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Development of a Pipe Contamination Monitor for the Waste Segregation Program at the AECL Chalk River Laboratories

by
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Introduction

The Waste Management and Decommissioning (WM&D), and Safety & Radiological Protection (SRP) groups at AECL's Chalk River Laboratories (CRL) operate a Waste Segregation Program (WSP) to optimize handling of the site's non-radioactive solid waste[1].

The decommissioning of buildings and equipment at CRL routinely generates large volumes of piping of all diameters. To minimize the continuing liability involved in managing piping as potentially radioactive waste, it is preferable to confirm that it is inactive and acceptable for unconditional release.

To be cleared for unrestricted release piping must be thoroughly monitored both inside and outside to ensure the absence of any surface contamination. Any small patches of radioactivity found must be located and excised if an entire piece of pipe is not to be rejected.

The interior of short sections of very large diameter pipes can be monitored with a hand-held instrument, but long sections of piping of any diameter are relatively inaccessible and present a forbidding practical challenge to monitor reliably. Monitoring with a hand-held instrument is tedious, not reproducible, and cannot ensure complete coverage of the surface of the pipe. Swipes can be taken from the inside surface, but this may not ensure complete coverage, can detect only loose (not fixed) contamination, and cannot establish the location or extent of any contamination.

By far the best approach to monitor piping is to use an automated pipe contamination monitor (PCM), and it was decided to acquire a PCM for the WSP. Having a PCM will allow our staff to monitor reliably a higher volume of potentially recyclable materials. The ability to rapidly and accurately monitor this material will reduce the liability that would otherwise be incurred in stockpiling it indefinitely.

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Requirements for a PCM for the WSP

To be practical and useful for the WSP, the PCM had to have several capabilities:

- **Simultaneous slow rotation and longitudinal indexing** of the pipe to optimize Minimum Detectable Activity (MDA), and achieve the WSP working criteria for unrestricted release (<1 Bq/cm^2 β-γ and <0.2 Bq/cm^2 α). Monitoring large, curved surfaces for levels this low by hand is tedious, time-consuming, and error-prone. An automated process is highly preferable. Mechanical movement of the pipe overcomes the problems of hand monitoring, and allows the location of any contamination to be determined.
- **Simultaneous monitoring inside and outside** the pipe to allow for better throughput. This also achieves better background suppression, as the same background condition exists for both detectors during the measurement.
- **Computerized measurement** evaluation system to read the signals from both detectors and identify inside or outside contamination above the alarm limits.
- **Compact and portable** system that can be transported to waste generator locations.
- **High sensitivity and discrimination** (of both β-γ and α). This can be achieved by a pair of thin window gas flow proportional counter tubes. An on-board preamplifier circuit in the detector that buffers the detector signal can prevent signal degradation over the long cable run to the electronics rack.
- **Computer controlled high voltage** to allow for automatic plateau analysis.
- **Computerized** instrument control, QA analysis, data reduction and operator interface.
- Ability to handle a **wide range of pipe diameters and lengths** to ensure that most or all pipes can be monitored.
- **Total cost** of building the monitor must be less than that of commercially available PCMs that are capable of fulfilling our technical requirements.

Developing our own PCM

No commercially-available pipe monitors meet all the requirements of the WSP, and the cost of externally-supplied custom systems is prohibitive. It was considered most cost effective to develop a PCM tailored to our particular needs as a collaborative effort between AECL and LCS. The AECL Mechanical Equipment and Seal Development (MESD) Branch undertook to develop and build the mechanical portion of the PCM. LCS agreed to develop and build the radiation detectors and the computer-controlled software and hardware to drive the mechanism.

Challenges

The creation of any new machine is prone to unforeseen challenges, shifts in vision, and production issues. The costs of surmounting such challenges for mass-produced commercial products are amortized in the economies of scale involved. Problems may be resolved in a series of prototypes before the final version is reached. In contrast, for customized one-off projects such as this one, the problems must be addressed in the prototype, which is also the final product.

