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CONTROLLING LABORATORY CONDITIONS AND PREVENTING THE PROBLEM: THE HEALTH PHYSICIST'S VIEWPOINT

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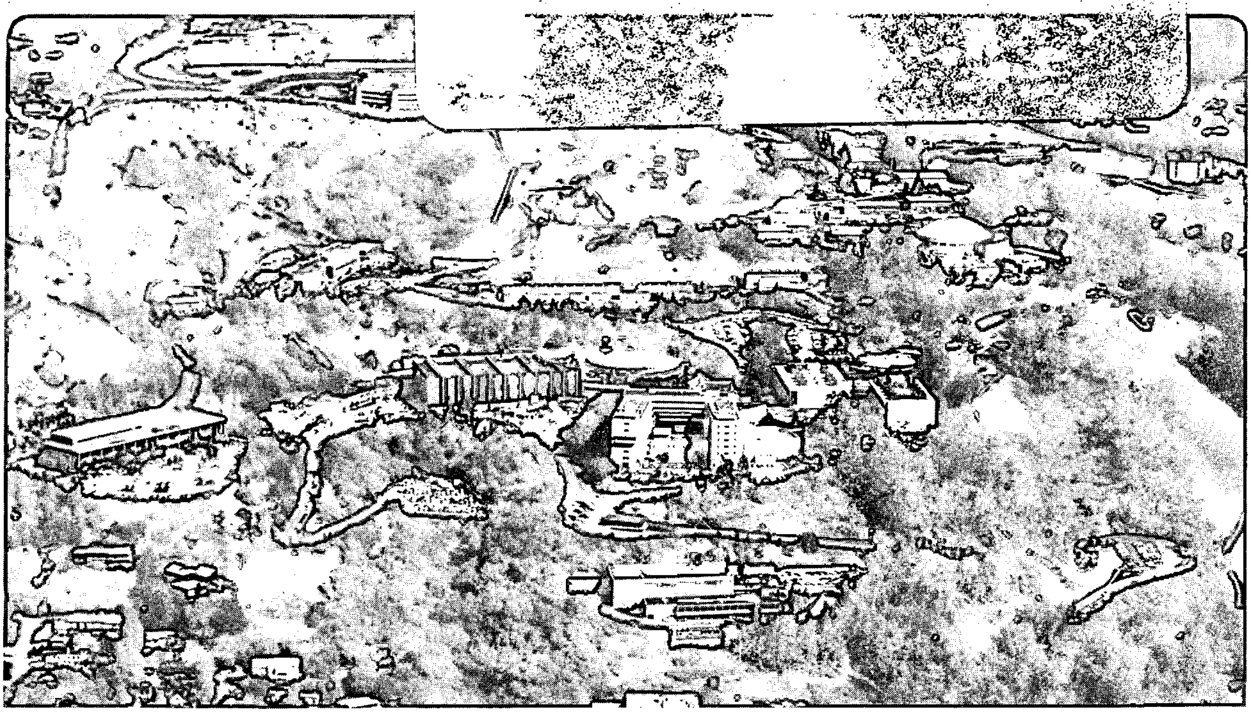

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CONTROLLING LABORATORY CONDITIONS AND PREVENTING THE PROBLEM: THE HEALTH PHYSICIST'S VIEWPOINT

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After having heard about the magnitude of the problem of safety in the use of analytical x-ray equipment and then learned of the consequences of exposure to these x-rays, it is hard not to be convinced that a problem exists. Also being aware of the degree of responsibility in the event of an accident, it is clear that steps must be taken to prevent such occurrences. Controlling laboratory conditions is the key to prevention and, therefore, the solution to the problem.

Controls may be imposed administratively or with hardware. Administrative controls are easy and inexpensive to impose. Enforcement, however, is time consuming and difficult, since such controls need only be ignored to be compromised. Hardware controls are more positive and difficult to ignore. The bypassing of hardware controls is usually invasive on the equipment and leaves evidence.

When imposing controls it is necessary not to lose sight of the operational needs which brought the x-ray unit into your organization to begin with. Analytical x-ray machines are safest during massive power failures--but not very useful. Administrative and hardware controls which hobble the use of the equipment will be violated. Cooperation between the health physicist and the x-ray users can bring together the requirements of safety and utility to create controls which will work.

