Maintenance of Nuclear Instruments in South-east Asia

by P.H. Vuister and B. Hoop

INTRODUCTION

It is common experience that maintenance of scientific instruments of all kinds in developing countries presents numerous difficulties. Many factors contribute to these difficulties: severe environmental conditions, absence of factory-based service engineers, lack of local technical staff, shortage of spare parts, administrative complications, financial problems and others. Inadequate maintenance causes a waste of scarce human and economic resources: the physician cannot make his diagnosis, research is interrupted, instruments degrade, staff is underemployed, and laboratories are not optimally used.

In order to quantify the extent of these problems in the field of nuclear medicine and to assist the planning of remedial action on a realistic basis the Medical Applications Section of the International Atomic Energy Agency has carried out a survey on maintenance of nuclear medicine instruments in Southeast Asia. Surveys in other regions are at present being carried out or are in preparation.

This article summarizes the findings of the survey and outlines a programme now being established to improve maintenance of nuclear instruments in Southeast Asia under the Regional Co-operative Agreement (RCA).

DESIGN OF SURVEY

Since the primary responsibility for preventing, detecting, and repairing (or arranging for the repair of) breakdowns must rest with those who own and operate instruments, the survey was designed to involve as directly as possible the laboratory staffs and national specialists.

Eight national co-ordinators, appointed at the Agency's request by the Governments of Bangladesh, India, Malaysia, Pakistan, the Philippines, Singapore, Sri Lanka and Thailand, carried out the survey. They assisted the staff of the participating laboratories in the completion of questionnaires and report forms, and wrote a report on their findings regarding their countries. In total, 93 Nuclear Medicine Units participated by supplying all or a part of the requested information.

The survey sought three distinct types of information. First, a questionnaire asked the participating laboratories about their location, age, staff, method of procuring radionuclides, budgeting, and maintenance facilities, and about the number and types of nuclear medicine

Dr. Vuister is a staff member in the Medical Applications Section, Division of Life Sciences, IAEA
Dr. Hoop is presently in the Pulmonary Unit and Physics Research Laboratory of the Massachusetts General Hospital; he was formerly a staff member in the Division of Life Sciences, IAEA

procedures they performed. Second, a questionnaire requested data on each individual instrument: type, make, age, environment, existence of instruction and maintenance manuals and spare parts, operation, tests and maintenance. Third, six monthly report forms provided for a record of operation and breakdown experience for each instrument over the period October 1977 through March 1978. It is inevitable that differences arose in the interpretation of the questions and in the conscientiousness with which they were answered, but the resultant data offer a more quantitative picture of maintenance problems than has heretofore been available.

Besides providing data, the survey served a second important purpose of inducing each laboratory to confront its maintenance problems and to review its strategies for overcoming them.

EVALUATION OF THE DATA

The evaluation below is based on 289 instruments for which full information was submitted, representing 70 nuclear medicine laboratories in the 8 countries. A rough estimate suggests that these 289 instruments collectively cost about $ 5 000 000. For their deployment substantial additional expenditures must have been incurred: laboratory facilities, staff training, etc. Hence failure to maintain these instruments in effective working order would compromise an investment of many millions of dollars.

Nuclear medicine applications

The nuclear medicine applications in the countries surveyed tend to be similar to those in developed countries. Except for the special case of a survey of urinary morphine in troops in two countries (260 000 samples)*, studies of the endocrine system (overwhelmingly thyroid) dominated. As to measurement procedures, three were paramount: probe measurements of ^{131}I uptake by the thyroid (60 000 patients), imaging (mainly rectilinear scanning) of thyroid, liver and brain (40 000, 25 000 and 13 000 patients, respectively) and measurement of the concentration of various biological substances in biological fluids by *in vitro* assays (75 000 samples), using well scintillation counters and ^{125}I.

The instruments surveyed

The instruments surveyed are classified in Table 1 for the 8 countries collectively, and in Table 2 for the individual countries. The instruments found in greatest numbers (second column of Table 1) were (1) scintillation probe counters for assessing the amount of radioactive tracer in an organ of the body (e.g. thyroid) by external measurements, (2) well scintillation counters for measuring the activity level of a small sample (e.g. of blood), and (3) rectilinear scanners for imaging the distribution of the radioactive tracer in a region of the body. They were found in all countries (Table 2) approximately in proportion to the numbers of nuclear medicine laboratories. It is noteworthy that gamma cameras, now the dominant imaging instrument in developed countries, were not widely available in the region.

Three manufacturers supplied 66% of all instruments, the next 7 supplied 22%, and another 21 supplied the remaining 12%. Thus the co-operation of only 10 manufacturers would be

* All figures quoted in this paragraph are per annum.

Table 1. Instrument breakdown data segregated by instrument type

Type	Number of Instruments	Number of Breakdowns (long)	Mean Unavailability (%)
Liquid scintillation	15	16 (7)	30
Well (manual)	45	13 (4)	6
Well (automatic)	25	25 (4)	8
Probe (single)	49	14 (5)	6
Probe (dual)	32	23 (9)	11
Scanner	66	68 (14)	11
Camera	14	14 (5)	24
Calibrator	31	7 (5)	11
Miscellaneous	12	1 (1)	8
Total:	289	181 (54)	11

required to improve service and spare part supply for almost 90% of the instruments. All instruments except 75% of those in India were produced by foreign manufacturers. Half of the instruments were more than 5 years old and one quarter, more than 10 years.

