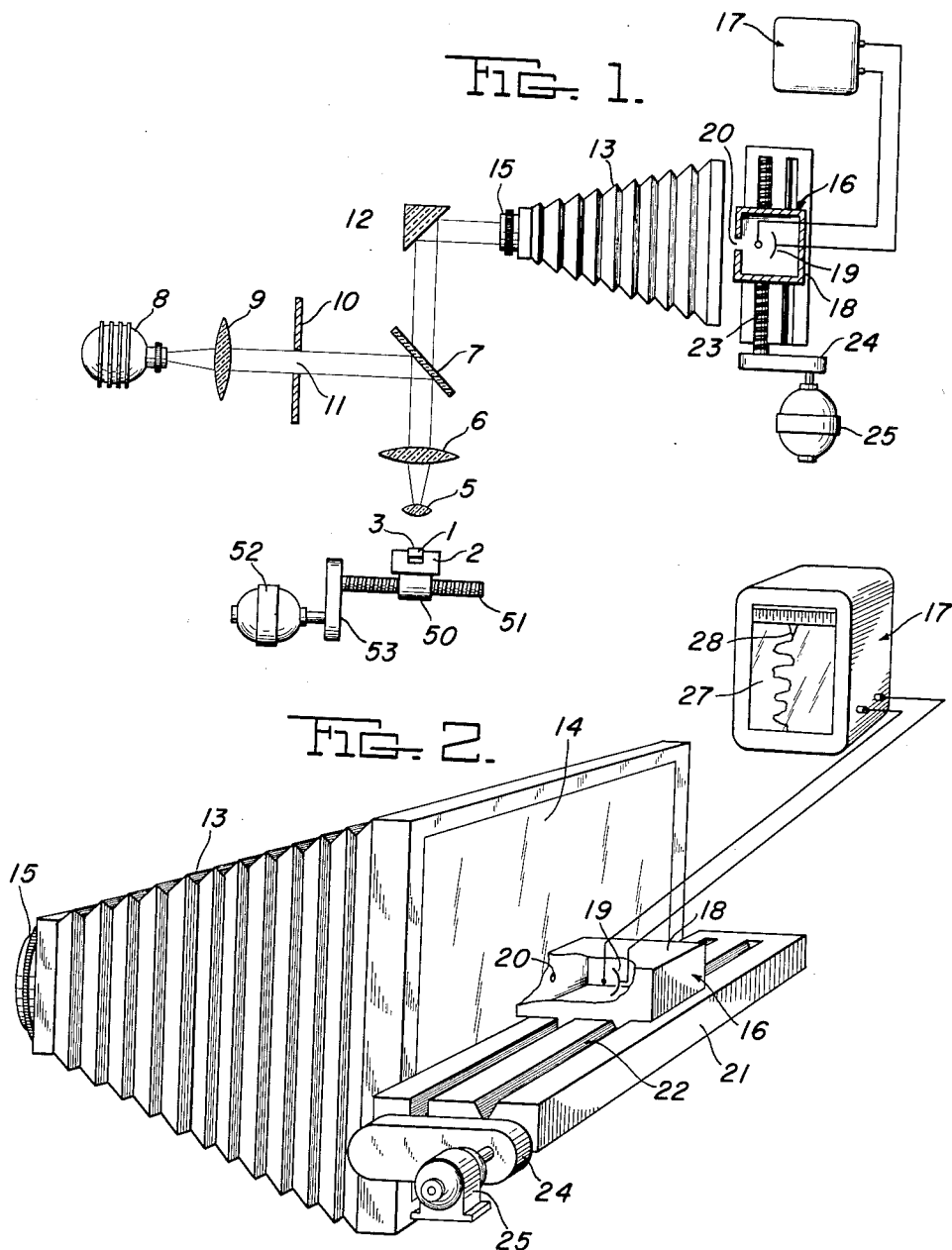


Jan. 24, 1956

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METHOD OF AND APPARATUS FOR DETERMINING THE
MICROCONSTITUENT CONTENT OF METALS

