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Gamma-Radiography in Shipbuilding and Engineering

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Within the past twelve months there have been several new developments in the practice of gamma-radiography, the most important of these being the ease with which artificial radio-active substances have become available from the Atomic Energy Research Establishment at Harwell. The introduction of three sources for industrial work, cobalt, tantalum and iridium has rendered the use of radium obsolete (although radon is still a very useful source in some cases), and has made desirable a review of the principles, and present practice, of gamma-radiography in Great Britain.

This paper will describe gamma-radiographic technique and application, and will indicate the factors which govern the choice of a suitable source. The problem of the safe handling of sources and of personnel protection is discussed, and some indication of the cost of gamma-radiography is given.

1. INTRODUCTION

Radio-activity was discovered by Becquerel in 1896 and gamma-rays were identified as part of the radiation emitted by radio-active substances some years later. In the meantime the best known of these substances, radium, had been separated and named by Mme. Curie. Atoms of radium in common with those of all other natural radio-active substances, spontaneously disintegrate and are tranformed into lighter atoms, this change being accompanied by the emission of alpha or beta radiation. These rays, which have very limited penetrating power, are not of interest in connexion with the present subject, but often they are each associated with the more penetrating gamma-rays, which represent the surplus energy left in the unstable atom after the primary disintegration. These gamma-rays can have a wide range of energies and in fact those emitted by radium sources cover the range from 250,000 to 2,500,000 electron-volts.

The electron-volt is the energy unit used in this work and radiation of say 1,000,000 electron-volts (1 MeV.) corresponds very roughly to that produced in an X-ray tube across which is applied a potential difference of 1,000 kV.

2. RADIUM AND RADON

When radium disintegrates, or decays, it spontaneously emits a radio-active gas called radon. This gas is introduced into small glass tubes in which is included a grain of charcoal. The gas is adsorbed on to the surface of the grain so that a large quantity of gas is concentrated in a very small volume. This is a very important consideration in the use of radon sources and will be referred to below. The gamma-rays from radon are identical in energy with those emitted by radium.

All gamma-ray sources have a property called their half-value period. Radio-active decay is such that the gamma-ray activity of any source constantly is being reduced. In one half-value period the gamma-ray activity falls to 50 per cent of the initial activity and in the subsequent period falls to 50 per cent again, or in two successive half-value periods the total drop in activity is 75 per cent. These half-value periods, or half-lives as they are commonly called, vary widely from one substance to another, radium for example having a half-life of 1,590 years while the half-life of radon is 3·8 days. Thus the gamma-ray emission from a radium source is practically constant from day to day, while that from radon decays very rapidly, falling to 25 per cent in just over one week.

The gamma-ray strength of a radium source is usually expressed in milligrams, this being the physical weight of the radium present. That of radon, and other sources, is expressed in millicuries, a unit which is open to much criticism since it does not allow the direct comparison of different types of source. The exceptions are radium and radon, for which equal number of milligrams and millicuries, respectively, have equal gamma-ray emissions.

3. RADIO-ISOTOPES

Artificially radio-active substances have been known for many years but until the advent of the atomic piles at Harwell they could not be produced in any quantity. For industrial use the only sources which have been produced efficiently are radio-isotopes of cobalt, tantalum and iridium. These are produced after the neutron irradiation of the natural elements in the atomic pile, when elements of the same chemical properties but different atomic weights are the result. These elements are said to be isotopic with the natural substances, or simply, their isotopes. In the three cases mentioned the isotopes of mass-number 60, 182 and 192, respectively, are the useful ones.

The qualities which effect the narrowing of the field to these three substances are: firstly, the ease of activation and the attainable specific activity; secondly, the energy of the gamma-rays emitted; thirdly, the half-life. No isotopes, other than cobalt-60, tantalum-182 and iridium-192, have yet been produced with more convenient values of these three factors.

The ease of activation can be expressed conveniently in terms of the irradiation time needed to produce a given activity per unit volume. For practical reasons the unit of volume used in this paper will be that of a 2 × 2mm. cylindrical source since those ordinarily available from the Atomic Energy Research Establishment, Harwell, are either 2 × 2mm., 4 × 4mm., or 6 × 6mm. The volumes of these sources are, of course, in the ratio 1 : 8 : 27, and the activity produced in them, under similar conditions of irradiation, will also be in this ratio, to a first approximation.

The value of the specific activity attained by any source, within a reasonable irradiation time, has also some practical significance, and will be roughly in inverse proportion to the irradiation times discussed above.

TABLE 1.

	Radium	Radon	Cobalt-60	Tantalum-182	Iridium-192
Activation time, weeks	—	—	400*	80*	4*
Specific activity, mC	12‡	—100,000‡	7†	35†	700†
Principal gamma-ray energies, MeV	1·12, 1·76	1·12, 1·76	1·17, 1·33	1·22, 1·13	0·61, 0·60, 0·58
Half-life	1,590 years	3·8 days	5·3 years	120 days	70 days
Tenth-value thickness, inch lead	1·7	1·7	2·0	1·8	0·42

* Irradiation time to achieve 100 mC for 2 × 2 mm. source.
‡ Activity obtainable in practice per 2 × 2 mm. cylinder.
† Activity attained by a 2 × 2 mm. source in 26 weeks.

Radium and radon are not produced by irradiation and have a specific activity which is a property of the technique of preparation and is not widely variable. In Table 1, the figures given are in terms of a 2 × 2mm. cylinder, although in practice radon sources are effectively 0·5mm. cubes and radium sources are cylinders with dimensions corresponding to the source strength. The table below also shows the energies of the principal gamma-rays emitted by these sources and also the tenth-value thickness, in lead, for the radiation. These last are an indication of the penetrating power of the radiation, that being more penetrating which has a greater tenth-value thickness, since it is that thickness of material the absorption of which is sufficient to reduce the gamma-ray intensity incident upon it to 10 per cent.

4. CHOICE OF GAMMA-RAY SOURCE

The practical effect of each of these factors in the choice of suitable radiographic sources must now be discussed.

The physical dimensions of the source are an important factor in the sharpness of the radiographic image. Since radiography is essentially the casting of shadows, a small source of radiation means a sharp image, or in radiographic terminology, good definition. The importance of having a small source is greater when the metal thickness involved is greater, since in such cases defects can be comparatively long distances from the film. Consequently the source has either to be of small linear dimensions, or be placed at a greater distance, to achieve the image definition required.

Since increased distance means a greatly increased exposure time (the intensity of the radiation falling off with the square of the distance) it is desirable to have sources of high specific-activity to minimize exposure time, both by having a high gamma-ray intensity and by making possible the use of short source-to-film distances. From Table 1 it is apparent that from this point of view radon is the ideal source, combining as it does, minute source sizes with large gamma-ray strengths.

However, definition is not the only criterion of radiographic quality but shares an equal place with image contrast, or the tone difference in the image between a defect and the sound metal around it. The important factor in the contrast of the radiograph is the energy of the radiation. It can be seen from the table that radium, radon, cobalt and tantalum have radiation of the same order of energy, a fact confirmed by the close agreement in tenth-value layers. Iridium-192, however, has radiation which is much more easily absorbed, a fact which is exemplified in the much smaller tenth-value layer, and consequently is capable of producing radiographs with a much higher image contrast than those resulting from the use of any of the other sources. The lower penetrating power of iridium radiation does, of course, increase the exposure times necessary and has the effect of setting a practical limit to the thickness of material which can be examined economically.

A very important consideration, which depends mainly on the penetrating power of the radiation, is that of the protection of sources so that operators can handle the equipment with safety. The subject will be explained in more detail below, but at the moment it can be mentioned that the greater the penetrating power the more difficult it is satisfactorily to protect the source.

Not only has iridium the advantage of giving radiographs of relatively high contrast, but it can be seen from the table that the specific activity obtainable is high and the irradiation time short. This enables sources which are small in physical size and of high strength, to be irradiated quickly.

The last property of radio-active sources which has a bearing on their practical value, and on the choice of a source suitable for a given job, is its half-life.

There is a common belief that at the end of the first half-value period the source is of no more use for radiography. This is, of course, not necessarily true and even after several such periods a source may retain sufficient gamma-ray activity to make its use a practical proposition.

It is true that for the same specimen, and under the same exposure conditions, the time to make the radiograph is double that used at the beginning of the previous half-value period. Whether this is economic or not depends on how long was the original exposure. But if the source is to be used for a series of examinations each less exacting than the last, then a decaying source may be used during the passage of several successive half-lives with every success. Naturally it is not always possible to arrange such a sequence of jobs, especially with a source as short-lived as radon, and in that case the gamma-ray intensity still existing at the close of the examination is, so to speak, wasted.

In the case of artificially active isotopes a simple alternation

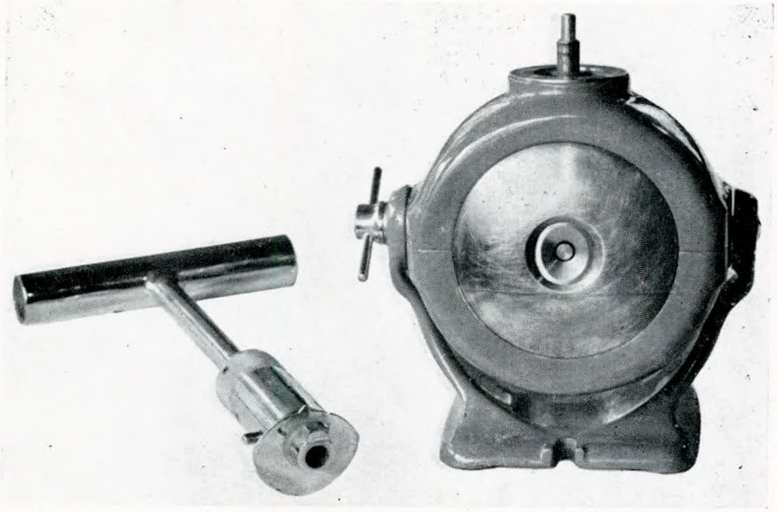


FIG. 1—*Container for radio-active sources. The source is shown exposed for radiography. In this condition the carrying handle is released to ensure that the container is not carried*

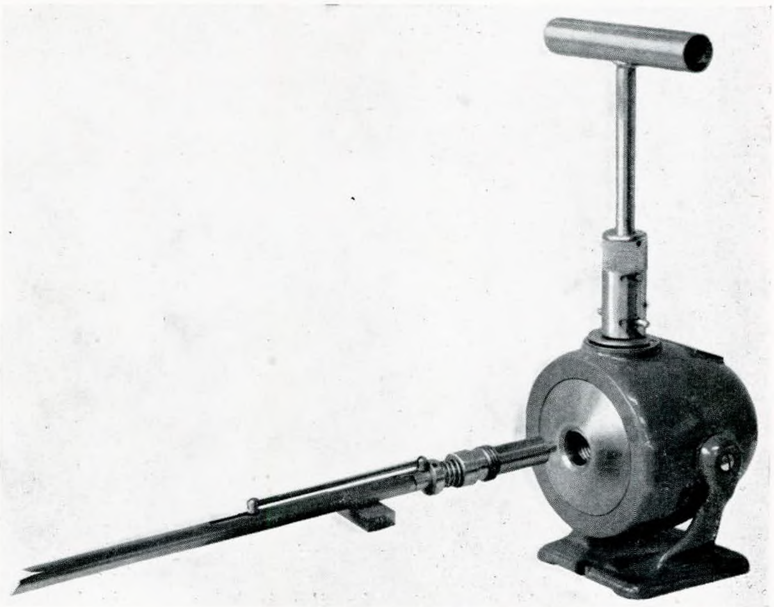


FIG. 2—*Container for radio-active sources. The source is shown after removal from the container for a panoramic exposure*

