X-Rays *in the* Signal Industry*

An explanation of the use of radiography in testing impregnated contacts, bakelite block, metal castings and other parts used in the manufacture of signal equipment

By

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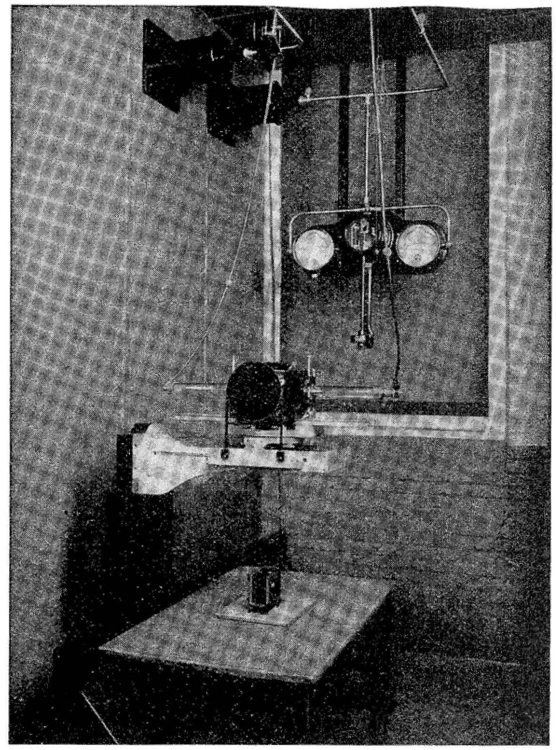


Fig. 1—Exposure room in the radiographic department of the General Railway Signal Company

X-RAYS in industry, though perhaps in a less spectacular way, is still an instrument for safeguarding human life. There is this distinction: In the hospital x-rays are used to determine the location and extent of damage already done and how an individual can best be repaired, restored, or patched up; while in industry, examinations are made of materials both before and after processing to avoid disaster and destruction to multitudes of people. In the building of the Boulder Dam, x-ray film is used by the mile. Can you imagine the calamity following the failure of this dam? The horrors of the Johnstown flood would be dwarfed to insignificance. Every inch of the 80 miles of welded seams of the 13,000 ft. (55,000 tons) of steel pipe, 8½ to 30 ft. in diameter and 2⅞ in. thick, and many other parts of this structure are radiographed to safeguard human life.

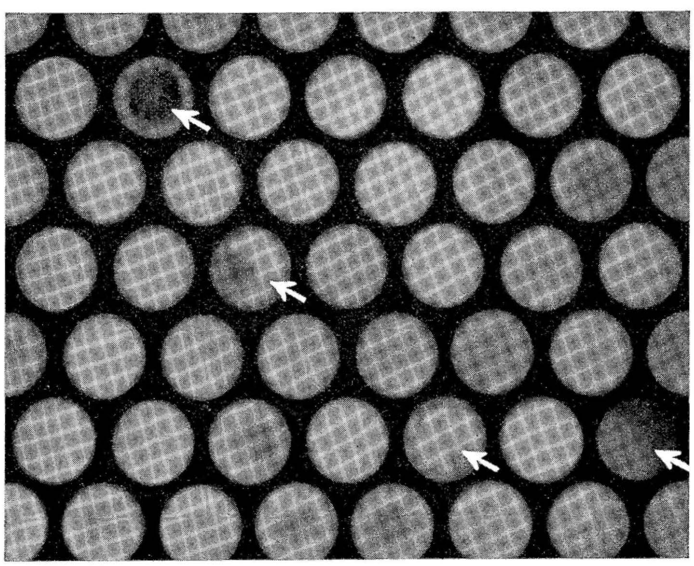


Fig. 2—Actual size section of the radiograph of impregnated carbon contact; note a few of the defective contacts indicated by arrows

Or can you imagine the holocaust that would follow the explosion of a boiler made from 3 in. steel and carrying hundreds of pounds of pressure per square inch? Many of these boilers are located in the densest sections of large cities and while their seams are welded for safety, it is common practice to radiograph them before installation.

