

July 9, 1940.

L. C. McNUTT

2,206,969

SCANNING APPARATUS

Original Filed May 20, 1938

2 Sheets-Sheet 1

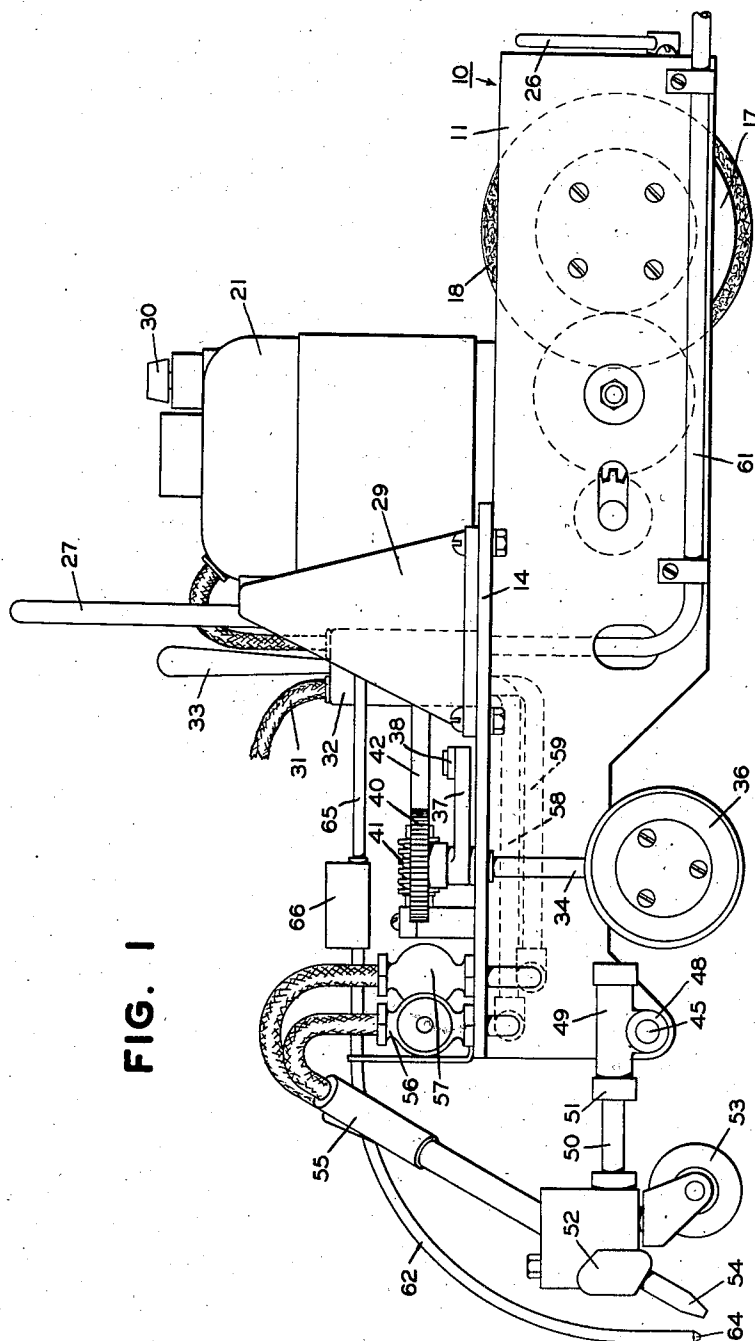


FIG. 1

INVENTOR
LOUIS C. McNUTT

BY *Virgil F. Davis*
ATTORNEY

July 9, 1940.

