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AN ELECTROGRAPHICAL  
METHOD OF  
ANALYSIS OF NICKEL  
IN STEEL

*Approved  
W. B. Gaylord  
May 14, 1934*

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Golden, Colorado

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J. P. W.

J. P. W.

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INTRODUCTION

Some few years ago study was begun on the macrostructure of metals, especially iron, by Glazunow and Krivochlavy at the college at Pribram, Czechoslovakia. Their work appeared to be an outgrowth of a thesis by Gutzeit of the University of Geneva in Switzerland. Gutzeit developed a number of reagents, some very complex, which he used in the qualitative determination of various anions and cations. Gutzeit employed a spot test, allowing the solution containing the anion or cation to be determined, and the reagent to be placed on a filter paper and the resulting color providing an indication as to the presence or absence of the substance.

Glazunow and Krivohlavy, on the other hand, carried the work a little farther and attempted to develop a quantitative determination for the presence of nickel in steel. In their procedure they allowed the specimen of steel to come in contact with a filter paper moistened with the necessary reagent. Another metal, inactive with respect to the reagent, was placed on the other side of the filter paper. Direct current was passed through the electrolytic cell thus formed and, if nickel was present, a precipitate was obtained. The time necessary to obtain this colored precipitate is only a few seconds. It is also to be pointed out that this procedure does not harm the specimen.

This method is substantially the one that has been used in the present work, wherein an attempt has been made to further investigate this electrographical method for the analysis of nickel in steel. As has been pointed out by Glazunow and Krivohlavy, this method is applicable to other alloying elements besides nickel; all that is necessary is that suitable reagents be

developed for these other determinations.

Exception is taken, however, by the above investigators in the cases of chromium, tungsten, and vanadium, which they claim are passive.

The value of this method, as can readily be seen, lies in its speed. There are two methods for the analysis of nickel that are in general use at the present time. The first and more rapid method is the titration with potassium cyanide, which in addition to being rather rapid is fairly accurate. This method is most always used for plant routine work and furnace control tests. The other method is the gravimetric procedure, which uses dimethylglyoxime to form a precipitate with nickel. This method has a higher order of accuracy than the titration method but it consumes more time. The accuracy of the titration is  $\pm 0.02\%$  for each per cent of nickel. This increases with increasing nickel percentage. The accuracy for the dimethylglyoxime method is about  $\pm 0.01\%$  for low nickel steels and  $\pm 0.03\%$  for higher nickel steels containing about 2.5 to 5.0% nickel. The gravimetric method finds its use in analysing steels with unusually high

nickel content, steels with very minute amounts of nickel, steels containing cobalt and copper for which the volumetric method is not accurate, and for the preparation of standard samples.

If the metal to be analysed were pure, then most of the reagents used in analytical chemistry would apply very nicely to this electrographical method. But as we deal exclusively with alloys, not all reagents will work. Hence the problem is one of finding a reagent which will react with the desired metal only or some way must be found so that only one metal will form a colored precipitate.

Glazunow and Krivohlavy have said that a reagent may fall into one of two classes. These classes are as follows:

1. The reagent is specific and forms a colored precipitate with the desired metal only.
2. The reagent may react similarly with several metals.

In the first case it is easy to see that no treatment is necessary to conduct the determinations.

But in the second case a treatment of some sort is necessary in order to arrive at any semblance of a result. This may be done by allowing the undesired metal or metals to form a precipitate with the reagent and then remove this precipitate by suitable methods. Or it might be possible to suppress the formation of the unwanted precipitate by the use of additional reagents. Finally, in the case of mechanical mixtures, the metals, if their solution pressures differ widely, may be separated by merely changing the potential. As we are working only with solid solutions, this last case will not enter into our investigations and it can be disregarded.

#### DETERMINATION OF NICKEL

In the particular determination of nickel, the reagent that is used in the gravimetric analysis is used in this electrographical method. This reagent is dimethylglyoxime and will give a bright red precipitate with nickel. The aforementioned investigators found that divalent iron would give a blood-red precipitate with dimethyl-

glyoxime in an ammoniacal solution and that trivalent iron would produce a brown discoloration of the filter paper. The divalent iron will be found to be the only one to contend with as the trivalent iron will not react ordinarily and besides it has a lower potential than divalent iron. However, if the filter paper has not been washed sufficiently, a brown discoloration will be observed which is due to ferric iron. This is probably not a primary reaction but is due to an oxidation in the air after precipitation.

If the determination is carried out with one part of a 1% solution of dimethylglyoxime and two parts of 1-20 acetic acid, the deleterious effects of the ferrous iron are done away with. The brown color due to ferric iron, particularly in alloys low in nickel, can be gotten rid of by washing the filter paper in dilute acetic acid followed by a wash in water. In all cases the filter paper should be washed immediately in water or oxidation of the ferrous iron to the ferric state will occur and a brown discoloration will be observed on the filter paper upon drying.

