and pulverizing coal, and of conveying and feeding the product to the kiln, together with fair allowances for replacements and repairs and for interest on the plant, will probably range from about 20 to 30 cents per ton of dried coal, for a 4-kiln plant. This will be equivalent to a cost of from 3 to 5 cents per barrel of cement. While this may seem a heavy addition to the cost of cement manufacture, it should be remembered that careful drying and fine pulverizing enable the manufacturer to use much poorer, and therefore cheaper, grades of coal than could otherwise be utilized.

Clinker Grinding.

The power and machinery required for pulverizing the clinker at a Portland cement plant using the dry process of manufacture are not much more than those needed for pulverizing the raw materials. This may seem at first sight improbable, for Portland cement clinker is much harder to grind than any possible combination of raw materials; but it must be remembered that for every barrel of cement produced about 600 pounds of raw materials must be pulverized, while only a scant 400 pounds of clinker will be treated, and that the large crushers required for some raw materials can be dispensed with in crushing clinker. With this exception, the machinery for treating the raw material and that for treating the clinker of a dry process Portland cement plant are usually almost duplicates.

The difficulty, and in consequence the expense, of grinding clinker will depend in large part on the chemical composition of the clinker and on the temperature at which it has been burned. The difficulty of grinding, for example, increases with the percentage of lime carried by the clinker, and a clinker containing 64 per cent of lime will be very noticeably more resistant to pulverizing than one carrying 62 per cent of lime. So far as regards burning, it may be said in general that the more thoroughly burned the clinker, the more difficult it will be to grind, assuming that its chemical composition remains the same.

The tendency among engineers at present is to demand more finely ground cement. While this demand is doubtless justified by the results of comparative tests of finely and coarsely ground cements, it must be borne in mind that any increase in fineness of grinding means a decrease in the product per hour of the grinding mills employed, and a consequent increase in the cost of cement. At some point in the process, therefore, the gain in strength due to fineness of grinding will be counterbalanced by the increased cost of manufacturing the more finely ground product.

The increase in the required fineness has been gradual but steady during recent years. Most specifications now require at least 90 per cent to pass a 100-mesh sieve, a number require 92 per cent, while a few important specifications require 95 per cent.

Addition of Gypsum.

The cement produced by the rotary kiln is invariably naturally so quick-setting as to require the addition of sulphate of lime. This substance when added in quantities up to 2½ or 3 per cent, retards the rate of set of the cement proportionately, and appears to exert no injurious influence on the strength of the cement. In amounts over 3 per cent, however, its retarding influence seems to become at least doubtful, while a decided weakening of the cement is noticeable.

Sulphate of lime may be added in one of two forms, either as crude gypsum or as burned plaster. Crude gypsum is a natural hydrous lime sulphate, containing about 80 per cent of lime sulphate and 20 per cent of water. When gypsum is calcined at temperatures not exceeding 400 deg. F., most of its contained water is driven off. The "plaster" remaining carries about 93 per cent of lime sulphate, with only 7 per cent of water.

In Portland cement manufacture either gypsum or burned plaster may be used to retard the set of the cement, but gypsum is universally employed in the United States. This is merely a question of cost. It is true that to secure the same amount of retardation of set it will be necessary to add a little more gypsum than burned plaster, but gypsum is much cheaper than burned plaster.

The addition of the gypsum to the clinker is usually made before it has passed into the ball mill, comminuter, or whatever mill is in use for preliminary grinding. Adding it at this point insures much more thorough mixing and pulverizing than if the mixture were made later in the process. At some of the few plants which use plaster instead of gypsum the finely ground plaster is not added until the clinker has received its final grinding and is ready for storage or packing.

HOW THEY MAKE THE TIME TABLES.*

By M. C. MILLER.