2,731,878

2 Sheets-Sheet 1



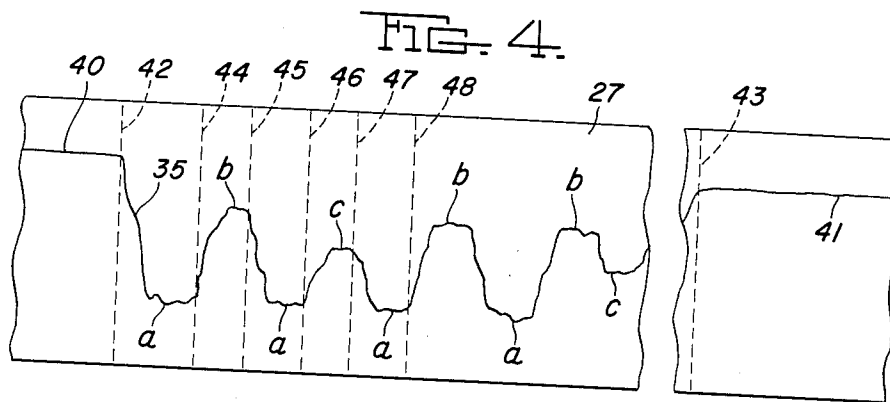
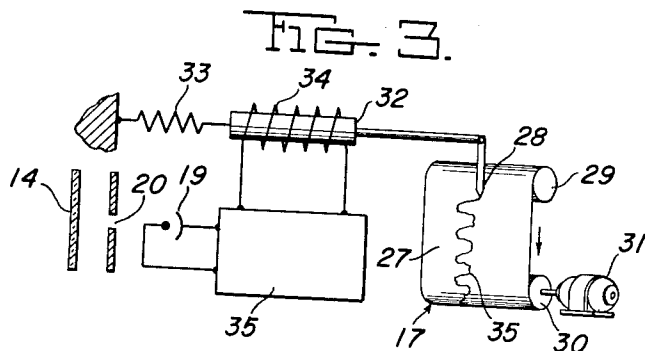
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METHOD OF AND APPARATUS FOR DETERMINING THE MICROCONSTITUENT CONTENT OF METALS

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4 Claims. (Cl. 88—14)

This invention relates as indicated to a method of and apparatus for determining the microconstituent content of metal specimens prepared by metallographic techniques.

More specifically, this invention is directed to the problem of obtaining a quantitative analysis of the constituents in metals, particularly steels and alloys thereof.

When two or more elements are alloyed or compounded together and the resulting alloy is frozen from a melt the resulting metal will not always be a homogeneous substance. In most instances (such as steel) the metal will be composed of a semi-orderly agglomeration of constituents each of which is associated with one of the basic elements and each of which contributes certain characteristics to the properties of the whole. Furthermore, in most metals (again steel is an example) heat treatment of the solid material will change its constituents in one or more ways such as type, size and distribution. Since it is recognized that the properties of a metal are closely allied to the type and distribution of its constituents the study of microconstituents is basic to research and study of most metals.

While the conventional metallograph has been developed extensively for the purpose of examining the arrangement and distribution of the constituents of metals and for making microstructural studies thereof, the problem of determining the quantity of selected ones or all of the constituents in any given metal has continued to be a source of considerable trouble. Conventional practices for making such determinations are not only tedious and difficult but consume considerable time in arriving at a determination which can be said to be reasonably accurate. With the difficulties of conventional practice in mind, this invention has as its principal object the provision of a method and apparatus which facilitate the determination of the microconstituent content of metals. To this end, and in a manner to be described, an illuminated and microscopically enlarged reproduction of an etched surface of a metal specimen, which may be either a photograph or reflected image, is examined electrically to obtain an integrated record of the light emitted by the reproduction along a line extending transversely thereof, and from which the microconstituent content of the specimen can be calculated.

In conducting metallographic studies of a metal specimen, a scratch-free surface of a metal specimen is prepared by cutting, grinding, and polishing, which is then etched in a conventional manner. After etching, the constituents have different light reflectivities which render their arrangement and boundaries visible to the metallographer. It is thus possible for the metallographer to examine the distribution and arrangement of the constituents, for example, cementite, ferrite, pearlite, austenite, etc. in selected metal specimens.

