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Aug. 16, 1949.

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2,479,309

MAGNETIC STABILIZER

Filed June 28, 1947

4 Sheets-Sheet 1

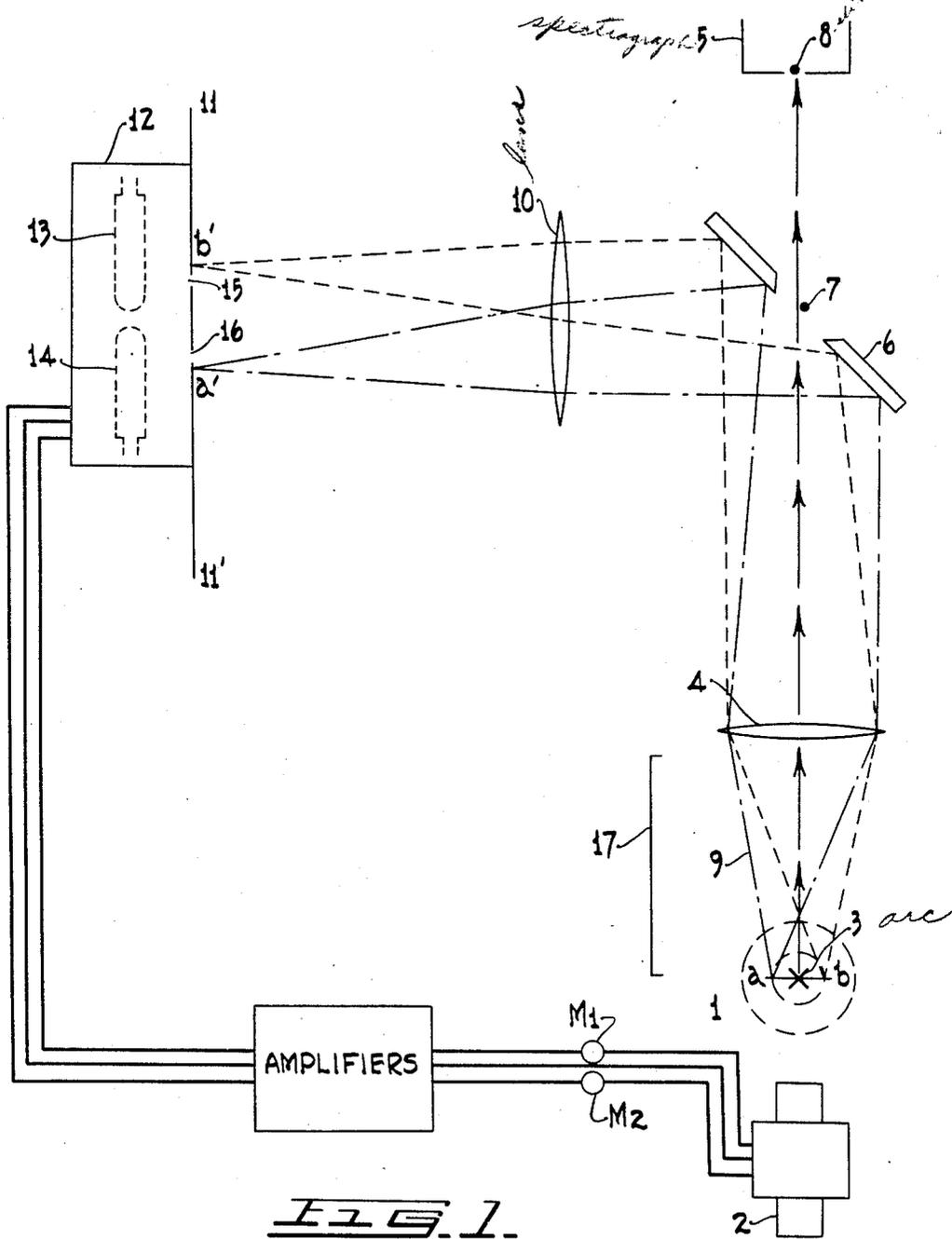


FIG. 1.