## DEVELOPMENT OF EQUATIONS

Glazunow and Krivohlavy have stated that the results may be obtained graphically or they can be calculated. The development of the equations used by these two men is as follows:

$$I = \frac{Q \times m}{E_0 \times t} \quad I$$

I = Current

Q = Area of surface

m = Mgs. of Ni and Fe that  
go into solution per  
unit area

E<sub>0</sub> = Electrochemical equi-  
valent of the alloy

t = Time in seconds

It has been assumed by the above two investigators that nickel and iron are the only two constituents in the alloy. This assumption was based on the premise that other alloying elements are usually present in small amounts and do not react with the reagent and, consequently, can be neglected. It has been observed, however,

that some difficulty is met with in the case of an 18-8 alloy. Little or no red precipitate is obtained with this alloy and it would lead one to believe that alloying elements are not always to be neglected and that they do not always exist in small amounts.

But for the sake of developing the remaining equations, we can assume a solid solution of iron and nickel alone. The investigators, Glazunow and Krivohlavy, have made the statement that, in the range of 6.5 to 51% nickel, a heterogeneous mixture exists. They are not definite as to the nature of this heterogeneous mixture, but it probably is a mixture of different solid solution phases. In this work no investigation was carried out on plain nickel steels above 5.20% nickel, with the exception of one sample of invar steel. The invar just mentioned gave a very bright precipitate in a very short time, but no quantitative conclusions can be drawn. However, if such a condition exists, the two components of the mixture will not travel at the same rate, but according to their respective potentials and the prints obtained will not give quantitative results.

As has been said before, we assume a single solid solution of nickel and iron. In this case the amount of nickel going into solution will bear the same relation to the amount of iron going into solution as the nickel content of the sample bears to the iron content. In a solid solution, as we have assumed, the iron and nickel ions will go into solution according to Faraday's Law.

In equation I there appeared the term,  $E_0$ , which was listed as the electrochemical equivalent of the alloy. Perhaps some word of explanation is necessary to define this term. Because a homogeneous alloy has been assumed and because the atomic weights of nickel and iron are close together, the previously-named investigators have assumed that there exists a linear growth of the electrochemical equivalent as the nickel percentage increases from zero to 100%. Using this idea, it is possible to set up the following equation for the electrochemical equivalent of any iron-nickel alloy that is homogeneous.

$$E_0 = 0.289 + 0.00015 \times \%Ni \quad \text{II}$$

Then it is possible to put into an equation a relation that has already been put into words; namely, that the ratio of the nickel ions going into solution to the iron going into solution is the same as the ratio of the nickel to the iron in the sample.

$$\frac{m_1}{m_2} = \frac{\%Ni}{\%Fe} \quad \text{III}$$

$m_1$  and  $m_2$  = Amounts of  
Ni and Fe going into  
solution in mgs.  
respectively per unit  
area.

It must be remembered that nickel and iron have been considered as the only metals present and going into solution. This may be expressed as follows:

$$\%Ni + \%Fe = 100 \quad \text{IV}$$

$$m_1 + m_2 = m \quad \text{V}$$

Then from equation III, we may write,

$$\frac{m_1}{m_1 + m_2} = \frac{\%Ni}{\%Ni + \%Fe}$$

By substituting equation IV and V in the above equation, the following can be obtained:

$$m = \frac{100 \times m_1}{\%Ni} \quad \text{VI}$$

Rewriting equation I.

$$m = \frac{I \times t \times E_0}{Q} \quad \text{VII}$$

Then by equatating VI and VII, the following equation is obtained:

$$m_1 = \frac{I \times t \times \%Ni \times E_0}{100 \times Q} \quad \text{VIII}$$

It is possible to find  $E_0$  by the use of equation II and from the equation just shown, VIII, we can find the amount of nickel going into solution for any given sample.

Also we can set up a modification of equation I, containing  $m_1$  and  $m_2$ , from which we can arrive at the amount of nickel going into solution.

$$I = \frac{Q \times m_1}{E_1 \times t} + \frac{Q \times m_2}{E_2 \times t} \quad \text{IX}$$

$E_1$  and  $E_2$  = Electro-  
chemical equivalents  
of nickel and iron  
respectively.