Several technical challenges that arose during development of the PCM were successfully overcome:

- as the mechanical development progressed, some modifications were required to address concerns not previously identified, e.g., procedures for pipe loading and unloading, system rigidity, etc.;
- a series of persistent, mysterious, hard-to-locate failures of circuitry in the PCM control system were tracked down to a deficient batch of solder;
- the software drivers for the computer interface were rewritten when the standard version did not work as documented;
- hard-to-obtain miniaturized components were used in the detector preamplifier instead of the more generic components used in the original circuit development.

After examining the software of various radiation monitoring software applications, a strategy was developed for how the instrument was to work. Not only would this machine have to monitor the pipes, it would need to develop a database of the measurement data and perform two dimensional analysis of the data. The user had to be able to select the main PCM functions from the main screen easily. The main screen was also to give immediate feedback on the incident radiation level detected by the PCM, as well as on the status of various sensors and instrument condition.

When a production run of machines is planned, the cost of purpose-designed components can be accommodated by making bulk purchases. In contrast, in this case, it was not cost-effective to purchase purpose-tailored cable to connect the machine to its control console. An existing type of cabling had to be adapted to our specific needs instead.

Development of the PCM was originally to be carried out in four phases, with the capabilities of the monitor being successively extended from simple to more demanding monitoring situations. In the event, because we had a clear idea from the outset of what the final design had to do, it was possible to incorporate the extra features earlier than planned at no extra cost by appropriate initial design and component choices.

The mechanical and electronic/software packages were developed in parallel, and their operating characteristics were interdependent. The challenge of maintaining effective communications between the AECL and LCS teams working in two widely separate locations was met by a constant stream of email.

Figure 1 shows the PCM with its control console behind it. At the time of writing, the mechanical portion and almost all of the detection and software of the PCM have been completed. The performance of critical components such as the detectors and drive motors has been verified. The remaining development is expected to be completed by May 2000, and AECL will then begin to examine its backlog of piping that has been removed from service and stored on an interim basis.