As a result of the travel habit, many persons can now determine from time tables, for themselves, what service is afforded by any railroad. Seldom, however, does a traveler stop to think—much less realize—what is involved in arranging a comprehensive schedule of trains. It is a complex problem, at best, to fix the schedules on a large system so that all will dovetail together and work smoothly when in practice, and, of course, much more intricate if operations are confined to a single track, when all trains must be arranged to meet and pass on station sidings, and that, too, without undue loss of time on the part of either. In addition, the schedules must be arranged so as to avoid a

conflict at terminals and particularly the largest ones.

The general passenger or freight agent may recommend changes in service or the running of additional trains, but when any change is determined upon by the management, the ultimate adjustment of the time table devolves upon the superintendent or chief train dispatcher.

Referring first to the passenger service, it is necessary to start the principal trains at such intervals as will accommodate the greatest number of through passengers, and at the same time arrange to have them reach terminal stations at convenient, seasonable hours, whether connecting trains are desired or not, as no one wishes to reach a destination or have to change cars very late at night or too early in the morning. Local or accommodation trains are obliged to keep out of the way of through trains, but, if unduly delayed thereby, their passengers chafe at such detention, so that local trains are frequently given preference to the track on many lines that have a heavy suburban travel, if through trains are late.

For systematic convenience, all regular trains are designated by numbers. If odd ones are used west or north-bound, even numbers cover trains moving in the opposite direction.

summer, over a portion of the White Mountains division of the Boston & Maine Railroad, an important link in one of the principal routes between Boston and Montreal all the year, while through trains to and from New York use another part of it during the summer. It connects with four other divisions of the Boston & Maine Railroad and three foreign roads, hence it has to care for considerable through, as well as local, travel and traffic; it has so many junctions that arranging satisfactory service and connections for the summer travel would be no easy matter if a radical readjustment was required, and it is a single track line, with heavy grades, both north and south of Woodsville.

Suppose it has been decided to put on a new through train daily, between Bretton Woods and New York, same to be known as Nos. 38 and 21; a conference is held, at which all interested division superintendents are present. After the character of the train has been determined, each superintendent states how much time will elapse before he can deliver it at the proper junction point, and then the time of arrival at, and departure from, each terminal station is fixed at what is considered the most suitable hour. It would be shown that, in order to reach New York at the agreed time and also connect with various other trains at the several

INLAND ROUTE.

FOR NORTHERN AND SOUTHERN TRAVELLING.

THE RICHMOND, FREDERICKSBURG AND POTOMAC RAIL ROAD COMPANY, in connection with the other Rail Road and Steamboat Companies, on the route, have adopted the following Schedule, by which the daily mail is now carried.

(NORTHWARD DIRECTION.)			
Leave			Arrive at
Blakely, N. C.	at 5 o'clock, P. M.	Petersburg,	at 10 o'clock, P. M.
Petersburg,	12 " A. M.	Richmond,	4 " A. M.
Richmond,	4½ " A. M.	Washington,	6 " P. M.
Washington,	7½ " P. M.	Baltimore,	10 " P. M.
Baltimore,	6 " A. M.	New York,	11 " P. M.

(SOUTHWARD DIRECTION.)			
Leave			Arrive at
New York,	at 4 o'clock, P. M.	Baltimore,	at 3 o'clock, P. M.
Baltimore,	5 " P. M.	Washington,	8 " P. M.
Washington,	10 " P. M.	Richmond,	2 " P. M.
Richmond,	3 " P. M.	Petersburg,	7 " P. M.
Petersburg,	1½ " A. M.	Blakely,	7 " A. M.

The whole time required between *Blakely* and *New York*, being Northwards, 54 hours; Southwards, 57 hours. Between *New Orleans* and *New York*, Northwards, 12 days and 13 hours; Southwards, 13 days and 8 hours. Of the whole distance between *Blakely* and *Baltimore*, 126 miles is travelled upon Rail Roads, and 50 miles by Steamboat.

The Stage Travelling, which is conducted by Messrs. J. Woolfolk & Co. and Messrs. J. H. Avery & Co. in the handsomest manner, being now only 67 miles, is becoming rapidly reduced by the extension of this Rail Road.