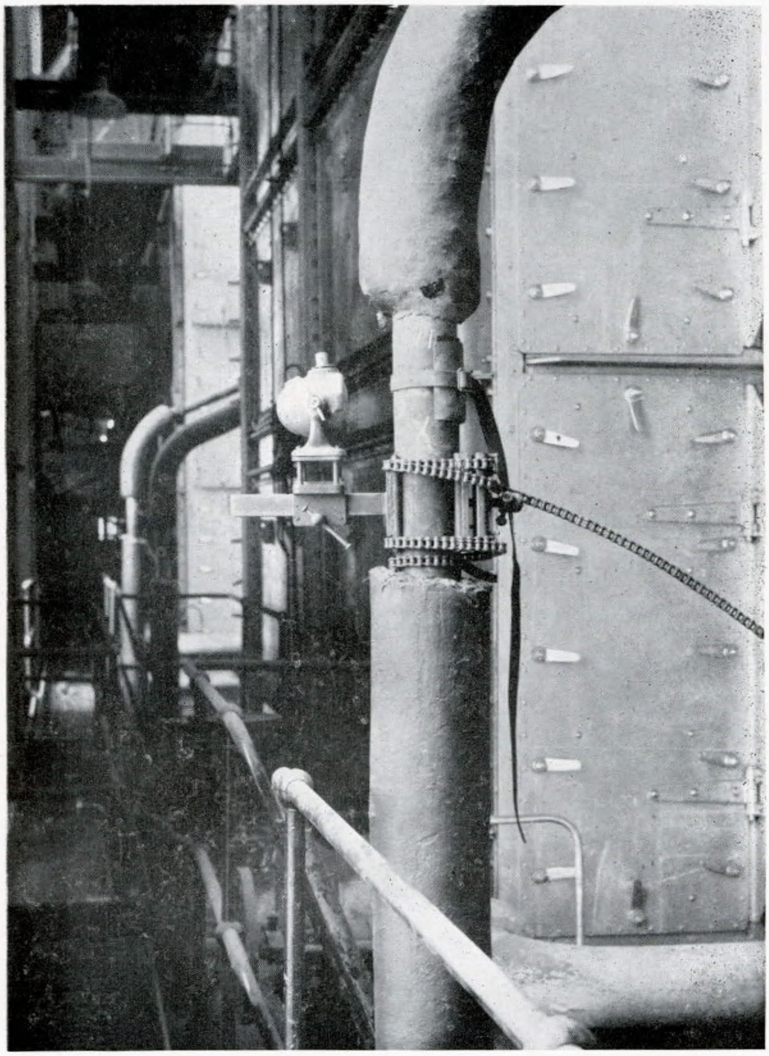
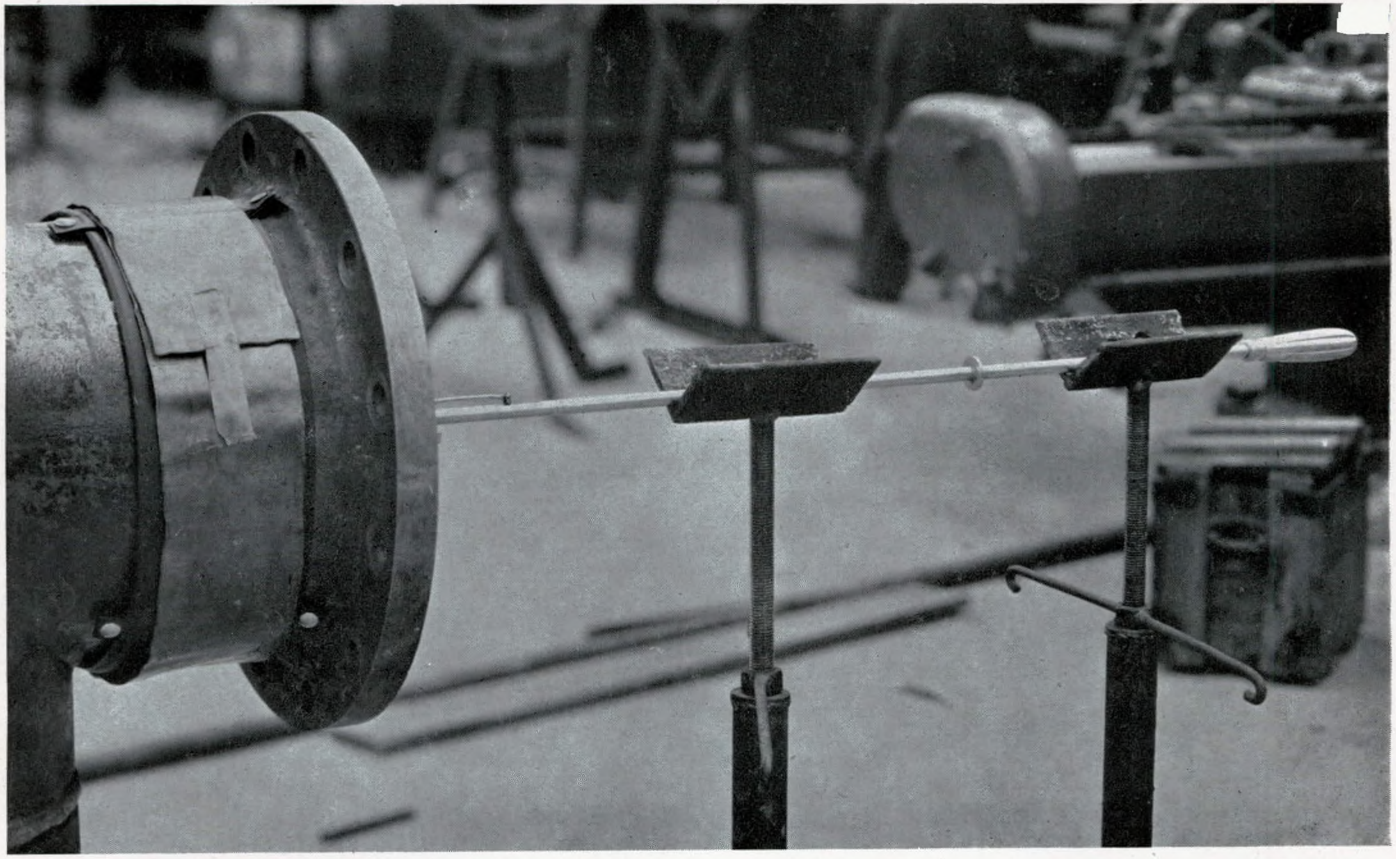
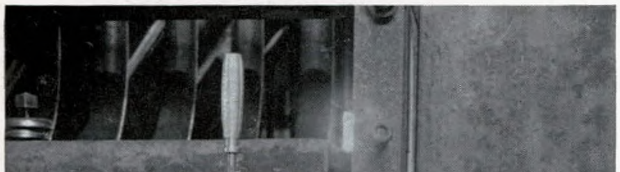


FIG. 3—*Container in use for the examination of pipe welds. The container is fixed to the pipe by the special chain-clamp. The film and lead backing is seen strapped round the welded joint. Only that section of the weld nearest to the film is being examined*

FIG. 4—*Source shown in use for panoramic exposures. Ten ferrous castings are being examined in whole or part*





FIGS. 5 and 6—*Source shown in use for panoramic exposure. Examination of welded joints in high pressure pipe lines is shown. Access is through a hole drilled in the pipe wall (as shown on the left) and through the end of the pipe (as shown above)* between two sources, one in use and one in the pile undergoing re-activation, gives 100 per cent availability of radiation whose intensity is never unduly reduced.

On the grounds of half-life alone one cannot perhaps see why cobalt and tantalum co-exist as alternative sources. The radiation from each is substantially similar and certainly the comparative radiographic results show no appreciable advantage one way or the other, except that for thinner sections, the soft gamma rays from tantalum produce a somewhat higher contrast in the radiograph. However, their activation times and attainable specific activities are markedly different, making tantalum essentially a short term proposition, to be used only while a first cobalt source is being activated, and then replaced by its long lived rival.

The foregoing can thus be summarized and one can reduce the choice of a source to the simplest terms. For thicknesses of steel up to about 2 inch (the limit depending on what strength of source is available) and for corresponding thicknesses of other metals, iridium-192 gives the best results, the other isotopes and radon not being recommended. Over 2 inch thick steel, tantalum and cobalt are considered most suitable, the choice being one of availability and the highest gamma-ray emission from sources of the same dimensions. When metal thicknesses of about 4 inch are reached and smallness of source is the over-riding need then radon comes to the fore. Its only limitation is its rapid decay, a feature which can be overcome to a certain extent by obtaining a high initial activity, with a consequent extension of its useful life. For thicknesses greater than about 6 inch of steel radon is almost indispensable if adequate definition is to be obtained, and advantage can be taken of the ease with which sources of 2 curies or more can be obtained within a 0·5mm. cube.

It was mentioned above that the unit of source strength most often used, the millicurie, was open to criticism since it did not allow the direct comparison of different types of source. At this point it may be well to list the gamma-ray emission of radium, radon and the three isotope sources.

It must be remembered that the radiographic effect is a function on the gamma-ray emission and the gamma-ray energy. Thus cobalt-60, although its mean radiation energy is almost identical to that from tantalum-182, has approximately double the gamma-ray intensity per millicurie, and hence double the radiographic effect. Radium and radon occupy a position between these two.

TABLE 2. GAMMA-RAY EMISSION OF SOURCES

Radium	0·84 mr*/hr/mgm at 1 metre
Radon	0·84 mr /hr/mC at 1 metre
Cobalt-60	1·30 mr /hr/mC at 1 metre
Tantalum-182	0·60 mr /hr/mC at 1 metre
Iridium-192	0·27 mr /hr/mC at 1 metre

* 1 mr = 1 milli-röntgen.

5. USES IN ENGINEERING

The obvious cases where gamma-rays have the advantage over X-rays are firstly, for metal thicknesses beyond the capacity of available X-ray equipment, and secondly, for use in situations where access for X-ray equipment is difficult or impossible. In the latter case the thicknesses involved may allow the choice of iridium and in such structures as ships, bridges, steel framed buildings, pipe work installations, and so on, this is often the case. An added advantage here is that the containers in which the iridium sources are transported, and which will often need manhandling in awkward situations, can be small and light even for the strongest sources. That illustrated (Fig. 1, Plate 1) weighs only 25lb. and gives sufficient protection for any obtainable source of iridium-192.

As well as these more obvious cases, gamma-rays are generally desirable when castings of complicated shape, or wide thickness variation, are to be tested radiographically. Complicated shape usually means difficult blocking, a very necessary proceeding when X-rays are employed if over-exposure of unprotected film is to be avoided, with the consequent loss of detail near changes of section or at the edges of the area under test. The very high contrast obtained with X-rays generated at medium voltages is the problem, and it can be solved by the use of high-voltage gamma-rays with their attendant low-contrast radiographs. Blocking when using gamma-ray sources is never necessary and the image is quite clear right to the edges. A wide range of metal thicknesses are all rendered in the radiograph with photographic densities within the practical range, whereas each section would have to be examined separately with X-rays. It should be noted, however, that despite the facility of carrying out the examination in one exposure, and with a minimum of trouble, when a gamma-ray source is used, the complicated and more tedious X-ray method does give the better result provided the blocking can be done effectively, and provided the sections are simple, and separate. Often this is not so, and more evidence is obtainable from the single gamma-radiograph than from a whole set of sectional X-radiographs.

