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AUTOMATIC ACQUISITION AND MANAGEMENT SYSTEM FOR NaI(T1) SPECTRA

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Contents

1) Introduction

Nuclear spectrometry with NaI(Tl) scintillators is still a very useful tool for the sample analysis and for the body burden assessment of people working in areas where the professional risk of internal contamination is high. The reason resides in the high sensitivity of these detectors.

The C.E.N./S.C.K. in Mol, has a unique facility for the measurement of samples and persons. This facility which has been developed for diagnostic and research purposes involves five counting rooms for the control of persons and seven lead shields for the analysis of samples.

Four rooms, shielded with steel plates, lead and brass are designed for the whole body counting, the lung plutonium burden assessment and the measurement of contaminated wounds. The fifth room is shielded by heavy concrete and designed for iodine burden in thyroid and can be used for WBC in case of high level of contaminations (major accident, clinical use of tracers,...).

The operation of this facility, which is able to proceed more than six thousand measurements a year, requires an efficient management of the spectral data, the measurement parameters, and the information of the patients and the samples. The archiving of measurement spectra is necessary. It is useful in case of controversy or litigation.

Till now, most of the operations were done manually because of the limited capabilities of the multichannel analysers available at the time of the erection of the facility and because of the computer system which was exclusively assigned for the mathematical analysis of the spectra. The computer has an internal memory of 32 kbytes which is not enough to manage the personal records nor the printing of measurement certificates. As a result, the planning of measurements including invitation of patients, transmission of results and quality control of the measurement systems required about 50 % of the operator's time.

The aim of the report is to present concisely the new measurement system and the automation of the administration.

2) Description of the new measurement network (figure 1)

2.1) General overview

The new system is based upon two personal computers linked together by a data transmission line:

- The first computer (processor 286 with 1 MB RAM, a hard disk of 20 MB and 5" floppy disk drive) is exclusively assigned for the acquisition of spectra by means of an internal "Memory Buffer Card" able to manage four different acquisition lines.

- The second computer (processor 386, 4MB RAM, hard disk of 120 MB , two floppy disk drives (5" and 3") and 110 MB tape streamer) is used for all the other operations:

  - Storage and back-up of spectrum files,
  - Library of 203 standards spectra for 9 different NaI detectors,
  - Operator controlled analysis of samples' and persons' spectra (linear regression method),
  - Printing of measurement certificates,
  - Plotting of spectra,
  - Record of measurement data for the medical service,
  - Link to other computers via a local area network (LAN).
  - Link to the main frame computer via the LAN,
  - Printing the invitation letters,
  - Quality Control of the measurement systems.

2.2) Detectors

The description of the detectors is summarised in table 1. All the detectors are NaI(Tl) scintillators except for the plutonium lung burden assessment where a twin proportional counter is used for the detection of the characteristics X-rays emitted during the internal conversion of the excited U-235 nucleus after the α-emission of Pu-239:

$$^{239}Pu \xrightarrow{\alpha} {}^{235*}U \xrightarrow{CI} {}^{235}U$$

The energy of the X-ray photons is 17 and 20 keV.

2.3) The measurement structure for spectra acquisition (see figure 1)

One of the most important parts of the new system is the multiple ADC/MCA acquisition lines managed by a single computer. This computer (AT 236) contains a Memory Buffer Card (*) able to run four ADC independently. The memory capacity of this card allows to control 8000 channels either for one acquisition line or equally shared between four independent lines (2000 channels per line). For the scintillation spectrometry, the requested number of channels is 200 (or 400 channels maximum for the thorium assessment), so that one of the lines (nr 4 in figure 1) can be shared into four different detectors with the aid of a mixer router. As this M-R can drive four detectors together (simultaneous start-stop), this line has been selected for the measurement of samples. The other lines are used for the measurements of people (WBC, Pu, iodine in Thyroid, Uranium and thorium).

A total of seven detectors can run simultaneously. The other detectors can be selected with manual switches e.g. if special types of measurement are requested (wounds, samples) or to test a new type of detector.

2.4) The computers

The first computer (AT-286) is linked via a asynchronous line to the second one (AT-386) which is used for all the tasks except the data acquisition. For this reason, a high speed processor has been chosen with a high memory capacity. In order to archive the tasks described in § 2.1, this machine is linked to different I/O ports (figure 1), e.g. to the printer, the plotter, and the LAN. It is equipped with different storage systems. The LAN connects the measurement system to other PC's within the building and with the main frame computer.

