ELECTROPLATERS' MANUAL

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BY
NEW YORK BRANCH
AMERICAN ELECTROPLATERS' SOCIETY

THIS manual was compiled by the Laboratory Committee of the New York Branch of the A. E. S.

It consists of standard information, tables, methods of analysis, etc. of constant use to the plater. This matter is presented in compact form for easy reference.

The book is so made up that valuable additions can be readily made from time to time and included in the original volume.

INTERNATIONAL ATOMIC WEIGHTS

NAME	Symbol	Atom. Wt.	NAME	Symbol	Atom. Wt.
Aluminum	Al	27.1	Molybdenum	Mo	96.0
Antimony	Sb	120.2	Neodynium	Nd	144.3
Argon	A	39.88	Neon	Ne	20.2
Arsenic	As	74.96	Nickel	Ni	58.68
Barium	Ba	137.37	Niton	Nt	222.4
Bismuth	Bi	208.0	Nitrogen	N	14.01
Boron	B	11.0	Osmium	Os	190.9
Bromine	Br.	79.92	Oxygen	O	16.00
Cadmium	Cd	112.40	Palladium	Pd	106.7
Caesium	Cs	132.81	Phosphorus	P	31.04
Calcium	Ca	40.07	Platinum	Pt	195.2
Carbon	C	12.00	Potassium	K	39.10
Cerium	Ce	140.25	Praseodymium	Pr.	140.9
Chlorine	Cl	35.46	Radium	Ra	226.0
Chormium	Cr	52.0	Rhodium	Rh	102.9
Cobalt	Co	58.97	Rubidium	Rb	85.45
Columbium	Cb	93.1	Rutheninum	Ru	101.7
Copper	Cu	63.57	Samarium	Sa	150.4
Dyzprosium	Dy	162.5	Scandium	Sc	44.1
Erbium	Er	167.7	Selenium	Se	79.2
Europium	Eu	152.0	Silicon	Si	28.3
Fluorine	F	19.0	Silver	Ag	107.88
Gadolinum	Gd	157.3	Sodium	Na	23.00
Gallium	Ga	69.9	Strontium	Sr	87.63
Germanium	Ge	72.5	Sulphur	S	32.06
Glucinum	Gl	9.1	Tantalum	Ta	181.5
Gold	Au	197.2	Tellurium	Te	127.5
Helium	He	4.00	Terbium	Tb	159.2
Holmium	Ho	163.5	Thallium	Tl	204.0
Hydrogen	H	1.008	Thorium	Th	232.4
Indium	In	114.8	Thulium	Tm	168.5
Iodine	I	126.92	Tin	Sn	118.7
Iridium	Ir	193.1	Titanium	Ti	48.1
Iron	Fe	55.84	Tungsten	W	184.0
Krypton	Kr	82.92	Uranium	U	238.2
Lanthanium	La	139.0	Vanadium	V	51.0
Lead	Pb	207.20	Xenon	Xe	130.2
Lithium	Li	6.94	Ytterbium	Yb	173.5
Lutecium	Lu	175.0	Yttrium	Yt	88.7
Magnesium	Mg	24.32	Zinc	Zn	65.37
Manganese	Mn	54.93	Zirconium	Zr	90.6
Mercury	Hg	200.6			

IDENTIFICATION OF PLATING SALTS

The purpose of the following tests and tables is to give the plater, simple methods, requiring no previous chemical knowledge for identifying the chemicals he uses in the plating room.

The chemicals are classified in groups according to their physical appearance—those chemicals, resembling one another the most and consequently most liable to be mistaken for each other, appearing in the same group.

No. 1. Solubility:—Certain generalizations, to which exceptions are few and unimportant, can be stated concerning solubility.

1. All sodium, potassium and ammonium salts are soluble in water.
2. All nitrates, chlorates, and acetates are soluble in water.
3. All chlorides are soluble in water except those of silver, mercurous and lead. Lead is slightly soluble in cold, but readily soluble in hot water.
4. All sulphates are soluble, except those of barium, lead, calcium (calcium slightly soluble). The silver and mercurous sulphates are only moderately soluble.
5. All carbonates are insoluble, except those of ammonium, sodium and potassium.
6. All oxides and hydroxides are insoluble except those of ammonium, sodium, potassium and barium, calcium hydroxide is slightly soluble.
7. All cyanides are insoluble, except those of sodium and potassium.

No. 2. Litmus Reaction.

1. Acids and some acid salts due to hydrolysis or presence of H(ions) turn blue litmus red.
2. Alkalies and some alkali salts (due to hydrolysis or presence of OH(ions) turn red litmus blue.
3. Neutral salts have no effect on litmus paper.

Dissolve about one ounce of the salt to be identified in two fluid ounces of water (60c.c.). In making the tests to identify the compound parts of the salt, use about ¼ fluid ounce (about 6c.c.) in a test tube.

All reagents should be dilute solutions, about 10%.

GROUP No. 1.—Granular Salts.

1. Ammonium Chloride—NH_4Cl.

Test for Ammonium:—NH_4—To the solution add an equal volume of a solution of sodium hydroxide. Gently heat, and over the mouth of the test tube hold a moistened piece of red litmus paper; paper will turn blue indicating that ammonia gas NH_3 has been driven off, and indicates the presence of ammonium—NH_4.

Test for Chloride:Cl—To the solution add 2-3 drops of nitric acid, a few drops of silver nitrate; a white curdy ppt., soluble in ammonia and reprecipitated by nitric acid is silver chloride, and indicates the presence of chloride—Cl.

2. Ammonium Sulphates:—$(NH_4)_2SO_4$.

Test for Ammonium:NH_4—To the solution add an equal volume of sodium hydroxide; gently heat; over and above the mouth of the test tube hold a moistened piece of red litmus paper; paper will turn blue indicating the presence of ammonium—NH_4.

3. Potassium Sulphate—K_2SO_4.

Test for Potassium:—K. Take a little of the chemical on a platinum wire and heat in a non-luminous bunsen flame. The color of the flame is violet, indicating potassium-K. It is necessary to look at this flame through several thicknesses of cobalt blue glass, as the presence of sodium which flame is of an intense yellow obscures the violet color of the potassium flame.

Test for Sulphate:—SO_4. To the solution add a few drops of hydrochloric acid, and then barium chloride or nitrate. The formation of a white ppt.—barium sulphate, indicates sulphate—SO_4.

4. Sodium Sulphate—Na_2SO_4.

Test for Sodium:—Na. Take a little of the chemical on a platinum wire and heat in a non-luminous bunsen flame. An intense yellow color of long duration indicates sodium—Na. Confirm absence of potassium by looking at flame thru blue glass.