Next an equation can be set up for  $m_1$  by substituting  $m_2$  from equation III and %Fe from equation IV in equation IX.

$$m_1 = \frac{I \times t \times \%Ni \times 0.087856}{(30.4 - 0.015 \times \%Ni) \times Q} \quad \text{X}$$

As a means of simplifying the equations as developed, it is possible to use an average value for  $E_0$ . This average value is the arithmetical mean of the two electrochemical equivalents and is expressed as follows:

$$E_0 = 0.5(0.305 + 0.289) = 0.295 = 0.3$$

The value thus obtained may then be substituted in equation VIII. The new equation appears as follows:

$$m_1 = \frac{0.3 \times I \times t \times \%Ni}{100 \times Q} \quad \text{XI}$$

In order to determine the amount of nickel contained in an unknown specimen, two samples were used. One was the unknown and the other a standard sample. Prints were first made from the standard sample, the current and time being carefully noted. Then prints were made with the unknown sample, attempting to reproduce the same color intensity as shown by the prints made with the standard sample. The investigators, Glazunow and Krivohlavy, varied the time of exposure to produce the like prints.

In the terms of the equations so far developed, making prints of equal color intensity means that equal amounts of red precipitate have been formed, or:

$$m_1 = (m_1)_y$$

Where y as a subscript  
refers to the unknown  
sample

It is possible to set equation X up for the standard and for the unknown sample. Then, as  $m_1$  and  $(m_1)_y$  are equal, the two equations may be set equal to each other. The

resulting equation is as follows:

$$(\%Ni)_y = \frac{30.4 \times Q_y \times (I \times t) \times \%Ni}{Q(I \times t)_y \times (30.4 - 0.015\%Ni) + Q_y(I \times t)\%Ni \times 0.015} \quad XII$$

As can readily be seen, this equation involves a number of terms and a simpler equation can be obtained by using equation XI in place of equation X in the preceding development.

The equation resulting is as follows:

$$(\%Ni)_y = \frac{(I \times t) \times \%Ni \times Q_y}{(I \times t)_y \times Q} \quad XIII$$

This equation can be further simplified if the specimens used are all of the same surface area and if the current is kept constant.

#### GRAPHICAL SOLUTION

It has already been mentioned that a graphical solution of the nickel percentage of an unknown specimen is also possible. Glazunow and Krivohlavy have used much the same basis for the graphical solution as that used for developing the equations. By the use of one of the foregoing equations, they have plotted a series of curves using the milligrams of nickel

deposited and the per cent nickel in the specimen as the coordinates. The series of curves are obtained by using different times of exposure. Figure 1 shows such a curve for the case where the current remains constant throughout each exposure. The above-named experimenters assumed a decreasing current throughout the test. However, they did not state whether they used an average value for the current or not.

To find the per cent nickel in an unknown by the use of this diagram, it is necessary again to use a standard sample along with the unknown. Prints of the same color intensity are obtained, the current being the same for both and the time being the only variable. By the use of the equations it is possible to find, on the correct time curve, the point corresponding to the standard sample. Then, as the amount of precipitate formed is the same in both cases, a line horizontally projected from the point found for the standard specimen will locate the same point for the unknown on its time curve. A line drawn from this latter point perpendicular

