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PORTABLE ISOTOPIC RADIOGRAPHIC UNITS

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AT THE Thirty-fourth Annual Meeting of the American Radium Society, Aebersold[1] reported on the use of radioisotopes in therapy. Today, a few years later, so much progress has been achieved that the application of radioisotopes in clinical diagnostic radiography can be considered.

The isotope to be used in clinical radiography and as a radiation source in a portable unit has to meet several requirements. It should emit, like a diagnostic roentgen tube, radiation in the range of 30–100 kv., it should have a high specific activity (curies per gram) to guarantee its application in a small, focal-spot-like size and its half life should be fairly long to avoid frequent replacement. Table I lists a number of isotopes which fulfill these requirements to a certain degree and which are under discussion for possible use in clinical radiography.

TABLE I

LIST OF ISOTOPES

For Possible Use in Clinical Radiography

Isotope	Half-Life	Radiation (Main group in mev.)			
		Alpha	Beta	Gamma	X-Rays
Group I (Beta, Gamma, X-Ray Emitters)					
$_{54}Xe^{133}$	5.3 d.	—	0.34	0.081	Yes
$_{55}Cs^{134}$	2.3 yr.	—	0.09 0.65	0.56–0.79	Yes
$_{58}Ce^{144}$	290 d.	—	0.17 0.30	0.13	Yes
$_{63}Eu^{155}$	1.7 yr.	—	0.15 0.24	0.085 0.099	Yes
$_{-69}Tm^{170}$	127 d.	—	0.88 0.97	0.084	0.052
$_{+95}Am^{241}$	470 yr.	5.4	—	0.026–0.059	2 Am 15 Np
Group II (Beta Emitters)					
$_{28}Ni^{63}$	85 yr.	—	0.062	—	—
$_{38}Sr^{90}(y^{90})$	~20 yr.	—	0.537 (2.18)	—	—
$_{61}Pm^{147}$	2.6 yr.	—	0.227	—	—
$_{81}Tl^{204}$	4.1 yr.	—	0.76	—	—

* From the Radiobiology Department, Army Medical Research Laboratory, Fort Knox, Kentucky. Presented at the Thirty-seventh Annual Meeting, American Radium Society, Washington, D. C., April 21–23, 1955.

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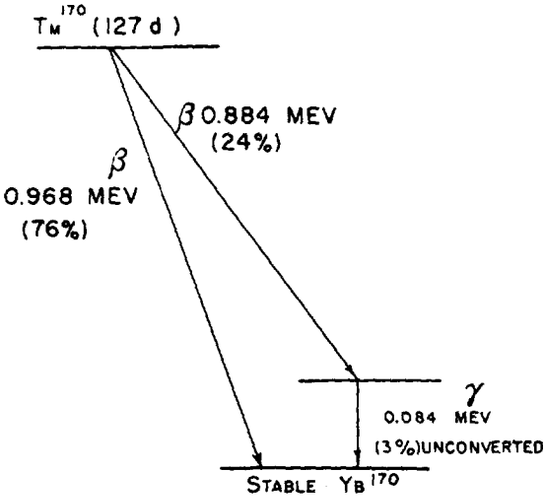
The first studies into the applicability of radioisotopes for clinical radiography were done exclusively with isotopes of Group 1. Cesium 134 was used in 1948 by Spangenberg[16] for dental radiography, thulium 170 and xenon 133 were applied in 1950 to 1952 by Mayneord[14] for radiography of teeth and body parts, cerium 144 was recommended by Dennis and DeLuca[5] and americium 241 was applied in diagnostic radiography by West.[20]

The decay scheme and the radiation spectrum of the isotopes of Group 1 are rather complicated. Even in such simple cases, like that of thulium 170, the spectrum becomes still more complicated by secondary effects, among which the production of Bremsstrahlung and "characteristic" radiation in the source material and its surroundings by the emitted beta radiation[6] plays an important role (Fig. 1 and 2).

So far, mostly thulium 170 has been used in portable radiographic units. The Argonne National Laboratory,[19] Litton Industries,[13] and the Army Medical Research Laboratory[2] have reported on different designs, using either a simple shutter mechanism or the principle of the "movable source"[7] for exposure control. Figure 3 gives a cross-section of the portable unit developed at the Army Medical Research Laboratory by Carpenter and his co-workers.[2]



INTERNAL CONVERSION X-RAYS		
K	0.053	MEV
L	0.008	MEV
M	0.002	MEV

FIG. 1. Decay scheme of thulium 170 (Tm^{170}).

