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Comparison and Indentification of Wire in a Coal Mine Bombing Case

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THE COMPARISON AND IDENTIFICATION OF WIRE IN A COAL MINE BOMBING CASE

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A bitter controversy in the coal fields of Southern Illinois between two rival coal mine unions during the period of time extending from 1932 to the latter part of 1935 created a serious situation approaching in many respects the proportions of a civil war. Bombings, murders, and wholesale intimidations had practically dispensed with the orderly processes established for the enforcement of law and the settlement of disputes.

It was the consensus of those who had followed the development of this mine warfare that if sufficient evidence could be obtained in any one instance, which would serve to fix the responsibility for the offense committed, there would result a cessation of these various acts of violence and an immediate improvement of the deplorable situation. However, the very nature of the offenses made it extremely difficult to conduct a successful investigation.

In their efforts to exhaust all possibilities in the process of investigating these crimes the state law-enforcement agencies retained the services of the Scientific Crime Detection Laboratory of Northwestern University School of Law.[1] Shortly thereafter there

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[1] The following state officials were particularly active in this respect: Governor Henry Horner, Attorney General Otto Kerner, and T. P. Sullivan, Superintendent of the Illinois State Bureau of Criminal Identification and Investigation.

occurred the bombing of the power house of the Valier Coal Mine, located at Valier, Illinois. The result of the Laboratory's participation in this particular investigation constitutes the principal subject matter of this paper.

At the time of the explosion the State's Attorney and the Sheriff of Franklin County were notified, and upon arriving at the mine they made a superficial examination of the remains of the power house and its contents. The battered remains of an alarm clock were recovered, together with four small dry cells.[2]

Because of certain activities known to the Sheriff and the State's Attorney, Mitchell McDonald and Robert Robertson, two former employees of the mine, were taken into custody and held for investigation pending the arrival of representatives of the Laboratory.

The scene of the explosion was carefully examined by two members of the Laboratory Staff[3] and a number of photographs taken of the remains. (See Figures 1, 2, and 3.) Two additional dry cells and several small brass gears were discovered, which were later found to have originally been part of the alarm clock recovered by the Sheriff. These articles were located in the generator pit at the entrance to a duct or conduit (Fig. 2, No. 1) through which the cables ran under the floor to the switchboard located on the east wall of the power house.[4]

Several small fragments of tin plate were recovered from the 2″ x 10″ rafters that originally supported the roof of the power house. These pieces of tin had been propelled with sufficient velocity to penetrate the wood rafters a distance of ½″ to ¾″. The pieces were so severely strained—as would be expected under these circumstances—that measurements of the thickness of the metal or tin-plate could not be depended upon One of the pieces, irregular in shape and measuring approximately ½″ in width, had running across it a portion of the original crimped seam of the can (presumably) from which it had been torn. The material (tin-plate)

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2 The six dry cells recovered were of the type assembled to form "B" and "C" radio battery blocks developing from 22½ to 45 volts. This would have been an ample potential difference to cause detonation of electric squib or blasting cap.

3 Leonarde Keeler and the writer. Mr. Keeler examined each of the suspects by means of the polygraph or so-called "lie-detector," the results of which confirmed the suspicions of the Sheriff and State's Attorney.

4 The fact that the batteries and the alarm clock timing device were found under the generator, and at end opposite the apparent localization of the explosive force, suggests the possibility that the detonating circuit had been connected to generator cables to provide a secondary means of detonating the bomb. At the time of the explosion the mine was shut down and the motor-generator was not in operation. The mine was scheluled to re-open just five hours after the explosion occurred.

FIGURE 1

Remains of power house of Valier Coal Mine. West wall in foreground. No. 1 locates position where alarm mechanism was recovered (on east side of generator). No. 1 and No. 3 locate motor-generator illustrated in Figure 3, infra.

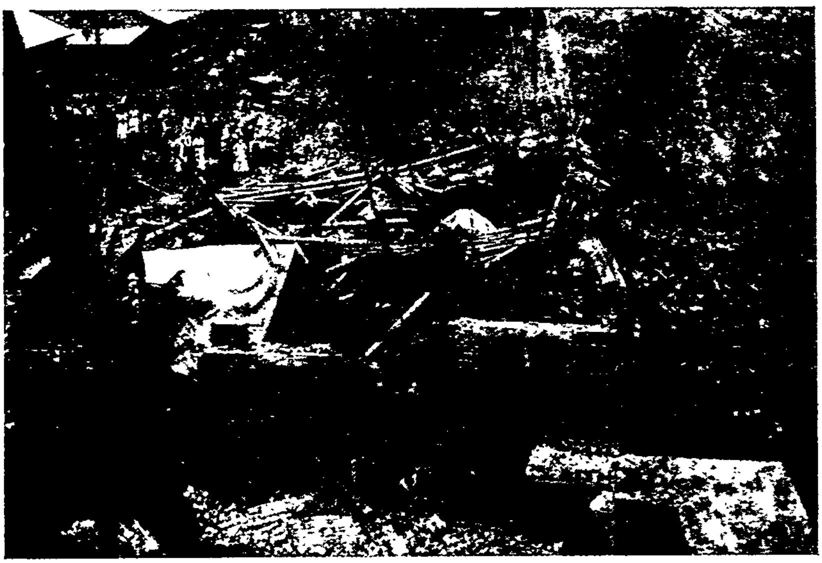


FIGURE 2

North wall of power house shown in foreground. Alarm mechanism recovered in position indicated by No. 1.

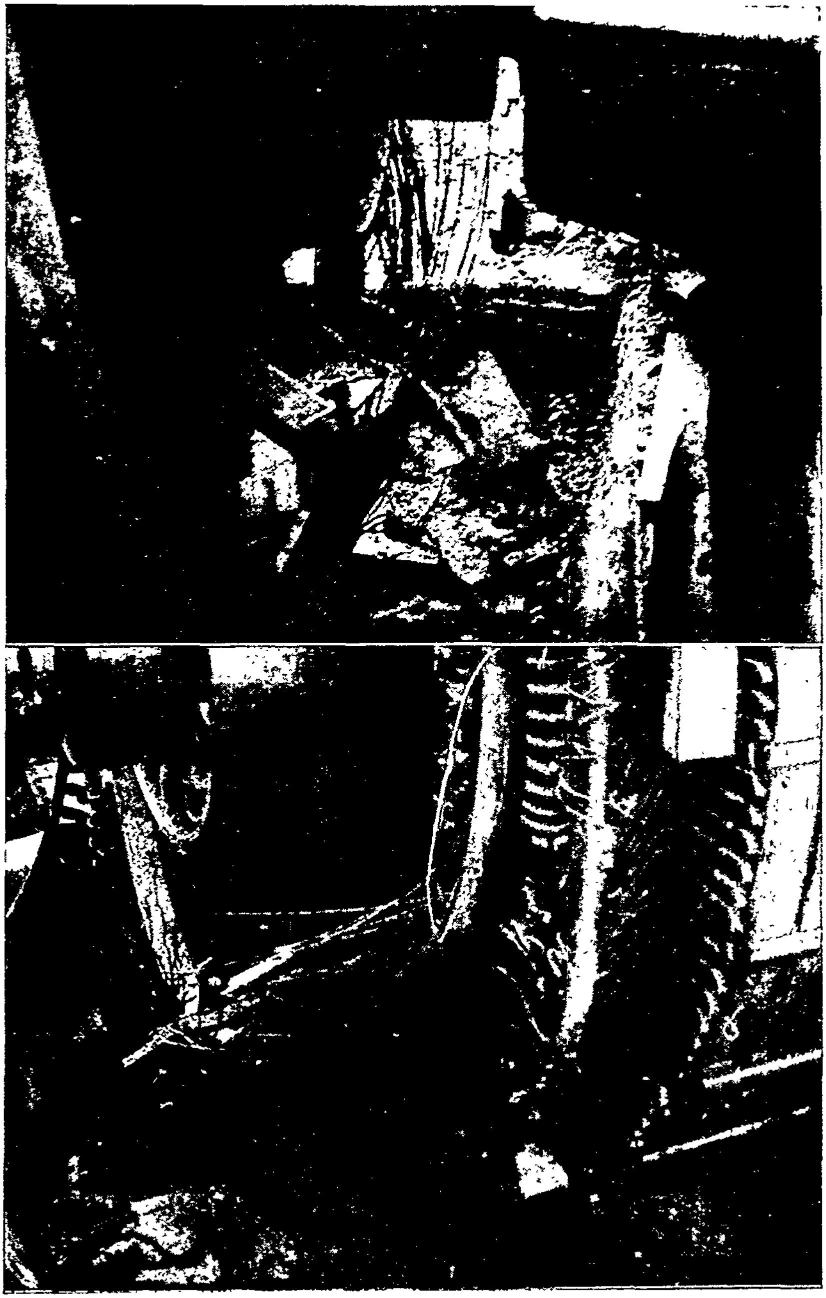


FIGURE 3

Localized shattering effect of the explosive at the base of the large motor-generator. Note localized rending damage to armature wrap wires.

and the seam were found to be similar to certain types of tin-plate used in the manufacture of the common square, five-gallon oil cans.[5]

Examination of the remains of the 1000 K.V.A. motor-generator, essential to the operation of the mine, revealed unmistakable evidence that the localization of the explosive force had been confined to the northwest corner of the concrete pit under the motor unit. (Fig. 3.) The machine, comprising four units (exciter, motor, flywheel, and 220-volt direct current generator), was mounted on a common shaft, and was supported by a cast-iron base which rested on a concrete foundation, level with the floor of the power house. Below the motor and generator units were two pits, the floor of which extended approximately 24″ below the power house floor level. Upon examination of the surface of the motor pit it appeared that the northwest corner had been freshly abraded or shattered, whereas the surface of the remainder of the motor pit and the entire generator pit had an accumulation of grease and dust which apparently had been acquired over a long period of time. Immediately above that corner of the motor pit the wrap-wires binding the armature windings had been torn loose, whereas on the opposite side of the armature the wrap-wires were intact. Moreover, a study of the direction of the flight of parts of the machine and debris indicated that their trajectories extended radially outward from the northwest corner of the pit. All these observations, together with the fact that only the north wall of the power house remained standing, pointed to the conclusion that the focus of the explosion must have been in the northwest corner of the pit.