An additional advantage to be obtained by using a gamma-ray source is in the emission of the rays in all directions. Thus a source set up in the centre of a circle of castings will expose the radiographs simultaneously, with the consequent saving of individual exposure times. The same remarks apply to the gamma-radiography of a circumferential welded seam, the source being placed centrally and a whole chain of films placed around the vessel. A special case of this and one which is much debated is the insertion of a small source into a welded pipe line and the simultaneous examination of a complete welded joint. The practicability of this technique not only depends on the wall thickness and the internal bore but on the possibility of the introduction of a source. In long pipes the only method normally available is by the provision of a hole in the pipe, a few inches from the joint, which is plugged after the examination is complete. Often, however, such a procedure is not practicable or necessary and pipe-joints can be examined by using the source externally, when the radiation passes through both walls, although only that part of the weld nearer the film is actually recorded on it. The type of source used will depend on the wall thickness and for a *total* steel thickness of up to 2 inch iridium-192 is recommended.

In the foregoing the metals under consideration are assumed to be ferrous or cuprous and not aluminium alloys. In fact, even iridium radiation does not give good results with this type of casting and in all such cases X-ray apparatus is essential, whether it is used for radiography or fluoroscopy. Even the results obtainable using the last technique, and especially so when a fine-focus tube is used, are far superior to anything obtainable with gamma-ray sources as known at present. This does not rule out the possibility of the discovery of an isotope with radiation of low enough energy, available in adequate strengths, to make the gamma-radiography of light alloys a practical technique.

6. RADIOGRAPHIC TECHNIQUE

Having discussed the factors governing the choice of a suitable radiographic source it now remains to describe how it is used to best advantage. It is always desirable to utilize the fact that radiation is emitted in all directions uniformly, and the technique of panoramic exposure is widely practised, thus effectively reducing exposure time by exposing many films at once. Advantage can also be taken of the fact that gamma-ray sources need no constant attention and exposures lasting all night or from Friday to Monday can be made in time which would normally be lost. It is a fairly common practice to make exposures exclusively at night and do preparation, processing, and other work during the day. In this way valuable laboratory or workshop space is released for use when otherwise it would be dangerous for personnel.

Since under these circumstances the exposure time is fixed, the only variable left at the discretion of the radiographer is source-to-film distance. By adjusting this, any specimen can be accommodated to the other fixed conditions. Thus for a number of identical objects the source-to-film distance would be identical for each one, whereas if thicker or denser objects were to be examined the source-to-film distance would necessarily be reduced and conversely for thinner specimens.

It is not strictly true to say the source-to-film distance is the only other variable at the radiographer's discretion. In fact the film used is another. There are two main types of film used in gamma-ray work; the so-called standard non-screen and the fine-grain non-screen films. Both these are used with lead-foil intensifying screens and the latter type is approximately three times slower than the former. That is, the latter needs an exposure three times that needed by the former (or alternatively the source-to-film distance must be reduced by about 43 per cent), but despite this fact, the fine-grain type is widely used and can be recommended strongly. The advantage of the fine-grain and the high emulsion contrast, resulting in radiographs of much higher quality, more than compensate for the inferior speed. In some cases where speed is paramount then the faster film can be used to give radiographs of moderate quality.

It is always good practice to expose at least two films in the same cassette. By using intermediate lead-screens this is easily accomplished and not only can badly estimated exposures be corrected to some extent in the development of the second film, but the pair of films constitute an invaluable check on the presence of spurious images due to faulty processing, materials, or handling. Any image which only appears on one film is not due to the structure of the work under examination. With the low contrast normally obtained in gamma-radiographs this point is of great importance.

When using non-screen film the best results are obtained by working to high film densities. The inherent contrast of the film emulsion increases as the working density increases and gamma-radiographs are often produced with densities of from 2·0 to 3·0. Some authorities go even higher, though of course, it must be remembered that for these densities extremely high levels of illumination are required for adequate viewing*. At these illumination levels very careful screening of the eyes from extraneous light must be achieved and maintained.

Finally, since the radiographic contrast is so low, every care must be taken to ensure that the processing of the films, especially in development, is carried out properly. It is very easy for defects to be obscured, or even simulated, by irregular densities due to faulty, or careless dark-room practice.

7. PROTECTION OF PERSONNEL

It is most important that organizations or firms introducing the gamma-ray inspection method should have a thorough understanding of the principles of protection. Gamma-rays, in sufficiently large quantities can be highly dangerous both to operators and others exposed to them. However, if gamma-ray sources are used with the necessary precautions, by trained personnel, there need be no fear of adverse effects.

Fortunately, the measures which must be taken can be based on fairly exact calculations. The amount of radiation emitted by any type of source is known within narrow limits as listed in Table 2, and the absorptive properties of the chief protecting substances can also be determined from published data. These figures coupled with the so-called tolerance dose enable an estimate to be made of how a source can be handled, and for how long, to ensure that no personnel receive a greater dose than that which can be tolerated by the human body. Thus the container illustrated in Fig. 2, Plate O, when loaded with iridium-192 will not give more than the tolerance dose-rate at the surface even with sources as strong as 4 curies. With 500 mC. of cobalt-60, however, the dose-rate at 1 metre is such that the weekly tolerance dose (0·5 röntgen) would be received in 20 hours. This is known as the weekly safe-handling time for this source and container and serves as a basis for all calculation of similar times for other distances and handling methods. It is essential that such data be obtained from manufacturers when purchasing containers, and advice on these matters can always be obtained from the Government establishments supplying the sources. As pointed out previously, the radiation emitted per millicurie of cobalt is considerably greater than that per mC. of radium or tantalum which makes the protection of cobalt, per mC, a much more difficult problem than that of the other sources. The safe-handling time for a container loaded with cobalt-60 will be considerably shorter than that for the same container loaded with an equal number of milligrams of radium. Since the energy of iridium gamma-rays is relatively low its protection is an easy matter and quite small thicknesses of absorber are sufficient to reduce intensities below the tolerance level.

Because of its high density the most popular absorbing material is a tungsten alloy. Lead, which suffers from the disadvantage of poor mechanical properties, is a cheap alternative. Since tungsten alloy is roughly 50 per cent more absorbing per cm. than lead, the weight of a container made of the alloy is approximately 45 per cent of one made of lead giving equal protection. This difference in weight is of extreme importance when the container is to be handled in positions difficult of access, or in confined spaces. In this latter case particularly, due care must be taken to allow for scattering of radiation from surrounding structures leading to an increase in the general level of radiation intensity. For this type of situation the radiation should be checked by using ionization dose-meters.

8. COST OF GAMMA-RADIOGRAPHY

It is difficult to give estimates of the cost of this type of work in a general case. Much depends on whether dark-room facilities and suitable staff are available, and on the actual application to be used. The price of sources can be obtained from the Atomic Energy Research Establishment, Harwell, or the Radiochemical Centre, Amersham, and a few representative figures are given in Table 3. An exposure container costs approximately £100 depending on its type and usefulness. The cheaper ones usually utilize lead as absorbing material and suffer from the disadvantage of a shorter safe-handling time, and a shorter useful life, owing to the readiness with which lead suffers damage. Those made of tungsten alloy are more expensive but allow longer safe-handling times and are almost indestructible.

Accessories such as cassettes, lead intensifying foil, penetrameters, etc., are also needed, but these can be relatively inexpensive items.

TABLE 3. COST OF RADIO-ACTIVE SOURCES

Source	Strength, mC	Cost
Radon	250 1,000	£7 10 0 £15 0 0
Cobalt-60	250 1,000	£20 0 0 £40 0 0
Tantalum-182	250 1,000	£10 0 0 £20 0 0
Iridium-192	250 1,000	£7 10 0 £15 0 0

9. CONCLUSION

The availability of artificial radio-active sources relatively free from the disadvantages of the natural sources, radium and radon, is giving radiographic inspection a new value in all engineering applications. Not only is X-ray apparatus (expensive in capital outlay and maintenance) made unnecessary, but in many fields of application better results can be obtained with gamma-rays. It must be remembered however, that there are still many cases in which X-ray examination is supreme, and where at present gamma-ray inspection has no place. Almost no application to light-alloys is of practical importance and for thin welded sections an X-ray set should always be used if possible. It is in the cases when the use of X-ray sets is im-

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*A film of density 3·0 transmits only 0·1 per cent of the light incident upon it.

practicable or uneconomic that gamma-ray sources find their main application.

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Discussion

MR. H. N. PEMBERTON (Member) said it was important that engineers should be well informed on the subject of radiography, and particularly nowadays on questions such as the use and availability of isotopes and their advantage, if any, over X-rays. He had formed the impression that in gamma-radiography they had available radium, radon, cobalt, tantalum and iridium, and that of all those sources of gamma-rays iridium gave the best results. He would be grateful if Mr. Hislop would expand on that and say whether iridium was indeed the best source of gamma-rays under all conditions.

The next thing the engineer would want to know was in what way gamma-radiography could assist him in testing the quality of materials and welding, and it was in the application of radiography that certain serious problems arose. Since 1934 Lloyd's Register had made it a compulsory requirement that Class I welded pressure vessels should be radiographed to one hundred per cent and throughout the years a large experience of X-radiography had been built up, and in his opinion up to, say, 2 inch thickness without any doubt X-radiography gave better results than gamma-radiography.

So far as steel castings were concerned there were being used in industry two methods of applying radiography: the first was in the control of casting technique, to improve homogeneity by ensuring proper disposition of headers and risers. That was particularly important where more than one "off" was involved in the production programme. Subsequently a periodic radiographic check could be made from the production line to see that the initial standard was being maintained. That system had been established at several leading steel foundries in the United Kingdom, and use had been made of that system of initial approval of casting technique and subsequent checking of casting standards in several important applications, such as high pressure oil valves and steel castings for heat exchangers and other high temperature services.

The second system used in the steel foundries was the routine radiographic examination of steel castings as an acceptance test, and whilst that application could become very expensive there were cases in which it had been found to pay dividends. As an example there was the case of some cast steel gear wheels in which the teeth were to be cut directly into the cast steel rim, and without prior radiography one could run into considerable expense in machining only to find in the end that the wheel had to be scrapped. A further example was in the examination of cast steel stern frames, where gamma-radiography was used not only to determine the extent of cracks but also, after a welding repair, to ensure that no further cracks had developed.

With regard to the problems arising from the application of radiography Mr. Hislop had made a brief and cryptic reference to the effect that "every care must be taken to ensure that the processing of the films, especially in development, is carried out properly. It is very easy for defects to be obscured, or even simulated, by irregular densities due to faulty, or careless dark-room practice". That, in brief, was the whole snag in regard to radiography, particularly when it was applied to complicated steel castings. Perhaps in steel casting radiography, more than in anything else, engineers were in the hands of the radiographer. The interpretation of radiographs of steel castings required a knowledge of metallurgy and foundry practice as well as radiography. That reliance on the radiographer had been recognized at Lloyd's Register by the adoption of a system of approved radiographic establishments or laboratories, and in that system of approval, where not only the technique but also the equipment of the radiographer was very carefully vetted, it was felt that at least something had been done to ensure that the engineer's reliance on the radiographer was not misplaced.

