumination.)

Even at much higher levels, it would be very difficult to read some of the smaller dosimeter displays.

Of the four dosimeters tested, only the Gammacom was fitted with a backlight for the LCD. This proved extremely effective. The manufacturers of the Merlin and the Appleford dosimeters were willing to modify their products to incorporate appropriate illumination of their displays. Siemens were not prepared to fit display illumination in their model.

In the firefighting environment, FEU considered appropriate display illumination to be essential if liquid crystal displays (LCDs) are used in the dosimeters. The Siemens prototype therefore could not be considered a suitable dosimeter for fire service use.

User Evaluation

A group of 12 fire officers on a Junior Officer Advancement course at the Fire Service College were invited to give their comments on the various dosimeters. Their general reactions can be summarised as:

- The dosimeters were unacceptable without display illumination if LCDs were used. The Gammacom display was considered the most readable, as it had the clearest numbers.
- The dosimeters were unacceptable without audible alarms. It was considered that it was not practicable to keep looking at the dosimeters whilst undertaking other tasks, and that the audible alarms would provide suitable protection provided that the activation thresholds were correctly specified.
- The Siemens alarm was considered poor, and the Merlin and Gammacom were good, but the tone of the Merlin was thought to be rather similar to that of the BA air supply low pressure warning.
- The control buttons on all the dosimeters could be operated with gloves. The Siemens control buttons were considered too complicated.
- The dosimeter should be fixed to the BA shoulder harness.

- The Gammacom clip was thought to be too weak. (To rectify this, the manufacturer has implemented a design change, and this has proved satisfactory.)

- The Appleford clip also served as an on/off switch, and this was considered dubious as the dosimeter might get knocked off the harness and accidentally turned off. (The manufacturer has redesigned this, producing a substantial clip and using a magnetic switch to turn the dosimeter on. These modifications have also proved satisfactory.)

DISCUSSION

As tested, none of the dosimeters met the specification.

Both the Merlin Gerin DM90 and the Stephens Gammacom 4200M were considered suitable for fire service use, provided certain modifications were made.

The Merlin Gerin DM90 did not have an illuminated display but the manufacturer has since changed this. It had a flammable case, but again the manufacturer has changed this. Otherwise it met the specification and was considered suitable for fire service use.

The Stephens Gammacom 4200 M appeared to met the specification, but needed to have a more robust clip fitted before it was suitable for fire service use. The manufacture has since changed this. It subsequently turned out that it could not be adjusted to give two levels of dose alarm. The manufacturer has since changed the programming to achieve this.

Versions of both of these are already in regular use internationally, and their reliability is proven. They both have features not required by the fire service, but these can be disconnected electronically for simpler operation. The use of either of these dosimeters could result in simplifications to operational procedures.

A number of significant changes were required to the Appleford prototype version before it could meet the specification.

The Appleford prototype did not meet the specification in that it gave no audible alarms, and it did not have an illuminated display. The manufacturer has since produced a pre-production version which now provides these facilities. Although the prototype did not meet the desirable requirement that it measure dose-rate, the manufacturer has changed the design so that an audible dose-rate warning is given, with its bleep-rate proportional to dose-rate, but no visual display of dose-rate is possible. Brigades should be aware of this distinction. This is reflected in the unit costs quoted to NRPB - £180 compared with £250-£300 for the other two.

As only one prototype existed at the time the FEU undertook the testing, there was no way of knowing how reliable the Appleford meter would be.

The Siemens Plessey NRPB EPD prototype did not meet the specification in that it could not be read at low light levels without the use of a torch. The manufacturers were not prepared to correct this, so it could not be considered suitable for fire service use.

To verify that the necessary modifications had been incorporated, the FEU have subsequently purchased production versions of the Merlin Gerin DM90 FS and the Stephens Gammacom 4200M FS and a pre-production version of the Appleford DMFS, and assessed them against the suggested specification in the appendix at the rear of this report.

The Merlin Gerin DM90 FS and the Stephens Gammacomm 4200M, as configured for fire service use, now fully conform to this specification.

The Appleford DMFS only meets the essential requirements of the specification, not the desirable ones. It does not display dose-rate, although it does give an audible dose-rate indication.

Changes to the Original Specification

In discussions with fire officers at the FEU, at the FSC, and on the JOA course, it was suggested that the alarms should not be preset for 15 mSv and 50 mSv, the values in the original specification, but for proportionately lower values to allow the firefighter time to withdraw without exceeding the limits. It has now been agreed that the two dose warning levels should be set to 10 mSv and 40 mSV, and these have been included in the suggested specification in the Appendix.

It was also suggested that, when BA is not used, the dosimeters should be mounted on the outside of a tunic pocket. When BA is used, the dosimeters should be mounted to the BA shoulder strap harness. In addition to the clip on the meter, the manufacturer should be required to produce a suitable fitting for the harness to which it can be clipped. The manufacturer must bear in mind the directionality of the meter as described above.

Possible Changes to Operational Procedures

If these new dosimeters are introduced into service, a variety of operating procedures will become possible:

- Brigades retaining Quartz Fibre Electroscopes will not need to change their procedures.

- The fire officers who were consulted felt that the best way to work with the new meters would be to rely primarily on the audible alarms. The facility of the Merlin, the Gammacom and the Appleford, to give bleeps whose frequency is proportional to the dose-rate, is particularly useful in giving the firefighters confidence that the meters are working and that they have not accidentally moved into danger. This means that the dosimeters have to be worn inside a gas-tight suit if used, or the alarms cannot be heard.