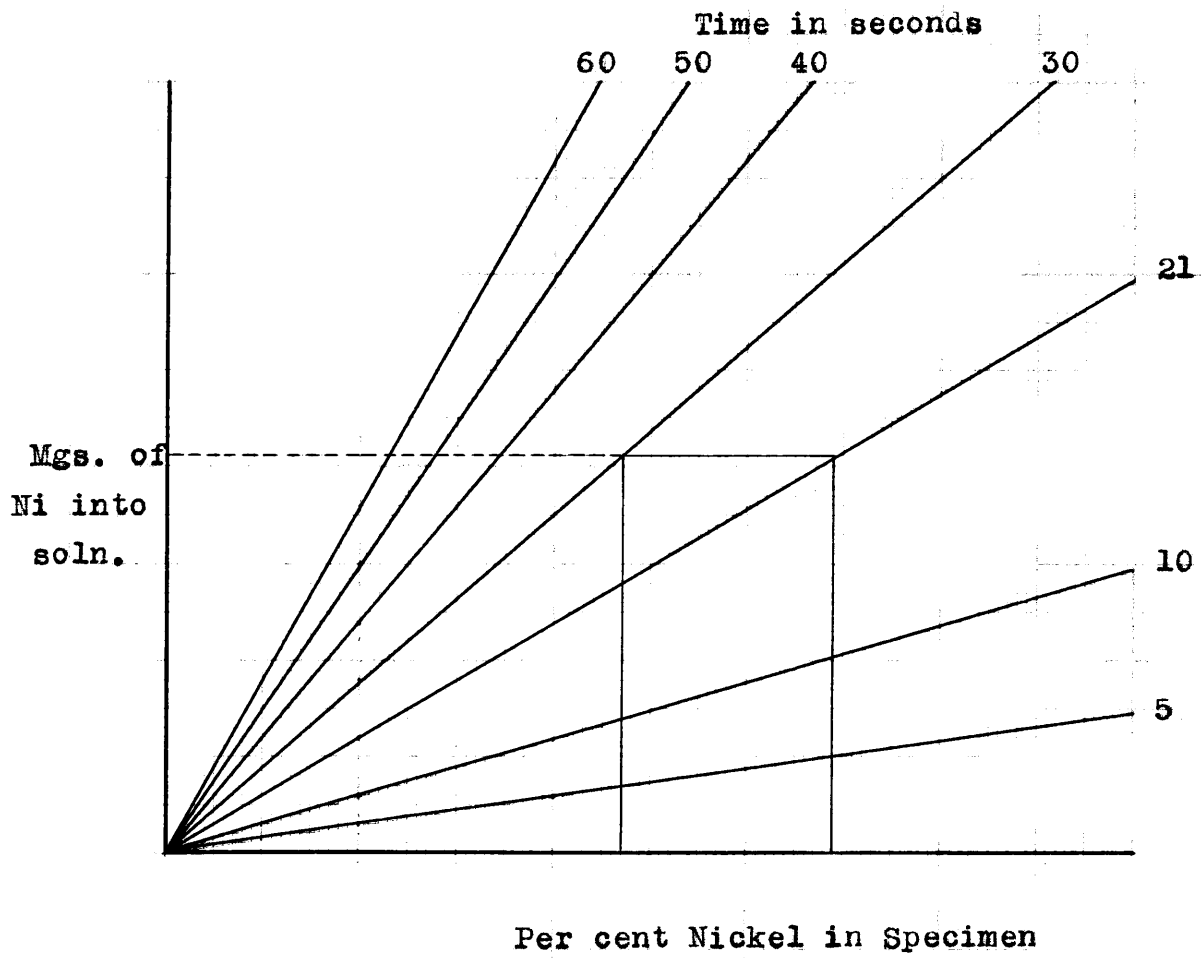


Figure 1

to the abscissa will fix the per cent nickel in the unknown sample.

It is to be noted that in the two methods of determination just described it was necessary that prints of the same color intensity be made. The work of the investigators, Glazunow and Krivehlavy, does not indicate that means other than the unaided eye were used to determine when prints of the same color intensity has been obtained. It was found in the present work that judging color intensities was a job impossible for the human eye to perform. Then, unless some means is found for comparing the color intensities, the equations and diagram just explained become, in the opinion of the writer, valueless.

#### EXPERIMENTAL WORK

##### COMPARISON OF COLOR

The very first work revealed the fact that the comparison of color was going to be

a very difficult job, especially if the unaided eye was the only tool to be used. It was seen that it would be impossible to produce prints of like color intensity for the different specimens. So the experiments were carried out with the current density and the time of exposure constant. This should produce a series of prints which should show a gradation of color intensity in the same manner as the nickel content in the specimens varied. And such a variation was noted in the prints. But the gradation of color was very gradual and the eye had difficulty noticing the difference in intensity of two prints when the nickel content of the corresponding samples varied as much as two per cent. The eye is a very inaccurate instrument at best and to use a set of standard colors to compare with prints of unknown specimens and to expect good results using the eye alone would be folly. There are other ways of making this comparison and one of them will be mentioned later on.

It was mentioned earlier in this writing that between 6.5 and 51% nickel a heterogeneous

mixture existed. It will be remembered that this statement was attributed to Glazunow and Krivohlavy. It was noted at that time that these two gentlemen gave no explanation for this condition. As it was suggested that a heterogeneous mixture of two solid solution phases of nickel and iron might exist. There is one point that hasn't been mentioned and that might produce the same result and give prints which do not give a quantitative measure of the nickel present. With a filter paper, or any other paper that may be used, only a certain amount of reagent can be held on, or close to, the surface. So, after the traveling nickel ions have reacted with all of the surface reagent, they will start to react with absorbed reagent that lies more toward the center of the paper and no increase in the intensity of the color will be noticed. Then, if two particularly high nickel steels of different nickel content are compared, no difference in the prints would be noticed unless the current and the time of exposure were both lowered to a very small figure.

#### INTERFERING ELEMENTS

While little or no work, as far as is known, has been done on the effect of other alloys in steel, it has been noted here that chromium, in the 18-8 alloys, seems to be an element which interferes with the realization of good nickel prints from that alloy. There probably is a solid solution formed between the chromium and the nickel and this might act in a manner much different from a solid solution of iron and nickel. It is also to be remembered that the investigators at Pribram said that chromium was passive to this method of analysis. However, nothing can be said here as to the correctness of this statement.

