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HALE SCIENTIFIC BUILDING

JOURNAL OF ENGINEERING

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ON THE RELATION OF TECHNICAL EDUCATION AND ENGINEERING IN SWITZERLAND.

By Arnold Emch, Ph. D., Professor of Mathematics, Kantonsschule, Solothurn, Switzerland.*

Considering the fact that only a small part of Switzerland is accessible to economic and profitable agriculture, it is not surprising to find the principal energies of the country concentrated upon trade, manufacture and the tourist industry.

If the goods manufactured in the little Alpine Republic compete favorably in the world's market with those of the surrounding great powers we naturally ask for the reason which makes such results possible. The answer to this question seems even more difficult on account of the fact that Switzerland has no mineral riches to speak of and that coal and raw iron have to be imported from Germany, France and Belgium. But those acquainted with the tremendous industrial progress of the United States and Germany during the last twenty years will answer correctly that success not only in Switzerland but also in other countries is due to progressive scientific and technical education.

Science must be taught not from a purely philosophical standpoint; it must be taught in view of its ultimate applicability.

At the head of technical or engineering education in Switzerland stands the Polytechnikum at Zurich. It is a government institution, and its annual running expenses, excluding the cost of new buildings, amount to nearly $300,000. Its different schools comprise all fields of agricultural and industrial activity; it is a polytechnic in the true sense of the word. Connected with their respective departments are a number of government stations, like the federal testing laboratory, the meteorological station, the experiment stations for agriculture and forestry, etc. All depart-

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* Formerly Professor of Mathematics, University of Colorado.

ments are equipped with up-to-date laboratories. The departments of chemistry, physics, astronomy, mechanical and electrical engineering, agriculture and forestry, strength of materials, all have their own buildings, while the others are housed in the large main building.

Probably the most impressive laboratories are those of mechanical and electrical engineering. In the turbine laboratory more than half a dozen different types of full sized hydraulic and steam turbines may be studied and tested in actual operation and in connection with dynamos and electric motors. The water power is furnished by a large canal from the city water works which leads directly into the laboratory. It is hardly necessary to state that enough steam power is produced in the building for any laboratory purpose. The men at the head of these departments are Professor Prasil and Professor Stodola. One is known all over the world as an authority on hydraulic turbines, the other as a steam turbine expert. It may be well conceived that for a country without any natural coal deposits a most thorough study of the problem to produce electric power by hydraulic turbines is of the utmost importance and this may be called the keystone of prospective engineering in Switzerland.

I shall confine myself to these two departments not because the others are less important, but on account of the limitations of this paper.

Next to the Polytechnikum are the so-called "Technikor," technical schools belonging to a number of Cantons, or States. The difference between these and the Polytechnikum is that the latter requires for admission graduation from a technical college, or from the industrial division of a cantonal college. From this it is seen that instruction at the Polytechnikum starts from a high level. The purpose of the "Technikor" is to train on the line of least resistance practical engineers, architects, chemists, etc. The graduates of these institutions are expected to carry out certain detail work in engineering. Originality and ability to plan and work out difficult pieces of engineering are not primarily aimed at in these schools. Beside the higher technical schools there are a great number of special schools for agriculture, mechanics, artisans, watch makers, silk weavers, commerce, etc., which are supported jointly by the federal government, the cantonal governments and by the communities. In all these schools the rule is a general education with a subsequent intensive special training for the chosen profession or trade.

In order to demonstrate the value of technical education it is sufficient to state a few facts concerning the present status of engineering in Switzerland.

While the marvelously accurate results of the survey of the Simplon Tunnel, carried out by Professor Rosemund of Zurich, are still in the minds of engineers, the Swiss government has just closed a contract with the firm of Brown, Bovery & Co., of Baden, Switzerland, to operate electrically all trains through the Simplon from Brieg to Iselle by June 1, 1906. It is the intention of the government to operate ultimately all trains of the Swiss railway system by electricity. For this purpose a commission consisting of the technical representatives of the government, of the professors of electrical engineering and hydrography at Zurich, of the firms of Brown, Bovery & Co., the electric companies at Örlikon, Basel and Geneva, etc., was appointed to study the important question. The report of the commission is not quite ready, but enough has been given to the press to show that the problem can be solved. In fact the available hydraulic power of Switzerland exceeds one million H. P., a power which is and will be sufficient for all purposes of traffic and manufacture.

The contract with the firm of Brown, Bovery & Co. to operate the Simplon Tunnel electrically is a preliminary arrangement. Steam locomotion over a tunnel length of 13 miles, on account of the smoke, is extremely obnoxious to the passenger traffic. It was therefore very desirable to have electric locomotives, and as no other firm was able to make the necessary installations within the given short time, the contract was closed for two years, in December, 1905, with Brown and Bovery, because by means of the *three-phase system* and their already available electric locomotives they will be able to run regular trains by June 1, 1906. This contract, of course, does not mean that the *one-phase system*, as proposed by the electric company at Örlikon, is inferior to the three-phase system. Örlikon had no completed engines available and could for this reason not compete within the given short time.

Thus, the Simplon Railway, which has caused the engineers many extraordinary efforts for the solution of intricate problems, will soon be open to the world. One thing of which Switzerland may justly be proud is the fact that the leading engineers engaged in the construction and operation of the Simplon Tunnel are graduates or former students of the Polytechnic of Zurich.

From these examples we can see that under the influence of engineering the world is progressing everywhere. As in the United States of America and other enlighted countries, power and industrial progress come mainly through the channels of scientific and technical education.

TRANSMISSION AND DISTRIBUTION SYSTEM RECORDS.

By Edward P. Dillon, B. S. (E. E.), 1899.

The tendency of modern business is to systematize methods of doing work. The obvious aim of this systematic arrangement is to get the greatest results from the least amount of work, or, in other words, to so arrange each man's work that he may, with his quota of energy rightly directed and expended, cover the greatest possible field for his employers.

There is an almost unlimited variety of systems on the market today for various kinds of accounting work, for the clerical force of any kind of an establishment.

The suggestions contained in this article have, on the other hand, to do with the records that an engineer may find himself called upon to devise and compile in connection with the operation of any central station distribution or transmission system. At times it is difficult to determine to what extent a company can afford to go into detail in keeping records of its production, distribution, etc. But the engineer who desires to have a firm grip on the entire system cannot trust much to memory, and therefore must resort to load sheets, maps and such other data as he may have at hand. It is hard to conceive of a system so small that some records are not warranted.

Let us assume, for example, a system having a main generating station or stations, a transmission system and sub-stations from which radiate the distribution system feeders.

Generating Station.—The general load sheet is of prime importance. This should show a daily record of the performance of the plant, the time of cutting in and out each unit, a full record of all switching, and the record of the output of the plant in kw. for the day, including such data as the peak load, minimum load, average load, load factor, etc. Each attendant's signature should appear, showing the time of his shift. All unusual accidents should be noted. Further reports may be arranged, showing coal burned per day, water used, or a full record of adjustment of gates, etc., if a hydraulic plant.

The same ideas will hold good concerning sub-stations and distributing points. All employees should be trained to carefully note all facts pertaining to the operation of the station during their particular shift.

In addition a log book is an excellent thing in all stations in which is noted all unusual occurrences, with the time and full detail written out. Such a record is often invaluable for reference after a subject has grown cold.

Transmission Line.—This should be carefully mapped and all details noted, such as special crossings over railroads, rivers, roads, telephone or telegraph lines, deep gulches, high ridges, or any important topographical feature. All poles should be numbered, and a careful record kept of the number of poles. If the transmission lines come together at various points the map should show positions of the various wires on the poles, so that the phases may be kept correctly, in order to tie two lines together, as is often necessary. An excellent rule in checking wire of a three-phase system is to "stand under the line with back to the 'Generating' station and signify the wires as Left, Middle or Right, as they occupy the relative positions on the pole above." This scheme is valuable in bringing two sections of line together at a distance from the plant.

Distribution Lines.—If the commercial distribution lines comprise a number of circuits, it is almost necessary to have these correctly mapped. A good scheme is to assume a uniform scale and a sheet of a uniform size. Obtain a loose leaf binder to hold the sheets. The map of the circuit may then be drawn on the loose leaf sheets, taking several to a circuit if necessary. Tracing cloth is convenient to use for the maps, as the map is easily copied on a new sheet should any portion of a circuit be altered.

These maps should show the pole position of each particular feeder on the pole, the size of wire at frequent intervals, the location and number of each transformer and any other important data that may seem advisable. This appears to apply directly to primary alternating current feeders; but it may be equally well used for direct current.

Transformers.—If the system entails the use of transformers for distributing feeders, too much cannot be said of the value of an adequate transformer record. This record can be either in the form of a loose leaf ledger, or it can be devised as a card scheme. Either way has merits. The record should show a complete description of the transformer, the Company number, manufacturer's number, type, size, ratio, number of circuit on which located, number of transformer it replaces, date of installation, return,—if destroyed, its cause, in fact all matters of vital importance in the history of each particular transformer.

Then, in addition, should be shown the name, address, number of lights—whether meter or flat—of each consumer fed by the transformer. From this can be kept an accurate record of the connected load and the demand on each transformer. The consumers' record should be kept up from day to day, as connections and disconnections are made.

By this means an accurate record can be kept of the duty on each transformer, and the size of the transformers can be adjusted to the load, preventing large transformers, low all day efficiency or small transformers and heavy overload, resulting in premature ageing of cores, high core and copper losses, burnt out transformers and poor service.

Arc Systems.—If the street lighting system is series arcs, considerable economy can be effected by proper records of this portion of the system.

The arc lamps should each be given a company number and its record kept, showing the location of the lamp and the causes for which it is changed, if at all.

The colored tack scheme is an easy means of showing the course of the circuits. A map of the city stretched on a board of soft pine is necessary. Using a different color tack for each circuit, the tacks are then put in the map at the location of each arc lamp. Silk thread of the same color as the tacks for each circuit is then run in on the map, following the same route as the wire of the circuit. This scheme is very valuable in aiding the trouble shooter in locating an open circuit, as, by reference to the map, he can familiarize himself with the exact route of each circuit. It is also a great help in planning extensions and installing new lamps, and may be used to great advantage in planning changes in circuits, often affording a great saving in wire.

The use of properly constructed maps and records outlined and suggested, together with a judicious amount of field inspection and observation will enable the engineer to get a most thorough and minute grasp of his entire plant.

Each system is a problem in itself and requires specific study, and the engineer in charge must devise means to take care of the individual features. However the suggestions outlined may be of interest and help in the practical handling of central station or transmission work.

NOTES ON MODERN GEOMETRY.

S. Epsteen, Ph. D., Assistant Professor of Mathematics.

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1. The chief object of this paper is to supplement, in some particulars, the chapters on the Theory of Inversion and Coaxal Circles in Casey's text book on Modern Geometry,[*] pages 95-126.

If P is any point in the plane of a given circle whose center is the point O and whose radius is r, and if Q is taken on the ray OP so that $OP.\ OQ=r^2$, the points P and Q are said to be *inverse to each other with respect to the given circle.* Casey attributes the invention of this theory[†] to Dr. Stubbs and Dr. Ingram in 1842. As a matter of fact, papers on this subject had been published by Quetelet[‡] in 1827, and by Magnus in 1832.

2. In the first proposition the connection of the Theory of Inversion with that of Concave Mirrors in Geometrical Optics is brought out.[§]

Let C be the center of the concave spherical mirror of radius $2r$, F the principal focus, O a point on the principal axis AF, I its image point. Let $AO=r_1$, $AI=r_2$, then by the well known formula of Geometrical Optics

$$\frac{1}{r_1}+\frac{1}{r_2}=\frac{1}{r}$$ [||]

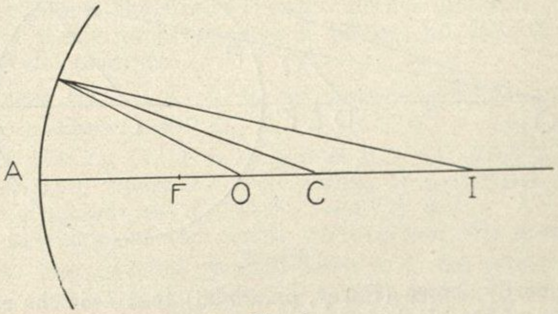

Fig 1.

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[*] Sequel to Euclid, John Casey, LL. D., F. R. S., Longman's, Green and Co., London, 1900.

[†] The Theory of Inversion has important applications in the study of induced electricity on conductors. See Clerk Maxwell's "Electricity," vol. I, chap XI.

[‡] Quetelet, Acad. de Bruxelles, vol. 4.—Magnus, Crelle's Journal für Reine und Angewandte Mathematik, vol. 5.

[§] See E. Mascot's Traité D'Optique, vol. I, p. 75, Gauthier-Villars, Paris, 1889.

[||] This formula is not strictly valid. It is approximately correct for small angles.

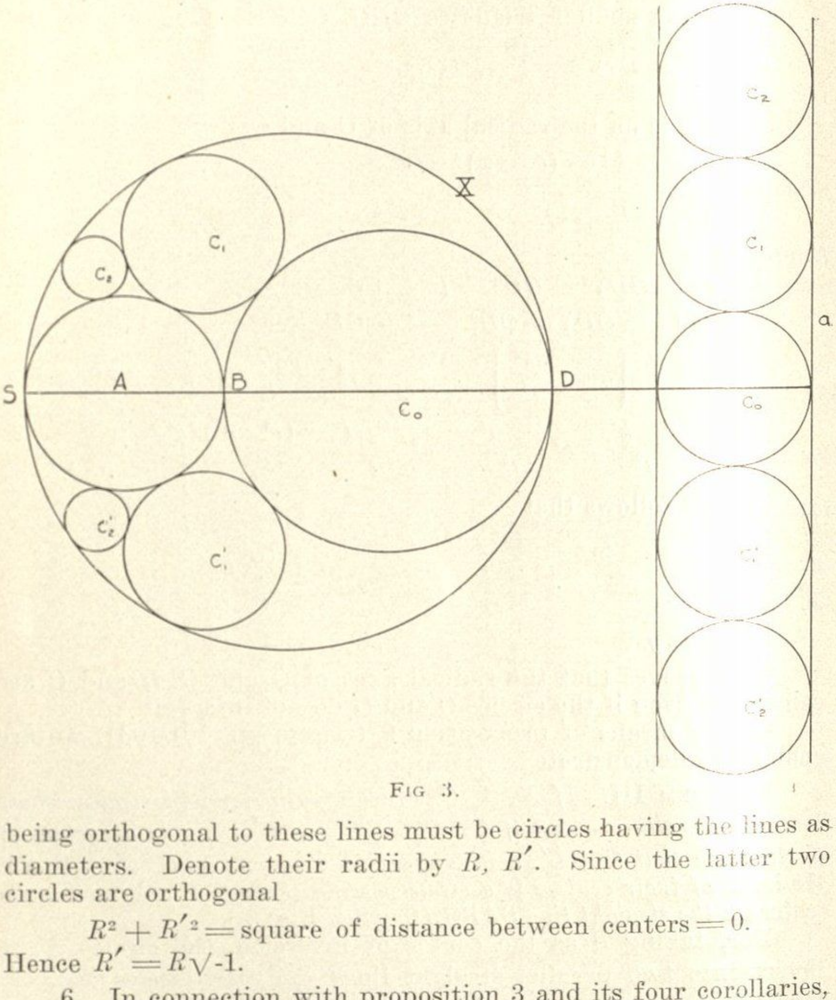

FIG 3.

being orthogonal to these lines must be circles having the lines as diameters. Denote their radii by R, R'. Since the latter two circles are orthogonal

$$R^2 + R'^2 = \text{square of distance between centers} = 0.$$

Hence $R' = R\sqrt{-1}$.

6. In connection with proposition 3 and its four corollaries, pages 115-116 (Casey), the following theorems are easily demonstrated:

THEOREM V. *Let A, B be two extremities of a diameter of any circle Y which is orthogonal to a given circle X, center O. Join A, B with O, intersecting Y again in D, E. Join DB, AE, intersecting in C. The triangle ABC will be self-polar (self-conjugate) triangle with respect to the circle X.*

By the proposition, A is the pole of BD. Since AEB is a right angle, and $OE . OB = OD . OA = r^2$, it follows that B is the pole of AE. Now the polars of A and B pass through the point C, which is therefore the pole of the line AB. Hence the triangle ABC is self-polar.

THEOREM VI. *Given a coaxal system of circles and any point A. The locus of the inverses of A with respect to the coaxal system is a circle through A which meets the system orthogonally.*

Designate the circles to the left of the radical axis by X_1, X_2, ... and those on the right of the radical axis by X'_1, X'_2 ...., the limiting points by L and L'. Let A_1, A'_1 ..... be the inverses of A with respect to X_1, X'_1..... Draw a circle through A, L, L'; it will be orthogonal to every circle of the system. Let B be the point of the circle ALL' diametrically opposite A. Join the center of X_1 to A, the point A_1 is the intersection of this line with the circle $ALBL'$. It follows in exactly the same manner that A_2, A_3 .... A'_1, A'_2 .... lie upon the same circle.

SETTING THE D-SLIDE VALVE.*

J. H. Wallace, B. S., Instructor in Engineering Drawing.

Let the problems be given to set the D-slide valve for given admissions; given cutoffs; given releases; and given compressions. By "admission," "cutoff," "release" and "compression," is meant the regulation of steam in the cylinder of the steam engine, by the valve, as those terms would imply. By "given" admission, etc., is meant the position of the piston in the cylinder corresponding to those events in the two ends of the cylinder.

In any engine the length of the crank is equal to one-half the total movement of the crosshead. The length of the connecting rod is equal to the distance between the crosshead center (when nearest the shaft) and the center of the shaft plus the length of the crank. The eccentric radius is equal to one-half the movement of the valve rod. The sum of the steam laps is equal to the distance between the cutoff edges on the valve minus the distance between the cutoff edges on the valve seat. In other words the sum of the steam laps is equal to the movement of the valve from position of cutoff for one end to position of admission for the other end. The sum of the exhaust laps is equal to the distance between the exhaust edges on the valve seat minus the distance between the exhaust edges on the valve. The sum of the head end steam and exhaust laps is equal to the distance between the head end cutoff and exhaust edges on the valve minus the width of the head end port. All these distances may be readily measured.

In a given engine the length of the crank is 6 in.; the length of the connecting rod 30 in.; the eccentric radius $1\frac{1}{8}$ in.; the sum of the steam laps 1 in.; the sum of the exhaust laps $\frac{1}{2}$ in.; the sum of head end steam and exhaust laps $\frac{15}{16}$ in.

Problem 1. To set the valve gear for cutoff at $\frac{2}{3}$ stroke, both ends of cylinder.

Necessary data: length of crank, length of connecting rod, eccentric radius, and sum of steam laps.

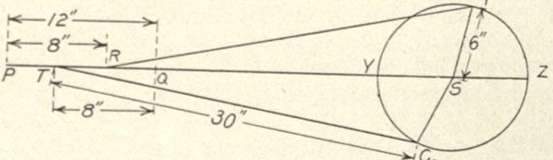

Fig 1

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* Copyright, 1906, by J. H. Wallace.

In Fig. 1, let S be the center of the shaft, PQ the movement of the crosshead center or any part of the crosshead or piston, RC_1, and TC_2, the length of the connecting rod, R and T the positions of the piston for cutoff head (P) end and crank (Q) end respectively.

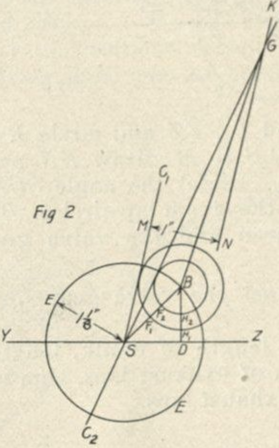
Fig 2

In Fig. 2, the line of stroke YZ and the positions of the crank C_1S and C_2S are reproduced from Fig. 1. SE is the eccentric radius. Produce C_2S to L and draw KN parallel to C_1S so that MN, the distance between C_1S and KN is 1 in., the sum of the steam laps. Bisect the angle NGS and find B the intersection of this bisector with the eccentric circle E. Then B is the center of the steam lap circles of the Bilgram Diagram.* The steam lap circles can be drawn tangent to the crank positions C_1S and C_2SL. The port opening SF_1 and the lead DH_1 can be measured for setting the valve gear.

To set the valve gear, place the eccentric center, by guess, on dead point away from cylinder and regulate the length of the valve rod for head end port opening SF_1; then place engine on head end dead point, accurately, (crank at Y) and shift eccentric on shaft to open the port equal to the lead DH_1. As a check on the setting, see if the values of port opening SF_2 and lead DH_2 are obtained in the crank end of cylinder.

Problem 2. To set the valve gear for admissions head end crank position 10° and crank end crank position 20°.

Necessary data: positions of crank, eccentric radius, sum of steam laps.