From the shattering effect of the explosion it was quite apparent that the damage resulted from a "high" explosive—that is, one with explosive velocity of 5,000 to 25,000 feet per second.[6]

[5] Investigations made in connection with other bombings in the coal fields of Southern Illinois revealed that 60% dynamite had often been packed in one and five gallon alcohol and oil cans preparatory to transporting it to the scene of a bombing.

[6] For a detailed explanation of the differences in the effects of "high" and "low" explosives see Muehlberger C. W., "The Investigation of Bombs and Explosions," J. Criminal Law and Crim., *28* (3, 4): 406-432; 581-607 (1937), and particularly at pp. 409-416.

(Editor's Note: At the trial of this case the photographs shown in Figures 1, 2, and 3, which were taken by Mr. Wilson, proved to be extremely valuable to the prosecution for the purpose of establishing the fact that a "high" explosive had been used and that therefore the damage could not have resulted from a "low" explosive with coal dust or gases as the causative agents. Dr. C. W. Muehlberger, the author of the articles referred to in footnote 6, utilized the photographs as the basis for his testimony that the effects of the explosion, as illustrated by the photographs, identified the causative agent as a "high" explosive.)

Some idea of the explosion can be gained from the following: A piece of the cast-iron base of the motor-generator weighing approximately 125 pounds was blown a distance of 150 feet; another piece of the same cast-iron base weighing 63 pounds was blown over the top of a one-story warehouse and landed a distance of 300 feet from its original position.

After completing the examination of the scene of the explosion, and after having inspected the battered remains of the alarm clock and other objects recovered, the writer made a thorough search of the home and private workshop of the two former mine employees under arrest.[7] It was thought that in the event these men were the guilty parties, some physical evidence might be located on their premises, and particularly in the workshop, which would be of value in establishing their participation in the crime.

The workshop had been used by these two men for repairing and overhauling radio receivers, and as might be expected in a shop of this kind, there existed the customary accumulation of parts of radio sets in various states of disrepair, a number of different types of wire, and tools. In a first-aid kit, in the shop, was found a portion of a roll of one inch white surgical adhesive tape, with two longitudinal strips missing from the end of the roll. In view of the fact that similar tape had been utilized on the rear of the recovered alarm clock for the purpose of fastening various pieces of wire, the roll of tape itself was preserved for further examination.[8] In addition to the tape, the following articles were recovered from the workshop and retained for laboratory examinations: Four wire-cutting tools; six samples of wire solder; twenty-four samples of solid wire ranging from No. 17 to No. 12 Brown and Sharpe gauge; five samples of stranded flexible insulated wire; and twenty yards of linen cord.[9]

Laboratory Examinations

Examination of the remains of the alarm clock timing device recovered from the scene of the explosion revealed the fact that

[7] Permission for the search had been obtained from the suspects, and therefore the attack upon the admissibility of the evidence on the grounds of illegal search and seizure was of no avail to them at the time of the trial.

[8] Subsequently Katherine Keeler of the Laboratory Staff made an exhaustive examination and comparison of this tape and the specimens removed from the alarm clock. The results are described by her in the accompanying paper.

[9] Mr. M. E. O'Neill of the Laboratory Staff examined and compared the linen cord specimens found in possession of the suspect and that removed from the alarm clock and found them to be similar as to color, number of strands, direction of twist, etc.

two types of wire had been used in arranging or constructing the mechanism so that it would close an electric circuit after the lapse of a predetermined time interval. (See Figure A-A, B, C.) In addition to the two types of wire, two pieces of white adhesive tape and a length of linen twine had been used in the construction of this device. (A facsimile of the entire mechanism appears in Figure 5-A, B.) The "movable" contact was made from a short piece of No. 12 Brown and Sharpe gauge steel core, copper coated wire approximately 3″ in length (Fig. 4-A) and had been wrapped with a piece of white adhesive tape (T_1—Fig. 5-A) to serve as insulation between the wire and the clock. A second piece of the same white adhesive tape was wrapped around the wire (T_2—Fig. 5-A), the first piece of tape, and the alarm key. Over this second piece of tape a number of turns of linen cord had been used as a "lash line" (Fig. 5-A, B). To one end of this piece of solid wire a flexible insulated wire had been soldered. What might be referred to as the "stationary" contact was arranged by soldering an extension on the time key. This was a second piece of No. 12 Brown and Sharpe gauge steel-core, copper-coated wire (Fig. 4-B). To the tip of this extension a length of flexible insulated wire had been soldered.

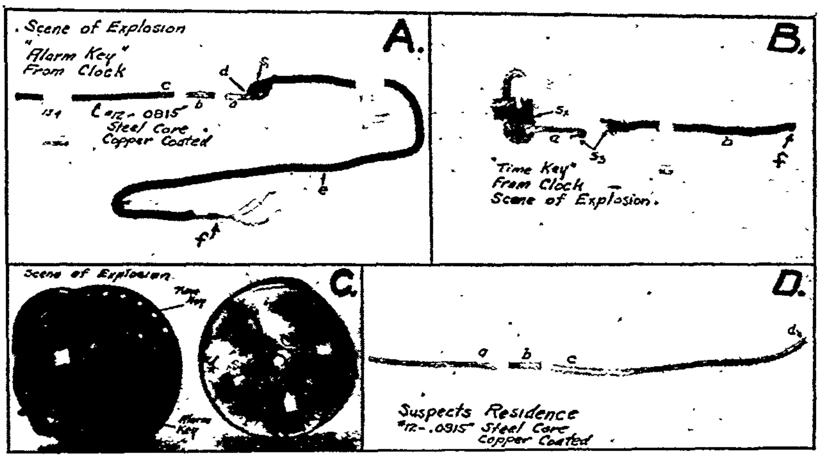


FIGURE 4

(A) Steel core, copper-coated extension (cut into three pieces, *a*, *b*, *c*, *d*, for purposes of examination), to which was soldered flexible insulated wire *e*, found secured to the alarm key of the clock recovered from the scene of the explosion.

(B) Steel core, copper-coated extension (*a*) soldered to time key, to which was attached the flexible wire (*b*).

(C) Remains of the alarm clock found at the scene of the explosion.

(D) Steel core, copper-coated wire 155 mm. long, average diameter .0815″, which was recovered from the workshop of the suspects.