See Test for Sulphate SO_4.

5. Sodium Chloride—$NaCl$.

See Test for Sodium:—

See Test for Chloride:—

6. Potassium Chloride—KCl.

See Test for Potassium:—

See Test for Chloride:

7. Potassium Nitrate—KNO_3.

See Test for Potassium:—

Test for Nitrates:—NO_3. To the cold solution, add an equal volume of ferrous sulphate and then slowly pour conc. sulphuric acid down the side of the test tube, so that a heavy layer of the acid forms at the bottom; a brown ring formed between the two layers indicates a nitrate—NO_3.

8. Aluminum Sulphate—$Al_2(SO_4)_3$.

Test for Aluminum:—Al. To the solution add ammonium hydroxide—a white gelatinous precipitate indicates aluminum—Al. To confirm, filter the precipitate and transfer a little into a small hole in a plaster slab; heat with blowpipe, moisten with cobalt nitrate solution and reheat with blowpipe. If Al, mass will be blue colored.

See Test for Sulphate:—

9. Zinc Sulphate—$ZnSO_4$.

Test for Zinc:—Zn. Heat some of the salt on a plaster slab with a blowpipe; moisten with cobalt nitrate, an emerald green colored mass indicates zinc—Zn.

See Test for Sulphate:—

10. Lead Acetate—Pb $(C_2H_3O_2)_2$.

Test for Lead:—Pb. Add potassium chromate; yellow lead chromate is formed; heat with a little sodium hydroxide, and the formation of orange colored lead chromate indicates lead—Pb.

Test for Acetate:—Heat some of the salt with a mixture of alcohol and conc. sulphuric acid. A characteristic fruity odor indicates acetate—$C_2H_3O_2$.
or treat substance with concentrated sulphuric acid gives odor of vinegar.

11. Sodium Citrate.

See Test for Sodium:—

Test for Citrate:—To the solution add calcium chloride solution. No ppt. appears, but upon boiling a white crystalline ppt. appears.

Note:—To distinguish citric acid from sodium citrate, test solution with blue litmus, which, turning red, indicates acid. Then to the solution add calcium chloride and an equal volume of alcohol. A white crystalline ppt. indicates citrate.

GROUP No. 2.—Powdered, Non-Crystalline Salts.

1. Boric Acid—H_3BO_3.

Test for Acid:—Blue litmus turns red.

Test for Borate:—To the solution, in an evaporating dish, add twice the volume of alcohol; ignite; a green colored flame indicates boric acid—Na_3BO_3.

2. Sodium Borate—$Na_2B_4O_7$. $10H_2O$.

See Test for Sodium:—

Test for Borate:—To the solution add 1 cc. conc. sulphuric acid an equal volume of alcohol and then ignite. A green-colored flame indicates borate—BO_3.

Note:—Boric acid is distinguished from sodium borate or borax, in that the borate test in the case of boric acid does not require the addition of sulphuric acid.

3. Potassium Sodium Tartrate—Rochelle Salt—K Na $C_4H_4O_6$. $4H_2O$.

See Test for Sodium:—

See Test for Potassium:—

Test for Tartrate:—To a copper sulphate solution in a test tube, add the tartrate solution, add sodium hydroxide; the absence of a precipitate indicates tartrate. To confirm, heat a little of the salt with conc. sulphuric acid, and a little resorcinol solution; a purple colored solution indicates tartrate—$C_4H_4O_6$.

4. Sodium Carbonate—Na_2CO_3.

See Test for Sodium:—

Test for Carbonate:—Add some of the salt to a gas generator filled up with a thistle tube and a delivery tube. Add dilute sulphuric acid and allow gas formed to pass into a test tube of lime water. A white ppt. indicates carbonates—CO_3.

5. Sodium Bicarbonate—$NaHCO_3$.

See Test for Sodium:—

See Test for Carbonate:—

Note:—Sodium carbonate and sodium bicarbonate are dis-
Two or three drops in sodium carbonate gives a
tinguished by their reaction with phenolpthalein.
deep violet red solution; in sodium bicarbonate, it
gives a faint pink solution.

6. Arsenous Oxide—As_2O_3.

White arsenic—heated in a test tube sublimes and deposits on cooler portions of the tube in small crystals.

Dissolve a little of the salt in hydrochloric acid; dilute and boil with a strip of copper; a grey deposit of metallic arsenic forming on the copper indicates —As_2O_3.

7. Aluminum Sulphate—$Al_2(SO_4)_3$.

See Test for Aluminum:—

See Test for Sulphate:—

8. **Calcium Carbonate: Whiting: $CaCO_3$.**

Test for Calcium:—Moisten the compound with hydrochloric acid, and heat in a non-luminous bunsen flame. The flame tinged dull red, indicates Calcium—Ca.

See Test for Carbonate—

9. **Zinc Cyanide—$Zn(CN)_2$.**

Test for Zinc:—Heat some of the compound on a plaster slab, with a blow-pipe; moisten with cobalt nitrate solution and reheat. The mass turned green indicates Zinc—Zn.

Test for Cyanide:—Add a little ammonium hydroxide, then few drops of yellow ammonium sulphide; evaporate to dryness. The residue is a thiocyanate. To the residue add hydrochloric acid and a little ferric chloride, a blood red color indicates a cyanide—CN.

Note:—The above test for cyanide is the one that is used when metal and cyanogen form an insoluble salt. When the metal and cyanogen form a soluble salt, the test is as follows:

Add a little ferrous sulphate, then ferric chloride; Sodium Hydroxide is added to alkaline reaction; heat, add Hydrochloric acid and a precipitate of Prussian blue is obtained.

GROUP No. 3.—Needle-Shaped Crystals.

1. **Magnesium Sulphate—$MgSO_4$.**

Test for Magnesium:—Add an equal volume of ammonium chloride, and then ammonium hydroxide; some sodium hydrogen phosphate is added, and a fine, white crystalline ppt. indicates magnesium—Mg.

See Test for Sulphate:—

2. **Boric Acid—H_3BO_3.**

Test with blue litmus paper for acid reaction.

To the solution in an evaporating dish, add twice the volume of alcohol; ignite; a green-colored flame indicates boric acid—H_3BO_3.

3. **Sodium Acetate—$NaC_2H_3O_2$.**

See Test for Sodium:—

See Test for Acetate:—

4. **Ammonium Oxalate—$(NH_4)_2C_2O_4$.**

See Test for Ammonium:—

Test for Oxalate:—Silver nitrate, giving a white ppt. soluble in nitric acid, indicates oxalate C_2O_4.