L. C. McNUTT

2,206,969

SCANNING APPARATUS

Original Filed May 20, 1938

2 Sheets-Sheet 2

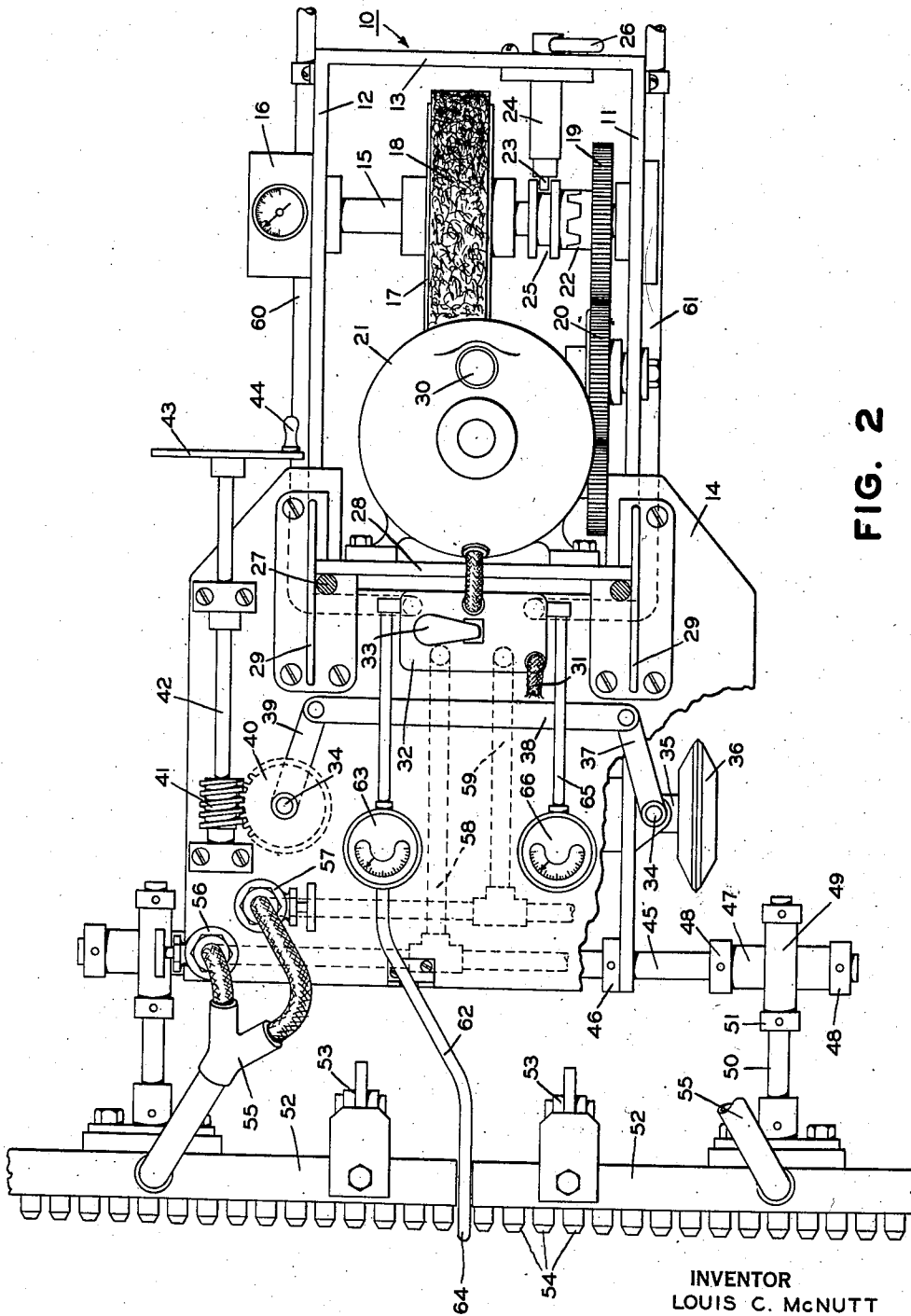


FIG. 2

INVENTOR
LOUIS C. McNUTT

BY *Virgil F. Davis*
ATTORNEY

UNITED STATES PATENT OFFICE

2,206,969

SCANNING APPARATUS

Louis C. McNutt, Scotch Plains, N. J., assignor
to M. W. Kellogg Co., New York, N. Y., a corporation of Delaware

Original application May 20, 1938, Serial No.
209,153. Divided and this application April
29, 1939, Serial No. 270,739

2 Claims. (Cl. 266—23)

This invention relates to the inspection of metal for the purpose of determining sub-surface defects.

This application is a division of my co-pending application Serial No. 209,153, filed May 20, 1938.

The sub-surface character of the metal employed in the fabrication of apparatus, such as the pressure vessels of the petroleum refining, chemical and similar arts, designed to withstand severe service conditions, is highly important. This is especially true of composite metal, i. e., metal that includes a base such as steel to which is united a comparatively thin protective lining of alloy of special properties. The bond between the alloy and the base is seldom perfect and it is not unusual to find areas of substantial size in an apparently perfect plate, or sheet, at which there is either no bond at all or the bond is so poor that it may fail in the intended service.