Another problem was that of accepting or rejecting an article or a casting as a result of radiography. That was the engineer's problem and responsibility, and it was in that aspect that the engineer could be "led up the garden" by an enthusiastic radiographer who, whilst being a good radiographer—or a good operating radiographer—might have little knowledge of the significance of the defects he had revealed. Therefore he (the speaker) would advise an engineer never to specify radiographic testing unless he had a clear appreciation of the mechanical significance of the defects in materials and in welds, and unless he had made up his mind beforehand what he was going to do if defects were revealed. It was so easy to decide that one would have this or that radiographed by gamma-rays or by X-rays, but it was not so easy, having produced the radiographs, to decide what one was going to do about particular shadows which one only imperfectly understood.

Therefore it was necessary for the engineers to have a precise knowledge of what the shadows in a radiograph really represented, and that in his view could be facilitated by standard radiographs, such as had recently been produced by the American Society for the Testing of Materials, based on many examples which had been carefully sectioned and analysed. That was what he hoped would be done by the British Standard Committee on Radiography, of which he was the Chairman, and that in due course they would produce guidance standards for engineers in this country such as were available in America. This country was rather lagging behind not in industrial radiography, but in the formulating of standards of acceptance for weld and casting defects, which the engineers could apply in a broad way. Without accurate knowledge, and without a suitable criterion on which to judge acceptance or rejection, it was better not to specify radiography. If the engineers did not know the proper significance of radiographic shadows it might be better for his peace of mind not to know that they existed, for there was some truth in the old adage "for what the eye does not see the heart does not grieve".

MR. C. CROXSON said that whilst he would hardly go so far as Mr. Hislop in claiming that there had been many new developments during the past twelve months in gamma-radiography, it was certainly true that isotope sources were being increasingly used, and it was most important that their physical properties and correct methods of use should be given the widest possible publicity, and also that this should be done by well-qualified authorities who, as in Mr. Hislop's case, had first-hand practical knowledge and experience.

There were three main comments he would like to make on the subject matter of the paper. The first concerned protective source containers, which probably many people would continue to call "exposure bombs". The radium bomb had first been used for industrial radiography about twenty years ago at Woolwich, and its development in recent years had been peculiar to this country, in contrast with American practice whereby unshielded sources were mostly used and were suspended from cords or fixed in some other suitable way.

These bombs were quite efficient when they contained only, as they did for ten years or so, radium sources of from 100 to 250 milligrams of radium, but nowadays it was common practice to use sources of 500 to 750 millicuries and even, occasionally, of 1 or 2 curies. In the near future it was very likely that sources of several curies in strength would come into general use, and these strong sources introduced serious problems in protection. The size and weight of a single container were obviously limited by practical considerations and therefore the amount of protection that could be obtained was also limited, so that the use of a protective container might in fact give a false sense of security.

It was a very real problem, for while it was not impossible to keep the whole body exposure, in using such apparatus, within the limit of 0·5 röntgen per week it would be very difficult indeed to keep the dose received by the hands within the limit of 1·5 röntgens per week laid down by the International Committee on Protection. Taking the values for a 500 mC. cobalt source which were quoted by Mr. Hislop, the safe time for which the hands could actually be in contact with a container in setting up and taking off exposures would work out at no more than about nine minutes per week or about two minutes per day. That was not a very long time because, as every practical radiographer would know, in most cases it was quite impossible to avoid actually handling the container twice during each exposure, even though that might only be for a brief period. He was inclined to think that the method introduced at Woolwich in 1943 of using an unshielded source supported on the end of a rod three, four or even six feet in length, was on the whole a preferable method for strong sources. If the source was painted an orange colour then there was a close analogy with a red-hot rivet held in tongs, and the operator was constantly reminded to be on his guard. Special holders, of which one form had been demonstrated by Mr. Hislop, needed to be designed in order to give the necessary mechanical control and flexibility, and that was undoubtedly a field in which further development might be anticipated.

The second comment that he wished to make referred to the comparative cost of X-ray and gamma-ray radiography. It was sometimes claimed that gamma-radiography was the cheaper method, but the costs of laboratories, salaries of staff, consultants' fees, photographic films, and so on were common to both methods and were quite the major items in the overall costs.

His third comment was a criticism of Mr. Hislop's statement that in many fields of application gamma-rays gave better results than X-rays. In his opinion in the great majority of cases X-rays gave the better results. Gamma-rays were almost invariably a bad second to X-rays. He had noticed in the radiographs exhibited that the penetrameter sensitivity attained when using isotope sources was of the order of 3 per cent, as compared with less than 1 per cent of the X-ray radiographs of the same specimens. The gamma-ray results for uniform thicknesses of steel only began to approach those of X-rays for thicknesses above about 2 inch. The chief advantages of isotopes were their small bulk and the relatively simple radiographic technique, but against these had to be set the comparatively longer exposure times and the poorer sensitivity.

MR. D. J. DAVIES, speaking as a practising bridge engineer who had done a certain amount of war-time work on welded ships, said the point with regard to welding was that many would not believe that the inside of a weld was necessarily as good as the engineer said it was. In this country welding had not, to his knowledge, given much trouble in bridge work; there had been no bridges which had failed through welding, either to a small extent or a catastrophic extent. Nevertheless clients had to be satisfied, and perhaps after they had tried the radiographic procedure in certain instances they would gather confidence, having proved to themselves that the welding was satisfactory. They would then consider the use of radiography with discrimination afterwards, because undoubtedly the procedure did cost money.

The main issue seemed to revolve round the question which Mr. Pemberton had mentioned, namely the processing of the film and the interpretation of the results obtained. If his recollection was correct there had been a number of meetings of the Radiographic Society where acceptance standards had been discussed, but it seemed, so far as he knew, that no standards applicable to, say, structural work, as compared with high-pressure vessels, had been set down. That was answered to some extent by the fact that there had not been a great deal of structural bridgework done since the war, on account of the fact that the Treasury would not allow much bridge building in the way of capital investment.

The relation given by Mr. Hislop between the source of radiation in terms of electron-volts as compared with that from X-ray tubes had cast new light on the subject so far as he was concerned, and the half-life period which the author had mentioned raised a query in his mind. If one had a bridge site situated in the wilds somewhere, was it necessary to use an aeroplane in order to get the source to the site before the half-life had gone? Admittedly Mr. Hislop had stated that although the half-life was the main period, the source was not necessarily obsolete after that time; one could make further use of it but, of course, with longer exposure times. He had already been faced with this difficulty of getting a source to a distant isolated site, although afterwards the construction of the bridge had not gone ahead because of financial issues. In that instance the source was radon (it was before the Harwell isotopes became available) and it had been necessary to make provision for the rapid transportation of the source employed. The present use of iridium-192 made the question of source supply a much easier one, although he did not know, until the preparation of the paper, how the cost compared with radon sources.

It was not clear to him from the illustrations he had seen, whether the 2 × 2 mm. type of source was likely to be the most suitable type for structural work, i.e., material generally up to 2 inch in thickness. It appeared to be related in a rather complex manner with other factors, and possibly a little more time spent in studying the paper might provide the answer.

The image contrast for iridium-192 was a point to bear in mind in relation to acceptance standards. Engineers were rather in the hands of the radiographers on the question of selecting suitable types of source, but "higher image contrast" was a phrase which impressed him as something which would have to be kept in mind.

The issue of protecting personnel against exposure to lethal rays was a very important one. In dealing with bridge work, for example, one could not afford to have workmen kept clear of a bridge for a great number of hours because of tests by radiography. No doubt it could sometimes be arranged for the radiographic work to be carried out overnight, but in many instances bridge work was done overnight as well as by day, especially where there was railway occupation, and that particular point was one which would have to be related to either the use of gamma-ray tests or X-ray tests. A very recent example seemed to indicate that the latter might need as long a time as gamma-ray tests because it took so long to set up the apparatus. Therefore if it was intended to use X-ray testing this should be made known to the designer of the structural steel so that he could co-operate with the radiologist and arrange for portable attachments to be suitably located, and of a very simple type, so that the X-ray tube could be properly mounted in a very short time. It was no good having X-ray equipment hung up on pieces of rope, as although results could be obtained in that way adjustments had to be made which took up much time.

In making a comparison between gamma-ray testing and X-ray testing on two recent jobs, the cost of gamma-radiography had worked out at £5 per radiograph of 4 inch × 7 inch, which was a lot of money although, it must be admitted, there were only eight radiographs taken. In that case iridium-192 had been used, but in the case of a larger number of X-ray radiographs the cost had worked out at £3 10s. per radiograph. The latter figure had been influenced by the time spent on the site in setting up the apparatus.

In carrying out radiographic inspection the idea was to inspect as much work at one time with radon or gamma-ray as was possible with one source. That was the virtue of the gamma-ray method, whereas for X-ray inspection one had to move much heavier apparatus around the structure.

As compared with ship construction, a bridge structure was very much less complicated and an entirely different inspection technique had to be followed. Various welds might be tested with advantage in the ship, especially those under the stern where vibration was likely to be an important issue.

In any question of radiographic weld testing it was necessary to make a selection of those welds where one hundred per cent of them required testing, and those where a certain percentage of welds required tested more or less as sample inspections. In his experience it was essential to instruct fabricators that there was going to be radiographic inspection because welding procedure and the type of electrodes used might be different if radiography was to be subsequently employed. There was, of course, no excuse for bad welding; and whatever testing was to be done afterwards the welding was expected to be of a suitably high standard.

A bridge over a railway was a case where the radiographic inspection of welds on site would present certain problems in regard to site-occupation. The only times when traffic might be at all slack would be at certain times during the night or at week-ends, and then it might be necessary to arrange for a stoppage of the traffic altogether in order to carry out certain of the tests. The type of radiograph taken depended on whether it would be possible to use long exposure gamma-ray inspection or whether one would be obliged to use quickly set-up short exposure X-ray apparatus for such an inspection.

MR. K. C. BALMER, speaking as a user of gamma-radiography, said his firm were engaged in engineering contracts and the work was of such a nature that they had to be sure of a very high standard at all times. One of the most important uses of gamma-radiography had not been mentioned, and that was actually in testing and checking welders. It was an easy and quick way of obtaining a check. One could go to any part of the job and check a percentage—even if it was only ten per cent—of the welded work, and it would serve as a very good guide as to the quality which one was getting, and very often one could find out those particular operators who were producing work which was below standard. All the welders in his company were issued with a symbol which they stamped beside their work, so that they could be identified if it was found by gamma-radiography that their work was below standard.

With regard to the paper, Mr. Hislop might well have stressed the difference nowadays in gamma-radiography with the isotopes as compared with radium, particularly, and perhaps radon. The principal difference was that a source of very small size could be used, for example an iridium source 2 × 2 mm. in size. It was a cylindrical thing 2 millimetres in in diameter and 2 millimetres long, and because of that small size as compared with a 250 milligram radium capsule, which was about 6 × 7·5 mm., the definition was very much better and, as the author had said, the contrast was also better.

Another point was that the average X-ray tube, especially if of about 250 kV., had a target of about four or five millimetres, which again was larger than an iridium source, and one could get equivalent definition to an average X-ray tube with an iridium source or small source at a closer distance.

Dealing with the question of films, there had been recent developments in that field because the photographic firms had become more interested in gamma-radiography and they were now producing films which had been specially evolved for use with isotope sources. The films produced for X-ray work were not necessarily as good for gamma-ray work, and quite recently one film had been produced which, although it had certain disadvantages, was extremely fast and with it one could, for instance, in radiographing a pipe take a radiograph of a $\frac{3}{8}$-inch thick pipe in two minutes and, of course, the equipment itself was very much more portable than any X-ray set would be.

