ft. between parapets by 91.9 ft. effective span) is about 21s.

Summary.—We may now sum up the results of the experience gained in the construction of the above and other bridges by Mr. Leibbrand. The object of forming three of the joints (at the crown and haunches) of thin lead sheet of a width of only one-third the thickness of the arching is to insure that the line of resistance shall be confined within narrow limits at those joints, thereby approximately fixing its position throughout, and thence rendering the approximate calculation of the thrust of the arch a matter of certainty instead of a mere vague guess (as heretofore).

In consequence of this uncertainty, the thickness of the arching has hitherto been computed by empirical formulæ from the span and rise only, taking no account of the load carried nor of the strength of the material of the arch ring; but with the removal of this uncertainty, it will now be possible to compute the thickness of the arch ring in a rational manner. To carry out this object, the lead should be in such thin strips as to be worked up to its yielding point; for spans of less than 130 ft., soft laminated lead yielding at 1,700 lb. per square inch should be used, and for larger spans hard lead yielding at 4,270 lb. per square inch should be used. In large spans, stone of great strength, e. g., basalt, granite, etc., should be used in the voussoirs next the leaded joints. To secure the advantages fully, it is further necessary that the lead strips should be in actual contact with the voussoirs before and until the keying of the arch: this may be managed by not setting the joints near the lead joints in mortar until shortly before keying; they may be temporarily filled with sand, or may be set in mortar at first only near their centers, and finished in mortar shortly before keying.

It is not necessary that the voids in the leaded joints should be filled up with mortar; if filled at all, the filling should be done after all the masonry is done. In all Mr. Leibbrand's bridges the striking of the centerings was begun as soon as the mortar was well set; but the lowering was very gradual, by steps of about $\frac{1}{16}$ in. at a time, spread over several weeks.

H. M. FIRST-CLASS CRUISER GIBRALTAR.

RECENTLY there was launched from Messrs. Napier's yard at Govan the first-class cruiser Gibraltar. We give an illustration of the ship as she would appear in Belfast Harbor. That situation has been selected because a previous Gibraltar, one of the old line-of-battle ships, lies there, and has been introduced into our picture for the sake of comparison.

The new Gibraltar is a steel twin-screw cruiser of 7,700 tons displacement and 12,000 indicated horse power, with triple-expansion engines by Messrs. Napier, the builders of the hull. She is 360 ft. in length and 60 ft. in breadth, and she will, when ready for sea, draw rather over 24 ft. of water. There are six boilers with forty-eight furnaces. The cylinders are 45 in., 59 in., and 88 in. in diameter, respectively, with a 51 in. stroke. It is calculated that developing 5,500 horse power the ship will have a speed of 16 knots; developing 10,000 horse power, a speed of $18\frac{1}{2}$ knots; and developing 12,000 horse power, with forced draught, a speed of $19\frac{1}{2}$ knots. The coal capacity is 850 tons, and the radius of action at economical speed is 10,000 miles. The armament will consist of one 9.2-in. 22-ton gun; two 6-in. 5½-ton quick-firing guns; ten 6-in. 5½-ton quick-firing guns, mounted five on each broadside, six being on the upper, and four, in sponsons, on the main deck; twelve 6-pounder quick-firing; three 3-pounder quick-firing; eight machine guns; two field or boat guns; and four 14-in. torpedo ejectors. The protective deck has a maximum thickness of 5 in., and a minimum thickness of 2 in., and is of steel. Above and below the slopes of it there are coal bunkers. As the engines rise somewhat above the steel deck, the upper parts of them are protected by 5 in. inclined plates backed with teak. The conning tower is of 12 in. plates; the larger guns are protected by steel shields, and, in addition to very numerous watertight compartments, there is a

double bottom amidships. The total estimated cost of the vessel is just over £340,000, of which about £188,000 is for hull, masts and rigging, and £100,000 for machinery. The Gibraltar will have two funnels and two light masts, and will, like the others of her class, be fitted as a flagship. The launch was quite satisfactory. The present Gibraltar is the eighth of the name; the seventh—shown to the left in our engraving—is known

the track, and treated according to the best judgment of the person in charge of the track, to secure the best results. The proper method to pursue in constructing the race track will be as follows:

I will assume that the shape and size of the track to be constructed has been decided upon, but that a site has not as yet been selected. If there are several available sites, it will be advisable to have surveys of

as the Grampian. She is a wooden screw ship, built at Devonport in 1860, and is used as a training ship for boys at Belfast. She was finished just about the time when wooden walls gave place to ironclads.—*The Engineer*.

THE CONSTRUCTION OF RACE COURSES.

F. B. KRAUSE, C.E.

At this time of the year, when the balmy days of spring are thawing out, so to speak, all horsemen who have secluded during the winter, and inspiring all to

each one made by a competent civil engineer, who will make maps, profiles and estimates of the cost of construction of the track on each site. By reference to them an accurate choice of the most suitable one can be made, and other knowledge gained for future use.

Having chosen the site, the track will be accurately laid out. By reference to the diagrams the requisite dimensions of the several tracks will be found, with other useful figures. Diagram No. 1 represents the mile regulation track, No. 2 the mile kite-shaped track, and No. 3 the half mile regulation track; No. 4 is a plan of a half mile kite-shaped track. To lay out the

activity in making preparations for the season, and new race tracks are being built, or about to be built, and old ones repaired, an article on the construction and maintenance of race tracks, it is presumed, will be of interest.

The writer will give such information herein as is necessary and useful for the construction of the fastest possible race course, of the shapes shown in the diagrams, and for maintaining the track in the best condition. As each track has its peculiarities due to soil, location and climate, these conditions and features must be practically studied in constructing and maintaining

regulation track, the center line, as shown on the diagrams, should be staked out, setting stakes at the points, A, B, C and D; stakes should then be set at right angles to the center line at the points, E, F, G and H. The turns and stretches will then be staked out. Stakes should be set 50 or 100 feet apart on the stretches; on the turns for a mile track regulation shape, stakes may be set 30 ft. apart, or less if desired; for the turns of a half mile track regulation stakes may be set 15 ft. apart or less. In staking out the kite-shaped track, stakes should be set at the points, B, D, C and G, in the center line and at right angles to the

THE BRITISH FIRST-CLASS CRUISER GIBRALTAR.

center line at E and F, also at the commencement of the stretches, one hundred and twenty-five feet and seven-eighths of an inch from the points, E and F, for the mile kite-shaped track, and sixty-one feet five and one-quarter inches from the points, E and F, for the half mile kite-shaped track. Stakes may be set forty feet apart or less on the turns of a mile kite-shaped track and twenty feet apart or less on the turns of the half mile. The stakes for the stretches of the kite-shaped track may be set the same distances apart as on the stretches of the regulation tracks. The engineer will use the most convenient method for laying out the curves for the turns.

The diagrams of the tracks, as given in this article, show the turns laid out in the usual manner with cir-

cular curves, but I advocate transition or spiral curves as being a very desirable improvement on them. It is well known by drivers that as tracks are usually, in fact I may say always have been, laid out (with but one exception, and that within the present year), the turns, beginning abruptly as they do with circular curves, are an obstacle in the way of speed making. With circular curves it is necessary to begin the sloping of the turns some distance on the stretches and not attain the proper rise until the same distance on the turns; this inconsistency is done away with entirely by spiral curve.