Note:—Oxalic acid is distinguished from any other oxalate salt, by turning blue litmus red.

5. **Zinc Sulphate—$ZnSO_4$.**

See Test for Zinc:—

See Test for Sulphate:—

GROUP No. 4.—Large Massive Crystals.

1. **Lead Acetate—Pb $(C_2H_3O_2)_2$.**

See Test for Lead:—

See Test for Acetate:—

2. **Thiosulphate of Sodium—"Hypo" $Na_2S_2O_3$.**

See Test for Sodium:—

Test for Thiosulphate:—To a concentrated solution add conc. HCl acid; evolved sulphur dioxide identified by ppted. sulphur, indicate thiosulphate—S_2O_3.

3. **Potassium Aluminum Sulphate—Alum—$K_2Al_2(SO_4)_2$.**

See Test for Potassium:—

See Test for Aluminum:—

See Test for Sulphate:—

Note:—Alums besides being potassium alums might be also of sodium and ammonium.

4. **Sodium Carbonate—Washing Soda—Na_2CO_3.**

See Test for Sodium:—

See Test for Carbonate:—

VALANCE CHART

Positive				Negative			
1	2	3	4	1	2	3	4
K	Fe	Fe	Si	F	O	N	Si
H	Pb	Cr	Pt	Cl	S	P	C
Na	Cu	Bi		Br	(SO_3)	B	
Ag	Zn	Sb		I	(SO_4)	(PO_4)	
Hg	Mg	As		(NO_2)	(CO_3)		
(NH_4)	Hg	Al		(NO_3)	(SiO_3)	(AsO_4)	
(CH_3)	Ca	Au		(ClO_3)	(C_2O_4)		
(C_2H_5)	Ba	(C_3H_5)		(OH)		BO_3	
Cu	Cd			$(C_2H_3O_2)$	$Zn(CN)_2$		
	Mn			CN			
	Sn			$Ag\ (CN)_2$			
	Ni			$Cu(CN)_2$			

RADICALS

Ammonium	NH_4	Acetate	$C_2H_3O_2$
Methyl	CH_3	Sulphite	SO_3
Ethyl	C_2H_5	Sulphate	SO_4
Glycer	C_2H_5	Carbonate	CO_3
Nitrite	NO_2	Silicate	SiO_3
Nitrate	NO_3	Oxalate	C_2O_4
Chlorate	ClO_3	Phosphate	PO_4
Hydroxide	OH	Arsenate	As_2O_4

Temperature Conversion:

Degrees Fahrenheit = degrees Centigrade X 1.8 + 32.
Degrees Centigrade = degrees Fahrenheit — 32 ÷ 1.8.

One avoirdupois pound = 454 grams.
One avoirdupois oz. = 28.35 grams.
One U. S. liquid gallon = 231 cubic inches.
One U. S. liquid gallon = 3.785 liters.
One liter = 1000 cubic centimeter.
One liter of water weighs 1000 grams.

To determine the approximate capacity of vats in gallons divide the cubical contents in cubic inches (up to the height of the solution) by 231.

To convert grams per liter (G/L) to ounces per gallon multiply by 0.134 or divide by 7.5. Thus, 50 G/L is equal to $50 \times 0.134 = 6.7$ oz./gal.

CALCULATION OF PERCENTAGE COMPOSITION OF CHEMICALS

From the formula of a chemical compound, one can calculate the percentage of any or all of its constituents. This is done by finding the molecular weight of the compound (the sum of the atomic weights of the elements composing it) and then dividing this result into the atomic or molecular weight of that constituent that one wishes to determine. Multiply result by 100.

1. Determination of Cyanogen in Sodium Cyanide—NaCN.

Atomic weight Na = 23.00.
Atomic weight C = 12.00.
Atomic weight N = 14.01.

49.01 molecular wt. NaCN

Atomic weight C = 12.00
Atomic weight N = 14.01

26.01 molecular wt. CN

$$\frac{26.01}{49.01} = .53$$

.53 X 100 = 53% C N in NaCN.

2. Determination of Percentage Nickel in Nickel Sulphate—

Ni $SO_4.7H_2O$.

Atomic Weight Ni = 58.68
Atomic Weight S = 32.07
Atomic Weight O = 16, 16x4 64.00
Molecular Weight H_2O = 18, 18 x 7 126.00

280.75 molecular weight $NiSO_47H_2O$

$$\frac{58.68}{280.75} = .209$$

$.209 \times 100 = 20.9\%$ Ni in $NiSO_4.7H_2O$.

ANALYSIS OF PLATING SOLUTIONS
ASSAY GALLON METHOD

The method of analysis to be followed depends upon making standard solutions in accordance with Prof. E. J. Hall's Assay Gallon. The pipettes used deliver respectively 12.2 c.c. and 13.4 c.c. for Troy and Avoirdupois determinations. These can be made and calibrated by any chemical supply house. Prof. Hall has recommended that solutions be made of such a strength that 1 c.c. of the solution would be equivalent to 1 decigram of what is to be determined. Then the readings on the burette would be numerically equal to Troy or Avoirdupois ounces. But solutions of such strength are difficult to handle, as the possibility of error is greater, the greater the concentration of the solution. Consequently it is recommended that the solutions be made of such strength that 1 c.c. will be equivalent to 1 centegram of whatever is to be determined. In this way 10 c.c. on the burette will numerically equal 1 ounce Troy or Avoirdupois per gallon. Each c.c. can be read to one-hundredths of an ounce. There is no necessity of standardizing the solutions if care is taken in making them up, and if they are made up with only the purest chemicals. These chemicals should be carefully put away after being stoppered up.