Passengers are never in danger of delay, reference being given to such as enter and continue on the line.

By arrangements which this company is making, Passengers, with their baggage, will be conveyed to and from the Depot, without charge. On the Rail Road, a coach will be especially appropriated to Northern and Southern Travellers; and in general, the Company's Agents will adopt all measures calculated to expedite and facilitate their journey.

Carriages and Horses are safely and expeditiously transported; enabling those travelling in them with the additional use of the Potomac Steamboat, and the Petersburg Rail Road, to accomplish, without fatigue to their horses, the journey between Washington and Blakely, N. C. in two days.

The Mail Train leaves Richmond at 4½ o'clock, A. M.; returning leaves the North Anna at 12 o'clock, M. The alternate Trains for Passengers and Freight, leave the North Anna at 7 o'clock, A. M. and 4 P. M.; and Richmond at 9 o'clock A. M. and 1 P. M.

All possible care will be taken of baggage, but it will be carried only at its owner's risk. RAIL ROAD OFFICE, Richmond, May 30, 1836.

AN OLD-FASHIONED TIME TABLE

With these fundamental principles in mind, coupled with an intimate knowledge of the profile and other characteristics of the road, the prospective schedule, instead of being laboriously (and perhaps erroneously) figured out, is first arranged on a board or chart. If the former is used, the movements are represented by colored cords, kept in place with pins, to facilitate readjustment at will. The charts are similar in general design, but on a smaller scale, and, as the movements represented thereon are tentatively made in pencil, subsequent necessary changes can be easily made. On some double-track roads, however, it is customary for experienced men to figure the schedules first and then prove them by means of the board or chart just mentioned.

As will be seen, the time from twelve o'clock midnight to the next midnight is divided into spaces of five minutes each by perpendicular lines, and the stations are shown in geographical order opposite horizontal lines that are proportionally as far apart as the stations themselves. The latter ruling necessarily must be adapted to the needs of each road and be accurately drawn to a certain scale, or the contemplated movements will not work out properly in actual practice.

The accompanying illustration shows a section of such a chart, with scheduled train movements between the hours of 9 A. M. and 4 P. M., as prepared for last

junction points *en route*, the southbound train (No. 38) could leave Fabyans at 9 A. M. and reach Wells River (across the Connecticut River from Woodsville) for delivery to the Passumpsic division at 10:25. A train of this character requires the right of way during this hour and twenty-five minutes, and, concurrently with the apportionment of this time, the question is presented of what rearrangement of other trains is necessary, practicable, and desirable, with corresponding consideration of the situation as affecting the proposed new northbound train.

Assuming other scheduled trains were moving substantially as indicated, an inspection of the chart would show that provision must be made to meet and pass local freight train No. 11 and accommodation passenger train No. 303, at suitable points, and the same situation would have to be considered in arranging for the movement of the Boston express, No. 40. The train movements are much more numerous and complicated over that portion of the road between Woodsville and Concord, and in arranging the schedule for a division of this character, some time must be allowed for meals at Plymouth, while the 1 and 5-10 per cent grade for ten miles south and eighteen miles north of Glencoff reduces the speed as trains approach that station.

By depicting first the through passenger trains, then

* The New York Evening Post.

the local or accommodation trains, followed by the through freights and local or way freights, while concurrently considering the character and equipment of each train, coupled with grades, length of passing sidings at stations, and a knowledge of what results have been accomplished by trainmen in actual practice, the necessary meeting points are established, as shown by the intersecting lines. The responsible official is also enabled to secure what might be considered a bird's-eye view of the entire situation on his division at any given time of day, as each scheduled train appears in its proper relation to all others, although, at first sight, the result appears to indicate a severe and concentrated electrical storm.