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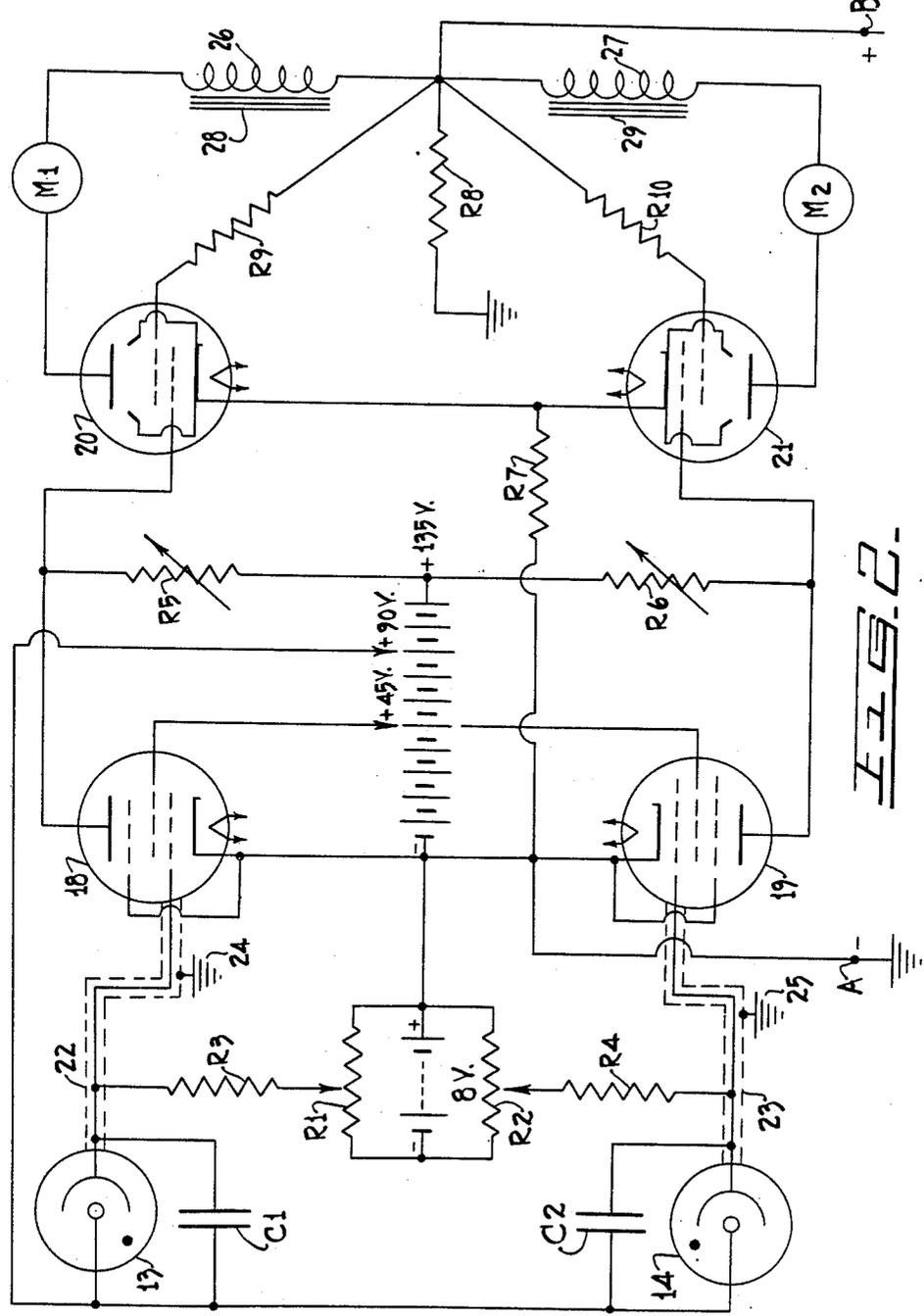
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MAGNETIC STABILIZER