3) Data processing

Three steps have been considered for the processing of the data with the AT-386: The analysis of spectra, the storage of data and the management of results. The asynchronous communication line between computer I and computer II is operated under the supervision of a communication program (KERMIT). It is the only operation requiring a simultaneous use of both computers. The data are transmitted at a baud-rate of 38400 bauds.

(*) Silena: Memory buffer card, mod. 8308.

Beside that, the two computers are completely independent (see §5).
The operations required after the spectrum transmission are controlled by means of a batch file in order to reduce as much as possible the operator's typing errors (definition of detector, type of measurement, date of spectrum acquisition,...). These operations are described in the flow charts of figures 2 and 3. Most of spectra are analysed by the least-square regression method on a predefined zone of the spectra and with the aid of standard spectra measured with the BUSH phantom containing calibrated isotopes. The choice of the library of standard spectra being automatic, the only manual operation is the choice of the isotopes for the analysis by the least square method. The operations between point A and B in the figure can be repeated according to the decision of the operator. An example of analysis result obtained with the standard method is shown in figure 4.

4) Non-routine procedures

Besides the routine procedures, controlled by means of a batch program, special measuring techniques and control procedures are required for different tasks. Some of these, because they are seldom used, are not automated.

4.1) Among these, the measurement of a high level of body burden, which is not feasible with our large detectors, is done by means of the 2"x2" NaI(Tl) scintillator normally designed for thyroid measurements. The acquisition occurs in the concrete room where the position of the person can be adapted according to the contamination level. As there are no standard spectra available, the regression method can not be used. The peak surface analysis as well as a three dimensional gamma-attenuation calculation are required.

4.2) Gamma-Scanning: It is sometimes interesting to determine the location of radioactive burden in the body or in a sample by doing a gamma-scanning. For this purpose, a collimator adaptable to the 12"x4" detector has been build which can be moved along the body. The speed can be adapted to the burden level and the collimator width can be selected according to the required resolution.

4.3) Another task demanding special attention is the quality control of each measurement line. Although scintillation detectors are easy to use, they are very sensitive to moisture, and to the fine setting of the photomultiplier tubes. For this reason, they are checked every two months by a quality control program.

The gain and the resolution of the acquisition chains are verified. The tests are done with three types of phantoms (distilled water, K-40 solution and a mixture of Cs-137, Co-60 and K-40 solutions).

4.4) Finally, nearby is situated a graphite-gas reactor (BR1), which is air cooled. It is the source of Ar-41, a neutronic activation product of the air. The radioactive gas is aspirated by the ventilation system into the WBC rooms and enhances the background (figure 5). An electronic alarm system can shut down the ventilation system. However within a few hours, the bad air quality of the non-ventilated counting rooms renders the system impracticable. In practice, the operator substracts the Ar-41 contribution by selecting the Ar-41 standard.

5) Troubleshooting possibilities

The simultaneous management of seven acquisition lines, and the operations required for the analysis of spectra and data files is based on three hardware components: the memory buffer card and two computers.

The functioning of the internal contamination measurement system is required at any time (specially in case of accidents). So it was necessary to foresee different ways for the acquisition and analysis in case of breakdown of one of these masterpieces.

5.1) Memory Buffer Card (*)

This card, implemented into computer I is an important part of the system because it is responsible for the management of seven detectors and their associated ADC/MCA hardwares.

In case of breakdown, it is foreseen to replace this card by a multichannel analyser which will be linked to computer I or directly to computer II as shown in figure 1.

In this case, the maximum number of simultaneous measurements will depend on the mixer-router capabilities which will be connected to the multichannel analyser (**). The current number of inputs in the Mixer-router is four. These measurements will be started and stopped simultaneously.

(*) Silena Mod 8919 PC.
(**) Canberra, "35+" spectrometer.

5.2) Computer I

This computer (AT-286) is easily replaced by a similar one. In our service their are three identical computers.
The replacement nevertheless, demands two or three hours of work for the displacement of hardwares (memory buffer card, connection lines) and softwares.

5.3) Computer II

There is no identical computer available to replace the AT-386 (with hard disk and tape streamer).

For this reason, all programs requested for the analysis of spectra are placed into computer I. Only two connection lines (printer and plotter) have to be moved. However, this is only a temporary solution because one computer is not enough for the whole management of the acquisition and analysis system during a long period. The purchase of an identical computer is planned.

6) Processing the measurement results

Different types of softwares have been adapted to take into account the different types of measurements (samples, persons: WBC, Plutonium, thorium or uranium assessment, etc...).
These programs are linked with the data files (persons' or samples' parameters) and with the results of the measurements. This reduces the operator's interventions and as a consequence the possibilities of erroneous entries.
Furthermore, subsequent operations are done automatically:

- Transmission of results to the requestor's service,
- Annual compilation of measurements,
- Study of burden history for chronically exposed workers.