The author had referred to the density that one should work to in the case of films, and had said that some people went higher than a density of 3. Films of that density were very very dark indeed, and if a succession of them were put in front of a lantern the viewer would be alternately blinded by the very bright light which was necessary in order to see through them and then peering at the film to try and make out what was on it. On the whole people were tending to attach too much importance to this question of density.

Mr. Hislop had concluded his paper by saying that an X-ray set should always be used, if possible, on thin sections. He was not quite sure what the author meant by "thin sections" because he would have thought it was on a thin section where gamma-radiography could be very useful. The most serious defect that one could get in a weld was a crack, and on the thin section one was less likely to get a crack than on the thicker sections, so if there was any doubt about gamma-radiography at all the thin section was obviously the place where it could be used without any fear.

Finally, he would like to ask Mr. Hislop if he could help in elucidating some of the terms used, as there seemed to be a tremendous amount of confusion and he personally was not at all clear exactly what the terms meant or how accurate they were or how one could use them. He was referring to the relationship between milligrams of radium and millicuries in the case of isotopes, and milliröntgens when one was considering protection. He would like to know how those terms compared with X-ray units: what, for instance, was the output of a 400 kV. X-ray unit, expressed in milliröntgen units, from the protection point of view?

MR. R. L. DURANT drew attention to the fact that in the paper there was no information concerning exposure times with the various sources. This might have been intentional, although in Table 1 particulars were given which were relevant to estimating the comparative penetrating powers of the various sources, information which could be derived more satisfactorily from radiographic exposure curves. Incidentally the figures quoted agreed with those put out by the A.E.R.E., Harwell. The principal gamma-ray energies quoted for radium and radon appeared to bring them on a par, so far as radiographic contrast was concerned, with cobalt and tantalum; a fact which is roughly found in practice. Unfortunately these energies were not even the principal (i.e., the most intense) gamma-ray energies, which were 0·62 MeV. and 0·39 MeV., and which would tend to show that radium and radon gave higher contrast than even iridium; a conclusion completely at variance with the facts. It was found that the gamma-ray of the highest energy gave the characteristic contrast of each of the sources after penetration of the first half value layer or so, and for radium there was a gamma-ray of energy about 2·2 MeV., and in his experience this energy gave a truer picture of the contrast given by radium and radon. As far as the cobalt, tantalum and iridium were concerned, he was in agreement with the figures given by the author.

A further indication of contrast given by the gamma-rays was in the tenth-value thicknesses, although he did not know why the author had quoted it in lead because radiographers did not often come up against specimens of lead. Presumably those figures had been quoted from the protection point of view, and they did give an indication of the protection required for the different sources. Although radium and radon gave out more penetrating gamma-radiation than cobalt, the radiation from the latter seemed to get through the limited thickness of lead required for protection purposes with a greater intensity, and therefore the more equalized values given were a better indication of the amount of protection required for cobalt as compared with radon. In any case, in his view, those figures appeared to give an exaggerated idea of the amount of protection required for the different sources, since the tenth-value thicknesses varied with the amount of pre-filtration of the radiation, and in a different fashion for the four sources.

Mr. Hislop seemed to have a preference for cobalt, but there were one or two points in favour of tantalum, namely that it could be activated to a higher strength more quickly than cobalt and also that for a given activation time it gave sources of a higher specific strength, thus allowing radiographs of higher definition to be produced and on that count alone it was most useful for radiography. Its only disadvantage was in the short half-life period, although even there 120 days was very great compared with that of 3·8 days for radon, which had been more or less the standard gamma-ray source for many years.

The author had mentioned the fact that 2 curies or more of radon could be obtained, but it was not clear whether he meant that it was physically possible to get 2 curies within the 0·5 mm. cube or that sources of this strength could actually be bought commercially. He did not think that radon sources could be bought at such strength normally, and indeed it was undesirable that they should be made available owing to the protection difficulties.

In the section dealing with radiographic technique the author had mentioned very little about film, although he was glad to note that the author showed a preference for fine-grain film. It might be worth mentioning that fine-grain film could be developed for longer than usual, and became faster according to the amount of extra development, and might even be as fast as the faster non-screen types of film. The new type of film to which the previous speaker had referred was about twice as fast as normal fast non-screen film and would be useful when very thick sections had to be penetrated, and where its graininess and moderate contrast were not important compared with the increased speed.

The working density of a radiograph depended entirely upon the film; if a fast non-screen film was being used there was little point in having a density even as high as 2, but if a fine-grain film was being used where presumably the highest possible contrast was required then densities of up to 3 should be used, but he agreed that a density much above 3 was too great for normal viewing.

MR. J. W. COULTHARD (Member) said that his firm was called in during the previous autumn to deal with a large cast steel press cylinder which was found leaking. This cylinder, weighing several tons, worked at a pressure of 5,650lb. per sq. in. and was 3½ inch thick in the wall which was leaking. A small piece about 2½ inch long to depth of 1 inch was cut out and welded but the weld deposit cracked on cooling so this too was cut out. Cutting a little deeper exposed extensive porosity until finally it was necessary to cut out a cavity 14 inch × 3½ inch × 2½ inch deep each side of the cylinder. It was found that the porosity consisting of holes up to ½ inch in diameter was some 1½ inch thick mid-way through the wall. and covered a large area. Owing to the size of the cylinder and the job of dismantling it it was decided to attempt to repair in place. The temperature was raised to about 200 deg. F. by steam at atmospheric pressure, the only safe method on the site owing to fire hazard. Welding of the cavities was then commenced but before fully closed up it was found that the parent metal was cracked adjacent to the edge of the weld. It was obvious that the casting was too brittle to weld on site and it was agreed to dismantle the cylinder and also to obtain an analysis of the steel.

Before making a further attempt on the repair under more favourable conditions they were asked to arrange for tests to ascertain the extent of the porosity to see if the cylinder was worth repairing. Thinking in terms of X-rays they had scoured the southern part of the country for equipment capable of dealing with 3½ inch thick steel and finally were put on the right track by the National Physical Laboratory who suggested the Armament Research Department. Mr. Croxson of that Department had very kindly taken a great deal of interest in the job and suggested using gamma-rays. Gratefully accepting the offer to help he had asked what was the procedure, the reply was "Get it down, put it in a store where nobody can get near it for twenty-four hours and leave the rest to us". That was done and, using a radon source and fine-grain film, a series of gamma-radiographs were developed in order to find where the porosity was. As the cylinder had been carefully marked to correspond to each section of film it was possible, by taking four exposures, to cover the periphery over a large area. From the radiographs it was possible to visualize the interior of the wall, pin-pointing the porosity, so that whilst cutting away the defective weld and adjacent metal to reach sound material it was found necessary to extend the cavities each side to a distance of 18 inch and 5½ inch wide and to cut right through the wall to the inner face.

The question of the welding of this cylinder was another story but, very briefly, although the carbon content was found to be of the order of 0·45 per cent a successful repair was made by placing it in a fire-brick muffle and maintaining it at a temperature of 600 deg. F. whilst welding continuously.

It would be noted that the cylinder was 3½ inch thick and owing to porosity had lost 1½ inch in effective thickness yet when the owners had applied to five manufacturers for quotations for a new cylinder three of them had written back saying it was too thin and should be made 5 inch thick to withstand the working pressure. This cylinder had been working for nine and a half years.

Possibly some designers allowed a fair margin for defective castings. One was therefore brought to the serious consideration of radiographic testing of welds and the question of acceptance limits. He had been reading recently that owing to the high rejection of welds showing the minutest inclusions of slag proving uneconomical it had been necessary to accept something less than perfection.

This would suggest that the authorities concerned might be asked to state what could be regarded as safe limits having in mind that steel as rolled plate, forged or cast could contain undesirable defects.

For instance, when radiographic tests of steel castings were asked for the price went up; he believed the steel foundry people were reluctant to accept such tests since it was difficult to avoid all porosity.

He was in agreement with a former speaker who had mentioned that if welds were to be tested with X-rays or gamma-ray apparatus the welders should be told, in fact, any form of projected test if known to the operator would ensure the best possible results. Good welders would produce consistently good results whether their work was to be tested or not.

Mr. R. V. Walker said that Mr. Hislop gave the impression, and it was rather an unfortunate impression, that the question of the radiography of pipe welds and the position of the source and the examination of pipe welds was much debated. The last three words were the author's own, and the impression left was that the debate was over the radiographic quality produced by the position, one, of the source inside the pipe and, two, outside the pipe. He felt that impression should be dispelled as soon as possible by saying that the debate was likely to cease after comparison between radiographs obtained by the different methods, the first with the source inside the pipe, on the axis, and the second with the source outside the pipe, using the double-wall technique; the judgment to be passed solely on radiographic quality. He was certain that such a comparison would result in agreement that placing the source at the centre of the pipe produced a far better radiograph.

From the point of view of economy, placing the source at the centre of the pipe shortened the source-film distance—in fact it halved it at least—and the source size also had to be reduced by half. The effect of those reductions on exposure time cancelled out: by placing the source at the centre the exposure time was reduced in two ways—one by the fact that the radiation had only to pass through one wall thickness, and the second—and very useful one—by the fact that there was only one exposure necessary, and in the case of an examination using gamma-ray sources that saving was considerable because the exposures did tend to be rather long. A further factor was that by placing the source at the centre of the pipe the interpretative difficulties which sometimes arose due to obliquity were removed by there being in fact no obliquity whatever.

Wherever possible he would always place the source at the centre of the pipe, and he had spent many hours attempting to design a source-holder which would enable him to do that in the case of 1-inch, 2-inch and 3-inch bore pipes. He had to give it up ultimately, not from the point of view of there being any particular difficulty in getting the source there but for other reasons rather outside the scope of that discussion. However it was quite clear to him that the only debate would revolve around the practicability of placing the source in the centre of the pipe.

Perhaps the greatest advantage attached to the introduction of gamma-ray sources was that they gave an opportunity for the examination of pipe welds in situations where it was extremely difficult to get an X-ray set.

Mr. R. G. Burt said that naturally the British Welding Research Association were very interested in gamma-radiography, as they were in all non-destructive methods of test. In fact they had a Committee dealing with that subject at the present time.

The author had mentioned that iridium-192 was suitable for thicknesses up to 2 inch, but he had not mentioned the downward limit. He believed it was correct to say that iridium-192 could now, with the improved techniques being used, give radiographs which were comparable to the standard required for Class I pressure vessel work down to ½ inch thickness. Perhaps Mr. Hislop would be good enough to confirm that.

It had also been said that gamma-radiography was very useful if it could be used in non-working hours, and there was an interesting point there in that apparatus had now been developed by which the exposure could be given automatically by an electrically operated mechanism actuated by a time-switch, so that the time of commencing and finishing the exposure could be pre-set. This also dealt with the point of the desirability of developing a mechanism which would reduce the handling risk raised by a previous speaker.

They had heard vague rumours of a new technique in gamma-radiography, originating, he believed, in America, by which radio-active isotopes were introduced and a geiger-counter was used on the outside, but they had no details of the method at all. He imagined it was a technique designed to give a quick scan of welds, and with possibly spot radiographs afterwards, but perhaps Mr. Hislop would be able to give them some information on the subject, for which his Association would be very grateful.