The environment of the instruments

There are two important environmental factors which may strongly interfere with the proper functioning of instruments: the atmosphere in which they are kept and the AC electrical power supply The survey disclosed that 75% of the instruments were used in air-conditioned rooms, but that more than 60% of the air conditioners were switched off during the nights, weekends and holidays, thus allowing a buildup of humidity in the air and a very detrimental condensation of water on instruments.

Power failures occurred frequently. One laboratory reported as many as 27 during the six-month survey period. The very large fluctuations and surges which appear when the power supply is restored may be very destructive for electronic instruments. No data were collected on voltage fluctuations and surges.

Breakdowns experienced

The survey supplied data on instrument failure rate, duration of resultant inoperation ("breakdown duration"), and types of failures. Furthermore, for breakdown durations a differentiation could be made among types of instruments and between short ($\leqslant$ 15 working days) and long (> 15 working days) breakdowns.

Table 2. Instrument breakdown data segregated by instrument type and by country

Country	A		B		C		D		E		F		G		H	
Type	NI	NB	NI	NB	NI	NB	NI	NB	NI	NB	NI	NB	NI	NB	NI	NB
Liquid Scintillation	1	1	1	1	0	0	1	1	2	2	1	0	6	7	3	4
Well (manual)	4	1	2	0	4	1	7	1	2	0	0	0	8	0	18	9
Well (autom.)	0	0	2	1	1	2	5	3	4	1	1	0	10	16	2	2
Probe (single)	3	2	2	0	7	1	11	1	1	0	2	1	8	4	15	6
Probe (dual)	3	2	1	0	2	0	3	0	0	0	1	1	9	4	13	16
Scanner	2	3	3	0	8	1	10	4	1	0	2	3	19	27	21	30
Camera	0	0	0	0	4	6	4	5	1	0	0	0	4	3	1	0
Calibrator	2	0	1	0	5	2	9	2	0	0	1	2	10	0	3	1
Miscellaneous	4	0	0	0	0	0	3	0	1	0	0	0	2	0	2	1
Total:	19	9	12	2	31	13	53	17	12	3	8	7	76	61	78	69
Long break-downs		4		1		3		8		0		6		12		18
Mean Unavailability		10%		4%		9%		8%		1%		34%		8%		14%

NI = Number of Instruments
NB = Number of Breakdowns

The numbers of breakdowns reported are shown in Table 1 (third column) for all countries taken together, with the number having "long duration" in parentheses. In Table 2 the numbers of reported breakdowns are given for each country. The reported mean failure rate for all instruments in all countries except one is approximately once a year. Segregated by instrument type, the failure rate for manual well counters, probe systems and radioisotope calibrators taken collectively is once in two years, whereas for automatic liquid scintillation counters, automatic well counters, scanners and gamma cameras taken collectively it is twice per year. In the country that was singled out, special circumstances make the data statistically not equivalent. The failure rates there were almost twice as high as in the other countries.

The data on failure rate and breakdown duration have been combined to yield the total duration of instrument inoperation. When divided by survey duration the result is the percentage of time the instrument was unavailable for use. Such data, pooled for each instrument type, are shown in the last column of Table 1. When the instruments were segregated by country (Table 2), rather large and apparently real differences were found among the countries. While the data do not reveal the causes of these differences, it is noteworthy that the country with the best record had a well-functioning central maintenance service. Differences among individual laboratories were even greater than those among countries: 3 laboratories reported mean unavailability for all instruments exceeding 50%, 6 fell in the range 26–35%, 7 in the range 16–25%, 8 in the range 6–15%, and 23 in the range 0–5%. Twenty-three laboratories did not experience any failure at all.

As for types of failures, among the 181 reported breakdowns, 73 were primarily mechanical failures of motors, readout devices, sample changers and other items. They greatly outnumbered the 31 failures of detector systems (high voltage supplies, detectors, photo-multipliers and preamplifiers), the 15 low voltage power supply breakdowns and the 15 electronic circuit failures The relatively high number of failures of detector systems may reflect an important role of humidity in causing breakdowns. The failures of low voltage power supplies may be caused in part by the fluctuations and surges of the AC power supply.

The tables show that mechanically complex instruments (automatic sample counters, dual probe counters, scanners) and gamma cameras were more likely to break down than simpler instruments, although these breadkowns did not necessarily lead to large mean inoperation times. Only the automatic liquid scintillation counters and gamma cameras rather consistently showed large mean unavailability figures. For the other instruments the capability seemed to exist to repair most failures within a few days.