It is not possible to determine, by examination of test pieces, the existence of the unbonded areas in composite metal or the existence of sub-surface defects such as laminations, slag and impurity inclusions, gas pockets, etc., in unlined metal. Satisfactory results can only be obtained by an examination of the whole metal body. The prior art does not disclose a simple and inexpensive method for effecting such an examination.

It is an object of this invention to provide appropriate apparatus for carrying out in practice, a novel method for inspecting bodies to determine the existence of sub-surface defects, which apparatus is characterized by its simplicity, efficiency and low cost of operation.

The further objects and advantages of the invention will be better appreciated from a consideration of the following description taken with the accompanying drawings, in which

Fig. 1 is a side elevation of a present preferred form of novel apparatus for practicing the method of this invention, and

Fig. 2 is a plan view, with a portion broken out, of the apparatus of Fig. 1.

Metal whether in the cast or worked condition, is seldom free from sub-surface defects. This is true of composite metal, i. e., metal that generally is made up of a steel base to which is united a comparatively thin coating of alloy of special properties, as areas will appear in which there is either no bond at all between the steel base and the alloy coating or the bond is of imperfect character.

It becomes necessary, as for instance, when composite metal is used as the material for pressure vessels, such as the pressure vessels of the

petroleum refining, chemical and similar processing arts, that in use are subjected to extreme temperature and pressure conditions, to determine the sub-surface character of the metal so that it may be classified as acceptable or not acceptable for the service. It also becomes necessary, as for instance in the circumstances just above alluded to, to locate sub-surface defects so that these may be removed and the metal repaired.

The novel method of this invention is a complete solution of the inspection problem since it not only makes it possible to determine the existence of sub-surface defects but leaves a permanent record of their location and outline on the surface of the metal. Furthermore, the novel method is a simple one and can be carried out quickly and easily with a minimum of apparatus.

In the present preferred manner of practicing the novel method a source of heat is progressed at a uniform rate over the surface of the metal body to be inspected so that each increment of the surface has applied to it a like quantity of heat at a like temperature. If the body of metal is of homogeneous character each increment of the heated surface will attain the same maximum temperature. If, however, the body is not homogeneous but includes sub-surface defects, as for instance, in composite metal, areas in the zone of union between the alloy covering and the steel base in which the bond is non-existent or is imperfect, the heat transfer rate through these areas is less than through the remainder of the zone of union so that the surface of the metal body overlying these areas attains a higher temperature than the rest of the surface. This difference of temperature, and hence the existence of sub-surface defects may be indicated in various ways.

Thus, for instance, a plurality of spaced temperature responsive devices, positioned across the heated band, may be progressed with the source of heat, but in back of it. The devices may serve to merely indicate temperature, in which case an operator will mark the high temperature areas, or the devices may be of the recording type so that they will automatically provide a permanent record. At present, I prefer to produce a permanent record on the surface, over which the source of heat is progressed, of the location as well as the outline of the sub-surface imperfections.

I accomplish this desirable result by employing a heat source which is capable of supplying large quantities of heat at extremely high tem-

peratures and progress the source over the surface to be examined at such a rate that the areas thereof over imperfections of, or greater than, a predetermined minimum area and above a predetermined depth of the metal, are heated to a high enough temperature to produce a permanent and characteristic discoloration upon cooling to ordinary temperature. The heat source may be an oxygen-hydrocarbon flame, an oxygen-hydrogen flame, an electrical resistance, an electric arc discharge between substantially non-consumable electrodes, etc. At present, I prefer to employ a flame and particularly an oxygen-acetylene flame. To render the method more practical it is preferable to employ a plurality of sources at one time, the sources being properly spaced to uniformly heat a comparatively wide band of the surface, as wide as several feet or more depending on the size of the metal body to be inspected.

By using a heat source of the character just set forth, not only do the portions of the surface above imperfections attain higher temperatures than those below in which no imperfections occur but they may be made to attain temperatures high enough to render them visible. By choosing a proper rate of progression of the source, the areas above the imperfections may be heated to a dull red heat, or higher, without raising the temperature of the metal of the rest of the surface to temperatures sufficiently high to materially affect its properties and characteristics. Thus, heat treated metal may be inspected without materially affecting the properties developed by the heat treatment.