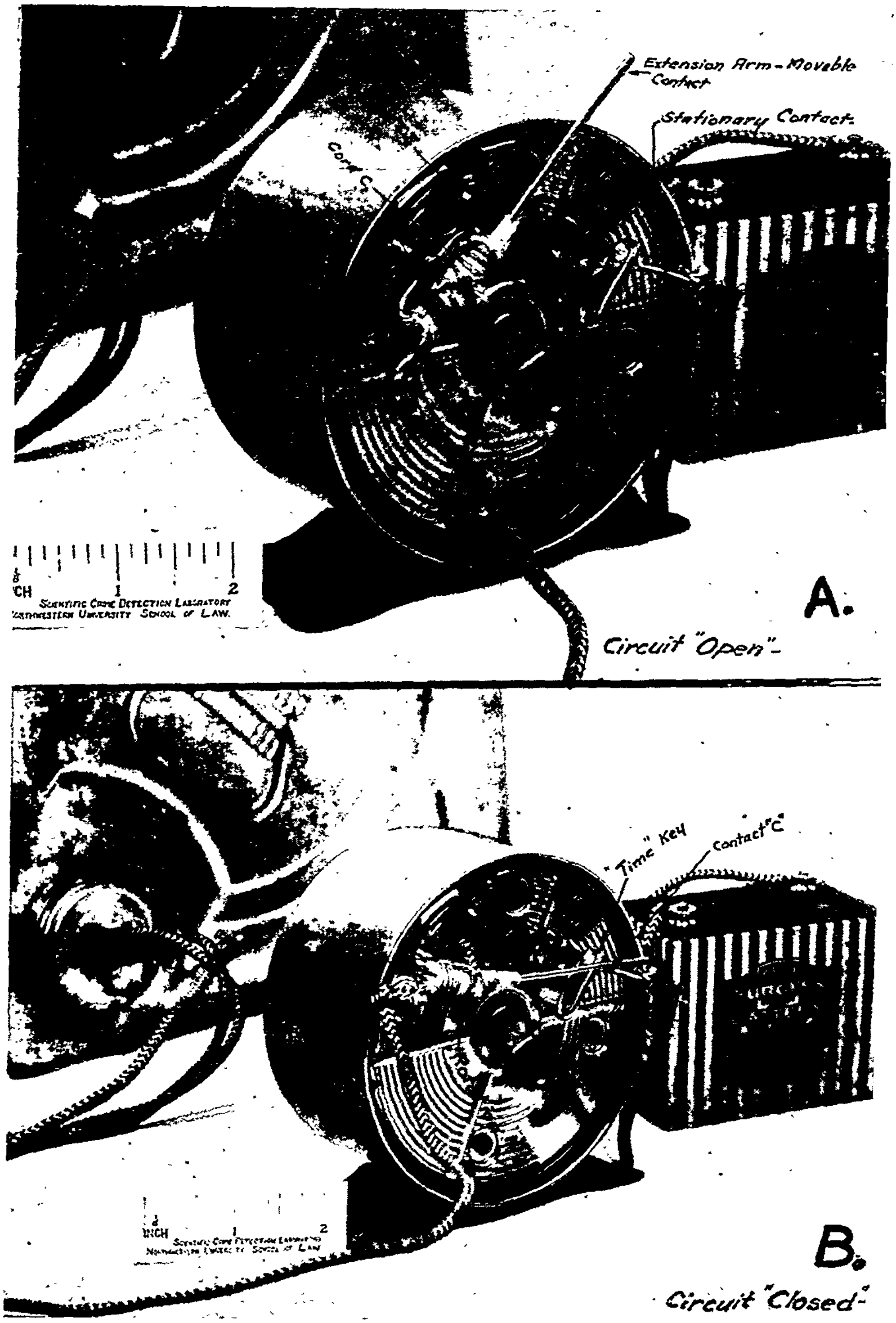


FIGURE 5

Alarm clock arranged as delayed circuit closing device—reconstructed as recovered from th scene of the explosion. (A) In open or "ready" position—circuit open; (B) In closed o contact position—circuit closed.

The construction of this device would permit it to operate in the following manner: The "time" and "alarm" mechanisms of the clock are wound and the alarm key set in a "ready" or "open" position as shown in Figure 5-A. The alarm is set to ring after any desired lapse of time interval to twelve hours. After this time has elapsed, the alarm mechanism will then be released, the alarm winding key revolving in a clockwise direction, bringing the movable insulated solid wire extension in contact with the stationary wire extension soldered to the time key (Fig. 5-B), thus closing an electric circuit in which a source of potential difference (battery) and an electric blasting cap had been included.

The flexible leads for the time mechanism (*e* and *f* of Fig. 4-A, B) were found to have been made from a stranded copper wire having a rubber and dyed green-yellow cotton braided insulation. The strands were found to consist of sixteen strands of No. 30 Brown and Sharpe gauge copper wire.[10]

Comparisons were made involving these two pieces of stranded flexible wire and the five specimens of stranded flexible insulated wire recovered from the workshop of McDonald and Robertson. The five specimens of stranded wire were all found to have been made from sixteen strands of No. 30 B. & S. gauge wire, and each had a rubber insulation with a woven outer wrap of green and yellow dyed cotton strands. Two of the five specimens were eliminated from further consideration since the copper strands were found to have been tinned, whereas the three remaining specimens and the flexible leads *e* and *f* (Fig. 4-A, B) were plain copper. Comparisons were made involving the woven outer green and yellow woven cotton wrap and the cotton serving of the three specimens and a small piece of the original dyed green and yellow outer cotton serving (approximately ¼″ in length) found attached to flexible wire "b" (Fig. 4-B) at the time the alarm mechanism was recovered. This comparison revealed that they were of the same

[10] The ends of the strands of these two pieces of flexible wire were observed to be distinctly different in the method employed in severing from adjacent wire. Strand ending *f* of Figure 4-A gave evidence of having been cut from adjacent wire and, in addition, the rubber insulation had been removed for a distance of approximately ¾″, as would be done in preparing the wire to make an electrical connection. Strand ending *f* of Figure 4-B tapered toward the fractured tips as in the case when wire is stressed beyond its elastic limit. The appearance of these ends was similar to *e* of Figure 16-A.

See Türkel, S., "Kontinuitälstrennung von Metallen (Drähten)" in Beitrage Zur Kriminalistischen Symptomatologie und Technik (1931) 84-85, in which the author gives an excellent photographic representation of the characteristic differences of endings of drawn wires which have been severed by different methods.

type and size and had been made by the same manufacturer. Further, they corresponded as to the number and arrangement of the green and yellow cotton strands in the outer wrap. Finally, the extent of the fading of the dyed cotton strands compared very favorably.

The flexible wire *e* (Fig. 4-A) had been secured to the movable wire extension *a* (from "alarm" key) by wrapping the flexible strands around "d-a" and then soldering *s*. The second flexible wire *b* (Fig. 4-B) had been secured to the stationary wire contact *a* by soldering s_3. This stationary wire extension or contact had been secured to the alarm clock "time" key by soldering s_2.

Spectrographic comparisons were made of a small portion of the specimens of solder recovered from Robertson and McDonald's workshop. The characteristic line spectra of one of the solder specimens from the alarm key (s_1 of Figure 4-A) and of one of the several specimens recovered from the workshop of the suspects indicated the *probability* of the same original source. No such conclusion could be drawn from the other comparisons because of insufficient identical characteristics in their spectra.[11]

The second type of wire used in constructing the alarm mechanism was found to be No. 12 B. & S. gauge. This wire (*a*, *b*, and *c* of Fig. 4-A, and *a* of Fig. 4-B) was found to have a steel core with an outer copper sheath.

The twenty-four specimens of solid wire which had been recovered from Robertson and McDonald's workshop were segregated on the basis of type and size. Of these wire specimens all except a single piece (*a*, *b*, and *c* of Figure 4-D) were eliminated from further consideration as to the possibility that sections from them had been used in the construction of the alarm mechanism because they were of either a different size or type than *a*, *b*, and *c* of Figure 4-A, and *a* of Figure 4-B. This piece of wire, 155 mm. in length,

[11] A quartz spectrograph was used. Materials were vaporized in an electric arc between graphite electrodes. On four different spectrographic plates (a total of 47 exposures) an inconsistent indication of the presence of barium in the same specimens was observed. This suggested the possibility of this element occurring as a surface contamination rather than as being included as an impurity or contamination in the composition of the solder specimens examined. Controls were established by obtaining 25 different types of solder in paste, wire, and bar form and making spectrograms of each. The following elements were identified as being present in practically all specimens examined: Lead, tin, antimony, bismuth, copper, iron and silver.

For a detailed explanation of spectrographic analysis generally, and of its application in an interesting criminal case, see Wilson, C. M., "Spectrographic Analysis as an Aid in Identification Problems," J. Criminal L. and Crim., 25 (1): 160 (1934).

was found to be No. 12 B. & S. (average diameter .0815"),[12] and, further, the wire was a bimetallic product having a steel core with a copper sheath, thus corresponding as to type and size with solid wire from the alarm mechanism.

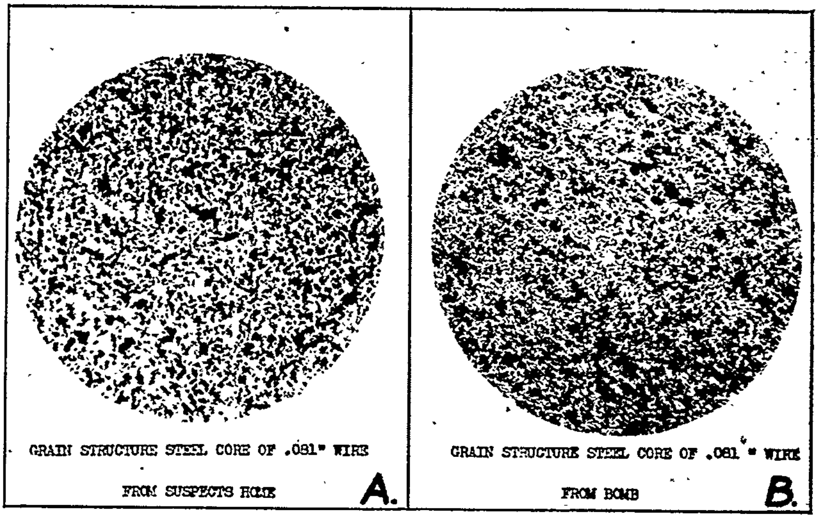


FIGURE 6

Grain structure and inclusions of low carbon steel cores of 12-gauge copper coated wire. (A) Core of wire from defendant's workshop. (B) Core of wire from alarm clock mechanism from scene of explosion.

Original photomicrographs taken at 400X, using Bausch and Lomb type ILS metallurgical microscope. Specimens prepared by polishing and etching with a dilute solution of alcohol and nitric acid.