Finally, the implementation of a program for the calculation of doses according to the ICRP models will be simplified thanks to the directly accessible values of incorporated burdens.

Fifty programs, written in batch, BASIC and FORTRAN (a total of about 5000 programmation lines) have been developed for the complete structure. These programs have been written in a general way so that they can be used in other applications (e.g. spectrometry with germanium detector as shown in figure 6).

Furthermore, the management of patients' data (birth date, Company, morphological data,...) has been greatly simplified by the automation. More than 3000 personal files are accessible for the establishment of measurement results. The data are protected against unauthorised access. When the system will be fully operational, 70 % of the manual work will be automated and the possibilities of human errors will be reduced.

Detector	Type	Applications
WBC 1	NaI(Tl) 8"x4"	Whole body Counting
WBC 2	NaI(Tl) 12"x4"	Whole body Counting Thorium burden Uranium burden Body scanning
THYROID	NaI(Tl) 2"x2"	Iodines in thyroid, WBC for high level contamination
Pu	Proportional counter (twin)	Plutonium in lungs
W	NaI(Tl) 1"3/4 x 1" 2" x 2"	Plutonium in wounds
3x3	NaI(Tl) 3" x 3"	Counting of samples
3BB	NaI(Tl) 3" x 3"	Counting of samples
QS2	NaI(Tl) 7" x 6"	Counting of samples
QS3	NaI(Tl) 7" x 6"	Counting of samples
3x3/1	NaI(Tl) 3" x 3"	Counting of samples
3x3/2	NaI(Tl) 3" x 3"	Counting of samples
ThNaI	Thin NaI(Tl)	Counting of samples

Table 1: Description of the detectors used in the WBC facility.