All man-made things fail. Railway signaling is so designed that if failure occurs, it must be on the side of safety—that is, a train may be stopped or delayed by a failure. One such failure may occur once in a million operations of a railway signal device, yet these devices must be so manufactured, installed, and maintained that a failure will not cause a dangerous condition. Hence, the necessity for the utmost care in the selection of materials and in the processing, assembling, and inspection of these materials.

Inspection of Signal Parts

Inspection of signal material includes x-ray examination of certain important parts, such as the silver-impregnated carbon contacts used in relays. Whenever a circuit is opened at one of these contacts, a tiny arc is formed tending to fuse the contact. During an electrical storm, when static charges are induced in the signal wires, the arc may be quite appreciable. These contacts must be nonfusible, hence, carbon is used for the basic material. They must be of low electrical resistance, hence molten silver is forced into the minute pores of the carbon structure. The proportion of silver and carbon must be quite exact and the silver must be evenly distributed throughout the carbon.

*Abstracted, with permission, from Radiography and Clinical Photography.

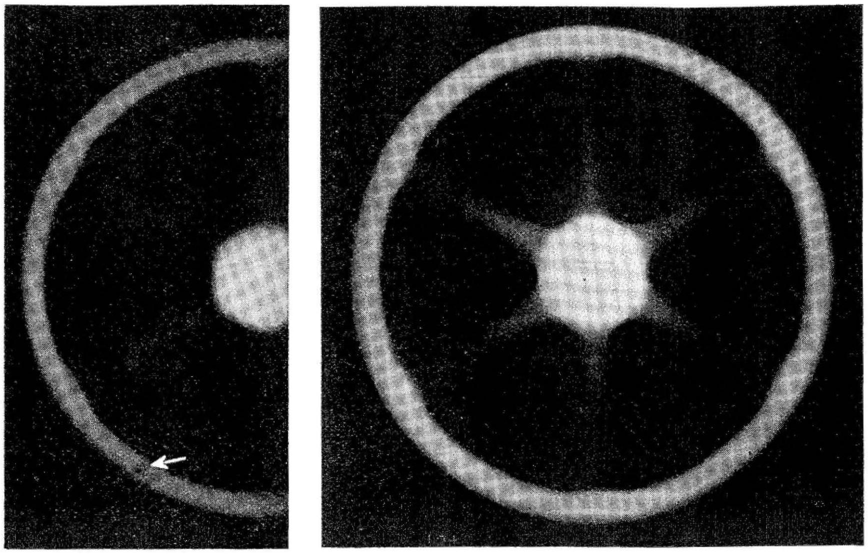


Fig. 3—Radiographs of gear blanks. A—Original type of casting showing gas pockets. B—Casting of lot wherein foundry technic was corrected to produce a better product

There must *not* be any continuous thread of solid silver extending through the carbon as this might fuse to the other member and cause a dangerous failure. These contacts are purchased in large quantities and every such contact is x-rayed (about 1,000 pieces on a 14-in. by 17-in. film). The radiographs are carefully inspected. A few characteristic samples, rich and poor in silver, are also selected for chemical analysis to determine the proportion of carbon and silver. All contacts on any radiograph that are obviously satisfactory are sent to stock for use. All that are in any way questionable are set aside and when the lot is finished, they are again x-rayed in two positions on the same film. This second radiographic record is very carefully examined under a magnifying glass, the defective contacts are destroyed and good ones sent to stock for use as and when required, with the certain knowledge that all in stock are suited to function as intended.

Purpose of X-ray

While our x-ray apparatus was purchased primarily for the examinations of these contacts, it was soon found very valuable for other purposes; i. e., gray iron, malleable iron, and steel castings; butt (pressure) welds, flame welds, and arc welds; molded bakelite parts having metal inserts or suspected of containing metal inclusions; apparatus assembled in metal or other opaque cases where the relative position of parts can not be seen after assembly.