While the arrangement and distribution of the constituents can be examined readily by the use of a metallographic apparatus, a determination of the quantity of any given constituent in a metal specimen is frequently

desirable for metallurgical studies. In making such determinations, it has been established that the percent by volume of a given microconstituent in a metal specimen is equal to the percent of the area of a polished plane section of the specimen which is occupied by such constituent. It has also been established that the percent by volume of the constituent in the sample is equal to the percent of a straight line taken at random across the surface of a polished plane section which coincides with the total length of the constituent grains lying along such line. Both the area percentage and the linear percentage occupied by the constituent in a polished plane section have been utilized in determining the quantity of the constituent in a metal specimen, the linear determination representing conventional practice since it is quicker and more accurate. However, the accuracy of conventional practices based on a determination of the linear percentage is dependent on the visual perception of the metallographer, and several determinations must be made from which an average is taken to reduce the margin of error.

A further object of this invention is, accordingly, to provide a method of and apparatus for determining the percentage of microconstituents in a metal in which the accuracy of the determination is not dependent on the visual perception of the operator.

Another object is to provide a method of and apparatus for recording the intensity of light emitted by an illuminated reproduction of a polished and etched surface of a test metal specimen along a line extending transversely of the illuminated production.

A still further object is to provide an apparatus and method of the character just referred to in which the record of the linear light intensity of the illuminated reproduction is obtained by photoelectrically scanning the reproduction.

Other objects and advantages of the invention will be apparent from the following description.

In the drawings, there is shown a preferred embodiment of the invention. In this showing:

Figure 1 is a diagrammatic plan view of an apparatus embodying the principles of this invention;

Figure 2 is a perspective view of a portion of the apparatus shown in Figure 1;

Figure 3 is a diagrammatic view showing the essential electrical components of the photoelectric scanning and recording units shown in Figures 1 and 2; and

Figure 4 is a partial plan view of a record tape having a record thereon of a schematic nature for the purpose of illustrating the manner in which the percentages of microconstituents in a metal sample are determined.

In Figure 1, the essential parts of a conventional metallograph for producing a microscopically enlarged reproduction or image of a polished and etched surface of a metal specimen or objective on a ground glass screen are illustrated schematically. In this showing, the numeral 1 designates a test metal specimen which is mounted in a table 2 and has an upwardly facing surface 3. The surface 3 is polished and etched in the conventional manner for metallographic observation prior to mounting the specimen 1 in the table 2. Parallel rays of light are projected against the surface 3 by lens elements 5 and 6 from a reflector 7 which receives light from a source 8 by way of a lens 9 and a plate 10 having a light passing aperture 11 therein. Reflected light from the surface 3 is delivered by the lens elements 5 and 6 through the reflector 7 to a prism 12. The prism 12 in turn delivers the reflected light to the bellows 13 of a metallographic camera having a ground glass screen 14 (see Figure 2) at its outer end. The bellows 13 includes a focusing lens (not shown) at its small end 15 which receives the reflected image of a portion of the surface 3 transmitted

thereto by the prism 12, and which focuses a microscopically enlarged reproduction of such surface on the screen 14 for visual observation. There is thus produced on the ground glass screen a microscopically enlarged and illuminated reproduction of a portion of the object surface 3. The parts of the apparatus thus far referred to for producing the illuminated image on the screen 14 are conventional.

A record of the intensity of light emitted by the screen 14 along a line extending transversely thereof is produced by a scanning unit designated as a whole by the numeral 16 and a recording instrument 17. The units 16 and 17 are conventional types which are produced commercially in a number of forms suitable for the purposes of this invention. Accordingly, it will be understood that the showings of the components of these units in the drawings are schematic for the purpose of explaining the principles of this invention, and that such showings are not intended to illustrate the precise structure of the conventional apparatus actually employed.

The scanning unit 16 comprises a light excluding enclosure or housing 18 having a photoelectric cell 19 mounted therein and an aperture 20 through which light is delivered to the cell 19. The photoelectric cell may be either a self-generating photo-voltaic cell or a phototube having an external energizing source of potential. The housing 18 is mounted on a table 21 with the aperture 20 facing and positioned closely adjacent the surface of the screen 14 so that the light projected against the cell 19 will be dependent upon the intensity of the light emitted by the portion of the screen 14 opposite which the aperture 20 is located. The housing 18 is mounted on the table 21 by ways 22 which provide for a guided rectilinear movement of the housing 18 and its aperture 20 along a line extending transversely of the screen 14. The housing 18 has a micro-drive including a screw 23, a speed reduction transmission 24 and a variable speed electric motor 25 for moving it at a controlled rate of speed along the table 21 and laterally of the screen 14, the housing having a drive nut (not shown) connecting it to the screw 23 for traverse movement thereby in the manner of conventional screw machines.