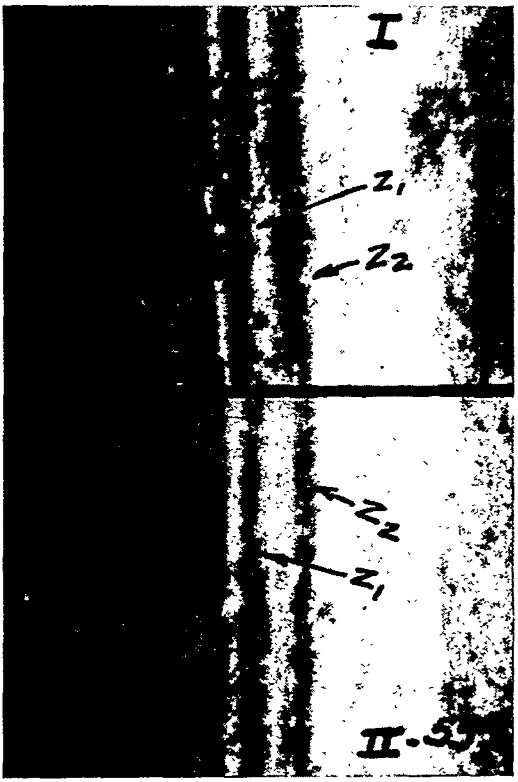
Comparisons of the grain structure and inclusions in the steel core were made involving *a* of Figure 4-A, and *d* of Figure 4-D, in the following manner: Samples were cut from the two wire specimens and mounted in Woods metal, after which they were polished. The surface of the steel core was etched by immersing in a dilute solution of alcohol and nitric acid, after which photomicrographs were made at 400X. These photomicrographs (reproduced in Figure 6-A, B) indicate the similarity of grain size, and of inclusions, of these two low carbon steel specimens.[13]

Comparison microscope studies were made of the outer copper

[12] In the manufacture of this wire the variation of diameter permitted is in accordance with A. S. T. M. specifications, the tolerance being ± 1% of .081".

[13] For a discussion of this type of examination see Mathews, J. H., "Metallographic Analysis in Crime Detection," Am. J. Police Science, *1* (4):440-443 (1930).

surfaces of wire found attached to the alarm clock[14] (*b* in Figure 4-A) and wire from Robertson and McDonald's workshop (*b* in Figure 4-D). In this examination marked similarity was observed to exist in the surface irregularities common to both specimens of wire. In making this series of comparison microscope photomicrographs[15] both pieces of wire were rotated in unison, thus demonstrating "match positions" around the entire circumference of the copper sheath. (See Figs. 7-A, B; 8-A, B, C, D.)



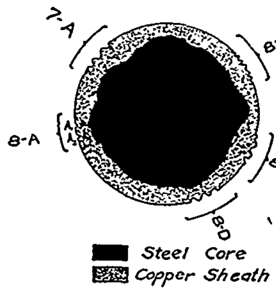


FIGURE 7

(A) (left) is a comparison microscope photomicrograph of die marks evident on surface of steel core copper coated wire; (I) from the workshop; (II) from alarm key extension.

(B) (above) is a diagramatic cross section representation of the wires photographed so as to illustrate the relative locations of areas included in photomicrographs (Figures 7 and 8).

Included among these illustrations are diagramatic cross section representations of the wires photographed so that the relative

[14] See Symons, C. T., Police Chronicle for Nov. 8, 1935, and also J. Crim. L. and Crim., 26 (5):756-757 (1936), wherein were given reports of a case involving the comparison and identification of wire by spectrographic analysis and comparisons of cut ends. Unfortunately the details of the examinations made in this case are not recorded.

[15] The comparison microscope was equipped with paired Ultropak objectives (E. Leitz & Co.) 6.5X-N.A. .20.

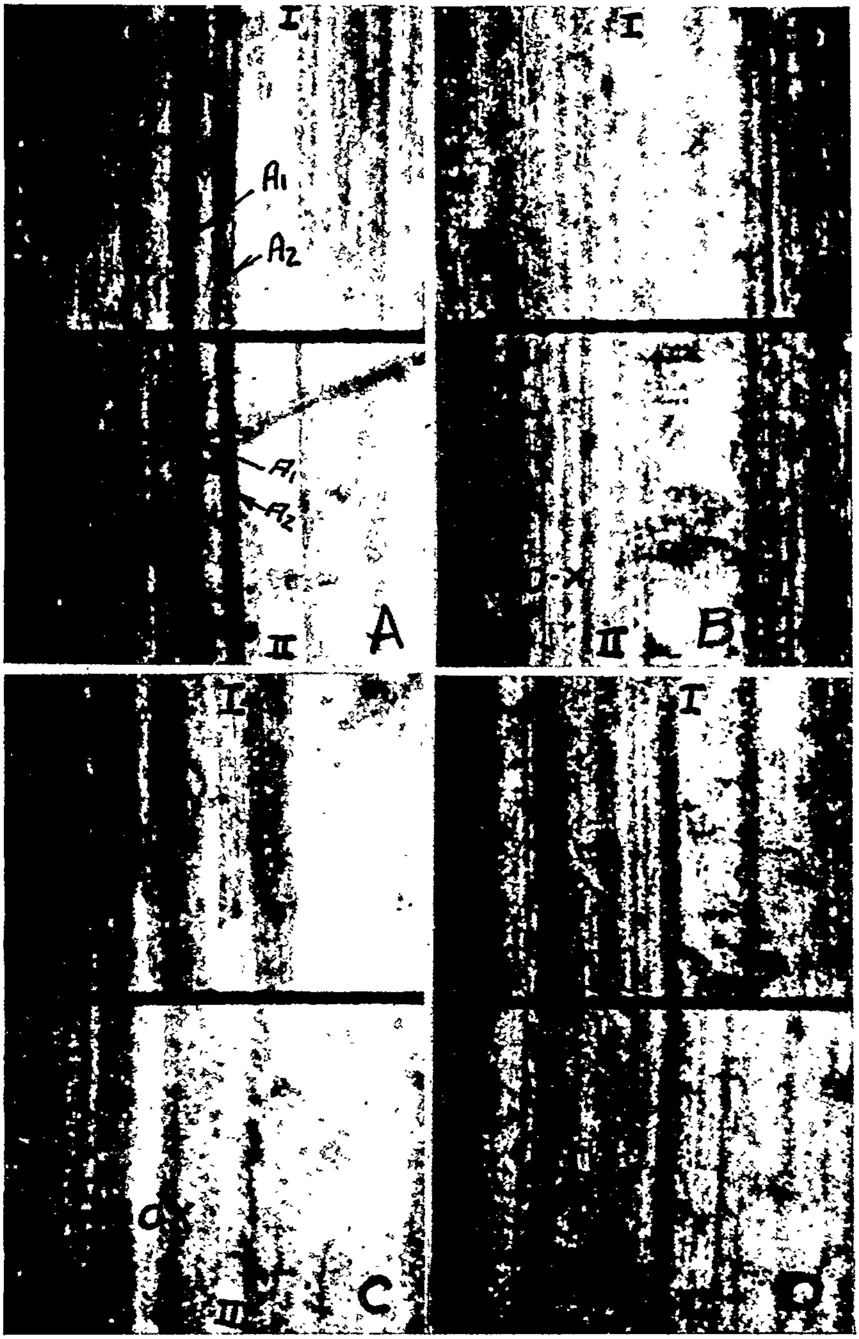


FIGURE 8

Comparison microscope photomicrographs of the die marks evident on the copper surface of the wire. Original photomicrographs 130X, approximately. (I) Surface of wire from defendant's workshop. (II) Surface of wire from alarm key extension. See Figure 7 which locates relative positions of areas on (I) and (II).

FIGURE 9

Comparison microscope photomicrograph illustrating similarity of transverse abrasions found to occur on corresponding portion of circumference near end *d* of Figure 4-D and also on the extension wire *d* of Figure 4-A. (Originals 60X.)

position of photomicrographs on the surfaces of the wires may be shown (Fig. 7-B). Two distinctive die marks, A_1 and A_2 of Figure 8-A, were used as reference or starting points on the circumferences of the wires photographed; thus, in Figures 6-A and 7-A are reproduced comparison photomicrographs of the corresponding portion of the surfaces of wires with A_1 and A_2 in the center of the field. The photomicrographs illustrated in Figure 8-B, C, D were made after revolving both pieces of wire in a counterclockwise direction an equal portion of a turn from the original position. From this it was demonstrated that "match" positions of the surface striations existed around the circumference of both pieces of wire.

The possibility that the wire from the alarm clock timing mechanism was originally attached to and cut from the wire taken from McDonald and Robertson's workshop was first suggested by the comparison microscope photomicrograph shown in Figure 9 in which both pieces of wire are "matched" as shown by coincidence of the prominent die marks A_1 and A_2 previously referred to. In the center of the fields will be observed a number of transverse mechanical abrasions or "nicks" (*b, c, d, e,* and *f*), which apparently were received by the wire surface after it passed through the last die in the wire mill. This could be concluded because these surface abrasions obliterated the die marks in that area. See *e* and *f*.)

It was also observed that these abrasions were confined to one end of each piece of wire, and particularly to the corresponding portion of the circumferences of both pieces of wire with respect to die marks A_1 and A_2. The similarity of these abrasions suggested the possibility that both pieces of wire were at one time immediately adjacent to each other, and which before severing had received the same or similar unusual surface mutilations.