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* For a discussion of the Bilgram Diagram, see "Elements of Steam Engineering," by Spangler, Greene, Marshall, page 169; "Valve Gears," by Halsey, etc.

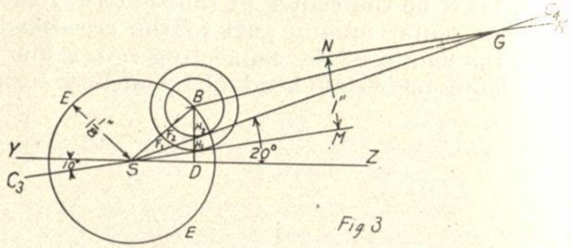

Fig 3

In Fig. 3, C_3 and C_4, YZ and circle E are the basis of proceedure. Produce C_3S to M; draw KN parallel to SC_3 so that MN is equal to 1 in.. Bisect the angle SGN and locate B as in problem 1, and draw the steam lap circles. The port openings and leads can be measured and the valve gear set as previously outlined.

Problem 3. To set the valve gear for compressions at ⅚ stroke.

Necessary data: length of crank, length of connecting rod, eccentric radius, sum of exhaust laps, sum of steam laps, sum of head end steam and exhaust laps.

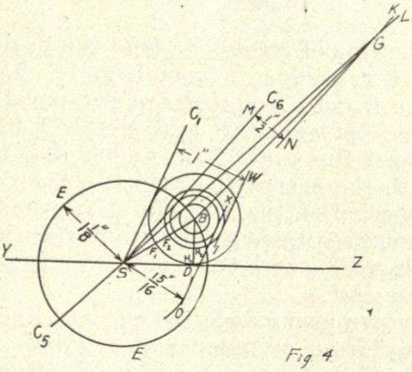

Fig 4

Proceed as outlined in Fig. 1 to get the crank positions C_5 and C_6, Fig. 4. With the positions thus obtained, produce C_5S to L; draw KN parallel to SC_6 so that MN is equal to ½ in.; bisect the angle SGN and locate B as in the preceding problems. Draw the exhaust lap circles, with B as center, tangent to C_6S and C_5SL. With S as center, and $\frac{15}{16}$ in. as radius, describe an arc as shown. Draw OX tangent to the arc and the head end exhaust lap circle as shown. Through S draw C_1S parallel to OX. C_1S is the position of the crank for the head end cutoff. With B as center draw a circle tangent to C_1S. This is the head end steam lap circle. Draw WI parallel to C_1S at a distance of 1 in., the sum of the steam laps, and draw a circle with B as center tangent to *WI*. This is the crank end steam lap circle. The values of port openings and leads can now be found as in previous problems, and the valve gear set accordingly. Note that the figure shows a head end lead of almost zero value which is purely accidental.

Problem 4. To set the valve gear for positions of crank, head end 20° and crank end 25°.

Necessary data: crank positions, eccentric radius, sum of exhaust laps, sum of steam laps, sum of head end steam and exhaust laps.

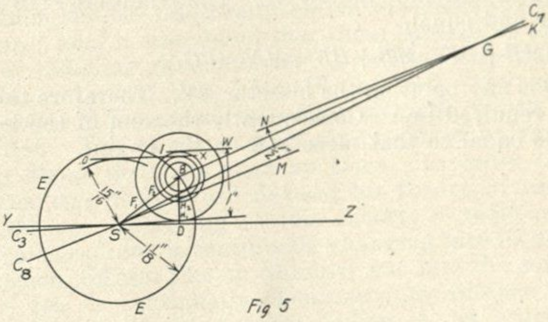

Fig 5

In Fig. 5, C_7S and C_8SM are the positions for head end and crank end release respectively. Draw *KN* parallel to *SM* so that the distance *MN* is ½ in.; bisect the angle *NGS*; find *B*, and draw circles tangent to SC_7 and *SM*. These are the exhaust lap circles. Describe an arc as shown with *S* as center and radius $\frac{15}{16}$ in. Draw *OX* tangent to this arc and the head end exhaust lap circle. A line C_3S drawn parallel to *OX* through *S* is the position of the crank for head end admission. Draw *WI* parallel to C_3S at a distance of 1 in., and with *B* as center draw circles tangent to C_3S and *WI*. These are the head end and crank end steam lap circles respectively. The values of port openings and leads can readily be measured for setting the valve gear.

It will be observed that when one method for setting the valve gear is followed, the valve gear cannot be set to satisfy the other conditions at the same time. However each method will enable a rational consideration of the regulation of the steam.

Fig. 6 is drawn to illustrate the theorem of Geometry, which is the basis for locating the point *B* in Figs. 2, 3, 4 and 5.

Given to find a line such that any point in that line shall have the sum of its perpendicular distances to two given intersecting lines, equal to a given length.

Let *SC* and *SL* be the two intersecting lines; *PQ* the given length. Draw *NK* parallel to *SC* at a distance *MN* equal to *PQ*. Let *G* mark the intersection of *SL* and *NK*, *GV* bisect the angle *SGN*, and *B* be any point on the bisector. Let *MN* pass through *B*

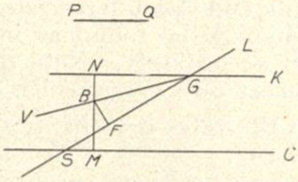

Fig. 6.

and draw BF perpendicular to SL. The triangles FGB and NGB are similar and equal.

Then $MB+BF=MB+BN=MN=PQ$.

But B is any point on the bisector GV. Therefore the bisector GV is the required line. Consequently the sum of the laps in the solutions is equal to that measured on the engine.

THE EFFECT OF HEAT ON THE INDUCED ACTIVITY OF RADIUM.

By William Duane, Ph. D., Professor of Physics.

1. Soon after the discovery of radio-activity by Becquerel, and of radium and the other radio-active substances by the Curies and Debierne, etc., it was found that these substances possess the property of inducing radio-activity on bodies in their neighborhood. Shortly after this, also, Rutherford discovered that thorium produced from itself a radio-active gas, which he called an emanation. The corresponding gas produced by radium was discovered about the same time by Dorn. In order to explain these phenomena, Rutherford devised his theory of radio-active transformations. According to this theory, a radio-active substance, such as radium, is continually changing into its emanation. The emanation diffuses like an ordinary gas into the surrounding space. It, too, is continually changing into another substance which deposits itself upon solid bodies in its neighborhood. Further experiments have shown that this deposited substance is also undergoing transformations. In fact, there is a series of substances formed, one after the other, to which the names have been given: Radium A, Radium B, Radium C, etc. These substances apparently are solid at ordinary temperatures.

There is a great deal of experimental evidence in favor of the theory of radio-active transformations. Among the most important experiments bearing on the subject are those in which it is shown that these substances have the properties of material bodies, for example,— that they can be condensed, volatilized, electrolized, etc. It is with the volatilization of the radium products that the present article has to do.

2. The volatilization of induced radio-activity has been investigated by Miss Gates, von Lerch, Curie and Danne, Miss Slater, and Bronson. These investigators have found that the various substances producing the induced activity are volatilized to varying amounts, and have reached many important conclusions in regard to the radio-active changes. The present article has to do with the volatilization of Radium A, B and C.

3. Before describing in detail the experiments, I shall state briefly the general principles by which the radio-active substances are detected and measured. A radio-active substance emits rays, which have, among others, the following properties: (a) they effect a photographic plate in somewhat the same way as light does, making it possible to take radio photographs; (b) the rays

illuminate a phosphorescent screen, as X-rays do; (c) some of the rays carry electric charges with them; (d) if the rays pass through a gas they ionize it, *i. e.*, they split up the molecules of the gas into ions, which are atoms or groups of atoms charged with either positive or negative electricity. Any one of these characteristics may be used as the basis of a method for studying radioactivity. For most purposes the most accurate experiments are made by using the ionizing properties of the rays. If an electrically charged body is surrounded by ionized gas, the ions are moved through the gas, under the action of the forces of attraction and repulsion between their charges and that of the charged body. The ions, having a charge similar to that of the charged body, are repelled from it, and those oppositely charged are attracted toward it, the latter moving up to the body tend to neutralize the original charge. The rate at which the body loses

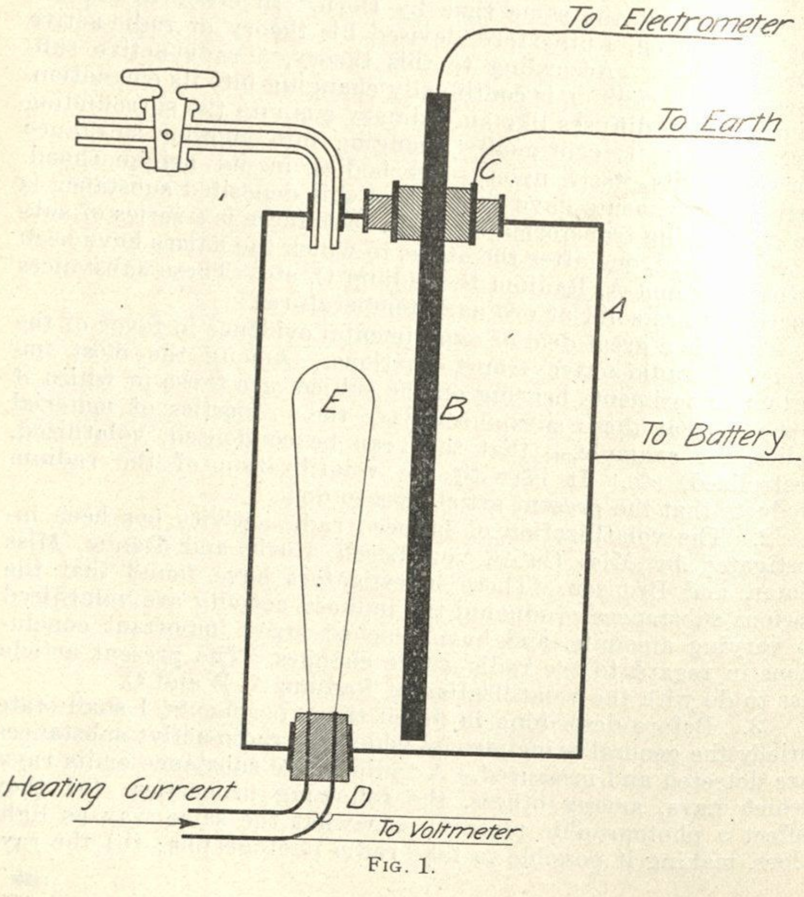

FIG. 1.

its charge is proportional to the number of ions produced per second in the gas, and the rate of production of the ions is proportional to the quantity of the radio-active substances present.

4. In the experiments described in this article, the apparatus was arranged as follows: A cylindrical metal vessel (A, Figure 1), containing about two litres of air, was connected to one pole of a battery, the other pole of which was connected to the earth. A metal rod B was fastened along the axis of the cylinder and insulated from it. C in the figure represents a ring of metal insulated both from the electrode B and the vessel A. This ring was connected to earth and prevented a leak of electricity from the vessel to the electrode through the insulation. Under these conditions, if electricity passed from the vessel to the electrode, it must have passed through the air. The electrode B was connected to an electrometer, by means of which the rate of accumulation of the electricity on it was measured. When a radio-active substance was placed within the cylinder, its rays produced ions in the air, and these ions moved toward or away from the electrode, under the action of the electric field, charging the electrode up, and the rate at which the charge accumulated was a measure of the amount of the radio-active substance present.

In order to study the amount of induced activity volatilized at a given temperature, the active substance was deposited on a wire E. The wire was then inserted inside of the cylinder, as represented in the figure, and a current of electricity sent through it by means of the heavy copper wires D, which passed through a cork. The current heated the wire E to a temperature that could be estimated by measuring its resistance. The high temperature of the wire volatilized a portion of the induced activity which was deposited on the cold surfaces of the cylinder and electrode. After the heating, the wire E was removed and the rate of flow of electricity to the electrode measured. This rate of flow gave an estimate of the amount of induced activity volatilized during the heating.

5. More accurately stated, the method of procedure in the experiments was as follows: Some radium emanation was blown into a second metal vessel, into which the cork carrying the wire E was inserted. The metal vessel was connected to the positive pole of a battery, and the wires D to the negative pole. Under these circumstances, much more of the induced activity collects on the wire than would collect if it were not charged, for it has been found that the induced activity is attracted toward a negative charge of electricity. The wire E was left in the emanation vessel for thirty minutes, after which it was removed and quickly inserted in the testing vessel A. It was then heated by the heating current for thirty seconds. After this it was taken out of the testing vessel and a current of air blown through the vessel to remove any emanation that may have been carried over on the

wire from the emanation vessel to the testing vessel. About one minute after the heating process stopped, the first measurement of the rate of flow of electricity to the electrode was made. This measurement gave an estimate of the induced activity volatilized. The wire E was then inserted again in the testing vessel, connected metallically to its sides, and another measurement of the flow of electricity to the electrode made. This measurement gave an estimate of the total quantity of activity originally on the wire, that is, the part volatilized plus the part that was not volatilized. The wire E was then removed and another measurement taken, and so on, alternately, one measurement being taken each minute at first and less frequently afterward, the whole series of measurements lasting one hour. In this way two series of values were obtained, one giving the decay of the total activity, and the other the decay of the volatilized part of the activity.

The temperature of the wire during the heating was estimated by measuring the heating current and the electromotive force between the two wires D, the ratio of the latter to the former being its resistance. The variation of the resistance with the temperature of the wire was determined in a separate experiment, up to a temperature of 390°. For temperatures above this, Calendar's formula for the change of resistance with the temperature was used. This formula agreed very well with the experiments up to the temperature of 390°. Nevertheless the estimate of the high temperatures can not be regarded as more than rough approximations.

6. The curves in figure 2 represent the data obtained, the abscissas being the times in minutes and the ordinates, the currents, in arbitrary units, flowing toward the electrode. The highest curve represents the decay of the total activity deposited upon the wire, and the others the decay of the activity volatilized during thirty seconds heating, at the temperatures marked above them. The curves in figure 3 represent the decay of volatilized activity when the temperature of heating was less than 400°. In the experiments represented by all of these curves the wire E was of platinum.

7. Before discussing the curves in detail, it will be necessary to consider briefly the form of decay curve obtained under different conditions. In the first place, if a wire is made active by the deposit of a single radio-active substance, the decay curve is exponential. If, however, two or more radio-active substances are present initially on the wire, the decay curve has quite a different form. It has been found that Radium A and Radium C are radio-active, but Radium B is not radio-active, so that, if a quantity of Radium B alone were deposited upon a wire, at first there would be no radio-activity. The radio-activity, however, would increase as fast as Radium B changed into Radium C and would reach a maximum, after which it would decrease again as the two sub-

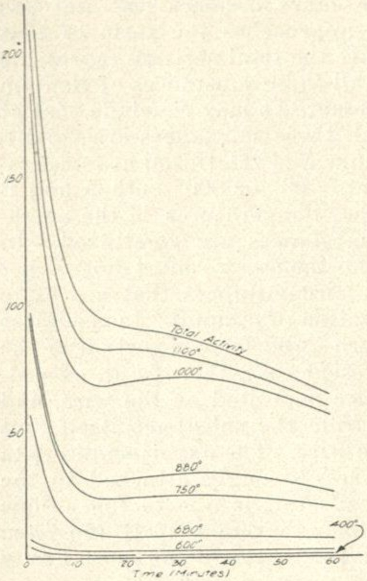

FIG. 2.

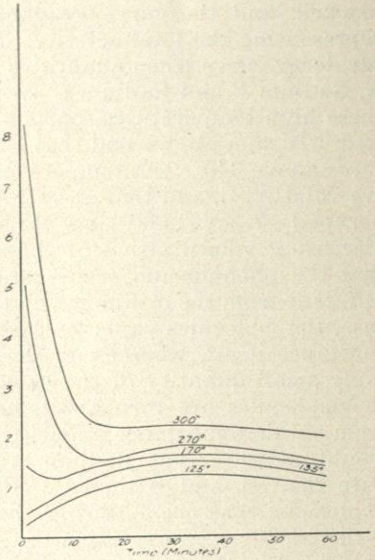

FIG. 3.

stances gradually disappeared. It has been found, experimentally, that in the case of Radium B and C, the maximum occurs at the end of about thirty-seven minutes. The lower curves in figure 3 are examples of this kind of decay curve. If, now, there is present initially on the wire a quantity of Radium A alone, the decay curve falls very rapidly at first, because Radium A changes rapidly into Radium B. At the end of fifteen minutes the curve remains about horizontal, and ten or fifteen minutes later begins to fall again. This is the form of curve obtained experimentally after a very short exposure to the radium emanation, in which case the quantity of Radium A deposited on the wire predominates.

8. To return now to the interpretation of the curves. It will be noticed in the curves in figure 3 that if the heating temperature is below 400°, the amount of activity volatilized is only a fraction of one per cent. of the total activity. As the heating temperature is increased, however, the initial part of the curve begins to shoot up, indicating the volatilization of a large amount of Radium A. Below 200° it will be noticed that the decay curves have a decided maximum at about thirty-five minutes, indicating a preponderance of Radium B volatilized. We will return to a discussion of these curves later. The curves corresponding to temperatures of 700° or 800° have both the initial drop and the maximum strongly marked. We may conclude from this that, at these temperatures, both Radium A and Radium B are volatilized. At still higher

temperatures the maximum in the curve becomes less and less marked, and the curve gradually approaches the form of that representing the total activity. Since the total activity represents the decay curve when quantities of all three substances of Radium A, Radium B and Radium C are present, we may conclude that at these high temperatures, parts of all three substances are volatilized. To sum up, we find that Radium A is volatilized at temperatures above 340°. At temperatures of 700° or 800° both A and B are volatilized, and that at still higher temperatures, in the neighborhood of say 1,000°, all three substances are volatilized. In discussing volatilization of these substances, we must not forget that the phenomenon occurs under circumstances that are quite different from the ordinary volatilization of a liquid. In the latter case, the molecules vaporized are torn away from a portion of the substance itself, whereas, in the present case, there is an exceedingly small quantity of the substance deposited on the wire, and the molecules are torn away, not from the substance itself, but from another substance, namely, the wire. The experimental data would indicate that Radium A is less strongly attached to the wire than B, and B than C. Perhaps this is due to the atomic explosions that occur during the changes from A to B and from B to C, after each explosion the surviving atom being more firmly imbedded in the surface of the wire.

The curves for temperatures below 200°, represented in figure 3, are apparent exceptions to the above rule, and the volatilization at these temperatures, it would seem, must have a different cause. If instead of heating the wire immediately after it is taken out of the emanation, it is allowed to remain for fifteen minutes and then placed in the testing vessel and heated, no such curves as these are obtained, provided the temperature is not raised above 200°. There is an exceedingly small quantity of induced activity volatilized under these circumstances, which so far as could be judged, decayed exponetially to zero. Now, after fifteen minutes Radium A has practically disappeared, and it would seem that the presence of Radium A was required in order that B should be volatilized at these low temperatures. Perhaps the explosion when A changes into B is responsible for the volatilization of B under these circumstances, and the small amount of activity volatilized after waiting fifteen minutes may be a quantity of C expelled by the explosion when B changes into C.

9. The curves drawn in figures 4 and 5 represent the decay of activity originally deposited upon wires of copper and iron instead of platinum. The same general characteristics are present in these curves as in those for wires of platinum, and apparently the volatilizations take place at, approximately, the same temperatures. The quantities of the radio-active substances volatilized, however, seem to be somewhat more variable than in the

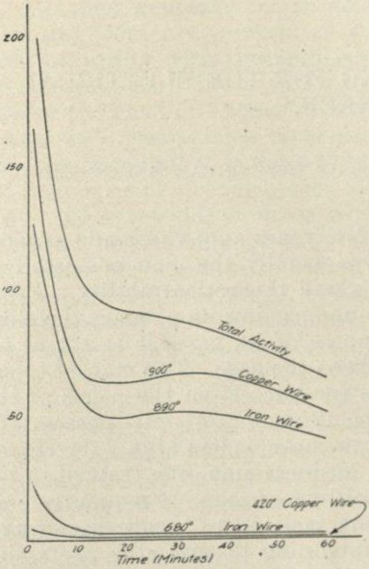

FIG. 4.

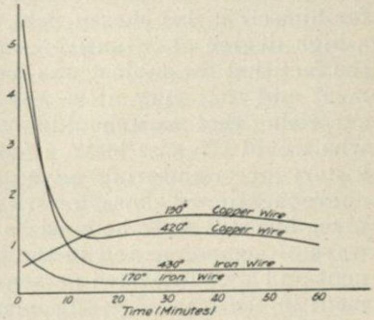

FIG. 5.

case of platinum, especially if the wires are covered with oxides. If there is a heavy layer of oxide on the wire the volatilization at temperatures below 200° is frequently suppressed.

taken mainly from the graduating classes in electrical engineering of our universities and technical schools, though men who have never taken a degree, or in fact had any technical training whatever, are sometimes employed because of special fitness due to other electrical training.