The best method to obtain accuracy in volumetric analysis is as follows: Run the titrating solution in at 2 c.c. bulks, and find the extreme limits between which the end point lies. Suppose that at 8 c.c. the end point is not visible, but at 10 c.c. it is. Then the end point lies between 8 and 10 c.c. Then taking another sample of the solution 8 c.c. are run in directly, and from there on the solution is titrated drop by drop. If a method such as this is followed it will be found that overrunning the end point will be avoided, and much tedious and unnecessary work will be eliminated. Following is a table of the various solutions to be analyzed, with what chemical, and with what indicator. The table should be posted in a convenient place where the analytical work is carried on:

Solution Analyzed	For	With	Grams Per Litre	Indicator	Remarks
Silver	Ag	NaCNS	7.49	Ferric Alum	
	CN	$AgNO_3$	32.65	KI	Keep in dark bottle
Copper	CU	NaCN	30.88	NH_4OH	32.145 gram of 96 %NaCN is used. Keep in dark bottle.
		or			
		$Na_2S_2O_35H_2O$	39.03	Starch paste	
	Acid	Na_2CO_3	10.81	Methyl Orange	
	CN	$AgNo_3$	32.65	KI	Dark bottle
Zinc	Zn	$K_4Fe(CN)_63H_2O$	43.05	Ammonium Molybdate	Dark bottle
	Acid	Na_2CO_3	10.81	Methyl Orange	
	CN	$AgNO_3$	32.65	KI	

Brass and Bronze Analyzed for Cu, Zn, and free CN with the same solutions as used for Copper and Zinc

Solution Analyzed	For	With	Grams per Litre	Indicator	Remarks
Nickel	Ni	NaCN	33.41		34.802
		&		KI	grams of
		$AgNO_3$	57.90		96% NaCN
					is used.
	Cl	$AgNO_3$	47.89	K_2CrO_4	
Gold	Au	$Na_2S_2O_35H_2O$	25.15		
		&		Starch paste	
		I_2 dissolved	12.86		
		in KI	25.00		
	CN	$AgNO_3$	32.65	KI	
Lead	Pb	$Na_2S_2O_3.5H_2O$	35.94	Starch paste	
Sulpho- Cyanate					34.802 of
	Ni	NaCN	33.41		96% NaCN
Black Nickel		&		KI	is used
		$AgNO_3$	57.90		
	Zn	$K_4Fe(CN)_63H_2O$	43.05	Ammonium	
				Molybdate	
	CNS	$AgNO_3$	29.35	Ferric Alum	
Arsenic	As_2O_3	I_2	25.65		
		dissolved in		Starch Paste	
		KI	50.00		

ANALYSIS OF SILVER SOLUTIONS

1. Determination of silver with NaCNS. The method depends upon the fact that when an acid solution of silver and alkaline thio-cyanates are mixed in the presence of ferric sulphate or ferric alum, so long as silver is in excess, the thio-cyanate of silver is precipitated, and any brown ferric, thio-cyanate that is formed is decomposed. The end point is reached when the solution turns faint brown colored, showing that all the silver has been removed. The method may be used in the presence of copper up to 70%, also Antimony, Iron, Zinc, Manganese, Lead, Cadmium, Bismuth, Cobalt, and Nickel unless in such proportions as to interfere by intensity of color.

(a) 12.2 c.c. of the silver solution are taken and diluted to 100 c.c. and heated to boiling. Then ppt. as Ag_2S with H_2S, and after precipitation is complete, filter. The precipitate is dissolved with HNO_3, boiled to expel nitrous acid fumes, cooled and diluted to 100 c.c. Two drops of indicator (10% ferric alum) are added. The solution is now titrated with the standard NaCNS.

Example:
23.5 c.c. NaCNS solution used in titration.
Since 1 c.c. NaCNS = 1 centigram Ag.
23.5 c.c. NaCNS = 2.35 decigram Ag. = 2.35 ozs.
Troy per gallon.

Note:—By moving the burette reading, one decimal to the left ozs. per gallon are read off.

2. Determination of free cyanide with $AgNO_3$. The method depends upon the fact that when a solution of $AgNO_3$ is added to a solution that contains uncombined cyanide and a little KI as an indicator, as long as there is any uncombined cyanide the precipitated AgCN and AgI first formed are redissolved, and the complex soluble cyanides formed. The end point is reached when all the free cyanide is used up, the solution turns a faint canary yellow. Dilute 13.4 c.c. to 100 c.c. and add two drops of 10% KI and then titrate with the standard $AgNO_3$ solution until a perceptible turbidity is formed. This is the end point.

Example:
12.2 c.c. $AgNO_3$ solution used in titration.
Since 1 c.c. $AgNO_3$ solution = 1 centigram CN.
12.2 c.c. $AgNO_3$ solution = 1.22 decigram CN = 1.22 ozs. avoid. CN per gallon.

To convert CN to NaCn multiply by 1.884; to convert to KCN multiply by 2.503.

ANALYSIS OF ACID COPPER SOLUTIONS

1. Determination of Copper with NaCN. The method depends upon adding to a slightly acid or neutral solution NH_4OH to form the deep blue characteristic color of the ammonium copper ion. By adding NaCN, this color is destroyed by the decomposition of the complex copper ammonium to form the complex salt $Na\ Cu\ (CN)_2$. When the last of the copper ammonium ion is decomposed, the blue color disappears. Take 13.4 c.c. of the copper solution. If the solution is strongly acid add 10% NaOH to nearly neutralize the acid and then add NH_4OH until the precipitate first formed dissolves making a dark blue solution. If the solution is not strongly acid the NH_4OH may be added directly. The solution is then diluted to 100 c.c. and titrated with the standard solution. The end point is a faint violet color which may disappear upon standing.

Note:—If solution contains iron salts just before adding NH_4OH add 5 grains ammonium tartrate.

Example.

34.7 c.c. NaCN solution used in titration.

1.0 c.c. NaCN solution = 1 centigram of Cu.

34.7 c.c. NaCN solution = 3.47 decigram CU = 3.47 oz. Avoid. Cu per gallon.

2. Determination of Copper by Iodide Method. The method depends upon the fact that when KI is added to a slightly acid solution, cuprous iodide is precipitated and a chemically equivalent amount of iodine is liberated. This liberated iodine is titrated with standard $Na_2S_2O_3$. Since the titrated iodine is chemically equivalent to the Cu, the value of each c.c. of $Na_2S_2O_3$ is equivalent to one centigram of Cu.

Dilute 13.4 c.c. of the solution to 100 c.c. If strongly acid neutralize with NaOH until a faint precipitate forms. Clear solution with dilute HCl. Warm solution, pass in H_2S gas to ppt. copper as CuS. Filter and throw away filtrate. Wash ppt. twice with H_2S water. Warm some nitric acid (1:1) and pour it over the CuS to dissolve it. Care should be taken not to use more HNO_3 than is necessary ot actually dissolve the ppt. Wash filter paper thoroughly, collecting washings with main solution. Then concentrate the solution carefully, and when a small volume is obtained, continue evaporation over a water bath or a sand bath until a syrupy mass is obtained. Exceptional care must be taken not to burn the salts as $Cu\ (NO_3)_2$ will decompose, forming insoluble CuO. After all acid has been removed, allow to cool, and add 50 c.c. of water. An absolutely clear solution must be had at this point. Add NH_4OH until the faint ppt. is formed. The precipitate is dissolved in dilute $HC_2H_3O_2$ (1:10), and then 5 c.c. in excess. Add 10 grams KI, being sure that it is completely dissolved before going on with titration. If the volume of the solution at this point is not 100 c.c. make it so. Titrate with the standard $Na_2S_2O_3$ until the brown color of iodine disappears and changes to yellow. Add a few drops of starch solution and continue titration with standard $Na_2S_2O_3$ until blue color disappears.