The numbers shown against each line on the chart are for convenience in tracing the respective train movements. Other through freight trains, called "extras," are run without appearing on the chart, as the volume of traffic from day to day may warrant, so that the track is really occupied to a greater extent than indicated. As may be inferred from their slow progress, Nos. 22 and 13 are local freight trains, that perform considerable switching at stations *en route*.

If cars are to be taken on or off, or large quantities of baggage, mail, or express matter are regularly handled by certain trains at specific points, allowance must be made therefor, as it is much more satisfactory to have a train run according to schedule, even if the time

Each additional or annulled train results in more or less disorder along the line. When the eighteen-hour trains between New York and Chicago were inaugurated, a material rearrangement in some portions of the schedule was necessitated by the long, fast, run and superior character of the service.

On double track roads the same principles govern, except, of course, that trains running in opposite direction do not affect each other, as they can pass anywhere; hence, generally speaking, only those moving in one direction require concurrent consideration—for time-table purposes.

In order not to give too many cars and locomotives at either end of the line, as well as accommodate the public, it is customary to run the same number of trains in both directions although, under certain conditions, an occasional return movement may be made out of service, or "deadhead," as it is termed.

After the chart has been completed, the figures indicated thereby are copied (with characters showing at what stations stops are to be made and what days each train is to run), in shape for printing the official time tables that are furnished to engineers, conductors, and other interested employees. Ample notice has to be given, that all concerned may familiarize themselves therewith, prior to the date on which the new schedule is to become effective, and all employees are enjoined to study it carefully and be sure that every

principal stations, in the second the character of the equipment employed, and in the third the point of origin and destination of each car hauled by that particular train, desirable simplicity was at once secured; the whole situation is revealed to a prospective traveler at a glance.

The process of evolution that time tables have undergone during the past seventy years is well illustrated by the reproduction of one published May 30, 1836, by the Richmond, Fredericksburg & Potomac Railroad. This is believed to be the oldest regular railway schedule in America. Two of these originals were found in the company's archives, and one of them was exhibited in the Transportation Building at the World's Fair in Chicago and then donated to the Field permanent museum in that city. This company was chartered in 1834, hence it is one of our oldest railway corporations. Probably every road that has been built since that time has expanded by leasing, or consolidating with, other lines, under a new name, or gone through a receivership and consequent reorganization, but, in this respect, the Richmond, Fredericksburg & Potomac Railroad is in a class by itself, as it has continued successfully to operate substantially its original mileage under its original charter.

The plates for the maps in the best folders constitute the principal first cost. It is not generally known that representative American lines frequently receive applications for their folder maps from abroad for educational purposes; in fact, a map showing the through route to Asia, which was prepared by the New York Central passenger department some time ago, has been much sought by schools and representatives of this and other governments, as being the most complete and up-to-date of its kind in the world.

The railway and some steamship companies print increased quantities of time tables each year, many of which are handsome in design and clear and concise in type and text, as well as beautifully illustrated. Those that contain descriptions of some summer and winter resorts or tours are often printed in artistic colors, and they are as well written and carefully edited as many magazines. Some of those issued by the trunk lines cost \$25 per 1,000, although they are for free distribution. Elaborate and well-illustrated folders would cost considerably more, hence the roads hardly "break even" when applicants are asked to send one or more postage stamps for them.

In the largest cities, the distribution of these folders has become quite a business in itself. Approximately four million of these time tables were given away during 1905 in New York city alone. Each month, in this city, the Pennsylvania Railroad distributes 70,000 folders, the New York Central circulates 65,000, the Central Railroad of New Jersey 50,000, and the New Haven and Lackawanna 20,000 each, with others in proportion, while, among the Western roads, the Burlington route distributed nearly 2,500,000 throughout the country last year, the Chicago & Northwestern issued approximately 2,000,000, and the Union Pacific put out nearly as many as the Northwestern.