The length of time assigned for the completion of the course varies somewhat in the different companies, but is usually in the neighborhood of two years.

The apprenticeship department is under the control of a general foreman and his assistants. The work is divided into sections, each section being directed by a head with one or more assistants, usually "test men" who have been in the works a year or more. The rate of pay, taking the General Electric Company as a representative example; is fifteen cents per hour for the first six months, seventeen and one-half cents the second six months, and so on. It is safe to say, however, that few college men put in the full length of time assigned to the course before receiving some recognition in the way of assistantships or transfer to more advanced work, gaining in pay as they receive more important duties and greater responsibility. The working week consists of fifty-five hours with one hour extra pay each week if no time is lost. The "day men" begin work at 7 A. M. and quit at 5:30 P. M. and at noon on Saturdays. The "night men" come on at 7 P. M. and work until 7 A. M., but do not work Saturday or Sunday nights and in addition receive a slight bonus for the night service. This arrangement of hours and pay gives the "day men" a rate of $8.40 per week at the start and the "night men" slightly more than $10.00. The "day men" are quite often required to carry a test over until the night shift arrives, and in such cases receive overtime pay. The Company reserves the right to place men on the night shift during at least three months of their course, if they find it necessary. As a rule the men prefer to spend a part of the time working nights, asking for the transfer themselves, and some even prefer to work nights altogether, as the Company is usually more willing to grant transfers and a greater amount of freedom to the night men than to the day men, thus enabling them to get a greater amount of experience in a given length of time.

In the sections devoted to electrical testing, each machine or piece of apparatus after being assigned to its section is turned over by the head of that test to one of the older men, who is thus made directly responsible for the proper carrying out of the tests to which the piece is to be subjected. He is given several helpers from among the newer men to assist him. If you are the new man on the job, after the apparatus is properly wired up and ready to start, everyone helping in this, you will probably have to "pull water boxes," "hold speed," or do work of a similar nature. This is not particularly enjoyable or instructive, but is the price you must pay for being new. Depending on the relative time you have served in the particular section, your work will range from the places just mentioned to full charge of the machine. When through with this test, application is made for transfer to some other, and when so transferred the same process of working up has to be gone through with again. Through the various steps from "new man" to "old man" on all the apparatus run through each section, thorough familiarity is gained regarding the mechanical and electrical construction and operation of all types of apparatus.

The order in which the tests are taken is far from uniform, as is also the time taken by each. The schedules serve only as a guide and rarely, if ever, are followed in detail. Some men prefer to leave out one test, and some, another, depending possibly on the particular line in which each expects to specialize. Considerable freedom is permitted by the company in this arrangement after a man has been with them a short time. It would scarcely be possible to go into detail in the matter of what tests are carried out on various machines; suffice it to say, that such are applied as guarantee the satisfactory operation of the apparatus under all probable conditions in actual service, the conditions as a rule being much exaggerated. Thus a man is not only made thoroughly familiar with the performance of the apparatus, under all normal conditions, but in addition gains the knowledge of what to do in case of trouble, as it is quite certain he will, at one time or another, have opportunity to observe the development and correction of most of the troubles to which electrical apparatus is heir. In addition to the regular work, one of the most important features of the test is the opportunity, which is always present, of observing electrical apparatus of every description in process of construction; and the chance to learn the results of numberless experimental tests of a special nature, on new types and designs of dynamos, motors, lamps, circuit breakers, oil switches, etc.

Providing the testor has progressed through the works in regular order and has not stopped in some section to wait for an assistantship, which by the way is usually very bad policy, his next move should be a transfer to the calculating department, where the results of the tests on every machine and piece of apparatus sent through the shops are finally worked up. This is one place that should not be missed. While the work may be more or less routine, if a man keeps awake, he will gain innumerable valuable points.

After some time spent here he may apply for transfer to the drafting rooms where good practice may be obtained in general arrangement of apparatus, particularly switch-boards.

Lastly, a move is possible to the engineering or commercial departments, and in these latter a man usually takes up the line of work toward which he has been directing his energy. Here especially, he must beware of the danger of getting into a rut in some subordinate position.

In the calculating and engineering departments the hours are shorter and the pay higher; fifteen dollars per week is the rate paid in the calculating room and somewhat more in the engineering departments.

The following schedule, from a man who spent approximately two years with the G. E. Company, is fairly representative and serves to indicate what may be expected:

Induction motors	9	weeks.
Hysteresis laboratory	1	"
Medium sized generators and motors	14	"
Marine sets	1	"
Small motors	2	"
Transformers	9	"
Government	1	"
Number 16 (large A. C. and D. C. generators and motors, rotary converters, and transformers)	17	"
Calculating department	30	"
Transformer engineering department	20	"

This man says regarding his experience: "I would not exchange my two years work with the company for twice or three times that in general practice or advanced school work."

How long a man can afford to remain in the student's course is a much disputed question and it would seem that the answer must depend on the man. Some have had more or less practical experience before entering the tests; others, when they finish their university course, have reached such an age that they feel it is impossible to spend more time in further preparation than seems absolutely necessary. It would be safe to say, however, that the average man will not be wise in seeking for an opportunity to leave the course in less than eighteen months. If a good offer comes unsought before that time, it must be treated as a special case and considered accordingly. There is something valuable to be obtained as long as a man may choose to stay, but as suggested by one who has been through it, there is a time when you come to the knee of the curve plotted between time spent and knowledge acquired, and passing this, you pass the point of greatest efficiency. This is each man's "characteristic," and he must work it out for himself. There are men who stay on the test three and four years, usually those who have been appointed to an assistantship or have charge of a section. No doubt they continue to learn something new as long as they stay, but their choice is of questionable wisdom. They would undoubtedly have been better off if they had gone into work where the possibilities were greater. It is the old story of human weakness,—a man shrinks from leaving a fairly good job for another of uncertain conditions, though he may know the opportunities are better.

When the course is finished, many stay with the company, while others are recommended to good positions with its customers.

A man who has been through such a course of training as this, which brings him in direct contact with electrical work and commercial conditions, is well fitted to take a place among the successful engineers of the future.

SPAN AND DIP TABLES.

BY HARRY E. WAGNER, B. S. (E. E.), 1899.

Below are presented the results of a study of the problem of "Span and Dip."

FORMULAE.—In order that the limits and possibilities of the two accompanying tables may be more readily comprehended, the deduction of the formulae by which they are constructed will be briefly given.

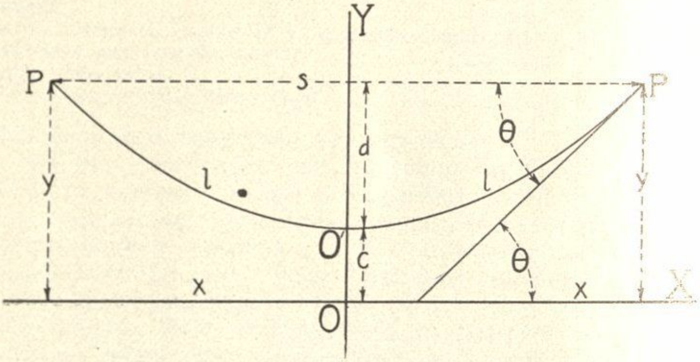

FIG 1.

In Fig. 1 let

$PO'P_1$ represent a catenary on the coördinate axes X and Y,
$L = 2l =$ length of wire in feet,
$s =$ span in feet.
$d =$ dip, or versed sine of curve, in feet,
$\theta =$ angle of wire with horizontal at the insulator.
$c = p/w =$ modulus of the catenary,
$y = t/w =$ ordinate at the insulator $= c + d$.

Also let

$p =$ tension in pounds at the vertex O',
$t =$ tension in pounds at the insulator,
$w =$ weight of wire per ft. in pounds.

The principal equations of the catenary, whose solution can be found in any standard work on the Calculus, are

$$y = \frac{c}{2}\left(e^{\frac{x}{c}} + e^{-\frac{x}{c}}\right), \qquad (1)$$

$$x = c \log_e \frac{y + \sqrt{y^2 - c^2}}{c}, \tag{2}$$

$$l = \frac{c}{2}\left\{e^{\frac{x}{c}} - e^{-\frac{x}{c}}\right\} = c \tan\theta, \tag{3}$$

in which (e) is the base of the Naperian system of logarithms.

Expand the functions $\left\{e^{\frac{x}{c}}\right\}$ and $\left\{e^{-\frac{x}{c}}\right\}$ by Maclaurin's theorem, which gives

$$e^{\frac{x}{c}} = 1 + \frac{x}{c} + \frac{x^2}{2!c^2} + \frac{x^3}{3!c^3} + \frac{x^4}{4!c^4} + \dots, \text{ and}$$

$$e^{-\frac{x}{c}} = 1 - \frac{x}{c} + \frac{x^2}{2!c^2} - \frac{x^3}{3!c^3} + \frac{x^4}{4!c^4} - \dots$$

Add and insert in (1)

$$y = \frac{c}{2}\left\{2 + \frac{x^2}{c^2} + \frac{x^4}{3\ 4c^4} + \dots\right\}. \tag{4}$$

Also subtract and insert in (3)

$$l = \frac{c}{2}\left\{\frac{2x}{c} + \frac{x^3}{3c^3} + \frac{x^5}{3.4.5\,c^5} + \dots\right\}. \tag{5}$$

From (3) it is also seen that

$$\tan\theta = \frac{x}{c} + \frac{x^3}{6c^3} + \frac{x^5}{120\,c^5} + \dots \tag{5'}$$

(2), (4), (5) and (5′) are the fundamental equations, and the coördinate values of the various parts of the curve can be calculated to as close an approximation as desired. In practice all terms of the series beyond the second or third are omitted, giving as approximate formulae:

$$y = c + \frac{x^2}{2c} + \frac{x^4}{4!c^3}, \text{ and} \tag{4}$$

$$l = x + \frac{x^3}{6c^2}. \tag{5}$$

Substituting $y = c + d$ in (4) gives

$$d = \frac{x^2}{2c} \text{ and } c = \frac{x^2}{2d} + \frac{d}{6}, \text{ or nearly } \frac{x^2}{2d}.$$

Since $x = s/2$ and $c = p/w$,

$$d = \frac{s^2w}{8p}, \text{ and} \tag{6}$$

$$p = \frac{s^2w}{8d}. \tag{7}$$

In (5′) substitute $x = s/2$ and $c = x^2/2d = s^2/8d$.

This gives $\tan\theta = \frac{4d}{s}$. (5′)

From the relation $y = t/w = c + d$, can be deduced the approximate value $t = \frac{s^2w}{8d} + \frac{7dw}{6}$, or nearly $\frac{s^2w}{8d}$. (8)

By simple substitution (5) can be reduced to

$$l = \frac{s}{2} + \frac{4d^2}{3s}, \text{ from which } L = s + \frac{8d^2}{3s}. \tag{9}$$

Expressions representing the relations of elongation due to strain and dilation due to temperature will now be introduced.

These relations are expressed by the formula

$$L_1 = L\ (1 \pm n\,\delta)\ [1 + \epsilon\,(t_1 - t)] = L\ (1 \pm n\,\delta) \left(1 + \frac{t_1 - t}{aE}\right), \tag{10}$$

in which

L_1 = length of wire after a change in temperature,
L = original length,
n = number of degrees change in temperature,
δ = coefficient of dilation per degree Fahrenheit,
ϵ = coefficient of elongation per pound $= \frac{1}{aE}$,
t_1 = new tension in pounds,
t = original tension in pounds,
a = area of wire in square inches,
E = modulus of elasticity.

Assume a given span at a given temperature.

Then $L = s + \frac{8d^2}{3s}$ and $t = \frac{s^2w}{8d}$.

If the temperature now increases n degrees Fahrenheit,

$$L_1 = s + \frac{8d_1^2}{3s} \text{ and } t_1 = \frac{s^2w}{8d_1}.$$

On substituting these values of L, L_1, t and t_1 in (10), this becomes

$$s + \frac{8d_1^2}{3s} = s + \frac{8d^2}{3s} + ns\delta + \frac{s}{aE}\left(\frac{s^2w}{8d_1} - \frac{s^2w}{8d}\right) + \cdots,$$

neglecting small fractions.

Hence $n = \frac{8}{3s^2\delta}(d_1^2 - d^2) + \frac{s^2w}{8aE\delta}\left[\frac{1}{d} - \frac{1}{d_1}\right]$, or transforming so that formula will apply with d_1 and d used in inches,

$$n = \frac{1}{54s^2\,\delta}(d_1^2 - d^2) + \frac{3s^2w}{2aE\,\delta}\left[\frac{1}{d} - \frac{1}{d_1}\right]. \tag{11}$$

For convenience the working formulae (5′), (6), (7), (8), (9) and (11) are now collected below:

$$tan\ \theta = \frac{4d}{s}, \tag{5'}$$

$$d = \frac{s^2w}{8p}, \tag{6}$$

$$p = \frac{s^2w}{8d}, \tag{7}$$

$$t = \frac{s^2w}{8d} + \frac{7wd}{6}, \tag{8}$$

$$L = s + \frac{8d^2}{3s}, \tag{9}$$

$$n = \frac{1}{54s^2\,\delta}(d_1^2 - d^2) + \frac{3s^2w}{2aE\,\delta}\left[\frac{1}{d} - \frac{1}{d_1}\right]. \tag{11}$$

Before showing how the tables were computed, attention may be called to the following points:

From (6) it is seen that dip varies directly as the square of span and is independent of the size of wire (w/p constant). With this in mind the tables can readily be extended beyond their present limits.

It is evident from (7) and (8) that for a given span and dip, the tension varies directly as the size of wire, and is a minimum at the vertex, and maximum at the insulator.

Deriving (8) with respect to (d) and placing equal to zero, gives as the condition for minimum tension or maximum span

$$\frac{7w}{6} - \frac{ws^2}{8d^2} = 0,$$

from which $d = s/3$ approximately, and $\theta = 53°\ 8'$.

As wire is strung in practice the second term in the right-hand member of (9) is a very small quantity, so that it is only necessary to consider the span length when buying wire or figuring resistance.

From (11) it is seen that the coefficients of elongation and dilation enter into the equation as a ratio, one tending to neutralize the other, the effect of strain, however, being the greater. This may be illustrated by considering one or two specific cases.

The calculation for dip in a 1,000 ft. span at 100° F., neglecting elasticity, gives $d = 21$ ft. 2 in., while Table II gives $d = 14$ ft. 7 in. For the same span at 0° F., the dips are 13 ft. and 10 ft. 3 in., respectively.

For a 300 ft. span the dips are: at 100° F., 5 ft. 10 in., and 1 ft. 10 in.; at 0° F., 3 ft., and 11¾ in., respectively.

The above and similar examples would lead to the conclusion that elasticity has the most effect on short spans at summer temperatures, and that in long spans at low temperatures the elongation and dilation more nearly balance each other.

THE TABLES.—Table I is a modification and extension of the table in common use, while Table II is new.

Wires are selected, on which to base the tables, whose physical constants are fairly well known and reliable. For Table I, a No. 8 B. W. G. hard-drawn copper wire, A. T. & T. Co. Specifications No. 1739, was used; and for Table II, a No. 8 B. W. G. special steel wire, A. T. & T. Co. Specifications No. 1705.

The following constants were assumed for the No. 8 copper wire:

Diameter	.165 in.,
Minimum breaking weight per sq. in.	62,500 lbs.,
Factor of safety at —40°F.	2+.
Modulus of elasticity in lbs. per sq. in.	19,000,000,
Coefficient of dilation per degree F.	.00000925,

and for the No. 8 steel wire the following:

Diameter	.165 in.,
Minimum breaking weight per sq. in.	187,000 lbs.,
Factor of safety at —40°F.	4,
Modulus of elasticity in lbs. per sq. in.	30,000,000,
Coefficient of dilation per degree F.	.00000685.

From Formula 12, the dip for various spans may now be obtained. This is for the condition of greatest strain on wire, which it is assumed will be at —40°F.

Next, assuming a definite increment of temperature, say 20°F., and substituting the various constants in Formula 11, a value can be assumed for d_1 which will satisfy the equation. This is the required dip for the new temperature.

The tension may now be found from Formula 8.

The constants for hard-drawn copper and iron wire are so uniform and so nearly equal, that a table calculated for copper applies equally well for soft iron wire.

The constants for steel, however, vary so greatly that ordinarily a separate table would be required for each quality. To avoid this and make a comprehensive table for all grades of high tension wire, a number of "factors" were calculated by which to multiply the table dips for the various degrees of tensile strength.

In calculating these multiplying factors, it was assumed that the modulus of elasticity is the same for all grades, which will lead to but small error, if any. Following are the factors which are used to simply multiply the dips and divide the tensions given in Table II in order to find the corresponding dips and tensions for the quality of wire under consideration.

QUALITY OF STEEL.		FACTOR.
Minimum breaking weight per sq. in......	60,000 lbs.	3.12
" " " " " "	80,000 "	2.34
" " " " " "	100,000 "	1.87
" " " " " "	120,000 "	1.56
" " " " " "	220,000 "	0.85

If, for any reason, a different factor of safety, *f*, than that given in the tables, should be desired, in Table I multiply the dips and divide the tensions by *f*/2, and in Table II multiply the dips and divide the tensions by *f*/4.

It may be readily seen from the manner in which the formulae were obtained and the uncertain nature of the physical constants used, that the values in the tables are by no means absolute quantities, but only fair approximations. Formula 8, from which the tensions are computed, involves *d*, the dip, and a slight variation in *d* makes considerable difference in the tension. The values for *d* are figured as closely as possible, but at best are not entirely accurate, at one time being a little large, and at another a little small. The tensions will show a corresponding variation, and any apparent lack of uniformity that may be observed in the tables is probably due to this cause. Practice has demonstrated that the formulae give reliable results for ordinary spans, and theoretically they should do so for long spans.

Before stringing wire by the table, the constructing engineer should be fairly sure that the dips and tensions taken from table correspond to the grade of wire he is using and to the temperature at which it is strung, and then should see that the values chosen are closely followed. A few calculations will show that there is room for the use of considerable judgment in choosing these values.

For example, take a 500 ft. span No. 8 wire at —40°F. A difference of one-tenth of an inch in the dip means a difference of 36 pounds at the insulator, which difference becomes about 8 pounds for a 1,000 ft. span, and 100 pounds for a 300 ft. span. For a 500 ft. span at 100°F., the difference is 8 pounds at the insulator, which becomes 3 pounds for a 1,000 ft. span, and 19 pounds for a 300 ft. span.

From the above it will be observed that, when closely measured, the dips are the more reliable guides; otherwise, the tensions give better results. More care is evidently necessary in stringing wire in the winter than in summer. In stringing wire by the dynamometer or tension method, a wider range of variation from the table is allowable in winter than in summer.

It should be noted that the various external forces, such as snow and wind, are accounted for in the table only by assuming a factor of safety. The calculation of stresses due to storm is quite uncertain and of more theoretical than practical value. A formula expressing the relation between original strain and that due to a storm is as follows:

$$t_1 = t\sqrt{1 + \left\{\frac{p}{w}\right\}^2},$$

in which p is the pressure on the wire per foot due to the storm.

A calculation by this formula for a No. 8 steel wire, 187,000 lb. quality, at 0°F., subject to a violent snow and wind storm, whose maximum pressure is 40 lbs. per square foot, gives $t_1 = 5{,}393$ lbs. for a 1,900 ft. span, 5,101 lbs. for a 1,000 ft. span, and 4,808 lbs. for a 300 ft. span. With a factor of safety of 6, $t_1 = 3{,}697$ lbs. for a 1,900 ft. span at 0°F., and the wire would in all probability stand the storm.

The factor of safety of 4 is evidently not sufficient for long spans under the worst possible conditions, and a larger factor should be chosen than for short spans of the same quality of wire.

INSULATORS ON DIFFERENT LEVELS.—The foregoing applies rigidly only to spans in which the insulators are approximately on the same level. Should they be on different levels, each span becomes a special problem and must be worked out accordingly. In ordinary mountain toll line construction, the factor of safety will take care of unequal strain at the insulator, due to the difference of level, and it is only very long spans or exceptional differences of level that require special study.

The equations for this problem may be deduced as follows:

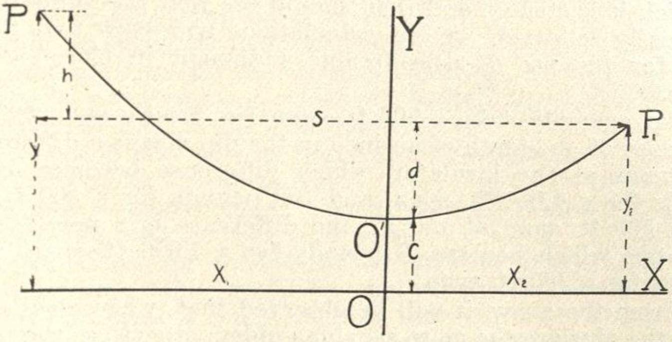

FIG. 2.