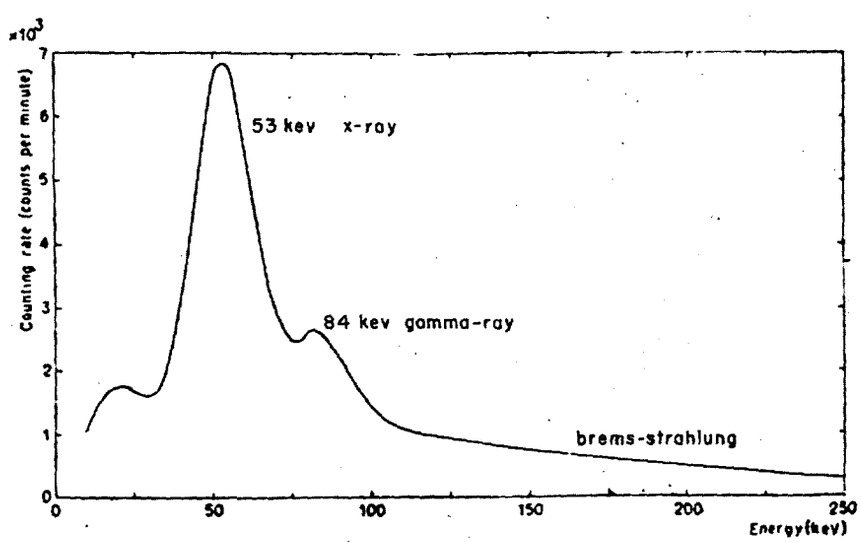


FIG. 2. Experimental distribution of the gamma-rays, x-rays and bremsstrahlung from a homogeneously activated thulium 170 source with 1.0 g./cm².

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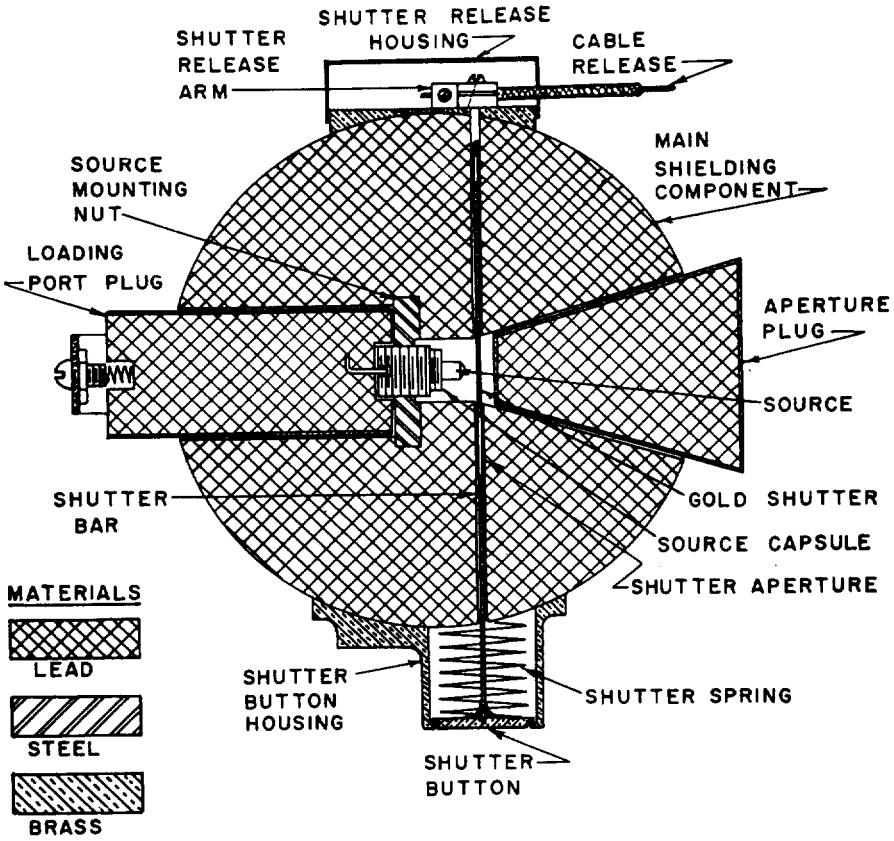

Fig. 3. Hemi-sectional sketch of Army Medical Research Laboratory isotopic radiographic unit.