#### DESCRIPTION OF APPARATUS

From the preceding discussion it is evident that the apparatus used in this experiment can boast of exceeding simplicity. For holding the sample a spring clamp was developed which held the sample vertically against an aluminum

cathode. Between the two, of course, was placed the reagent-soaked paper. The power supply consisted of two six-volt storage batteries, connected in series. The only reason for using two batteries was because the current passing was not sufficient to allow the use of the necessary regulatory resistance and at the same time remain in the range of the milliammeter, when only one battery was used. This milliammeter was a Weston instrument with a scale reading from zero to 1000 milliamperes. To regulate the current a 90 ohm slide-wire resistance was employed. Outside of a second clock and a washing box this completes the apparatus used.

#### REGULATION OF CURRENT

The regulation of current was one of the first problems ran up against in the experimental work. The resistance of the external circuit was negligible in comparison to the resistance at the contacts with the filter paper. As each test progressed, the resistance at this

point usually rose and the current fell. This made it difficult to determine the average current flowing throughout the test.

One method for avoiding this difficulty would be the use of a coulombmeter. An ordinary silver or copper coulombmeter would not be satisfactory because of the small amounts of current flowing and the time necessary to determine the amount of electricity that had passed through the meter. Two direct-reading coulombmeters have been suggested and, perhaps, could be worked into this method. The first is the gas coulombmeter, which consists of a H tube filled with water and provided with platinum electrodes at the bottom of each leg of the H. Passage of current results in the decomposition of the water and the hydrogen and oxygen formed collect in the upper arms of the H and the volume, and, therefore, the amount of electricity, can be measured by a graduated scale on the tubes. The other type is a mercury coulombmeter, which consists of two calomel electrodes. Mercury is deposited at the cathode upon the passage of

current and the increase in volume of the mercury can be measured in a capillary tube connected to the mercury well at the cathode of the cell. This tube could be graduated to read directly in coulombs. This type coulombmeter is suitable for very small currents only. A coulombmeter would measure the absolute amount of electricity that had passed through the circuit. Any variation of the current during the experiment would, then, make no difference as it is the total electricity that is the final factor. Then, too, the element of time would be eliminated from consideration. However, it is probable, especially in the case of the gas coulombmeter, that the current would be too small and the time interval too short to have much effect upon the instruments. Also the calibration would be rather difficult and the coulombmeter would require much attention.

On the other hand, if a milliammeter is going to be used, some method for keeping the current constant and for measuring the time would have to be devised. It was found during the present experiment that a manually-operated

variable resistance served very nicely to keep the current at a constant value and a photographic second clock proved to be satisfactory for measuring the time of exposure.

It probably has been noticed in the foregoing discussion that it was said that an attempt was made to keep the current constant and no mention was made about the current density. However, it was assumed that the specimens were all of the same area at the surface of contact. This being the case, keeping the current at a constant value would result in the current density remaining constant. But as the current density is the factor that should be kept constant, corrections of the total current would have to be made with specimens of different areas of contact.

#### PREPARATION OF SAMPLE

While no extensive preparation need be performed on the sample, there are a few details that should be carried out in this connection. It is advisable that the specimen be of round

stock, preferably of constant cross sectional area. Round specimens lend themselves much nicer to the spring clamp used in this work and also to the determination of the area of contact. It is not necessary to do much mechanical work on the specimen, but the surface would best be ground smooth and perpendicular to the length of the piece. Also after several tests the surface in contact with the reagent becomes oxidized and mechanically picks up some of the red precipitate of nickelglyoxime. For this reason it is well to brighten up the surface at regular intervals.

#### PAPER USED

In the first experiments filter paper was used as the absorbent agent for the reagent. Fair prints were obtained with reasonable care. Finally the tests were run using blotting paper instead of filter paper and a greatly improved print was obtained. A loosely-made blotting paper gave the best results because of the cushion

effect of the paper. Also it was noted that this more porous paper offered less resistance to current passage than did the more compact papers. This was undoubtedly due to the increased amount of reagent absorbed by the porous paper.

#### PRESSURE APPLIED TO SAMPLE

It is desired that the specimen be held flat against the reagent-soaked paper with a constant pressure in all tests. Varying pressures result in changes in resistance and if the specimen does not press flat over its whole surface, only part of a print is obtained. A little practice will, however, overcome these difficulties.

#### TIME OF SOAKING OF PAPER IN REAGENT

A series tests were run to determine what effect, if any, resulted from different lengths of soaking time for the blotting paper. After five seconds time no effect could be noted with the naked eye, although investigation with a photoelectric cell might bring out some differ-

ences. After an hours time, however, it was noted that the paper became slightly yellowish and would disintegrate much easier than if soaked for a shorter period. Any reasonable short period of time will then suffice to properly saturate the paper. It is also wise to allow excess reagent to drain from the paper because, if left on, it will react to form some precipitate which, when washed, will float off the surface of the paper. The paper should not be allowed to dry in the air, however, or insufficient reagent will be present and a false color intensity would be obtained.