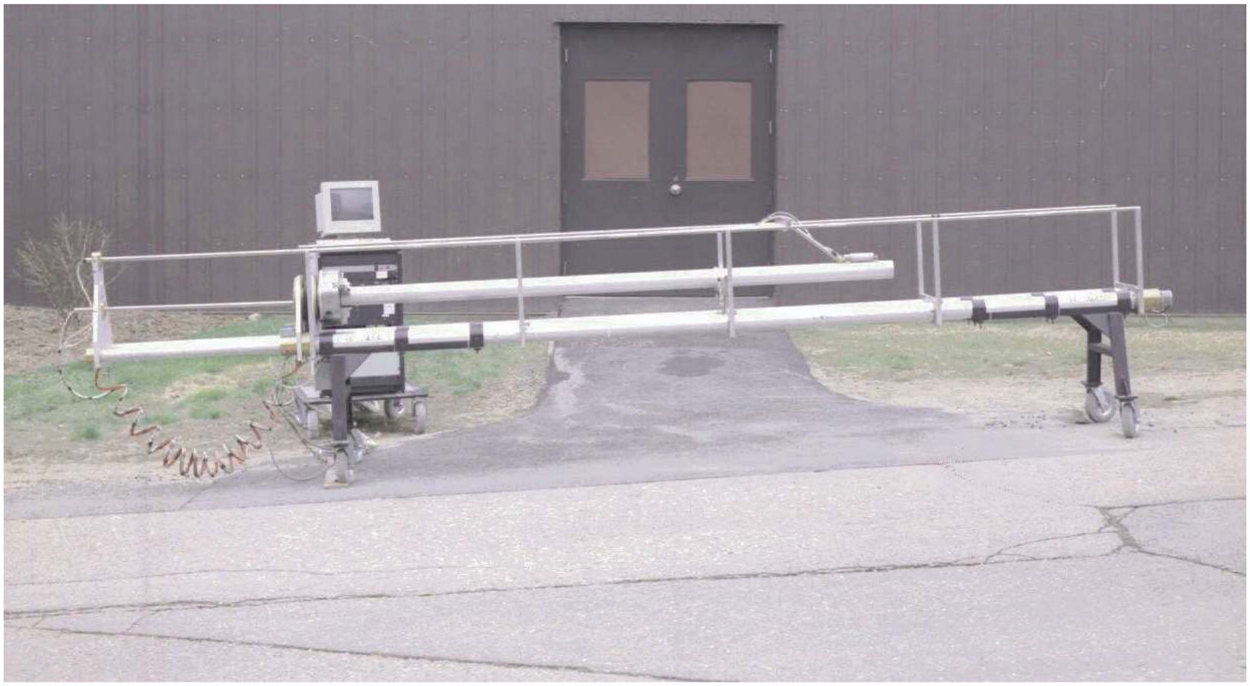

Figure 1: The PCM with its control console behind it

Characteristics of the PCM

As built, the machine is capable of simultaneous β-γ and α-monitoring of the inside and outside of nominally straight pipes up to 3.6 m long, of inside diameter as small as 6 cm, and outside diameter as large as 38 cm. The machine can reliably detect and locate β-γ activity as low as 0.2 Bq/cm^2 and α activity as low as 0.05 Bq/cm^2, under ideal conditions with a stable background and at the slowest scan speed. Pipes can be monitored longitudinally at about 2 cm/minute, and can be rotated at about 0.5 turns/minute; slowing these indexing speeds greatly enhances sensitivities.

The PCM software interprets the raw detector data by averaging as many as six successive results to overcome spurious signals. A sliding slope search identifies radioactive peaks, which trigger alarm reports. The interpreted results are displayed on the console in a WINDOWS-based format.

Using the PCM

The piping being removed from buildings typically consists of long sections of straight piping joined by right-angle bends and T-junctions. The PCM can handle piping with slight bends and undulations in the surface, but right-angles and T-junctions must be removed and monitored separately.

To monitor straight sections of pipe in the PCM, the operator lowers the side gate on the machine, places the pipe to be monitored on the support wheels and tightens the drive chuck gripping the end of the pipe (See Figure 2). The pipe can be installed manually or using a crane if required.

Figure 2: Loading a pipe into the PCM for monitoring

The device is positioned with the radiation monitors at the end of the pipe nearest the chuck. This requires the device to be in its extended position, roughly 8.9m long. (See Figure 3.)

The desired monitoring characteristics, such as rotational and axial speed, are pre-selected. The button on the control console screen is clicked to start a measurement. Figure 4 shows the external detector head riding on its skis on the outside top surface of the pipe. The second internal detector head is simultaneously riding on the inside bottom surface of the pipe. The operator is free to do other work while the machine does the actual monitoring of the pipe. The results of the scan are shown in a 2-dimensional display on the console screen.

It was decided that the software for the PCM was to be written in Visual Basic 5.0 for Windows 95. This choice was made because software drivers were available for this language and operating system, and would make it possible to use an EG&G Labmaster interface card as the connection from the PC to the outside world. A passive bus Pentium-based industrial PC was used as the target platform.

Figure 3: The PCM at its fullest extension

Figure 4: The external detector head riding on the top of the pipe being inspected

An instrument rack was assembled to hold the CPU, stepper motor driver and power supply, as well the analog signal processing electronics and AC power distribution. This rack is approximately four feet high; a VGA monitor and keyboard sit on top. A glide pad (instead of a mouse) allows for cursor manipulation.

The software drivers install on system boot up. The PCM software then boots up if a shortcut has been installed in the Start Up group in Programs. After a few moments, the main screen is displayed (See Figure 5). Count data are displayed in real time. Pipe rotation angle and absolute horizontal position are also shown. From the Main Screen, the user can perform several functions typical of a radiation monitor. A source check, a background measurement and the measurement of a pipe can be performed by clicking on buttons. As the CPU does not know where the pipe monitoring detector positioning mechanism (transport) is upon start up, a 'Reset' function moves the mechanism to 'zero' and prepares the PCM for loading a pipe.