In Fig. 2 let
$h =$ difference in level of insulators in ft.,
$y_1 =$ ordinate at upper insulator,
$y_2 = y_1 - h =$ ordinate at lower insulator,
$x_1 + x_2 = s$, the horizontal length of span.

For the part of curve on the left of Y - axis substitute y_1 for y in Equation 2, and for the part on right substitute $y_2 = y_1 - h$ for y.

Then $x_1 = c \log_e \dfrac{y_1 + \sqrt{y_1^2 - c^2}}{c}$, and (12)

$$x_2 = c \log_e \frac{(y_1 - h) + \sqrt{(y_1 - h)^2 - c^2}}{c}. \qquad (13)$$

Adding,

$$s = c \log_e \frac{[y_1 + \sqrt{y_1^2 - c^2}][(y_1 - h) + \sqrt{(y_1 - h)^2 - c^2}]}{c^2}. \qquad (14)$$

By trial c can be found from (14), after which the vertex may be located by substituting the value of c in (12) and (13). The other values desired may be found by application of the preceeding formulae.

In conclusion the writer wishes to acknowledge the kindly aid given by Mr. C. E. Scribner, of the American Telephone and Telegraph Co., in this compilation.

TABLE No. 1.

HARD DRAWN COPPER AND IRON WIRE.

Span in Feet.	Size	-40°F.			-20°F.			0°F.			+20°F.			+40°F.			+60°F.			+80°F.			+100°F.			Size	Span in Feet.
		Tension	Dip Ft.	Dip In.	Tension	Dip Ft.	Dip In.	Tension	Dip Ft.	Dip In.	Tension	Dip Ft.	Dip In.	Tension	Dip Ft.	Dip In.	Tension	Dip Ft.	Dip In.	Tension	Dip Ft.	Dip In.	Tension	Dip Ft.	Dip In.		
75	No. 8	630			464			464			348			348			278			232			174			No. 8	75
	No. 10	420			309			309			232			232			185			154			116			No. 10	
	No. 12	255			187			187			140			140			112			94			70			No. 12	
	No. 14	150		1.1	111		1.5	111		1.5	83		2.0	83		2.0	66		2.5	55		3.0	42		4.0	No. 14	
100	No. 8	630			495			413			413			309			248			190			146			No. 8	100
	No. 10	420			329			285			275			206			165			127			97			No. 10	
	No. 12	255			200			166			166			125			100			77			59			No. 12	
	No. 14	150		1.95	118		2.5	98		3.0	98		3.0	74		4.0	59		5.0	45		6.5	35		8.5	No. 14	
115	No. 8	630			584			546			468			364			298			234			173			No. 8	115
	No. 10	420			389			363			311			242			198			156			115			No. 10	
	No. 12	255			236			220			189			147			120			74			69			No. 12	
	No. 14	150		2.6	139		2.8	130		3.0	112		3.5	87		4.5	71		5.5	56		7.0	41		9.5	No. 14	
130	No. 8	630			523			465			381			299			246			190			167			No. 8	130
	No. 10	420			348			309			253			199			164			127			111			No. 10	
	No. 12	255			211			187			153			121			89			77			67			No. 12	
	No. 14	150		3.3	125		4.0	111		4.5	97		5.5	71		7.0	59		8.5	45		11.0	40	1	5.0	No. 14	
150	No. 8	630			557			464			391			328			265			214			180			No. 8	150
	No. 10	420			371			309			265			218			176			143			119			No. 10	
	No. 12	255			225			187			160			132			107			86			92			No. 12	
	No. 14	150		4.5	133		5.0	111		6.0	95		7.0	78		8.5	63		10.5	51	1	1.0	43	1	3.5	No. 14	
200	No. 8	630			550			472			413			342			283			236			215			No. 8	200
	No. 10	420			366			314			275			227			188			157			143			No. 10	
	No. 12	255			222			190			166			138			114			95			87			No. 12	
	No. 14	150		7.8	131		9.0	112		10.5	98	1	0.0	81	1	2.5	62	1	5.5	56	1	9.0	51	1	11.0	No. 14	
300	No. 8	630			557			495			429			378			319			279			248			No. 8	300
	No. 10	420			371			329			285			251			212			185			165			No. 10	
	No. 12	255			225			200			113			152			128			112			100			No. 12	
	No. 14	150	1	5.5	133	1	8.0	118	1	10.5	102	2	2.0	90	2	5.5	76	2	11.0	66	3	4.0	59	3	9.0	No. 14	
400	No. 8	630			566			508			450			396			354			314			283			No. 8	400
	No. 10	420			376			337			298			264			235			208			188			No. 10	
	No. 12	255			227			205			182			160			142			126			114			No. 12	
	No. 14	150	2	742	135	2	11.0	121	3	3.0	108	3	8.0	95	4	2.0	84	4	8.0	75	5	3.0	68	5	10.0	No. 14	
500	No. 8	630			563			516			467			419			382			348			316			No. 8	500
	No. 10	420			381			344			307			278			255			231			210			No. 10	
	No. 12	255			230			208			186			168			154			140			128			No. 12	
	No. 14	150	4	1.11	137	4	6.0	123	5	0.0	110	5	7.0	100	6	2.0	91	6	9.0	83	7	5.0	75	8	2.0	No. 14	

NOTE: In above table Nos. 8 and 10 are B.W.G., Nos. 12 and 14 N. B. S. Diameters are as follows: No. 8, .165 in.; No. 10, .134 in.; No. 12, .104 in.; No 14, .08 in.

TABLE No. 2.

STEEL WIRE.

Span in Feet.	Size BWG.	-40°F. Tension.	Dip. Ft.	Dip. In.	-20°F. Tension.	Dip. Ft.	Dip. In.	0°F Tension.	Dip Ft.	Dip In.	+20°F Tension.	Dip Ft	Dip In	+40°F Tension	Dip. Ft	Dip. In	+60°F Tension.	Dip. Ft	Dip. In.	+80°F. Tension.	Dip. Ft.	Dip. In.	+100°F. Tension	Dip. Ft.	Dip. In.	Size BWG.	Span in Feet.
300	No. 6	1520			1401			1252			1132			1015			892			774			669			No. 6	300
	No. 8	1000			920			822			743			668			585			508			439			No. 8	
	No. 10	658			604			540			488			445			386			334			288			No. 10	
	No. 12	434	0	9.65	399	0	10.5	356	0	11.75	322	1	1.0	289	1	2.5	254	1	4.5	220	1	7.0	190	1	10.0	No. 12	
400	No. 6	1520			1401			1246			1137			1026			918			805			709			No. 6	400
	No. 8	1000			915			817			746			673			602			528			464			No. 8	
	No. 10	658			602			537			490			442			396			347			305			No. 10	
	No. 12	434	1	5.16	397	1	6.75	354	1	9.00	324	1	11.00	292	2	1.5	261	2	4.5	229	2	8.5	201	3	1.0	No. 12	
500	No. 6	1520			1397			1277			1160			1041			934			826			743			No. 6	500
	No. 8	1000			917			838			761			683			612			542			487			No. 8	
	No. 10	658			603			551			500			449			403			356			320			No. 10	
	No. 12	434	2	2.81	397	2	5.25	363	2	8.0	330	2	11.25	296	3	3.25	266	3	7.75	235	4	1.5	211	4	7.0	No. 12	
600	No. 6	1524			1402			1287			1171			1065			965			872			790			No. 6	600
	No. 8	1000			919			844			768			699			633			572			518			No. 8	
	No. 10	658			604			555			505			459			416			376			341			No. 10	
	No. 12	434	3	2.61	399	3	6.0	366	3	9.75	333	4	2.25	303	4	7.25	274	5	1.0	248	5	7.5	225	6	2.5	No. 12	
700	No. 6	1524			1402			1292			1191			1083			989			911			826			No. 6	700
	No. 8	1000			918			848			778			710			649			597			542			No. 8	
	No. 10	658			604			557			512			467			426			393			356			No. 10	
	No. 12	434	4	4.55	398	4	9.25	368	5	2.0	338	5	7.5	308	6	2.0	281	6	9.0	259	7	4.0	235	8	1.0	No. 12	
800	No. 6	1525			1415			1308			1203			1102			1016			935			865			No. 6	800
	No. 8	1000			927			858			789			723			667			613			567			No. 8	
	No. 10	658			610			564			519			475			438			403			373			No. 10	
	No. 12	434	5	8.64	402	6	2.0	372	6	8.0	342	7	3.0	313	7	11.0	289	8	7.0	266	9	4.0	246	10	1.0	No. 12	
900	No. 6	1525			1417			1312			1215			1123			1043			967			895			No. 6	900
	No. 8	1000			929			860			797			736			684			634			587			No. 8	
	No. 10	658			611			566			524			484			450			417			386			No. 10	
	No. 12	434	7	2.87	403	7	9.5	373	8	5.0	346	9	1.0	319	9	10.0	297	10	7.0	275	11	5.0	254	12	4.0	No. 12	
1000	No. 6	1525			1422			1330			1230			1144			1069			994			935			No. 6	1000
	No. 8	1000			933			872			807			750			701			653			613			No. 8	
	No. 10	658			613			574			535			493			461			429			403			No. 10	
	No. 12	434	8	11.25	404	9	7.0	378	10	3.0	350	11	1.0	325	11	11.0	304	12	9.0	283	13	8.5	266	14	7.0	No. 12	
1100	No. 6	1525			1424			1337			1253			1171			1100			1031			971			No. 6	1100
	No. 8	1001			934			877			821			768			721			676			636			No. 8	
	No. 10	658			614			577			540			505			475			445			419			No. 10	
	No. 12	434	10	9.77	405	11	7.0	380	12	4.0	356	13	2.0	333	14	1.0	313	15	0.0	293	16	0.0	276	17	0.0	No. 12	
1200	No. 6	1525			1428			1346			1260			1184			1111			1048			995			No. 6	1200
	No. 8	1001			936			883			826			776			732			687			652			No. 8	
	No. 10	658			616			581			544			511			482			452			430			No. 10	
	No. 12	434	12	10.44	406	13	9.0	383	14	7.0	358	15	7.0	336	16	7.0	317	17	7.0	298	18	9.0	283	19	9.0	No. 12	
1300	No. 6	1525			1433			1356			1275			1203			1139			1081			1026			No. 6	1300
	No. 8	1001			940			889			837			789			747			709			673			No. 8	
	No. 10	658			618			585			550			519			491			466			442			No. 10	
	No. 12	434	15	1.25	407	16	1.0	385	17	0.0	362	18	1.0	342	19	2.0	323	20	3.0	307	21	4.0	291	22	6.0	No. 12	
1400	No. 6	1526			1439			1360			1284			1221			1155			1096			1046			No. 6	1400
	No. 8	1001			944			892			842			801			758			719			686			No. 8	
	No. 10	658			621			587			554			526			498			473			451			No. 10	
	No. 12	434	17	6.21	409	18	7.0	386	19	8.0	365	20	10.0	347	21	11.0	328	23	2.0	311	24	5.0	297	25	7.0	No. 12	
1500	No. 6	1526			1450			1370			1297			1237			1178			1124			1072			No. 6	1500
	No. 8	1001			951			898			850			811			773			738			703			No. 8	
	No. 10	659			625			591			560			533			508			485			462			No. 10	
	No. 12	434	20	1.31	412	21	2.0	389	22	5.0	368	23	8.0	351	24	10.0	334	26	1.0	319	27	4.0	304	28	8.0	No. 12	
1600	No. 6	1527			1456			1379			1311			1248			1192			1140			1093			No. 6	1600
	No. 8	1002			955			905			860			819			782			748			717			No. 8	
	No. 10	659			628			595			566			539			514			492			472			No. 10	
	No. 12	434	22	10.36	413	24	0.0	392	25	4.0	372	26	8.0	354	28	0.0	338	29	4.0	323	30	8.0	310	32	0.0	No. 12	
1700	No. 6	1527			1465			1396			1334			1273			1220			1170			1121			No. 6	1700
	No. 8	1002			961			916			872			835			801			768			733			No. 8	
	No. 10	659			632			602			575			549			526			504			483			No. 10	
	No. 12	434	25	9.95	416	26	11.0	396	28	3.0	379	27	7.0	361	31	0.0	346	32	4.0	332	33	9.0	318	35	3.0	No. 12	
1800	No. 6	1527			1466			1401			1334			1280			1227			1181			1135			No. 6	1800
	No. 8	1002			962			921			875			840			805			775			745			No. 8	
	No. 10	659			633			606			576			552			529			509			490			No. 10	
	No. 12	434	28	11.49	416	30	2.0	398	31	6.0	379	33	2.0	363	34	7.0	348	36	1.0	335	37	6.0	322	39	0.0	No. 12	
1900	No. 6	1528			1465			1406			1342			1288			1244			1197			1155			No. 6	1900
	No. 8	1002			959			922			880			844			816			785			757			No. 8	
	No. 10	659			632			606			578			555			536			516			498			No. 10	
	No. 12	434	32	3.17	415	33	8.0	399	35	1.0	381	36	9.0	365	38	4.0	353	39	8.0	339	41	3.0	327	42	9.0	No. 12	
2000	No. 6	1528			1467			1410			1355			1304			1257			1213			1172			No. 6	2000
	No. 8	1002			962			925			889			855			825			796			769			No. 8	
	No. 10	659			632			608			584			562			542			523			505			No. 10	
	No. 12	434	35	9.0	416	37	3.0	400	38	9.0	384	40	4.0	370	41	11.0	356	43	6.0	394	45	1.0	333	46	8.0	No. 12	

Diameters of above wires: No. 6, .203 in.; No. 8, .165 in.; No. 10, .134 in.; N .12 .109 in.

the top of the mountains. Three No. 8 B. & S. gauge cables, composed of six aluminum strands with hemp core, forming the vertices of a 6-foot equilateral triangle are strung on 15-inch Locke insulators; the upper one being fastened by a bracket to the top of pole. Cast iron pins are cemented to insulators. The poles average 36 feet long with a 250 foot span. The longest span is 1,100 feet, the cable being supported from wooden towers. With other spans over the average length, either a 2-pole tower, each pole carrying an insulator and the cross-arm the third one, or 2 poles set tandem, double arming with large insulators being impracticable, are used as required.

The Silverton sub-station is a building similar to the power plant and contains all the necessary protective apparatus, oil switches, etc., for transforming from 50,000 volts to 17,000 volts. The transformers are similar to those in the power house, an extra one being provided in case of accident. All switches, both at Silverton and at the power house, are automatically controlled by time limit relays, which will open the circuits only on overloads dangerously prolonged, as by a "dead short," and will hold during the starting of a large induction motor. By using inverse current relays, a dead short coming upon the transmission line in use will operate automatically the switches at both stations, and transfer the load to the other transmission line, without interruption or noticeable effect to the customers.

From Silverton sub-station there is about 50 miles of distributing line reaching out west, northwest and north. This part of the construction has presented some thrilling incidents, not usual in such commonplace matters as line building. A knowledge of the nature of the country covered, where the lines have had to cross the range, rising from 9,000 feet to over 13,000 feet, over the most rugged mountains, where horseback riding is impossible, may give some idea of the difficulties encountered and problems solved in bringing material to place and constructing the line. All the distributing circuits were completed after the heaviest snow fall of the year. The men bravely endured the hardships of camp life, with the thermometer 20 and 30 degrees below zero, and the possibility of pneumonia, which summoned several, and worked up to their waists in snow raising poles and stringing wire.

A few finishing touches will complete this enterprise, which will undoubtedly result in immense benefit to Silverton and the surrounding San Juan country.

THE PASSIVE STATE OF IRON.

By A. S. Dennison, Electrical Engineering, 1906.

The fact that iron becomes passive when exposed to concentrated nitric acid has been known for a great while. Roscoe and Schorlemmer make the following statements:

"Dilute nitric acid dissolves iron when cold, without forming any gas, and with the formation of ferrous nitrate, $Fe(NO_3)_2$; when heated, or, with stronger acid, oxides of nitrogen are formed, and ferric nitrate, $Fe(NO_3)_3$."

"Under certain circumstances iron is not acted upon by nitric acid at all, nor does it precipitate copper from solutions of its salts. Iron in this state is called passive, and the condition is brought about by dipping the metal into concentrated nitric acid, and then washing it."

At least two applications of this passive state have given promise of commercial success: one being the stripping of brass from iron tubing in an electrolytic cell with sodium nitrate, and the other being its use as cathode in the Jacques carbon cell.

Jacques' cell was thoroughly investigated by Dr. F. Haber and Dr. L. Bruner. With regard to the iron electrode, they say: "This passive iron represents an oxygen electrode on which the atmospheric oxygen acts similarly, but better, than on a platinized platinum electrode dipped into an aqueous conducting solution." (Elec. Review, Vol. 45, p. 514.) The theoretical value of the carbon cell, and the gas cell, gives the passive state an added importance in the light of this statement. A cheap substitute for platinum brings us one step nearer to the successful utilization of carbon as the attackable electrode in a commercial cell.

Various theories have been suggested to account for this peculiarity, which, by the way, is not confined to iron. Faraday offered the suggestion that it is due to the formation of a film of oxide on the surface of the metal, which protects it. However, it is usually the case that a freshly formed oxide is more readily attacked by an acid than is the metal itself. The formation of an oxide is supposed to account for the action of sulphuric acid on copper, but to prevent the action of nitric acid on iron. This theory has been discarded by later investigators. Although it is definitely known that films of a complex nature form on metals, especially on aluminum, when placed in certain electrolytes, the explanation does not seem to apply to iron in nitric acid, at least so far as an oxide film is concerned. More recent theories are that it is due to some electrical phenomena, or that it is due to an allotropic form of the metal.

Whatever the true reason, it is evident that the temperature has a great effect. Using a strip of commercial sheet iron and nitric acid of specific gravity 1.42, if the iron is dipped in the acid and then held in the air, when the temperature is above 25° C., the acid will not have dried before violent action takes place, with evolution of oxides of nitrogen.

Also, the strength of acid used is of importance. If iron is taken out of concentrated acid and placed in dilute, no action occurs, but if nitric acid be slowly added to pure water, action will begin when solution reaches a strength of about 25 per cent, and hydrogen and oxides of nitrogen are given off.

In conclusion, the writer wishes to propose that the passive state is brought about by the formation of an insoluble salt, which may be caused to dissolve by the catalytic action of another salt, or by NO_2. This is suggested by the fact that a moderately dilute solution of nitric acid will almost always act on iron, even after being treated with concentrated acid, if the first solution has previously been used to dissolve iron. In other words, the writer believes the action is similar to that of chromous chloride on chromic chloride. The latter salt is insoluble in water, but upon the addition of a trace of chromous chloride, it dissolves rapidly. (Harper's Magazine, Jan., 1906, The Chemistry of Commerce.) This opinion is further supported by the fact that if a passive piece of iron is scratched and then dipped into dilute acid, action begins along the scratch and spreads over the entire piece of metal.

MANUFACTURE OF TRANSIT CENTERS.

By George Hamburger, Jr., Mechanical Engineering, 1907.

Few engineers realize the accuracy required in the construction of centers and sockets for engineering instruments of precision, and fewer still are familiar with the methods pursued in a modern instrument factory, enabling the attainment of the required accuracy in these parts, which is the very foundation of the instrument.

Consider the fact that, with a twenty-power telescope, an angular variation of from three to five seconds of arc is easily discovered, that occasionally telescopes of nearly double this power are used, and that the maximum error must be divided between the eight surfaces of the groups, viz: (see figure) the outside conical surface of the center (A); the conical hole, and the outside conical surface of the socket (B); the conical hole in C; the shoulders of A and B in contact at D; and the shoulders of B and C in contact at E; and the accuracy required for each of the narrow surfaces can easily be appreciated.

The following is an outline of the method used in the factory of Wm. Ainsworth & Sons, at Denver, which, in a measure, indicates the painstaking accuracy necessary in producing the centers for precision transits.

The center A is usually made of bell metal. First the casting is roughed out in the turret lathe, centered in a special centering machine, which insures perfect alignment of the centers in each end, then taken to the dead center lathe, (so named because neither head nor tail center revolves), where the surfaces F and G, which receive the vernier plate, the shoulder at D, and the taper and thread for nut H are cut and finished, after which it is ready to receive the socket B.

Socket B is roughed out in the same manner as the center, after which the taper hole is reamed by hand. This is now put on an arbor in the dead center lathe, and the shoulder at D turned and finished. It is then fitted to the center A by hand grinding, and the nut H put on to hold A and B together, allowing B to revolve on A. These parts are then taken to the dead center lathe, and, with A clamped to prevent its turning, B is revolved on A, and the surfaces I and J (which are to receive the limb), the surface K, the shoulder at E, and the taper are turned and finished, thus making these surfaces true with the taper hole in B.