The diagram number 9 shows a comparison of the circular and spiral turns. The spiral turn is represented by the full lines and the circular by the dotted lines. Beginning at D, the spiral turn gradually increases in sharpness until the sharpest point of the turn is reached at F, then the turn gradually eases off until it vanishes at the point, E. This allows of sloping the turns gradually from the stretch, increasing until the greatest slope is reached at F, then diminishing gradually to the stretch as the turn becomes easier. At every point the slope of the turns may be just sufficient to counteract the centrifugal force. The transition from stretch to turn

and back to the stretch again will be perfectly easy, and all abruptness and consequent danger avoided. The principal gain will be in the speed of the track, which will be, with properly laid out spiral turns, nearly two-thirds of a second. It is needless to say that two-thirds of a second is worth saving or gaining in speed. Horsemen can appreciate the value of such a gain when it gets down below 2:10.

Accurate levels and cross sections of the track should be taken by the engineer and the most easy and economical grades chosen, care being taken, if the soil is suitable for the formation of the roadbed without top-dressing, to conform as nearly as possible to the natural surface of the ground. If the track is to be built on contract, accurate estimates and explicit specifications should be drawn up and inserted in the contract. Having chosen the best grade for the track, stakes should be set to grade beside the stakes that were set in laying out the track. If the cut or fill is too great in places for setting stakes to grade, stakes should be set with the cut or fill marked on them. The stakes should be numbered to designate them. In numbering the stakes it will be convenient to begin at the point, F, for

the regulation track, and number the stakes according to their distance from that point. Each one hundred feet should be called a station, and the amount over an even hundred feet, plus; thus if a stake were three hundred and fifty feet from the starting point, it would be numbered three plus fifty (3 + 50).

Diagram number 8 shows a plan for a mile kite-shaped track without the stretches crossing, which does away with the danger of collisions, at the cross-

ings of the stretches, that exists on the kite-shaped tracks built as shown by diagrams Nos. 2 and 4. The objection to this form of track, on account of the turn immediately after the finish, is not as great as it appears at first thought, for the turn is nearly as easy as that of the regulation track. This form of track does not cut the field up as badly as the other, though it occupies as great an area.

When grading the track, where there are fills, as much teaming as possible should be done over the material deposited, so as to pack it in place thoroughly. The nearest fills should be made first. The best con-

dition of the ground for grading is when it is neither too dry nor too wet, but in a moist state, and the best time for grading a track will usually be in the fall of the year, so that it will be thoroughly settled by spring. If the track is to be top-dressed, allowance should be made in the grading, the fills being made to within six or eight inches below the height of the desired grade.

For draining the track a ditch should be dug around the inside of the course six or eight feet from the rail. The stretches should be sloped about one-eighth of an inch to the foot toward the inner edge of the track, so as to allow the water to flow off readily after a heavy rain.

When the grading has been completed, the surface of the track should be harrowed thoroughly to break up the lumps, then thoroughly rolled and sprinkled to bring it to a compact state. A scantling surface dresser, such as is shown in the diagram, Fig. 5, will be found very convenient to keep the roadbed free from waves and to remove pebbles and other such small obstructions. To make the surfacer, get ten 2 x 4 scantlings sixteen feet long and two twelve feet long. Bore holes

well kept, makes the best natural surface for the track.

The sloping of the turns is a point which should be particularly observed to secure a fast track; but for a training track they should not be sloped too much. For a fast regulation mile track the turns should be sloped one and one-half inches per foot; for a fast half mile track, two and one-quarter inches per foot; for a fast kite-shaped track the turns should be sloped one and three-eighths inches per foot, and for a half mile track, two inches. For a training track, one inch per foot will be sufficient slope for a mile, and one and one-half for a half-mile track. The slope of the turns should begin about a hundred feet from the commencement of the turns on the stretches, and attain one-half of the full slope by the time the turns are reached, and increase to the full slope the same distance on the turns. Particular attention should be given to keeping the turns in perfect order and to preserve as perfectly uniform and as waveless a surface as possible.

Grades should be avoided as much as possible, especially on the turns. If there are any grades, it will be best to have them in the first half of the mile or half mile, and as far as possible to have the down grades on turns and home stretch. Very light grades, two or three inches in the hundred feet, will not affect the speed of the track materially. The effect of grades may be appreciated, when one considers that, say with a grade of six inches per one hundred feet and a speed of 2:10, the weight of the horse, driver and sulky combined being 1,200 pounds, the horse has to perform work equivalent to lifting 240 pounds one foot high per second on account of the grade.