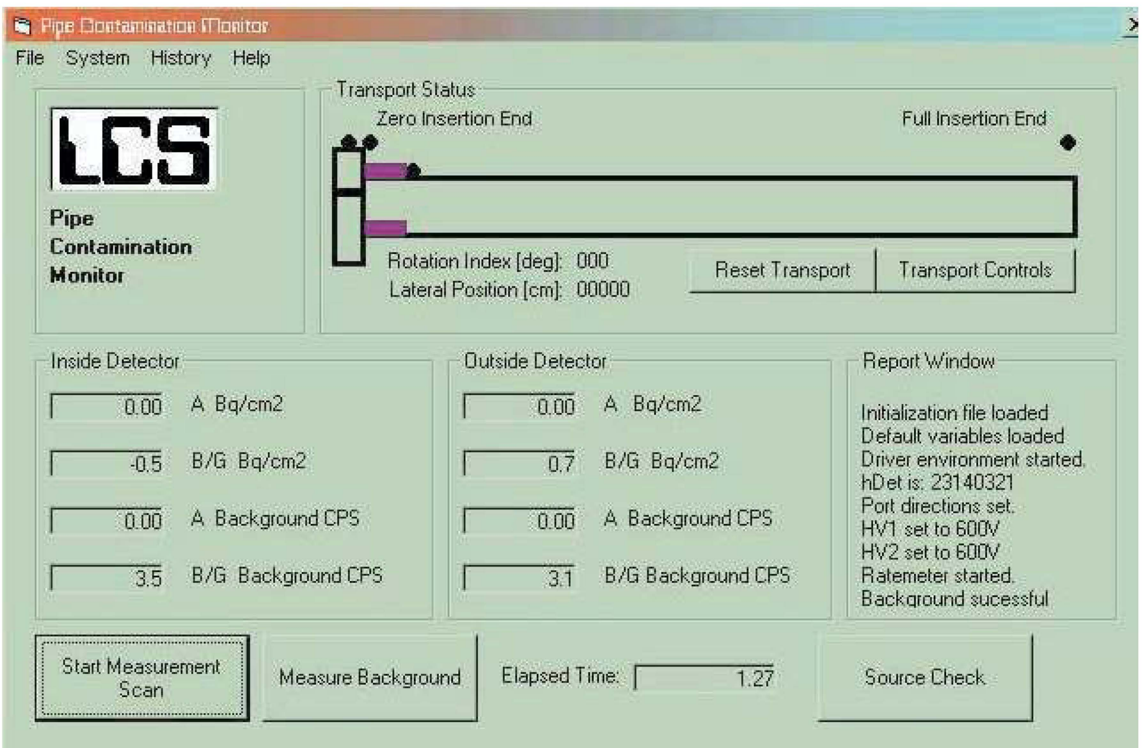

Figure 5: Main screen on the display console

Clicking on a button marked 'Transport Controls' opens a window that allows control of the PCM transport to position the detectors anywhere on the pipe. A feature also exists to go to a predetermined location on the pipe. Pipe rotation can also be controlled here. System parameters and history files are accessed through the menu bar. When accessed, more windows open where these parameters can be edited (See Figure 6), the data can be viewed, etc.