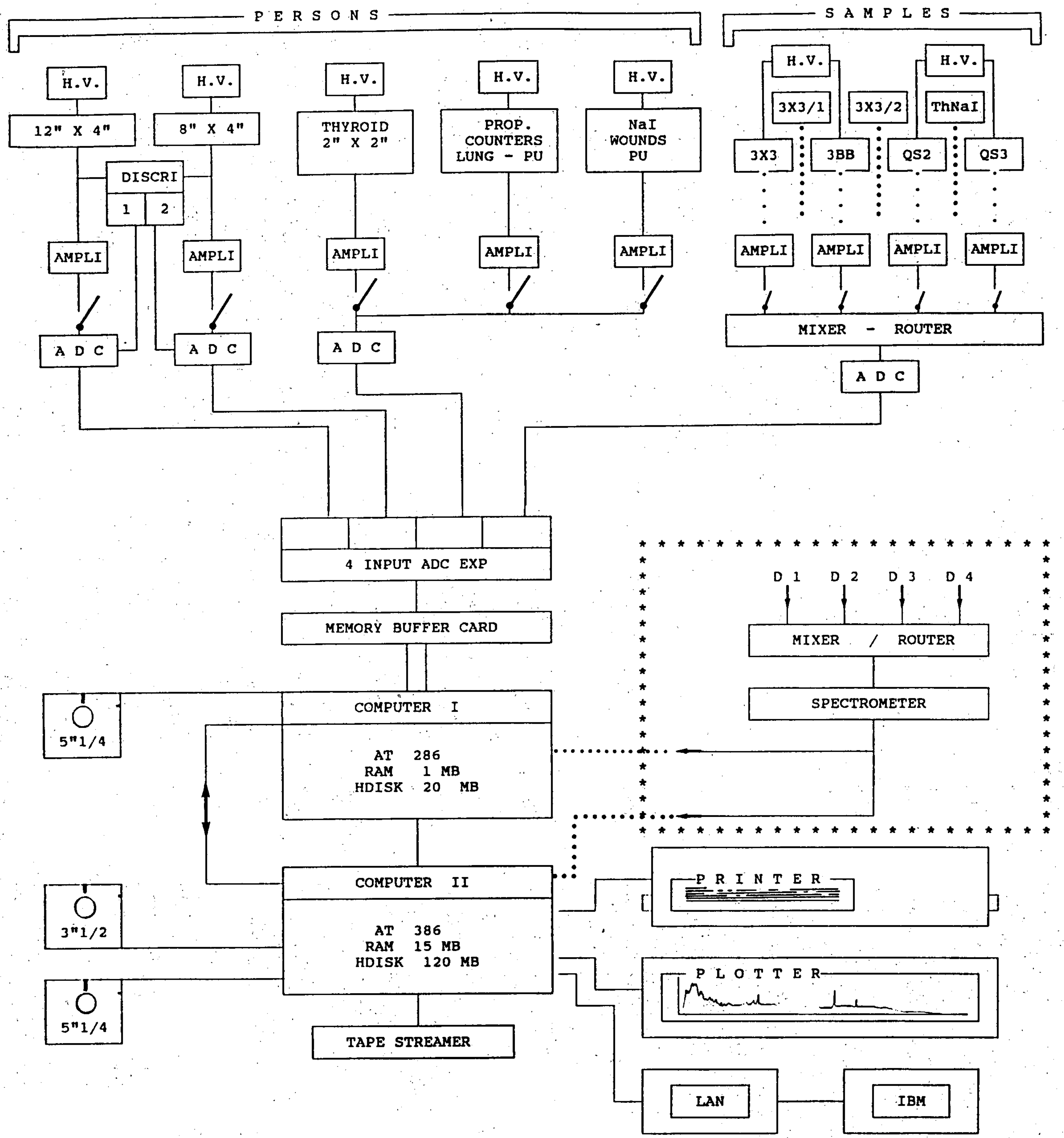


FIGURE 1: Measurment Network for internal contamination measurment and sample analysis.