Filed June 28, 1947

4 Sheets-Sheet 2



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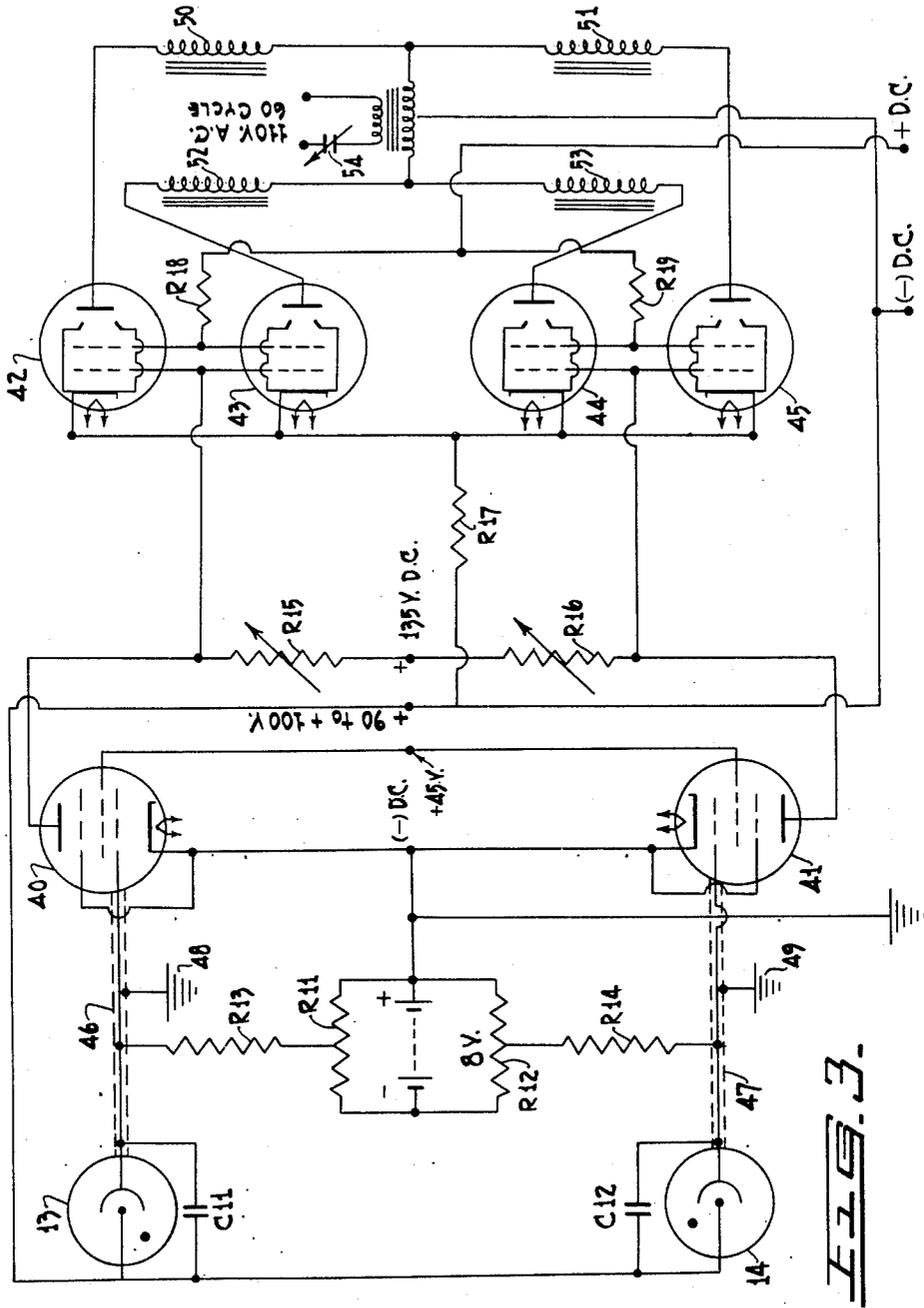
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MAGNETIC STABILIZER

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Filed June 28, 1947

4 Sheets-Sheet 3



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MAGNETIC STABILIZER

Filed June 28, 1947

4 Sheets-Sheet 4

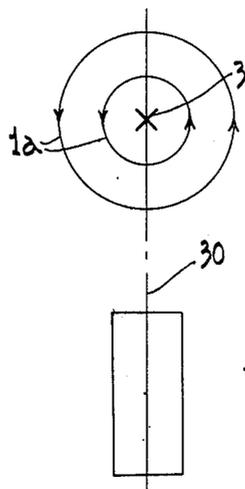


FIG. 4.

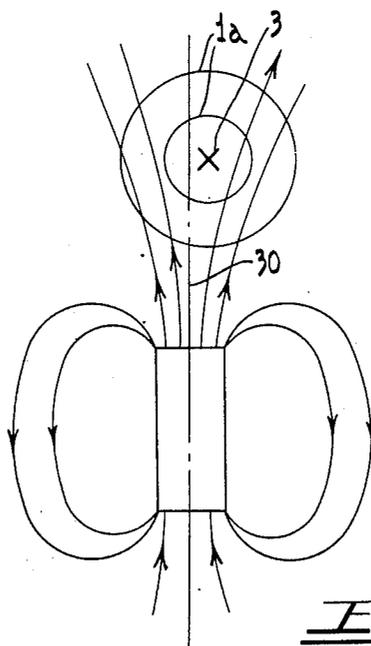


FIG. 5.