At first, time schedules, with advertisements, were printed on huge framed posters that were hung on the walls of hotel offices and other public places, and most of them were the reverse of artistic. When "Jim" Fisk was a constant patron at the Broadway Central Hotel, as it was a common practice elsewhere, he hung numerous Erie Railroad placards in the public rooms, and, not to be outdone, other railroad agents naturally followed suit. The result can be better imagined than described, and the proprietor finally cleared them all out, after remarking, "I paid \$1,000 to decorate this office, and haven't had a chance to see what I got for my money." As many others began to feel the same way, that form of time table has been almost entirely superseded by the much more convenient folder, and the framed time table is not now obtrusive, even in station waiting-rooms.

With the advent of, and demand for, folders, each road attended to its own distribution, but this was found to be quite expensive, and companies were formed to make a systematic distribution in the principal cities. The pioneer company in this city has branches in Boston, Philadelphia, Baltimore, and Washington, and its automobile distributing car in this city has been quite noticeable for some time past. Prior to starting this systematic distribution, the companies purchased and placed suitable racks, containing 110 spaces, for as many different issues of time tables, in all the large hotels, and their operations became of international scope. A few years ago it was seldom that an English time table could be found in a New York hotel, but, under the arrangement just mentioned, London & North-Western Railway and other foreign folders may be found in hotel reading-rooms beside those issued by American roads, and the folders of the leading European hotels.

Just prior to the Russo-Japanese war, a dispute about the Siberian Railroad arose between two men at a New York hotel. One of them called a boy and said: "Go to the rack and get me a time table of the Siberian Railroad in Russia."

His companion laughed and said: "I'll bet you a dinner you don't get it."

Inside five minutes, however, the boy came back with the desired schedule.

The nature of gravitation is as unknown as the nature of life itself. We know how it acts, and that this action is millions of times quicker than light, but that is all, and the one who unravels the mystery will deserve to rank with the greatest of discoverers.

WHITE MOUNTAINS DIVISION--SCHEDULE No. 15.

PORTION OF CHART BY MEANS OF WHICH A DIVISION TIME TABLE IS PREPARED.

consumed is as great, than to have it often or always late because of insufficient time in which to do the work required.

In this connection, those who are disposed to find fault with the management or trainmen whenever a train is delayed, may be interested to learn that the conductor makes a special report to the superintendent each time his train is delayed on the road or at stations, giving all the circumstances in detail. For example, these blanks classify the detention, if caused by a locomotive failure, under several heads, viz., hot boxes or bearings, hot or broken eccentrics, air-brake failures, broken side or main rods, and steam failures. The latter includes bad coal, bad fire, dirty flues, improper firing, leaky flues, etc. A careful investigation of each detention is made, and necessary repairs are effected as quickly as possible; but, if the detention was caused by an engine failure, such as improper firing, dirty flues, etc., the engineers are sure to be called upon for an explanation. These reports are recorded, and, with this system of surveillance in vogue, every man who wishes to remain in the service is bound to do his best, or he is sure to be soon superseded by one who will render satisfactory service.

While rearrangements may occur at any time, there are usually but two general changes each year; one, to care for the summer travel, and the other to cover the winter and spring months, when freight traffic predominates.

Conditions on the principal roads are now such that additional trains can seldom be run at times when the track is comparatively free, because, at such times, there would probably also be but few, if any, passengers in waiting at important stations.

change in time or running rules is noted and thoroughly understood.

As soon as the operating time table has been printed and, upon careful comparison, found to be correct, a copy is furnished to the general passenger agent. The passenger or advertising department then notifies newspaper publishers along the line of impending changes and prepares folders showing all the passenger train service, omitting the time at stations where stops are not made, but giving additional information required by the public, such as stop-over rules, dining, parlor, or sleeping car service and charges; whether trains run daily or otherwise; a description of the equipment run on the principal through trains, and a condensed schedule of the service afforded by connecting roads to and from most junction points.