The recording device 17 is a conventional instrument having a moving tape 27 and a marking device 28 operated by a galvanometer type of mechanism for recording changes in electric potential or an electrical force thereon. As shown in Figure 3, the tape 27 is mounted on spaced reels 29 and 30 and is driven in the direction indicated by the arrow by a variable speed electric motor 31 or other prime mover connected to the reel 30. The marking device 28 is actuated linearly and transversely with respect to the tape 27 by a solenoid 32 against the action of a biasing spring 33 in accordance with current variations in its operating coil 34. The terminals of the coil 34 are connected with the output terminals of an amplifier 35 which has its input terminals connected in circuit with the photoelectric cell 19. As the light emitted by the screen 14 and projected through the opening 20 against the photoelectric cell 19 varies with movement of the housing 18 across the face of the screen 14, a corresponding variation in the voltage produced by the cell 19 is effected. This changing voltage is amplified in the amplifier 35 and produces a changing current in the coil 34 which is effective through the solenoid 32 and biasing spring 33 to move the marking device 28 transversely with respect to the movement of the tape 27 by amounts corresponding to the varying intensity of the light projected through the opening 20. The movement of the tape 27 in the direction of the arrow by the motor 31 will of course be related to the movement of the scanning unit 16 by the motor 25, and the linear length of the line 35 along the length of the tape 27 will thus have a predetermined relation to the traverse movement of the scanning unit across the face of the screen 14, and this relation may be varied readily by adjusting the relative speeds of the motors 25

and 31. The lateral deflections of the line 35 by transverse movements of the marking device 28 will of course afford an indication of the microconstituents scanned during the scanning movement of the unit 16.

The manner in which the record on the tape 27 provides an indication of the microconstituent scanned by the unit 16 along a line transversely of the microscopically enlarged reproduction on the screen 14 and from which the percent by volume of any given microconstituent may be determined will be best understood by reference to Figure 4. In this showing, the line 35 on the tape 27 has been drawn for the purpose of illustrating the principles of the invention, and it will be understood accordingly that this line is not one which was obtained by a use of the invention. Before referring further to Figure 4, it will be recalled that the various constituents have different intensities of illumination in the microscopically enlarged reproduction of an etched surface of the specimen on the screen 14. By reason of the different intensities of illumination of the constituents, each constituent will cause a different deflection of the marking device 28 as the aperture 20 of the scanning unit moves over a particle of such constituent. Assuming that the metal specimen is comprised of three constituents, which will be designated here generally by the letters *a*, *b*, and *c*, the line 35 along the length of the tape 27 will be comprised of a series of peaks *a*, *b* and *c*, such peaks being due to the different intensities of illumination from such constituents as the particles thereof are examined by the scanning unit. In Figure 4, the straight portions 40 and 41 of the line 35 represent the mark made by the device 28 just before and just after the scanning unit moves over the enlarged reproduction as, for example, when the unit 16 is scanning the frame along the edges of the glass screen 14. The linear length of the tape between the dotted lines 42 and 43 represents the total length of the reproduction scanned. As the scanning of the reproduction is started at the line 42, the record line 35 rises to a peak *a* which is determined by the intensity of illumination from the constituent *a*. At the line 44, the record line 35 drops to a lower peak *b* which is determined by the intensity of illumination from the constituent *b*. The distance between the lines 42 and 44 represents the length of the first particle of the constituent *a*. At the line 45, the record line 35 starts increasing, and the distance between the lines 44 and 45 represents the length of the first particle of the constituent *b* which is scanned. Between the lines 45 and 46, the record line 35 rises to a second peak *a* and the distance between the lines 45 and 46 gives a representation of the length of the second particle of the constituent *a*. Between the lines 46 and 47, the record line drops to an intermediate peak *c*, and the distance between these lines similarly represents the length of a particle *c*. In like manner, the distance between the lines 47 and 48 give an indication of the length of the next particle of the constituent *a*. Since the record line 35 is comprised of a series of peaks *a*, *b* and *c* along its length, it provides a record of the number and lengths of the particles of the constituents *a*, *b* and *c* along the line of the reproduction traversed by the scanning unit 16. The percent by volume of such constituents may be readily and accurately determined by adding together the distances between the beginning and end of each of the peaks along the record line 35. The total thus obtained is divided by the linear distance between the lines 42 and 43 and the quotient gives the percent by volume of each constituent in the specimen examined. The constituents designated by the letters *a*, *b* and *c* above may, for example, be cementite, ferrite, and austenite in a steel comprised essentially of these constituents.