The endings of these same two specimens (*d* of Figure 4-A, and *d* of Figure 4-D) were next examined and compared. (See Figure 10.) It was found that the endings of these two pieces of wire had both been severed from the adjacent wire in the following manner: The copper sheath and been "nicked" at an acute angle wth the axis of the wire (b^1). This had swaged or distorted the copper. The wire had then apparently been bent so that the steel core was fractured as indicated by the characteristic fractured surfaces *i* and *d*. It was found that the projecting fractured end (*d*) of one specimen corresponded very favorably with the fractured cavity *e* of

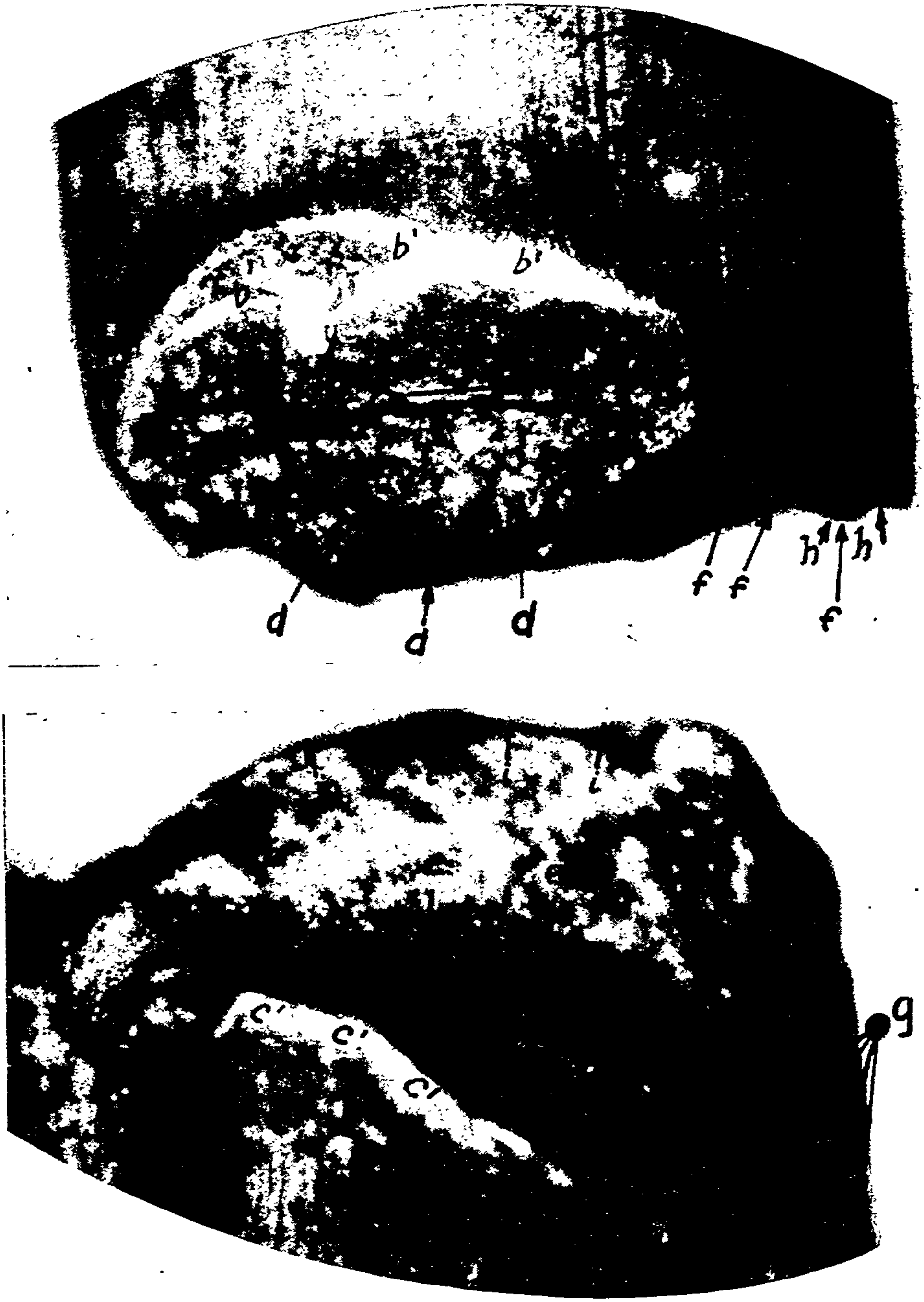


FIGURE 10
Comparison microscope photomicrograph of ends of copper coated steel core wire. Above: wire from the workshop. Below: wire from alarm key extension. (Originals 55X, approx.)

the other specimen. Below the projecting end *d* was a cavity or depression which corresponded very favorably with the protruding fractured area *c* in the other specimen. All of the similarities of the ends of the two pieces of wire were oriented with respect to the "matching" of the die markings previously referred to (A_1 and A_2).

The final comparisons of the same endings of these two pieces of wire were made by cross sectioning both pieces. (See Figure 11, in which *X* corresponds to the cut and fractured ends shown in Figure 10.) A "plug" of the shaft of one specimen of wire was cut (at *s*) by using a fine-toothed jeweler's saw, and then mounting in Woods metal, after which both ends were polished. The same process was repeated with the other specimen, the cut made at approximately the same distance from the end. After polishing, cross sections were etched in a dilute solution of nitric acid and alcohol, and then photomicrographs were made. See Figure 12—1, 2, 3.)

The steel-copper junctions appear in the photomicrographs as an irregular black line. The similarity of the general shape of the irregular steel core is immediately apparent. The orientation of the irregular shape of the steel core in the interior of the wire with respect to the die marks on the outer copper surface was accomplished by locating the prominent die marks A_1 and A_2. In Figure 11, No. 1 and No. 2 represent the opposite ends of the same plug of wire (.486″ in length) from the specimen taken from the suspects' workshop. No. 3 represents the cross section of the wire from the alarm clock mechanism.

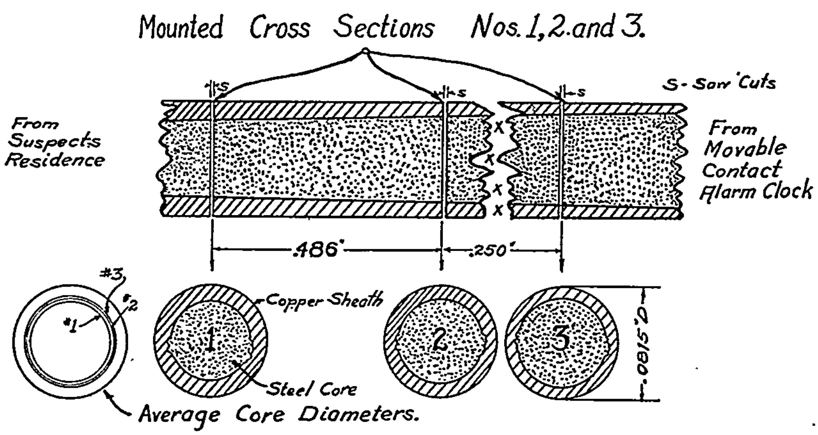


FIGURE 11

Diagramatic representation of endings of wires (Fig. 10) from which cross sections were made.

To illustrate the similarity of contours the comparisons of the shape of the copper-steel junctions were made by tracing the black line of each on a piece of clear film (4 of Fig. 12).[16] In this composite tracing the contour of the copper steel junction of cross-section No. 1 in Figure 11 is represented by a dotted line. The contour of No. 2 is represented by a solid line, and contour No. 3 by an interrupted line.

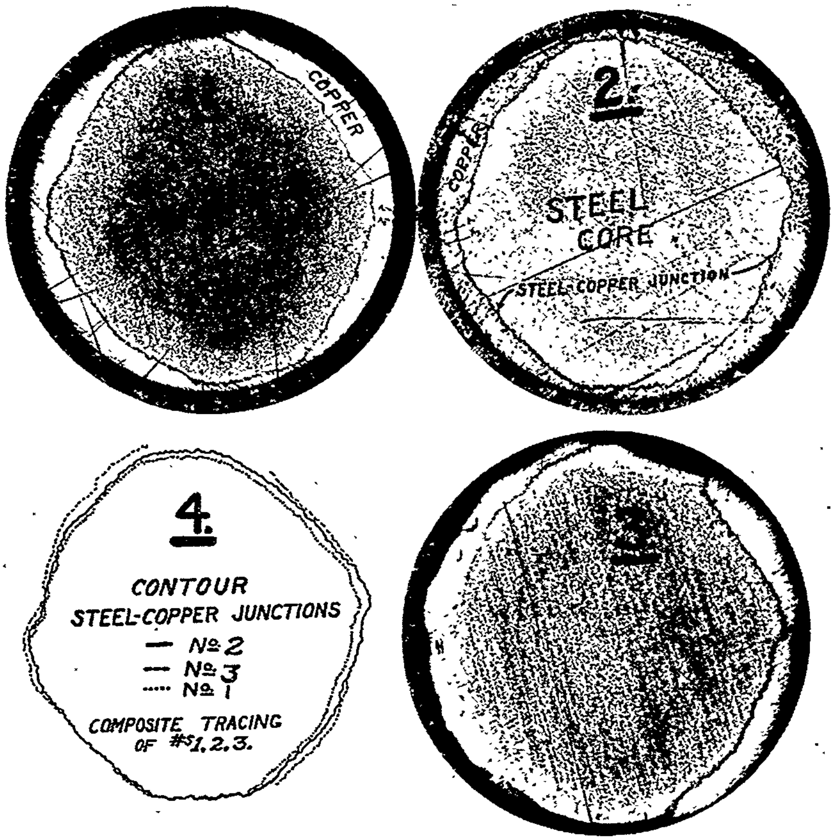


FIGURE 12

(1), (2) and (3) are cross sections of steel core copper coated wires (Fig. 11) after polishing and etching. (4) is a composite tracing of copper-steel junction contours (1), (2) and (3).