Although these comprehensive folders are very popular, especially when accompanied, as many of them are, by a good map, the men engaged in preparing them are constantly striving to improve them in every way that experience and ingenuity suggest. Originally they were printed on sheets of paper about a yard long, which made them unwieldy to handle when open, and the Union Pacific is credited with having been the first road to devise the very convenient book form that is now generally used for the purpose.

The Union Pacific road has also introduced various innovations in its folders from time to time. For instance, one excellent and decided innovation was first made when its December, 1903, issues were put out, showing the condensed schedule of its through trains. By using three columns on a page, under the number and distinctive name of each train, and showing in the first the time of departure from, and arrival at, the

THE MECHANICS OF LUMINOSITY.

SOME Continental critics have been rather inclined to ridicule a certain practice, almost confined to the British school of scientific thought, that is to say, the practice of picturing a mechanism capable of reproducing the phenomena of molecular physics, and of reasoning about this arbitrary concept, instead of confining themselves to a mere study of certain differential equations. Such critics have, it is true, been to a large extent silenced by Helmholtz's confession that the method had led to remarkable results in the way of the advance of discovery, and it has, moreover, the further advantage of permitting a plain man, ignorant of higher mathematics, to obtain some idea as to the nature of the phenomena in question.

Prof. J. J. Thomson, perhaps the leading living physicist, possesses this characteristic of the British school of science in a marked degree; and for this reason his Friday-evening lectures at the Royal Institution are of especial interest to those who, though incapable of following in their entirety the remarkable series of researches by which the Cavendish Laboratory at Cambridge has become a sort of Mecca for the student of physics, are nevertheless anxious to gather some gleanings from the fruits of these important investigations. Nothing could better serve this end than the highly suggestive lecture on "Some Applications of the Theory of Electric Discharge to Spectroscopy," delivered last Friday evening at the Royal Institution by Prof. Thomson. In opening his discourse, he stated that when an electric current passed through a gas, the color of the light and the character of the spectrum depended not only on the chemical nature of the gas, but also on the nature of the current, the spectrum being often entirely different with an arc discharge from what it was with a spark discharge. Moreover, in certain cases the color of the spectrum was entirely different in different parts of one and the same tube. This was shown by Prof. Thomson with a Plucker tube containing air, the peculiarity of the tube being that it consisted of two wider portions connected by a capillary channel. The color of the glowing gas in this narrow channel was entirely different from its color in the bulbs. Recent investigations, he proceeded, had thrown a good deal of light on what actually took place when a gas became luminous by the passage of a discharge, and he intended that evening to explain in what manner the different effects observed were accounted for by theory, and a comparison of the difference in the nature of the luminosity produced with different voltages threw, moreover, a good deal of light on the generation of spectra. These researches had, he remarked, been much facilitated by the observation that when lime or barium oxide was used as the cathode, an extraordinary number of negative corpuscles were emitted at all temperatures of the cathode. Thus, using lime, a P.D. of only 18 to 100 volts would give a very bright discharge, and alterations of the current strength and potential difference within a very wide range were thus much easier to make than with other substances as cathode. The apparatus used was that shown in Fig. 1. The lime here was deposited on a thin platinum wire carried by stout leads, as shown. An independent current passing through these leads served to keep the platinum wire red-hot, while a third wire led from the center of the cathode thus formed to the negative terminal. A bulb of this kind could also, he stated, be used as a rectifier, since the current would only pass through the tube when the lime was the cathode. The discharge in the tube shown by Prof. Thomson was blue, and was very sensitive to the action of a magnet, which not only deflected the moving particles, but concentrated them along the line of force.

A peculiarity of the discharge, he pointed out, was the abruptness with which luminosity made its appearance. In the laboratory a difference of 1-100 volt was sufficient to cause the tube to pass from perfect darkness to quite a bright discharge. The light therefore made its appearance instantly, and did not start as a faint glow, and gradually get brighter. This fact he considered was most important in the mechanics of luminosity, and the conclusion he had come to was that owing to the bombardment of the atoms of the residual gas by the flying corpuscles, the internal energy of the atoms was increased. This increase of energy required time for it to be radiated off, and if the impacts followed each other sufficiently rapidly, the value of the internal energy was raised to a critical value at which the equilibrium became unstable, when the atom itself flung off a corpuscle, and the shock of the discharge threw the rest of the atom into vibration, giving rise to light, which, therefore, was the direct consequence of atomic instability.