The rail should be set as regulation now requires, three feet from the line of the mile or half mile course. Four feet would probably be nearer the correct location, so that a horse would travel no more than a mile in making the circuit, but the regulations do not admit

of setting the rail further from the line than three feet. The style of rail is shown in the diagram No. 7; the poles should be from ten to twelve feet in height and about eight inches in diameter. It will be well to paint them red and white in alternate bands and to varnish them, to have poles that will be plainly visible at a distance. The poles should be set in range from the judges' stand to the point in the line of the course where the quarter, half or three-quarters mile distance comes. Poles should be set in range on both sides of the track. Eighth-mile poles will be convenient. The judges' stand should set back from the track about twelve feet, and for a regulation half mile track, about 180 feet from the turn. The diagram shows location of the judges' stand for kite-shaped tracks. The wire should extend across the track at right angles. There should be two wires, one being perpendicularly above the other about three feet. There should be distance stands located as shown on the diagrams. The grandstand should be set back from the track twenty feet, and the pitch of the seats should be about two feet in three. To secure the best view, the grandstand should be set at an angle with the track of about ten feet in a hundred. The other buildings should be within convenient distance of the judges' stand and track. The grandstand and other buildings will of course be built to suit the convenience and tastes of the parties for whom they are to be constructed, and they will be the judges as to the extent of the buildings necessary to be

first-class road scraper or roller and one or two harrows will be necessary implements to have for the proper maintenance of the roadway; also a sprinkling wagon with tires six or eight inches wide. Some tracks will require wider tires than others, on account of the nature of the soil.

Much care will be required to maintain the track in the best condition for speed. The use of the road scraper will be required occasionally, but mostly after heavy

erected for the purposes for which the track is to be used.

The areas of the fields required for the various tracks are given in the diagrams; and with the exception of the kite-shaped tracks, include only enough land for the tracks. The amount of land required, outside of that necessary to contain the tracks, will have to be decided by the persons building the track.

Although a kite-shaped track is from two to three seconds faster than a regulation track, it has its unfavorable points. The principal disadvantages are that it is not adaptable for distances greater than a mile, half mile, or whatever the size of the track may be; that as good a view of the horses cannot be obtained for the full distance of the heat; and that it requires more land for its construction and will cost more to build than the regulation track.

In reference to the spiral curves, I would advise the reconstruction of the turns with spiral instead of circular turns. The expense of reconstruction would be small, and would make very little apparent alteration in the location of the roadway, and the advantages to be gained would pay many times over for the cost and work necessary. The value of the increase in speed would be difficult to estimate, but certainly well worth gaining.

Leaving the rest to those in whom the care of the track rests, and trusting that the foregoing may be of some benefit, however great or little, for limit of time I must close, believing that such minor details as present themselves, which in the present article I have omitted, will be properly solved by them.—*American Horse Monthly*.

THE TECHNOLOGY OF THE PAPER TRADE.

ALMOST as important as the introduction of machinery has been the application of chemicals in the manufacture of paper. We have already seen what important parts soda and chlorine and alumina play in the various stages of the process, and now it falls to us to consider the nature of the commercial chemicals containing these active agents. First in point of time, if not also in importance, we have caustic soda. This agent, as now used, was unknown as a commercial article until little more than a quarter of a century ago. It is now manufactured in very large quantities, and is used extensively in soapmaking, bleaching, papermaking, and—in smaller proportion—in many other trades. We shall first look at the chemical structure of this substance, and of the salts formed by its union with carbonic acid, which are also useful to the papermaker. Then we shall glance in succession at the commercial methods of producing these agents; at their employment in the paper mill; the methods of testing or valuing them; and the methods of recovering them after they have done their work, and of reusing them in the mill.