(Original photomicrographs made on Bausch and Lomb type ILS metallurgical microscope.)

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16 The direct comparisons were made by superimposing negatives. Translite film, which was not available when these comparisons were made, would have provided an excellent method of comparison. See note in J. Criminal L. and Crim., *28* (1):126-127 (1937).

Examination of this composite tracing reveals that copper-steel junctions No. 1, No. 2 and No. 3 all correspond exactly in the lower portions of Nos. 1, 2, and 3. With the exception of the area where a "match" was obtained, it was found that the contour of cross section 1 was consistently smaller than 2 and that contour 3 was consistently larger in diameter than 2. This indicates that the average diameter of the steel core increases as we cross section the wire from McDonald and Robertson's residence toward the end of wire from the alarm mechanism.

As the result of the comparison of the cut and fractured ends and of the cross sections it was the opinion of the writer that not only had both pieces of wire been drawn from the same die but that they had originally been immediately adjacent to each other in the same shaft of bimetallic wire. It was improbable that such perfect matching of the cut ends would be found in two pieces of wire from different sources. Likewise, it was highly improbable that two pieces of wire would have the same die marks in combination unless they had been drawn through the same die.[17]

Before arriving at this conclusion, and in an effort to properly interpret and evaluate the results of the above described examinations, the writer examined numerous control specimens obtained from various manufacturers. Moreover, he visited a number of wire mills and thus obtained valuable first hand information relating to mill practices.

For the information of other Laboratory technicians who may have occasion to conduct similar examinations the writer appends hereto a somewhat detailed explanation of the processes involved in the fabrication of bi-metallic wire as it is related to the identification of wire. This explanation will at the same time, of course, tend to substantiate the ultimate conclusion arrived at in this case.

The two suspects, Robertson and McDonald, were indicted, tried, and convicted for the bombing of the power house of the Valier Coal Mine.[18] Each received an indeterminate sentence of

[17] The reverse impressions of these die imperfections are transferred to the surface of wire drawn through a die. The examinations undertaken in the control studies strongly indicated that the finer of these surface imperfections would have changed more than was observed to have occurred had the two pieces of wire been several thousand feet apart in the same shaft of wire.

[18] This was the effect of the indictment and trial, although technically they were tried under an indictment charging them with "the manufacture, procuring, or disposing of dynamite or other explosive compounds with the intent to sell the same or that the same might be used for unlawful injury to or destruction of property." Illinois statutes do not provide for the bombing of a non-residence.

from five to twenty-five years in the penitentiary. Practically all of the evidence described herein was admitted at the trial,[19] and its admissibility upheld by the Supreme Court of Illinois, which sustained the trial court's conviction.[20]

The Fabrication of Bi-Metallic Wire

In general, the manufacturing processes used in the production of many types of wire such as copper, brass, iron, bronze, aluminum, etc., closely follow the practices employed in the fabrication of copper and copper-coated steel wire. The control studies undertaken in the preparation of this case were, however, confined to copper, copper-clad and copperweld wire.

Copper-coated steel core wire has been produced in this country by several manufacturers and by various processes. The Duplex Metals Company produced a wire of this type until 1910-11. The Standard Underground Cable Company produced a copper-steel bimetallic wire known as "copper-clad" but its manufacture was discontinued in 1928-29. Since that time a similar type of wire has been produced by the Copperweld Steel Corporation of Pennsylvania, "copperweld" being the trade name applied to the copper-coated steel core material made by the molten-welding process.

Hot rolled copperweld rods are supplied to the wire mills of a number of other manufacturers who, like the Copperweld Steel Company, cold draw the rod to form wire in various sizes. The copperweld material is formed into rods, wire, nails, and similar

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19 Testimony and photographs relative to the spectrographic and metallographic analyses were omitted at the trial because it was thought inadvisable to present to the jury an "overdose" of scientific evidence—in view of the apparent sufficiency of more easily understood evidence which was actually used.

20 People v. McDonald, 365 Ill. 233, 6 N. E. (2d) 182 (1937). It is of interest to note that apparently as a result of this conviction the acts of violence in this warfare practically ceased. Below is a partial list of the acts of violence over a two-year period preceding the conviction in this case:

Nature of Offenses	Number Reported	Killed	Injured	Arrests	Prosecutions	Convictions
Murder	9	10	4	14	5	0
Assault with intent to kill	55	1	55	41	0	0
Bombings	101	0	6	18	0	0
Attempted bombings (failed to explode)	17	0	0	4	1	1
Homes fired into	30	0	2	0	2	0
Kidnapping	2	0	0	0	0	0
Death threats	7	0	0	0	0	0
Riots	63	10	113	388	2	1
Arson	10	0	0	4	0	0
	294	21	180	469	10	2

products in which a protective exterior coating of electrolytic copper is molten welded to the steel core.

The first step in the manufacture of this material is the forming of a cylindrical steel billet approximately 48″ long and 7″ in diameter. After cleaning and fluxing, the steel billet is centered in a circular mold which has an inside diameter of approximately 9″. After sealing the top, the mold and the steel billet are placed in a furnace and heated. When the mold and billet have reached the proper temperature they are removed and molten copper is poured into the space between the steel billet and mold, thus forming a composite bimetallic ingot weighing approximately 260 pounds (see Figure 13). The manufacturers of this material claim a true weld between steel and copper by interlocking the crystalline structure of the two metals.

The older, now obsolete, process of producing copper-clad ingots differed from the copperweld process essentially in that instead of molten-welding the copper to the steel core, a seamless copper tube was formed, and after being heated, was shrunk on the steel core which had been cleaned and fluxed. In this way a composite, bimetallic ingot was formed, having a copper jacket surrounding a steel core.

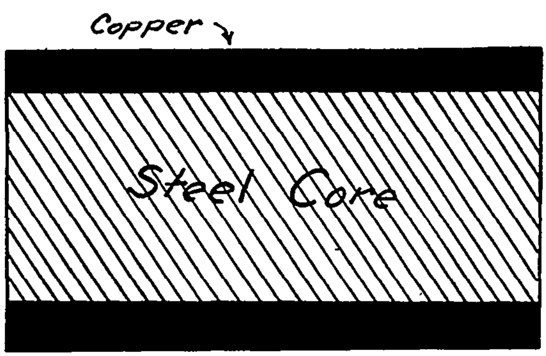


FIGURE 13

Transverse cross section diagram of bi-metallic ingot formed as first step in manufacture of copper-clad or copperweld wire.

In the process of producing either copper-clad or copperweld wire the copper-steel bimetallic ingot is hot-rolled (Fig. 14) so as to form a ⅜″ circular bimetallic rod. The fabrication of this bimetallic hot-rolled rod is accomplished in the following manner: The bimetallic ingot is heated to a dull red heat in a soaking pit or furnace and is then passed between steel rolls rotating in opposite directions (Fig. 14). In this hot, rolling operation the diameter of the ingot is decreased and the length increased. The successive

passes of the rod being formed as between rolls on the surface of which are semicircular cavities (*a* and *b*—Fig. 14); the radii of these cavities are such that they successively decrease the rod diameter, proportionately increase its length, and at the same time preserve its circular form. The final rolling cavities produce a 3/8″ circular rod which is coiled and allowed to cool.

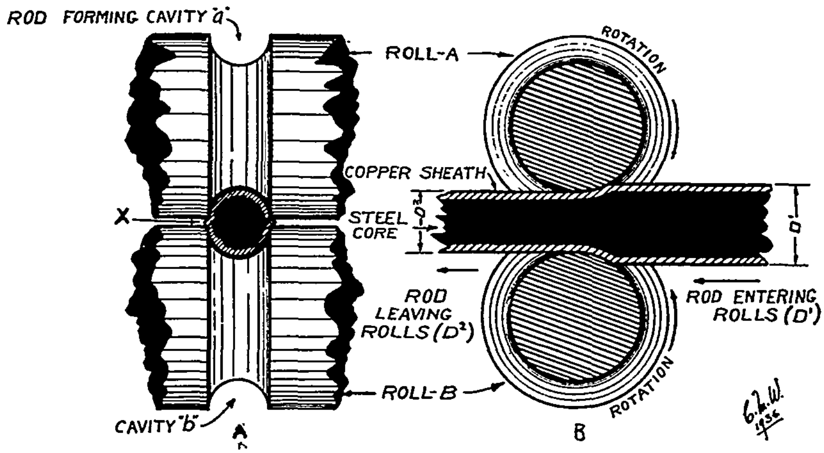


FIGURE 14

Diagramatic representation of hot-rolling operation. By successive passes between rolls A and B, each set of rolls having cavities *a* and *b* of successively smaller diameter, is reduced to 3/8″.

Throughout the hot-rolling and subsequent cold-drawing operations the relation of the diameter of the steel core to the total thickness of the copper coating or sheath remains practically the same as in the original billet.