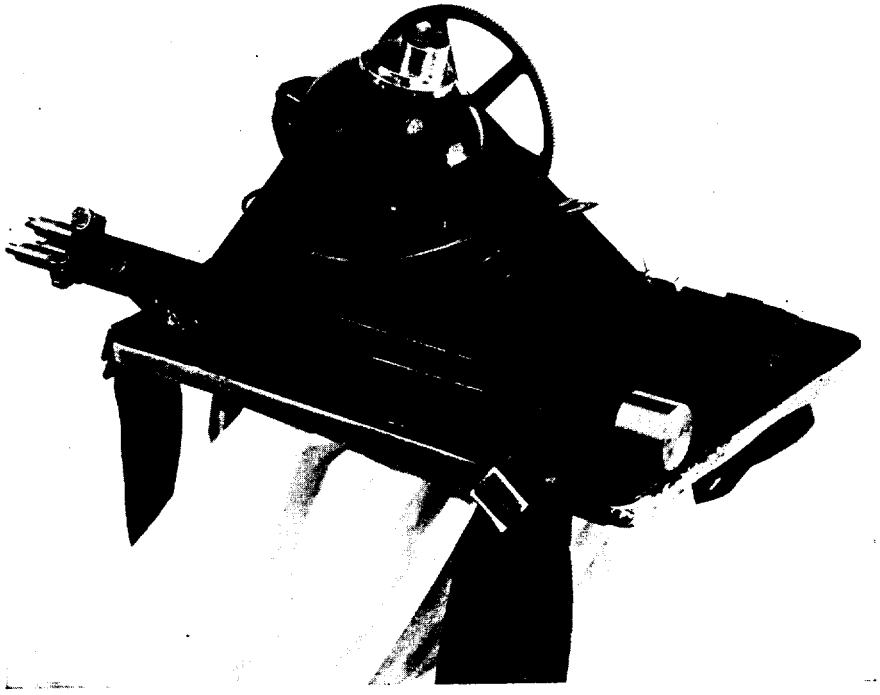

Fig. 4. Portable isotopic radiographic unit.

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The technical details of this unit are: *Source:* thulium-metal pellet, 4 mm. thick, 4 mm. diameter, 400 mg. weight; double-sealed in aluminum, helium welded; activated in Material Testing Reactor, Idaho Falls, Idaho. Source strength as of August, 1954, 40 curies. *Shield:* lead-sphere, 5 in. diameter, with loading port and aperture port. Dose rate at surface of sphere: 15 mr/hr. *Shutter:* aperture plug, movable gold foil, spring operated, remotely controlled.

The source is mounted on a pack frame (Fig. 4) and can be strapped easily to the back of an aide. The total weight is close to 40 pounds. A new design, using very pure thulium-metal free of tantalum contamination, has a weight of about 20 pounds at a source strength of about 70 curies.

The portable unit consists of the described source and a specially built self-contained, non-darkroom cassette. It uses a rapid development method and on-the-spot radiographs can be made in three to four minutes. The exposure times run with an 18-inch source-object distance from 20 to 50 seconds, the exposure doses vary from 10 to 160 mr, depending on the body part to be radiographed. Special measurements of the relative biologic effectiveness of

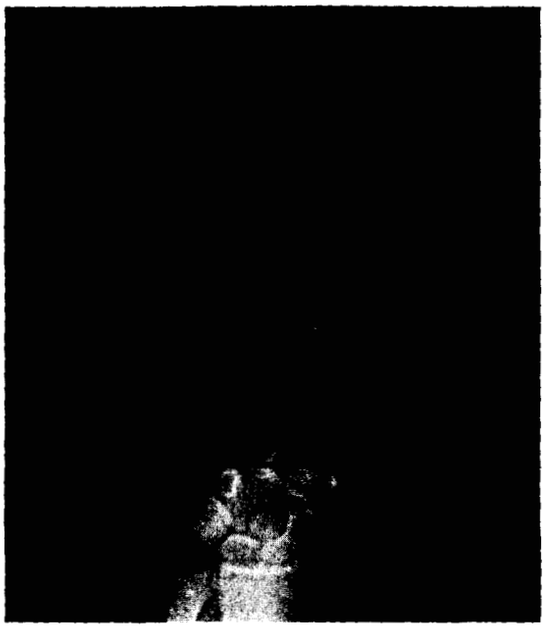

Fig. 5. Radiograph taken with portable unit in Figure 4. Eighteen-inch source-specimen distance, 20 sec. Power Paper, intensifying screen.