Caustic soda consists essentially of the metal sodium combined with oxygen and hydrogen. When sodium is burned in oxygen gas, two equivalents of the metal combine with one of the gas, and sodium oxide (Na_2O) is the result. This substance has a powerful affinity for water, with which it combines, forming sodium hydrate (NaHO). The reaction may be symbolized thus: $\text{Na}_2\text{O} + \text{H}_2\text{O} = 2\text{NaHO}$. This agent, contaminated with varying proportions of soda and other salts, is known in the arts as "caustic," or caustic soda. As its name implies, it is highly caustic or burning in its nature. It is so very deliquescent that, if left exposed in the air for some little time, it will become liquefied by the water it absorbs.

For all substances of an acid nature caustic soda has a strong affinity, and it is in virtue of this property that it is so eminently serviceable in the treatment of raw fiber yielding vegetable substances. When exposed to the air, it not only absorbs moisture, as already stated, but also carbonic acid, carbonate of soda being the result. The exact composition of this substance in the anhydrous condition is Na_2CO_3 . When this is formed from sodium hydrate, a molecule of water is involved in the reaction, thus: $2\text{NaHO} + \text{CO}_2 = \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$. Soda ash and soda crystals consist essentially of carbonate of soda, the former being anhydrous, and the latter combined with seven equivalents of water of crystallization. The soda recovered by incineration from the waste soda leys is also a carbonate, indeed, a crude soda ash often quite as rich in available soda as ordinary commercial ash. The impurities are, however, generally of a more objectionable nature.

Common salt is the native sodium compound upon which the chemical manufacturer operates, to produce the numerous soda salts met with in commerce. Upon this he brings oil of vitriol, or sulphuric acid, to bear, with the result that it is split up into two, the chlorine going off with the hydrogen as hydrochloric acid, which is in turn also split that the chlorine may be got to make bleaching powder. The sodium takes the place of the hydrogen which has been eliminated from the sulphuric acid, and thus becomes the basis of a new chemical structure known as sulphate of soda, or salt cake. This substance is of no value to the papermaker, but it is the first step toward producing what is really wanted.

The salt cake is mixed with limestone or carbon, or small coal, and heated to fusion in a reverberatory furnace, the practical result being the production of soluble soda—partly caustic, partly carbonated—and insoluble sulphides of calcium. Lixivation dissolves out the valuable soda products, leaving the insoluble calcium and sulphur compounds to be disposed of as best the manufacturer can, so as to minimize the nuisance which must necessarily result from their gradual decomposition, and the formation of soluble sulphides.

The soda solution may either be evaporated, and the product furnaceed into soda ash, or it may be treated with caustic lime, and the resulting caustic liquor concentrated and finally kept in a state of fusion at a red heat until the impurities are so reduced in quantity that the product may test 60 or 70 per cent. of real soda (sodium oxide), as may be required. What is known as caustic soda ash contains variable proportions of its soda in the caustic state, the bulk of it, however, being carbonated. Ordinary ash contains but little caustic, and the difference is produced by employing different methods of evaporating the crude liquor, and calcinating the product. Refined soda ash is just ordinary soda ash freed from

color and certain impurities by resolution, clarification and evaporation, or by the treating of the finest of the crude liquors with small proportions of nitrate of soda, to oxidize the sulphides. It is not necessarily, or, indeed, usually, stronger than ordinary ash. Freedom from color, sulphur, and mechanical impurities are its characteristics. When a hot saturated solution of refined soda ash is allowed to cool, nearly pure carbonate of soda crystallizes out, in combination with seven equivalents of water—the crystallized product being what is so well known as soda crystals.