Correspondence

Mr. H. W. Hogben (Associate) wrote that as a potential user of radio-active isotopes he had read the paper with interest. He would have liked to see, for purposes of comparison (a) radiographs of the same object taken with X-rays and different radio isotopes; (b) radiographs of a defect with varying film densities. Gamma radiographs showing various common types of defects would also have been interesting. Perhaps the omission of these was due to the fact that radiographs lose definition and contrast on being printed.

More details of the gamma-ray container would be welcomed. As far as he knew, the isotope was contained in a small aluminium alloy capsule sealed with a glass cover. Presumably this capsule was supplied by Harwell in a protected package. How was the isotope capsule extracted from the package and affixed to the rod (shown in Fig. 2) without exposing the operator to an overdose of gamma-rays?

From the left-hand photograph on Plate 4, it appeared from the position of the rod inserted through the pipe and the relative offset position of the film, that the rod was linked and that the linked portion (carrying the source) could be turned through 90 deg. by remote control to bring the radio isotope into the correct position. It seemed that much might be done in the way of intelligent design of fixtures, in view of the varying nature of the objects to be examined, in order to ensure that the source was placed in the ideal position. The time that an operator needed to be exposed to the source, during setting up for an exposure, might be reduced materially by the use of dummy containers, etc. A dummy container or rod could be accurately positioned and adjusted, and when the correct position had been settled the dummy could be replaced quickly by the actual source container and no further time need be spent on adjustments.

In order to avoid, as far as possible, penumbral effects on the radiograph it was desirable to use the smallest source available. With a 2 × 2 mm. iridium-192 source the saturation point of irradiation appeared to be about 750 mC. in twenty-eight weeks. It was, therefore, rather difficult to depend upon an alternation of only two sources, unless one was prepared to go to long exposures with the "working" source when its activity had been reduced to a small proportion of the original. Would the author advise changing over to 4 × 4 mm. sources or increase the number of 2 × 2 mm. sources being used in rotation?

Would the author care to stipulate a definite thickness governed by his conclusion "for thin welded sections an X-ray set should always be used if possible"?

The author had, perhaps wisely, avoided the subject of radiographic interpretation, although it was realized that this facet of radiography was not peculiar to gamma-rays alone. Radiography had one initial drawback as an inspection tool—

there were no standards by which one might reject. A firm, installing gauges and testing machines in their inspection departments, knew that a criterion was established by which individual parts might be accepted. In many cases no skill was needed in the use of such gauges and machines. With the installation of gamma-ray plant, or costly X-ray sets, definite results (as regards 100 per cent assessment of the radiograph) would be obtained only when the radiographer had had vast experience of this work. It was desirable, therefore, that a radiographer, or a radiologist as he believed he should be called, should have some knowledge of foundry and welding technique in addition to that of pure radiography.

He was glad to notice that the author pointed out that the availability of radio isotopes had not rendered obsolete the employment of X-rays. It could not be emphasized too strongly that both gamma- and X-rays had an important part to play in engineering inspection. Other non-destructive methods of testing, such as crack detection, should be employed also when suitable.

MR. K. V. TAYLOR (Graduate) wrote that the recent progress in the manufacture of artificial radio-active substances would undoubtedly favour the use of gamma-radiography, particularly as the smaller shipbuilding firms were not in favour of spending large sums of money on expensive X-ray equipment. An outlay of several hundred pounds was viewed with more sympathy than several thousand pounds. With a more plentiful supply from Harwell, firms might be encouraged to make more use of gamma-radiography and the author's paper gave valuable information not only for the nature and size of sources available, but also on the techniques used and the protection of operators and workmen. However, while cheapness was a good reason why gamma-radiography was likely to increase, as far as the examination of ships' welding was concerned a 150 kV. X-ray set was far more useful than several gamma-ray sources for thicknesses up to 1¼ inch and where there were no inaccessible spaces.

He had only one small criticism to make of the paper and that was it would have had added value if the actual subject of examination and interpretation had been discussed together with the difficulties experienced in radiographing various types of welded connexions and the minimum standard required for acceptance. Naturally the author's work did not confine him to marine engineering and he had many other problems to tackle, but these questions greatly concerned the shipbuilders especially as more and more of the ship's structure was being welded. At present Lloyd's Register of Shipping required only the radiographic examination of pressure vessels, but the day might come when the shipbuilder would be required to submit radiographic proof of his welding before the vessel was classified.

MR. L. J. SAYER wrote that he wished to draw attention to the undesirability of using excessive development as a compensation for under exposure or in order to increase density. The absolute maximum should be about seven-eight minutes for fine grain type film, and about ten minutes for ordinary non-screen type film. If developed longer, graininess would result. Over-development was practised in some quarters, and he was sure the author would agree in strongly deprecating it, and in warning against the possible misintepretation of his remarks on exposing two films in one cassette.

He would also like to emphasize that the source strength sizes of the isotopes given in Table 1 were based on an irradiation time of twenty-six weeks and were not the maximum. In the case of iridium, for instance, a strength of 1·5 curies in a 2 mm. cube was quite practicable, with a source prepared in the Harwell pile. Later on considerably greater strengths would be feasible. The relationship between these isotopes would perhaps be clearer were the specific strengths related to a time of irradiation equal to the half-life.

Author's Reply

MR. J. D. HISLOP, replying to the discussion, said that he would take the points more or less in the order in which they had been raised. Mr. Pemberton had first asked how true it was to say that iridium always gave the best results of the various gamma-ray sources, but it was very difficult to give a general answer to that question. There was no doubt that providing no other factors entered into it but steel thickness, then up to a limit iridium certainly gave very much better results, and his own preference would always be to use it. That limit, as had been mentioned later on in the discussion by Mr. Burt, was usually quoted as about 2 inch of steel, but it did depend on quite a wide variation of other factors, the main one being what did one want to see? In other words how fine or coarse a technique was one prepared to use? The finer the technique the lower were the limits, in general, and consequently the limit of thickness was bound up with the final technique. The thickness limit, which, of course, applied to X-rays too, could never be stated explicitly. The fact was that the economic limit depended upon the technique one was prepared to use: if one was prepared to use a low film-density, coarse-grained film, short source to film distance, and so on, the limit was raised considerably; but if one wanted the finest possible film, lead intensifying screens and long source to film distance, then the limit was correspondingly down. 2 inch was normally quoted because that was the thickness which was economic using the sources which were obtainable. 1 or 2 curies of iridium could now be obtained, and up to 2 inch of steel exposure times were reasonably short. Provided one was prepared to wait one could use iridium for even greater thicknesses.

With regard to the question of applications, he had deliberately avoided any detailed suggestions since he knew there were people present who were very much more qualified to talk about the engineering side. Consequently he agreed entirely with what Mr. Pemberton and others had said about the various ways in which the technique could be used, not only as an acceptance test but also as a quality control for welding methods and foundry technique. In addition there were many applications which he could not mention specifically but which they would all be able to think out for themselves.

The questions of the qualifications of the radiologist, and the dependence of the engineer on the radiologist could only be solved by all the engineers learning all there was to know about radiography. Steps had been taken to ensure that at least most inspectors and engineers knew something about the techniques, but he was sorry to say there were a distressing number who knew very little, and radiologists were often expected to be experts not only in their own field but also in metallurgy, engineering, and so on, and even where they were not specifically asked to make a decision they were usually expected to give all the necessary information which would make the decision clear-cut for the engineer.

The problem of radiographs showing acceptance-standards was one upon which a lot of time, energy, heat and expense had been expended by all sorts of people, and he could only give his own opinion. This was that the only field where reasonable acceptance-standards could be laid down was that of Class I work—Class I pressure vessels and castings. There it was simple; if the surveyor saw anything in the radiograph it was cut out and repaired, if they saw nothing it was all right, and provided the radiograph was up to standard (which was very important) they did have a clear-cut decision. Admittedly there were border-line cases where the inspector could use his discretion and usually left the defect in, but generally speaking anything visible at all was cut out as a matter of course. Once one got on to the question of acceptance of defects which were visible radiographically it was invariably true to say that the inspector's opinion was final. Certainly the inspector should be guided by a knowledge of radiographic and engineering principles but in the long run, although he might have standard radiographs or mathematical rules he still would be guided to a great extent by intuition.

Referring to Mr. Pemberton's remark that it was sometimes better not to know what was wrong with a product, that was an attitude which he met time and time again. He would ask a manufacturer why he was not using radiography and the reply would either be that his products were so good that it was unnecessary or they were so bad that it was pointless! It was very important that when radiography was specified due attention must be paid to the problem of whether they were going to be able to make use of the results when they had obtained them. If they could make good use of them he would say "Go ahead and take radiographs", but if they were to be in the dilemma of not knowing what to do about the defects, and then, as usually happened decided that they could not do anything, it seemed quite futile to waste time and money in getting information of which they could not make use, and which only created doubt and uncertainty. In that event it was better to leave well alone.

He had agreed entirely with all that Mr. Croxson said, except that some misunderstanding had arisen on the subject of X-rays versus gamma-rays. He agreed that from the fundamental radiographic point of view there were very few cases where gamma-rays had any advantages over X-ray sets, but from the economic point of view of how cheaply to obtain the results which were required—not necessarily the best results but the results which were required—there were now many cases where gamma-radiography had a decided advantage.

With regard to the question of cost, he agreed that the standard cost for staff and laboratories was more or less the same for both types of work, except that the protective structure which was required for gamma-ray work might be less expensive, since, in general, protective structures were not of great value because of the low absorption of building materials and the relatively large effect of distance. In fact in most examples much more advantage was obtained from the thickness of a wall than from its absorption.

As to having the source unprotected, he could see that in certain circumstances to have a source on the end of a rod at a given distance and emitting a known intensity of radiation was a convenient handling technique, but there were many cases where that sort of handling could never be carried out. On site work, particularly, one very often had to handle sources in cramped positions, and with iridium the dosage on the surface of the container could be much below that which the human frame could tolerate, whereas if the source were on a rod the operator would still have to remain three, four, five or six feet away as the case might be. With sources of more energetic radiation it was a distinct problem to know exactly how far to go in protection. Containers weighing up to 50lb. were reasonably manageable on site but anything larger than that began to get a bit unwieldy, and it was doubtful whether one would gain very much by increasing the weight to 60, 70 or 80lb. By such an increase the necessary handling time would be increased and there would be greater exposure of the operator, so that in the end one might have gained nothing at all. In his opinion 50lb. was a practical limit under these conditions and anything over that was liable to make handling times much longer than they need be.

Mr. Davies had said he would like some explanation as to the relationship between the voltage on the tube and the MeV. value of the radiation, but in fact he never liked to say that a certain radiation from a gamma-source was equivalent to a certain X-ray because the two types of emission were quite different. It was a very approximate statement that a tube working at one million volts was approximately the same as gamma-radiation of 1 MeV. The differences were so fundamental that one could not, to be scientifically accurate, say that certain figures were equivalent, and radiologists were only making a rough approximation when they said that cobalt radiation, which was on the average 1·2 MeV., would be the same as that from an X-ray set working at 1,200 kV. It was not really very significant but it was something which they just could not equate.

Referring to the question of the usefulness of the source up to and after the expiration of the half-life, it depended a great deal with what one started and what one was prepared to tolerate in exposure time. If one started with an exposure which was shorter than one could tolerate it was possible to go on using the source during several successive half-lives until the exposure time became either uneconomically, or impracticably, long.