Upon cooling, the areas above the imperfections retain a color, usually blue, due to the film of oxide formed thereon. From numerous tests I have found that the colored areas are immediately above the imperfections and, furthermore, that they have substantially the identical pattern. The oxide coloring is a permanent record of the defects and may be used for comparison against a standard and, furthermore, is a great help in repairing the metal body.

To assure a true record it is advisable to remove all scale and other foreign matter from the surface of the body before the heat source is passed over it. This can be conveniently done by sand blasting. When the oxygen-acetylene flame is used I have also found it desirable at times to preheat the whole plate lightly to remove all moisture from the surface as at times water will produce stains which may be confused with the spots indicating imperfections.

The method may be employed in the determination of sub-surface imperfections located at various distances below the surface. By choosing a heat source of proper capacity and intensity and progressing the source over the surface at the proper rate, imperfections near the surface only, as little as a few hundredths of an inch, will be indicated, or all imperfections from adjacent the surface to a depth of one-half inch or more will be indicated. The limit of penetration cannot be accurately expressed as it depends on many factors such as the heat capacity of the metal, the heat transfer rate, the amount of heat that can be supplied, etc., and can best be determined in each case by experiment.

The method has a further flexibility in that it can be so controlled that all imperfections will be indicated, or only those imperfections that exceed a predetermined minimum size will be indicated, that occur between the surface and a pre-

determined depth. After the source is chosen that will give the proper penetration the size imperfections that it will indicate will be determined by the rate at which the source is progressed over the work. Thus, one rate will indicate all imperfections in the depth examined while a faster rate will only indicate the larger imperfections.

In the inspection of composite metal, having an alloy lining of $\frac{5}{16}$ of an inch in thickness I have been able with one speed of travel of the heat source to indicate all imperfections as small as $\frac{1}{16}$ inch in diameter, and less, to a depth of $\frac{1}{4}$ of an inch and by increasing the speed of travel of the heat source over the surface I have been able to indicate to the same depth only those imperfections having an average diameter of $\frac{1}{2}$ inch or more.

Further details of the novel method will be set forth in the description of the apparatus, illustrated in the accompanying drawings, which is especially suited for carrying out the novel method.

The apparatus includes a metal frame 10, made up of side pieces 11 and 12, end pieces 13, and a platform 14. The parts of the frame may be made of steel plate and joined together in any suitable way, as by welding.

A shaft 15 is supported in bearings carried by pieces 11 and 12 adjacent end piece 13. One end of shaft 15 is connected to a speed indicating device 16 which is preferably arranged to indicate speed of travel in convenient units as, for instance, feet per minute.

On shaft 15 is fastened a traction wheel 17 which serves to move the vehicle along its path. Wheel 17 is provided with a periphery of rubber or other non-skid material 18 to prevent slippage of the wheel relative to the metal body so that a uniform rate of travel may be obtained and accurately indicated at device 16. On shaft 15 adjacent side piece 11 is mounted a gear 19 that forms part of the speed reducing gear train 20 that is connected to the shaft of variable speed motor 21. Gear 19 is mounted for free rotation on shaft 15 and has attached thereto one half of jaw clutch 22. The other half of jaw clutch 22 is splined on shaft 15. A pin 23, mounted eccentrically on rod 24 that extends through end piece 13, projects into a groove 25 in the splined half of jaw clutch 22. By rotating rod 24, through handle 26, the halves of jaw clutch 22 may be brought into and out of engagement. Thus, by opening the halves of jaw-clutch 22 wheel 17 may be made to rotate independently of motor 20 and the apparatus may be quickly pushed about at will by means of handle 27 that is attached to platform 14.

Motor 21 is bolted to a plate 28, which in turn is welded to standards 29 that are bolted to platform 14. Motor 21 includes a speed changing control 30 by means of which the speed of rotation of motor 21 and consequently the speed of rotation of wheel 17 may be varied at will. Current for the energization of motor 21 is supplied through cable 31. Cable 31 passes through a control box 32 and a switch of the usual construction, not shown. The control switch for cable 31 is opened and closed by the manipulation of handle 33. Handle 33 also operates valves hereinafter to be referred to.