The important part which caustic soda plays in the economy of the modern paper mill is now well understood. I have already adverted to its action upon grease, oils, gluten, resin, and silica, as well as upon cellulose itself, and need only further remark that, while the agent is indispensable, it is also expensive—amounting to about 10 per cent. of the value of the product—and this being so, it is important that it should be used in the most economical manner consistent with effective work. That there is in this respect room for improvement in very many mills, there can be no doubt. I have seen much accomplished where the boiling arrangements had been previously considered perfect. It is sometimes found economical to purchase soda ash instead of caustic soda, dissolving it, and causticizing the solution with quicklime. When the waste lime sludge can be readily got rid of, it is possible to make a profit of this, but at most mills it is a serious matter to get rid of the sludge, as well as the other refuse matters which so rapidly accumulate. For size making, soda crystals are no doubt very suitable, being the purest form in which soda can be purchased commercially. From experiments made under my own direction, however, I am convinced that an equally good size can be made with soda ash, provided only it be quite free from color and mechanical impurities, and it should not be difficult to secure a supply meeting these conditions. The result of the use of ash as against crystals is a saving in the sizing charges.—*Paper Trade Review*.

DETECTING WATER IN PETROLEUM TANKS.

AN instrument for ascertaining and recording the amount of water lying beneath petroleum in a ship's

hold or a storage tank has just been brought out. This instrument is the joint patent of Messrs. Boverton and Robert Redwood and H. Barringer.

The object of the instrument is to overcome the disadvantages which attended the practical use of the instruments hitherto employed for this purpose. The action of the instrument depends upon the change produced by the water upon a strip of paper prepared by chemical means so as to be unacted upon by oil, while the same is speedily and permanently altered by the action of water.

The instrument is very simple, as will be seen by the accompanying illustration. It consists of a hollow weighted brass cylinder, somewhat larger at its upper extremity than at its lower. A shallow groove is cut on both sides of this cylinder, alongside of which is a scale divided into inches and tenths of an inch. On the cylinder there is also a brass ring, which slides over the cylinder, fitting tightly on the top, and thus securing the prepared paper in the groove cut for its reception. The bottom part of the cylinder, as shown in the sketch, is supposed to have been sunk into a tank at the bottom of which there was eight-tenths of an inch of water, which is registered by the white portion of the paper. The use of the instrument is simplicity itself, all that is necessary being to slide the ring A to the lower end of the cylinder. Take a strip of the prepared paper, pass it over the pin, the ends of which will be seen projecting at the bottom of the cylinder, and adjust it so that an equal length of the paper is on each side of the pin, the prepared (brown) surface being turned toward the pin. Pass the paper, one side at a time, between the ring and the cylinder at the point where the groove or channel commences, and holding the cylinder near the top in the left hand, retain the paper tightly in position in the channels by the finger and thumb. Then slide the ring to the top of the cylinder, and the paper will be found firmly fixed on each side with, of course, the prepared surface outward.

Having thus prepared the instrument for use, it is to be attached to a cord of suitable length and lowered into the tank the presence and depth of water in which is to be determined. When the instrument is nearing the bottom of the tank it should be lowered slowly and cautiously so that it may be retained in a vertical

position. On touching the bottom it should rest undisturbed for such time as may be necessary to effect the requisite alteration of the chemically-prepared surface (about 30 seconds is usually sufficient), and on then being drawn up, the depth of the water will be indicated on both sides of the instrument, thus giving a duplicate record, and showing in the majority of cases whether the instrument has retained its vertical position. The instrument is being made by Messrs. Fraser & Co., of London.—*Chemical Trade Journal*.

ELECTRIC METERS, MOTORS, AND MONEY MATTERS.*

By Prof. W. E. AYRTON, F.R.S.