The 3/8″ diameter circular bimetallic hot-rolled rod is cold-drawn to the desired size by repeatedly pulling or passing it through wire drawing dies which further successively decrease its diameter. In the diagramatic illustration in Figure 15 the rod or wire enters the wire drawing machine and passes through wire drawing die #1 which reduces the diameter due to the plastic deformation occurring as the wire passes through the cone-shaped die throat. Upon leaving die #1, the wire, having a diameter indicated as D^2, is wrapped around a circular capstan or block (B) which, due to the traction between the wire and the rotating surface of the capstan, pulls the remaining wire through the die. The direction of movement of the wire is reversed by passing around capstan A, after

which the wire enters die #2, whose diameter is such that the wire is again reduced (D^3) and then once more is wrapped around capstan B. Wire drawing machines are designed so that the die rack will accommodate a number of dies. As many as twenty drafts or reductions may be made in one machine.

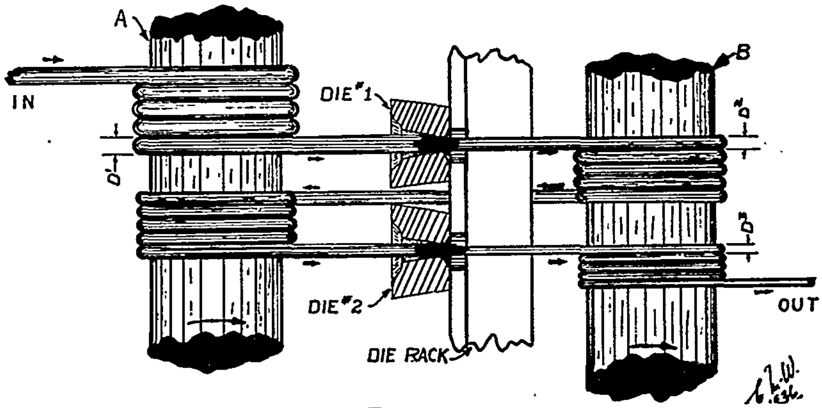


FIGURE 15
Diagramatic representation of continuous wire drawing machine.

Since the reduction of the diameter of the wire proportionately increases its length, the wire will have a greater surface speed in leaving die #2 than the surface speed at which it entered die #1. This difference in surface speeds is compensated for by "stepping" or increasing the diameter of successive blocks or capstans in the direction of draw. In addition, the "slip" of the wire on the surface of pulling capstans tends to compensate for slight difference of capstan surface and wire speed.

The process of cold drawing of wire is a burnishing operation. Because of the plastic deformation or cold working of the wire incidental to increasing its length and decreasing its diameter, and also due to friction between die throat and the wire surface, considerable heat is evolved. The destructive effects of the heat thus generated are minimized and controlled by coating the surface of wire or rod entering a drawing machine with tallow or grease and in addition the wire, capstans, dies and die racks are either immersed in or sprayed with an emulsion of soap, oil, and water. This lubricates the wire and also assists in transmitting the heat away from the wire and dies.

The cold drawing of wire hardens and increases the tensile strength of the metal being deformed or worked. This hardening

limits the cold work that can be successfully undertaken before the metal must be restored to its original crystalline form by annealing or heating under the proper conditions of temperature and surrounding atmosphere. After annealing the rod or wire it is cooled. This important process alters the crystalline structure of the metal so that it ceases to be brittle and in effect restores the material to its original ductile form so that it can again be cold worked or drawn. The question of how often the wire must be annealed depends upon the physical and chemical properties of the metal, the speed at which it was drawn, the number of passes and the reduction per pass through each die.

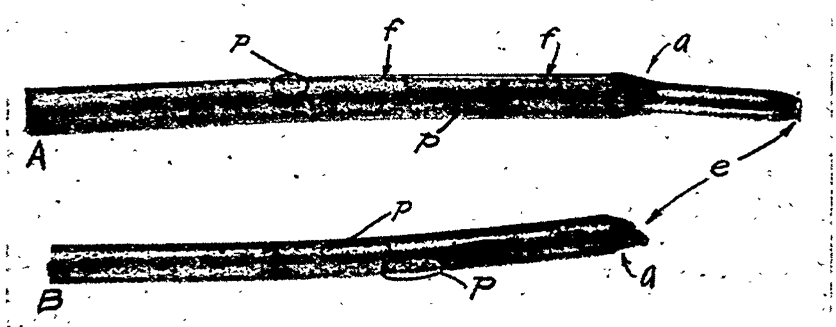
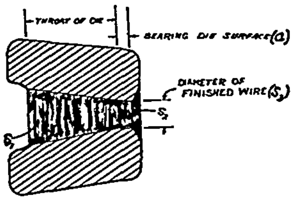


FIGURE 16

(A) Section of hot rolled copper rod which had been cold drawn to *a*. End *e* tapered to fractured end due to over-draft; *f* is fin raised in hot rolling; and *p* are microscopic pits due to pockets formed by scale being forced into rod.
(B) Section of copper wire similar to (A).

The annealing leaves a surface accumulation of hard oxide or scale. Before the annealed wire can be drawn again this scale must be removed by pickling in a hot acid solution. This pickling process fails to completely remove the scale. Some of the particles adhere to the wire surface, some remain lodged in surface pits or pockmarks (P of Fig. 16) or are carried into the drawing die with the lubricating liquid in which wire and dies are immersed. The result of the combined effects of the abrasive or cutting action of particles of scale, dirt, etc., pulled into the die by the wire being drawn and the stresses incidental to the plastic deformation of the wire is to produce a rapid progressive alteration of that portion of the die surface which comes in contact with the wire (Fig. 17). From the time a die is placed in service these progressive changes

of the die surface continue until the standards established by commercial practice force the wire mill to retire from service a die which will produce a wire which is off-size, out of round, brittle, or a wire whose surface contains certain objectionable defects. When a wire drawing die has been retired from service it is returned to the die shop and is lapped out or reshaped so it can again be used to draw a wire of larger size. This is particularly true of cemented carbide and diamond dies. If this were not done the cost of these dies would be prohibitive.



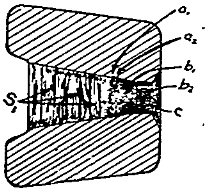
A

FIGURE 17

B

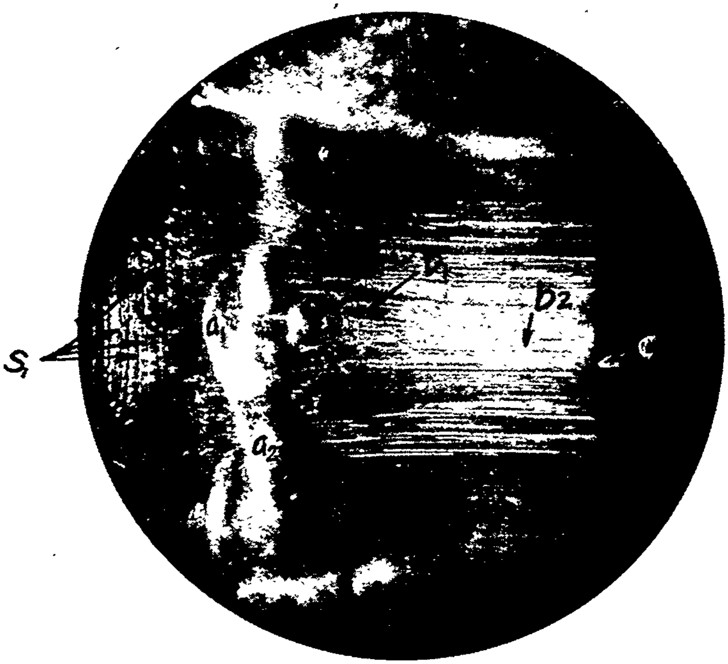
(A) Diagramatic cross section of chilled iron wire drawing die before use.
(B) Photomicrograph of portion of throat and bearing surface of chilled iron wire drawing die before use.

There are a number of different materials from which wire drawing dies have been made. Diamonds, steel, chilled cast iron, and carbides of titanium, tungsten and tantalum have all been successfully employed in making cold drawing wire dies. Because of the high initial cost, the use of diamond dies is largely confined to the drawing of the smaller sizes of copper wire. Carbide dies have come into very general use in the drawing of wire of many types. Chilled iron dies are extensively used in drawing the larger sizes of copper wire, and have been almost universally employed by the mills drawing copper-clad or copperweld wire.



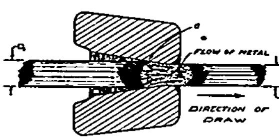
C

FIGURE 17



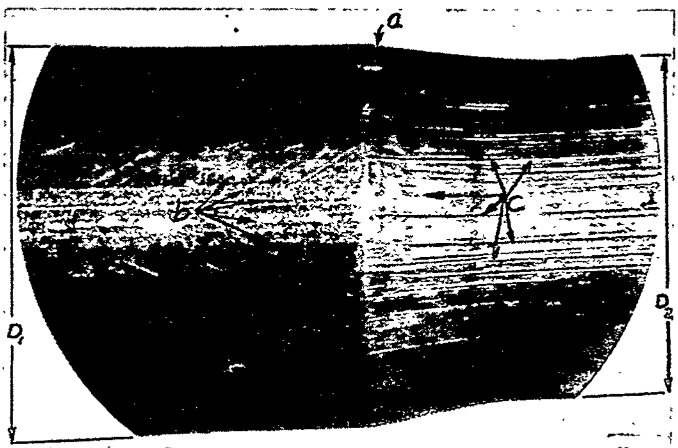
D

(C) Diagramatic cross section of die after use in cold-drawing copper wire.
(D) Photomicrograph, as in B above, after use.