3. Determination of Free Acid. When an acid and a base are brought together in the presence of an indicator, a change in color of the solution denotes that the titrated substance has had its properties destroyed. The amount of Na_2CO_3 as given in the table makes a solution of such strength that 1 c.c. will neutralize 0.1 decigram of 1.84 sp.gr. H_2SO_4, so that the readings on the burette numerically equal the amount of that acid in Avoid. ozs. Measure out 13.4 c.c. of the solution in a beaker and dilute to 100 c.c., add 3 or 4 drops of 5% methyl orange. The solution will be cherry red. Place the beaker upon a white surface, and titrate with Na_2CO_3 solution. The exact end point is indicated by the solution turning a golden yellow. This end point is difficult to obtain; however, a slight cloudness may be taken as the end point. Should the green precipitate be too heavy it is an indication that too much Na_2CO_3 has been added, and a new portion of the solution must be analyzed.

Note:—Fluid ozs. $H_2SO_4 = \frac{\text{ozs. Avoid. } H_2SO_4.}{1.84}$

ANALYSIS OF CYANIDE COPPER SOLUTIONS

1. Determination of Copper. Take 13.4 c.c. of the solution. Add slowly 10 c.c. conc. HCL to decompose the cyanides and heat to evaporate cyanogen and to dissolve CuCN precipitate; evaporate slowly to dryness. Add 5 c.c. con. HCL and heat slightly. Add 25 c.c. of water, heat to bring about solution of the salts. Cool solution, add 25 c.c. of water and proceed as under acid copper solutions.

2. Determination of Free Cyanide. Take 13.4 c.c. of the solution and determine as explained under Silver Solution.

ANALYSIS OF ZINC SOLUTIONS

1. Determination of Zinc with $K_4Fe(CN)_6$. The method depends upon the principle that $K_4Fe(CN)_6$ precipitates zinc from solution as $K_2Zn(Fe(CN)_6)_2$. Complete precipitation is indicated when ammonium molybdate paper is tinged brown. This paper is made by cutting strips of filter paper and allowing them to become saturated with a 20 per cent. ammonium molybdate solution. The papers are placed in a small bottle, after drying, and taken out as needed.

Acid Solutions. To 13.4 c.c. of the solution NH_4OH is added to produce a faint precipitate; then add conc. HCl to just dissolve the precipitate, and 2 c.c. in excess. Dilute to 100 c.c. and titrate with the standard $K_4Fe(CN)_6$ solution until a drop of the zinc solution produces a brown stain on the indicator paper.

Cyanide Solutions. Boil 13.4 c.c. of the solution with 10 c.c. conc. HCl until all the cyanides are decomposed. Use more HCl to bring about solution if necessary. Then proceed as explained with acid zinc solutions.

2. Free Acid. Take 13.4 c.c. of the solution and determine the acid as explained under copper solutions.

3. Free Cyanide. Take 13.4 c.c. of the solution and determine the cyanide as explained under silver solutions.

ANALYSIS OF BRASS AND BRONZE SOLUTIONS

1. Determination of Copper. Take 13.4 c.c. of the solution and add 15 c.c. of conc. HCl and boil until a clear solution is obtained. Dilute to 75 c.c. and heat the solution. When moderately warm H_2S gas is passed in until the copper is completely precipitated, as CuS. The ppted CuS is filtered off and washed with H_2S water several times. The filtrate is set aside for the zinc determination. The filter containing the CuS is removed from the funnel and the CuS washed into a 250 c.c. beaker. The small amount of CuS that cannot be removed from the filter by washing is dissolved by pouring hot dilute HNO_3 on it. Enough acid is added to the bulk of the sulphide to dissolve it. The excess of nitrous acid fumes are boiled out and the solution filtered to separate any sulphur that may have been formed. The copper is now ready to be determined by any of the methods already given.

2. Determination of Zinc. The filtrate from the CuS is boiled to expel the H_2S; and then the rest of the determination follows the method already given under zinc.

3. Free Cyanide. Determined in the same method as already given.

ANALYSIS OF NICKEL SOLUTIONS

1. Determination of Nickel with NaCN. The principle of this method depends upon converting the nickel ions to a part of a complex ion, thus removing them from the field of action. When this has been completely accomplished, the titrating NaCN begins to read with the indicator 13.4 c.c. of the nickel solution are taken; about a gram of ammonium tartrate is added to prevent subsequent precipitation of Fe should it be present. The solution is carefully made alkaline with minimum NH_4OH and the solution diluted to 100 c.c. As an indicator 5 c.c. $AgNO_3$ are added and also about 1 c.c. 2 per cent KI, which will throw down the silver as AgI. The solution is then titrated with the standard NaCN at 20 deg. C. When all Ni has combined with NaCN the precipitate will begin to be dissolved by the excess NaCN. This may be looked upon as the temporary end point. Since an excess of NaCN is usually added to dissolve AgI, this excess is taken up by running in $AgNO_3$ until a precipitate appears that is just cleared up by a drop of NaCN. The number of c.c. of $AgNO_3$ and NaCN used are noted.

As, for example:

24.75 c.c. NaCN used in titration.
8.35 c.c. $AgNO_3$ used in titration.

16.40 c.c. NaCN used to combine with Ni.
1.0 c.c. NaCN = 0.1 decigram Ni.
16.40 c.c. NaCN = 1.64 decigram Ni = 1.64 ozs. Avoid. Ni per gallon.

2. Free Acid. Due to the fact that various acids may be present in nickel solutions, it is impossible to make up a standard solution that will give accurate results. Therefore only the following qualitative methods are given:

Litmus—Blue Litmus turns red; this shows that free acid is present, but leaves one ignorant as to what acid is present, or what its derivation may be. Red litmus turns blue—indicates that the solution has turned alkaline.

Red Congo is not changed by H_3BO_3, but is turned blue by free H_2SO_4. If this happens, it is an indication that free H_2SO_4 is present besides H_3BO_3.

Tropaeolin—If the bath should contain citric acid, the above method is again insufficient, as citric acid colors red congo blue the same as does H_2SO_4. Tropaeolin paper is not altered by citric acid, but it turned violet by free H_2SO_4.