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UNITED STATES PATENT OFFICE

2,479,309

MAGNETIC STABILIZER

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Application June 28, 1947, Serial No. 757,817
In Canada June 4, 1946

11 Claims. (Cl. 250—41.5)

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The present invention relates to devices for use in spectroscopy and spectrochemical analysis.

The purpose of this invention is to provide magnetic stabilizing apparatus that will prevent or eliminate the sideways wandering of a light source, such as the direct current arc, used in spectrochemical analysis or in spectroscopy generally.

In the following description and claims the word "arc" shall mean any type of electrical source using continuous or discontinuous direct or alternating current. The word "arc" includes the commonly used direct current arc.

By spectrochemical, that is spectrographic, analysis is meant here the use of a spectrograph or spectroscope to analyse samples or solids or solutions, the latter usually being dried on a carbon cup. These samples are caused to emit characteristic groups of wave-lengths of light, which light is separated into its component wave-lengths by the spectrograph or spectroscope and then the intensity or integrated intensity of the light of each wave length is either measured directly with a photo-electric device, or is photographed, and the density of the spectrum lines either measured with a suitable microphotometer, or estimated visually. Various electrical sources are used to cause the sample to emit its characteristic group of wave-lengths. A common source is the direct current arc, between either carbon, metal, or briquetted electrodes. The present invention can be used on any type of arc.

Briefly the magnetic stabilizer of the present invention consists of the following arrangement of parts: Light-sensitive means comprising one or more pairs of phototubes in a housing are placed at or near the two vertical edges of an enlarged image of the arc. This image is obtained by reflecting light from the arc, by means of light-reflecting means such as an aluminized mirror with a hole in it, and using a convex lens to bring the reflected light to a focus at the phototube housing. Each phototube is connected through a direct-coupled amplifier to arc-stabilizing means such as a coil of an electromagnet placed behind the arc with its magnetic axis coincident with the optic axis of the spectrograph. There are thus two amplifiers, and two coils for a direct current arc and four coils for an alternating current arc, wound on a common iron core. Any sideways wandering of the arc illuminates the phototubes unequally, thereby producing a magnetic field about the electromagnet which, acting on the arc current, that is on the magnetic field of the arc, immediately recenters

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the arc. In analysis of samples of powdered rock, tests for reproducibility showed that greater accuracy and precision are obtained by using the instrument of the present invention.

5 The invention as applied to a direct current arc will now be described in detail with reference to the accompanying drawings which illustrate the invention diagrammatically and by way of example. In the drawings:

10 Figure 1 is a diagrammatic representation of one particular arrangement of the various parts of the apparatus;

Figure 2 is a diagram of an example of an electric circuit connecting the phototubes of the elec-

15 tromagnet;

Figure 3 is a diagram of a circuit for use with an alternating current arc.

Figure 4 represents the arc and the magnetic lines of force that surround it.

20 Figure 5 represents the arc displaced to the right and also the lines of force of the magnet.

It is generally recognized that although the direct current arc is a versatile source of excitation, it provides relatively poor reproducibility 25 when used for quantitative spectrochemical analysis. Apparently this defect is due chiefly to wandering of the cathode "spot," thereby producing both wandering of the arc and fluctuations in amperage with attendant changes in the discharge temperature. Very recently A. T. Myers and B. C. Brunstetter in Analytical Chemistry 19, 71 (1947) recommended a rotating magnetic field placed near the direct current arc.

The present invention deals with an instru- 35 ment which eliminates almost completely the wandering of a central horizontal slice of the arc. Almost any part could be rendered free of fluctuations, but in the present application attention is directed particularly to the part from 40 which the light is dispersed and photographed.

Normally, an arc is surrounded by a circular magnetic field, depicted by broken circles at 1 in Figure 1. By reasons of a well known principle, placing one pole of a horizontal bar magnet 45 2 near the arc 3, will cause the arc to move sideways in a direction at right angles to the magnet's polar that is, magnetic, axis. The magnetic field from a north pole moves the arc to the left of the magnet, a south pole moves it to the right.