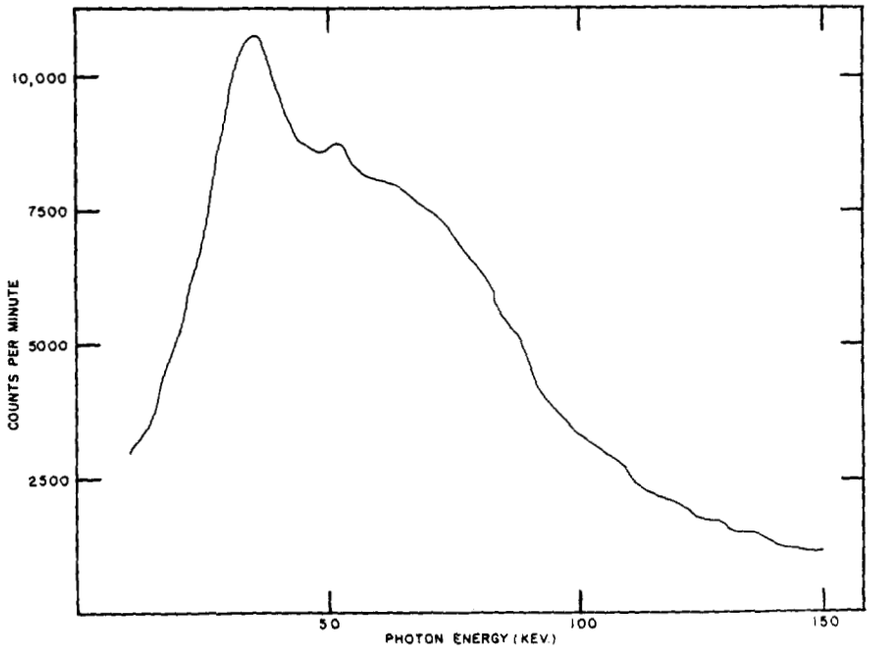

Fig. 6. Spectral distribution of the radiation emitted by the used medical applicator.

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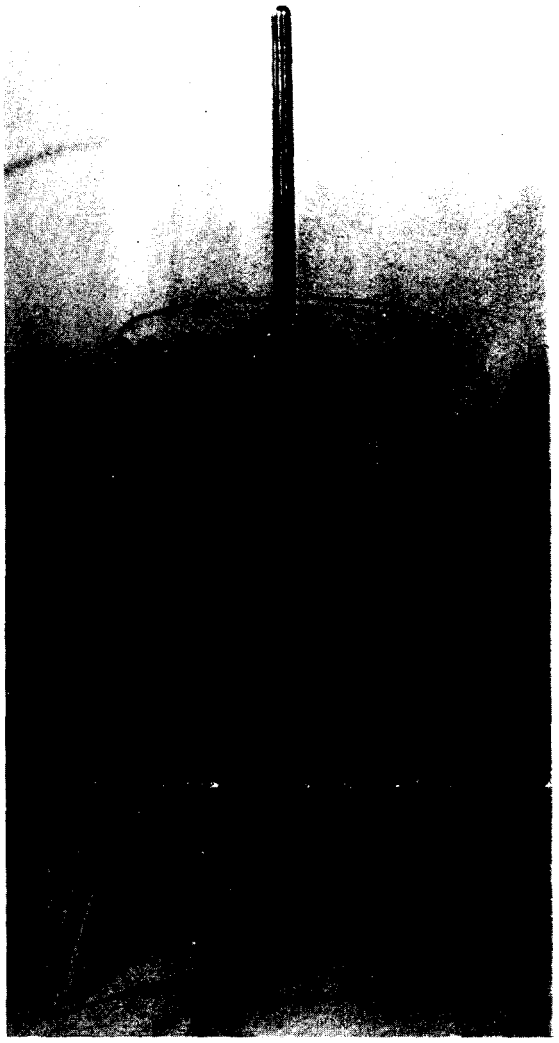

FIG. 7. Assembly with Tracerlab medical applicator for beta-excited x-radiography.

thulium-radiation showed the thulium-radiation to be practically as effective as 250 kvp. roentgen rays.