E

FIGURE 17



F

(E) Diagramatic cross section of chilled iron wire drawing die in use for cold-drawing copper wire.

(F) Photomicrograph of surface of copper wire drawn by hand through chilled iron die to *a* and then pulled out of die in opposite direction to draw. Surface irregularities *b* due to characteristic imperfections of last die through which it was drawn to diameter D. Irregularities c due to chacacteristic imperfections of die reducing wire diameter to D_2.

In forming or shaping a wire drawing die a circular or tapered hole is bored through the center of the nib or die blank (Fig. 16-A, B, C. D). In the case of diamond and cemented carbide dies this is an operation known as ripping and is performed in a machine which slowly rotates the die in one direction while a hardened steel wire or needle rapidly rotating in the opposite direction is raised and dropped in the center of the die. This steel wire or needle is charged with a mixture of oil and a powdered abrasive (Alundum, Crystalon, Carborundum, or diamond dust), which does the actual cutting. The result of this operation is to form a circular hole in the center of the die. After the circular hole has been formed the axis of the die is tilted with respect to the axis of the original hole and in the same machine the throat or tapering portion of the die is formed. The shape of the finished hole is then a right conical frustum (Fig. 17-A, C).

As has been pointed out, the forming of the wire cavity or throat in all types of dies by ripping, lapping or reaming is accomplished by rotating the die, the drill, or both. This leaves surface imperfections or striations which appear as annular rings in the die throat and bearing surface (S_1 and S_2 of Fig. 17-A, B, C, D).

In the drawing of copperweld and copper-clad bimetallic wire, as has already been pointed out, chilled iron dies are almost universally employed. The cost of one of these die blanks represents only a few cents but the life of the die is very short compared to the life of carbide or diamond dies. It was found that the average life of the chilled iron dies when used to draw copperweld wire would run from 250 to 1000 pounds of wire before the die was no longer fit for service. When the same type of die is used in drawing pure copper wire its life was found to increase to from 500 to 2500 or 3000 pounds of wire. Carbide dies, when used to draw pure copper wire, could be expected to run 35,000 to 120,000 pounds of wire. When used to draw copperweld wire the carbide die life could be expected to run from 10,000 to 30,000 pounds of wire. Pure copper wire has been drawn through carbide and diamond dies at speeds up to 5000 feet per minute. Copperweld wire, being drawn from .128″ to .081″, travels at speeds from 900 to 1100 feet per minute. As might be expected, at surface ironing or burnishing speeds of this order there are relatively rapid progressive surface changes taking place on the die throat and bearing surface of the die which is cold working the wire. The control studies made confirmed this beyond any question of doubt (Fig. 17). Figure 17-B

is a photomicrograph taken after breaking a chilled iron die which had been machined but had never been used to draw wire. Surface imperfections S_1, S_2 in the throat and bearing surface of die appear as annular rings and are the result of boring and reaming operations incidental to forming the die throat and bearing surface.

Figure 17-D is a photomicrograph of the corresponding area of the same type of die (chilled iron) after being used to draw approximately 1000 pounds of copperweld wire. In that portion of the die throat which did not come in contact with the surface of the wire being drawn the original annular rings S_1, S_2 are retained at a_1 and a_2 and an irregular series of cavities will be seen. These correspond in the die throat with the area against which the entering diameter of the wire impinged. (See *a* in E and F.) At b_1 and b_2 in D will be seen a large number of striations extending in the direction of draft of the wire. These surface striations are oriented in a plane at right angles with respect to orientation of finishing striations (S_1 and S_2). b_1 and b_2 are produced by drawing wire through the die. The reverse impressions of b_1 and b_2 are transferred to the surface of wire drawn through a die. The resulting imperfections produced on the surface of copper wire cold drawn by such a chilled iron die are shown in Figure 17-F, which is a portion of the surface of a piece of wire hand drawn by the writer through a chilled iron die up to *a* and then pulled out in the opposite direction. On the surface of this wire (*b*) will be seen the die marks or reverse impressions of imperfections in die reducing wire to diameter d_1. At *c* will be observed an entirely new set of die imperfections due to irregularities in the throat and bearing surface of die which reduced wire diameter to d_2.

It should be pointed out that in a continuous wire drawing machine where two or more dies are successively employed in cold drawing wire, the imperfections in the throat and bearing surface of one die may under certain conditions be transmitted to and produce a similarly shaped and located imperfection or group of imperfections in the next die in the direction of draw or draft.

In attempting to explain this inter-die influence it was found that when gross or major imperfections exist in the first die in a series, the reverse impression of these surface irregularities are as has been shown left on the surface of wire drawn through a particular die. These major or gross imperfections on the surface of the wire produce a localized area of accelerated friction or stress in a corresponding position on the interior of the second or third

die in the direction of draw. This localized area of increased stress will, with continued drawing, produce a similarly located and shaped surface imperfection in the throat or bearing surface of the next die or dies in the direction of draft. It was found that the wire surface imperfections at the point of origin differed from the other imperfections and that they were not as sharply defined as when leaving the original die making them. The highly individual characteristics produced by the last die in a series were found to be much more sharply defined and generally were much smaller than those originating in the second or third die preceding the last die in a series.

In Figure 8-A, A_1 and A_2 can be attributed to the last die through which the wire was drawn, whereas Z_1 and Z_2 in Figure 7-A can be considered to be in all probability the resultants of the combined effects of the last and next to the last die in the series through which this wire was drawn.

In connection with the irregular copper-steel junctions illustrated in Figure 12, control studies were undertaken for the purpose of investigating the possibility that the irregular contour of the copper steel junction constituted an individual characteristic in which progressive changes occur as we proceed along the axis of a given piece of wire of this type. In this study a number of specimens of bimetallic wire were prepared: (1) by cross-sectioning the shaft of wire at uniform intervals along its axis (as had been done in the case study—Figures 11, 12); and (2) by removing the outer copper coating by acid and electrolytic deposition of the copper sheath. The results of these examinations indicated that the shape or contour of the copper-steel junction constituted a highly individual characteristic peculiar to a particular piece of wire and also peculiar to a particular section along the axis of the shaft of a piece of wire.

In seeking an explanation of the source or cause of these irregularities it was found there was a considerable divergence of opinion among metallurgists and mill men as to the specific or immediate cause. It is concluded by the writer that the irregularities are due to a combination of a number of possible causes resulting from the hot rolling of the rod and the cold drawing of the wire.

In Figure 14-A it will be seen that at X the rod is unsupported by the rolls. This unsupported portion on opposite sides of the circumference of the rod would result in a spreading of the rod, producing a fin extending along the outer circumference of the

copper rod (*f* in Fig. 17-A). As the rod is passed through subsequent reducing passes the copper fin will be folded over, thus thinning the copper sheath. This non-uniform condition will produce a variation in the working or plastic deformation of both steel and copper along the steel-copper contact of the rod or wire being produced.

If the weld between steel and copper is not complete and continuous along the rod, there is the possibilty that gas pockets between steel and copper may result. This would contribute in producing a non-uniform working and shape of copper-steel junction from which the bimetallic rod is made.

Comparing the rate of the reduction per pass in cold drawing copperweld and copper clad wire it was found that reductions up to 30% of the entering wire diameter was common practice in the wire mills. Crane[21] has pointed out that copper in being drawn to 30% of its original diameter produces a unit stress of approximately 25,000 pounds per square inch, whereas .10 carbon steel will produce a unit stress of approximately 40,000 pounds per square inch. As might be expected, simultaneous cold working of two metals under these conditions will, unless both metals are truly homogeneous, produce a directional segregation of non-homogeneous inclusions in either metal.

Crane,[22] Harris,[23] and Nädai[24] have pointed to the fact that in the cold working of metals the internal stresses produced are not uniform throughout, the metal being plastically deformed by cold working. Sauveur[25] points out the fact that there exists in metals which have been cold worked certain directional banded structures or segregations within the metal being cold worked.

If in either the copper sheath or the steel core there exists a non-uniformity as to the hardness of the two metals then we would expect a segregation to occur in the direction of draw. This is assigned as a contributing factor in deciding the probable source of the irregular nature of the copper-steel junction previously referred to. As has been pointed out, these irregularities were found to be an individual characteristic peculiar to a particular piece of

[21] Crane, E. V., Plastic Working of Metals and Power Press Operations (1932) 127.

[22] *Op. cit. supra* note 21 at p. 149.

[23] Harris, F. W., "Distribution of Tensile Strength in Drawn Wire," Am. Inst. Mechanical Engs. for Feb., 1928.

[24] Nadai, A., Plasticity (1931) 269.

[25] Sauveur, A., The Metallography and Heat Treatment of Iron and Steel (4th ed., 1935) 186-188.

wire and also peculiar to a particular section along the axis of a piece of wire.

Considering the results of the copper steel junction control studies made, with the observations made involving the wire from the scene of the explosion and the wire from the workshop of Robertson and McDonald, the similarities become strikingly significant when, in addition to the copper-steel junction similarities (Fig. 12), it was found that the die marks on the outer copper circumference or sheath (Fig. 7-A; 8-A, B, C and D) "matched" or simultaneously corresponded.