There is no such thing as *perfect* material or a faultless workman; hence, an inspection department. It is only possible to accept such material as is amply suitable for the purpose intended. A certain allowance or "tolerance" must always be made and the apparatus designed accordingly. For example, commercial electric motors are so designed and made that they will carry a 10 percent overload continuously or a 50 percent or perhaps 100 percent overload for a certain short time, without damage to the machine. All things requiring strength are built with a factor of safety. A bridge with a factor of safety of 5 should carry a load 5 times as great as it is ever expected to carry. These things are fundamental.

Every metal casting is expected to (and does) have some gas pockets, sand inclusions, shrinkages, etc. All lumber has some knots, season cracks, shake, wane, etc. The only question is how much of any or all of these defects can be allowed. In every casting there are some parts where defects must not occur and other parts where it is amply strong (made so for other reasons) and therefore can stand quite large defects without detriment to the purpose intended. By changing the foundry technic, defects can be either eliminated or made to appear only where they will do no harm. Perhaps they can be driven into the risers or gates for such parts are cut off before the castings are used.

Of course, it is not commercially practical, necessary, or advisable to x-ray all castings. It is well known that if a correct foundry technic is once established and maintained, suitable castings will be produced. When difficulty is experienced in making a suitable casting from any pattern, sample castings are x-rayed. It is always found that the defects are similar in all samples. The foundry technic is then changed and more samples x-rayed. This is continued until suitable castings are obtained and the new foundry technic established. Thereafter, occasional castings are taken from production and x-rayed to see that the practice continues to bring satisfactory results.

Test of Castings

An example of this procedure is shown in the radiograph of a gear blank (Fig. 3A) in which flaws occurred in the rim of the wheel where the gear teeth are cut and were of such a nature that the teeth were abnormally weakened. The first samples showed the faults in the same lo-

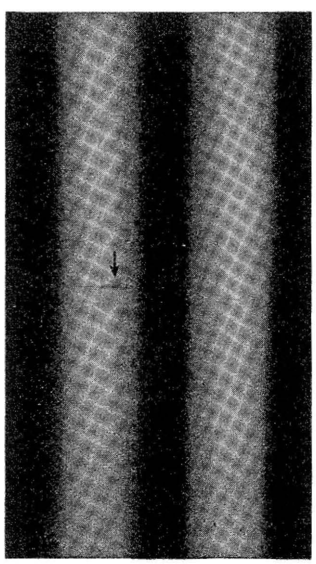


Fig. 4—Radiograph of butt welds. Left—Example of a bad weld. Right—Example of a perfect weld.

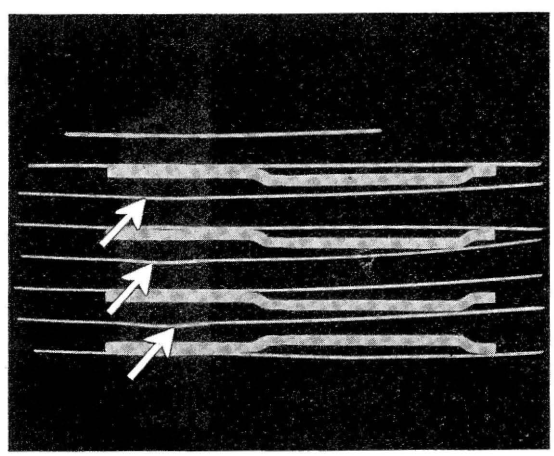


Fig. 5—Radiographs of molded bakelite with metal inserts. Note the distorted inserts indicated by arrows. A correction in molding eliminated the distortion.