As with any type of control, it is necessary to have the administrative and financial support of management. Without the resources and authority from such support, there is little chance of successful implementation.

Administrative Controls

Operational Safety Procedures

One administrative control is the Operational Safety Procedure (OSP). This is a document which summarizes all the safety provisions for a given x-ray machine. More than that, however, it is a binder in which one can collect all of the information pertaining to the use of that x-ray machine. The OSP thus serves as an information resource for the x-ray user. Many items are included in the OSP. It is a place were iden- tifying information can be found as well as listings of acces- sory devices available for use, and descriptions of the safety provisions which have been included. Statements are also included detailing the management provisions which will be used to ensure the safe use of the apparatus. Data regarding installed modifications, accident/incident history--if any, and a diagram of the room layout are included.

The operating procedures are listed but with notations and cautions regarding safety. Here is where the meanings of the various safety indicators and alarms are explained. When an operator response is required, the procedures detail the correct action. Alignment procedures are also listed. This tends to emphasize and define the elements of machine use which are to be left to designated individuals.

Appended to the OSP are copies of the relevant rules and regulations pertinent to the operation of this equipment.

The designation of users is an important part of the OSP. It brings focus upon those users who have the extra training to allow them to do the operations which entail a higher accident risk. Thus those who may instruct new users, do alignment operations or who are allowed to service the unit are listed. There is also an X-Ray System Supervisor designated. This allows control and management of the x-ray machine to be co-ordinated through one, clearly identified person.

Included in the OSP binder are Certification of Training forms which have been signed by the instructor and the trainee. This form contains an outline of the subjects which are considered necessary to cover for the safe use of the machine. This helps guide the instructor, who is usually one of the equipment users, and is more concerned with the elements of use which will bring about a successful analysis. This form also serves to document the training and testify that the instructor and trainee both agree that the message has been passed on. The requirement of signatures by both parties serves to emphasize that the safe use of analytical x-ray equipment is a serious matter.

Logbooks

Logbooks can also be an administrative agent in promoting the safe use of x-ray machines. The user of the machine is identified by name and project. If problems occur this information can be used to identify the persons affected, or in some cases responsible for the problem, and in need of further training. The logbook also serves as a place to note operational difficulties and can thus be used to track service problems or project operational and replacement costs.

User Surveys

The requirement for users to frequently survey the equipment setup is an administrative control which can spot safety problems early, and prevent leaks from getting larger or causing exposure for prolonged periods of time. These surveys are also useful in spotting changes which may otherwise go unnoticed, such as the omission of a hidden shield during a service operation. These surveys should also be logged for documentation and to spot trends which may be occurring.

Hardware Controls

Hardware controls can be considered hardline safety. They can be very reliable since they never forget what it is they are supposed to do. These controls don't feel the pressures of deadlines and won't debate the point of whether they can relax their vigil just this one time.

Well-designed hardware controls are those which arise from the cooperative efforts of safety personnel and x-ray users. They can allow the vast majority of operations to proceed without compromise. Well-designed hardware controls do include provisions for override, but not casually and and only under administrative control. Multiple hardware controls will enhance flexibility since the authorized and supervised bypassing of one control will not remove all protection.

Lastly, hardware controls can be expensive, but do not have to be. If they are designed to achieve a general purpose as opposed to providing a specific function, then innovation and imagination can yield great savings. Safety personnel can provide the intent of the controls, while the user determines the limits to their interaction with the x-ray machine. Design engineers can then bring these requirements together. There are, of course, times when an impossible task arises, then administration is there to arbitrate.

Area Monitors

If I had to choose only one piece of hardware for the safety of an analytical x-ray machine, it would not be a happy choice, but it would definitely be the area monitor.

An area monitor is like having an assistant whose only job is to watch out for your safety. It is a constant survey of the radiation environment. Even the best area monitor cannot always warn of the presence of a collimated beam on XRD equipment, but few can miss an open port. It is clear from reading reports that many accidents could have been prevented if only the operator had known that the beam was on. It is clear that such a device is very useful.

To be able to provide adequate warning, the area monitor must have a sufficiently low mass window to be able to detect low energy x-rays. Its response to energy or intensity need not be linear nor well calibrated since a warning is a yes/no situation. It does need to be stable and provide little trouble (or someone will disable it--rather unceremoniously).