C is made of hard bronze. This is roughed out in the same manner as the other pieces described. The hole is finished and reamed by hand. The piece is then put on an arbor in the dead center lathe, in which the shoulder at E is finished and a thread is cut for the half ball L. The work is now completed with the exception of the holes M for the leveling screws, which are drilled and tapped in another machine.

If the foregoing work is carefully done, none of the surfaces should be eccentric by an amount exceeding one second. An expert workman can usually keep the combined errors well within two to five seconds of being correct for each group of centers.

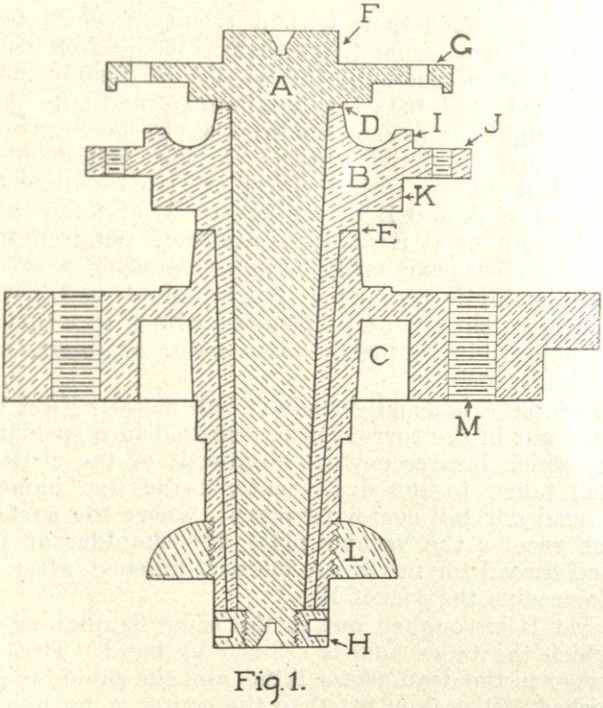

Fig. 1.

THE DESIGN OF RETAINING WALLS.[*] [†]

By Milo S. Ketchum, C. E., Dean of the School of Applied Science and Professor of Civil Engineering.

Introduction.—A retaining wall is a structure which sustains the lateral pressure of earth or some other granular mass which possesses some frictional stability. The pressure of the material supported will depend upon the material, the manner of depositing in place, and upon the amount of moisture, and will vary from zero to the full hydraulic pressure. If dry clay is loosely deposited behind the wall it will exert full pressure due to this condition. In time the earth becomes consolidated and cohesion and moisture make a solid clay, which often causes the bank to shrink away from the wall and there will be no pressure exerted. On the other hand if a considerable amount of water is applied, the normal pressure rapidly increases and approaches that due to a liquid having the same specific gravity.

In this discussion only the first condition will be considered and the earth or other filling will be assumed to be a dry granular mass, a semi-fluid, without cohesion, and to be held in place by the friction of the particles on each other.

To fully determine the pressure of the filling on the retaining wall it is necessary that the resultant of the pressure be known (a) in amount, (b) in direction, and (c) in point of application. Many theories have been proposed for finding the pressure, each differing somewhat in the assumptions as to the direction and point of application of the resultant pressure. The most important theories are as follows:

(1) Rankine's Theory.—In this theory the filling is assumed to consist of an incompressible homogeneous granular mass, without cohesion, the particles are held in position by friction on each other; the mass being of indefinite extent, having a plane top surface, and resting on a homogeneous foundation, and being subjected to its own weight. These assumptions lead to the ellipse of stress and make the resultant pressure on a vertical wall parallel to the top surface. The pressure on other than vertical walls can be determined by the ellipse of stress.

(2) Weyrauch's Theory.—In this theory the filling is assumed to be without cohesion and to be held in equilibrium by

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[†] From a forthcoming book on "The Design of Walls and Bins," Engineering News Publishing Company, New York. Ready August, 1906.

friction of the particles on each other. It is also assumed that the forces upon any imaginary plane-section through the mass of earth have the same direction. These assumptions lead to two formulas, one giving the amount of the thrust, and the other giving its direction, the angle that the resultant makes with a normal to the wall. The formulas deduced by Weyrauch may be obtained more simply by means of the ellipse of stress, and are therefore subject to the same limitations.

(3) COULOMB'S THEORY.—In this theory it is assumed that there is a wedge having the wall as one side and a plane called the plane of rupture as the other side, which exerts a maximum thrust on the wall. The plane of rupture lies between the angle of repose of the filling and the back of the wall. It may coincide with the plane of repose. For a wall without surcharge (horizontal surface back of the wall), and a vertical wall the plane of rupture bisects the angle between the plane of repose and the back of the wall. This theory does not determine the direction of the thrust, and leads to many other theories having assumed directions for the resultant pressure.

(4) CAIN'S THEORY.—Professor Wm. Cain assumes that the resultant thrust makes an angle with the normal equal to ϕ', the angle of friction of the filling on the back of the wall, or equal to ϕ, the angle of repose of the filling, if ϕ^1 is greater than ϕ.

Other authorities assume that the resultant thrust is normal to the back of the wall. For a vertical wall without surcharge, all of the above formulas lead to the same result for the amount, direction, and point of application of the resultant thrust.

In the following discussion the formulas for the thrust of the filling on retaining walls will be deduced (a) according to Rankine's Theory, and (b) a general formula will be derived based on Coulomb's Theory of a Maximum Wedge.

RANKINE'S THEORY.

ELLIPSE OF STRESS.—It will now be necessary to investigate the relations between the stresses in an unconfined incompressible granular mass, which is held together by friction of the particles on each other, and which has no cohesion.

Case 1.—*Equal-like Principal Stresses.*—If a pair of principal stresses at a point be like (both compression or both tension), and be equal in intensity, the stress on a third plane through the point is of the same intensity and is normal to the plane.

In (a) Fig. 1, p and q are equal compressive stresses acting on the principal planes A-A, and B-B, respectively through the point O. It is required to find the intensity and direction of the stress, r, acting on the plane C-C through the point O.

Let AOB in (b), Fig. 1, be a differential triangular prism at O, having its faces in the planes. The prism is then in equilibrium

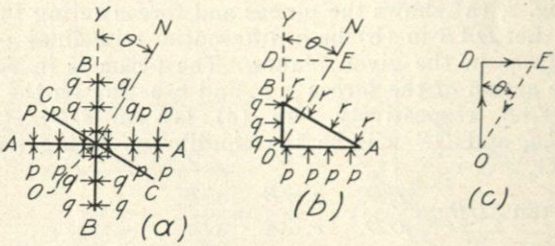


FIG. 1.

under the action of the forces p, q, and r, acting on the faces OA, OB, and AB, respectively. In (c) lay off $OD =$ total stress on $OA = p.OA$, and lay off $DE =$ total stress on $OB = q.OB$. Now complete the force triangle OBE, and $OE =$ the equilibrant $= AB.r$, in amount and direction.

$$\text{Now } \tan DOE = \frac{q.OB}{p.OA} = \frac{OB}{OA},$$

since $p = q$.

Therefore, angle $DOE =$ angle $OAB = \theta$, and OE is perpendicular to AB.

$$\begin{aligned}\text{Also}\quad OE^2 &= DO^2 + DE^2,\\ &= p.^2OA^2 + q.^2\,OB^2,\\ &= p^2(OA^2 + OB^2),\\ &= p.^2AB^2,\\ \text{and}\quad OE &= p.\,AB.\end{aligned}$$

But $OE = r.AB$, and therefore $r = p = q$, which proves the theorem.

Case 2.—Equal-unlike Principal Stresses.—If a pair of principal stresses at a point be unlike (one compression and the other tension), and be of equal intensity, the resultant on any plane through the point is of the same intensity, and is inclined to the normal to the plane of principal stress at an angle θ, but on the opposite side from the resultant in Case 1.

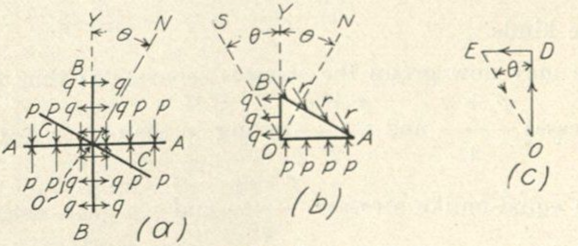


FIG. 2.

In Fig. 2, (a) shows the planes and forces acting through the point O. Let OAB in (b) be a differential triangular prism at O with its faces in the given planes. The prism is in equilibrium under the action of the forces p, q, and r, acting on the faces OA, OB, and AB, respectively. In (c) lay off $OD = OA.p$, and $ED = OB.q$, and OE will be the equilibrant acting on the face $AB = AB.r$.

$$\text{Now } \tan EOD = \frac{ED}{OD} = \frac{q.OB}{p.OA} = \frac{OB}{OA},$$

since $p = q$.

Therefore, angle $EOD = \theta$ and EO makes an angle with the normal to OA equal to θ, but on the opposite side from Case 1.

Now $OE^2 = DO^2 + DE^2$,
$= p.^2AB^2$, and $OE = p.AB$, as in Case 1,
but $OE = AB.r$,
and $r = p = q$.

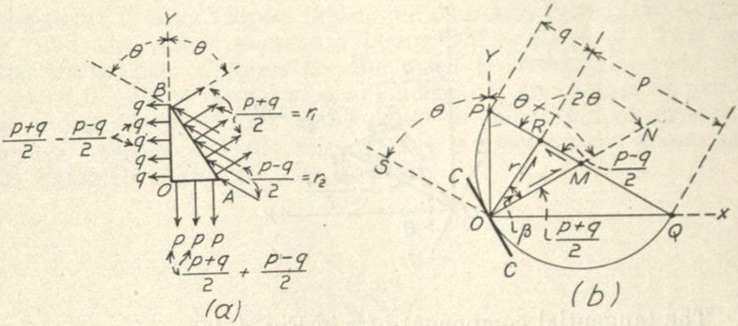
Case 3. Given the principal stresses of the same kind but having unequal intensities to determine the intensity and direction of the stress on a third plane. If p and q represent the intensities of the forces on the planes A-A and B-B, respectively, acting through the point O, in (a), Fig. 3, p being the greater, we have by algebra

$$p = \frac{p+q}{2} + \frac{p-q}{2} \quad \text{an identity,}$$

$$\text{and} \quad q = \frac{p+q}{2} - \frac{p-q}{2} \quad \text{an identity.}$$

Now we may look on the plane A-A as having two separate stresses equal to $\frac{p+q}{2}$ and $\frac{p-q}{2}$ of the same kind, while upon the plane B-B we will have two stresses $\frac{p+q}{2}$ and $\frac{p-q}{2}$ of opposite kinds.

We may now group the stresses separately; thus the equal-like stresses $\frac{p+q}{2}$ and $\frac{p+q}{2}$ acting on the planes A-A and B-B, and the equal-unlike stresses $\frac{p-q}{2}$ and $-\frac{p-q}{2}$ acting on the same planes A-A and B-B, respectively.



(a) (b)

FIG. 3.

Now the stresses on the plane C-C for the equal-like stresses $\frac{p+q}{2}$ and $\frac{p+q}{2}$ is the force $r_1=\frac{p+q}{2}$ acting normal to plane C-C. The stress on the plane C-C for the equal-unlike stresses $\frac{p-q}{2}$ and $-\frac{p-q}{2}$, will be a stress $r_2=\frac{p-q}{2}$, and inclined at an angle θ to the line of principal stress. In (b), Fig. 3, we have the stresses acting as above and it is required to find the resultant of the stresses on the plane C-C.

In (b) lay off $OM=\frac{p+q}{2}=r_1$, normal to C-C, and from M lay off $MR=\frac{p-q}{2}=r_2$, and parallel to $\frac{p-q}{2}$ in (a). Now $OR=r$ will be the resultant force in direction and intensity. From the construction it will be seen that in (b) $MP=MQ=OM=\frac{p+q}{2}$.

Also $QR=MQ+MR$,

$$=\frac{p+q}{2}+\frac{p-q}{2},$$

$$=p.$$

$$PR=MP-MR,$$

$$=\frac{p+q}{2}-\frac{p-q}{2},$$

$$=q.$$

$$\angle RMN=2\,\theta.$$

$\angle ROM=\beta=$ obliquity of r.

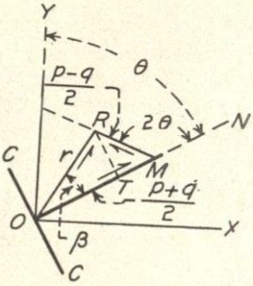


FIG. 4.

The tangential component of r in Fig. 4, is

$$R\,T = M\,R \sin R\,M\,T,$$
$$= \frac{p-q}{2} \sin 2\,\theta,$$
$$r_t = (p - q) \sin\theta \cos\theta. \tag{1}$$

The normal component of r is

$$O\,T = O\,M - M\,T,$$
$$= O\,M + M\,R \cos 2\,\theta,$$
$$= \frac{p+q}{2} + \frac{p-q}{2} (\cos^2\theta - \sin^2\theta),$$
$$= \frac{p+q}{2} (\sin^2\theta + \cos^2\theta) + \frac{p-q}{2} (\cos^2\theta - \sin^2\theta),$$
$$r_n = p \cos^2\theta + q \sin^2\theta. \tag{2}$$

Note.—If t_n is the normal component of the stress on a plane D-D, a plane normal to C-C,

$$t_n = p.\cos^2(\theta + 90^\circ) + q.\sin^2(\quad + 90^\circ),$$
$$= p.\sin^2\theta + q.\cos^2\theta.$$

Now adding r_n and t_n

$$t_n + r_n = p\,(\sin^2\theta + \cos^2\theta) + q\,(\sin^2\theta + \cos^2\theta),$$
$$= p + q. \tag{3}$$

which proves that the sum of the normal stresses on any two rectangular planes is a constant, and is equal to the sum of the principal stresses.

Now as the plane C-C in (b) Fig. 3, moves through all angles the point M will describe a circle around O, with a radius $= \frac{p+q}{2}$, and R will describe a circle about M, with a radius $= \frac{p-q}{2}$, OM and OR keeping equally inclined to the vertical (direction of principal stress) on opposite sides of it. The locus of the point R is an ellipse, the major semi-axis being $OM + MR = p$, and the minor semi-axis being $OM - MR = q$. This is called the ellipse of stress for the point O within the body at the point O. Its principal axes are normal to the planes of principal stress, the semi-axes being equal to the principal stresses. The radii vestores OR, OR_1, etc., are the stresses on the planes at O, to which OM, OM_1, etc., are normals.

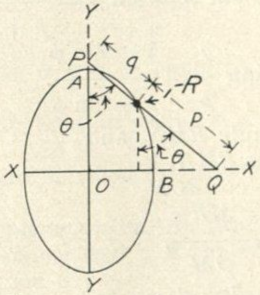


Fig 5.

Equation of Ellipse of Stress.—The ordinary ellipsograph consists of a piece like PRQ, Fig. 5, whose extremities P and Q slide in two grooves YOY and XOX, respectively, at right angles to each other, while the point R traces an ellipse whose semi-axes are $PR = q$, and $RQ = p$.

Take coördinates of R as x and y,

$$\text{and } x = PR.\sin\theta = q.\sin\theta,$$

$$\frac{x}{q} = \sin\theta,$$

$$y = RQ.\cos\theta = p.\cos\theta,$$

$$\frac{y}{p} = \cos\theta.$$

Squaring and adding,

$$\frac{x^2}{q^2} + \frac{y^2}{p^2} = \sin^2\theta + \cos^2\theta = 1. \qquad (4)$$

Maximum value of $\beta = \phi$, the angle of obliquity of stress on plane C-C. It can be seen in Fig. 4, that β will be a maximum when MR is perpendicular to RO. For suppose triangle MOR constructed with angle ORM not a right angle, drop a perpendicular from M to OR at R^1, then $\sin\beta^1 = \frac{MR^1}{OM}$. But MR^1 is less than MR, and β^1 will be less than β.

In this case since angle $ORM = 90°$,

$$OR^2 = OM^2 - RM^2,$$

$$r^2 = \left\{\frac{p+q}{2}\right\}^2 - \left\{\frac{p-q}{2}\right\}^2,$$

$$= p \cdot q,$$

$$\text{and } r = \sqrt{p \cdot q},$$

$$\text{also } \sin\phi = \sin\beta = \frac{p-q}{p+q},$$

$$\text{and transposing } \frac{q}{p} = \frac{1-\sin\phi}{1+\sin\phi}. \tag{5}$$

$$\begin{aligned} \text{now } 2\theta &= \text{angle } RMN, \text{ and} \\ \cos 2\theta &= \cos RMN, \\ &= -\cos ROM, \\ &= -\frac{MR}{OM}, \\ &= -\frac{p-q}{p+q}. \end{aligned}$$

Now in a granular mass the particles will tend to slide on each other, the angle ϕ being the angle of internal friction in which the coefficient of friction is $\mu = \tan\phi$.

From equation (5) if p represents the vertical stress at any point in an unlimited homogenous granular mass with a horizontal surface, the ratio of the vertical stress p to the horizontal component q will be $\frac{q}{p} = \frac{1-\sin\phi}{1+\sin\phi}$.

For a perfect fluid $\phi = 0$, and $p = q$ which we already knew.

The Retaining Wall.—Loose earth will remain in equilibrium with its face at slopes whose inclinations to the horizontal are less than an angle ϕ, which is called the angle of repose. If piled at a greater slope, cohesion will hold the face at a greater slope than ϕ for a time, but the earth will soon crumble down, until the slopes do not exceed ϕ.

Angle of Repose.—In (a) Fig. 6, two troughs filled with earth are acted upon by the two forces P and Q. The forces P tend to press the earth together, while the forces Q tend to cause slipping. If Q is just sufficient to cause slipping, then the coefficient of friction will be $\mu = \frac{Q}{P}$. Now if the forces Q are omitted and the forces P are inclined at an angle θ, when the earth is just on the

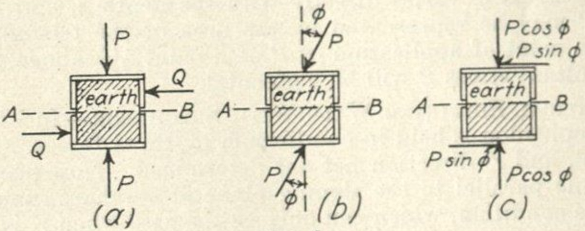


FIG. 6

point of slipping, angle θ will be equal to ϕ, the angle of repose and the coefficient of friction will be $\mu = \dfrac{P.\sin\phi}{P.\cos\phi} = \tan\theta$ which gives the relation between the coefficient of friction μ, and the angle of repose ϕ.

Now in a homogeneous unlimited, granular mass with a level surface, if p is the vertical and q is the horizontal stress at any point, then $\dfrac{q}{p} = \dfrac{1-\sin\beta}{1+\sin\beta}$, where β is the angle of obliquity of the resultant stress r. Now if there is to be equilibrium the obliquity, β, cannot be greater than ϕ, the angle of repose, and the greatest ratio between q and p will be $\dfrac{q}{p} = \dfrac{1-\sin\phi}{1+\sin\phi}$.

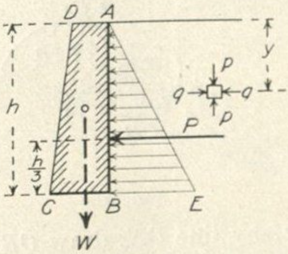


FIG. 7.

VERTICAL RETAINING WALL WITHOUT SURCHARGE.—In Fig. 7, a vertical wall supports a filling with a horizontal slope ($\delta = 0$). Then from the preceding discussion the horizontal pressure at any point will be $q = w.y.\dfrac{1-\sin\phi}{1+\sin\phi}$, where y is the depth and w is the weight of a cubic foot of earth, and the total pressure will be

$$P = \tfrac{1}{2}\, w.\, h.^2 \frac{1-\sin\phi}{1+\sin\phi}. \qquad (6)$$

The stress q, varies directly with the depth y, and the total stress P may be represented by the area of the triangle $A\,B\,E$, with the point of application of P at a point $\frac{1}{3}h$ above the base. The resultant stress P will be horizontal.

VERTICAL RETAINING WALL WITH SURCHARGE.—In Fig. 8, the parallelopidedon is held in equilibrium by three forces, r vertical, s normal, and r^1 direction not yet determined. Now every point in a plane parallel to the sloping plane of surcharge must be in the same condition, which can only be the case when r^1 is parallel to the plane of surcharge (this may be proved by means of the ellipse of stress).

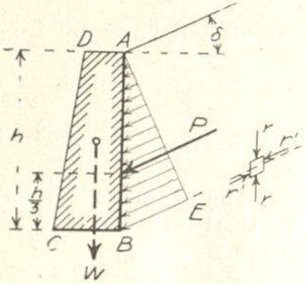


FIG. 8.