50 Light from the arc 3 passes through a quartz lens 4. This lens is not part of the stabilizer; it is part of the spectrograph 5 itself, and is used to bring the image of the arc to a focus at the grating. An aluminized front surface mirror 6 with a hole 7 in the centre is set between the

quartz lens 4 and the spectrograph slit 8. The central part of the beam of light 9 from the properly centred arc passes through the hole in the aluminized mirror 6 thence to the dispersing system of the spectrograph, in the normal way. But light from the peripheral part of the beam is intercepted by the mirror 6 and reflected, passing through a second convex lens 10 to form at plane 11-11' an enlarged image of the arc. The purpose of lens 10 is to bring the arc to a focus at plane 11-11'. The optical path for the beam striking plane 11-11' may be 94 cm. in length but by changing the focal length of the lens 10 this optical path length can be altered to suit the space available to the spectroscopist. At 11-11' is a box 12 housing two phototubes 13 and 14 set horizontally as shown in Figure 1. The inner vertical side of the phototube housing 12 has two adjustable slits 15 and 16, one directly in front of each phototube. These slits are to allow light from the arc to strike the phototubes 13 and 14. The slit openings may for example be 1.2 cm. high, 0.15 cm. wide, and the two slits 4.9 cm. apart; but these dimensions will depend on the type of spectrograph used, the type of sample analysed and on the focal lengths of lenses 4 and 10. The distance between the slits is adjusted so that the visible vertical edges of the arc's image, formed on face 11-11' of the phototube housing 12 partially or completely encompass the two slit openings. It is advantageous to make each slit opening of such a height that no more than the horizontal slice of the arc utilized in producing a spectrogram is used to illuminate the slits of the phototube housing.

The height of the centre of the hole 7 in the mirror 6 and the height of the centre of the lens 10 are made so that they are in the same horizontal plane as the centre of the arc and the centre of the grating or prism of the spectrograph. The height of the phototube housing 12 is preferably adjustable. Normally it is advantageous to have it of such a height that the centre of its slits are in the same horizontal plane as the centre of the grating or prism of the spectrograph.

A baffle 17 may be installed to shield the slits of the phototube housing 12 from the direct light of the burning arc and if desired baffles (not shown) may be used as shields against the lights of the room.

Alternatively, the lens 10 may be a quartz lens and a filter may be inserted in front of the two slits of the phototube housing 12 so as to allow only ultra-violet light from the arc to reach the phototubes 13 and 14. Then only one baffle between arc and phototube housing would be necessary.

Each of the phototubes 13 and 14 is connected to a direct current amplifier. Two amplifiers are required, one for each phototube, and are connected as shown in Figure 2 which is the circuit diagram and includes amplifier tubes 18, 19, 20 and 21. This circuit has proven to be satisfactory.

To the voltage divider, 450 volts D. C. are supplied from a conventional full wave rectifier supplied from 110 volts A. C. using a 5Y3G rectifier tube and a condenser input filter system. Matched 6J7G tubes are used. The leads from the phototubes to the grids of the 6J7G tubes are shielded at 22 and 23 and the shields grounded at 24 and 25. GL-868-PJ23 phototubes may be used but other types are also suitable. In particular GL-441 phototubes are to be rec-

ommended, in which case a 250 volt supply may be used instead of the 90 volt supply for the #868 phototubes. Where a filter allowing only ultra violet light is used in front of the slits of the phototube housing 12 then phototubes particularly sensitive to ultra-violet light are used.

In Figure 2 there are shown resistors R1 to R10, condensers C1 and C2 and D. C. milliammeters M1 and M2. C1 and C2 are of 0.0001 mfd. capacity and R1 and R2 are potentiometers each of 1 megohm. R3 and R10 are resistors and have the following values:

R3, R4	4.7 megohms
R5, R6	250,000 ohms (variable)
R7	2,000 ohms
R8	100,000 ohms
R9, R10	25,000 ohms
M1, M2	D. C. milliammeters

These values have been used by applicant but all of them, including C1 and C2 and the coils 26 and 27 mentioned below may be altered. The values for R3 and R4 will depend on the kind of arc used and the kind of sample analysed.

There are two coils 26 and 27, shown in Figures 1 and 2, each having a resistance of 4000 ohms. Laminated iron cores are shown at 28 and 29. The coils were wound in sections and balanced to give the same resistance and distribution of magnetic flux. When equal currents flow in the two coils, the resultant magnetic field about the electromagnet is zero or nearly so. The electromagnet may be mounted with its magnetic axis coinciding with the optic axis of the spectrograph, and with the end nearest the arc 6 cm. from the arc but this distance may be changed. The end nearest the arc may be insulated with asbestos board. It is convenient to construct a metal support so that the electromagnet can be swung away from the arc stand to facilitate loading and positioning of the electrodes.