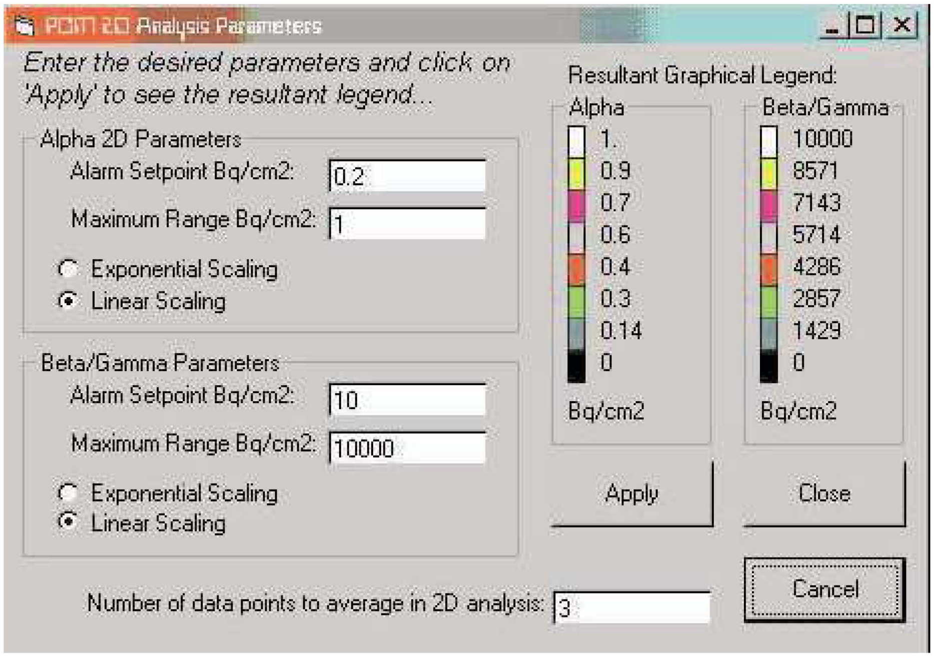

Figure 6: Screen for setting values of 2D analysis parameters

During the measurement, a graphic representation of the radioactive topography of the pipe surfaces is displayed (See Figure 7). The measurement can take several hours if high sensitivity (i.e. lowest minimum detectable activity [MDA]) is required. Once scanning is complete, a two-dimensional smoothing of the data can be performed which

Figure 7: Graphic representation of the radioactive topography of the pipe surface

helps to reject anomalous alarms. Then a slope analysis type peak search is performed which identifies 'hot spots'. If a hot spot exceeds the alarm threshold setting, an alarm is noted and reported when the run is complete. A pass through the ↵ data is performed, followed by a pass through the —≠ data.

Quality Assurance

The PCM produces an electronic log of background measurements and constancy measurements as a Microsoft Access database. The last 300 or so measurements are maintained. The log can be viewed in the PCM software or copied and viewed in an Access-compatible database viewer. Pipe measurements are recorded as long (several hundred Kbytes each!), uniquely-named ASCII comma-delimited files, with analysis parameter data used for evaluation encoded within them. These data can be used later to redraw the graph and show the activity found on the pipe. This makes it possible to relocate the spot(s) of contamination on the pipe to be excised, and provides a record of the monitoring for any checks of the monitoring process that regulatory authorities may wish to make.

Potential Future Developments

Some modifications to the PCM have been considered and may be suitable for future applications. These include:

- development of a stand-alone data reader application;
- direct down-loading of data to a mainframe computer for processing and archiving;
- accommodation of a selection of detectors, (for example, Geiger-Müller tubes) to enable trade-offs in cost, and sensitivity and speed of detection;
- fabrication of smaller detectors to allow the machine to handle piping as small as 2.5 cm diameter;
- adaptation to handle pipes of a fixed size range;
- additional software features.

Future Applications of the PCM

The PCM was developed specifically for AECL to clear for unrestricted release the large amounts of piping that arise from building renovations or decommissioning. Other nuclear operations, such as the nuclear generating stations in Canada and abroad, likely also have similar volumes of piping they may wish to reuse or dispose of on an unrestricted basis. A large operation may consider it justified to purchase such a machine of their own, while a smaller station may prefer to lease a PCM for the period needed to deal with a backlog of piping on a campaign basis.

Conclusion

The pipe contamination monitor machine we have built is practical and effective. It achieves the performance level needed and will go a long way towards improving the efficiency of waste diversion efforts at CRL.

References

1. M. Stephens, G.A. Walker, R. Nowell, M. ter Huurne and L. Champagne, *Waste Clearance and Diversion at AECL's Chalk River Laboratories, Chalk River, Ontario, Canada*, Proceedings of the Second International Symposium on Release of Radioactive Material from Regulatory Control. Published by TÜV Nord. Hamburg, Germany, 1999 December.