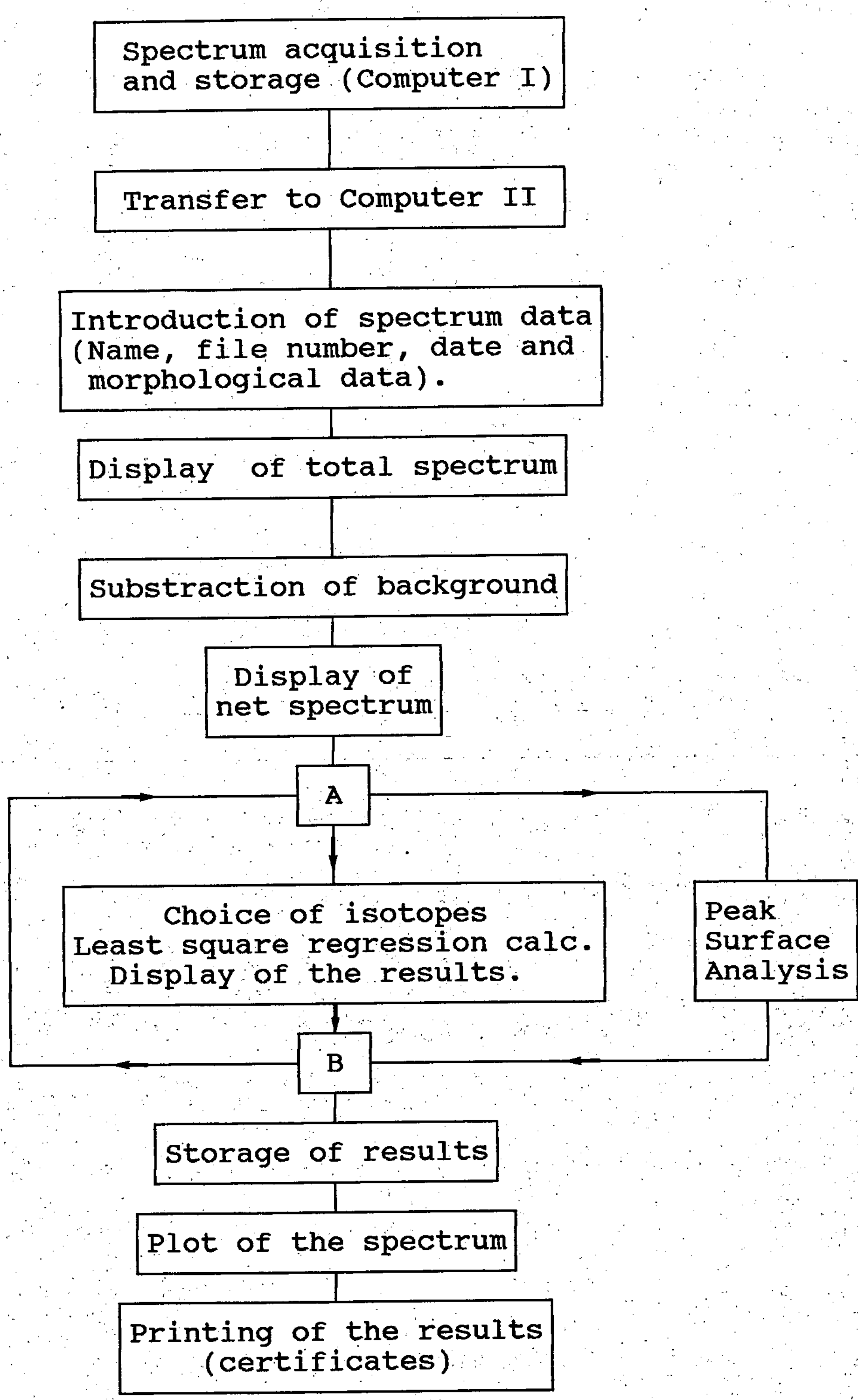


Figure 2: Flow chart describing a complete analysis.

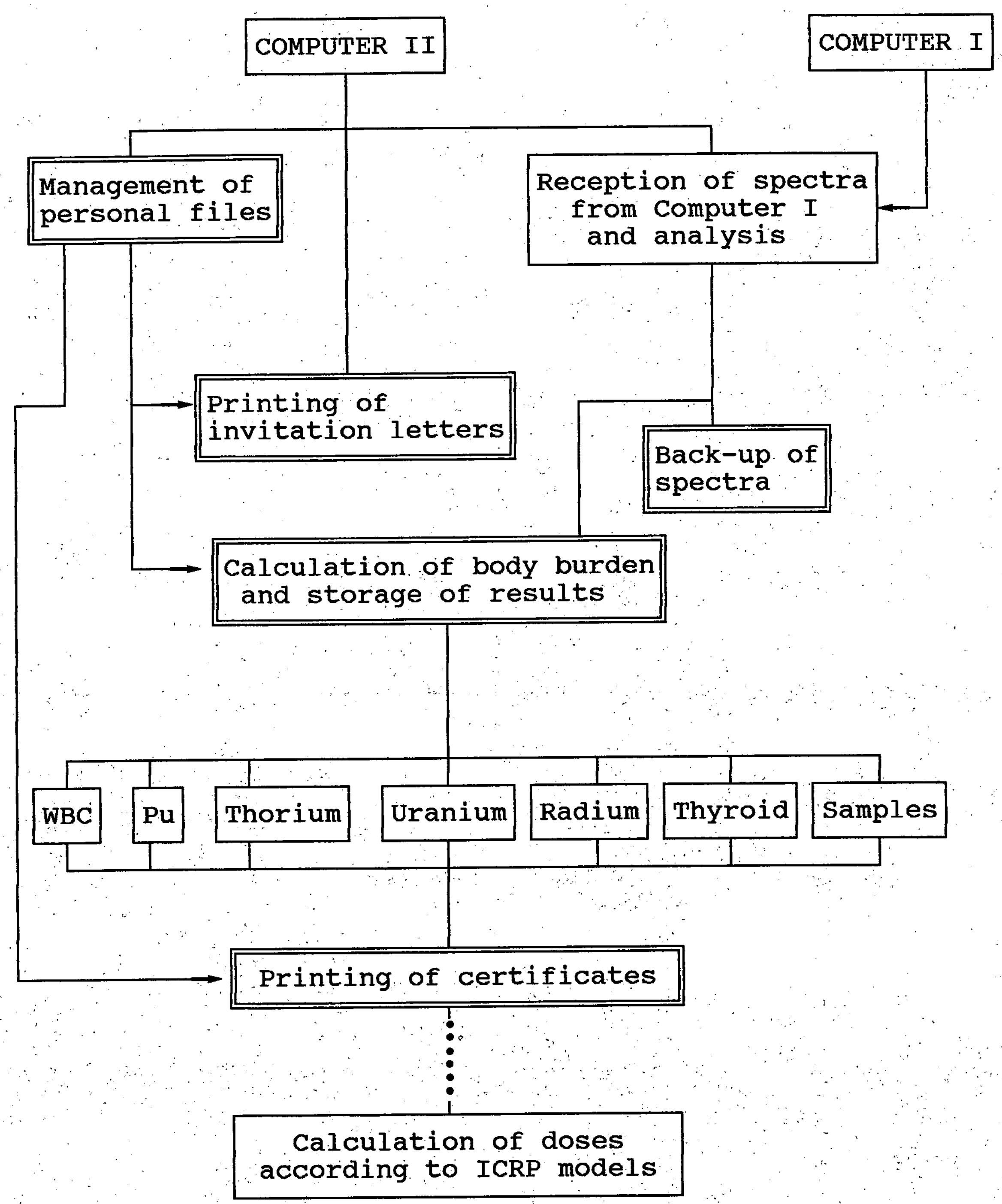


Figure 3:
Processing the certificates and the personal files.