To find the ratio of the intensity of the conjugate stresses r and r^1 whose obliquity is δ, proceed as follows:

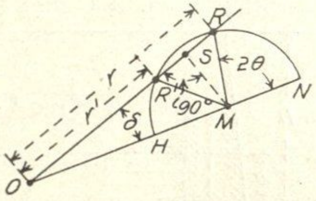


FIG. 9.

In Fig. 9, draw any line ON, draw OR making an angle δ with ON, lay off $OR = r$, and $OR^1 = r^1$, and from S, the middle point of RR^1 erect the perpendicular SM. Draw MR, MR^1, and arc HR^1RN.

Now $OM = \frac{p+q.}{2}$ and $MR = \frac{p-q}{2}$ as can be seen in Fig. 4.

$$\frac{OS}{OM} = \cos MOS, \text{ and solving}$$

$$OM = \frac{\frac{1}{2}\,(OR + OR^1)}{\cos\delta} = \frac{r + r^1}{2\cos\delta}.$$

But $OM = \frac{p+q}{2}$, and

$$\frac{p+q}{2} = \frac{r+r^1}{2\cos\delta}. \qquad \text{(a)}$$

Also $MR^2 = MS^2 + RS^2$,

$$\begin{aligned} &= (OM^2 - OS^2) + RS^2, \\ &= \left(\frac{p+q}{2}\right)^2 - \left(\frac{r+r^1}{2}\right)^2 + \left(\frac{r-r^1}{2}\right)^2, \\ &= \left(\frac{p+q}{2}\right)^2 - rr^1, \\ &= \left(\frac{r+r^1}{2\cos\delta}\right)^2 - rr^1. \qquad \text{(6)} \end{aligned}$$

Therefore, $\frac{p-q}{2} = \sqrt{\left(\frac{r+r^1}{2\cos\delta}\right)^2 - rr^1}$. (c)

From Fig 9 $\cos 2\theta = 2.r.\frac{\cos\delta - p - q}{p-q}$. (d)

Now squaring (a) and (c), and dividing (c) squared by (a) squared, we have $\left(\frac{p-q}{p+q}\right)^2 = 1 - \frac{4rr^1\cos^2\delta}{(r+r^1)^2}$.

But when earth is just in equilibrium

$$\frac{p}{q} = \frac{1+\sin\phi}{1-\sin\phi}, \text{ or } \sin\phi = \frac{p-q}{p+q}.$$

Therefore, $\sin^2\phi = 1 - \frac{4rr^1\cos^2\delta}{(r+r^1)^2}$, and

$$1 - \sin^2\phi = \cos^2\phi = \frac{4rr^1\cos^2\delta}{(r+r^1)^2},$$

$$\frac{\cos^2\phi}{\cos^2\delta} = \frac{4rr^1}{(r+r^1)^2},$$

$$(r+r^1)^2 = 4rr^1\frac{\cos^2\delta}{\cos^2\phi}. \qquad \text{(e)}$$

Now subtract $4rr^1$ from both sides and

$$(r-r^1)^2 = 4rr^1\left\{\frac{\cos^2\delta}{\cos^2\phi}-1\right\},$$

$$=4rr^1\frac{\cos^2\delta-\cos^2\phi}{\cos^2\phi}. \qquad \text{(f)}$$

Divide (f) by (e) $\left(\frac{r-r^1}{r+r^1}\right)^2 = \frac{\cos^2\delta-\cos^2\phi}{\cos^2\phi}\cdot\frac{\cos^2\phi}{\cos^2\delta},$

$$=\frac{\cos^2\delta-\cos^2\phi}{\cos^2\delta},$$

and $\frac{r-r^1}{r+r^1} = \pm\sqrt{\frac{\cos^2\delta-\cos^2\phi}{\cos^2\delta}}$. (g)

Now by composition and division

$$\frac{r}{r^1} = \frac{\cos\delta \pm \sqrt{\cos^2\delta-\cos^2\phi}}{\cos\delta \mp \sqrt{\cos^2\delta-\cos^2\phi}}. \qquad \text{(h)}$$

Now equilibrium of the wall will take place with the upper signs, and, reversing the fractions

$$\frac{r}{r^1} = \frac{\cos\delta - \sqrt{\cos^2\delta-\cos^2\phi}}{\cos\delta + \sqrt{\cos^2\delta-\cos^2\phi}}. \qquad \text{(i)}$$

Now r is equal to $w.x.$ cos δ, for the reason that the stress p is distributed over the area a sec δ, and

$$r^1 = w.x\cos\delta\,\frac{\cos\delta - \sqrt{\cos^2\delta-\cos^2\phi}}{\cos\delta + \sqrt{\cos^2\delta-\cos^2\phi}}. \qquad \text{(j)}$$

Now the maximum value of r^1 will be

$$r^1 = w\,h\cos\delta\,\frac{\cos\delta - \sqrt{\cos^2\delta-\cos^2\phi}}{\cos\delta + \sqrt{\cos^2\delta-\cos^2\phi}}. \qquad (7)$$

and

$$P = \tfrac{1}{2}\,w\,h^2\cos\delta\,\frac{\cos\delta - \sqrt{\cos^2\delta-\cos^2\phi}}{\cos\delta + \sqrt{\cos^2\delta-\cos^2\phi}}. \qquad (8)$$

Equations (6) and (8) are commonly called Rankine's Method. As such the method is very unsatisfactory. The two cases above are only special cases of the general method which follows.

INCLINED RETAINING WALL.—The ellipse of stress can be used to determine the resultant pressure on an inclined retaining wall. This solution determines the amount and direction of the resultant and leads to the same equations as deduced by Weyrauch by a much longer process.

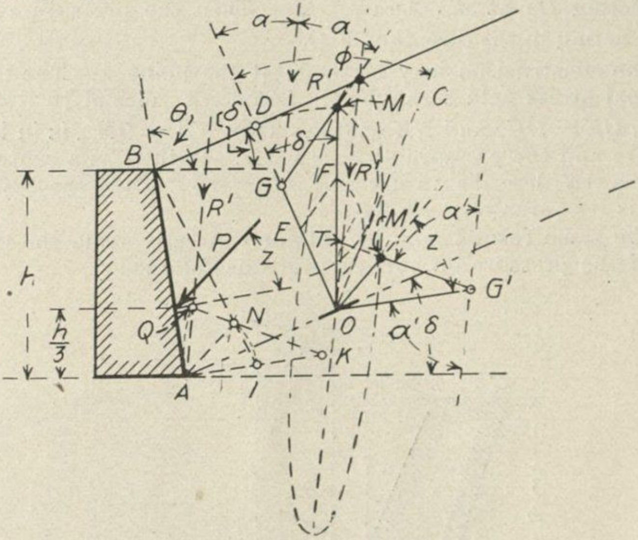


FIG. 10.

In Fig. 10 a retaining wall inclined at the angle θ with the horizontal sustains the pressure of a filling with a surcharge δ. The angle of repose of the filling is ϕ.

Ellipse of Stress at Point A.—Through A draw AO parallel to the top surface, and at any convenient point O, in AO, draw OD normal to AO. With point O as a center and a radius OD describe an arc intersecting a vertical line OM at the point M. Draw OC making an angle ϕ with OD. At any point E in OG describe an arc which shall be tangent to OC and cuts the vertical OM at F. Draw EF, and through M draw MG parallel to EF. Bisect the angle DGM, and draw $R'G$. Through O draw OR' parallel to $R'G$. Now $OM.w$ is the stress, r, on the plane A-O, $OG = \dfrac{p+q}{2}$ and $GM = \dfrac{p-q}{2}$; OG and GM make equal angles with the principal axis OR'. If OG revolves around O, and GM around G; OG and GM always making equal angles with the principal axis OR', the ellipse of stress will be described as shown. To determine the cussing this method have failed to understand the underlying principles. The objection that the angle z may be greater than ϕ is not founded on fact, as is shown in Figs 10 and 11.

COULOMB'S WEDGE OF MAXIMUM THRUST.

Algebraic Method.—In Fig. 12, the wall with a height h, slopes toward the earth being inclined to the horizontal at an angle θ, and the earth has a surcharge with slope δ, which is not greater than ϕ, the angle of repose. It is required to find the pressure P against the retaining wall, it being assumed that the resultant pressure makes an angle z with the back of the wall.

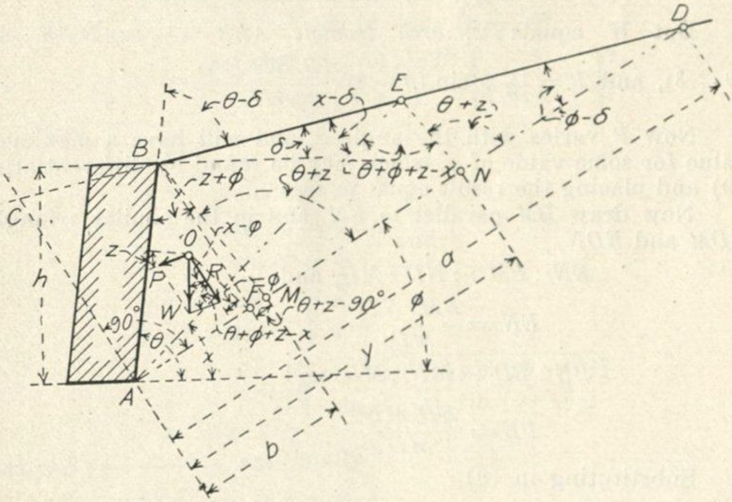


FIG. 12.

It is assumed that the triangular prism of earth above some plane the trace of which is the line AE will produce the maximum pressure on the wall and on the earth below the plane, and that in turn the prism will be supported by the reactions of the wall and the earth. Let OW represent the weight of the prism ABE, the length of the prism being assumed equal to unity, let OP be the reaction of the wall, and OR be the reaction of the earth below.

Now the forces OW, OP, and OR will be concurrent and will be in equilibrium; OP and OR will therefore be components of OW. When the prism ABE is just on the point of moving OP will make an angle with the back of the wall equal to z (different authorities assume values of z from zero to ϕ^1, the angle of friction of earth on masonry, or ϕ, the angle of friction of earth on earth); while OR will make an angle with the normal to the plane of rupture AE equal to ϕ. Let P represent the pressure OP against the wall, W represent the weight of the prism of earth and w the weight per cubic foot.

In the triangle OWR angle $WOR = x - \phi$, and angle $ORW = \theta + \phi + z - x$. Through E draw EN, making the angle $AEN = \theta + \phi + z - x$ with AE. Then the triangle AEN is similar to triangle ORW, and

$$\frac{P}{W} = \frac{EN}{AN}\text{, and}$$

$$P = W\frac{EN}{AN}.$$

But W equals w. *area triangle* $ABE = \tfrac{1}{2} w.AB.BE.$ sin $(\theta - \delta)$, and

$$P = \tfrac{1}{2} w.\sin(\theta - \delta)\frac{AB.BE.EN}{AN}. \qquad (9)$$

Now P varies with the angle x, and will have a maximum value for some value of x, which may be found by differentiating (9) and placing the result equal to zero.

Now draw BM parallel to EN, and in the similar triangles BDM and EDN,

$$EN : BM :: ND : MD\text{, and}$$

$$EN = \frac{BM.ND}{MD}.$$

$$BE : BD :: MN : MD\text{, and}$$

$$BE = \frac{BD.MN}{MD}.$$

Substituting in (9)

$$P = \tfrac{1}{2} w.\sin(\theta - \delta)\frac{AB.BM.BD}{MD^2}\left\{\frac{MN.ND}{AN}\right\}. \qquad (10)$$

Where all the variables are in parenthesis. It will be seen that EN moves parallel to its present position as x varies. Now let $AN = y$, $AD = a$, and $AM = b$, and then

$$\frac{MN.ND}{AN} = \left\{\frac{(y - b)(a - y)}{y}\right\}. \qquad (11)$$

Differentiating (11) and placing the result equal to zero; we have a maximum when $y = \sqrt{ab}$.

Substituting in (10) we have

$$P = \tfrac{1}{2} w.\sin(\theta - \delta)\frac{AB.BM.BD}{MD^2}\cdot\frac{(a - \sqrt{ab})^2}{a}. \qquad (12)$$

But $a = AD = AB \dfrac{\sin(\theta - \delta)}{\sin(\phi - \delta)}$,

$$MD = a - b,$$

$$BD = AB \frac{\sin(\theta - \phi)}{\sin(\phi - \delta)},$$

$$BM = AB \frac{\sin(\theta - \phi)}{\sin(\theta + z)}.$$

Substituting in (12)

$$P = \tfrac{1}{2} w \frac{\sin^2(\theta - \phi)\, AB^2 \,(a - \sqrt{ab})^2}{\sin(\theta + z)\,(a - b)^2},$$

$$= \tfrac{1}{2} w \frac{\sin^2(\theta - \phi)\, AB^2}{\sin(\theta + z)} \left\{ \frac{1}{1 + \sqrt{\frac{b}{a}}} \right\}^2.$$

Now

$$\frac{AM}{AB} = \frac{\sin(z + \phi)}{\sin(\theta + z)},$$

$$\frac{AB}{AD} = \frac{\sin(\phi - \delta)}{\sin(\theta - \delta)}, \text{ and}$$

$$\sqrt{\frac{AM}{AB} \cdot \frac{AB}{AD}} = \sqrt{\frac{b}{a}},$$

$$= \sqrt{\frac{\sin(z + \phi).\sin(\phi - \delta)}{\sin(\theta + z).\sin(\theta - \delta)}},$$

also, $AB = \dfrac{h}{\sin\theta}$, and finally

$$P = \tfrac{1}{2} w h^2 \frac{\sin^2(\theta - \phi)}{\sin^2\theta.\sin(\theta + z)\left\{1 + \sqrt{\dfrac{\sin(z + \phi).\sin(\phi - \delta)}{\sin(\theta + z).\sin(\theta - \delta)}}\right\}^2}. \tag{13}$$

$$= \tfrac{1}{2} w h^2 K. \tag{14}$$

which is the general formula for the pressure on a retaining wall.

Now if z in (13) is made equal to ϕ, the angle of repose of earth on earth,

$$P = \tfrac{1}{2} w h^2 \frac{\sin^2(\theta - \phi)}{\sin^2\theta.\sin(\theta + \phi)\left\{1 + \sqrt{\dfrac{\sin^2\phi.\sin(\phi - \delta)}{\sin(\theta + \phi).\sin(\theta - \delta)}}\right\}^2}. \tag{15}$$

which is Cain's Formula.

If z in (13) is made equal to δ, and θ made equal to 90°,

$$P = \tfrac{1}{2} w h^2 \frac{\cos^2\phi}{\cos\delta \left\{1+\sqrt{\dfrac{\sin(\phi+\delta).\sin(\phi-\delta)}{\cos^2\delta}}\right\}^2}. \tag{16}$$

which is Rankine's Formula in another form.

If z in (13) is made equal to zero,

$$P = \tfrac{1}{2} w h^2 \frac{\sin^2(\theta-\phi)}{\sin^3\theta \left\{1+\sqrt{\dfrac{\sin\phi.\sin(\phi-\delta)}{\sin\theta.\sin(\theta-\delta)}}\right\}^2}. \tag{17}$$

which gives the normal pressure on a wall.

If θ in (17) = 90°,

$$P = \tfrac{1}{2} w h^2 \frac{\cos^2\phi}{\left\{1+\sqrt{\dfrac{\sin\phi.\sin(\phi-\delta)}{\cos\delta}}\right\}^2}. \tag{18}$$

If δ in (18) = 0°,

$$P = \tfrac{1}{2} w h^2 \frac{\cos^2\phi}{(1+\sin\phi)^2},$$

$$= \tfrac{1}{2} w.h^2 \tan^2\left\{45^\circ - \frac{\phi}{2}\right\}. \tag{19}$$

$$= \tfrac{1}{2} w h^2 \frac{1-\sin\phi}{1+\sin\phi}. \tag{20}$$

which is Rankine's Formula for a vertical wall without surcharge.

Graphic Method.—In Fig. 13 the retaining wall AB sustains the pressure of the filling with a surcharge δ, and an angle of repose ϕ. It is required to calculate the resultant pressure P.

In similar triangles BMD and END,

$$EN : BM :: ND : MD, \text{ and}$$

$$EN : BM :: (a-y) : (a-b),$$

$$EN = BM \frac{(a-y)}{(a-b)}. \tag{21}$$

In similar triangles ENA and QMA,

$$EN : QM :: y : b,$$

$$EN = QM \frac{y}{b}.$$

Equating the two values of *EN*,

$$BM\frac{(a-y)}{(a-b)} = QM\frac{y}{b}, \text{ and}$$

$$BM : QM :: \frac{y}{b} : \frac{a-y}{a-b}, \text{ and by}$$

subtraction

$$BM - QM : BM :: \frac{y}{b} - \frac{a-y}{a-b} : \frac{y}{b},$$

$$BQ = BM\frac{a(y-b)}{b(a-b)}\frac{b}{y} = BM\frac{ay-y^2}{(a-b)y},$$

$$= BM\frac{(a-y)}{(a-b)} = EN. \qquad (21)$$

Therefore triangle *ABE* = triangle *AEN*.

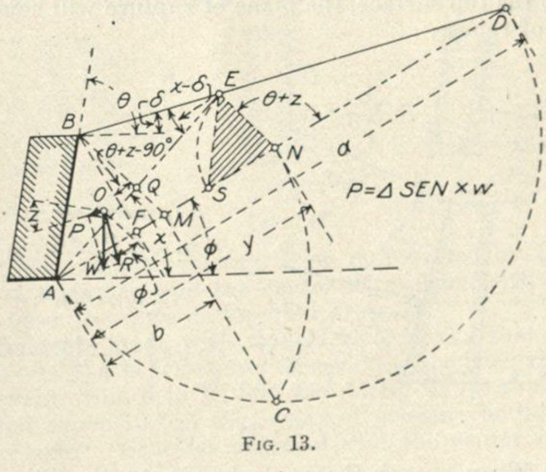


FIG. 13.

$$\text{Now } P = W\frac{\sin(x-\phi)}{\sin(\theta+\phi+z-x)}, \text{ and} \qquad (22)$$

$$W = \textit{area triangle } ABE.w,$$
$$= \textit{area triangle } AEN.w. \qquad (23)$$

Now in triangle *AEN*,

$$\frac{EN}{AN} = \frac{\sin(x-\phi)}{\sin(\theta+\phi+z-x)}, \qquad (24)$$

and area triangle $AEN = \tfrac{1}{2} EN.AN.\sin(\theta+z)$.

From equations (22), (23), and (24)

$$P = \text{area triangle } AEN \frac{EN}{AN} w,$$

$$= \tfrac{1}{2} EN^2 \sin(\theta + z)\, w. \qquad (25)$$

Now in triangle SEN, $SN = EN$, and area $SEN = \frac{1}{2} EN^2 \sin (\theta + z)$, and (26)

$$P = \text{area triangle } SEN.w. \qquad (27)$$

The angle of rupture, x, and the resultant pressure, P, can therefore be calculated graphically as follows:

Through B draw BM making an angle with BF, the normal to AD, equal to $\theta + z - 90°$, the angle that P makes with the horizontal. With diameter AD, describe arc ACD, and $AN = y$. Draw EN parallel to BM. With N as a center and radius EN describe arc ES. Then AE is the plane of rupture, and $P = \triangle SEN.w$.

Where the surcharge $\theta = \phi$ the angle of repose, and P is parallel to the top surface, the plane of rupture will coincide with the plane of repose.

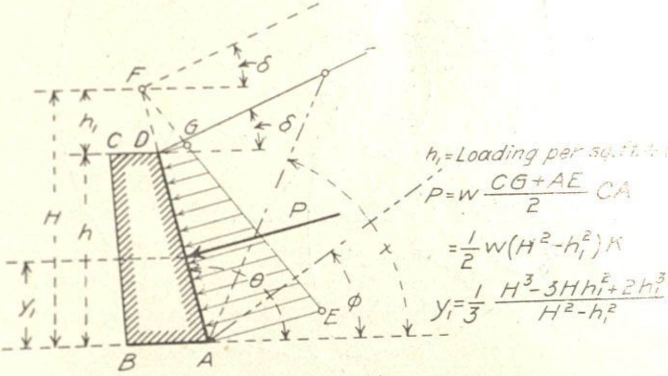


FIG. 14.

WALL WITH LOADED FILLING.—In Fig. 14, the filling is loaded with a uniformly distributed load. Calculate h_1 by dividing the loading per square foot by w. Let $h + h_1 = H$. Then the resultant pressure for a wall with height H, will be

$$P_2 = \tfrac{1}{2} wH^2K, \text{ and} \qquad (28)$$

the resultant pressure for a wall with height h_1, will be

$$P_1 = \tfrac{1}{2} wh_1^2K. \qquad (29)$$

The pressure on the wall AD will be

$$P = P_2 - P_1 = \tfrac{1}{2} w (H^2 - h_1^2) K, \qquad (30)$$

and the point of application is through the center of gravity of *ADGE*, which makes

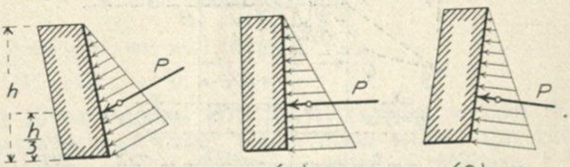
$$y_1 = \tfrac{1}{3}\,\frac{H^3 - 3\,Hh_1^2 + 2h_1^3}{H^2 - h_1^2}. \qquad (31)$$

DESIGN OF RETAINING WALLS.