The sensitivity should be sufficient to detect scattered x-rays, but not so sensitive as to alarm with exposure rates normally present. Exactly how sensitive, or insensitive this must be depends upon the location of the detector.

The positioning of the area monitor is important. It must be able to "see" all of the operation, but not be in the way. An area monitor mounted close to the beam may need multiple detectors for adequate coverage. However, only one detector is needed if it is located a few feet overhead or to one side, although it would then need to be much more sensitive.

The area monitor should alarm when an excessive level of radiation is sensed. It should not be necessary for the operator to watch a meter or listen to clicks. Additionally the area monitor should have a failure alarm, some means of detecting that it is no longer able to sense radiation and needs immediate service.

At LBL we have built a large volume ion chamber area monitor. It is made from a design originated at Argonne National Laboratory. This unit has a failure alarm and is set for a high level alarm at 0.4 mR/hour. Since the time constant for the level sensing circuit is long, it also has a rate-of-rise alarm circuit that provides a warning of a fast rise to a level close to that of the alarm level. These units experience some "settling in" difficulties, but after the first 6 months provide years of unattended service. The units are sensitive enough to be mounted above the action and, therefore, out of harm's way. This is fortunate since, like most ion chamber devices, they are quite delicate. This mounting location also allows one detector to "view" all four ports on an XRD unit.

I would like to see another sort of area monitor. This one would have a "hydra" appearance with one end-window GM detector for each active port. These detectors would be mounted on the ends of flexible shafts so that they could be appropriately positioned when needed and then moved out of the way when not. Small detectors could be used since they could be close to the beam, thus the device would not be unduly obtrusive.

Unfortunately, I have not seen any commercially available devices which are like either of these. The units I have seen are usually not sufficiently sensitive for where they would have to be mounted. They do have good low energy characteristics, nor do not have failure alarms. If such do exist, the manufacturers must not advertise in journals or catalogues read by Health Physicists.

One company I know of has a proprietary solid state detector which would be ideal for this application, but they use it only in a high-priced, portable survey instrument.

Interlocked Enclosure Hoods

Interlocked enclosure hoods provide nearly absolute safety for the routine user, but also enhance the safety of all users. A well-designed enclosure will allow routine use without the need to have the beam ON with the access open. Such an enclosure will also provide sufficient space to allow for the flexibility required for less static operations. Overrides must be provided for some alignment operations but should be key controlled to avoid casual or constant use. While in this mode of operation there should be an alternate means of indicating that the beam is ON, since even the best warning light may not be visible or it may not be convenient to observe it. I prefer an audible tone that is difficult to ignore. Such a tone will also discourage continual running in bypass mode. In addition, provision should be made to allow cables, hoses and the like to enter the experimental area without the need to run with the interlocks bypassed.

Enclosures provide safety for non x-ray users as well as experimental security. Long runs may operate unattended without concern for the safety of others in the laboratory, or for interruption or modification of the experiment.

The purpose of these enclosures is to disallow entry of body parts into the primary beam. Shielding is usually unnecessary. This means that they can be constructed of light materials. Human engineering of an enclosure can allow access to many of the controls while making it physically impossible to reach the beam. Design engineers should consider this a design challenge.

When the enclosure is open it should provide easy access. This is especially true if alignment operations are necessary with the beam ON and enclosure open. This also allows maintenance and setup operations without the total removal of the enclosure, thus requiring fewer things to be restored to operation before testing.

It is also very important that the enclosure not shield or "blind" the area monitor. The two safety devices should be designed to work together.

The interlocks for the enclosures must be redundant or failsafe. If they are not it would be just as well if they were not there at all. A good interlock system will be relied on for safety protection. If it can fail easily and in an unsafe configuration, it will provide a very false security.

At LBL we have adopted an enclosure which is an inverted plastic box. This box rides on vertical rails attached to nearby walls or to the x-ray unit. Some of the enclosures have no tops; this prevents shielding the area monitor overhead. The plastic construction helps to make them appear less massive, thus lessening the appearance of clutter.