3. Chlorine Content Determined by $AgNO_3$. Since through the aid of chlorides one is enabled to assist in the solubility of the anodes and thereby keep the Ni content constant, it is a good plan when once the chlorine has been determined that is necessary to aid the solubility of the anodes, it be kept constant. To 13.4 c.c. of the solution add $NaCO_3$ solution, if acid; if neutral or alkaline, make only slightly alkaline. Add 2 or 3 drops of a 10 per cent. K_2CrO_4 solution and dilute to 100 c.c. Titrate with the standard $AgNO_3$ solution. AgCL is precipitated and the end point is indicated by the appearance of a faint red coloration, showing the formation of silver chromate—Ag_2CrO_4.

ANALYSIS OF GOLD SOLUTIONS

1. Determination of Gold by Iodine Method. 12.2 c.c. of the solution are boiled wtih HCI until all the cyanides are decomposed. KI is now added until Aul first precipitated is redissolved. A clear starch solution is added which gives the solution a deep blue color. This color is removed by the addition of the standard $Na_2S_2O_3$ solution. The standard I_2 solution is now run in until the solution takes a faint rose color which indicates the end point.

For example:

0.99 c.c. $Na_2S_2O_3$ used in titration.
0.24 c.c. I_2 used in titration.

0.75 c.c. $Na_2S_2O_3$ actually used in titration.
1.00 c.c. $Na_2S_2O_3$ = 1 dec. Au.
0.75 c.c. $Na_2S_2O_3$ = 0.75 dec. Au. = 0.075 ozs. Troy Au. per gallon.

2. Free Cyanide. Free cyanide is determined by the usual method.

ANALYSIS OF LEAD SOLUTIONS

1. Determination of Pb with $Na_2S_2O_3 5H_2O$. (a) Cyanide and other alkaline solutions. To 13.4 c.c. of the solution add dilute H_2SO_4 to precipitate the lead as lead sulphate ($PbSO_4$) and allow to cool thoroughly. (b) Acetate, fluoborate, fluosilicate solutions. To 13.4 c.c. of the solution add H_2SO_4 to precipitate the $PbSO_4$ and allow to cool thoroughly. The lead sulphate in either case, after washing, is dissolved in:

$HC_2H_3O_2$ (99 per cent.)	30 c.c.
NH_4OH (conc.)	15 c.c.
H_2O	60 c.c.

Boil the subsequent solution obtained; filter, and wash filter with boiling water. The solution containing the Pb is neutralized to a heavy precipitate with Na_2CO_3, and then cleared with $HC_2H_3O_2$. Add $K_2Cr_2O_7$ to completely precipitate all lead as $PbCrO_4$. Boil precipitate until it becomes orange colored and readily settles out. Decant the clear supernatant liquid through a filter and wash $PbCrO_4$ in the beaker until it is free of chromates. To beaker containing the precipitate add 15-20 c.c. of 10 per cent. KI. Dissolve the residue on the filter with warm HCl (1:1) allowing the drippings to fall in the beaker containing the precipitate and the KI. Wash the filter carefully with hot water to remove all the chromic acid, allowing the washings to enter beaker containing the lead. Now pour the mixture into a six (6) inch evaporating dish or place the beaker on a white surface and add the standard "hypo" solution until the mixture in the dish is of a yellowish green color and then add starch paste and titrate till the color is discharged.

ANALYSIS OF BLACK NICKEL SULPHO-CYANATE SOLUTIONS

1. Determinations of Ni with NaCN. 13.4 c.c. of the solution are measured out and diluted to 25 c.c. Two (2) grams of ammonium tartrate are added to prevent any zinc or iron from interfering with the accuracy of the results. The solution is made slightly alkaline with NH_4OH, and the solution diluted to 100 c.c. Add 5 c.c. of standard $AgNO_3$ and about 1 c.c. of 2 per cent. KI to act as indicator. The solution is now ready to be titrated at 20 deg. C. with the standard NaCN solution in the same manner as the regular Nickel solution.

2. Determination of Zn with $K_4Fe(CN)_6 3H_2O$. 13.4 c.c. of the solution are taken and diluted to 25 c.c. with water. Then NH_4OH is added until alkaline. If the solution is already alkaline no ammonia need be added. Now it is necessary to remove the nickel. Boil the solution and acidify with acetic acid, and then add 1 per cent alcoholic solution of dimethylgloxime till precipitation is complete. Gently heat the solution, making sure that the solution contains a slight excess of acetic acid. Allow the solution to stand for one and one-half hours and then filter. Wash the precipitate, collecting the washings with the filtrate, which contains the zinc. The filtrate is neutralized wtih NH_4OH to produce a slight precipitate; conc. HCL is added to just dissolve the precipitate and 2 c.c. in excess. Dilute to 100 c.c. and titrate with the standard $K_4Fe(CN)_6.3H_2O$ in the same manner as was done with zinc solutions.

3. Determination of Sulpho-Cyanate with $AgNO_3$. This method depends upon the same principles as that of the determination of Ag with NaCNS, only here the process is reversed. Take 13.4 c.c. of the solution, make slightly acid with dilute H_2SO_4 and dilute to 100 c.c. The nickel need not be removed, as the solution is so slightly green that the reaction is not interfered with. Add two drops of ferric alum as indicator, which turns the solution brown colored; titrate with standard $AgNO_3$ solution until the brown color disappears. The reading will give the amount of CNS. To convert to NaCNS multiply by 1.396; KCNS by 1.673; to NH_4CNS multiply by 1.311.

ANALYSIS OF ARSENIC SOLUTIONS

1. Determination of Arsenous Oxide (As_2O_3) in Arsenic Black Solutions. The following method of analysis is to be applied to only those solutions that consists of arsenic dissolved in cyanide. The determination of arsenous oxide by this method depends upon the fact that when arsenous acid is brought in contact with iodine in the presence of water and free alkli, it is converted to arsenic acid, and the blue color does not appear until all the arsenous acid has been converted to arsenic acid; 13.4 c.c. of the solution are treated with dilute HCl to destroy the cyanide. Then concentrate the solution to about 15 c.c. To dissolve any precipitated arsenic, concentrated HCl is added and the solution is gently heated to bring about solution. Add 2 grams of KI and boil until all iodine vapors are dissipated. The arsenic acid (H_3AsO_4) reduced to arsenous acid (H_3AsO_3). Add 5 c.c. of glycerine and allow to cool; Na_2CO_3 solution is added to neutrality, then 20 c.c. conc. sodium bicarbonate solution ($NaHCO_3$); dilute to 100 c.c. and a little starch solution and then titrate until a blue color appears with the standard iodine solution.