CENTER OF PRESSURE.—It will be seen that for all cases the resultant pressure on the back of the wall will be given by the formula

$$P = \tfrac{1}{2}\, w\, h^2 K. \qquad (14)$$

Where K is the ratio of the horizontal to the vertical pressure, and is independent of the weight of the filling or the height of the wall, and depends upon the inclinations of the back of the wall, θ, the angle of repose, ϕ, the angle of surcharge, δ, and the angle that the resultant thrust makes with a normal to the back of the wall, z. For any particular wall, K will be a constant and the unit pressure at any point will vary as the height h. In Fig. 15, the resultant pressure, P, is represented by the area of the shaded triangles, and the center of pressure will be at $\tfrac{1}{3}h$ from the base, the same as for fluid pressure.



(a) (b) (c)

FIG. 15.

Experiments made with models have shown that the center of pressure $= \tfrac{1}{3}h$ is sometimes exceeded. Goodrich recommends that for walls from 6 to 10 feet the center of pressure be taken at $0.4\,h$ and above 10 feet the center of pressure be taken at $\tfrac{1}{3}h$ above the base.* Scheffler assumed that the center of pressure is at $0.4\,h$.

It should be remembered that experiments have been made on small models and are liable to considerable error. It would appear reasonable with our present knowledge to always take the center of pressure at a point $\tfrac{1}{3}h$ above the base.

STABILITY OF RETAINING WALLS.—A retaining wall must be stable (1) against overturning, (2) against sliding, and (3) against crushing the masonry or the foundation.

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* Trans. Am. Soc. C. E., Vol. LIII, p. 295.

Overturning.—In Fig. 16, let P, represented by OP', be the resultant pressure of the earth, and W, represented by OW, be the weight of the wall acting through its center of gravity. Then E, represented by OR, will be the resultant pressure tending to overturn the wall.

Draw OS through the point A. For this condition the wall should be on the point of overturning, and the factor of safety against overturning would be unity. The factor of safety for $E = OR$ will be $f_0 = \dfrac{SW}{RW}$. (32)

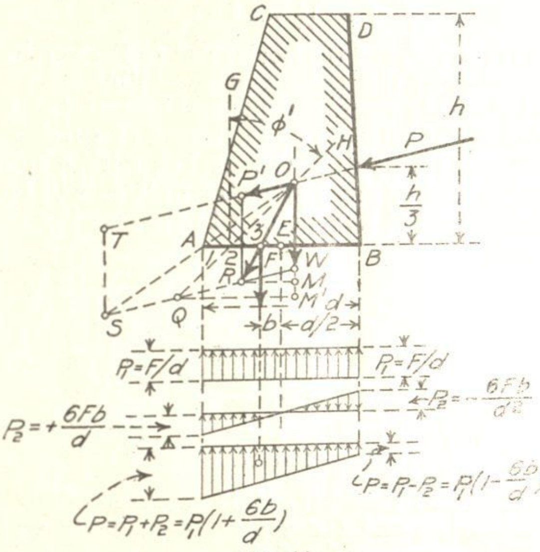


FIG. 16.

Sliding.—In Fig. 16 construct the angle $H2G$ equal to ϕ^1, the angle of friction of the masonry on the foundation. Now if E passes through 2, and takes the direction OQ, the wall will be on the point of sliding, and the factor of safety against sliding, f_s, will be unity. For $E = OR$, the factor of safety against sliding will be $f_s = \dfrac{QM^1}{RM}$. (33)

If the resultant at 3 be resolved into a vertical force F, and a horizontal force H (not shown in Fig. 16), then

$$f_s = \frac{F}{H} \tan \phi^1 \qquad (34)$$

which will give the same result as above.

Retaining walls seldom fail by sliding.

Crushing.—In Fig. 16 the load on the foundation will be due to a vertical force F, which produces a uniform stress $P_1 = \frac{F}{d}$ over the area of the base, and a bending moment $= F.b$, which produces compression, P_2, on the front and tension, P_2, on the back of the foundation. The sum of the tensile stresses must equal the sum of the compressive stresses due to bending $= \frac{1}{4} P_2 d$. These stresses act as a couple through the centers of gravity of the stress triangles on each side, and the resisting moment is

$$M^1 = \tfrac{1}{4} P_2\, d.\, \tfrac{2}{3}\, d = \tfrac{1}{6} P_2\, d^2. \tag{35}$$

But the resisting moment equals the overturning moment and

$$\tfrac{1}{6} P_2\, d^2 = F b, \text{ and}$$

$$P_2 = \pm \frac{6 F b}{d^2}. \tag{36}$$

The total stress on the foundation then is

$$P = P_1 \pm P_2 = P_1 \left(1 \pm \frac{6b}{d}\right). \tag{37}$$

Now if $b = \frac{1}{6}\, d$, we will have

$$P = 2P_1, \text{ or } 0.$$

In order therefore that there be no tension, or that the compression never exceed twice the average stress the resultant should never strike outside the middle third of the base.

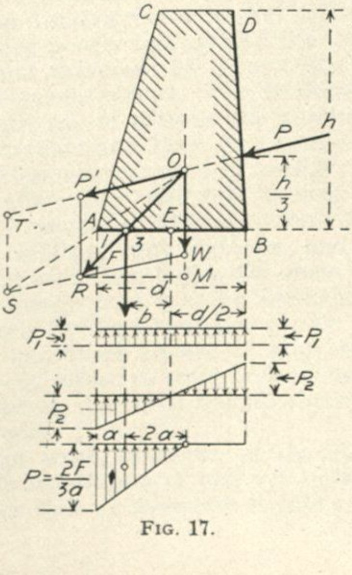


FIG. 17.

If the resultant strike outside of the middle of a wall in which the masonry can take no tension, the load will all be taken by compression and can be calculated as follows:

In Fig 17, the resultant F will pass through the center of gravity of the stress diagram, and will equal the area of the diagram.

$$F = \frac{3}{2} Pa, \text{ and}$$

$$P = \tfrac{2}{3} \frac{F}{a}. \qquad (38)$$

which gives a larger value of P than would be given if the masonry could take tension.

PROBLEMS OF THE ILLUMINATING ENGINEER.

By Norman Read, B. S. (E. E.), 1905.

The science of illumination or Illuminating Engineering is still in its infancy and is growing to be one of the most important to the modern central station manager. Since the advent of gas and electricity for illuminating purposes these agents have practically driven all others from the commercial field.

In former years people were satisfied to get any artificial light that would enable them to distinguish objects but now the demand is for a lighting that in effect will approach nearest to that given by daylight.

There are two general phases of illumination which present absolutely different problems, that of outdoor and that of interior lighting. These again are divided into spectacular and decorative work.

In nearly all illumination electricity has superseded gas on account of ease of distribution and in interior work on account of the absence of fumes and heat.

Perhaps the most important branch of outdoor illumination is that of street lighting. Formerly in this work large units such as arc lights, etc., were used at the street intersections. This mode of lighting had its disadvantages in that points midway between the lamps were very poorly lighted and the large units tended to dazzle the eyes and therefore by comparison to make the dark spots look just so much darker. The modern practice therefore is to use small units say of fifty to one hundred candle power at more frequent intervals and thus give a more even distribution with the same or less consumption of energy. In some instances gas can be very effectively used but its cost of installation and distribution of light makes it inferior to the electric light.

Spectacular lighting, both exterior and interior, must be designed to attract attention, but at the same time set off lines of buildings or any design that is to be accentuated. This work is done almost entirely by the use of low candle power incandescent lamps with here and there an arc of high candle power as the central point. Very effective work indeed may be accomplished as has been shown at the three recent expositions, viz: Buffalo, Omaha and St. Louis.

The important work, however, of the illuminating engineer is the design and installation of interior lighting. This problem not only embraces that of adequate lighting with the least consumption of energy, but that of properly selecting and placing the lamps and the general decorative effect. Too small units cannot be used on account of having to place them so low that they hang below the line of vision, and too large units will give spotty effects. For figuring the light on any given space it has been the custom to compute by the law of inverse squares, viz: that the illumination in candle feet on a given plane is equal to the candle power divided by the square of the distance. This, however, holds true only for a point source of light and is therefore not applicable for use with Incandescent, Nernst, Tube lights or any form where the light is distributed along a light giving element. To obviate this, instead of computing on a candle power basis, it is simpler to find by experiment with the various lamps, by comparing the useful candle power and watts consumed, the mean number of watts required per square foot of illuminated surface, with lamps hung at given heights, and having found the required number of lights, by a study of the distribution curves of the units, to decide upon the plan of arrangement.

The color quality of the light is also a very important factor and must be taken into consideration. For hardware stores, machine shops, etc., the problem resolves itself into a consideration of quantity and not of quality. The light required for such places must be well diffused and placed in such a manner that all dark corners are illuminated and all shadows practically done away with. On this account the lighting of such places by means of the mercury vapor lamp and vacuum tubes is gaining in favor. On the other hand the lighting of department stores and places where colors are shown, demands that the quality of light be as near that of daylight as possible. Now the light from most artificial illuminants is lacking in one or the other of the spectrum colors and this must be suppplied by the use of some kind of corrective globe or shade. There are many forms of these and most of them are made to act also as diffusers of the light. The use of reflectors is a very important item and these must be selected for the special work which they are to perform. No lamp without shade, globe, or reflector has a distribution that can be practically used. By the study of the distribution and the proper selection of reflectors the lamps may be so chosen that the illumination becomes equal at all points.

Window or display lighting has become a very important part of the work and is a branch that requires special study of its conditions. Where windows are to be illuminated to attract attention and not to show goods, the lights are generally arranged in some decorative way in full view of the passerby. Where the idea is to show goods, however, the lamps must be arranged to light the goods brilliantly but must be placed in such a manner that they will be shielded from the person looking in the window. This again is accomplished by the use of reflectors, generally made of polished metal or silvered glass. Bare lamps in a window cause a dazzling light that paralyzes the eye and causes the rest of the window to look comparatively dark.

The above are only a few of the problems that confront the modern illuminating engineer. He must be a thoroughly up-to-date, practical engineer and must be conversant with every form of artificial lighting, not only must he know of them, but he must be thoroughly acquainted with the light quality, the distribution of light, and the efficiency. He must be resourceful, and be able to tell at a glance what form of lighting is best adapted to any particular condition. This branch of engineering is becoming more important every day and the illuminating problem has now become a science instead of guesswork.

THE INCREASE IN THE ELECTRICAL RESISTANCE OF CONCRETE.

By R. W. Pereau, Electrical Engineering, 1906.

In the course of experimental work in concrete, the increase in electrical resistance of some specimens was observed. The accompanying curves show the variation of resistance with time, in two cases.

The concrete from which curve A was derived, was made of Puzzolan cement, sand and broken stone, in the proportions, 1, 3 and 5. In the other case, the proportions were 1, 3, and 6. In both instances the concrete was in a small wooden box, holding about one cubic foot.

For good contact, the connecting wires were soldered to cylindrical bars of mild steel about seven inches long, and four inches apart, in the first box; and to wrought iron bars of about the same size, but six inches apart, in the second box. After soldering the wires to the metal, the joints were wound with insulating tape, coated with shellac and allowed to dry. In both cases the concrete was well tamped around the pieces.

The concrete was allowed to partially "set" for four days, when 110 volts, direct current, was applied to the terminals of each box, and from this time resistance measurements were taken at intervals of twenty-four hours.

The experiment was conducted in a room that was kept at a temperature of 65° to 75° F. The concrete had no chance to freeze, but dried rapidly, no attempt being made to keep it moist.

The curves, plotted with days as abscissae, and ohms (in thousands) as ordinates, show interesting relations between the coördinates.

From a study of the conditions, the increase of resistance was undoubtedly due to some or all of the following causes:

1. The drying out of the concrete.
2. The "setting" of the concrete.
3. Some chemical change in the concrete caused by the passage of the electric current through it.
4. Possible changes in the electrical contact resistance.

The first mentioned may be the main factor, as the increase in resistance of earth and stone due to loss of moisture is a well known fact.

According to the best chemical authorities, the real setting of concrete seems to take place about fifteen days after mixing.

Both curves would indicate that some radical change took place in the chemical composition of the mixture, after it had been mixed about twenty days. This was probably caused by the setting which might have been delayed slightly by the electric current.

Nothing very definite is known concerning the chemical reactions which take place during the setting of cement. In his "Dictionary of Applied Chemistry," F. E. Thorpe says: "The subject is one of great difficulty; researches, some of an elaborate nature, carried on during the last hundred years, have not entirely satisfied our want of knowledge of the cause of the setting of cements, whether of natural or artificial origin."

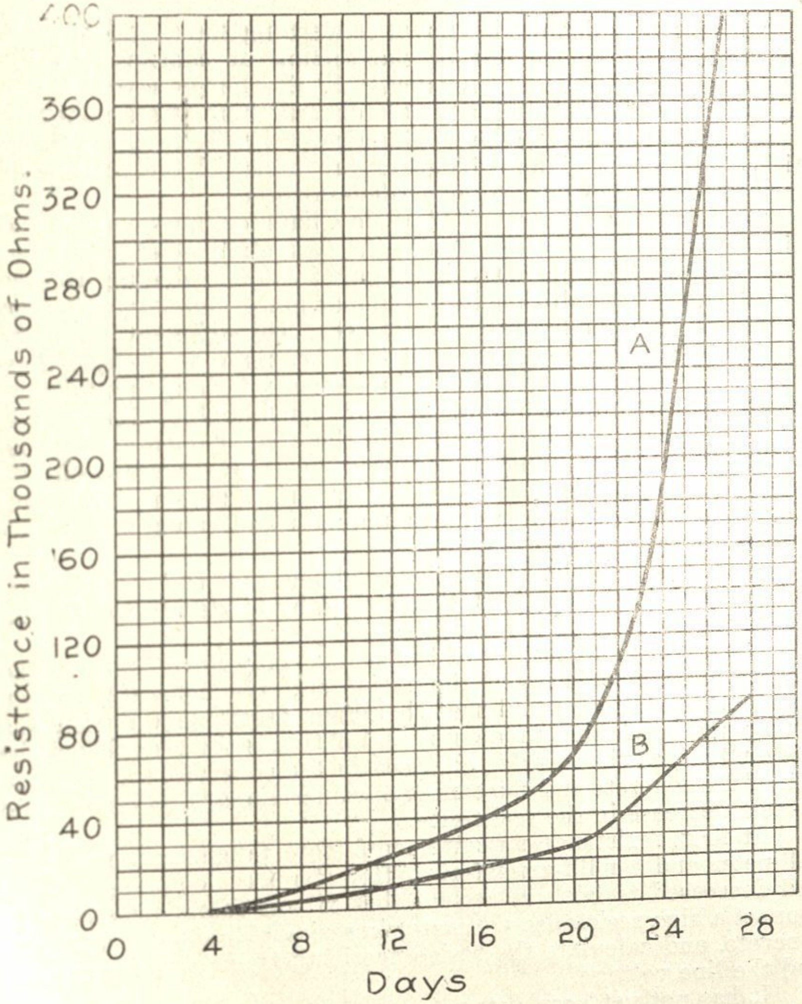
In giving the researches of M. le Chatelier, he says: "The action of water on cements causes the formation of several compounds; that which plays the chief part in the hardening process is a substance crystallizing in hexagonal plates, analogous to the crystals of calcium hydrate, $Ca\ H_2\ O_2$. No sufficient quantity has been obtained to make it possible to determine its composition. * * * In quickly setting aluminous cements long needles are formed which interlace and are of considerable dimensions. * * * The setting is caused, as in the case of plaster of paris, by the cement becoming a confused mass of crystals of the hydrated compounds mentioned" (hydrated crystalline orthocalcic silicate, hydrated calcium aluminate and calcium alumino-ferrite).

Now it is possible, as mentioned above, that the electric current delayed, to some extent, the setting, by hindering the formation of the crystals of the hydrated compounds.

The drying and setting of the cement may have changed the contact resistance between the metal and the concrete. From works on concrete we find that shrinkage takes place during the setting and hardening processes; and if this is the case, it will be evident that, as the metal is enclosed in the concrete, the contraction of the concrete and the consequent increase of pressure should cause a decrease in the resistance.

At first, resistance measurements were taken by means of a voltmeter and a milli-ammeter. After about a week, the current had decreased to such an extent that it was found necessary to connect a high resistance voltmeter in series with a box containing concrete, and calculate the resistance in the box from its reading and the line voltage.

It has not yet been determined whether a similar increase in resistance takes place with different proportions of cement, sand and broken stone, or as to the effect of other conditions, but experiments now in progress take account of these variables, and other data will be available soon.


Resistance in Thousands of Ohms.
400
360
320
280
240
200
160
120
80
40
0
A
B
0
4
8
12
16
20
24
28
Days

THE DESIGN OF DIRECT CURRENT ELECTRICAL INSTALLATIONS FOR INDUSTRIAL PLANTS.

By F. A. Wardenburg, B. S. (E. E.), 1900.

In the following article some hints are given in regard to the design and installation of direct current systems for industrial plants. It will be understood, however, that no hard and fast rules can be laid down for the installation of all plants, but certain general principles can in almost all cases be observed, which principles it is the purpose of this article to treat.

Voltage.—The standard voltage for the majority of present day installations of this type is 220. It is chosen in preference to 110 for the saving in copper, and in preference to 550 because of its greater safety in case of accidental contact by an unintelligent class of labor; and for the more important reason, the possibility of using the same generators for both lighting and power. It is entirely satisfactory and practicable to use a voltage of from 220 to 250 for lighting, notwithstanding that the efficiency and life of incandescent lamps are lowered, together with the efficiency of the arc lamp.

Switchboards.—One panel should be provided for each generator, equipped usually with one triple pole switch, one circuit breaker, one ammeter, one voltmeter switch receptacle for throwing the generator across the voltmeter busses, and the necessary devices for the control of the field circuit. The bringing of the equalizer to the switchboard, rather than the use of a switch near the generator to throw the machine on to the equalizing bus, is strongly advised, as, although requiring a slight increase in the amount of copper used, it is much simpler, and less liable to cause trouble due to forgetfullness on the part of the attendant.

There should be provided an ample number of feeder circuits and no greater mistake can be made in designing an extensive plant than to economize on the number of these circuits. Each circuit should be provided with a double pole switch, a circuit breaker, and a pilot lamp, which will indicate from a distance just what circuits are on or off.

Design of Copper.—Having laid out the lines of the distributing system, the computations for the sizes of wire to be used is the next operation to be performed. This is usually done by the well known formula:

$$CM = 21.6 \frac{L \times A}{e},$$

where CM is the area of the required wire in circular mils, L the length of the line one way in feet, A the current to be carried in amperes and e the allowable drop on the line in volts. It may sometimes be found convenient to make a table containing these various quantities, and also the product $21.6 \times L \times A$. After a little experience the designer will be enabled to easily estimate the drop and size of wire for any section of line after this product is known.

MOTORS.—In selecting the size of motors it will be found an excellent plan to adopt standard sizes of a standard make, making use of three or four of these sizes. In case of an intermediate size being theoretically required, the next larger size should be chosen. This plan minimizes the repair parts necessary to be kept on hand, decreases the number of sizes of brushes to be kept in stock, and in case of several motors of the same size, allows the carrying of a spare armature, or even an extra motor, thus providing a reserve, which will reduce to a minimum delays from accidents to motors.

Only in exceptional cases should motors be hung on ceilings or walls. They will be more accessible and freer from vibration if set on a solid foundation near the floor level. In dusty locations they may advantageously be placed in separate rooms, made possibly of light stuff, and having the partition on the pulley end closed around the back bearing, leaving the pulley outside of the motor room. This is preferable to cutting holes in a partition for the belt to run through, as in the former plan dust carried with the belt cannot reach the motor.

In cases where motors must start machinery having great inertia, especially if the location be subject to very cold weather, causing all bearings to be stiff, motors with a compound winding may be employed. This will increase the torque on starting, and with a starting rheostat of liberal design, will allow of the starting of the machinery without undue strain on the motor. This assumes that the variation in speed caused by the compounding will not be objectionable.

For varying the speed of the usual shunt wound motor, a rheostat in series with the field will give a variation of 25%. In cases where this is insufficient, resort may be had to special motors built by various manufacturers. For pumping, the variation of 25% will be found quite satisfactory, assuming that the improved type of centrifugal pump is used. The delivery of this pump decreases more rapidly than the actual decrease in speed, so that a 25% variation will provide a much larger variation in the water delivered, the limits being usually far enough apart for satisfactory service.