It will now be clear that if the arc is properly centred, equal amounts of light will be falling on each phototube, and the currents through coils 26 and 27 will be equal, thereby producing no magnetic field. But if the arc wanders sideways then one phototube will be illuminated more than the other. This will produce unequal photocurrents, and hence unequal currents in coils 26 and 27. The magnetic field thereby produced will, be acting on the magnetic field of the arc, immediately re-centre the arc. In actual practice the magnetically controlled section of the arc never appears to move off centre, so effective is the magnetic stabilizer.

In the phototube housing 12 the preferred distance between the slit openings is such that the two slits are just inside the vertical edges of the arc's visible image. Different lengths of optical path from arc to phototube housing and different electrode shapes and sizes, will determine the optimum distance between slit openings. The composition of the sample can be expected partly to determine the optimum distance between slits, because the sensitivity of a phototube is a function of the wave-length of incident light. But applicant has analysed a wide variety of ores without having to change the distance. It is therefore necessary for each spectroscopist to find the most suitable distance for his particular set of conditions.

The optimum width of each slit opening will depend on the amount and wave-lengths of light reaching the phototubes. Obviously each slit

should be the same width. For a wide variety of ores the applicant has found that a slit opening 0.15 cm. wide is satisfactory. It has been found that if the slit openings are too wide, or if the slits are too far apart, or if the magnet is too near the arc, or if the amplifier has too high a "gain," then an oscillation is set up in the circuit with the result that the arc oscillates sideways and appears visually as a wide fan-shaped discharge, the image of which appears to cover both slits though even under such conditions wandering of the arc is reduced. Therefore to use a normally shaped arc, it is necessary that each spectroscopist adjust the slits so as just to prevent the fan-shaped arc forming. If a fan-shaped arc does form regardless of how narrow the slit openings are or the distance between them then a remedy would be to move the electromagnet further away from the arc. Alternatively one could replace the 4.7 megohm resistors R3 and R4 in the phototube circuit by ones with a lower resistance, or else reduce the values for R5 and R6. If the magnetic field is not strong enough to re-centre the arc when it is displaced sideways, a remedy is to increase the value of resistors R3 and R4.

After closing the switches in the A. C. line the amplifier is allowed to "warm up" for 5 minutes. Then resistors R1 and R2 are adjusted so that equal currents flow in coils 26 and 27 when the arc is not operating. The preferred current is one of 30 milliamperes. This value drops to 23 milliamperes when the arc is operating, and this has been found to be suitable during arcing or ore samples. From time to time, the milliammeter reading should be observed, and if unequal, should be equalized by changing R1 or R2; but this adjustment should not be made while the arc is operating.

In Figure 1 may be seen the manner in which the mirror and lenses are used to produce at the photocell housing a real image $a'b'$ of the arc ab . It should be understood that the line ab depends on the type of sample and the shape of the electrodes. It is therefore not material to the invention. The arc may be about 1 cm. wide. The width $a'b'$ of the image will of course depend on the focal lengths of the lenses and these values are not material to the invention. The image normally obtained is about 5 cm. in width.

The arc never is seen to move off centre; that is, the image of the arc on the front wall of the photocell housing never appears to wander sideways. The arc would wander sideways without the stabilizer operating, and with the stabilizer operating it is natural to expect an extremely slight sideways shift, much too small to be observed and possibly of the order of 0.05 centimetre; but in a very minute fraction of a second, the stabilizer creates a magnetic field which shifts the arc sideways in the opposite direction of this 0.05 centimetre thus recentering the arc. Hence, it is substantially correct to say that most of the time the two phototubes are equally illuminated, and that occasionally a slight sideways shift of the arc illuminates one phototube slightly more strongly than the other.

The "magnetic strength" of the electromagnet is not of importance. Normally both phototubes are equally illuminated and hence equal currents flow in opposite directions in the two coils of the electromagnet, and the resultant magnetic flux density in zero. If, as suggested above, the arc moved sideways by 0.05 cm., then one photocell for a minute fraction of a second would become

very slightly more strongly illuminated than the other, thus causing the magnet to produce a momentary magnetic field at the arc. This field immediately re-centres the arc, and then becomes zero. Hence the magnetic flux density at the arc is the important factor. It can be adjusted to a desired value by (a) adjusting the distance between magnet and arc or (b) changing the values of resistors R3 and R4, or R5 and R6, and in other similar ways. Therefore the stabilizer will accommodate electromagnets of various "magnetic strengths."