Radiographs taken with this unit on Power Paper, using intensifying screen and on-the-spot development (Fig. 5), show contrast and definition sufficient for the purpose for which such units are built, for disaster and emergency cases.

Portable isotopic radiographic units, this may be emphasized again, are no replacement of, and no competition to, conventional roentgen-ray equipment which is essential for detail and definition. They are, however, in their independence of power supply, water supply and darkroom facilities, valuable equipment for first aid diagnosis in disaster and emergency cases of all kinds in the field as well as in civilian life situations. The possibilities of application are immense: road accidents, train wrecks, airplane crashes, industrial disasters, natural catastrophes such as hurricanes, tornadoes and floods, on ships at high sea, on expeditions, and in rural areas.

Portable units using gamma- and x-ray emitting isotopes have, however, one serious limitation. It stems from the fact that the quality of the applicable radiation is determined by the choice of the isotope. The radiation can only be altered by an exchange of the isotope. Of course, devices can be built, where one source contains three or more isotopes arranged in a revolving system, but in this case the shielding necessities counteract the principle of flex-

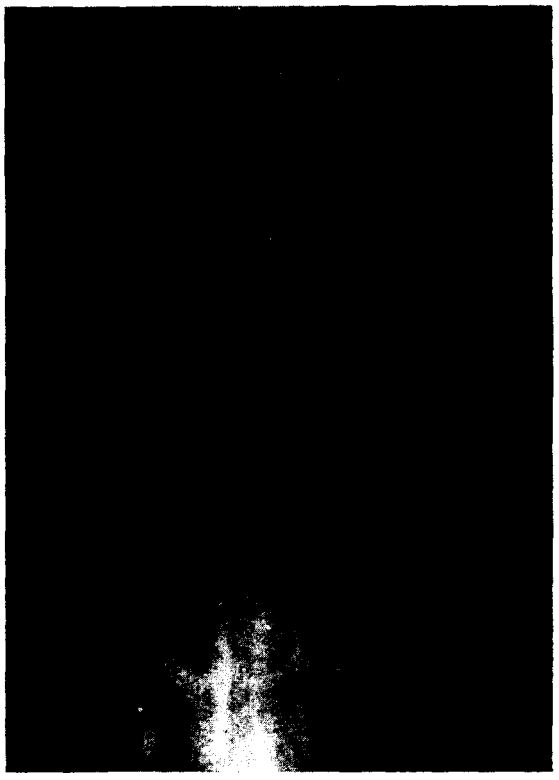

FIG. 8. Radiograph of rat body taken with portable unit in Figure 7: 10 cm. source-object distance; 5 minutes; intensifying screens.

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ibility and light weight, so essential for a portable unit.

Therefore, the question arose whether or not other isotopes than those naturally emitting gamma- and x-radiation could be made useful in diagnostic radiography. As mentioned already in the case of thulium, the beta-radiation emitted in its decay contributes in an undesired manner to the complexity of the spectrum. If it would be possible to design proper devices for production of applicable x-radiation by the use of beta radiation, the field of isotopic clinical radiography would be broadened.

These betas are energetic electrons and by decelerating them in proper target materials, x-radiation with specific qualities could be produced—in the same way as roentgen rays are produced in a roentgen tube by impingement of the electrons on the target material of the anode. The first studies into this phenomenon were done in 1908 to 1912 by Starke[17], Davisson,[4] Gray[6] and Chadwick,[3] who used beta radiation from radioactive elements (RaC, RaE) for the experiments.

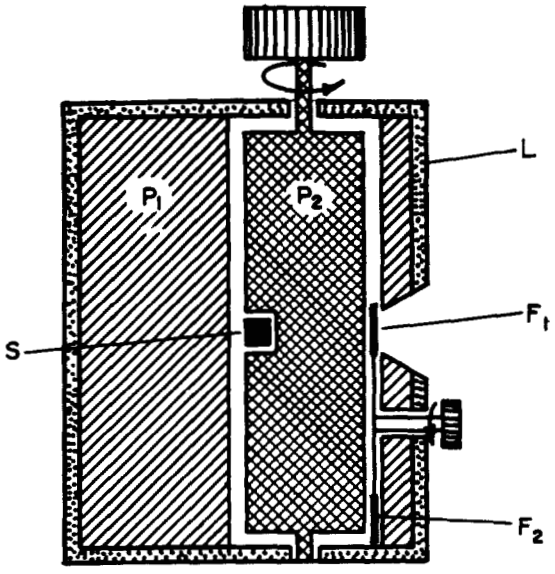

FIG. 10. Beta-ray excited portable radiographic unit (schematic drawing): S, beta emitting isotope; $F_{1,2}$, revolving target device; $P_{1,2}$, proper beta-shields; L, lead shield.