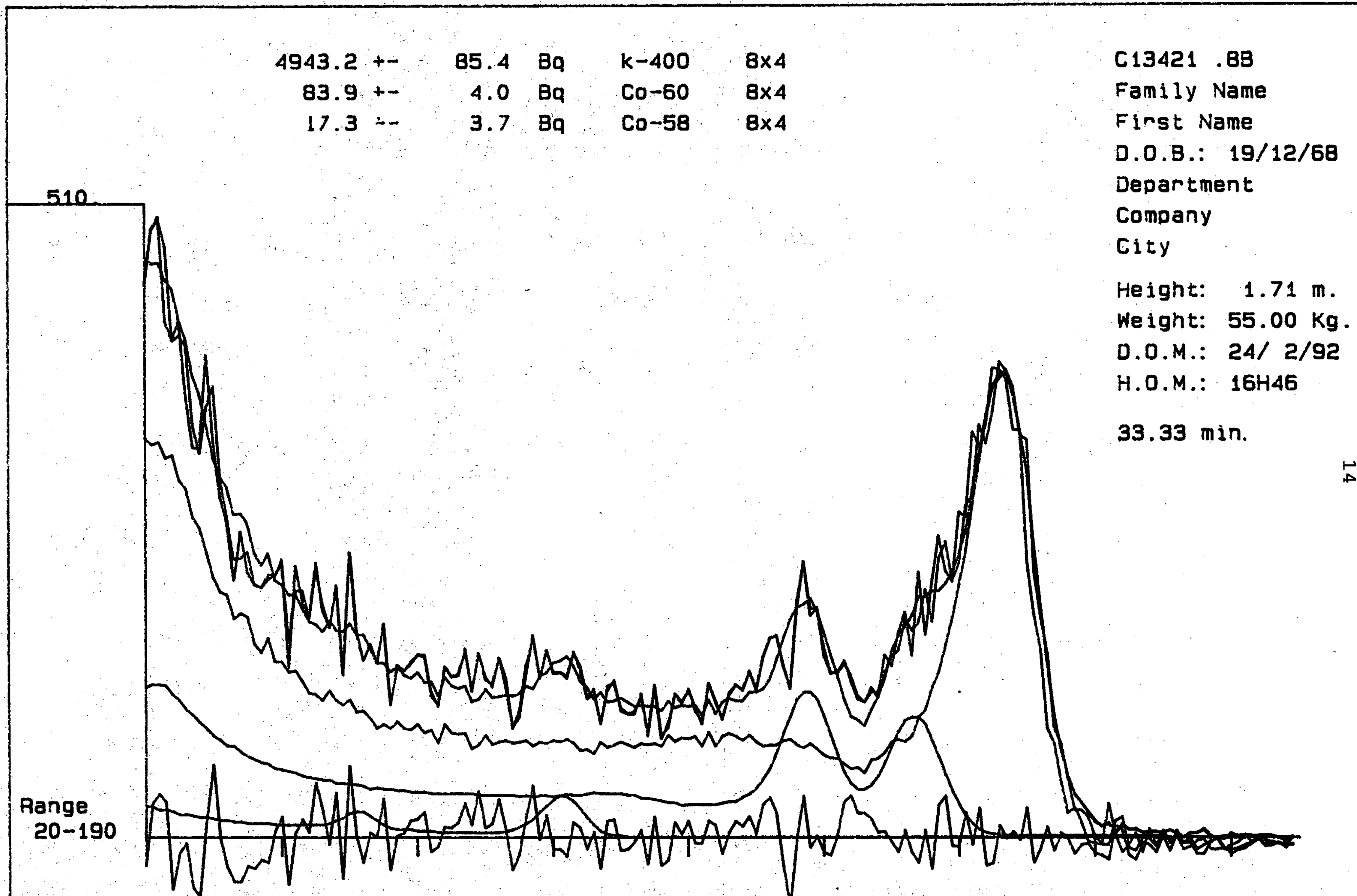


Figure 4: Exemple of spectrum analysis with the standard method.