THE professor began his lecture by illustrating the dependence of the electrical energy obtained in a given time from an electric current, both on the strength of the current and on the electrical pressure, by comparing the current to a supply through a pipe of colored water, to be paid for in proportion to the amount of color supplied. The amount of color supplied in a given time would be proportional to the product of the amount of liquid supplied in that time by the quantity of color in every cubic foot of the solution. Similarly the amount of electrical energy supplied from an electric main in a given time would be proportional to the strength of the current by the electrical pressure, and therefore the costs should be measured in the same manner. He pointed out that the Board of Trade unit of electrical energy, the price of which in London varied from 7d. to 8d., was obtained by multiplying a coulomb (the quantity of electricity carried across any section of a conductor in a second by a current of an ampere) into a volt, the unit of electrical pressure, and then multiplying the result by the number of seconds in 1,000 hours. The professor observed that instruments for measuring electric current, electric pressure, and electric energy were known as ammeters, voltmeters, and wattmeters respectively, the watt being the name given to the unit of electrical energy. The meters employed by the electric supply companies simply measured the number of coulombs passed through them, and should therefore be called coulomb meters. The name was not employed by these companies, who usually called these instruments electric supply meters, possibly because they had no desire to call attention to the fact that what was registered by the meter and what was charged to the consumer were two entirely different things. The quantity measured was the number of coulombs passed through the meter, while the quantity charged for was the product of this by the number of volts at which the electricity was supplied.

Two groups of lamps inclosed in glass-fronted cases, showing as models of electrically-lighted houses, were then exhibited, with the same current passing through each of them, but the pressure in one many times greater than in the other. In the former case the model house was brilliantly illuminated, while only a feeble light was obtained in the second case. This was owing to the electrical energy consumed in the one at higher pressure being many times greater than the amount consumed in the other, though in a given time a coulomb meter would give the same indication for each. Thus in order to convert the readings of a coulomb meter into Board of Trade units, it was necessary to assume that the pressure kept up in the electric mains from a supply station remains everywhere and at all times constant. It was physically impossible to do this, and, therefore, the Board of Trade allowed a variation of pressure within the limits of 4 per cent. above and 4 per cent. below the nominal pressure, or an extreme variation of 8 per cent. The effects on the light of such a variation of 8 per cent. in the electrical pressure was shown by means of the model houses.

The professor stated that a series of experiments had been made by himself and his students on the variation in light caused by a variation of 8 per cent. in the pressure. The experiments were confined to Edison-Swan lamps, as these were the only ones which could be used in this country while the existing patent was in force. They found that with these lamps the variation in the amount of light given was about seven times as great as the variation in the pressure; so that under the Board of Trade regulations a 16 candle lamp might vary from 12 to 20 c. p. Even larger fluctuations than this were often allowed to take place unnoticed by the consumer. It was easy to understand that a small fluctuation might pass unnoticed if the change took place slowly; but it would hardly be thought possible that the light could be reduced to half its previous amount without the change being observed.

It was greatly to the credit of the supply companies generally that the variations were usually kept well within the Board of Trade limits; but he could mention places not very far from Albemarle Street, where he was lecturing, at which the fluctuations very much exceeded these limits. He would therefore advise consumers to have the pressure on their house mains tested on their own account at frequent intervals. The professor pointed out that the consumer could obtain legal redress if the variations in pressure exceeded the prescribed limits.

If 97 volt lamps were employed on a 100 volt circuit, then if the pressure fell to 97 volts, it would cause a loss in electrical energy to the consumer of 3 per cent., while if 100 volt lamps were employed the loss would be 21 per cent. This would point to the advisability of using lamps of somewhat lower voltage than that nominally maintained on the circuit. On the other hand, if the actual pressure were higher than that for which the lamp was constructed, it would diminish the life of the lamp, and so run up the bill for replacing lamps; for the life of a lamp depended more on the maximum than on the mean pressure at which it is run, and a lamp was rapidly destroyed when the pressure was too high, just as a gun which might last a lifetime if not overcharged, might be seriously injured or destroyed by a single overcharge of powder.

The professor then exhibited some experiments showing that the fact that any particular type of lamp had a certain definite pressure at which it would be used most economically had its exact analogue in gas illumination. Any gas burner had a certain definite pressure at which it gave the greatest amount of light for

* Abstract of the Friday evening discourse at the Royal Institution on April 8, 1892.