The group of short-duration breakdowns ($\leqslant$ 15 days) comprised 127 failures, with a mean breakdown duration of 4 working days. The group of long-duration breakdowns ($>$ 15 days) comprised 54 failures, with a mean breakdown duration exceeding 3 months. The survey data revealed in part the causes of these long delays, suggested by the following categorization:

18 waiting for spares
2 waiting for mechanical parts to be produced locally
9 inability of manufacturer's agent to solve the problem
5 lack of technical know-how of laboratory staff
8 red tape and slowness of official repair services
3 slowness of manufacturer's repair services
1 fabrication failure
16 no indication why repair took so long

Thus, spare part supply, lack of technical know-how, inefficient service and bureaucracy are major maintenance problems.

Spare parts

It is widely believed, and is confirmed by the survey, that difficulty in the supply of spare parts is one of the main bottlenecks hindering quick repair The survey disclosed that for only half of the instruments was a **list** of parts available and for only one quarter of them was a **stock** of spares maintained. The value of the stock for 43 instruments amounted to US $63 000. The cost for the spares needed for 112 reported breakdowns of 211 instruments in seven of the eight countries is estimated very roughly at US $17 000, whereas that for the spares needed for 34 long duration breakdowns is estimated to be US $8 000. From the reported US $63 000 stock of spares, not more than a few thousand dollars' worth were useful in correcting breakdowns that actually occurred. Thus stocking spares is a exceedingly costly means to assure their availability. It must be concluded that problems encountered in the supply of spare parts are more organizational and administrative than financial: difficult or complicated ordering procedures, lack of budget provisions, excessive customs regulations, difficult contacts with instrument manufacurers, difficulties in identifying the parts, difficulties in paying for the supplied parts, etc.

Available maintenance facilities and skill

The data show that 70% of the reported failures were repaired within an average of 4 working days, indicating that to a certain extent repair skill and means were available. On the other hand, one quarter of the remaining failures could not be repaired due to lack of technical know-how on the part of either the manufacturer's agents or the laboratory staff. The survey disclosed also that only one quarter of the laboratories had a special area or workshop where instrument maintenance was carried out and only two thirds of them had more than half the items on a short list of equipment commonly used for instrument maintenance (pliers, screw drivers, wrenches, soldering equipment, drill, volt-ohm-ammeter, oscilloscope). This gives a clear indication of the extent to which the laboratories depended on external personnel to perform even simple repairs. Maintenance contracts existed for only 15% of the instruments. Satisfaction with service received in the past two years was expressed for 70% of all instruments surveyed The survey did not give any data about the level of know-how and experience of the personnel performing maintenance.

Instrument checks and quality control

For about 25% of the instruments, daily performance checks were reported and for another 25%, weekly checks. The remaining instruments were checked only monthly or occasionally. These figures suggest that the introduction of quality control for all instruments would certainly reveal more failures than found to date and allow for necessary reliability of the measurements.

REMEDIAL ACTIONS

Remedial actions must aim at diminishing the frequency and duration of breakdowns.

Frequency of failures can be diminished by appropriate conditioning of the environment. Air humidity and temperature should be kept at an acceptable level all year. Dust, and at institutes near the sea, salt, should be filtered out. For these purposes air-conditioners alone are often insufficient; dehumidifiers and sometimes special filters may be needed

Futhermore, the severity of surges and fluctuations of voltages on the AC power lines should be reduced by the installation of dedicated power lines, separate earth lines, voltage stablilizers, isolation transformers, surge suppressors, and drop-out relays. Those wishing to condition their AC power supply should choose the possibilities best adapted to circumstances prevailing in their laboratories. Other means to keep failure rate low are preventive maintenance, daily care of instruments and proper operator training.

Shortening of breakdown periods can be achieved by various measures including arranging for quick supply of spare parts, training or appointing maintenance staff, arranging for the appropriate maintenance facilities and tools, co-ordinating the approach to manufacturers for better service and streamlining regulations concerning budget, procurement and customs.

Reducing the failure rate is a technical problem that in principle is easy to solve although it requires some investment. Shortening the breakdown period is more difficult since apart from the training, for all necessary actions the improvement of existing administrative regulations and communications channels is required.

RCA PROJECT

The Medical Applications Section conducted the survey to collect data which could guide it in future remedial actions for nuclear medicine instruments. Since the situation in laboratories other than medical must be similar to those described above, the Agency is preparing regional projects to assist Member States in solving the maintenance problems of all kinds of nuclear laboratories. The first of these projects will be started in Southeast Asia under the Regional Co-operative Agreement for Research, Development and Training related to Nuclear Science and Technology (RCA). By October 1979, eight Member States of the region had informed the Agency of their wish to join this project

The RCA project will assist countries and laboratories to improve the efficiency, reliability and quality of the work done in nuclear laboratories by introducing or improving maintenance strategies and by the rationalization of technical assistance and training programmes related thereto. It will deal with environment conditioning, preventive maintenance, quality control, spare part supply, training of maintenance and operator staff, selection of instruments, and the streamlining of administrative regulations Co-operation between laboratories of each participating country and between the countries of the region will be encouraged: not every laboratory can employ high level maintenance engineers, and not every country can have full training facilities.

The project will start with a meeting of national project co-ordinators in December 1979 to initiate formulation of maintenance plans for laboratories, countries and the region. During 1980 the execution of these plans will be started.