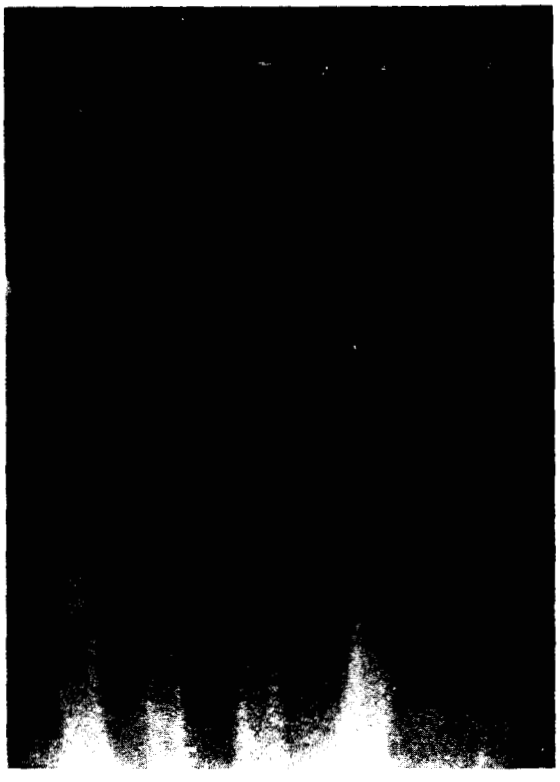

FIG. 9. Radiograph taken with portable unit in Figure 7: 10 cm. distance; intensifying screens; 5 minute exposure.

The advent of radioisopes emitting different beta spectra has stimulated new research in this field. The mechanisms and laws, in which beta particles produce x-radiation (characteristic x-radiation, internal and external bremsstrahlung) in matter is at present under intense experimental and theoretical investigation.[12] So far the experiments show, contrary to earlier theories, higher yields for beta-excited x-radiation than anticipated.[18]

Thus the successful application of beta-emitters in radiography by Kereiakes and Krebs[8,9] and by Reiffel[15] becomes understandable. Kereiakes and Krebs used for their experiments a strontium 90 source, encapsuled in a double hermetic seal of two mils of stainless steel and 10 mils of aluminum. The beta radiation from strontium 90 in equilibrium with its decay product, yttrium 90 (0.537 mev. strontium 90 beta, 2.18 mev. yttrium 90 beta; strontium 90 half life about 20 years), interacts with the

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FIG. 11. First roentgenogram of a hand, taken by Röntgen in 1896.

source material and its surrounding, resulting in the emission of "characteristic" x-radiation and of bremsstrahlung.

The actual spectrum of the applied source has not yet been measured. A first idea could be obtained from absorption measurements in aluminum and lead, and from studies by Leboeuf and Stark[10] with strontium 90 and tin targets. Figure 6 shows the spectrum emitted by tin targets when bombarded with strontium 90 yttrium 90 beta radiation.

The strontium 90 source, a Tracerlab medical applicator, is used in combination with a lucite cap for absorption of undesired beta radiation and a small photographic tripod. Figure 7 presents the assembly of these three parts as used for taking radiographs.

Figures 8 and 9 show radiographs taken with the beta unit. They were taken on Eastman Kodak Blue Brand film with intensifying screens above and below the film. Exposure times at about 12 cm. source-object distance run up to five minutes for the relatively weak strontium source of 300 mc. The radiographs show enough contrast and definition for an on-the-spot diagnosis. There is a certain penumbra due to the complexity of the source spectrum which may be cut down by proper filtration. Other ways of improving the image are the application of image intensifiers, of beta-ray focusing devices and/or the use of different target materials in a revolving system in front of a properly selected isotope. Figure 10 shows schematically such a device, where only one isotope, in this case promethium 147, will be used for the bombardment of different targets (Al, Ag, Ta, Pb, W).

How far these improvements will influence the quality of the radiographs remains to be seen. Comparing, however, the first roentgenogram of a hand taken by Röntgen in 1896 (Fig. 11) with roentgenograms from modern conventional equipment it becomes evident that clinical, diagnostic radiography with isotopes has a future.

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