In confirmation of this it was found that the negative corpuscles emitted when Röntgen rays fell on a metal had the same penetrative power whatever the intensity of the Röntgen rays, whereas were they dragged out of the atom by the electric field of the rays, their speed and penetrative power should increase with the strength of the radiation. This was not the case, since an increase in the strength of the Röntgen rays merely increased the number of corpuscles liberated, and did not increase their penetrative power. Lenard had further shown that the corpuscles expelled on letting ultra-violet light fall on metals had a velocity quite independent of the intensity of the light, which is what would be expected were the instability set up in the atom the real cause of the expulsion, while the rays or the ultra-violet light merely served as a sort of trigger.

When a corpuscle struck an atom in a vacuum tube, the internal energy of this atom was increased,

and might, as stated, accumulate to a critical value. As soon as the gas became luminous there was an enormous increase in the current, a difference of one-hundredth of a volt sometimes causing a sixty-fold increase in the current. The stage at which luminosity set in depended much on the temperature, the luminous point being reached with, say, 55 volts at high temperatures and 100 volts at low. An increase in the current density, moreover, tended to promote the luminous discharge, since each atom encountered more corpuscles in a given time. A single collision was insufficient to render an atom luminous. There must be many. Hence, as the action of a magnet tended to concentrate the discharge, a tube would become luminous at a lower P.D. when a magnet was held near it than when the magnet was absent. If single collisions sufficed to render an atom luminous, the intensity of the light should increase proportionately to the current; but this was not the case, the increase of luminosity being much more rapid than the increase in the number of cathode particles.

Hence, to get luminosity, we must, Prof. Thomson said, be able to raise the internal energy of the atom to a certain critical value, and the atom must not part with the energy thus received too rapidly, or this critical value would never be reached. Calling the rate at which the atom received energy α , and assuming that the rate at which it radiated off energy was proportional to its total internal energy, the rate at which this

energy increased with lapse of time was given by the expression—

$$\frac{dE}{dt} = \alpha - \beta E;$$

and the total internal energy at any time was thus

$$E = \frac{\alpha}{\beta} (1 - e^{-\beta t})$$

The maximum value which E could reach after the lapse of infinite time was $\frac{\alpha}{\beta}$. Typical curves showing E were represented in Figs. 2 and 3.

It appeared, Prof. Thomson continued, that there were two radiating systems in an atom. One of these was a poor absorber of energy from the corpuscles, and also a poor radiator, while the second was both a good absorber and a good radiator, so that the fraction $\frac{\alpha}{\beta}$ for this second system was less than for the first. For either system to give light a certain critical value of E must be attained, which for simplicity might be taken as the same for both systems.

Suppose, then, that in Fig. 2 the rate at which energy is supplied was small, but the supply was long-continued, and let also the dotted line represent the critical value for E at which luminosity appeared; then the upper curve represented the case of the poor absorber and poor radiator, which would, as represented, ultimately exceed this critical value, while the good radiator and good absorber represented by the other curve would not reach it. If, however, the rate at which energy was supplied were increased, then we obtained

the condition of affairs represented in Fig. 3, where both curves exceeded the critical value, and the good radiator did so first. If, moreover, the supply of energy ceased soon after this latter event, it would be seen that the poor radiator and absorber would not have time to reach the critical state, so that the spectrum corresponding to the second vibrating system would alone be seen.