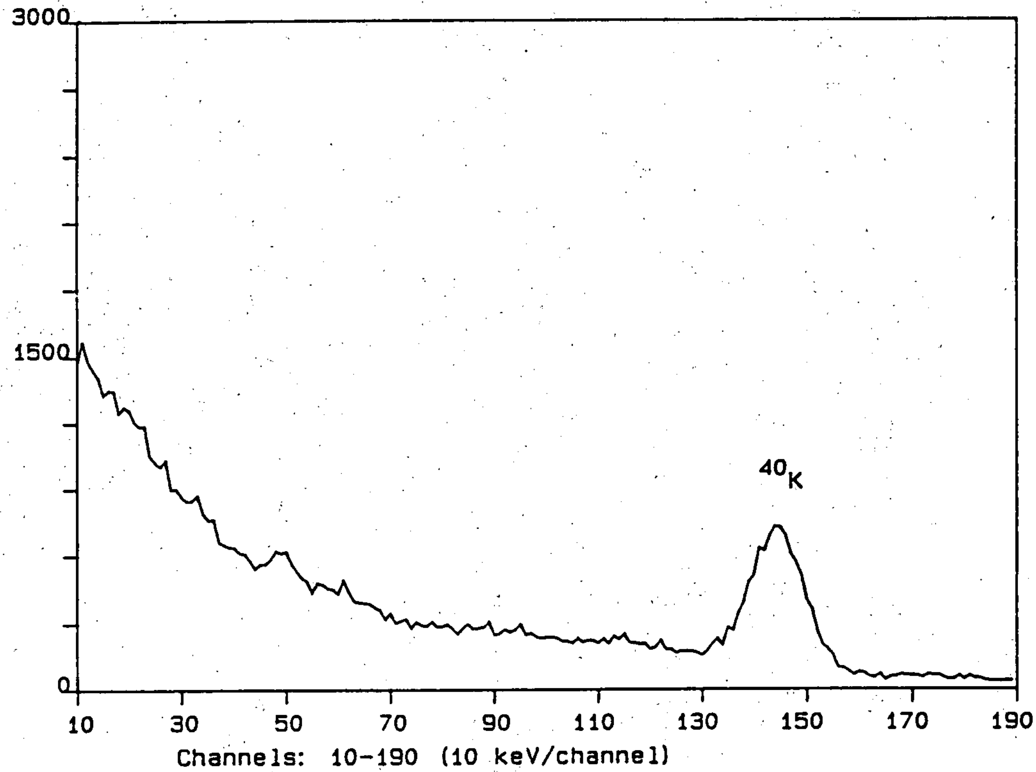


Figure 5A: WBC spectrum without contamination.