The question of source dimension or possibly that certain sources were more desirable than others, was something which again depended a great deal on the application. There was no doubt that starting from scratch, with no source at all it was better to use a big source provided the source-to-film distance was not restricted. Provided one could use as long a source-to-film distance as one liked it was definitely more economic to use a big source. Starting with a source of zero activity, and using 6 × 6 mm. instead of 2 × 2 mm. one got, in a given time, 27 times more activity in the 6 × 6 mm. than one did in the 2 × 2 mm. since activation was a volume effect. For a given job one then had to use a source to film distance which was three times greater in order to achieve the same degree of definition, and that meant a nine-fold increase in exposure. But one had 27 times more intensity so one was gaining by a factor of 3. When one came to a restricted source-to-film distance, such as for the examination of pipes from the inside (and there were other cases where the source-to-film distance was limited) then quite obviously the source had to be chosen according to this distance and the metal thickness. If one had a pipe of a certain thickness and diameter, then theoretically one should calculate the size of source required purely and simply on that geometrical basis to produce a radiograph of adequate definition, but his own contention was that provided one had unlimited source-to-film distance the larger the source the better. There were limits of course set by protection difficulties among other factors, but it was something which a great many people did not realize, or at least did not use to the full advantage.

He had already commented on acceptance standards but he should add that it was important to remember with standards of any sort, either interpretative standards, which he considered were very useful, or acceptance standards, which he did not think were so useful, that it was necessary to specify the radiographic technique as exactly as possible. The group of standard radiographs, which had been produced by the A.S.T.M. gave a whole series of illustrations showing what different defects looked like, without the slightest mention of the radiographic technique used. As many of them would know from experience, one specimen could be examined by three, four or five different methods and radiographs produced which one would not believe, at first sight, to be of the same specimen at all. So to produce a whole series of pictures saying "This is acceptable" or "This is not", without any mention of the technique which had been used, was just a waste of time. It was to be hoped that the British Standards Committee would specify the radiographic techniques at the same time.

The question of the use of sources and X-ray sets on sites brought up a lot of problems, and it was probably true to say that every case ought to be treated on its merits. It was very difficult to lay down hard and fast rules even on simiIiar jobs: conditions might be quite different because the job was being done in a hurry and the welders, stagers, painters, and all other operatives would give the radiographer no adequate time or space to carry out his work. Provided reasonable care was taken in fitting radiography into a construction programme it could be done quite efficiently and well by experienced men who were able to say to other trades "Go away for half-an-hour now and it will save a delay of four hours later on".

The design of units and accessories for a given examination was very important and it was usually necessary to adapt standard apparatus to suit each particular job. He had yet to find two jobs which needed the same equipment, accessories or handling technique, and provided one was prepared to sit down before the job began to design suitable tube supports, etc., then as much as fifty per cent of the time to be spent on a given job might be saved.

Referring to Mr. Balmer's contribution to the discussion, the psychological effect of knowing that radiography was to be carried out was very important. It had once been said by the then Director of Naval Construction that one had only to show an X-ray set in a shipyard, expose some fims and throw them away, for the standard of welding to go up one hundred per cent. That was undoubtedly largely true: provided people knew that there was a method of inspecting their work they would produce better work in consequence. If due notice was taken of the radiographic findings by the people responsible for construction procedure and supervision then, of course, the quality of the work would go up five hundred per cent.

He thought personally that only quite a small percentage of the trouble was due to the welder himself; especially in constructional welding, other trades concerned in putting up the steel work and preparing it for the welder were usually a lot to blame. The welder was considered mainly as a man to fill a hole, and if the hole was a bit bigger or smaller than he required, it was of no importance. Under those conditions no amount of good work on his part would produce a good result.

On the question of fast film and high film-density he admitted that there were ways and means of producing adequate results without having a film which was so black that one could not see through it under normal illumination conditions; but there was no doubt that there had been for the past ten years a distinct increase in the average density to which radiographs were exposed, and also there was no doubt that any increase in density did produce an increase in the contrast of the radiograph, which was often very useful. Whether or not it was wanted was something which one had to consider on every individual case, but he certainly thought that densities up to 2 should be retained, and with non-screen film densities up to 3. Mr. Balmer had mentioned that he was blinded by the bright light and then had to peer at the black films: it was certainly necessary to have a strong light, but one should on no account remove the film and leave the light switched on. Careful control of the illumination and the screening blinds, must be maintained, both when the film was in position and also when it was taken away.

There was a great deal of dispute between the various authorities on the subject of units, and he would do his best to explain it. In the first place, the milligram was a weight; and a one millgram source of radium contained radium which weighed one milligram. Since the emission from radium was directly proportional to its weight it could be used as a unit of gamma-ray intensity. However, with radon, which was the next source in order, one could not use weight because radon was in fact a gas, and so the millicurie was introduced, which was originally a comparison between radium and radon. 1 millicurie of radon was equivalent in gamma-ray emission to a milligram of radium. When artificially active substances came along, and for other naturally occurring gamma-ray emitters, the millicurie was still used. What they meant by one millicurie of cobalt was that the cobalt source was disintegrating at the rate of $3{\cdot}7 \times 10^7$ atoms per second. The intensity of gamma radiation emitted by a source could be expressed in the rhm. unit, or the number of röntgens per hour at a distance of 1 metre. A more usual unit was the milliröntgen per hour at 1 metre and this was used in his paper. The only difficulty about the rhm. was that if they had 0·25 milliröntgens per hour per millicurie of iridium and 1·3 milliröntgens per hour per millicurie of cobalt it did not mean that the radiation from one was five times more effective radiographically, or five times more dangerous from the protection point of view, because the question of quality had also to be considered.

The amount of radiation from sources of iridium and cobalt of equal rhm. values, after passing through a thickness of absorbing material would be entirely dissimilar. Thus there were two things which had to be quoted in order to give some idea of the radiographic effect of, and the protection needed by, a given source, viz.: the emission in terms of rhm's, and the absorptive value of any metal one liked, which was an indication of the penetrating power of the radiation. He was using in his paper the tenth-value layer in lead; he could have used any other metal, or any other attenuation but it would not have told him any more and it was not the usual practice.

The query about the output of an X-ray set had completely defeated him. He could only make reference to the last chapter of the Handbook of Industrial Radiology where the output for X-ray sets working at various voltages was given:—

Output of X-ray sets at various Kilovoltages

100 kV.	Constant potential 0·5 mm. Cu filter	160	mr. per min. per mA. at 1 metre.
250 kV.		1,900	
1,000 kV.		33,000	

As far as Mr. Durant's remarks were concerned, he would refer at once to that gentleman's excellent papers which had been published quite recently in the Journal of Scientific Instruments, in which he had gone very fully indeed into what could be done with films, and he had given an enormous amount of data. The variations in speed, contrast and graininess of films with development time were very important and all these facts were given in the papers by Mr. Durant. They were something for the practising radiographer to use with discretion, and certainly after a little of his own experience. He had not thought it wise to put them into a paper of the type which he had prepared, but it was as well to have one's attention drawn to the fact that things were not so straightforward as a lot of engineers sometimes thought.

As far as his own figures were concerned he had admittedly taken some of them directly out of catalogue No. 2 issued by the A.E.R.E. and some of them were rough calculations of his own. He could not assume that the Harwell results were completely accurate and beyond saying that they did give the overall picture quite adequately, he made no claim for them. They might quite well be in error in some respects. As for the tenth-value layers, he had no first-hand experimental knowledge to show whether those figures were right or wrong, but leaving other things out of consideration his own feeling was that cobalt radiographs were generally less contrasty than those made with radium, despite the fact that the cobalt radiation was considerably less in maximum MeV. The two gamma-ray energies quoted were only two out of about twenty-five, and if he had not given the two which were the most intense he had picked the two which gave the best sort of impression of the overall penetrating power of radium radiation.

The way in which the penetrating power varied with the degree of filtration was known very well. The first half-value layer was not nearly so great as the second. This was due to the elimination of the softer gamma-ray components by the initial filtration and the consequent effective hardening of the radiation.

The question of the possibility of using 2 curies of radon had been raised, and he could assure them that he had used a 2 curie source of radon and had obtained it commercially, but he did not know whether he was being given something which could not have been given to anybody else; he hoped not. 2 curie sources certainly had been used and they had been obtained from the standard place for getting such sources.

Mr. Coulthard had talked about acceptance standards and the reluctance in certain quarters to accept radiographic inspection mainly because acceptance standards were too high. However, provided it was not always used as an acceptance, or rejection, technique both foundrymen and welding engineers could use radiography far more than they did at present, and provided it was used in the proper way and every use was made of the information obtained then it could not do anything but good to both fields of engineering.

Referring to Mr. Walker's remarks about pipe-weld examinations he agreed that whenever it was possible the source should be placed inside the pipe, either on the axis or to one side when necessary. The debate which was mentioned centred around the validity of introducing the source through a specially drilled hole which had to be sealed afterwards, and this was definitely a problem. One did meet engineers who just would not have a hole drilled, and others who were only too glad to do it. The examination of the sealed hole had to be done through the double-wall, and it was important that it should be radiographed. There was no doubt that it was always preferable to put the source inside if it could be arranged. It did limit one in source-to-film distance, and the dimensions of the source should be chosen to give adequate definition. He had already dealt with the question of the effect on exposure of the different sized sources, but in this case the main issue was one of radiographic quality.

Mr. Burt had asked about a lower limit for the use of iridium. There was, of course, no rigid lower limit for using radio-active sources, just as the upper limit was also ill defined. The upper limit was always set by what one could tolerate in radiographic quality and exposure time, but the lower limit was fixed by how far one was prepared to go in the one-sided race between the clarity of X-radiographs and gamma-radiographs. In general as the thickness decreased so the disparity in the results of the two techniques got wider. Starting at very small thicknesses the X-ray result was infinitely superior to anything that one could get with gamma-rays, and as the thickness increased so the quality of the results became comparable, until with even greater sections one would probably find gamma-rays producing better radiographs. It depended a great deal on the X-ray equipment which was available, but in all cases it would be found that one was catching up on the other and possibly finally overtaking it, from the viewpoint of radiographic quality.

With regard to geiger-counters, he did not know very much about the possible application of the latter to welding examination although offhand he would feel rather doubtful about it. They had been used, however, both on the continent and very recently in this country, for the rapid screening of large castings for relatively large cavities. As for time switching devices, if for any reason one wanted to make a six-hour exposure in the middle of the night and one did not want to be there at midnight to start it and at six a.m. to finish it, then he would agree that a time switch would be useful, although he would prefer to increase the time and make it a sixteen-hour exposure with corresponding adjustment of source-to-film distance. A better radiograph would be obtained and one would not have to get up so early or go to bed so late! Others might find that time switches behaved perfectly for them, but they never did for him.

It was very true that radiographs lost a great deal in the process of reproduction and it was for this reason, as Mr. Hogben suggested, that no radiographs were reproduced with the paper. There had been a number of exhibits on show at the meeting and he would be pleased to show them to Mr. Hogben if the opportunity arose.

There were various types of source-container commercially available and all differed in detailed design. It was, however, necessary that the source should only be handled remotely. When a container was loaded initially, the source was usually handled by long tongs, but once loaded, handling rods such as those illustrated were used for the manipulation of the source for radiography.

He agreed that every care should be taken to make all preliminary adjustments of source position with a dummy container, to reduce the handling time of the active material. It was also essential to use a handling method which did not expose the operator to excessive quantities of radiation, and accessories such as those illustrated in Plate 4 had been designed to this end.