ANALYSIS OF CYANIDE BLACK NICKEL SOLUTIONS

Take 13.4 c.c. of the solution and dilute to 25 c.c.; add concentrated HCL to precipitate and decompose cyanides. Heating will be necessary to bring about solution and also occasional additions of acid. After solution is complete, pass in H_2S as long as precipitation occurs. Filter; precipitate contains sulphides of arsenic and copper. Wash precipitate and collect washings with filtrate and set filtrate aside.

1. Determination of Arsenous Oxide. The precipitate on the paper is thoroughly digested with warm NaOH, which dissolves out the arsenic; filter and wash precipitate, collecting the washings with the main arsenic filtrate. Acidify solution with HCL and then proceed with the arsenic determination as was done under Arsenic Solutions.

Note: Arsenic in brass solutions may be determined by taking 13.4 c.c. of the solution and following manipulations to this point.

2. Determination of Copper. Dissolve the precipitate that remained after dissolving out the arsenic precipitate with warm HNO_3 and wash filter out well. Boil to expel nitrous acid fumes and then proceed to determine the copper in the regular manner explained under Copper Solutions.

3. Determination of Nickel. The solution that remained after the precipitation with H_2S is boiled to expel the gas and then the nickel is determined as explained under Black Nickel Sulpho-Cyanate Solutions, and after that has been determined the same solution is used to determine the zinc.

4. Determination of Zinc. The solution in which the nickel has been determined is concentrated to 25 c.c.; HCL is added to decompose and bring into solution the cyanides. NH_4OH is added to make the solution alkaline, and then the nickel is removed as explained under Black Nickel Sulpho-Cyanate Solutions, and the zinc determined in the usual manner.

ELECTRICAL AND ELECTRO-CHEMICAL

Finding the weight of metal deposited or liberated by a given current in a given time.

1. $W = A \times I \times T$

W = weight in grams or ounces.
A = quantity liberated per ampere hour in grams or ounces.
I = current strength in amperes.
T = time in hours.

2. $W = E.C.E. \times I \times t$

W = weight in grams.
E.C.E. = electrochemical equivalent.
t = time in seconds.

To convert to ounces Avoid, or Troy multiply by 0.03527 or 0.03215 respectively.

Power required to deposit a given weight in a given time.

$$P = \frac{W \times E}{A \times T}$$

P = power in watts.
E = E.M.F. in volts.
W = weight in grams.
A = quantity liberated in one ampere-hour.

E.M.F. of a chemical reaction—decomposition voltage.

$$e = \frac{H}{23000}$$

e = electromotive force of the cell under investigation.
H = heat of formation expressed in calories per the chemical equivalent in grams.

PRACTICAL UNITS

Ampere = Unit of current. Denoted by I. It is the current strength that is required to deposit 0.001118 grams of silver per second.

Ohm = Unit of resistance. Denoted by R. It is the resistance offered by a column of mercury of uniform cross section, 106.3 cm. long and 14.4521 grams in mass at 0^0C.

Volt = Unit of electromotive force. Denoted by E. It is the E.M.F. which when steadily applied to a conductor of one ohm resistance, will produce a current of one ampere.

Coulomb = Unit of quantity. Denoted by Q. It is the quantity of electricity which one ampere conveys in one second.

Watt = Unit of power. It is the power expended by one ampere flowing under a pressure of one volt.

FARADAY'S LAWS

The first of these laws defines the relation between the weight of the products of electrolysis and the quantity of electricity passing through the electrolyte. There are always two simultaneous reactions; the anodic with its products appearing at the anode, and the cathedic with its products appearing at the cathode. If a definite reaction is regarded as taking place, the magnitude of the reaction depends only on the quantity of electricity that passes. This quantity is measured in coulembs or ampere-seconds. This means that the quantities of substances deposited or liberated at the anode or cathode depends only upon the current in amperes and the time. For example, in the copper sulphate solution, the same quantity of copper is deposited by 20 amperes in one second, as in two seconds by 10 amperes or in 4 seconds by 5 amperes. Also, the amount of copper deposited by 20 amperes in 4 seconds is 4 times as great as that deposited by 20 amperes in 1 second. Therefore, the quantity depends only upon the product of the current and the time, and is in no way affected by the voltage, size of the electrodes, or the temperature. This should be well understood, and is true provided only a particular reaction is taking place. Should the voltage be raised, so that new reactions are started, new conditions are introduced.

The second law expresses the numerical relation between the quantity of electricity and the quantity of material changed. It can easily be expressed in the case where the chemical reactions occurring at the anode or cathode are the liberation of a gas or the deposition of a metal. In these cases, the law states that the quantity of gas liberated, or metal deposited is proportional to the equivalent-weight of the liberated substances, and that 96,540 coulembs will liberate 1 gram-equivalent of the material. The equivalent-weight (or gram-equivalent) is defined as the atomic weight divided by the valency. That is to say, that 96,540 coulembs will liberate 107.88 grams of silver; also this quantity of electricity will liberate from the copper sulphate solution only 31.8 grams of copper, but from a cuprous chloride solution 63.6 grams.

The electro-chemical equivalent of an element is the quantity of it liberated per ampere-second.

An ampere-hour is 3600 ampere-seconds (coulombs); 60 amperes for 60 seconds = 1 ampere-hour; 1 ampere for 3600 seconds (1 hour) = 1 ampere-hour.

PHYSICAL AND ELECTROCHEMICAL CONSTANTS OF THE COMMON ELEMENTS

Element	Symbol	Atomic Weight	Molecular Weight	Valence	Equivalent Weight	Specific Gravity	Elctrical Conductivity at 0° C	Grams liberated per ampere second E. C. E.	Grams liberated ampere hour 3600 amperes	Ounces liberated per ampere hour
Aluminum	Al	27.1	......	3	9.03	2.56	324000	0.0000938	0.3377	0.0118
Antimony	Sb	120.2	......	3	40.0	6.71	27100	0.0004151	1.494	0.0528
Arsenic	As	74.96	299.84	3	24.986	5.73	28600	0.0002600	0.936	0.0330
Bismuth	Bi	208.	......	3	69.3	9.75	9260	0.0007194	2.590	0.0813
Bromine	Br	79.92	159.84	1	79.92	3.15	......	0.0008303	2.989	......
Cadmium	Cd	112.4	......	2	56.2	8.66	146000	0.0005814	2.093	0.0738
Chlorine	Cl	35.46	70.92	1	35.46	2.49	......	0.0003682	1.326	0.0478
Chromium	Cr	52.0	......	2	26.0	5.00	......	0.0002728	0.982	......
Chromium	Cr	52.0	......	3	17.33	5.00	......	0.0001819	0.6548	......
Cobalt	Co	58.97	......	2	29.485	8.65	83200	0.0003050	1.098	0.0387
Cobalt	Co	58.97	......	3	19.656	8.65	83200	0.0002033	0.732	0.0258
Copper	Cu	63.57	......	1	63.57	8.96	640600	0.0006578*	2.368	0.0831
Copper	Cu	63.57	......	2	31.785	8.96	640600	0.0003289†	1.184	0.0416
Fluorine	F	19.00	38.00	1	19.00	1.31	......	0.0001989	0.7159	......