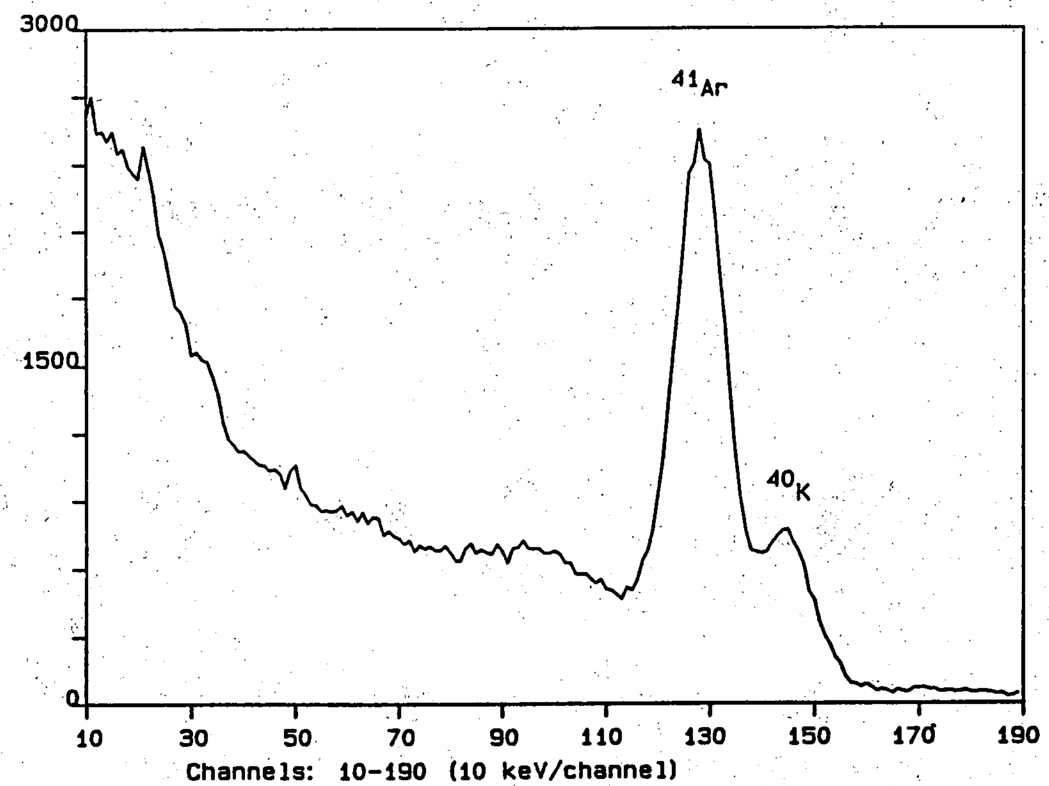
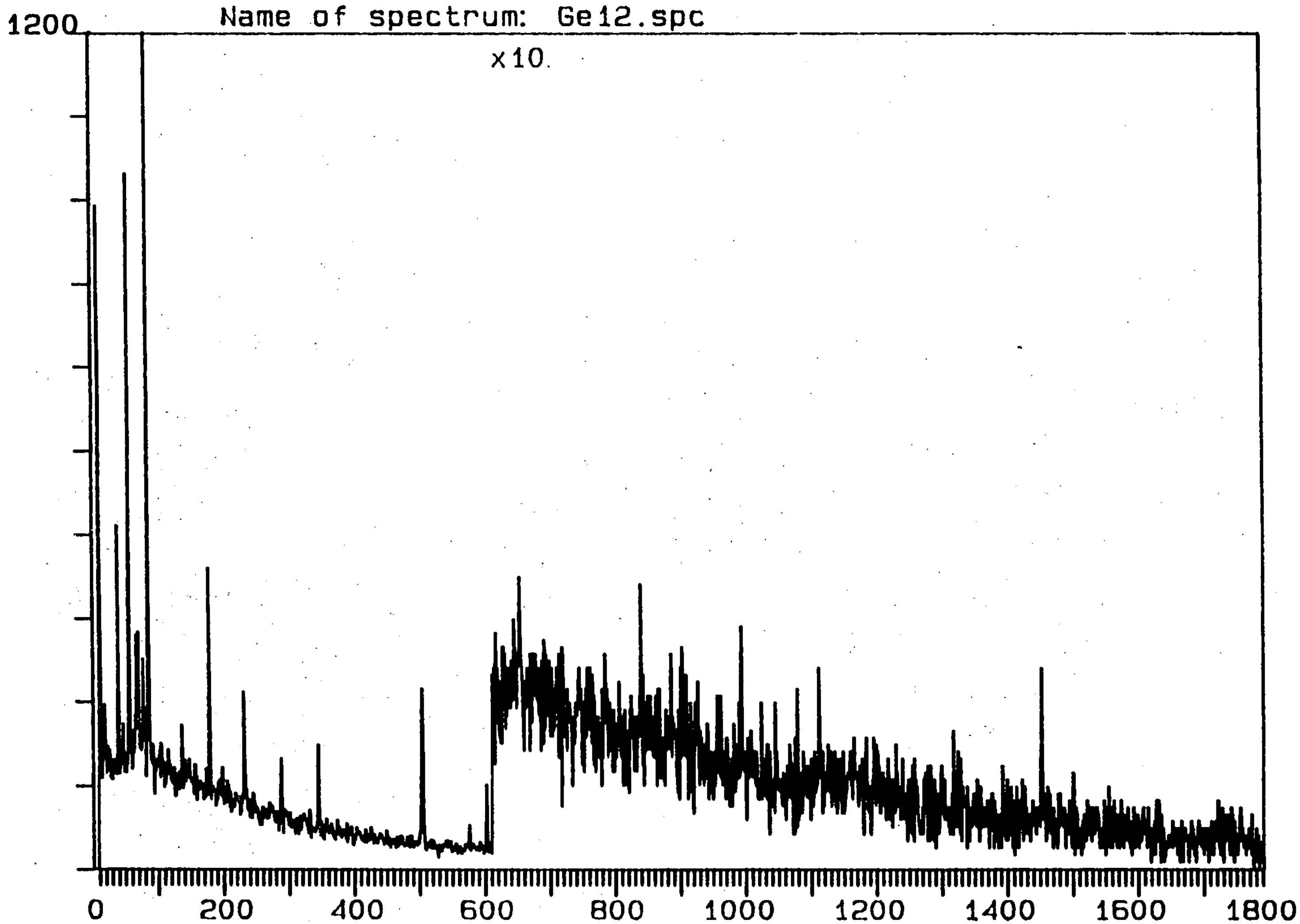


Figure 5B: WBC spectrum with high level of Ar-41 in the room.



Channels: 10 - 1800 (1 keV/ch) - New scale from 620.

Figure 6: Gamma spectrum with Ge detector.