Improved Warning Lights

If any one x-ray safety device needed to be improved, it was the warning light. Lights that are bright enough to be seen usually interfere with the operators ability to view a dim phosphor glow. Those that are dim enough not to interfere give an indistinct indication and are flooded out by high ambient light. Some are merely colored lights which give no warning at all to personnel unfamiliar with the facility.

At LBL we have designed a failsafe warning light which addresses all of these problems. It is an illuminated sign so it's meaning is clear. Through a combination of masks and filters it is virtually unreadable when OFF but clearly visible when ON, even next to fluorescent lighting fixtures. The angle of light emission has also been controlled so as not to cast light directly upon the experimental area.

The failsafe circuit of this light is utter simplicity and very reliable. This circuit was developed on the Berkeley campus many years ago and I haven't heard of a single incident where it has not functioned properly. It is the series combination of a 12.6 Volt filament transformer, a 6.3 Volt coil relay and a 12 Volt automotive signal light bulb--when the bulb burns out, the relay opens.

Improved Alignment Devices

Here I basically want to promote the use of tools and devices to simplify, eliminate, or provide remote control of alignment with the x-ray beam on.

Expensive remote controls will allow adjustments while not requiring the user to be close to an open beam. However, distance from the beam is only to lessen the chance of entry to the beam. Human engineering, mentioned above, will serve the same purpose and is often much cheaper.

Simple tools will also help. A hooked device to pull open a manual shutter through a hole in the enclosure is a good example. Tweezers to place collimator tubes into place is another one. Similar devices can be developed to improve the safety of some of your operations.

One of the researchers at LBL developed a sliding table arrangement for his group's cameras. This allows removal from the port and repositioning later with very little readjustment. This saves time and lessens the opportunity for exposure.

Another device in use at LBL was adopted from an article in a professional journal and brought to our attention by a graduate student. He was asking if we knew of a similar device, that was commercially available. There was none, so one was built for him--and a couple for us too. This device is a locking beam tube which acts as a key to allow a manual shutter to open, and which cannot be removed until that shutter is closed.

Routine Maintenance

Hardware safety is all very well, and worth putting time and thought into, since it only has to be done once for a given installation. Routine operations necessary for the safe operation of unmonitored open-beam units become superfluous when enclosures and area monitors are employed. Some day the regulatory people may catch up to technology and then the political need for these operations will be eliminated as well.

Routine inspection and testing is still necessary, only now it is the hardware which needs maintenance to correct for normal wear. This can benefit operations as well. Since the electrical and mechanical components of the safety apparatus need inspection and maintenance this can be combined with a preventative maintenance operation on the entire machine. This will mean more reliable operation with less unscheduled downtime.

From the Manufacturer

When we enclosed our x-ray machines we had very little company. Now it seems that new machines are coming with many of these provisions.

Many, but not all. Most that have interlocked enclosures, do not have redundancy built in. The overrides provided are actuated by an easily made plug. Key control of machine operation is not provided for firm control of unauthorized use. Provisions are not made for cable access, thus encouraging constant running in a bypassed mode, with no indication that such is the case. No thought is given to area monitors. And the warning light is not always failsafe and still has all the problems of the older designs.

Worst of all, it is difficult to assess which of these features are present from the literature provided as sales material or with a purchased unit.

I hasten to point out that not all machines fail in all these respects and that all these features are not required by any law or standard. Also some manufacturers provide even better protection than presented here.

All of these features could be on your next analytical x-ray machine if you demanded it and were willing to pay the extra cost. It would most likely be cheaper if bought with the machine than added on later. In any event added costs for a whole facility of machines to have these "extras" would cost less than the legal defense fees for one accident if a personal injury suit is brought--that's win or lose!

Further Reading

I have only one book to recommend for more information. This is A GUIDE TO THE SAFE USE OF X-RAY DIFFRACTION AND SPECTROMETRY EQUIPMENT, by E. B. M. Martin[1] The author has put all that you will ever need to know about the subject into one small manual. I had the good fortune to review this book for the Health Physics Journal. In addition to the free review copy, I was glad to see a manual on this subject that was practical and straightforward.

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[1] E. B. M. Martin, A Guide to the Safe Use of X-Ray Diffraction and Spectrometry Equipment (Science Reviews Ltd., in association with H & H Scientific Consultant Ltd., Leeds LS17 8RA, UK, 1983), ISBN 0-90592-7-11-7.

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