*–ic state †–ous state

PHYSICAL AND ELECTROCHEMICAL CONSTANTS OF THE COMMON ELEMENTS—Concluded

Element	Sym-bol	Atomic Weight	Molecular Weight	Val-ence	Equivalent Weight	Specific Gravity	Electrical Conductivity at 0° C	Grams liberated per ampere sccond E. C. E.	Grams liberated ampere hour 3600 amperes	Ounces liberated per ampere hour
Gold	Au	197.2	....	3	65.73	19.26	468000	0.0006827	2.458	0.0773 Troy
Hydrogen	H	1.008	2.016	1	1.008	0.0695	......	0.000010411	0.03748	0.0023
Iodine	I	126.92	253.84	1	126.92	4.95	......	0.0013174	4.738	......
Iron	Fe	55.84	....	2	27.92	7.86	131000	0.0002909†	1.047	0.0365
Iron	Fe	55.84	....	3	18.613	7.86	131000	0.0001940*	0.6984	0.0243
Lead	Pb	207.10	....	2	103.55	11.37	50400	0.0010744	3.868	0.1354
Nickel	Ni	58.68	....	2	29.34	8.70	144200	0.0003050	1.098	0.0384
Nickel	Ni	58.68	....	3	19.56	8.70	144200	0.0002033	0.732	0.0258
Oxygen	O	16.00	32.00	2	8.00	1.105	......	0.00008308	0.299	......
Platinum	Pt	195.2	....	4	48.8	21.50	91200	0.0005078	1.1828	0.0581 Troy
Potassium	K	39.10	....	1	39.10	9.87	150500	0.0004064	1.463	......
Silver	Ag	107.88	....	1	107.88	10.53	681200	0.0011183	4.026	0.1285 Troy
Sodium	Na	23.00	....	1	23.00	0.98	211000	0.0002394	0.8620	......
Tin	Sn	118.20	....	2	59.05	7.31	77600	0.0006184†	2.226	0.0778
Zinc	Zn	65.37	65.37	2	32.685	7.14	186000	0.0003389	1.220	0.0427

*–ic state †–ous state

WEIGHT AND THICKNESS OF METALS DISSOLVED OR DEPOSITED BY 10 AMPERES PER SQ. FOOT

METAL	GRAMS PER 10 AMPERE-HOURS	OUNCES PER 10 AMPERE-HOURS	INCH THICKNESS PER HOURS 10 SQ. FOOT
Copper—cyanide	23.64	0.831	0.001122 = 1/890 approx.
Copper—sulphate	11.82	0.416	0.000561 = 1/1780 "
Gold—chloride	24.5	0.773 Troy	0.000535 = 1/8070 "
Gold—cyanide	73.5	2.329 Troy	0.001605 = 1/623 "
Iron	10.4	0.365	0.000564 = 1/1770 "
Lead	38.5	1,354	0.001430 = 1/700 "
Nickel	10.85	0.384	0.000552 = 1/1815 "
Silver	40.25	1.285 Troy	0.001610 = 1/621 "
Tin—stannic	10.95	0.389	0.000625 = 1/1600 "
Tin—stannous	21.9	0.778	0.001250 = 1/800 "
Zinc	12.1	0.427	0.00074 = 1/13500 "

Note:—The denomination of the fraction shows the number of hours required to obtain a deposit of 1 inch thickness.

THE GENERATOR

The generator is a machine for converting mechanical energy into electrical energy or, in other words, it generates electric current when driven by mechanical power.

THE MOTOR

An electric motor is a machine for converting electrical energy into mechanical energy or, in other words, it produces mechanical power when supplied with electrical current.

Plating generators are wound in various ways, such as shunt, compound, interpole and separate excited. Self-excited machines have a limited range. That is where the range from no load to full load is not too great.

Self-excited shunt wound generators are not practicable. The constant fluctuation in voltage with the variation of the load is not suitable for electro-plating. Such machines are built only where price is a factor.

Compound wound machines develop a constant voltage and are not influenced by variation of the load.

Interpole generator, sometimes called commutating poles, are an advantage on any generator, their object being to prevent distortion of the flux from no load to full load. This condition is mostly noticeable in generators of 500 amperes or more. The armature forces the flux out of its natural position, hence the interpoles restore them or prevent this distortion of the magnetic flux, thereby preventing sparking and arcing at the brushes.

Separate excitation with interpoles is the only satisfactory method to pursue in any generators. It means that the field is kept at a uniform strength at all loads, with no sparking at the brushes from no load to full load.

RHEOSTATS

Every generator should have a rheostat of variable resistances, which should be as much a part of the machine as the armature.

The object of the field rheostat is to reduce the voltage, the amperage remaining the same.

The tank rheostat reduces both the amperage and voltage. These should have ample carrying capacity to take care of light load and full load of the tank.

CONDUCTORS

Conductors in all cases must be large enough to carry the full current and be preferably of copper rod.

If a conductor heats up it is usually due (providing no short-circuit or overload exists) to conductor being too small in circular mil area. Heat means loss; cut down the heat loss by increasing the circular mil area.

BRUSHES

Brushes are a means of conducting the current generated in the windings of the armature to the proper terminals.

Brushes are constructed of various materials—copper leaf, copper gauze, carbon, composition of graphite and copper bronze, etc.

Copper gauze has low resistance and good conductivity if kept clean and in proper shape. Composition brushes which are finding much favor have higher resistance, hence the brush area must be larger. They are cooler in operation than woven wire and do not fray out and are self-lubricating.

Whatever brush is used the pressure must be such as to make uniform contact without excess pressure and must be properly spaced and set on neutral point.

Never change the type of brush without consulting and getting the approval of the manufacturer.