#### TIME OF EXPOSURE TO CURRENT

At the start of the experimental work thirty seconds was used as the time interval. The prints for the higher nickel steels, it was noticed, were not particularly different as to color. The time was shortened to ten seconds and a much greater difference was immediately noticed. With the longer time interval the reagent at the surface was probably all used up and all further

precipitate was formed underneath with little change in color. With a shorter time interval there was probably enough excess reagent and the color gradation was noticeable. Care should be taken in this matter, especially in the case of the high nickel steels.

#### TIME OF WASHING

Especially when blotting paper was used, more washing was necessary to remove all of the reagent. Ferrous ions exist in solution in the reagent and upon exposure to the air these are oxidized to the ferric state and a brown discoloration is observed when the paper dries. A photographic plate washer was used to wash the prints obtained in this work. It was found by experiment that half an hour is about the minimum length of time for washing with this type of washer. As there is only a slow circulation of water through this washer, these results could probably be bettered with a washer allowing better circulation.

## PHOTOELECTRIC COMPARISON OF COLOR

At various points earlier in this writing it has been remarked that the comparison of the prints obtained by the electrographical method is impossible with the eye alone. At the suggestion of Professor Campbell a photoelectric comparator was set up to judge the different intensities of color of the various prints. The apparatus was very similar to that used in the comparison of paint samples. Figures II and III present the schematic arrangement of the comparator.

This set up is based on the premise that the amount of light reflected from the print is proportional to the intensity of color on the print. This in turn makes it proportional to the amount of red precipitate on the surface and finally to the amount of nickel in the original specimen. However, this will only apply to the amount of precipitate on the surface of the paper. When the condition is reached where all of the reagent on the surface has been used up, no difference in the amount of light reflected