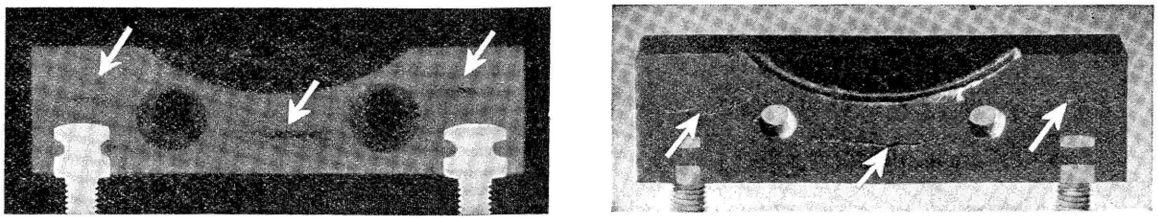


Fig. 6—Left—Radiograph of a molded bakelite block with inserts. Note porous regions due to improper curing of the bakelite, which destroys its insulating value. Right—A photograph of the same specimen which was sectioned to show porosities revealed in radiograph.

cation on each of five. A special melt of metal produced five superior samples. A third lot of samples made from standard metal to which had been added in the ladle a small amount of another metal, produced entirely satisfactory castings (Fig. 3B), almost as good as the second lot. It is obviously out of the question to melt tons of special metal to make a few pounds of gear blanks, but quite practical and simple to use the last method where a small part of any run of cast iron could be used to make a few small gear blanks by alloying it in the ladle. This procedure generally followed has enabled us to produce superior castings at only a very slight increase in the manufacturing cost.

Welds Tested

Arc and acetylene welded seams, while of utmost importance, have been too often described in published articles to need further attention here. Another form of weld known as *butt* or pressure weld has not been so often described. A certain type of rod—a most important part—if made of one piece was very expensive to manufacture, but if it could be made of two pieces of different size rod and

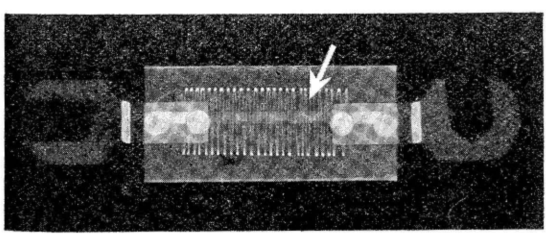


Fig. 8—Radiograph of enclosed wire-wound resistance unit with porcelain core. The whole unit is enclosed in a metal sheath. Arrow indicates poor spacing of wires which alters the resistance value.

welded together, it could be made at much less cost and would, we thought, be quite as strong as when made of one piece. We made a lot and x-rayed them, changed our forging technic a few times, x-raying successive steps, and finally our presentation of the radiographic proof (Fig. 4) was rewarded by the pleasure of our customer.

Bakelite insulation into which are molded metal parts, provides a fertile field for x-ray examination. Bakelite before molding is a very fine powder made of finely-ground vegetable fiber and synthetic resins. Under the influence of heat and pressure it is transformed first into a semi-liquid and then into an inert solid. It is, therefore, easily penetrated by the rays so that the metal parts stand out in sharp relief in the radiograph. In the bakelite blocks shown in Fig. 5, the metal parts are held rigidly in the mold outside the bakelite, but when the bakelite starts to flow, pressure tends to move or to distort the metal parts in the mold. If heat and pressure are applied in the correct manner, no distortion occurs. It is to determine this method that such parts are x-rayed when first molded and periodically thereafter to have definite evidence that the established routine is proving continuously satisfactory.

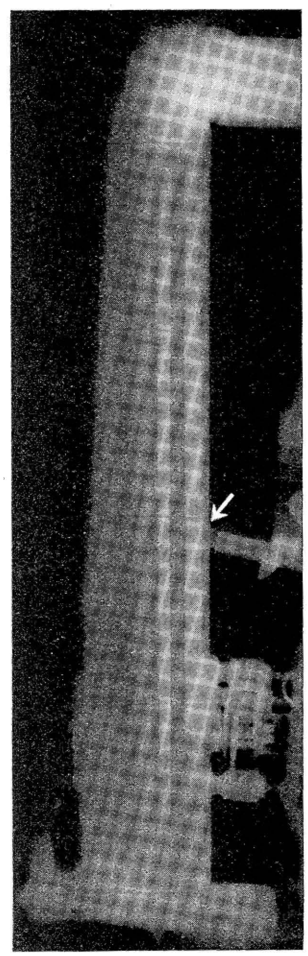


Fig. 7—Radiograph of a door of a metal mechanism case; one of the latches is too long, which prevents proper closing.