The question of optimum source size had been discussed earlier and it was not necessarily the best practice to use 2 × 2 mm. sources. If, however, it was necessary, then it might well be that more than two sources would be required. That was a question which must be considered in the specific circumstances. Although it took 28 weeks to saturate a 2 × 2 mm. iridium source, at 750 mC., it could be activated to about 500 mC. in a single half-life.

He had already dealt with the limits, both upper and lower, for the use of gamma-ray sources and it was only a generalization to say that if possible an X-ray set should always be used for thin welded sections. The decision usually hinged on the possibility, and not on the thickness.

He agreed with Mr. Hogben that there was no easy criterion of acceptance or rejection as a result of radiographic inspection and this might be regarded as a drawback. But his own feeling was that with radiography one could learn not only whether a product was unacceptable, but why. It was naturally very important that both radiographer and radiologist should know something of the item under inspection and the method of its production, so that the former could take the radiographs which would reveal the critical flaws, and the latter could correctly interpret them.

The author agreed with Mr. Taylor that an X-ray set could be used to better advantage on ships under construction than gamma-ray sources, where inaccessibility was not a problem, although this depended on the suitability of the X-ray equipment. However, at least one large shipbuilding firm had ceased to use anything but iridium for radiography on the building slip and it was contended that the saving in handling time, cranage and special services made it an attractive proposition. The output of radiographs was maintained, despite the longer exposure times, due to the reduction in the time spent in handling and setting up. His own opinion was that firms should have both facilities available for use in their proper spheres, but should rather have only one than neither.

He had avoided the cataloguing of welded joints and the methods used in radiographing them since the number of such examples was legion. In confining himself to general principles he had been unable to deal with all the complications of structural welding although it was perhaps fortunate that of recent years there had been a tendency to use butt-welding as much as possible, and not to indulge in so much of what he had heard described as "metal-joinery". The butt-weld was the simplest to radiograph satisfactorily, but the difficulties inherent in fillet weld examination were considerably reduced when gamma-rays were used.

Mr. Sayer's remarks on the inadvisability of over development of gamma-radiographs were very true. It was always best to err on the side of over exposure and either slightly reduce development time in consequence, or better still make use of the higher density so produced with improved viewing illumination. The main reason for the use of two films was to avoid the misinterpretation of spurious shadows, an ever present danger. Not only did increased development tend to increase the graininess of the film, but it also increased the fog level.

INSTITUTE ACTIVITIES

MINUTES OF PROCEEDINGS OF THE ORDINARY MEETING HELD AT THE INSTITUTE ON TUESDAY 13TH MARCH, 1951

An ordinary meeting was held at the Institute on Tuesday, 13th March 1951, at 5.30 p.m. Mr. W. J. Ferguson (Member of Council) was in the Chair. A paper entitled "Gamma-Radiography in Shipbuilding and Engineering" by Mr. J. D. Hislop, M.A., was read and discussed. Fifty-one members and visitors were present and eight speakers took part in the discussion.

Mr. C. C. Pounder (Vice-President, Belfast) proposed a vote of thanks to the author which was accorded with acclamation.

MEMBERSHIP ELECTIONS

Elected 7th May 1951

MEMBERS

Leonard Barnett
Maurice Bluet
Frank Bottomley
Jacob Edward Burnett
John James Westwood Bryne
Franciszek Jozef Czelusta
Thomas Grieve
Kenneth Humphrey Ingram
Frederick Ernest Inman
Samuel Haslett Morrow
David Muir
Edvard Otto Ryssel
Ernest Keener Simpson
Albert Sutherland
Kai-ng Tsang
Edwin Frederick James Woods, Com'r(E), R.D., R.N.R.

ASSOCIATE MEMBERS

Gordon Foy
Ernest Edwin Houlden

ASSOCIATES

Thomas Denny Armour
Gordon Leslie Bruty
Peter Atkinson Dale
Ahmad Fat'hi Mohamad Hassan El Mougy
Albert William Greathead
John MacDonald
William Arthur Henry Martin
George Richmond Matthews
Mushtaq Ahmed Khan Niazi, Sub. Lt.(E), R.P.N.
Kenneth Deans Kerr Oliver
John William Oswald
Ezio Panetti
Mangalasseril Varkey Philippose
George Gardner Pirie
Robert Prestwich
Terence Patrick Joseph Roche
John Derry Spittle
Robert Gordon Taylor
Johan Wilhelm van der Valk
John Weldon
Ronald Aubrey Wood

GRADUATE

Frank Cresswell

PROBATIONER STUDENT

Tirloki Nath Bhargava

TRANSFER FROM ASSOCIATE MEMBER TO MEMBER

John Charles Robert Sundercombe
Wilfred Marshall Newton

TRANSFER FROM ASSOCIATE TO MEMBER

Edulji Rustomji Dastoor
William Wright Martin
Douglas Parks
Percival George Partington
David Whitton

TRANSFER FROM GRADUATE TO MEMBER

Donald Arthur Keable, D.S.C., Lieut.(E), R.N.

TRANSFER FROM GRADUATE TO ASSOCIATE

Ernst Gabriel Frankel, B.Sc.
James Beatson Lewis

TRANSFER FROM STUDENT TO ASSOCIATE

Bernard Valentine Hill

OBITUARY

WILLIAM ANGUS BLACK (Member 10322) was born in 1901 and educated at a local Higher Grade School and the Marine School, South Shields. He served his apprenticeship with the Palmers Shipbuilding and Engineering Co., Ltd., Jarrow-on-Tyne, from 1917 to 1922. In 1926 he joined the Elder Dempster Steamship Co., Ltd., Liverpool, transferring to the Anglo-Saxon Petroleum Co., Ltd., in 1928. He obtained his First Class (Motor) B.O.T. Certificate in 1935 and was promoted Chief Engineer in 1940. He served with the Anglo-Saxon Petroleum Co., Ltd., until the time of his death which occurred on 15th March 1951. He was elected a Member of the Institute in 1945.

GEORGE COUTTS (Member 9279) was born in Aberdeen in 1893. He served his apprenticeship with Clyne, Mitchell and Co., Aberdeen, and joined the Andrew Weir Shipping and Trading Co., Ltd., in 1916. He remained with this company obtaining his First Class Certificate and rising from 4th Engineer to Chief Engineer (1926). He was promoted Superintendent in September 1939, which appointment he held until his death in November 1950. He was elected a Member of the Institute in 1941.

ALEXANDER BROWN EDMOND (Member 9718) was born in 1901 and educated at Woodside Higher Grade School, Glasgow, and at Glasgow High School. He served his apprenticeship from 1918 to 1924 with Clarkson and Beckitt, Glasgow, and The Fairfield Shipbuilding and Engineering Co., Govan. In 1924 he began his sea service with Alfred Holt and Co., transferring for a short time in 1930 to The Clyde Shipping Co.

In 1931 he took up an appointment as maintenance engineer at the Yoker Power Station of the Clyde Valley Electrical Power Co., Glasgow, becoming shift charge engineer at the Tongland Power Station, Galloway Power Co., in 1936. He joined I.C.I. (Fertilizer and Synthetic Products) Ltd., in 1941, as Technical Assistant, but remained with that company only until 1942 when he became charge engineer at Willesden Power Station, being promoted Boiler House Superintendent in 1936. He was appointed Assistant Power Station Superintendent at Brimsdown Power Station in 1948 which appointment he held until his death which occurred on the 17th February 1951. He was elected a Member of the Institute in 1943.

Samuel Mutters Pease (Member 3453) was born in 1877 at West Hartlepool and educated at the High Grade School and Technical School. He served his apprenticeship with William Gray, Ltd., Central Marine Engine Works. He then joined the shipping firm of John Coverdale, serving in several of their vessels until he obtained his First Class Certificate and following that he joined Shaw Savill and Albion Co., Ltd., trading between London and New Zealand. In 1909 he was appointed guarantee Chief Engineer for the Central Marine Engine Works, later becoming Assistant Outside Manager. In 1915 he was appointed Assistant Superintendent Engineer of Ellerman and Papayanni Lines, Ltd., remaining with that company until his retirement in 1945. During his sea experience as Chief Engineer he had the difficult and meritorious job of fitting a spare propeller to the steamer *Caterino* whilst the vessel was afloat at Port Augusta in the Spenser Gulf, S. Australia, with the assistance of the vessel's personnel only. The original propeller had been broken by striking sunken wreckage off Kangaroo Island and the nearest available Graving Dock being at that time at Sydney. He was elected a Member of the Institute in 1918. He died on 2nd April 1951.

Charles Percy Parry (Member 7245) was born in 1876 and educated in Liverpool. He served his apprenticeship with Adair and Co., Liverpool, from 1889 to 1896 and during the last two years he acted as Assistant Lecturer for the Technical Classes in Birkenhead. He then went to sea and served on various vessels until 1901, obtaining his Extra First Class B.O.T. Certificate in 1899, being the youngest engineer to pass this examination for many years. In 1901 he formed a partnership with Mr. Robert Stevenson and carried on an Academy preparing engineers for their certificates until 1917 when he closed down the school, Mr. Stevenson having died two years previously. Mr. Parry then commenced the soot blower business, forming the limited company of C. P. Parry, Ltd., in 1918. He was the pioneer of the side nozzle soot blower and many such blowers have been fitted to all classes of H.M. vessels including battleships and aircraft carriers, and merchant vessels of all types including *Queen Elizabeth, Queen Mary, Caronia* and smaller vessels. Soot blowers were also supplied for many hundreds of locomotives for South African, South American and Indian State Railways. Mr. Parry was elected a Member in 1933 and in 1936 read a paper before the Institute entitled "Observations on the Development of Combustion Technique". He was also a member of the Liverpool Engineering Society. He died on the 7th March 1951.

Radford Thompson Souter (Member 8085) was born in 1888 and educated at Robert Gordon's College, Aberdeen. He served his apprenticeship with J. Abernethy and Co., Aberdeen, from 1904 to 1910. He began his sea service with the Aberdeen White Star Line and then joined the British Tanker Co., being promoted Chief Engineer in 1917. He remained with that company until his retirement on medical grounds in 1941 and until his death which occurred on 17th January 1951, he was an invalid. He was elected a Member of the Institute in 1936.

Arthur Wilton (Member 10628) was born in 1891 and educated at Putney. He served his apprenticeship from 1905 to 1910 with Doran Taggart Co., Putney, and he remained with that company as draughtsman and engineer until 1912 when he joined J. White and Co., tug and launch builders, Fulham, as Chief Engineer. In 1914 he joined the Army as an engine fitter finally being promoted Staff Sergeant and being awarded the Meritorious Service Medal. He returned to J. White and Co., in 1919 as Works Manager and designer, and remained there until 1937 when he joined Alfred Lockhart (Marine) Ltd., Brentford, also as Works Manager. With that company he organized the building of the "Z" Class 4-tonner sailing craft, forty-nine of which were built before the beginning of the 1939-45 war. He was instrumental in laying the foundations for the Fairmile craft with Mr. Noel Macklin; together they worked out the specifications, materials and prices for the first Fairmile Type A boat, later known as ML100. During the war the number of these boats built ran in several hundreds. Mr. Wilton remained with A. Lockhart (Marine) Ltd., and one or two vessels such as the *Yaching World Jenny Wren* were constructed but owing to shortages of materials the firm began the manufacture of steel pipework and wooden cased flour milling machinery. He was elected a Member of the Institute in 1946. He died on the 7th March 1951.