- Brigades electing to purchase the Merlin or the Gammacom may be able to use them as dose-rate meters, though not as survey meters. The meters are not very accurate at low levels, but adequate at higher levels where the need for evacuation would have to be considered. In such circumstances it may not always be necessary for firefighters to be accompanied by a third carrying a dose-rate meter to warn them if they are approaching dangerous levels. Brigades might wish to consider this option in assessing their operating procedures.

Intrinsic Safety

It must be noted that none of the dosimeters are intrinsically safe, and none of the manufacturers intend to apply for certification.

BRIGADE PURCHASING

The tests which have been performed on these four dosimeters do not constitute any form of Home Office approval or certification testing. The specification in the Appendix is only suggested by the Home Office. Although the four meters tested were the only ones available at the time this work was undertaken which NRPB considered might meet the specification, other dosimeters may become available which also meet this specification. It would not be necessary for the Home Office to conduct any tests on such a dosimeter. Brigades would be free to purchase whatever dosimeter they wished, either requiring it to conform to the specification in this report, or to any other specification they considered suitable.

Brigades would need to discuss with the relevant manufacturer suitable procedures for weekly and annual tests of their dosimeter, and on the action to be taken following their use where dose readings were recorded. It may be appropriate to consider a maintenance contract as part of any purchase.

Equally important would be training in the use of the dosimeter. In particular, the manufacturer might be asked to provide a method of demonstrating the various alarms that the meter might give, as sometimes these cannot be triggered without the existence of a radiation source.

Brigades would also need to consider where the dosimeter was to be fixed to the firefighters' equipment, both with and without breathing apparatus. It may be appropriate to ask the manufacturer to supply the dosimeter together with a suitable strap to fix it to the breathing apparatus harness. Some sort of Velcro device may be suitable. When breathing apparatus is not being used, it may prove possible to clip the dosimeter to the outside of the firefighters' tunic or uniform jacket.

APPENDIX

SPECIFICATION FOR A FIRE SERVICE DOSIMETER

The dosimeter shall:

1. measure exposure to gamma radiation over the energy range of 50 keV to 3 MeV, and for dose rates up to 5 Sv/h, to an accuracy of 20%.

2. give an indication with resolution of 0.01 mSv of the measured gamma radiation dose over the range of 0 to 99.99 mSv.

3. desirably, give an indication with resolution of 0.01 mSv/hr of the measured gamma radiation dose-rate over the range 0 to 99.99 mSv/hr.

4. desirably have a facility for recording higher doses, received under exceptional circumstances.

5. display these indications by means of a four character display, capable of being easily read under service conditions, ie. when breathing apparatus is worn and in the dark or in a smoke laden atmosphere. A LED digital display is preferable, but a LCD digital display would be acceptable provided adequate integral illumination is provided.

6. be fitted with pre-sets to trigger immediate visible and audible (with mute facility) alarm signals at doses of 10 mSv and 40 mSv, if reached. The audible alarm shall produce a sound pressure level between 90 and 96 LA(eq)dB(A) measured 2 metres from the dosimeter.

7. be fitted with a bleeper to indicate dose rate audibly. The bleep rate shall be proportional to the dose rate such that, at 1 mSv/hr it gives about one bleep per second, and at 30 mSv/hr the bleep is continuous. The sound pressure level produced shall be as high as that defined in 6 above.

8. desirably have a data storage capability with a download facility to a computer register.

9. have the casing shaped to reduce the likelihood of inadvertent snagging when the wearer is negotiating areas of restricted access.

10. have on the casing an attachment device for securing the dosimeter to the outside of a pocket on the firefighter's tunic, or the front of a shoulder strap on a breathing apparatus harness when worn. The manufacturer shall also supply an easily-fitted method of securing this attachment device to the harness.

11. be of lightweight but robust construction appropriate to fire service conditions and shall be capable of operation immediately after:

(a) six subsequent drops in a random manner from 2 metres on to concrete;
(b) undergoing the fire resistance test given below;
(c) being submerged for 1 hour in water;
(d) 1 hour at -15°C;
(e) 1 hour at +75°C

12. have a high level of reliability.

13. give a service life of at least 20 years.

14. be powered by battery capable of 20 hours operation with 1 year battery life if in quiescent state.

15. incorporate a low battery warning.

16. have a self test facility.

17. have electromagnetic compatibility with communications, electronic and electrical equipment in fire service use.

18. be accompanied by an instruction manual which can readily be comprehended by the users of the dosimeter.

FIRE RESISTANCE TEST

1. The test shall be conducted in an environment where the air movement is less than 0.2 m/s at the start of the test and will not be influenced by mechanical devices during the test. There should be no reduction in the oxygen content of the environment during the test.

2. A gas burner, as described in BS 543:1989, fuelled by either commercial grade propane or butane gas, shall be positioned in a horizontal position with the lower edge of the burner tube 25mm above the bottom of a vertically mounted unit and 10mm from its surface.

3. The gas burner is ignited in the vertical position and the flame regulated such that the visible part is 25mm in height. The gas burner is then placed in the horizontal position as described in 2. and the flame presented to the casing of the unit for 30 seconds, after which the flame is extinguished or removed.

If at any time during the 30 seconds the unit ignites, the flame must be removed. If the unit then extinguishes within 5 seconds a further test shall be conducted on an unaffected part of the surface of the casing and the flame left in position for the full 30 second period.

If, after 30 seconds exposure to the test flame, the casing has not ignited or, if ignition has taken place but the casing has self extinguished within 5 seconds of flame removal, the casing material may be considered suitable.

Printed in the UK for HMSO Od.8382524, 9/93, C4, 38938

Designed by Home Office Design and Illustration Branch

ISBN 1-85893-025-1