Many mechanisms are assembled and permanently housed in metal cases. It is sometimes advisable to determine the actual relative positions of the parts in a closed case (Fig. 7). This can often be shown quite clearly by x-rays, especially if stereo-radiographs are made.

Wire-wound resistance units (Fig. 8) are sometimes permanently molded in ceramic or other opaque material. X-rays make easy and accurate inspection of such parts possible. Manufacturers of electronic devices similar to those used in radio receivers seem to have a penchant for making the glass enclosing tubes opaque by various methods. In planning new designs or seeking new sources of supply it is often desirable to know the exact relative location of their hidden parts without destruction of the device. This is easily and accurately accomplished by x-ray examination.

General Considerations

Industrial radiography does not always require the same delicate or artistic touch, perhaps, as medical radiography, yet the same principles apply. We all "shoot" for the parts we want to see. The radiologist uses a different technic for bony structure than for soft tissues in the same part, i. e., for the ribs and for the lungs. We have the same problem with metallic inserts in molded bakelite. We may want to determine the location or condition of the metal parts or to know whether the bakelite is properly "cured" in the mold. If it is not sufficiently cured, it will contain porous spots (Fig. 6) that absorb moisture and change it from an insulator to a conductor of electricity.

The radiologist must consider mobility, dosage, and the comfort of the patient. We may have to consider an idle section of the shop, and men out of work, or a delayed shipment of important material. The radiologist must produce a beautiful radiograph to suit the requirements of an overwrought surgeon. We must tell whether the material is suitable for the purpose intended and prove it by the radiograph.

The current used in any exposure is usually limited by the capacity of the tube and the length of exposures. At 5 m.a. the target of our "deep therapy" tube runs at white heat on all but the lighter exposures. The radiologist's voltages run from 35 to perhaps 100 kv., ours from 50 to 200 kv. or higher if the work requires it and if we can afford the more expensive outfit (300 kv. seems to be the present practical limit).

Time of Exposure

The main difference in technic comes in the time factor. Whereas the radiologist may use from 1/20 to 5 seconds, some of our exposures may in extreme cases run 45 minutes or even longer. Most exposures on metals are arbitrarily set at 5 minutes, 5 m.a., with the voltage as low as possible to get through the material. There is a greater variation in the density or penetrability of materials of the "patient" in industrial work than in the case of human beings. In medical radiography the extremes are bones and soft tissues. Our gamut runs from soft wood to rolled bars or plates of steel alloyed with tungsten, chromium, or other semi-rare metals.

Density a Factor

The difference in technic between these extremes is very great. We must consider many metals of different density and thickness. Defects no greater than 2 per cent of the thickness, as required by the United States Government specifications for boiler plate, can be shown. We also have materials of the same or different densities and of much different thickness in the same exposure. For example, we had one iron casting (Fig. 9) slightly larger than a 14-in. by 17-in. film having grooves and ribs ½-in. deep running across the plate in both directions on both sides of the plate so that there were five different thicknesses, ½-in., 1-in., 1½-in., 2-in. and 2⅛-in. We finally showed this all in one exposure by immersing the casting in a solution which was slightly more radioparent than the casting.