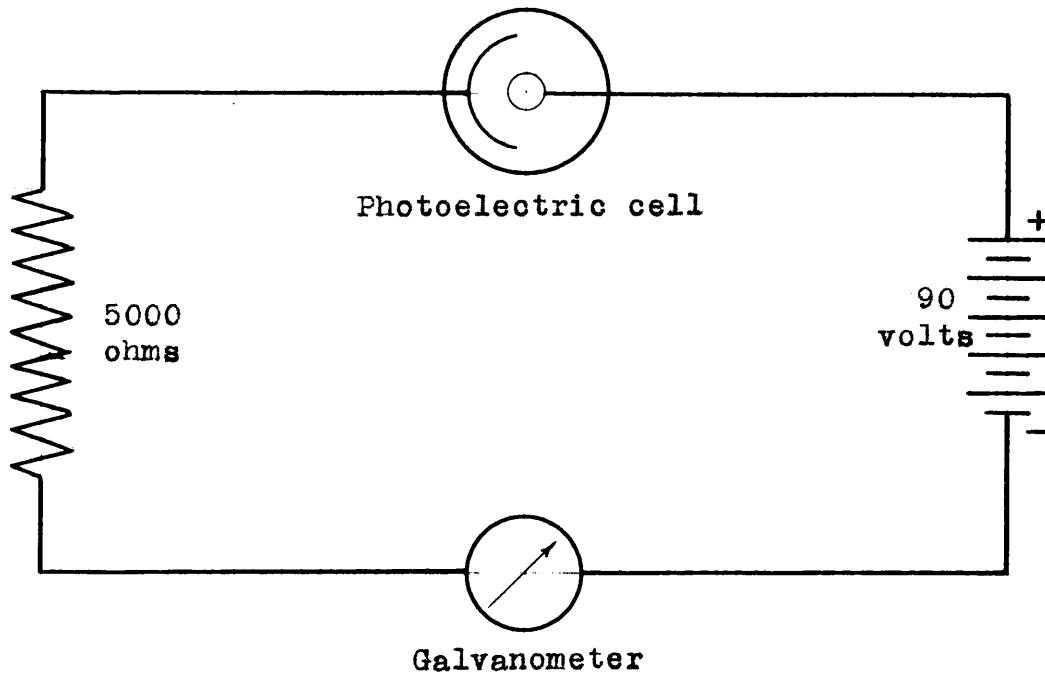


Figure II

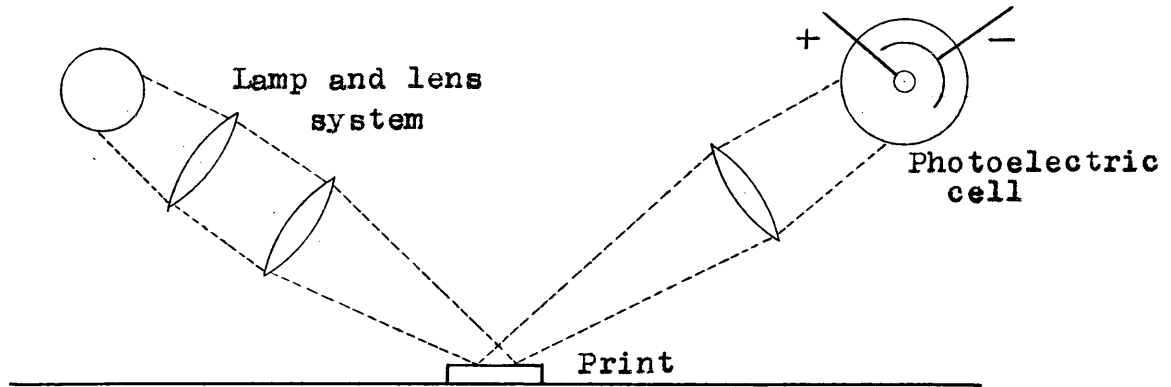


Figure III

will be noted by an increase in the amount of red precipitate.

The photoelectric cell used in this comparator was a Visitron number 5, the active surface of which is an alkali hydride. As a source of light a 108 watt small-filament bulb was used in connection with a lens system to direct a small beam of light on the sample. The cell current was measured on a galvanometer of the reflecting mirror type. While the photoelectric cell was not particularly sensitive, a measurable difference was noted on the galvanometer when prints representing samples of different nickel steels were placed in position in the comparator.

While the investigation was of necessity hurried and incomplete, indications point to it as a convenient and reliable method of comparing prints. The method has many possibilities for refinement. In the comparator as used here many mechanical details were very crude and much better results would, of course, be obtained by their improvement. In addition either a more sensitive cell or an amplifier on the present cell could be used to magnify the current obtained from the

reflection of a given amount of light. This would result in a greater difference between readings for the various prints.

Figure IV shows very well the results obtained from this comparator. On this curve the galvanometer deflection is plotted against the per cent nickel in the original specimen. As can be seen, the points lie nicely along a straight line. This curve provides much to encourage the belief that this method will allow the use of the electrographical scheme of analysis with a fair degree of accuracy.

The prints used in this experiment had been washed and dried. This procedure required several hours and to follow it would destroy the greatest advantage that the method possesses. But no reason can be seen why wet prints can not be used successfully in the comparator. The prints could be made, washed, perhaps the excess moisture pressed out, placed in the comparator, and the per cent nickel tabulated all in the space of ten minutes at the most. It would be necessary to standardize on a definite paper to use and on