As an illustration, Prof. Thomson suggested that E should be taken to represent a man's capital and α his income, and that the amount he spent was a constant fraction of E . Then the poor absorber and radiator corresponded to a man receiving a small salary, but also spending little—say, at the rate of one-thirtieth of his total capital existing at any time. If his salary were 1,000*l.* per annum, and a capital of 20,000*l.* would make him a "shining light," he would, if his salary lasted long enough, reach this limit, and, if he lived an infinite time, might accumulate 30,000*l.* If, on the other hand, a man's salary was 5,000*l.* per annum, and he spent at the rate of one-third of his capital, he could never, no matter how long he lived, accumulate more than 15,000*l.*, and hence would fail to reach the position of a "shining light." Suppose, however, that times changed, and the salaries became four times as great, but lasted a much less time; then the second man would attain the desired standard very quickly, while, if the good times were sufficiently short, the other might never reach it at all.

In these considerations was, he thought, to be found a clue to the passage from arc to spark spectra, and also of the influence on spectra of inductance and capacity. With the arc discharge one got a large steady current, the average value of which was practically the same as the maximum. With the spark discharge the average value of the current was small, but the maximum value, though it lasted for only a very short time, might be very great. Returning to the analogy just given, the saving man was favored by the arc, and the man with large earnings and large expenditure by the spark discharge. Again, where the discharge passed through a capillary tube the current density was great, and therefore the internal energy of an atom encountered might be increased by the numerous impacts, so that the second system was put into vibration; while in the wider parts of the tube only the first system alone reached this critical stage. The spectrum of the discharge in the two portions would thus be different.

Similar considerations applied to the alteration produced in spectra by varying the capacity and inductance in the spark circuit. An increase in capacity increased the maximum rate at which work was done in the circuit, while self-inductance had a precisely contrary effect, so that with a large inductance the discharge approximated to the arc type. This was well shown by vacuum tubes containing argon, which, as discovered by Sir William Crookes, gave a light of an entirely different color, according to the relative inductance and capacity of the spark-circuit in which they were included. Prof. Thomson showed that when such a tube was connected up to a spark-circuit of large capacity, but small inductance, it glowed with a red light, while the addition of a large inductance to the circuit caused the color of the discharge to alter to a bright blue; similarly, a neon tube glowed yellow when the inductance in the circuit was small, and green when it was large. To illustrate the kind of action which was held to be responsible for this change the lecturer exhibited the piece of apparatus shown diagrammatically in Fig. 4.

Hence, a red and a blue lamp were arranged in parallel on the same source of supply. The red-lamp branch has a large inductance and a low resistance, while the blue lamp formed part of a circuit of high resistance and low inductance. Concerning the device with a source of continuous current, the red lamp alone lit up; but on an alternating circuit this remained dark, and the blue lamp was the one which glowed.

On these lines he thought it was possible to account for the double spectrum of argon without assuming any decomposition of the atom of the gas. Both of the vibrating systems postulated were interior to the atom, and either one or the other would be set in vibration according to the character of the discharge. It would, he continued, be of great interest to watch the behavior of the gas while the inductance was slowly increased, and to note whether the change of spectrum took place gradually, the new one making its appearance line by line; or whether all the lines of the new spectrum appeared simultaneously. Some experiments by Prof. Wood had a bearing on this. In these the luminosity of sodium vapor was excited by means of light, and the color of the spectrum was found to depend on the wave-length of the incident light. With a certain wave-length a spectrum containing certain lines was observed. Altering the wave-length of this incident light, the spectrum disappeared entirely, until by continuing the alteration an entirely different spectrum suddenly made its appearance, the whole of the lines of which appeared simultaneously. On the hypothesis made this was to be expected. Either vibrating system, when it reached the critical point, taking simultaneously all its possible modes of vibration.

It should further be noted that the rate at which the atom received energy by impact depended also on the nature of the projectiles as well as on their kinetic energy. If these were moving corpuscles, there would also be a particular speed at which the amount of energy transferred to the vibrating system was a maximum. The quicker the natural period of this system the higher was the speed at which the corpuscle must move for the maximum transference of energy to take