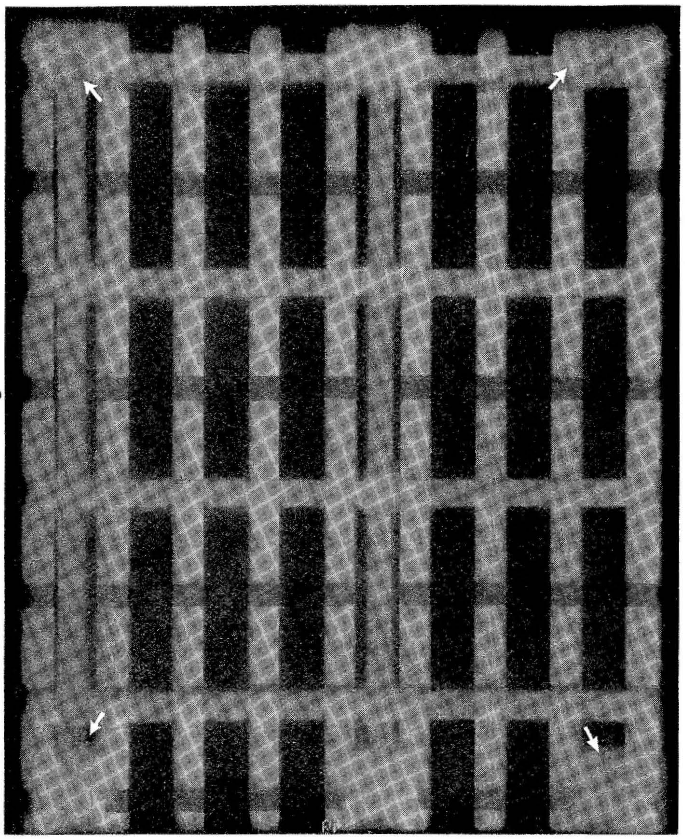
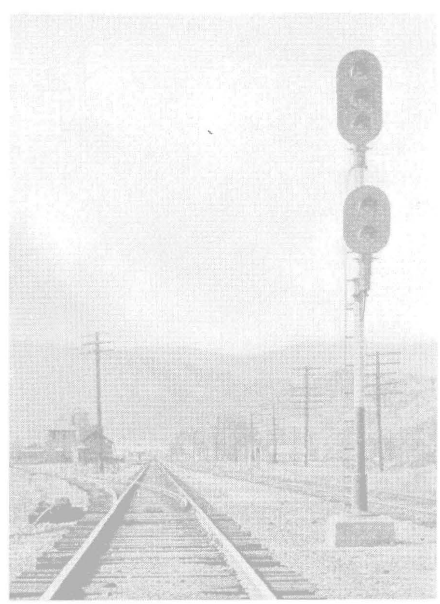


Fig. 9—Radiograph of a casting having ½ in. grooves on one side, ½ in. ribs on the other, and "bosses" 2⅛ in. thick on the corners. Note uniform density of the radiograph, and the defects at corners of the casting as indicated by the arrows.

Another job (this word is used advisedly) requiring nearly two hundred exposures on 6-in. by 17-in. films was that of cast-steel beams weighing 350 lb. each. In service these beams were repeatedly subjected to severe and frequent shocks, and were breaking after only short usage. The breaks occurred at four separate points on each beam. X-ray examination of similar beams in stock showed hidden shrinkage cracks at one or more of the four points on all beams. A complete new set of beams was ordered and all of them x-rayed. Each radiograph was numbered consecutively and a corresponding number stamped on the beam. When the radiographs were finished, the defects were plainly marked on each film. Then, each was laid on the corresponding beam, and the location and extent of the hidden crack marked on the beam. An oxy-acetylene cutting torch was then used to cut a wide kerf through the hidden crack longitudinally—to literally cut out the defect—and relieve the cooling strains in the remaining metal. A welding torch was next employed to fill in this kerf. When a number of these welds were again x-rayed the radiographs showed the material in the welds to be quite as good as the surrounding metal. These beams have been in service for a year and a half and no complaints have been heard about them. This was a rather expensive job but not nearly so costly as the loss of a valued customer.

Industrial radiography is the same in general principle as medical radiography; it is different only in detail.



Remote control switch and signals on the Northern Pacific at Garrison, Mont.