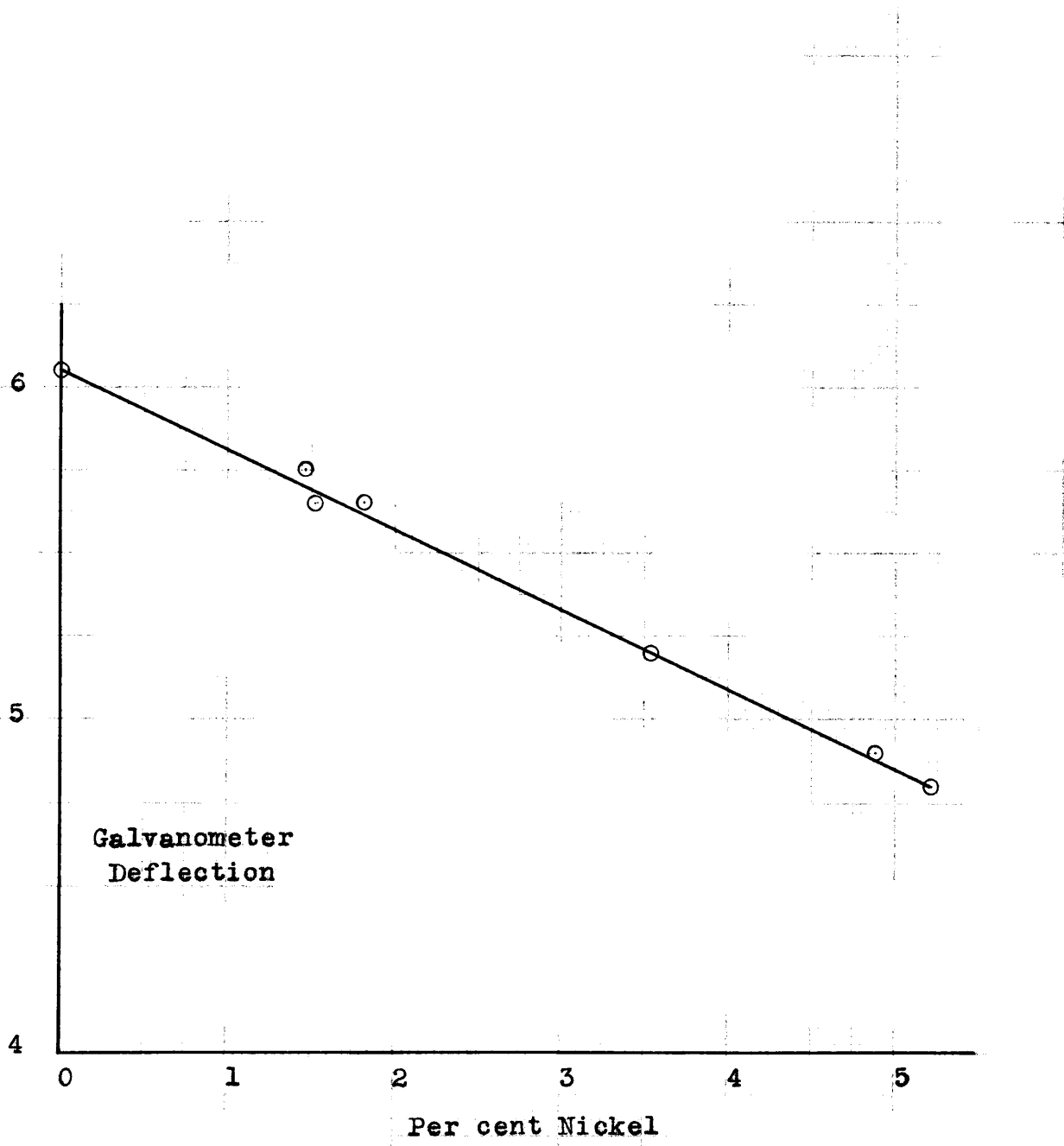


Figure IV

a definite procedure to follow. And this would have to be followed the letter for both the unknown and the standard specimens.

#### CONCLUSIONS

As a method of qualitative analysis, the electrographical method proves to be very successful. The reagent, dimethylglyoxime in dilute acetic acid, seems to be specific. But for quantitative analysis the application is much more difficult. The procedure has been developed to the point where no interfering colors are noted and chromium seems to be the only element that interferes with the precipitation and this only when chromium is present in relatively large amounts. The remaining difficulty is then the comparison of the colors obtained. The use of the photoelectric cell provides an extremely likely method of accomplishing this. With more investigation it is firmly believed that a workable color comparator can be set up. This type of comparator has been used elsewhere and with reasonable success. This accomplished, it would

be possible to use either the equations or the graphical solution of Glazunow and Krivohlavy. Both of these methods require the production of prints of like intensity. While this is entirely possible with the photoelectric cell, it is believed that too much time would be spent in obtaining these prints and little, if anything, gained by doing it.

The method that would probably prove best is as follows: Prints would be made as was done in this work; that is, prints of varying color intensity made but the time of exposure and the current density used in their production remaining constant. The comparator would be permanently set up and a set of standard prints used to calibrate the galvanometer directly in per cent nickel. The per cent nickel could then be easily and quickly found when a print from an unknown specimen was inserted in the comparator. It would be necessary to make up new standard prints at regular intervals from new standard specimens to check the calibration of the meter. This is suggested because it is believed that

the instrument might easily slip out of its original adjustment as a small and seemingly unimportant change in procedure might serve to render the old calibration inaccurate. Then, too, it would be necessary to be on the alert for the presence of impurities and note what change they might make in the results. But, even with these precautions, the method has many possibilities and evident advantages over the existing methods.

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Table 1.

Sample No.	Per cent Nickel
30	0.07
29	0.09
2	0.51
1	0.54
19	1.18
20	1.21
4	1.47
3	1.53
28	1.67
21	1.71
27	1.75
22	1.82
6	3.51
5	3.54
8	4.88
7	5.20

Table 2.

Sample No.	Diameter inches	Area sq. in.	Current milliamps
30	0.75	0.44	72
29	0.75	0.44	72
2	1.03	0.83	135
1	1.00	0.79	130
19	0.74	0.43	71
20	0.73	0.42	69
4	1.00	0.79	130
3	1.04	0.85	140
28	1.04	0.85	140
21	0.62	0.30	49
27	1.04	0.85	140
22	1.03	0.83	135
6	1.04	0.85	140
5	1.01	0.80	130
8	0.99	0.77	130
7	0.99	0.77	130