MOTOR WIRING.—It will be found a most excellent idea to provide for each large motor a starting panel, on which is mounted a knife switch, a circuit breaker and an automatic release starting rheostat. The use of a circuit breaker on each motor will be found a profitable investment in the time saved in case a motor is at any time over loaded, as there are no fuses to replace, and in addition a more reliable protection to the motor is provided. The starting rheostat should in all cases be of the automatic release type, unless the size is prohibitive. This is made necessary on account of the class of labor usually employed in the industrial plant.

In cases where it is necessary to know the amount of power used by a motor, so that an exact charge may be made against the department in which the motor is used, an integrating wattmeter may be connected permanently in the motor circuit. It has been the experience of the writer that a curve drawing instrument is not suitable for this work under ordinary conditions, on account of the manual labor necessary to arrive at the amount of power used, and the inaccuracy of the curve if the load is variable.

TROLLEY WIRING.—The electric locomotive is now coming into general use, and provides a most satisfactory means from the standpoint of continuous service for handling material, when the amount of material handled justifies the expense. In designing these installations a separate study of each case must be made, some little experience being required to provide a system of wiring that will be entirely free from interruptions of service.

CRANE WIRING.—The method of carrying the line wires for cranes is as a rule determined by the crane manufacturers, and may, except in extraordinary instances, be followed.

LIGHTNING PROTECTION.—A most satisfactory installation from the standpoint of efficiency and appearance, may be made by placing the lightning arresters and accessories in a small building outside of the power plant. A choke coil and lightning arrester should be provided on each side of each feeder circuit, unless one side of the circuit is grounded. At several points on the line also, depending on the extent of the system, arresters should be installed. A few dollars expended in this way may be the cause of a large saving at some future date.

DESCRIPTION OF AN INDIVIDUAL INSTALLATION.—To illustrate some of the points in the foregoing article, there is appended a brief description of an extensive installation recently designed by the writer, and now in course of construction. The direct current installation only is described, although an alternating current plant of 800 K. W. capacity is to be installed at the same place to furnish light and power to apparatus at some distance from the plant.

The two 400 K. W. generators are of General Electric make, direct connected to Nordberg cross compound Corliss engines, the voltage being 230 at no load, and 250 at full load. The generator leads are of double 1,500,000 circular mils section, and are taken to the switchboard under the reinforced concrete floor, which is placed over a fully excavated basement.

The switchboard consists of two generator panels of ordinary construction, an integrating wattmeter being, however, provided on each generator to measure the total output. Six feeder panels of two circuits each are provided, two circuits being used for electric locomotives, one for cranes, one for electric pumps, three for general motor circuits, one for office and shop lighting, two for general inside lighting, one for outside lighting, and one for future use. Each circuit is provided with a circuit breaker, switch and pilot lamp.

The distributing system is shown on the diagram accompanying this description, which is, however, not complete. From the feeder panels, the wires are led underground to the main pole line running through the plant. These wires at the end of the underground conduit pass into the lightning arrester house, placed between the four poles shown, which form part of the main pole line. On the walls of this house are mounted the choke coils and lightning arresters, two for each circuit. The wires are thence run up the poles to connect with the line wires.

From this main line, which on account of the weight of the wires to be borne, is made of two poles set side by side, with crossarms between them, branch lines are run at right angles to reach the different buildings, these branches being in all cases of single poles.

Four sizes of motors have been adopted as standard, as follows:

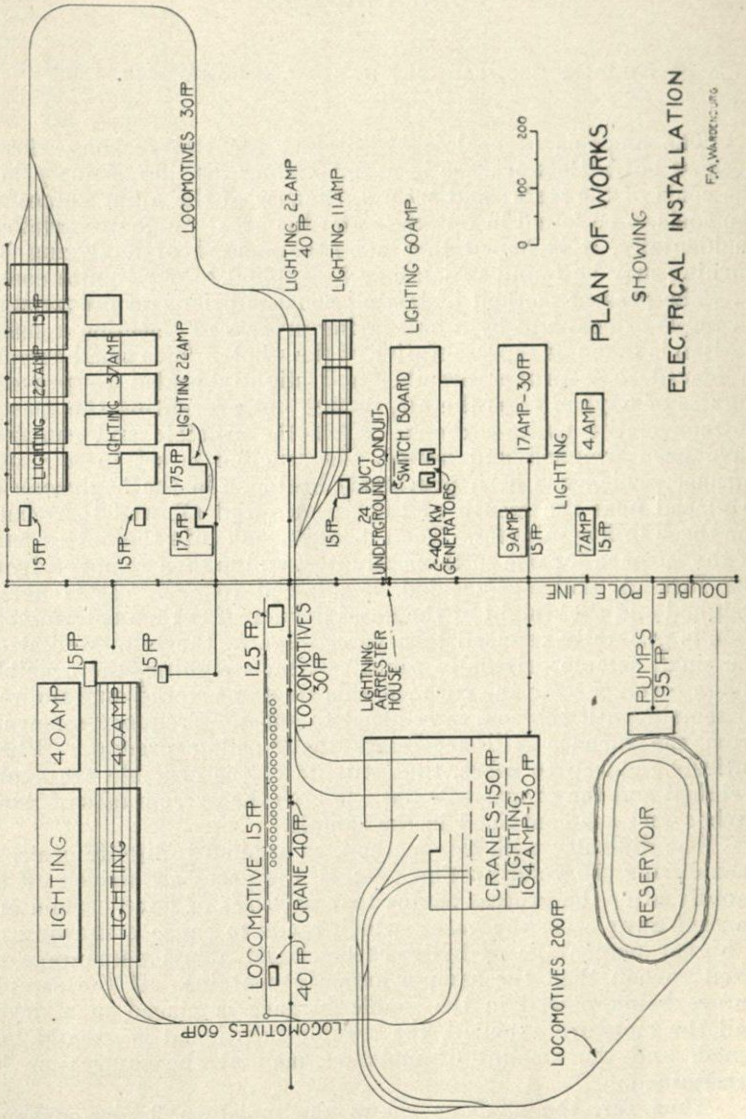
Fifteen horse power, of which there are fifteen.
Forty horse power, of which there are three.
Sixty-five horse power, of which there are three.
Eighty-five horse power, of which there are six.

Each motor has its own black enameled slate panel, having mounted upon it a circuit breaker, fusible knife switch, automatic release starting rheostat, and ammeter. All motors and panels are of General Electric make.

There will also be installed nine electric locomotives, requiring five miles of trolley wire, and three electric cranes, each having four motors.

The lighting system consists of ninety-five 220 volt multiple arc lamps, and some eight hundred 240 volt incandescent lamps, both on the outside and inside circuits. Enclosed fuses are used exclusively for capacities of ten amperes and over.

In addition to the 250 volt power and lighting system, there will be installed a telephone system of fifteen 'phones, and a Gamewell fire alarm system of ten stations, the wires for both the telephone and fire alarm systems being carried in a lead covered cable, to avoid the large number of wires on the poles. The entire plant requires some forty-five miles of wire, not including the alternating current system, which would add about fifteen more.


PLAN OF WORKS
SHOWING
ELECTRICAL INSTALLATION
F.A. WARDENBURG
0 100 200
LOCOMOTIVES 30 HP
LIGHTING 22 AMP
40 HP
LIGHTING 11 AMP
LIGHTING 60 AMP
LIGHTING 22 AMP 15 HP
LIGHTING 37 AMP
LIGHTING 22 AMP
175 HP
175 HP
15 HP
15 HP
15 HP
24 DUCT UNDERGROUND CONDUIT
SWITCH BOARD
2-400 KW GENERATORS
17 AMP-30 HP
LIGHTING
4 AMP
9 AMP 15 HP
7 AMP 15 HP
DOUBLE POLE LINE
125 HP
LOCOMOTIVES 30 HP
LIGHTNING ARRESTER HOUSE
15 HP
15 HP
40 AMP
40 AMP
LIGHTING
LIGHTING
LOCOMOTIVE 15 HP
CRANE 40 HP
40 HP
CRANES-150 HP
LIGHTING 104 AMP-130 HP
PUMPS 195 HP
RESERVOIR
LOCOMOTIVES 200 HP
LOCOMOTIVES 60 HP

COAL ANALYSIS.

By Charles Cochran, Mechanical Engineering, 1906.

The analysis of coal is of interest for two reasons,—first, because but little work has been done along the line of analyzing the coals of the state; and second, because of the great values of the coals to be found in Colorado and the great range of varieties. Incidentally, it is hoped that a better method of analyzing by burning may be found which may be applied to our lignite coals.

The present method of testing consists briefly in pulverizing a sample of coal and by a quartering process of selection a small portion is taken as representative of the whole. This small sample is placed in a proper crucible and slightly sealed to prevent ingress of oxygen from the air, though not preventing the escape of the volatile hydro-carbons. After the crucible and contents have been weighed and sealed, the crucible is set in a muffle furnace, which has been previously heated. In the beginning it is placed near the mouth of the furnace and allowed to remain for three to five minutes. Then it is set back into the hotter part of the furnace for one to three minutes, and is then removed from the furnace, and, still sealed, is allowed to cool. It is again weighed and the weight of the gases driven off is thus determined. This is generally reduced to a percentage of the total weight of the small sample originally taken. After weighing, the crucible is again returned to the furnace, this time uncovered and allowed to remain until the coal is reduced to ashes. Frequent removals from the furnace will accelerate the burning process. When entirely reduced to ashes, the contents of the crucible are again weighed and the proper calculations give the percentages of fixed carbon and ash contained in the sample.

The difficulty with this method, as applied to lignite coals, is that during the volatilization process, the gases are driven off so rapidly after the process begins that particles of fixed carbon are carried away with the gases, which tends to cause a showing of a higher percentage of hydro-carbons and a less percentage of fixed carbon than the sample actually contains. If the sample before being placed in the muffle furnace is placed in a dryer and the moisture expelled, the trouble mentioned is greatly lessened, and the amount of moisture may at the same time be determined.

Thus far, the analysis shows the moisture, hydro-carbons, fixed carbon and ash by percentages as they appear in the coal. Next the calorific value of the coal is determined. Again a small sample, this time one-half a gram is taken and carefully dried.

This is placed with a chemical high in oxygen in a bomb which is screwed together so as to be air tight. This bomb is then immersed in two litres of distilled water, about 3° F lower in temperature than the room, the water being contained in a carefully constructed calorimeter so that no heat may be taken on from or given off to the outside air. The bomb is then rotated until the temperature of the water becomes constant, when the charge of coal and chemical is fired by means of an electric spark. The rise in temperature of the surrounding water due to the burning of the coal is noted on a thermometer reading to tenths of a degree Fahr. Corrections are made and the B. T. U. required to raise the water through the temperature noted are calculated and this gives the calorific value of the coal.

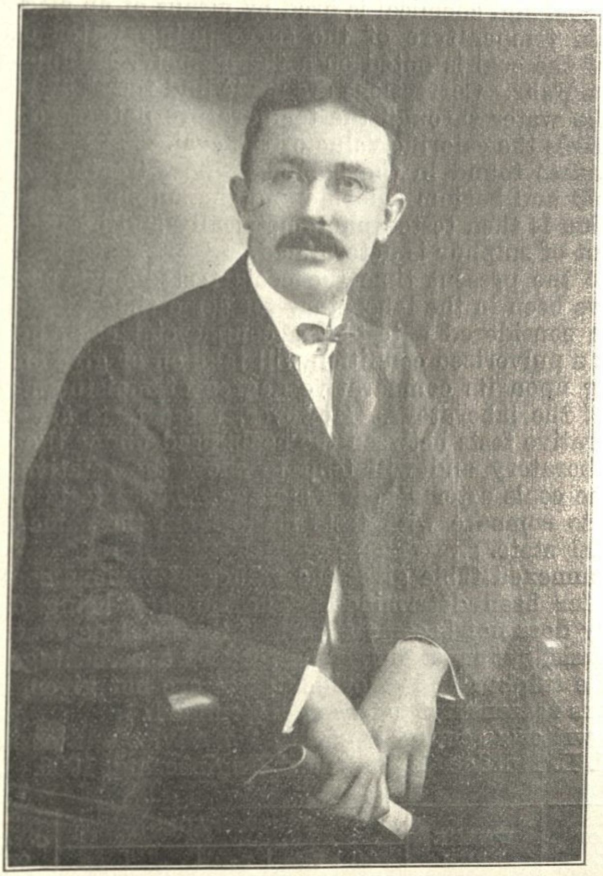
The ashes found in the bomb are now treated with hydrochloric acid and barium chloride and the sulphur is precipitated. The solution is then tested photometrically and by use of a table the amount of sulphur is determined.

Up to the present time the coals tested have been samples which have been in the laboratory for some time. Such tests can hardly be considered a test of a commercial coal, because any sample in a pulverized condition will take on or give off moisture, depending upon its comparative degree of moistness to that of the air of the laboratory. However, these tests are very good as comparative tests between the coals used under the conditions of the laboratory and will tend to show the relative values of these same coals after a year's storage. These tests will also be valuable to compare with tests made from the same coals in a commercial state.

The annexed table gives the values of various coals as they have so far been determined. The surphur being determined separately does not become a part of the total percentage in the first analzsis, but must simply be read as a percentage by itself. Where the sulphur and calorific values are not given, they have for various reasons not yet been determined.

The writer's acknowledgments for advice and assistance are due to H. E. Murdock, Mechanical Engineering, 1906.

NAME OF COAL	WHERE FROM	PERCENTAGES					COLOR OF ASH	COLORIFIC VALUE IN B.T.U.
		Moisture	Hydro-Carbons	Fixed Carbon	Ash	Sulphur		
Baldwin	Gunnison Dist	7.80	30.39	58.62	3.19		Brown	12581
Crested Butte	Crested Butte	.52	2.16	89.32	8.00		Red	14688
Rex	Louisville	17.64	26.98	50.68	4.70	1.50	Brown	11760
Black Diamond	Boulder	7.12	39.84	50.75	2.29		Brown	11821
Rugby	Rugby	2.32	32.68	54.60	10.40		Grey	12477
Anthracite	Anthracite	4.30	3.25	87.61	4.84		Red	
Crested Butte (cok'g)	Crested Butte	.76	33.14	62.22	3.88		Red	
Hezron	Hezron	1.42	34.95	55.75	7.88	1.00	White	13255
Chandler	Chandler	5.34	31.35	53.48	9.83	trace	Salm'n	11853
Nonac	Canon City	4.86	33.91	55.30	5.93	1.07	Drab	12383



MILO S. KETCHUM, C. E.

JOURNAL OF ENGINEERING

No. 2. UNIVERSITY OF COLORADO. 1905-1906.

MILO S. KETCHUM.

It was at the suggestion of Professor Ketchum (whose picture appears on the opposite page) that the publication of this magazine was attempted and also due to his careful coaching that the first number was so creditable. Since coming to the University two years ago as head of the Civil Engineering Department he has developed and extended the course and won the esteem of the students by the lively interest he has taken in their affairs.

He is essentially a western man, having been born and educated in Illinois, from which state university he received the degree of B. S. in civil engineering in 1895 and a C. E. in 1900. After serving as assistant professor in civil engineering at the University for two years he identified himself with the Gillette Herzog Manufacturing Company as bridge and structural engineer. In 1899 he returned to the University of Illinois where he remained for four years as professor of civil engineering. He then became contracting manager of the American Bridge Company of New York in charge of the Kansas City office and in September, 1904, accepted the professorship in the University of Colorado which he now holds. Last year he was made Dean of the School of Applied Science.

Professor Ketchum is an associate member of the American Society of Civil Engineers, a member of the American Society for Testing Materials, is secretary of the Society for the Promotion of Engineering Education and wears the bent of Tau Beta Pi. His "Surveying Manual" (edited jointly with Prof. W. D. Pence) is used in many of the best engineering schools and the "Design of Steel Mill Buildings," published in 1903, has been well received. The article in this issue on retaining walls is taken from the "Design of Walls and Bins," to be published by him in August.

ENGINEERING TRIPS.

A very important feature of the engineering courses was introduced last year in the Annual Inspection Trip. It is the intention of the faculty to have the senior and junior classes take this trip throughout some part of the state each year visiting power plants, mines, manufacturing and commercial establishments, and public works.

Last year a party of forty students and three professors went to Pueblo and spent two days at the Minnequa plant of the Colorado Fuel and Iron Co. After visiting other plants at Pueblo they went to Cripple Creek over the Short Line and there inspected various mines and mills. At Victor the party obtained rigs and drove twelve miles to the reservoir and power plant of the Pike's Peak Power and Electric Co. The inspection of the Hydro-Electric Co.'s plant at Manitou and the electric plants at Colorado Springs concluded the trip. The courtesy shown the party by old Colorado men and by officers in charge of the various plants visited was encouraging to the students and made the trip pleasant as well as profitable.

This year about fifty students and three professors composed the party, the itinery including Denver, Georgetown and Idaho Springs. The principal places visited were as follows: Equitable Building, Symes Block (under construction), Daniels and Fisher Building, City Engineer's office, Denver Post, Fourteenth Street viaduct, Larimer and Lawrence street steel bridges, West Colfax concrete arch, Colorado Telephone Co. main exchange, Pullman Car Works, Colorado Iron Works, Davis Iron Works, Colorado Ice and Storage Co.'s plant, west station of the Denver Gas and Electric Co., filter beds of the Denver Union Water Co. at Platte Canon, tile works of the Denver Sewer Pipe and Clay Co., Globe Smelter, West Denver pumping plant, Denver Iron and Wire Works, gas plant of the Denver Gas and Electric Co., and the central station of the Denver City Tramway Co. At Georgetown the United Hydro-Electric Co.'s plant, the "Loop," and several mines were inspected and at Idaho Springs the Newhouse Tunnel and the various mills. The party reported at the Albany Hotel in Denver Monday morning and returned to Boulder the following Saturday night completing as can be seen a trip of general engineering nature.

The outcome of these two experiments has proven the Annual Inspection Trip a success and offers the engineering students of the University an opportunity to be found in but few institutions of this kind.

DOCTOR EMCH.

Among the contributions to this number of the JOURNAL will be noticed one by Dr. Arnold Emch of Solothurn, Switzerland.

The presence of Dr. Emch at the University of Colorado has been too recent to need recalling, his engagement here terminating only with the last school year. He received his education at the Cantonal College, Solothurn, Zurich Polytechnikum and Kansas University, and has been assistant professor and professor at Kansas, Biel, Switzerland, and Colorado. In recalling him to the land of his birth, the Swiss people have gained a master intellect, and we, of course, have been the losers. We understand that he occupies a position of great responsibility at Solothurn, and no doubt his merit receives full recognition, which, we are afraid, was not entirely the case here. Dr. Emch's research work has been along the line of transformations by means of linkages, problems of closure, applications of elliptic functions, projective geometry, etc., and his one book on "Projective Geometry and Its Applications," is coming to be recognized as the leading work on this subject in the English language.

We predict for Dr. Emch in a few years a place among the world's foremost mathematicians, and we regret that Colorado is not to share in his advancement.

THE HONOR SYSTEM.

The ancient custom of "cribbing," which at some institutions of learning could well be classed among the exact sciences (not that highly developed here), we believe is about to have assigned its proper place, *i. e.,* along with the practice of hazing and other discarded relics of the past.

A determined effort was begun in the early part of the present school year to eliminate from our Engineering School what remained of this rather baneful custom. An agreement was signed in December last, by all but twenty-one of the one hundred ninety students of this department, to refrain from all unfair practices in quizes and examinations during attendance at the University, and, as far as we can learn, the word of honor thus given has been kept to the letter.

In March of the present year an attempt was made to further extend and clinch this agreement. A committee, representing the three engineering societies, reported in favor of an honor system, modeled after that prevailing at Princeton, University of Virginia, and possibly one or two other institutions. The basic principles were: 1st, the signing of a statement after each quiz and examination that no unfair practices had been indulged in; and 2nd, the formation of a senate, to consist of the president of each class and the president of the Engineering School, to investigate violations and recommend to the faculty that discipline deemed consistent with the offence.

This proposition was voted down by a small majority of the student body, as was also an alternative system proposed, the main opposition being concentrated on the student senate, which has been the cause of the failure of similar systems at several other schools, and which seemed to many to have very objectionable features. It is hardly probable that such a system will go into effect this year, if at all, although something along a slightly different line may be adopted.

Whatever may eventually take place, the agitation of this matter cannot fail to result in a great deal of good. All that is necessary to do away with a practice of this sort is an aroused student sentiment, which we now have as a consequence of the campaign passed through. Mere thoughtlessness was responsible for most of the former "cribbing," and now that the decided unfairness of this means of getting over the hard places in an engineering course has been thoroughly impressed on all concerned, we confidently expect little further trouble from this source.

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