At all times while the direct current arc is burning it will be surrounded by circular magnetic lines of force, as shown in Figure 4 where 3 is a plan of the arc, and the circles a depict the magnetic lines of force with their direction. The polar axis of the magnet is designated by the vertical line 30. With the arc centred, the resultant magnetic field of the magnet is zero that is the two coils have equal currents flowing in opposite directions as shown in the drawings.

With the arc displaced say 0.05 cm. to the right one phototube is illuminated slightly more than the other. Hence the two coils of the magnet have unequal currents, and the magnet's magnetic lines of force are approximately as shown in Figure 5. Hence the two superimposed magnetic fields on the left of centre partly cancel, while on the right they reinforce, thus moving the arc to the left, to centre.

When the arc is displaced 0.05 cm. to the left, the other phototube becomes more highly illuminated, and again the two coils have unequal currents; but this time the coil which previously had the lesser current now has the greater, and since the two coils are oppositely wound, the polarity of the magnet is reversed, and the resultant direction of the magnetic force is from left to right, thus centering the arc.

It is important to note therefore that, in accordance with established principles, the magnet produces stabilizing forces at right angles to its magnetic axis.

It should be understood that it is possible, using the same stabilizer equipment and arrangement heretofore described, to produce an oscillation of fairly high frequency in the amplifier circuit. This oscillation produces an oscillation of the arc itself, that is, the arc oscillates from side to side at right angles to the magnetic axis of the electromagnet. The amplitude of this oscillation of the arc can be controlled by (a), (b), (c) below, or in other similar ways. The result is that light from probably the entire width of the arc is sampled many times a second and enters the spectrograph. This sampling of the light from probably the entire width of the arc may with certain kinds of material increase the precision of quantitative spectro-chemical analysis. This oscillating arc illuminates first one photocell much more strongly than the other, then the reverse, many times a second, and in this respect is different from the heretofore described results, where both phototubes are always equally illuminated. The oscillation can be obtained by increasing sufficiently the electromagnet's magnetic flux density at the arc, such as by (a) increasing the amount of light each phototube receives; (b) increasing the "gain" of the amplifiers, (c) decreasing the distance from magnet to arc.

While only one stabilizer unit has been described, it should be noted that by using two or more stabilizers, other portions of the arc could be stabilized. Thus, using two stabilizers, with

one pair of phototubes immediately above the other pair, and with two electromagnets, one above the other but with their magnetic axis parallel, two distinct horizontal slices of the arc could be stabilized.

The arrangement shown in Figure 1 is used for the sake of convenience only since the apparatus may be set up in any convenient manner. It would for example be possible to eliminate the mirror 6 and the lens 10 and to locate the phototubes one on either side of the entrance of the spectrograph thus stabilizing the arc directly rather than by reflection. Alternatively the mirror 6 and lens 10 can be eliminated, and the phototubes located one on either side of the grating or prism, inside the spectrograph itself.

While the invention as described so far has been applied to a direct current arc, nevertheless by keeping the arrangement of parts shown in Figure 1, and by making slight alterations to the amplifiers, and by adding an extra pair of coils to the electromagnet 2 in Figure 1, then the invention can be used to stabilize an alternating current arc. This is so because an alternating current arc differs from a direct current arc essentially only in that for the alternating current arc the direction of the current reversed each half cycle; hence the direction of the circular magnetic field around the alternating current arc will reverse every half cycle. In Figure 3 there is shown a circuit for use with an alternating current arc. The phototubes 13 and 14 are connected to amplifiers, these being shown at 40, 41, 42, 43, 44 and 45; 40 and 41 being preferably 6J7 tubes while 42, 43, 44, and 45 may be 6L6 tubes, the leads from the phototubes to the grids of the 6J7 tubes are shielded at 46 and 47 and the shields are grounded at 48 and 49. Resistors R11 and R19 are shown and condensers C1 and C12. C11 and C12 are of 0.0001 mfd. capacity while R11 and R12 are 1 megohm potentiometers. R13 and R19 are resistors and have the following values.

R13, R14	4.7 megohms
R15, R16	250,000 ohms (variable)
R17	500 ohms (approx.)
R18, R19	25,000 ohms

All of these values may be altered if necessary or desired.