A pair of shaft 34 are supported for rotation in platform 14 adjacent the forward end of frame 10. To the lower end of each of shafts 34 is fastened an axle 35 upon which a guide wheel

36 is mounted. Guide wheels 36 are each provided with a hardened and sharpened periphery to enable them to bite into the plate over which the apparatus is progressed to facilitate the steering of the apparatus. Shafts 34 are connected together by means of levers 37, 38 and 39 so that a rotary movement of one shaft 34 produces a like rotary movement of the other shaft 34. At the upper end of one of shafts 34 is carried a worm wheel 40 that engages a worm 41 carried by shaft 42. Shaft 42 terminates in a wheel 43 that is provided with a handle 44. By rotating shaft 42 wheels 36 are oriented as desired to steer the apparatus.

15 A shaft 45 passes through side pieces 11 and 12 adjacent the forward end of frame 10. Shaft 45 is held against axial movement by set collars 46. On each end of shaft 45 is mounted a bearing 47 that is held against axial movement by set collars 48. Crosswise to bearing 47 is attached a bearing 49 which supports shaft 50 for rotation therein. Shaft 50 is held against axial movement by set collars 51. Each of shaft 50 support a torch member 52. Torch members 52 are also each supported by a pair of casters 53 equi-spaced from shaft 50. By reason of the arrangement just described each of torch members 52 is free to move as required to maintain a predetermined position when irregularities are encountered on the metal surface.

Each torch member 52 includes a plurality of flame tips 54 that communicate to a central bore. Tips 54 are so mounted and spaced that a flame of substantially uniform intensity is produced across their full extent. Each torch member 52 has screwed into it, in communication with the central bore, a mixing chamber 55 provided with a Y-shaped top. One branch of the Y is connected through a flexible hose to a valve 56, the other branch is similarly connected to valve 57.

Valves 56 are on manifold 58 and valves 57 on manifold 59. Manifold 58 connects with line 60 through a valve located in control box 32 and manifold 59 connects with line 61 through a valve also located in control box 32. The valves just mentioned, and the electrical switch previously mentioned are so arranged that by throwing handle 33 in one direction the valves will be opened and the switch closed and by throwing handle 33 in the opposite direction the valves will be closed and the switch opened. By means of this arrangement the flames cannot be ignited without simultaneously initiating the progression of the apparatus over the work, nor can the progression of the apparatus be stopped without simultaneously shutting off the flames. Thus, the apparatus will always be in motion when the flames are burning so that no damage can be done to the metal inspected by reason of an overlong contact with the high intensity flames.

The free end of pipe 62 terminates in a small burner tip 64 that serves as a pilot flame for the ignition of the flames of torch members 52. A pressure gage 63 is carried by pipe 62. A pipe 65, carrying a pressure gage 66, is also tapped into line 61.

While, as stated, the flames may be oxygen-hydrogen or oxygen-hydrocarbon flames I, at present, prefer to employ oxygen-acetylene flames. The acetylene is led from a suitable source, such as the usual pressure cylinder through a flexible line to line 60 and the oxygen is led from a suitable source, also, the usual pressure cylinder through a flexible line to line 61.

I claim:

1. In apparatus of the character described, a frame, means for driving said frame over the surface of a workpiece, means for steering said frame over the workpiece, an axis of rotation defining support member carried by said frame and disposed transversely of the longitudinal axis of said frame, a member supported by said axis defining member for substantially free rotation about the defined axis, a second support member rotatable with said supported member and defining a second axis parallel to the longitudinal axis of said frame, means supported by said second support member for substantially free rotation about the second defined axis, a torch member carried by said supported means and movable therewith, and means attached to said torch member and equi-spaced from said supported means adapted to bear on the surface of the workpiece as the frame and torch member are moved thereover, whereby said torch member is adapted to rotate about said defined axes to maintain a predetermined spacing with regard to the surface of the workpiece beneath it.

2. In apparatus of the character described, a frame, controllable means for driving said frame at a desired rate and in a desired path over the surface of a workpiece, a shaft supported in said frame disposed transversely of the line of travel of said frame, a cross-bearing member having one bearing positioned for substantially free rotation on said shaft, a second shaft positioned for substantially free rotation in the second bearing of said cross-bearing member, a torch member attached to said second shaft, said torch member including a body portion extending laterally on both sides of the point of attachment to said second shaft, and spacing means attached to the body portion of said torch member and equi-spaced from the point of attachment of said torch member and said second shaft adapted to contact the surface of the workpiece to maintain said torch member at a predetermined distance from the surface of the workpiece beneath it.

LOUIS C. McNUTT. 60