In the above description, the microscopically enlarged reproduction has been described as being produced on the ground glass screen 14 of a conventional metallographic camera. However it will be understood that the prin-

ciples of the invention are applicable to other types of illuminated metallographic reproductions. For example, the reproduction scanned by the unit 16 may be a photomicrograph and in such case, the unit 16 would scan the light reflected from the face of the photograph from a source of light trained on its surface. In like manner, a negative of the photograph could be used and in this case the negative would be positioned between a source of light and the scanning unit 16.

It will also be understood that the principles of the invention are applicable to enlarged reproductions in which the constituents are shown in different colors. In such case, the scanning unit by the use of suitable colored filters can be made responsive to a single microconstituent.

In the above description, traverse movement is imparted to the scanning unit 16 with respect to the microscopically enlarged reproduction of the metal specimen being examined. However, it will be understood that the scanning unit 16 may be made stationary and traverse movement may be imparted to the enlarged reproduction. A modification for this purpose is shown in Figure 1 wherein the specimen mounting table 2 is shown as having a nut 50 engaged with a screw 51 which is operated by an electric motor 52 through a speed reduction transmission 53. Movement of the table 2 by its micro-drive will result in a shifting image on the ground glass screen 14. In the use of this modification, the housing 18 is preferably held in the position shown in Figure 1 with its aperture 20 opposite the center of the screen 14 while the table 2 is moved relative to the image reproducing lens elements. In this manner, the unit continually scans a moving reproduction which is produced by the center portions of the image producing lens elements. Somewhat more accurate results may be obtained in this manner since inaccuracies due to distortion at the edges of images produced by lens elements are eliminated.

While one embodiment of my invention has been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. A method of determining the metallographic constituent content of a metal specimen which comprises producing an illuminated reproduction of an etched surface of the specimen, and electrically scanning the intensity of illumination from each point of said reproduction along a line extending transversely thereof to produce

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electrical intelligence in the form of an electric force varying with the intensity of illumination along said line.

2. A method of determining the metallographic constituent content of a metal specimen which comprises producing an illuminated reproduction of an etched surface of the specimen, electrically scanning the intensity of illumination from each point of said reproduction along a line extending transversely thereof to produce electrical intelligence in the form of an electric force varying with the intensity of illumination along said line, and recording the variations in said electric force to provide a record of microconstituents of said specimen.

3. A method of determining the metallographic constituent content of a metal specimen which comprises producing an illuminated reproduction of an etched surface of the specimen, moving a photoelectric scanning unit relatively with respect to said reproduction along a line extending transversely thereof to obtain an electric force varying with the intensity of illumination from each point of said reproduction along said line, recording the variations in said electric force, and using said recording to determine the metallographic constituent content of the specimen.

4. In apparatus for determining the microconstituents of an illuminated reproduction of an etched metal specimen, a recording instrument having a moving tape, a marking device mounted for movement transversely of said tape, and means responsive to a varying electrical force for actuating said marking device, a scanning unit having an aperture facing said reproduction and including means for producing an electrical force which varies with the intensity of light entering said aperture, means for moving said unit and reproduction rectilinearly and relatively with respect to each other whereby the light entering said aperture varies with the intensity of illumination from each point of said reproduction along a line extending transversely thereof, and circuit means connecting said electrical force producing means in said scanning unit with said electrical force responsive actuating means in said instrument.

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