In Figure 3 the electromagnet comprises four coils. Coils 50 and 51 correspond exactly to coils 26 and 27 of Figure 2. Coils 52 and 53 are another pair of coils, identical in construction with coils 50 and 51. Hence for the alternating current arc the electromagnet has four coils wound on a laminated iron core, instead of the two coils used for a direct current arc.

Referring to Figure 3, it is seen that alternating current is fed to the plates of the 6L6 tubes, 42, 43, 44 and 45 from the secondary of a transformer. The primary of the transformer has some common phase shifting device in it such as a condenser, shown at 54 which will bring the alternating current in the secondary of the transformer into phase with the alternating current in the arc. During one half cycle current flows through coils 50 and 51 only, and during the other half cycle it flows through coils 52 and 53. Coils 50 and 51 are wound in opposite directions so that for a centred arc the field about the electromagnet is zero; and coils 52 and 53 are likewise wound in opposite directions to each other, for the same reason. But if the arc wanders "off centre" currents in coils 52 and 53 or 50 and 51 depending

on which pair is working will be unequal, and a magnetic field will result which recentres the arc and so then becomes zero. The way the electromagnet's field recentres an alternating current arc is the same as has been described above for the direct current arc. Figure 4 applies to both arcs.

It may be seen by comparing Figures 2 and 3 that the operation of both amplifiers is much the same; for the direct current arc, direct current is supplied to the plates of the 6L6 tubes; for the alternating current arc, alternating current is supplied to those plates. Figure 1 applies to both alternating current and direct current arcs, and the operation of the invention for an alternating current arc rests upon the same principles as have been described above for its successful operation upon a direct current arc.

The foregoing description is presented by way of example only, it being understood that the invention may be modified to any degree within the scope of the appended claims.

What is claimed is:

1. Magnetic arc-stabilizing apparatus for use in conjunction with a spectroscopy or spectrograph and comprising; an arc, light-sensitive means and arc-stabilizing means electrically connected therewith and controlled thereby.

2. Magnetic arc-stabilizing apparatus for use in conjunction with a spectroscopy or spectrograph and comprising in combination; an arc, light-reflecting means, light-sensitive means and arc-stabilizing means electrically connected therewith and controlled thereby.

3. Magnetic arc-stabilizing apparatus for use in conjunction with a spectroscopy or spectrograph and comprising in combination; an arc designed to transmit into a spectroscopy or spectrograph light to be analysed, light-reflecting means designed to change the direction of a representative section of the beam from said arc, light-sensitive means situated within the path of said reflected beam from said arc, arc-stabilizing means situated in stabilizing relationship with said arc, said arc-stabilizing means being electrically connected with said light-sensitive means and controlled thereby.

4. Apparatus as claimed in claim 2, said light-reflecting means reflecting a portion only of the beam from said arc and comprising a mirror situated angularly with respect to the direction of said beam.

5. Apparatus as claimed in claim 2, said light-sensitive means comprising at least one pair of phototubes situated within the path of the light reflected by said light-reflecting means.

6. Apparatus as claimed in claim 2, said arc-stabilizing means comprising at least one electromagnet.

7. Apparatus as claimed in claim 5, said phototubes being enclosed within a housing, said housing being equipped with light admitting means.

8. Apparatus as claimed in claim 2 comprising in addition a direct-coupled amplifier, the said light-sensitive means being connected through said amplifier to the said arc-stabilizing means.

9. Magnetic arc-stabilizing apparatus for use in conjunction with a spectroscopy or spectrograph and comprising in combination; an arc designed to transmit into a spectroscopy or spectrograph light to be analysed, light-reflecting means designed to change the direction of a representative section of the beam from said arc, light-sensitive means situated within the path of

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said reflected beam from said arc, arc-stabilizing means situated in stabilizing relationship with said arc, said arc-stabilizing means being electrically connected with said light-sensitive means and controlled thereby, said light-sensitive means and said arc-stabilizing means being arranged in independent sections, each section of each means being in opposition, one section of each means being in cooperation, the separate sections acting to oppose any tendency toward instability in said arc.

10. Arc-stabilizing means comprising electromagnetic means and light-sensitive means connected to said electromagnetic means and positioned to receive light from the arc to be stabilized.

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11. Apparatus as claimed in claim 2, wherein means are provided for causing stabilized oscillation of the arc.

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