the conduit, providing it can be successfully accomplished. Some of the foremost of the construction companies are working at the problem with all the skill at their command. Let us hope that every success may crown the efforts of some enterprising inventor, and then the electric railroad on our busy streets would become a thing of beauty and a joy forever.

ON ERRORS IN BOILER TRIALS.

MANY engineers and experts, in making boiler trials, measure the weight of fuel, the weight of water, and the other quantities, without paying the slightest attention to the relative accuracy with which these quantities should be determined. The object of this article, from the *Locomotive*, is to show that such considerations may be of importance when a very accurate result is required.

As an illustration of the point we wish to make, let us take the following example · At a certain boiler trial the amount of coal actually burned was 2,354 pounds, and the amount of water evaporated was 20,640 pounds. These figures give ns an evaporative efficiency of 8.77 pounds of water per pound of coal.

Now let us assume that an error of 50 pounds was made in weighing the water, so that the apparent amount of water evaporated was 20,690 pounds, instead of 20,640 pounds, the actual amount. $20{,}690 \div 2{,}354 = 8.79$. so that the apparent evaporative performance of the boiler is 8.79 pounds of water per pound of coal, instead of 8.77 pounds, which is the correct result. The difference introduced by an error of fifty pounds in weighing the water, it will be seen, is only .02.

Now let us make a different supposition. Let us assume that the water was weighed correctly, but that an error of fifty pounds was made in weighing the coal, the apparent weight of coal being 2,304 pounds. Then $20{,}640 - 2{,}304 = 8.96$, so that the apparent evaporative performance of the boiler is 8.96 pounds of water per pound of coal, instead of the true result, 8.77 pounds. The difference in this case is quite appreciable, and the example shows that it makes quite a difference whether a given error is made in weighing the coal or in weighing the water.

The moral of this is, we suppose, that we should pay particular attention to the weighing of the coal. The scales should be very accurately balanced for the weight of the barrow, and the readings should be taken closely. The value of the kindlings, expressed in pounds of coal, should also be carefully ascertained. Furthermore, if we wish an accurate estimate of the evaporation per pound of *combustible*, we should be very careful about wetting down the fire after it is hauled; for the error introduced by the weight of the moisture in the ash produces as great an effect on the result as an equal error in weighing the coal.

The ideal way of carrying out a test is to make all the measurements in such a manner that the error committed in making any one of them shall have the same effect on the result as the error committed in making any other one. The principle is the same, to use an excellent but threadbare illustration, as in making a chain. Don't make one link any stronger than any other one, for if you do you are wasting labor. This can be achieved in evaporative tests by weighing the coal with 8 or 9 times the accuracy used in weighing the water, the ordinary evaporation per pound of coal being from 8 to 9 pounds. Of course we do not mean that this should be done with any very great degree of precision, but what we do mean is that the water should be weighed with ordinary care, and the coal with ordinary care.

Another very necessary operation in testing evaporative efficiencies, is the determination of the dryness of the steam generated. The ordinary method of conducting this part of the work is described in *The Locomotive* for March, 1890, on page 35, and to this description we would refer the reader. In the place of the steelyards there shown, a spring balance of some sort is often used. This should never be done unless the spring balance is of special construction, so as to weigh very accurately. The ordinary spring balance will not weigh closer than an ounce—or, at the outside, half an ounce. The total weight of *steam admitted being 16 ounces, half an ounce is one thirty-second* of the whole amount, and an error of one thirty-second in the amount of steam admitted will produce approximately the same effect as an equal error in noting the rise in temperature of the water in the pail. For instance, let us suppose that a given sample of steam actually contains 3 per cent. of moisture, but that we *have* admitted 16½ ounces of steam, when we think we have admitted only 19 ounces. The error, half an ounce, is one thirty-second of the whole amount. The rise in temperature would have 102° Fah. if we had really introduced only 16 pounds; but the real rise in temperature will be one thirty-second greater than this, since we have introduced one thirty-second more steam than we think we have. A thirty-second of 102° is 3°, which added to 102° gives 105°; and this is the *actual* rise in the temperature of the water in the pail. Thus we see that although the steam really contained 3 per cent. of moisture, the error of half an ounce in the weight of the pail would make us conclude that it was absolutely dry. The moral of this is, that there is no use in measuring the rise in the temperature of the water to within one per cent., if we are going to commit an error of at least three per cent., and perhaps six per cent., in weighing the water.

We may call attention here to another error that one is liable to, in determining the dryness of steam by the ordinary method —an error that at first sight seems quite insignificant. When the steam is still entering the pail, and the steelyards are approaching equilibrium, the easiest way to secure an accurate balance is to leave the pail in position, with the steam pipe still dipping below the surface of the water, and close the valve just at the right instant. The final weighing is thus performed with *the steam-pipe submerged; while ordinarily the ten pounds of* water originally put in are weighed without the steam-pipe. For the sake of investigating the effect of this let us assume that the pipe dips 5 inches below the surface of the water, and that the area of its cross section is half a square inch. When in position, therefore, it displaces 2½ cubic inches of water, and therefore increases the weight of the pail and contents by nearly an ounce and a half. It will be seen from this, and from the previous calculation of the effect of an error of half an ounce, that it is a highly important matter to have the steam-pipe dipping into the pail when the original ten pounds of water are weighed out. The most satisfactory way is to make a suitable mark on the pipe, and bring this mark to the level of the water in the pipe whenever a weighing is made.

VARIATIONS IN THE E. M. F. OF CELLS.*

THE description of the apparatus, the capillary electro-meter, and method of working are given fully in the paper. The following conclusions are drawn from the results of the experiments:

I. When the metals, copper, silver, bismuth and mercury, are introduced into purified nitric acid of different degrees of concentration, and a couple made with platinum, the E. M. F. of such a cell increases considerably from an initial point until it reaches a constant and in most cases a maximum value. The rise of E. M. F. is attributed to the production of nitrous acid by the decomposition of the nitric acid, and the final value is considered to be due to the former acid only, while the initial value is due for the most part to the latter acid, though it is affected to a remarkable degree by the amount of impurity of nitrous acid, either initially present or produced by minute and unavoidable uncleanliness of the metallic strip and the containing vessel.

II. If nitrous acid has been previously added to the nitric acid, then the maximum E. M. F. is reached at once.

III. If the conditions—namely, increase of temperature, of impurity, and of concentration of acid—are such as would favor a more rapid solution of the metal, and consequently a more rapid production of nitrous acid, then the rise of E. M. F. is concomitantly more rapid.

IV. Conversely, if the conditions are unfavorable to the production of nitrous acid, the rise of E. M. F. is less rapid.

V. If any substance, such as urea, be added which would tend to destroy the nitrous acid as fast as it may be formed, then the rise of E. M. F. is extremely slow, being dependent upon the number of molecular impacts of the nitrous acid upon the surface of the metal. Thus, the results obtained by the electrometer are confirmatory of those obtained by the latter author with the chemical balance.

The authors propose to carry on further investigations on kindred problems.

*Abstract of a paper on "The Variations of E. M. F. of Cells, consisting of certain Metals, Platinum and Nitric Acid," read by Messrs. G. J. Burch and V. H. Veley, University Museum, Oxford, before the Royal Society, Nov. 27th, 1890.